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The Development and Evaluation of a Benthic Index of Biological Integrity for the Cedar River Watershed, Washington

Prepared in cooperation with the
WATERSHED MANAGEMENT DIVISION OF
SEATTLE PUBLIC UTILITIES

Water-Resources Investigations Report 99-4203

U.S. Department of the Interior
U.S. Geological Survey

Seattle Public Utilities
Watershed Management Division

Cover - Photo of Cedar River by Dave Beedle, Seattle Public Utilities, Watershed Management Division, Seattle, Washington.

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Tacoma, Washington
1999

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VERTICAL DATUM

Sea Level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)--a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

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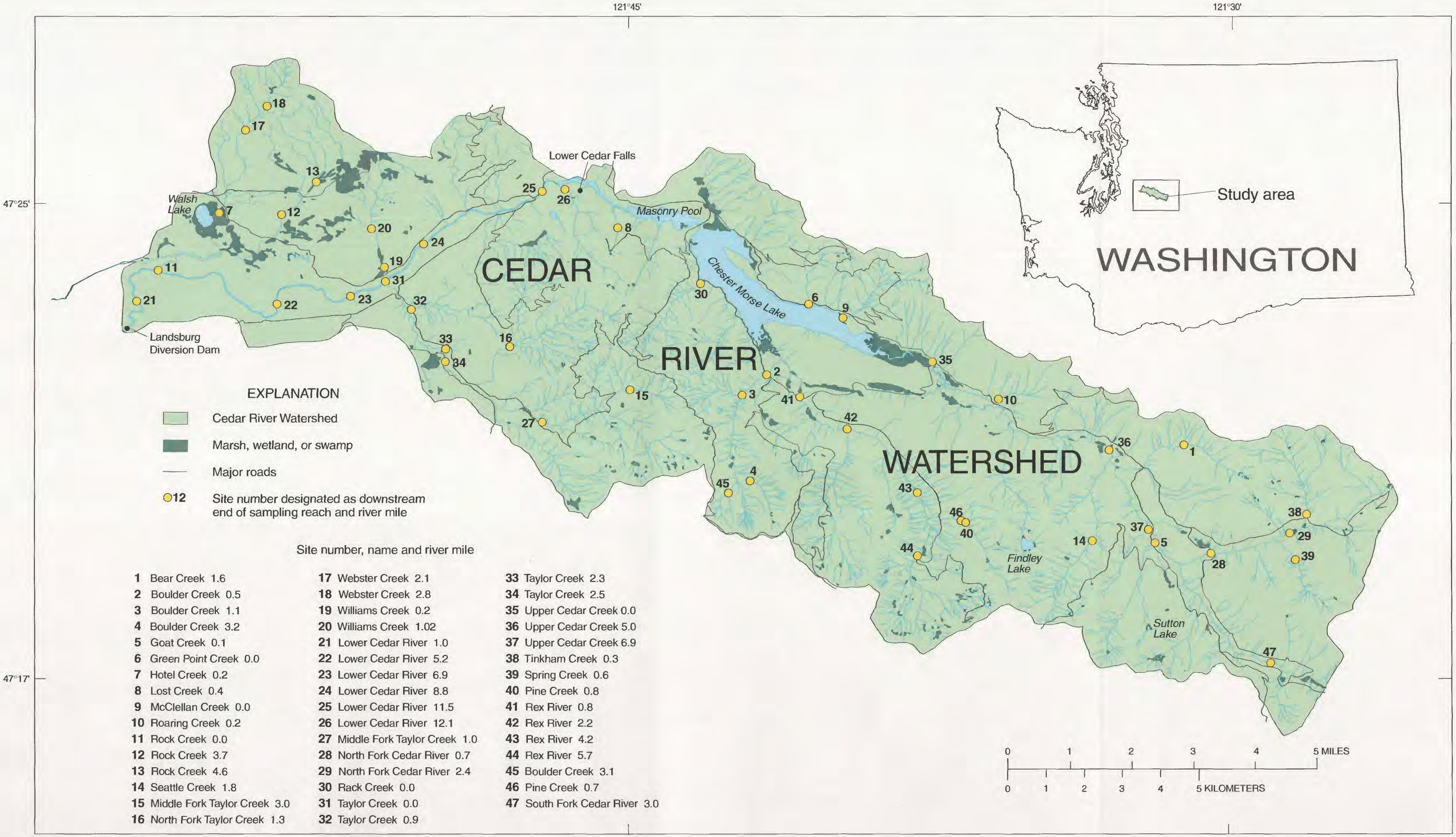
ABSTRACT

As part of the City of Seattle's Cedar River Watershed Aquatic System Monitoring Plan, macroinvertebrates were collected from 45 sites in 1995 and 39 sites 1996. The samples were primarily collected from riffle and some pool sites within the upper Cedar River Watershed in the Cascade Range of Washington. The watershed is protected and supplies municipal drinking water to the City of Seattle. While a large portion of the watershed is undisturbed, some logging has occurred. The macroinvertebrate data collected were used to identify a series of biologically meaningful community attributes or metrics. Metrics were combined into a multimetric index and scored, forming a benthic index of biological integrity (BIBI). Each successfully developed BIBI multimetric list and score was used to evaluate the current biological integrity of selected sites with varying degrees of land management influence within the watershed. The BIBI's developed for these sites also provide a framework in which to evaluate future similar sites. For small, low order streams in the watershed, a series of metrics was combined into two statistically significant BIBI's capable of differentiating sites. The BIBI created for low-elevation and high-elevation, small stream sites were each composed of a unique set of metrics. Although the BIBI's were capable of differentiating sites, many of the BIBI site scores were highly variable between sampling years. The variation in some BIBI scores was large enough to result in a shift in the biological integrity assessment of some sites in spite of no known change in land management activity within the watershed between years. Under ideal circumstances, a BIBI will produce scores that are relatively insensitive to annual variability resulting from natural factors. For low-elevation, large stream sites a statistically significant BIBI capable of differentiating between sites could not be derived. The results presented suggest that BIBI's developed in watersheds with a narrow range of disturbance, such as the Cedar River Watershed, may be subject to annual shifts in BIBI scores. The future use of the BIBI presented in this study for the assessment of biological integrity should be done with great care and with other Cedar River Watershed aquatic system information.

INTRODUCTION

Background

The Cedar River Watershed is located in the western Cascade Range of King County, Washington (fig. 1), and is the primary water supply for the Seattle metropolitan area. In August of 1995, the City of Seattle began a water-quality monitoring project for the watershed which was approved by the Washington State Department of Ecology (Seattle Water, 1995). The purpose of the monitoring project was to implement a program to monitor the chemical, physical, and biological attributes of the Cedar River Watershed. This was done to help evaluate the condition of the aquatic system; identify human impact or land management influences (LMI's) on the aquatic system from activities such as timber harvesting, road construction, and road maintenance; and prioritize watershed restoration projects. The monitoring plan contained three sections: hydrologic monitoring, water quality monitoring, and biological monitoring.



This map produced by the Water Resources Division of USGS, Tacoma District Office, as part of a cooperative project with the Watershed Management Division of Seattle Public Utilities. Geographic data was provided by Seattle Public Utilities (Copyright 1998, City of Seattle, with all rights reserved; no warranties of any sort, including accuracy, fitness, or mercantibility accompanying).

Figure 1. Benthic invertebrate sampling locations in the Cedar River Watershed.

This report addresses part of the biological monitoring section of the plan and reflects the effort of the U.S. Geological Survey (USGS) in cooperation with the City of Seattle to develop a benthic index of biological integrity (BIBI).

Objectives

There are three objectives in the biological monitoring section of the watershed monitoring plan. These objectives are to establish a data base of current benthic communities within the watershed, analyze the influence of past and current land management activities on benthic communities by the development of an index of biological integrity, and provide a framework for a macroinvertebrate data collection program for monitoring land management practices. Under the guidance of the Cedar River Watershed Aquatic System Monitoring Plan (Seattle Water, 1995), the City of Seattle began water quality monitoring and collected 2 years of physical habitat data and benthic macroinvertebrate samples from select sites throughout the watershed. The USGS analyzed the benthic macroinvertebrate samples and developed the BIBI.

Biological Index History

In the last decade, water resources management, monitoring, and protection efforts have experienced a major shift in philosophy. Earlier efforts to regulate aquatic systems by measuring their chemical and physical properties resulted in an incomplete assessment of the health of biological communities due to the temporal nature of the sampling. One way to evaluate the health of aquatic biological communities is through a multi-index (multimetric) analysis. This type of analysis involves defining an array of indices, or metrics, that individually provide information on diverse biological attributes and, when integrated, give an overall indication of the condition of the biological community (Barbour and others 1995; Norris 1995). These metrics may include community richness measures (such as total taxa), composition measures (such as percentage of mayfly species), tolerance measures (such as percent of sediment tolerant species), and trophic measures (such as percent filter feeding species). These metrics and others have been correlated with human impact (Karr, 1991 and 1993). One of the most well-known and frequently applied uses of the multimetric approach is known as the index of biological integrity (IBI). Karr and others (Karr 1981; Karr and others 1986) developed the IBI approach in response to a growing belief that water chemistry and toxicity testing do not adequately measure ecological health or biological integrity. IBI's were originally used to address the Clean Water Act's mandate to restore and maintain the biological integrity of the nation's waters, and have been used in studies across the country to evaluate human impact on stream communities. The original IBI's were calculated using warm water freshwater fish communities in the Midwest United States. However, in the Pacific Northwest, it has been more difficult to develop IBI's in cold water streams because they contain fewer fish species. Therefore, IBI work in the Pacific Northwest has, in some cases, focused on benthic macroinvertebrates. The use of macroinvertebrate communities to assess the biological integrity or health of streams has been successfully applied in the Pacific Northwest (Kleindl, 1995; Fore and others, 1996). The IBI approach that uses benthic macroinvertebrates as its community indicator is known as the benthic index of biological integrity (BIBI). The following report presents the results of a BIBI evaluation of the Cedar River Watershed.

The Cedar River Watershed is protected and considered to be pristine, compared with many watersheds within the Puget Sound region. However, there has been some influence through historic timber harvest and road construction. An IBI for a minimally impacted watershed has not been developed in the Pacific Northwest. Some metrics that work in more extensively impacted areas may not work in the Cedar River Watershed.

Purpose and Scope

The purpose of this report is to present the macroinvertebrate taxonomic data for each sample collected by the City of Seattle and to statistically evaluate metrics as they relate to three LMI's: percentage of site watershed logged within the last 40 years; road density, in miles of road per square miles of the site watershed; and percentage of stream miles in a site watershed within 100 meters of a road. The scope of the sample analysis was limited to 2 years of samples (1995 and 1996) collected from 47 sites within the Cedar River managed watershed.

Description of Study Area

The 90,495 acres of the protected Cedar River Watershed provides 63 percent of the drinking water for 1.3 million people in the Seattle metropolitan area. The watershed is located in the central Cascade Mountains and contains two ecoregions; the low-elevation (less than 3,000 feet) and the high-elevation (greater than 3,000 feet) Western Cascade Mountains. Elevations within the watershed range from 538 feet to 5,449 feet above sea level. The Cedar River main stem flows in a generally northwest direction for approximately 51 miles before entering Lake Washington, which flows into Puget Sound.

The Chester Morse Lake Reservoir and the Masonry Pool, the largest lakes within the watershed, are capable of storing approximately 70,000 acre-feet of water. Originally built for hydroelectric power generation, the Masonry Dam presently controls the water level of the lake. Out of its 70,000 acre-feet of storage capacity, only 30,000 acre-feet are actually available for downstream flow (Seattle Water, 1995). This regulated flow does affect downstream macroinvertebrate populations and land management influence in the lower watershed. The land management influence calculated for the Cedar River main stem sites, downstream of the reservoir, considered only the watershed area below the dam.

The Cedar River Watershed is 94 percent forested, with only 29 percent of the watershed harvested in the last 40 years, a road density of 4 miles per miles squared, and approximately 40 percent of all stream miles within 100 meters of a road.

The watershed topography ranges from flat Puget Sound lowlands to steep, high mountainous terrain. The watershed is underlain with a series of volcanic and volcaniclastic rocks (Frizzel and others, 1984). Alpine deposits consisting mostly of basal till dominate the surficial geology in the eastern portion of the watershed and outwash in the lower river valleys, and the western portion of the watershed is dominated by glacial outwash. The volcaniclastic areas are highly weathered and are landslide hazard areas (Foster Wheeler Environmental Corporation, 1995). The overall watershed landslide density is 0.350 slides per 160 acres, which is much lower than in the land surrounding the watershed.

The western Washington climate is marine with mild, wet falls and winters and drier summers with average annual precipitation from 70 inches in the lowlands to over 120 inches in the higher elevations. Precipitation generally falls as snow in places above 3,000 feet, with rain-on-snow events regularly occurring that are the major cause of flooding in the watershed (Seattle Public Utilities, 1998).

The magnitude and duration of flows in the watershed control the stream channel shape and configuration. The volume and timing of these flows determine the type and amount of habitat available to fish and aquatic macroinvertebrates. Activities such as timber harvesting or road construction can alter infiltration rates and increase flood flows. This in turn may increase streambed and bank scour, cause degradation of aquatic habitats (Seattle Public Utilities, 1998), and alter the aquatic communities. For example, an increase in solar energy reaching a stream as a result of logging in the riparian zone could increase stream temperatures and algae production. This could cause a shift in the macroinvertebrate communities from predator or shredder dominated to grazer dominated (Allan, 1995). An increase in temperature could also directly alter species composition from more temperature sensitive to temperature-insensitive species. Therefore, monitoring the macroinvertebrate community composition is important to evaluate the effect of land management activities on aquatic communities in the watershed.

During the fall and winter of 1995 and winter of 1996 there were major floods in the watershed. The first was a rainfall storm event in October of 1995 that occurred at the time of the 1995 macroinvertebrate sampling and resulted in a 2- to 5-year storm event. The second major storm event occurred at the end of November 1995 and was a rain-on-snow event that affected mainly the eastern portion of the watershed. The largest storm of the winter was also a rain-on-snow event at the end of January and the beginning of February 1996 and affected mainly the western portion of the watershed. The flow in Taylor Creek subwatershed from the February storm was the largest flow for the period of record (41 years). The difference in flow between 1995 and 1996 in the smaller tributaries ranged from no difference at Green Point Creek to 48 cubic feet per second (ft^3/s) at Taylor Creek. The difference in flow between years in the larger rivers ranged from 70 ft^3/s for the Cedar River at Bear Creek to 340 ft^3/s for the Cedar River near Landsburg (Seattle Public Utilities, 1998). These flow changed between years may have had an influence on macroinvertebrate communities but will not be addressed in this report.

The watershed provides habitat for numerous species of terrestrial and aquatic wildlife. Fish found throughout the watershed include rainbow trout (*Oncorhynchus mykiss*), cutthroat trout (*Oncorhynchus clarki*) and various species of sculpin (*Cottus* sp.), and bull trout (*Salvelinus confluentus*) have been found in the upper part of the watershed, including Chester Morse Lake. Pygmy whitefish *(Prosopium coulteri*), golden trout (*Oncorhynchus aguabonita*), largemouth bass *(Micropterus salmoides*) and yellow perch (*Perca flavescens*) have also been found in the lakes and reservoir within the watershed. The migration of anadromous fish, including steelhead trout (*Oncorhynchus mykiss*), sockeye (*Oncorhynchus nerka*), coho (*Oncorhynchus kisutch*) and chinook salmon (*Oncorhynchus tshawytscha*), into the watershed is blocked by the Landsburg Diversion Dam, which is located at the most downstream point within the Cedar River Watershed. The diversion dam isolates approximately 12 miles of main stem habitat between the dam and Lower Cedar Falls. The bull trout and chinook salmon are species of special concern in the study area because they are both listed under the Endangered Species Act.

METHODS

Sampling Sites

The sampling sites for development of the BIBI study were chosen to represent a range of physical characteristics, such as elevations and stream order, and LMI categories. This was done in order to develop effective metrics (biological community attributes) that would clearly change with the magnitude of LMI. The selection was done in a stair-step fashion using physical criteria, then LMI criteria.

Physical Site Categories

Valley Segment Classification

The geomorphology of the stream channels for the selected sites was recorded. This was done to determine gradient, shape and structure of stream segments in order to assure that sites being compared were physically similar. Only stream segments with a gradient of less than 20 percent were classified and selected for site consideration.

Elevation

Since there are natural differences in biological communities at low and high elevations and between ecoregions, sites were divided between less than (<) 3,000 feet (low elevation) and greater than (>) 3,000 feet (high elevation) above sea level. The two elevation types will be referred to as <3,000 or low elevation, and >3,000 or high elevation for the remainder of the report. The majority of the sites were chosen at the lower elevations due to their lower gradients and LMI criteria.

Stream Order

The number of branches in a stream classifies it in size from headwaters (no branches, first-order stream) to large rivers (numerous branches, fifth- or sixth-order stream). When branches of the same order come together, the numbering (order) increases by one (Dunne and Leopold, 1978). The streams in the Cedar River Watershed are divided into two groups: those with stream orders of 1-3 (small streams), and those with stream orders of 4-6 (large streams). For example, the Cedar River at Landsburg is a sixth-order stream.

Land Management Influence (LMI) Categories

Three characteristics or influences chosen to measure the LMI were road density (road miles per watershed area above a site), percentage of timber harvested in the last 40 years within a site watershed, and percentage of stream miles in a site watershed within 100 meters of a road. A site watershed is the drainage area above a sampling site. These three influences were divided into categories of high, medium and low.

The separation of high, medium and low LMI sites was done graphically by plotting the influence values against each other and determining the site groupings. To illustrate, figure 2 shows road density plotted against timber harvest for several hypothetical sites. This type of graph was prepared for all combinations of the three LMI's for all of the Cedar River Watershed sites. Some of the LMI combinations for the Cedar River sampling sites did not give a clear separation between high, medium and low influence as seen on figure 2.

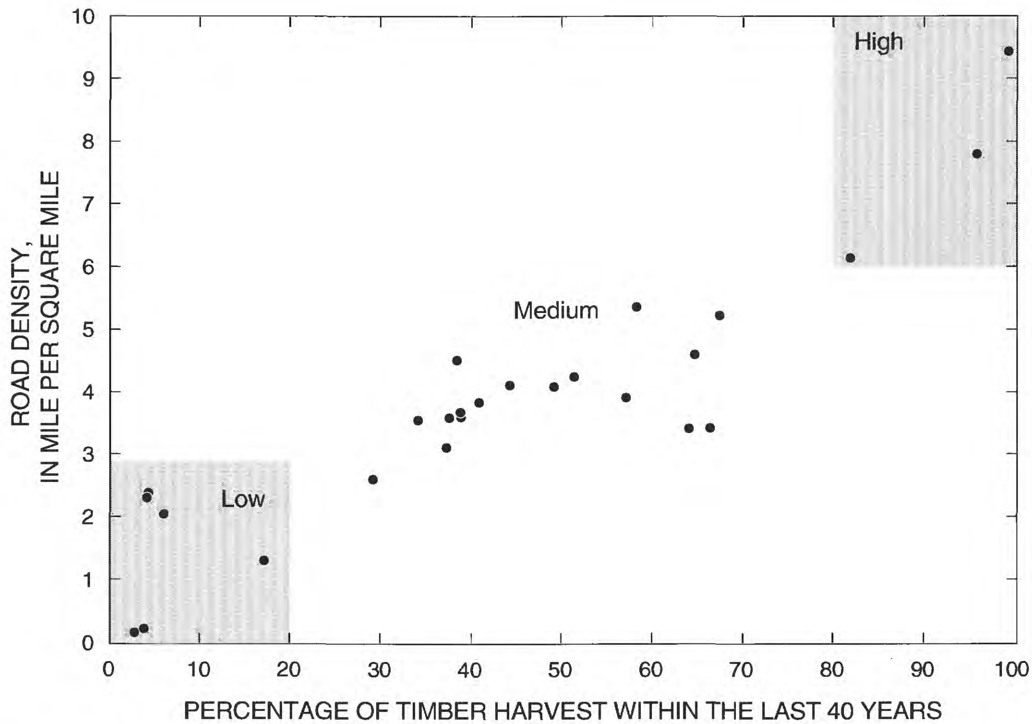


Figure 2. Hypothetical relationship between road density and percentage of timber harvest within the last 40 years showing the division between high, medium, and low land management influenced sites.

Although Cedar River Watershed sites have been used as baseline reference sites to compare other, more impacted sites in the Puget Sound Basin, it was necessary to establish reference conditions within the watershed to develop an effective BIBI. Reference sites or low LMI sites are necessary to determine the biological health of water bodies. The sampling sites for this study were established to represent a range of conditions affected by LMI, from high to low influence. The low LMI sites are considered the reference sites, but these reference conditions will be continually refined as more information is gathered.

LMI criteria played the biggest role in developing the BIBI for different elevation and stream order classifications. The primary criterion for site selection was an even distribution of high, medium, and low LMI sites, but due to stream access and flow conditions, this was not always possible. The LMI criteria and sampling sites are given in table 1. Additional sites were also sampled to evaluate the effectiveness of the BIBI process. These sites are identified as test sites in table 1.

Sample Collection and Benthic Macroinvertebrate Identification

Benthic macroinvertebrate samples were collected by the City of Seattle using methods consistent with the Washington State Department of Ecology's Instream Biological Assessment Monitoring Protocols: Benthic Macroinvertebrates (Plotnikoff, 1994). These protocols were also similar to the U.S. Geological Survey's Methods for Collecting Benthic Invertebrate Samples as Part of the National Water Quality Assessment Program (Cuffney and others, 1993). Three samples were taken from one riffle at each site per year for 2 years. The three samples are referred to as replicates called R1, R2, and R3 throughout this report. The samples were collected in the fall, usually during September and October. This provided a good time for the instream environment to stabilize after natural disturbances, such as spring snowmelt runoff; and it also provides a representation of the benthic macroinvertebrate species when communities reached maximum diversity. The purpose of this sampling design was to measure variability within any riffle as well as between sites.

A modified Surber sampler (415 microns) was used to collect the samples. The stream bottom was thoroughly disturbed within the area delineated by the Surber by scrubbing every removable rock and stirring up the stream bottom.

Pool samples were also collected from three sites for quantitative comparisons with riffle samples collected at the same sites. The pool samples were not used in the development of the BIBI.

The macroinvertebrate field samples were preserved in 85 percent ethanol with 10 percent formalin and stored in plastic bags. Each sample was labeled with the name of the stream sampled, site name, date and time of collection, and collector's name. Proper preservation of the samples was critical to the success of the project by preventing loss of organisms through deterioration. There was some evaporative loss of preservation material from the plastic bags, which caused sample deterioration and some labels to deteriorate. In the future, tightly sealed jars would be preferable for sample storage.

The samples were sorted and completely examined for macroinvertebrates by the City of Seattle. The quality assurance for the sorting procedure consisted of resorting 10 percent of all samples. To do this, a sample was spread evenly in a sorting tray, and 10 random scoops were taken and examined under a dissecting microscope. If no more than 10 macroinvertebrates were recovered, the quality assurance was considered complete. If more than 10 macroinvertebrates were recovered, then the process was continued with another 10 random scoops of the remaining sample. This process continued until the entire sample was reprocessed.

In order to perform a meaningful and accurate assessment of the aquatic ecosystem using BIBI, an accurate identification and enumeration of the benthic macroinvertebrates samples was completed and taxa were identified by EcoAnalysts, Inc., Moscow, Idaho to the lowest level possible. Quality assurance of identification was done by reidentifying 10 percent of the samples. This involved placing the entire sample back into the vial and reidentifying and recounting the individuals. The reidentification was considered successful when the recount was within 10 percent of the original. Also, taxonomic accuracy was evaluated by the USGS Biological Investigation Laboratory in Arvada, Colo. A voucher collection was assembled by EcoAnalysts, Inc. containing specimens of each taxon, sent to the U.S. Geological Survey lab, and verified by an aquatic entomologist. Macroinvertebrate data can be found in Appendixes A and B.

During the sampling period of 1995 and 1996, over 61,000 individual macroinvertebrates were sorted and identified. Five predominant aquatic taxonomic orders were discovered in the samples: Diptera (38 percent), Ephempotera (28 percent), Trichoptera (20 percent), Plecoptera (10 percent) and Coleoptera (4 percent). These taxonomic orders were composed of 167 and 169 unique taxa in the 1995 and 1996 samplings, respectively. A total of 199 unique taxa were identified for both sampling years. The voucher collection used to evaluate the taxonomic accuracy of the macroinvertebrate identification laboratory showed that eight taxa were misidentified at the genus-species level. An identification error of less than 5 percent based on the total number of taxa identified and a 1-percent error based on the total number of individuals identified was viewed as acceptable.

Metric Data Analysis

A benthic index of biological integrity (BIBI) approach was utilized to assess the overall ecological health of the Cedar River system as part of the Cedar River Watershed Aquatic System Monitoring Plan. The BIBI helps to identify influences on aquatic communities from timber harvest and road construction, and to identify areas in the watershed in need of restoration. The BIBI approach extracts relevant community patterns from aquatic macroinvertebrate taxa lists and quantitatively relates those patterns to land management influences (LMI's) within a watershed. The community patterns or attributes are sometimes called metrics and this approach is often referred to as a multimetric approach (Karr and others, 1986; Barbour and others, 1995; Fore and others, 1996).

Prior to developing a BIBI for the Cedar River Watershed, sampling sites representing different levels of LMI had to be established, as discussed above. Following site selection, a BIBI framework was developed using methods outlined in the Cedar River Watershed Aquatic System Monitoring Plan (Seattle Water, 1995) and in a Puget Sound lowland study (Kleindl, 1995). The framework consists of selecting biologically meaningful metrics, selecting the best metrics, developing a range of metric scores, testing the BIBI scores across a range of LMI, and the application of the BIBI in the Cedar River Watershed.

Table 1. Stream names, river mile, degree of influence and land management influence criteria for invertebrate samples taken from the Cedar River Watershed in 1995 and 1996 as part of the Cedar River Watershed Aquatic System Monitoring Plan

[*, estimated value; mi/sq/mi, miles per square miles]

				Land management influence				
Stream name	River mile	Map site number	Degree of land management influence	Percentage of basin harvested in 40 years	Road density (mi/sq/mi) 1995	Road density (mi/sq/mi) 1996	Total percentage of stream miles within 100 meters of road, 1995	Total percentage of stream miles within 100 meters of road, 1996
Sites at elevation less than 3,000 feet above sea level and stream order 1 to 3								
Hotel Creek	0.2	7	Low	4	3.79	3.79	37	37
Rock Creek[1]	0.0	11	Low	4	2.39	2.39	26	26
Rock Creek[1,2]	3.7	12	Low	4	2.31	2.31	19	19
Rock Creek	4.6	13	Low	6	2.05	2.05	20	20
Goat Creek	0.1	5	Medium	39	3.64	3.64	30	30
Roaring Creek	0.2	10	Medium	41	3.84	3.84	14	14
Williams Creek[2]	0.2	20	Medium	0	3.68	3.68	37	37
Williams Creek4	1.0	21	Medium	1	3.67	3.67	36	36
Green Point Creek[2]	0.0	6	High	31	6.96	6.96	64	64
Lost Creek	0.4	8	High	99	9.44	9.44	73	73
McClellan Creek[2]	0.0	9	High	30	5.84	5.84	57	57
Middle Fork Taylor Creek	3.0	16	High	57	3.92	3.92	40	40
Seattle Creek	1.8	15	High	65	4.61	4.61	46	46
Webster Creek	2.1	18	Test	4	4.57	4.57	34	34
Webster Creek	2.8	19	Test	*4	4.50	4.50	29	29
Sites at elevation less than 3,000 feet above sea level and stream order 4 to 6								
Lower Cedar River	1.0	22	Medium	12	4.64	4.64	42	42
Lower Cedar River	5.2	23	Medium	15	4.70	4.70	42	42
Lower Cedar River	6.9	24	Medium	15	4.63	4.63	42	42
Lower Cedar River	8.8	25	Medium	14	5.27	5.27	45	45
North Fork Cedar River	0.7	29	Medium	29	2.61	2.61	29	29
North Fork Taylor Creek	1.3	17	Medium	8	6.38	6.38	49	49
Taylor Creek[2]	0.0	32	Medium	19	4.35	4.35	40	40
Taylor Creek	0.9	33	Medium	21	4.37	4.37	41	41
Boulder Creek[2]	0.5	2	High	64	3.67	3.42	29	26
Boulder Creek	1.1	3	High	66	3.43	3.43	25	25
Middle Fork Taylor Creek	1.0	28	High	38	4.52	4.52	41	41
Rack Creek[1,2]	0.0	31	High	58	5.36	5.36	42	42
Rex River	0.8	42	High	51	4.25	4.25	35	35
Rex River	2.2	43	High	44	4.12	4.12	34	34
Rex River	4.2	44	High	49	4.10	4.10	37	37

Table 1. Stream names, river mile, degree of influence and land management influence criteria for invertebrate samples taken from the Cedar River Watershed in 1995 and 1996 as part of the Cedar River Watershed Aquatic System Monitoring Plan—Continued

				Land management influence				
Stream name	River mile	Map site number	Degree of land management influence	Percentage of basin harvested in 40 years	Road density (mi/sq/mi) 1995	Road density (mi/sq/mi) 1996	Total percentage of stream miles within 100 meters of road, 1995	Total percentage of stream miles within 100 meters of road, 1996
Sites at elevation less than 3,000 feet above sea level and stream order 4 to 6—Continued								
Rex River	5.7	45	High	67	5.23	5.23	49	49
Lower Cedar River	11.5	26	Test	39	6.32	6.32	53	53
Lower Cedar River	12.1	27	Test	44	5.84	5.84	48	48
North Fork Cedar River	2.4	30	Test	37	3.11	3.11	34	34
Taylor Creek	2.3	34	Test	22	4.46	4.46	41	41
Taylor Creek	2.5	35	Test	22	4.45	4.45	41	41
Upper Cedar River	0.0	36	Test	34	3.61	3.55	34	34
Upper Cedar River	5.0	37	Test	38	3.64	3.59	35	35
Upper Cedar River[2]	6.9	38	Test	39	3.68	3.68	36	36
Sites at elevation greater than 3,000 feet above sea level and stream order 1 to 3								
Bear Creek	1.6	1	Low	3	0.16	0.16	0	0
Spring Creek	0.6	40	Low	4	0.22	0.22	0	0
Pine Creek[3]	0.7	47	Medium	40	0.95	0.95	8	8
Pine Creek	0.8	41	Medium	42	1.09	1.09	9	9
Boulder Creek	3.2	4	High	96	7.80	7.80	55	55
Boulder Creek[3]	3.1	46	High	75	1.01	1.01	3	3
South Fork Cedar River	3.0	48	Test	82	6.15	6.15	60	60
Tinkham Creek	0.3	39	Test	17	1.31	1.31	18	18

[1]Pool samples also collected at these sites.
[2]Samples only collected in 1995.
[3]Samples only collected in 1996.

Biologically Meaningful Metrics

It was important to choose biologically meaningful macroinvertebrate metrics that are correlated with LMI's. A number of agencies and studies have proposed and utilized numerous metrics thought to respond to land management activities in predictable ways (table 2). These metrics can be grouped in four general classes: absolute abundance or richness (such as Ephemeroptera taxa), relative abundance or richness (such as percent dominance using the three most abundant species), tolerance measures (such as percent sediment tolerant species), and trophic measures (such as percent predators).

Table 2. Macroinvertebrate metrics used by other studies

[Ecology, Washington State Department of Ecology; DEQ RBP, Oregon Department of Environmental Quality rapid bioassessment protocols; BIBI, benthic index of biological integrity; spp, species]

Metric	Ecology	Puget Sound Lowland studies[1]	Oregon DEQ RBP studies	Oregon BIBI studies[1]	Aquatic Biology Associates	Tennessee Valley[1]	Ohio Biological Criteria	Rapid Bioassessment Protocol
				Absolute abundance / richness measures				
Total taxa	X	X	X	X	X	X	X	X
Abundance	--	--	--	X	X	--	--	--
Relative abundance	X	--	--	--	--	--	--	--
EPT taxa	X	--	X	--	X	--	X	X
Ephemeroptera taxa	--	X	--	X	--	X	X	--
Ephemerellidae taxa	--	--	--	--	X	--	--	--
Ephemerellidae and Heptageniidae taxa	X	--	--	--	X	--	--	--
Plecoptera taxa	--	X	--	X	--	X	X	--
Trichoptera taxa	--	X	--	X	--	X	X	--
Rhyacophilidae taxa (predaceous caddis)	X	--	--	--	X	--	--	--
Dipteran taxa	--	--	--	--	X	--	X	--
				Relative abundance / richness measures				
EPT taxa, percentage	--	--	X	--	--	--	--	--
Ephemeroptera taxa, percentage	--	--	--	--	--	--	X	--
Trichoptera, percentage	--	--	--	--	--	--	X	--
Simuliidae, percentage	--	--	--	--	X	--	--	--
Percentage of dominance (3 spp)	--	--	--	X	--	--	--	--
Percentage of dominance (1 spp)	X	--	X	--	X	--	--	--
Oligochaetes, percentage	--	--	--	--	X	--	--	--
Leeches	--	--	--	--	X	--	--	--
Chironomids, percentage	--	--	X	--	X	--	--	--
Cricotopus Nostococladius. percentage	--	--	--	--	X	--	--	--
Tanytarsini midges, percentage	--	--	--	--	--	--	X	--
Other Diptera and non-insects, percentage	--	--	--	--	--	--	X	--
Planariidae and Amphipoda abundance, percentage	--	X	--	--	--	--	--	--
Voltinism (number of life cycles)	X	--	--	--	--	--	--	--

Table 2. Macroinvertebrate metrics used by other studies—Continued

Metric	Ecology	Puget Sound Lowland studies[1]	Oregon DEQ RBP studies	Oregon BIBI studies[1]	Aquatic Biology Associates	Tennessee Valley[1]	Ohio Biological Criteria	Rapid Bioassess-ment Protocol
				Tolerance measures				
Intolerant taxa	--	X	--	X	--	--	--	--
Intolerant EPT, percentage	X	--	--	--	--	--	--	--
Tolerant taxa, percentage	--	X	--	X	--	--	X	--
Intolerant Ephemeroptera, percentage	--	--	--	--	X	--	--	--
Intolerant Ephemeroptera	--	--	--	--	X	--	--	--
Tolerant Ephemeroptera	--	--	--	--	X	--	--	--
Intolerant Plecoptera, percentage	--	--	--	--	X	--	--	--
Nemouridae taxa (shredder stonefly)	--	--	--	--	X	--	--	--
Long-lived taxa	--	X	--	--	X	--	--	--
Pteronarcys taxa (long-lived stonefly)	--	--	--	X	X	--	--	--
Tolerant Trichoptera, percentage	--	--	--	--	X	--	--	--
Intolerant Trichoptera, percentage	--	--	--	--	X	--	--	--
Tolerant beetles, percentage	--	--	--	--	X	--	--	--
Tolerant beetle taxa	--	--	--	--	X	--	--	--
Hydropsychidae (tolerant caddis), percentage	X	--	--	--	--	--	--	--
Glossosomatidae (intolerant scraper caddis), percentage	X	--	--	--	X	--	--	--
Philopotamidae (sediment sensitive caddis), percentage	--	--	--	--	X	--	--	--
Arctopsychidae (long-lived caddis), percentage	--	--	--	--	X	--	--	--
Psychomyiidae (sediment sensitive caddis), percentage	--	--	--	--	X	--	--	--
Sediment intolerant taxa	--	--	--	X	--	--	--	--
Sediment tolerant, percentage	--	--	--	X	--	--	--	--
Tolerant Dipterans, percentage	--	--	--	--	X	--	--	--
Tolerant molluses, percentage	--	--	--	--	X	--	--	--
Tolerant crustacea, percentage	--	--	--	--	X	--	--	--
Tolerant odonates, percentage	--	--	--	--	X	--	--	--
Hilsenhoff biotic index	X	--	X	--	X	--	--	--
Diversity index, H'	--	--	X	--	--	--	--	--
Community loss index	--	--	--	--	--	--	--	X
Family biotic index (modified)	--	--	--	--	--	--	--	X
Ratio EPT/Chironomid abundances	--	--	--	--	--	--	--	X
Contribution dominant family, percentage	--	--	--	--	--	--	--	X
Biotic Condition Index	X	--	--	--	--	--	--	--

Table 2. Macroinvertebrate metrics used by other studies—Continued

Metric	Ecology	Puget Sound Lowland studies[1]	Oregon DEQ RBP studies	Oregon BIBI studies[1]	Aquatic Biology Associates	Tennessee Valley[1]	Ohio Biological Criteria	Rapid Bioassess-ment Protocol
			Trophic measures					
Plecoptera and Trichoptera shredders	X	--	--	--	--	--	--	--
Shredder taxa	--	--	--	--	X	--	--	--
Shredder, percentage	X	--	X	--	--	--	--	--
Scraper taxa	--	--	--	--	X	--	--	--
Scraper, percentage	X	--	X	X	X	--	--	--
Xylophage taxa (wood eater)	--	--	--	--	X	--	--	--
Predator	--	--	--	--	X	--	--	--
Predator, percentage	X	X	--	--	--	X	--	--
Gatherer, percentage	X	--	--	--	X	--	--	--
Parâsite, percentage	--	--	--	--	X	--	--	--
Filterers, percentage	X	--	X	--	--	--	--	--
Ratio of schredders / total	--	--	--	--	--	--	--	X
Ratio of scrapers / filter collectors	--	--	--	--	--	--	--	X

[1]Proposed metrics to be used in the Cedar River Wtershed benthic index biological index (BIBI).

Previously established hypotheses about how each metric responded to disturbance were used to evaluate them for use in this study (Cummins and others, 1989; Karr and Kerans, 1991; Karr and Chu, 1997). For example, it was hypothesized that the total taxa would decline as the extent of LMI increased. Conversely, it was hypothesized that the proportion of tolerant macroinvertebrates would increase with increased LMI's. Many different metrics have been used in previous studies; of these, 15 were selected for this study based on previous work done in the Pacific Northwest (Kleindl, 1995; Fore and others, 1996; Karr and Chu, 1997). The 15 metrics and their hypothesized responses to LMI's are presented in table 3.

Table 3. Attributes of aquatic invertebrate community assemblages (metrics) and predicted responses to human disturbance

Metric	Predicted response
Total taxa	Decrease
Ephemeroptera taxa	Decrease
Plecoptera taxa	Decrease
Trichoptera taxa	Decrease
Intolerant taxa	Decrease
Long lived taxa	Decrease
Pteronarcys sp.	Decrease
Clinger taxa	Decrease
Sediment intolerant taxa	Decrease
Total abundance	Decrease
Dominance of 3 taxa, percentage	Increase
Tolerant species, percentage	Increase
Sediment tolerant species, percentage	Increase
Scrapers, percentage	Decrease
Predators, percentage	Decrease

Macroinvertebrate taxa tolerance and sediment tolerance were based on information found in Wisseman (1996) and Kleindl (1995), respectively. For tolerance measures, the most and least tolerant taxa were identified rather than assigning a tolerance ranking to each taxa. The number of clinger taxa, percent scrapers, and percent predators were all identified based on Merritt and Cummins (1984). The species that are included in these metrics are given in appendixes A and B.

The tolerant and intolerant taxa are defined mainly by the quality of habitat in which they are found and are subject to the experience of entomologists working with particular macroinvertebrate communities. For example, percent intolerant species would be cold-water adapted and intolerant of fine sediment, would require high oxygen levels, and would be sensitive to high winter scour and resorting of substrates (Wisseman, 1996). Tolerant species exhibit high tolerance to warmer water, fine sediment, and/or nutrient enriched situations (Wisseman, 1996).

An additional metric used in this study included long-lived taxa. Long-lived taxa are macroinvertebrates that live two or more years to complete their life cycle (Kleindl, 1995).

In some samples it was difficult to identify macroinvertebrate taxa to the lowest taxonomic level, and adjustments were made to the data set used to calculate metrics for each replicate sample at a site. For example, terrestrial insects and Hymenoptera were removed from the data set because they were either not aquatic or were considered to be lake organisms. Prior to calculating richness values, the data set was modified to avoid duplicating taxon counts. Taxa that could not be identified to the lowest level possible were considered to be an immature or unidentifiable form of another species within that family or genera. For example, if two individuals at a site were identified as *Ironedes* sp. (a genus of mayfly) and *Ironedes grandis* (a species of mayfly), *Ironedes* sp. would be considered an immature or unidentifiable form of *Ironedes grandis*. In this case, the *Ironedes* sp. taxon count would be zero for this site. Table 4 provides other examples of how the data set was modified prior to the calculation of the 15 chosen metrics. Once the data set was modified, 15 unique metric values were calculated for each of the 3 replicates, collected at each site in 1995 and 1996. Examples of all metric values for all samples can be found in Appendixes C and D.

Table 4. Alteration of raw data for richness metric calculations

[The data manipulation was done on the data prior to the calculation of richness metrics that include total taxa, Ephemeroptera taxa, Plecoptera taxa, Trichoptera taxa, intolerant taxa, sediment intolerant taxa, long-lived taxa, and *Pteronarcys* taxa; sp, species]

Order	Family	Taxon	Site 1	Site 2
Ephemeroptera	--	--	[1]100...0	[1]24...0
Ephemeroptera	Heptageniidae	--	[1]4...0	[1]1...0
Ephemeroptera	Heptageniidae	Ironodes sp.	0	[1]3...0
Ephemeroptera	Heptageniidae	Ironopsis grandis	4	5
Ephemeroptera	Heptageniidae	Rhithrogena sp.	27	9
Ephemeroptera	Leptophlebiidae	--	[1]8...0	2
Ephemeroptera	Leptophlebiidae	Paraleptophlebia sp.	2	0
--	--	Total taxa	3	3
--	--	Total abundance	145	54

[1]Taxa were changed to (...) zero.

Best Metrics

After compiling the macroinvertebrate data and identifying meaningful metrics, the next step is identification of the best metrics for inclusion in the BIBI. The best metrics are those that respond predictably to land management influences (LMI's), vary enough across sites to distinguish between the low LMI and high LMI sites, are similar across the area of interest and influence conditions, are not correlated with other metrics, and exhibit consistent patterns over time.

To evaluate these factors and identify the best metrics, a graphical interpretation method similar to that used by Fore and others (1996). The average of each metric value calculated by site was plotted against each of the three LMI factors used to assign high, medium, and low influence sites. Prior to calculating average metric scores for each site, replicate samples with less than 100 individuals were not included in the BIBI calculations. It has been shown that samples with limited numbers of individuals can produce variable BIBI results (Fore and others, 1994), and suggested that samples with less than 100 individuals may be inappropriate for use in a BIBI analysis (Karr and Chu, 1997). Plots were created for the low elevation-small and large streams for 1995 and 1996, and the high elevation-small streams for 1996. This resulted in the creation of 225 metric evaluation graphs (Appendixes E and F). Each graph was examined to determine if the metrics followed the hypothesized trend presented in table 3. For example, if a metric was predicted to decline with increasing LMI, a negative relationship was expected. To help assess the statistical relationship between metrics and types of disturbance, a Spearman's rank correlation coefficient (Sokal and Rohlf, 1981) was calculated. The correlation coefficients were used to help establish trends rather than reject or accept specific metrics for inclusion in the BIBI. Metrics with little or no overlap between high LMI and low LMI sites and arrayed medium LMI sites between the extremes (figure 3) in 1995 data were selected and compared with data from 1996. Only those metrics that responded to a gradient of influence and clearly separated the high LMI and low LMI sites for both 1995 and 1996 were selected for inclusion in the BIBI analysis.

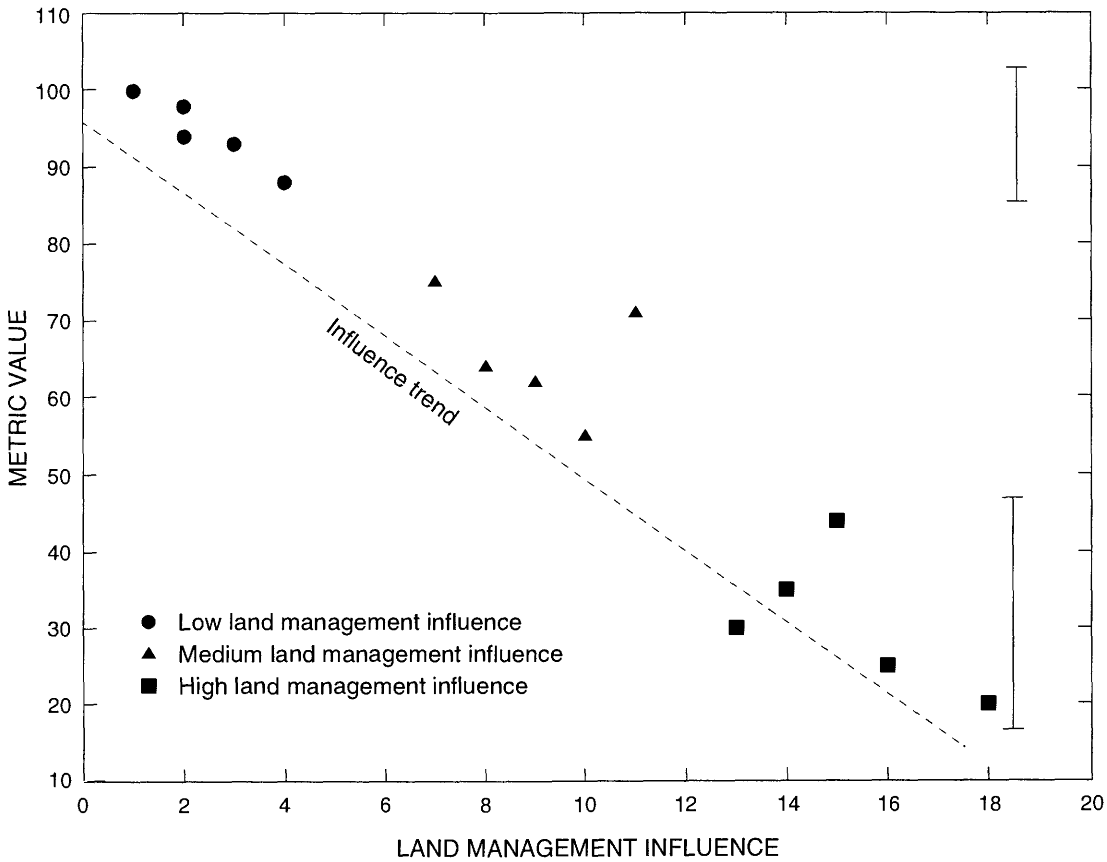


Figure 3. Trend in average metric values as land management influence increases. Note the separation in low and high influence site metrics highlighted by the bars on the right side of the figure.

Range of Index Scores

A range of index scores for each chosen metric was developed in three classes: 1 for high LMI sites, 3 for medium LMI sites, and 5 for low LMI sites. To establish ranges of scoring criteria, a cumulative distribution function (CDF) was plotted for each of the chosen metrics. An example of CDF graphs can be seen on figure 4. A CDF distribution tells what percent of the total observations in the data collection are of a particular value or lower (Kachigan, 1986).

The data used in the CDF plots included the mean metric values from the replicate samples with more than 100 invertebrates by site calculated for 1995 and 1996 data. CDF plots were created for each best metric chosen at the low elevation-small stream and the high elevation-small stream sites. As noted by Fore and others (1996), general rules for setting metric scoring criteria are difficult to define. If natural breaks occurred in the CDF, metric scores were assigned to reflect these breaks. For example, on figure 4a the CDF from hypothetical metric values show two distinct breaks. Based on these breaks, a metric score of 1 would be assigned to all those sites with metric values less than 8, a score of 3 to sites between 8 and 18, and a score of 5 to sites greater than 18. If the CDF plots did not exhibit any natural breaks, as seen on figure 4b, the distribution was divided at the 33rd and 67th percentiles.

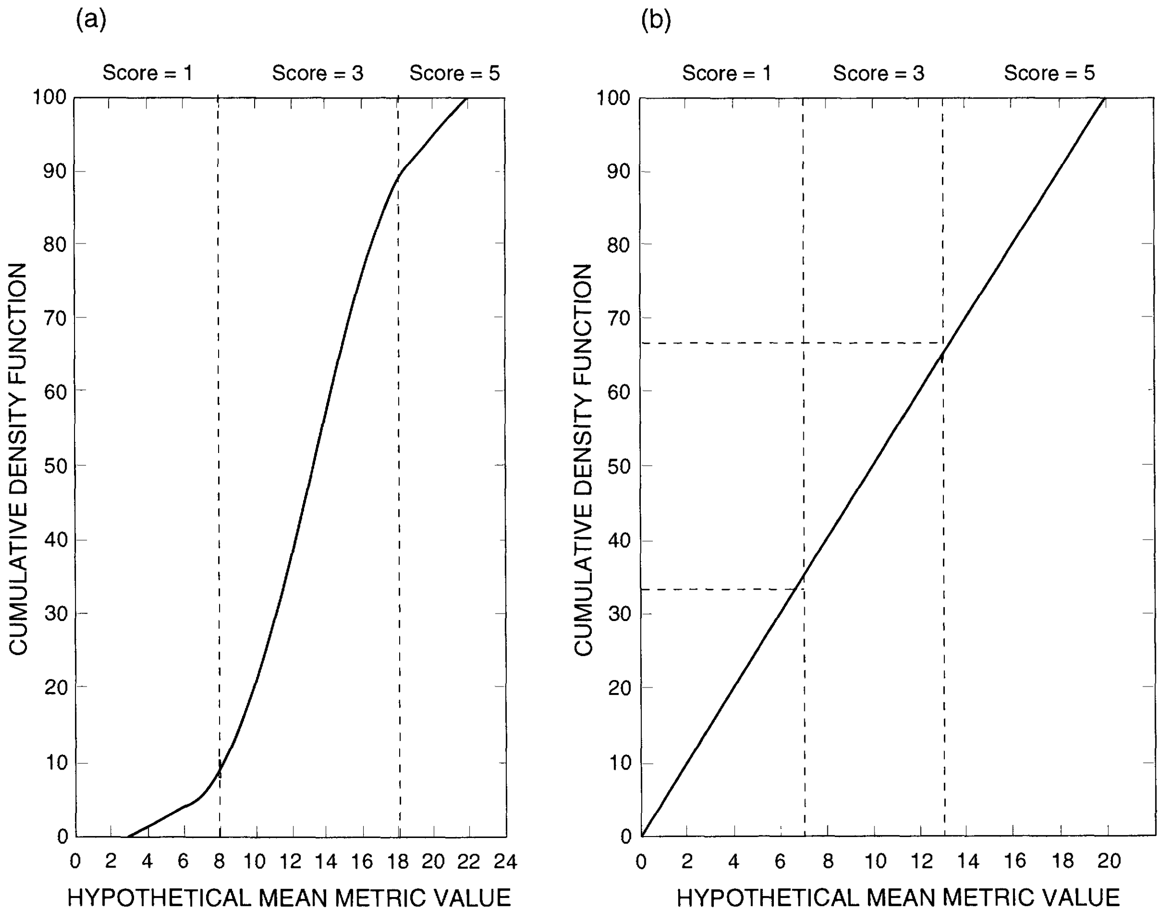


Figure 4. Example of the calculation of metric scores based on graphing cumulative density function using hypothetical metric values. Graph (a) shows the metric scoring divisions based on natural breaks in the cumulative density function. Graph (b) shows the scoring divisions at the 33rd and 67th percentiles.

For the Cedar River Watershed, it was suspected that there would be very little variability between sites within each of the three physical site categories. Therefore, the medium LMI category (score = 3) was broadened to include more sites, thus making it more difficult for a site to score a 1 or a 5 (Fore and others, 1996). For the high-elevation sites, there were only four sites used in the CDF plots, and in some cases only a score of 1 or 5 was generated. The sum of all metric scores was used to produce a single BIBI score for each sample collected.

Testing the Benthic Index of Biological Integrity (BIBI) Scores

One of the main objectives of this study was to develop a BIBI that could discriminate between sites that have experienced different levels of LMI. The Cedar River Watershed has restricted access to protect the drinking water for the City of Seattle, so human influence has been relatively minor. However, as noted above, logging has occurred within the watershed. Historic logging activities (such as timber harvest and road construction) were used to assign each sampling site to a high, medium, or low LMI category (table 1). The BIBI scores developed for each sample collected at each site were used to statistically evaluate the biological integrity of sites within each physical site category.

For low-elevation stream sites, two hypotheses were proposed. The first was the hypothesis that there was no difference in the mean BIBI scores between low, medium, and high LMI sites for low elevation-small streams. The second was the hypothesis that there was no difference in the mean BIBI scores between medium and high LMI sites for low elevation-large stream sites. While the low-elevation, small stream sites had three LMI categories (high, medium, and low), the low-elevation, large stream sites had only two LMI categories (high and medium). The low-elevation, large stream sites drain larger watersheds and receive a higher degree of LMI. Therefore, there were no low LMI sites sampled in the large streams. To test these hypotheses a nested analysis of variance (ANOVA) and post-hoc multiple comparison design were proposed (Sokal and Rohlf, 1981). Given the 100-individuals-per-replicate requirement for a sample to be included in the BIBI, a number of samples were excluded from the analysis, and the proposed nested ANOVA could not be completed. This necessitated using an ANOVA rather than a nested ANOVA design.

For the high-elevation, small stream sites, two hypotheses were proposed for testing using two-sample t-tests (Sokal and Rohlf, 1981). The first hypothesis proposed was that there was no difference between the difference in mean BIBI scores for two sites in the Pine Creek Basin that have been subjected to different logging practices. The one major difference between these sites is that the forest stand adjacent to site PIN 0.8 has been clear-cut within the last 30 years, whereas the forest adjacent to site PIN 0.7 is considered old growth. Unfortunately, these sites did not have an adequate number of invertebrates to test this hypothesis. Another hypothesis tested for the high-elevation, small stream sites was that there was no difference in the mean BIBI scores for high LMI sites compared to the low LMI sites.

A statistical comparison between metric values calculated for pools and riffles was done to evaluate if collecting macroinvertebrates only from riffles would produce an effective BIBI. Previous studies have used invertebrate samples collected from pools to create a BIBI (Kerans and Karr, 1994). Fifteen metric values were calculated for pool and riffle samples collected from select sites (Appendixes C and D). The hypothesis that pool metric values are the same as riffle metric values was analyzed using a non-parametric Wilcoxon's signed-ranks test (Sokal and Rohlf, 1981).

Lastly, the hypothesis that there is no significant difference between metric values for high-elevation, small streams and low elevation-small stream was tested using a non-parametric Mann-Whitney test (Sokal and Rohlf, 1981). This was done to evaluate the influence of elevation on individual metric scores.

Application of the Benthic Index of Biological Integrity (BIBI)

The final item in the BIBI framework is the utilization of the BIBI relationships to assess the biological integrity of the Cedar River Watershed and help determine management actions within the watershed. Further assessments are needed to detect trends in management actions. The BIBI results presented in this study should be incorporated with the results from the other components of the Monitoring Plan (Seattle Water, 1995) and evaluated as a whole.

Habitat Data Analysis

In addition to the collection of macroinvertebrate samples, several habitat parameters were also measured at the BIBI sites. One of these was percent canopy cover calculated with a spherical densiometer (Appendix G). Several qualitative assessments were taken that included percent fine material, percent in-stream cover, percent embeddedness, percent woody debris, channel shape, pool-riffle ratio, width-depth ratio, percent bank vegetation, and bank stability (Appendix H). Width and depth were measured at a number of locations throughout the reaches in which macroinvertebrate were collected (Appendix I). This data was used to calculate the width-depth ratio for the statistical analysis described below. Riparian vegetation measurements were taken at each site, such as percent big trees at a site (Appendix J). Substrate conditions at each site were also recorded (Appendix K). A more detailed discussion of the methods used to collect the habitat variable data can be found in Seattle Water's (1995) Cedar River Watershed Aquatic System Monitoring plan.

Detailed habitat measures are not required to develop an effective BIBI. However, some preliminary statistical correlations between some of the habitat measures and final BIBI scores for some sites were evaluated and may help to interpret these scores. A backwards stepwise regression procedure (Kachigan, 1986) was used to determine if there was a relationship between some of the habitat variables and the BIBI scores. This procedure requires all variables to be added to the regression analysis. The least useful predictor habitat variable is removed, and the regression model reevaluated. This procedure continues until the variables left in the regression model have met a predetermined quantitative inclusion value (alpha level). The alpha level is a numerical limit put on the variables significance at influencing the BIBI scores between sites. The habitat data and BIBI scores calculated for 1995 and 1996 data were separated by elevation class (>3,000 ft. and <3,000 ft.) and analyzed separately. Initial graphs of the habitat variables and BIBI scores provided a visual relationship in order to develop a list of the most influential variables to be included in the stepwise regression.

The low-elevation habitat variables chosen to be included in the stepwise regression were percent canopy cover, in-stream substrate embeddedness, percent sand, stream width, maximum water depth, in-stream width-depth ratio, and average big trees and average barren ground in the riparian zone. The high-elevation habitat variables chosen were the percentages of sand, gravel, cobble, and boulders in-stream at each site, in-stream substrate embeddedness, percent canopy cover, and average number of big trees in the riparian zone.

RESULTS AND DISCUSSION

Low-Elevation, Small Stream Sites

Metric Selection

Initially, a total of 13 low-elevation, small stream sites were examined, 5 high LMI, 4 medium LMI, and 4 low LMI. Two additional sites were set aside to test the outcome of the BIBI (table 1). While the goal was to sample these sites in both 1995 and 1996, four sites were not sampled in 1996 due to low flow conditions. In addition, a number of sites were excluded from the BIBI analysis for both years because none of the three replicate samples for a particular site had more than 100 invertebrate individuals. Low flow conditions in 1996 and replicate samples with fewer than 100 invertebrate individuals resulted in the following breakdown of sites used in the BIBI development: 6 sites in 1995 (1 high LMI, 1 medium LMI, and 4 low LMI) and 5 sites in 1996 (1 high LMI, 1 medium LMI, and 3 low LMI). The outcome of plotting the mean value of each metric for each site against the three measures of LMI for 1995 and 1996 are presented in Appendixes E and F.

In 1995, 5 out of 15 metrics were identified as meeting the criteria for best metrics outlined in the methods section. These metrics included numbers of total taxa, long-lived taxa, Trichoptera taxa, clinger taxa, and sediment-intolerant taxa. Correlation coefficients were used to measure the degree and direction of the linear relationship between each metric and LMI category (table 5). A coefficient of 1 or –1 indicates a perfect positive or negative relationship, respectively, between a specific metric and LMI category. Negative correlations were expected for the five selected metrics. As noted in the methods section, a statistically non significant correlation does not mean that a metric should be discarded (Yoccoz, 1991). The five selected metrics did successfully separate the high and low LMI sites along a gradient of human influences (Appendix E), and the correlations were generally negative. But a number of correlation coefficients between some of the metrics and the percent of stream miles within 100 meters of a road were positive. These results can be explained by the one medium LMI site on Roaring Creek (site number 10), which appears to be an outlier. Although this site has a low percentage of stream miles upstream within 100 meters of a road, many of the metric values were lower than expected. For this site, the medium LMI category may not be as effective at determining human influence as the other two categories.

A similar evaluation was carried out for the data collected at low-elevation, small stream sites in 1996. As noted previously, only 5 of the original 13 sampling sites in 1996 were appropriate for inclusion. Three metrics satisfied the metric selection criteria for the 1996 low elevation-small stream sites (Appendix F). These metrics included total taxa, sediment-intolerant taxa and total abundance (table 5). As expected, all of the correlations were negative. Only two of the metrics selected from the 1995 and 1996 data sets were the same; the total number of taxa, and the number of sediment-intolerant taxa. These metrics were the only two used to develop the BIBI for low-elevation, small stream sites.

Table 5. Selected metrics and Spearman rank correlation coefficients by land management influence for first through third order sites less than 3,000 feet above sea level in the Cedar River Watershed

[Correlation coefficients of 1 and -1 indicate perfect positive and negative correlations, respectively.; LMI, land management influence]

Metric	Predicted response to increase in LMI	Percentage of basin harvested in last 40 years	Road density (miles per square miles)	Percentage of steam miles within 100 meters of a road
		1995		
Total taxa	Decrease	-0.08	-0.48	-0.41
Ephemeroptera taxa	Decrease	-0.02	-0.47	-0.44
Trichoptera taxa	Decrease	0.01	-0.41	-0.24
Clinger taxa	Decrease	-0.09	-0.53	-0.41
Sediment intolerant taxa	Decrease	0.07	-0.35	-0.47
Total abundance	Decrease	-0.08	-0.53	[1]-0.62
		1996		
Total taxa	Decrease	-0.31	-0.49	-0.28
Sediment intolerant taxa	Decrease	-0.29	[1]-0.70	-0.57
Total abundance	Decrease	-0.40	-0.51	-0.19

[1]Correlations significantly different from 0 at $p = 0.05$.

Metric Scoring Criteria

Because the selected metrics differed in scale, it was necessary to transform them to a similar scale prior to combining them into a BIBI site score. CDF plots were created for the total taxa and sediment-intolerant taxa metrics for 1995 and 1996 data to establish these scores (figure 5). Once the scoring criteria were established, a metric score was assigned to each of the replicate samples containing more than 100 invertebrate individuals collected at each site in 1995 and 1996 (tables 6 and 7). Scores for total taxa and sediment-intolerant taxa were added to get a final BIBI score for each replicate, and a mean BIBI score was calculated. Mean BIBI scores ranged between 4, for the high LMI site in 1996, and 8, for some of the low LMI sites in both 1995 and 1996.

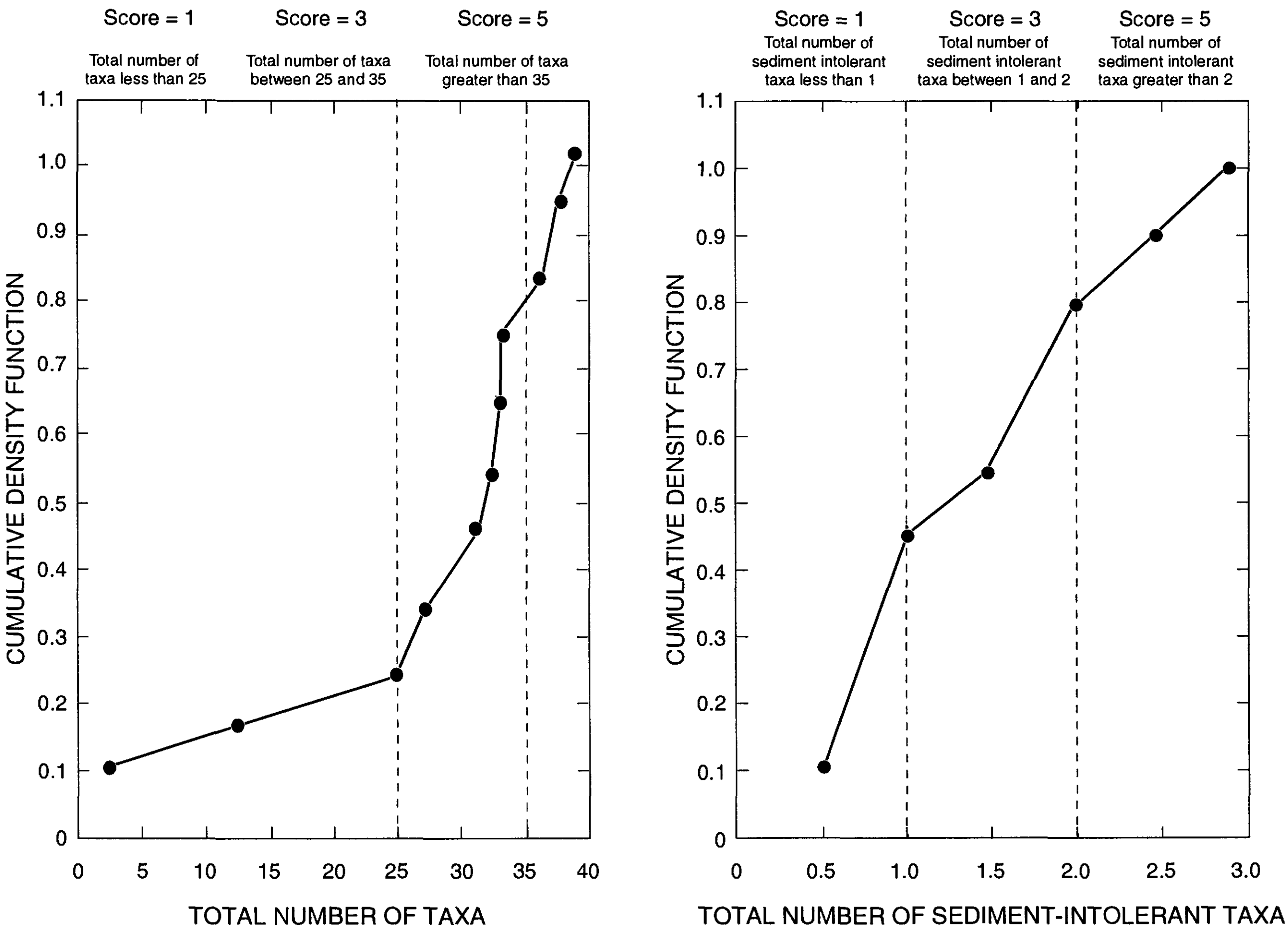


Figure 5. Cumulative density functions used to calculate metric scores for total number of taxa and total number of sediment intolerant taxa for first to third order sites less than 3,000 feet above sea level in the Cedar River Watershed.

Table 6. 1995 metric values, metric scores, and benthic index of biological integrity (BIBI) scores for first through third order sampling sites less than 3,000 feet above sea level in the Cedar River Watershed

[Replicate values and scores for each site are separated by commas. For scoring criteria, see figure 5]

Land management influence category	Site name	River mile	Map site number	Metric values: Total taxa	Metric values: Sediment intolerant taxa	Metric scores: Total taxa	Metric scores: Sediment intolerant taxa	Total BIBI scores by replicate	Mean BIBI score
High	Greenpoint Creek	0.0	6	2, 6, 2	0, 0, 0	1, 1, 1	1, 1, 1	2, 2, 2	2
	Lost Creek	0.4	8	27, 9	2, 1	5, 1	3, 3	8, 4	6
	McCellan Creek	0.0	9	4, 6, 7	0, 0, 0	1, 1, 1	1, 1, 1	2, 2, 2	2
	Middle Fork, Taylor Creek	3.0	16	23, 23, 18	2, 2, 3	3, 3, 3	3, 3, 5	6, 6, 8	6.7
	Seattle Creek	1.8	15	9, 24, 26	1, 2, 1	1, 3, 5	3, 3, 3	4, 6, 8	6
Medium	Goat Creek	0.1	5	19, 8, 4	1, 1, 0	3, 1, 1	3, 3, 1	6, 4, 2	4
	Roaring Creek	0.2	10	8, 15, 9	2, 3, 1	1, 3, 1	3, 5, 3	4, 8, 4	5.3
	Williams Creek	0.2	20	5	1	1	3	4	4
	Williams Creek	1.0	21	24, 5, 4	1, 0, 1	3, 1, 1	3, 1, 3	6, 2, 4	4
Low	Hotel Creek	0.2	7	24, 31, 33	2, 2, 3	3, 5, 5	3, 3, 5	6, 8, 10	8
	Rock Creek	0.0	11	39, 14, 16	2, 1, 2	5, 3, 3	3, 3, 3,	8, 6, 6	6.7
	Rock Creek	3.7	12	28, 37, 13	2, 2, 1	5, 5, 3	3, 3, 3	8, 8, 6	7.3
	Rock Creek	4.6	13	32, 31, 18	2, 4, 1	5, 5, 3	3, 5, 3	8, 10, 6	8
Test Sites	Webster Creek	2.1	18	33, 21, 30	3, 3, 3	5, 3, 5	5, 5, 5	10, 8, 10	9.3
	Webster Creek	2.8	19	34, 30, 27	3, 4, 3	5, 5, 5	5, 5, 5	10, 10, 10	10

Table 7. 1996 metric values, metric scores, and benthic index of biological integrity (BIBI) scores for first through third order sampling sites less than 3,000 feet above sea level in the Cedar River Watershed.

[Replicate values and scores for each site are separated by commas. For scoring criteria, see figure 5]

Land management influence category	Site name	River mile	Map site number	Metric values: Total taxa	Metric values: Sediment intolerant taxa	Metric scores: Total taxa	Metric scores: Sediment intolerant taxa	Total BIBI scores by replicate	Mean BIBI score
High	Lost Creek	0.4	8	5, 7, 19	0, 0, 1	1, 1, 3	1, 1, 3	2, 2, 6	3.3
	Middle Fork Taylor Creek	3.0	16	4, 2, 4	0, 0, 0	1, 1, 1	1, 1, 1	2, 2, 2	2
	Seattle Creek	1.8	15	18, 21, 30	0, 0, 1	3, 3, 5	1, 1, 3	4, 4, 8	5.3
Moderate	Goat Creek	0.1	5	6, 8, 4	0, 0, 0	1, 1, 1	1, 1, 1	2, 2, 2	2
	Roaring Creek	0.2	10	14, 16, 10	0, 2, 1	3, 3, 1	1, 3, 3	4, 6, 4	4.7
	Williams Creek	1.0	21	16, 27, 25	1, 1, 1	3, 5, 3	3, 3, 3	6, 8, 6	6.7
Low	Hotel Creek	0.2	7	47, 43, 39	1, 1, 1	5, 5, 5	3, 3, 3	8, 8, 8	8
	Rock Creek	0.0	11	34, 32, 29	1, 1, 1	5, 5, 5	3, 3, 3	8, 8, 8	8
	Rock Creek	4.6	13	37, 37, 36	1, 1, 1	5, 5, 5	3, 3, 3	8, 8, 8	8
Test Sites	Webster Creek	2.1	18	8, 32	0, 1	1, 5	1, 3	2, 8	5
	Webster Creek	2.8	19	17, 31, 21	0, 4, 1	3, 5, 3	1, 5, 3	4, 10, 6	6.7

Testing the Benthic Index of Biological Integrity (BIBI) Across the Range of Land Management Influences

One of the main objectives of this study was to develop a BIBI that could discriminate between sites that have different levels of LMI. To accomplish this, the hypothesis that BIBI scores were different across a full range of LMI in the Cedar River Watershed in 1995 and 1996 was tested. Data for each year were analyzed separately to determine if observed patterns in BIBI scores remained consistent between years. Patterns in BIBI scores between years were expected to be similar, given the fact that LMI's remained constant.

In 1995, an ANOVA detected a significant difference in BIBI scores in response to one or more of LMI categories ($p = 0.05$, table 8). To determine which LMI categories were significantly different, post-hoc comparisons were done. These comparisons found that sites classified as low LMI had significantly higher BIBI scores than those sites classified as high or medium LMI sites (figure 6). There was no significant difference in BIBI scores between the medium and high LMI sites, based on the post-hoc comparisons.

Mean BIBI scores for 1995 were plotted against each of the three LMI criteria. In addition, two test sites were also plotted in order to test the effectiveness of the BIBI (figure 7). Sites characterized as belonging to the low LMI category were generally clustered in the upper left-hand side of each graph. Sites characterized as a high LMI site were generally found in the lower right-hand side of each graph. The test sites had high BIBI scores, suggesting that they represent sites with high biological integrity. The plot of BIBI scores against road density did not show the desired outcome of the test sites clustering around the low LMI sites. So, road density may not be a good LMI category for the test sites.

In 1996 data, a significant difference was found in BIBI scores plotted with the LMI categories ($p = 0.02$, table 8). Post-hoc comparisons found a significantly higher BIBI score for low LMI sites compared with the high LMI site (figure 6). The medium LMI site was not significantly different from either the low LMI sites or the high LMI site. Plots of 1996 BIBI scores against the three LMI criteria resulted in low and high LMI sites being clustered in the upper left-hand and lower right-hand side of each graph, respectively (figure 7). As was the case with the 1995 data, the plot of BIBI scores for 1996 data against road density also produced unusual results. Once again, the test sites were not clustered with the other low LMI sites as would be expected, given their high BIBI scores. Additional macroinvertebrate biomonitoring work that includes a more robust data set would be helpful to determine the usefulness of road density as a measure of human influence in this watershed.

While the patterns were similar for 1995 and 1996 data in terms of LMI clustering, individual BIBI scores for some sites changed between years. For example, site numbers 11 and 18 had mean BIBI scores of 8 and 7.3 in 1995 and 6 and 6 in 1996, respectively (tables 6 and 7). Given the narrow range of possible BIBI scores (2 to 10), any change in the BIBI score could alter the assessment of the biological integrity of these sites between years. As noted previously, there were no known anthropogenic events that may have caused these changes in BIBI scores. If the difference in scores between years reflects natural variability, then inappropriate metrics were selected. A second alternative could be errors introduced into the data sets during the collection and identification of the invertebrates or analysis of the data. Finally, a BIBI score generated from two metrics does not give a wide enough range of scores to adequately account for inevitable sources of variability associated with a procedure that relies on the collection of macroinvertebrates.

Table 8. Analysis of variance results for benthic invertebrate index of biological integrity (BIBI) scores for first through third order sampling sites less than 3,000 feet above sea level

Factors	Sum of squares	Degrees of freedom	Mean squares	F-ratio	p-value	Percentage of variance explained by each factor[1]
			1995			
Land management influence (LMI) categories	75.4	2	37.7	14.1	0.000	40
Sampling sites within LMI categories	64.9	10	6.5	2.4	0.038	20
Error	61.3	23	2.7	--	--	40
			1996			
Land management influence (LMI) categories	96.3	2	48.1	25.0	0.000	51
Sampling sites within LMI categories	51.5	6	8.6	4.5	0.006	26
Error	34.7	18	1.9	--	--	23

[1]Percentage of variance explained by each factor was calculated based on methods presented in Sokal and Rohlf (1981).

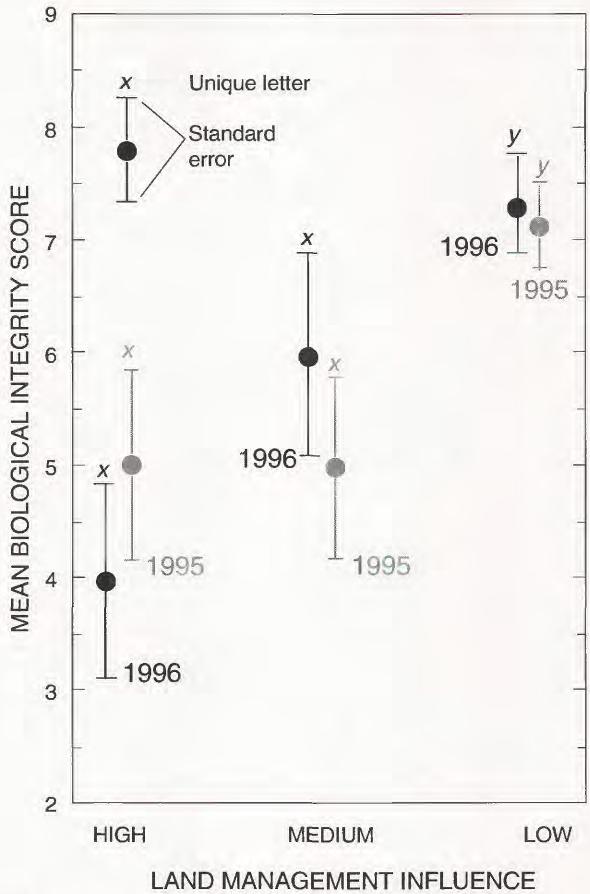


Figure 6. Mean benthic index of biological integrity (BIBI) scores and land management influence categories for first through third order sites less than 3,000 feet above sea level in the Cedar River Watershed in 1995 and 1996. Means with unique letters (*x*, *y*) are significantly different at p=0.05 within years.

High-Elevation, Small Stream Sites

Metric Selection

Eight high-elevation, small stream sites were identified: 2 high, 2 medium, 2 low LMI, and 2 test sites in 1995 and 1996 samplings. Although all eight sites were sampled in both years, a number of sites had replicates with fewer than 100 individuals. Given this limitation, the 1995 data were unusable and only the 1996 high-elevation, small stream sites were used to develop a BIBI. The outcome of plotting the mean value of each metric for each site against the three LMI categories for 1996 are presented in Appendix F. In 1996, 8 of the 15 metrics were identified as meeting the criteria for best metrics outlined in the methods section. Correlation coefficients for each metric and LMI category were calculated for 1996 data (table 9). All of the metrics declined or increased with increasing LMI as expected, resulting in negative or positive correlation coefficients, respectively. Many of the correlation coefficients between a metric and LMI category were -1 or 1, indicating a perfect negative or positive relationship, and they were considered significant (Kachigan 1986). However, it is unlikely that all of these relations are perfect, and it is more likely that the limited number of sites (4) and the presence of extreme metric values are responsible for these perfect correlations.

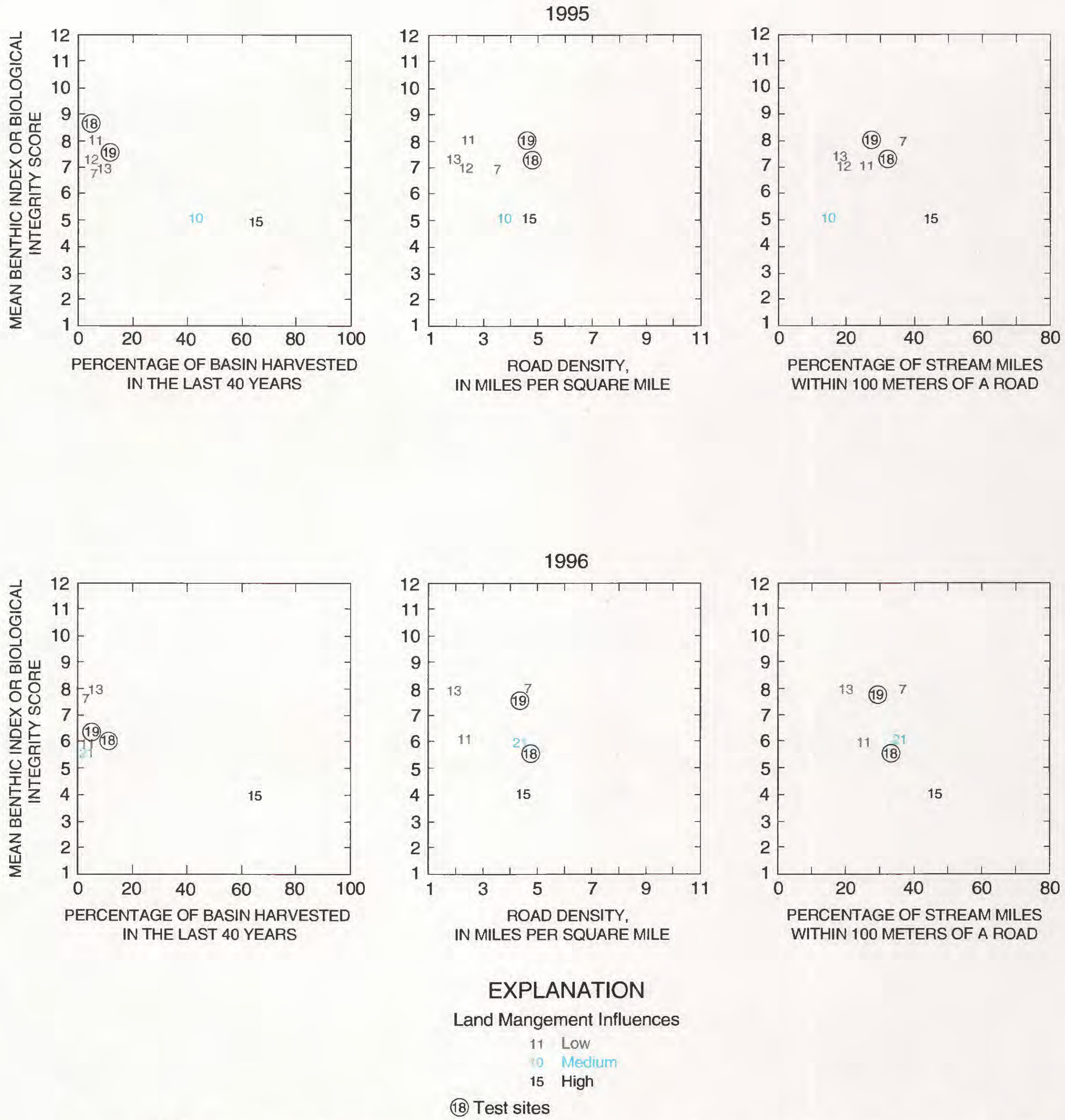


Figure 7. Mean benthic index of biological integrity (BIBI) scores for first through third order streams less than 3,000 feet above sea level in the Cedar River Watershed, and land management influences. See table 1 for a list of sites corresponding to figure codes.

Table 9. Selected metrics and Spearman rank correlation coefficients by land management influence factors for 1996 first through third order sites above 3,000 feet above sea level

[Correlation coefficients of 1 and -1 indicate perfect positive and negative correlations, respectively. LMI, land management influence]

Metric	Predicted response to increase in LMI	Percentage of basin harvested in last 40 years	Road density (miles per square miles)	Percentage of steam miles within 100 meters of a road
Total taxa	Decrease	-0.72	[1]-0.87	[1]-0.99
Ephemeroptera taxa	Decrease	-0.79	-0.59	-0.32
Trichoptera taxa	Decrease	-0.54	-0.77	-0.77
Clinger taxa	Decrease	-0.77	[1]-0.89	[1]-1.00
Sediment intolerant taxa	Decrease	[1]-0.84	[1]-0.93	[1]-0.93
Total abundance	Decrease	-0.03	-0.26	-0.60
Plecoptera taxa	Decrease	-0.83	[1]-0.94	[1]-0.94
Intolerant taxa	Decrease	-0.77	[1]-0.89	[1]-0.89
Long lived taxa	Decrease	-0.77	-0.83	-0.66
Dominance of 3 taxa, percentage	Increase	[1]1.00	[1]0.94	[1]0.89
Scrapers, percentage	Decrease	-0.60	-0.31	-0.14
Predators, percentage	Decrease	-0.60	-0.66	-0.37

[1]Correlations significantly different than 0 at p = 0.05.

Metric Scoring Criteria

For the eight selected metrics, a range of values was established for the 1996 high-elevation, small stream sites in order to put them into one of three metric scoring categories (1, 3 or 5) using CDF plots of mean metric values (figure 8). The specific range of metric values assigned to each score is presented in table 10. Once the scoring criteria were established, a metric score was assigned to each of the replicate samples collected at each site in 1996 (table 11). As was done with the low-elevation, small stream sites, the scores for each metric were added to get a final BIBI score for each replicate. The overall BIBI score for high-elevation, small stream sites included the scores for percent scrapers, percent predators, percent dominance of three species, total number of taxa, percent tolerant species, and number of Plecoptera taxa, intolerant taxa, and sediment-intolerant taxa. Mean BIBI scores ranged between 14, for a high LMI site, and 32, for a low LMI site.

Testing the Benthic Index of Biological Integrity (BIBI) Across the Range of Land Management Influences

As noted previously, there were too few sites to adequately assess the biological integrity of sites sampled in 1995. In addition, the two Pine Creek sites specified to be evaluated in the monitoring plan had fewer than 100 invertebrate individuals in all of the replicate samples taken in 1996 which prevented them from being included in the BIBI development and any additional analyses. One hypothesis was tested for the 1996 high elevation-small streams which stated that there was no difference in biological integrity between the low and high LMI sites using a t-test on the mean BIBI scores. As seen on figure 9, the low LMI sites had a significantly higher BIBI score than the high LMI sites ($p<0.001$).

As was the case with the low-elevation, small stream sites, a plot of the 1996 scores did cluster high and low LMI sites with timber harvest, as expected (figure 10). However, plots of BIBI scores against road density and percentage of stream miles within 100 meters of a road were not well defined.

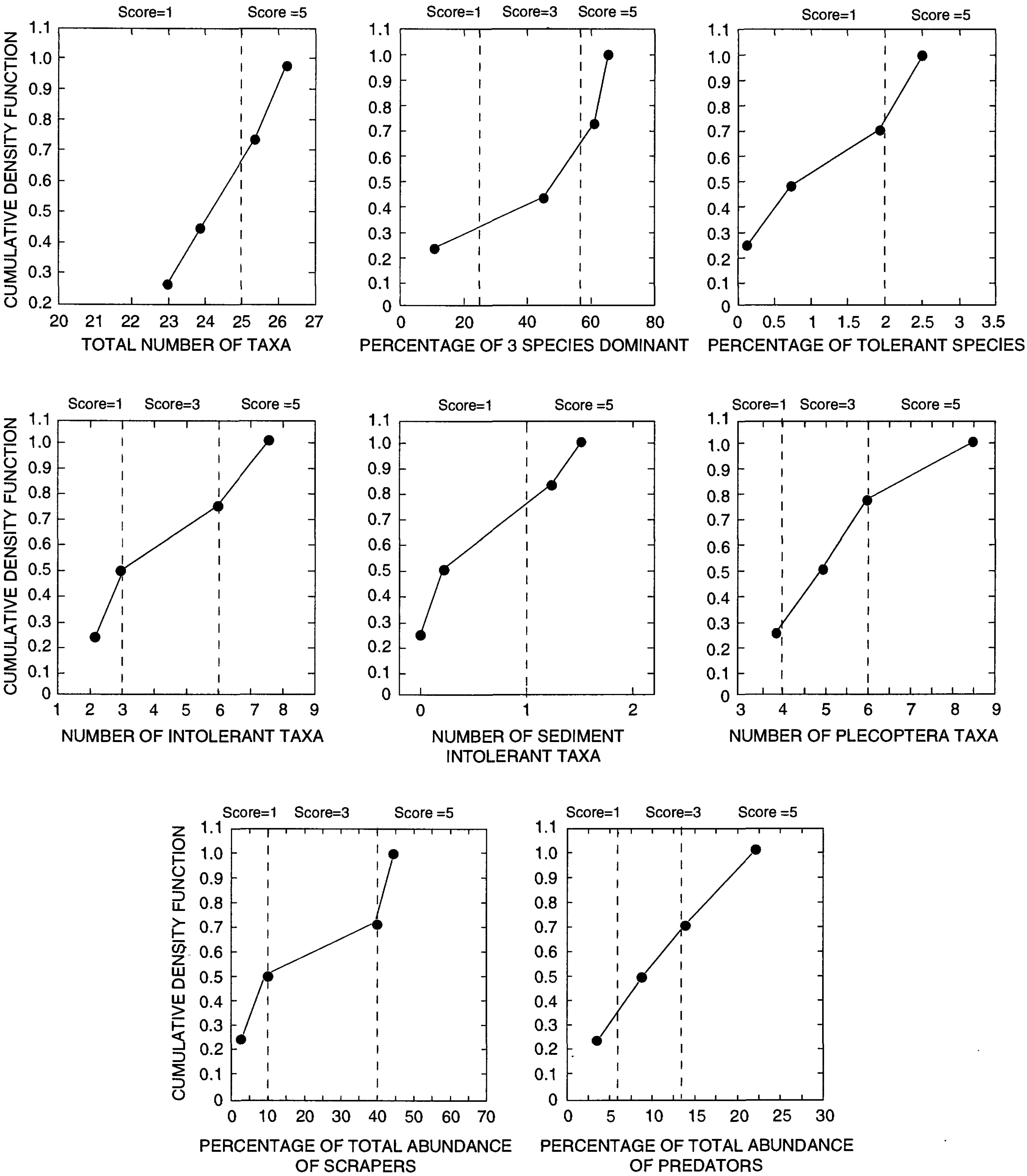


Figure 8. Cumulative density functions used to calculate metric scores for total number of taxa, percentage species dominant, percentage of tolerant species, number of intolerant taxa, number of sediment intolerant taxa, Plecoptera taxa, percentage of scrapers, and percentage of predators for first through third order sites greater than 3,000 feet above sea level in the Cedar River Watershed. (For example of figure breaks, see figure 4)

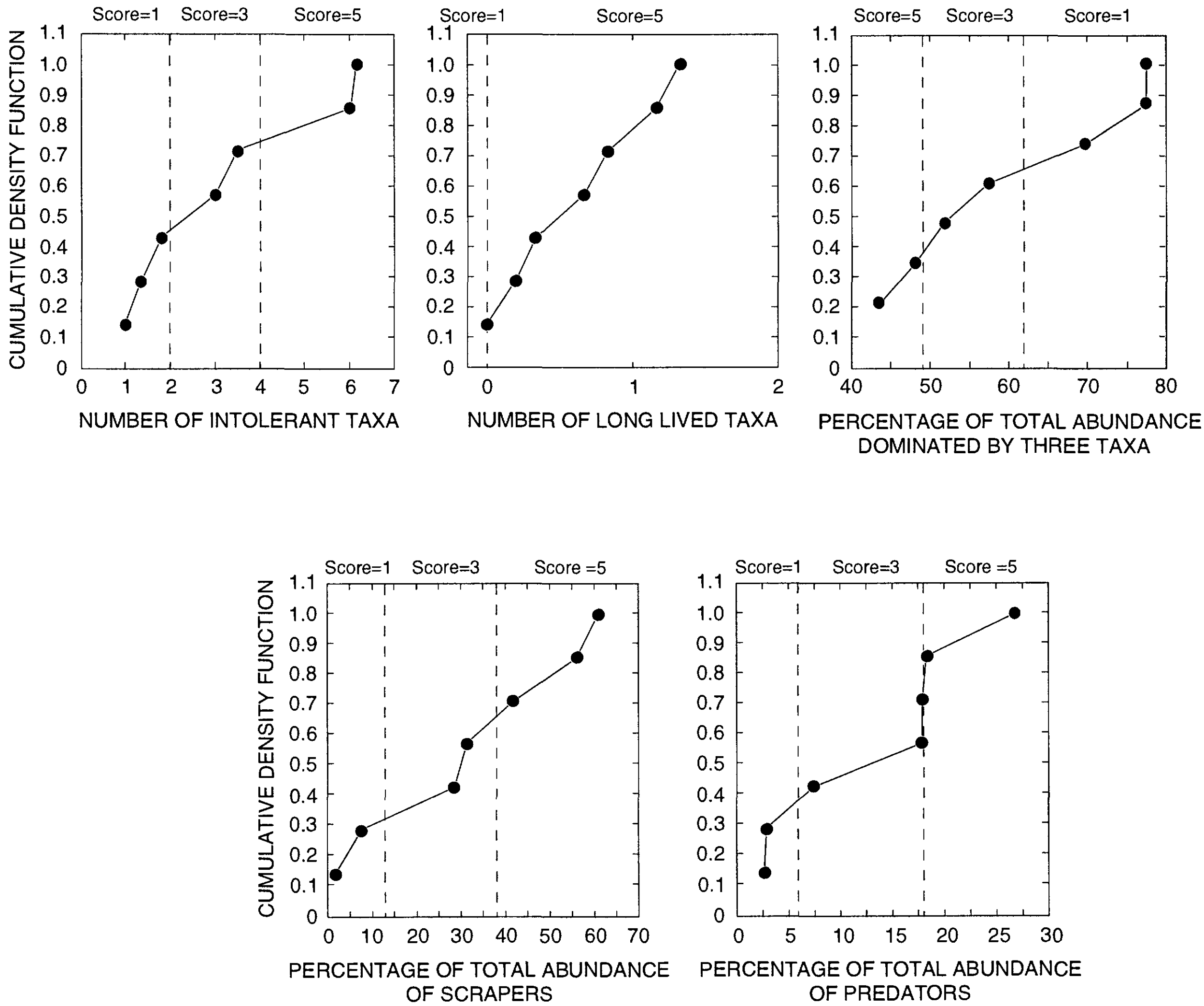


Figure 8. Continued

The Boulder Creek site (site number 46) has a low road density and low percentage of stream miles within 100 meters of a road, but it has a low BIBI score, which does not follow the expected trend. It is possible that a measure of timber harvest may be a better indicator of anthropogenic effects than these two LMI's.

High-Elevation, Small Stream Sites Compared With Low-Elevation, Small Stream Sites

The two elevation groups, low elevation-small stream (<3,000) and high elevation-small streams (>3,000) reflect the two ecoregions present within the Cedar River Watershed. Ecoregions exemplify homogeneity in characteristics such as climate, soils, geology, vegetation, and physiography (Omernik and Gallant, 1986). Given a set of unique and homogenous environmental factors, aquatic invertebrate communities within each ecoregion should also exhibit a unique set of characteristics. Establishing reference sites and identifying unique macroinvertebrate community characteristics within each ecoregion helps to develop effective BIBI's. To determine if macroinvertebrate communities in high- and low-elevation ecoregions were significantly different, a statistical comparison of total number of taxa and sediment-intolerant taxa from high and low-elevation, small streams was done for 1996 data. The analysis was limited to data collected at low LMI sites, to be able to generate a reference site comparison.

Table 10. Metrics and scoring criteria for the benthic index of biological integrity (BIBI) for first through third order sampling sites greater than 3,000 feet above sea level in the Cedar River Watershed

[A low deviation from the predicted response to land management influence will get a score of 1, a medium deviation will get a score of 3, and a high deviation will get a score of 5. LMI, land management influence; >, greater than; <, less than; --, no value calculated]

Metric	Predicted response to increase in LMI	1	2	3
Total taxa	Decrease	<11	11-14	>14
Ephemeroptera taxa	Decrease	<3	3-4	>4
Plecoptera taxa	Decrease	<2	2-4	>4
Trichoptera taxa	Decrease	<3	3-5	>5
Intolerant taxa	Decrease	<2	2-4	>4
Long lived taxa	Decrease	0	--	>0
Sediment intolerant taxa	Decrease	0	--	>0
Clinger taxa	Decrease	<7	7-10	>10
Dominance (3 taxa), percentage	Increase	>62	49-62	<49
Scrapers, percentage	Decrease	<13	13-38	>38
Predators, percentage	Decrease	<6	6-18	>18

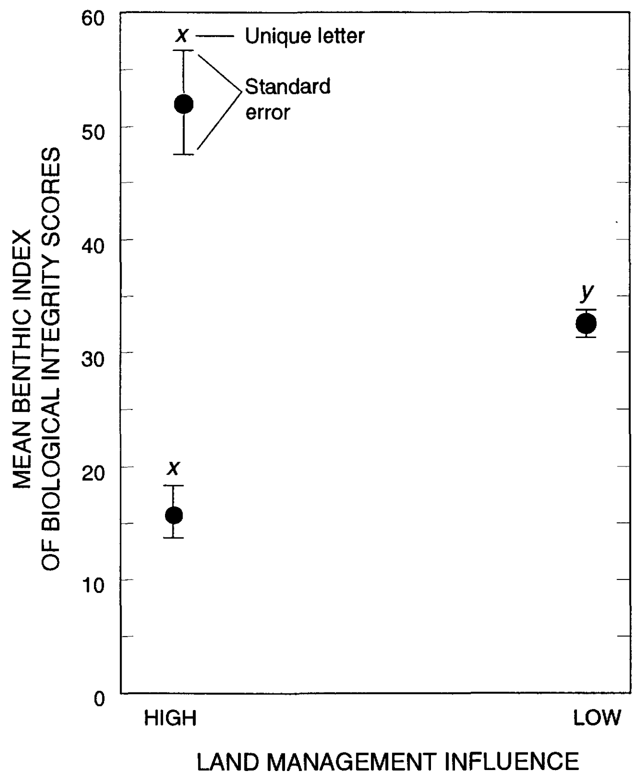


Figure 9. 1996 mean benthic index of biological integrity (BIBI) scores for high and low land management influence sites in the first through third order sites greater than 3,000 feet above sea level in the Cedar River Watershed. Means with unique letters (*x*,*y*) are significantly different at the p=0.05 level.

Table 11. 1996 metric scores and benthic index of biological integrity (BIBI) scores for first through third order sampling sites greater than 3,000 feet above sea level in the Cedar River Watershed by land management influence

[Replicate scores for each site are separated by commas]

			Metric scores											
Site name	River mile	Map site number	Percent-age of scrapers	Percent-age of predators	Percent-age of dominant 3 taxa	Total taxa	Ephemeroptera taxa	Plecoptera taxa	Trichoptera taxa	Intolerant taxa	Sediment intolerant taxa	Long-lived taxa	Clinger taxa	Total BIBI scores by replicate
High land management influence														
Boulder Creek	3.1	46	1, 1, 3	1, 3, 3	1, 3, 1	1, 5, 1	1, 5, 1	1, 5, 1	1, 5, 1	1, 3, 1	1, 1, 1	1, 5, 1	1, 5, 1	11, 41, 15
Boulder Creek	3.2	4	1, 1, 1	1, 3, 1	3, 3, 1	5, 5, 5	1, 5, 1	3, 5, 3	3, 5, 3	3, 3, 1	5, 1, 1	1, 5, 1	3, 5, 3	29, 41, 21
Medium land management influence														
Pine Creek	0.7	47	1, 3, 5	5, 5, 1	5, 5, 1	3, 5, 1	5, 5, 1	3, 5, 1	3, 5, 1	3, 5, 1	1, 5, 1	5, 5, 1	3, 5, 1	37, 53, 15
Pine Creek	0.8	41	5, 5, 5	3, 1, 1	5, 1, 1	3, 1, 3	5, 1, 5	5, 1, 3	1, 1, 1	1, 1, 3	1, 1, 1	1, 1, 1	3, 1, 1	33, 15, 25
Low land management influence														
Bear Creek	1.6	1	5, 5, 3	3, 3, 5	3, 5, 5	5, 5, 5	3, 5, 5	5, 5, 5	5, 5, 5	5, 3, 5	5, 1, 5	5, 5, 5	5, 5, 5	49, 47, 53
Spring Creek	0.6	40	3, 5, 5	3, 3, 3	5, 3, 5	5, 5, 5	3, 3, 3	5, 3, 5	5, 3, 5	5, 5, 5	5, 5, 5	5, 5, 5	5, 5, 5	49, 45, 51
Test														
Tinkham Creek	0.3	39	3, 3, 3	3, 5, 3	3, 5, 5	1, 1, 5	3, 3, 5	1, 3, 5	1, 1, 5	1, 1, 5	1, 1, 1	1, 5, 1	1, 3, 5	19, 31, 43
South Fork Cedar River	3.0	48	1, 3 ,1	3, 5, 5	3, 5, 3	5, 5, 5	5, 3, 5	5, 5, 5	5, 5, 5	3, 1, 1	1, 5, 1	5, 5, 5	5, 5, 5	41, 47, 41

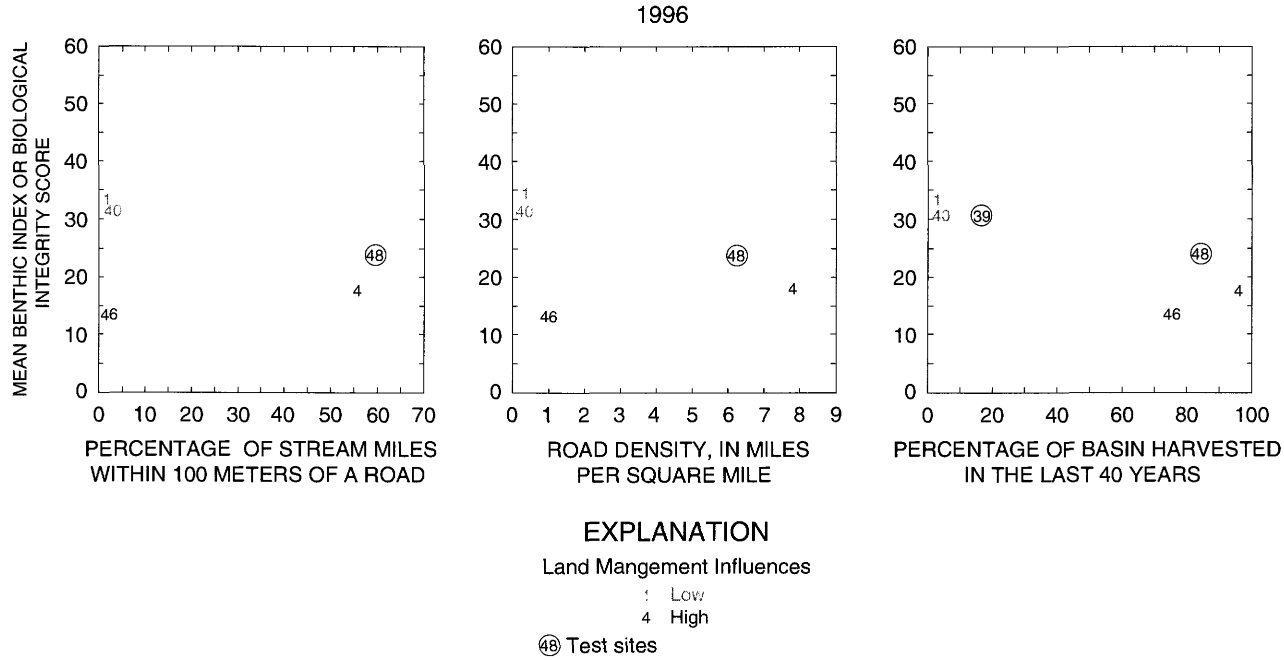


Figure 10. Mean benthic index of biological integrity (BIBI) scores for first to third order sites greater than 3,000 feet above sea level in the Cedar River Watershed plotted against land management influence factors. See table 1 for a list of sites corresponding to figure codes.

The total number of taxa found at low LMI sites in 1996 was significantly higher at low-elevation than at high-elevation sites (p = 0.004, figure 11). A reduction in number of taxa with elevation is to be expected (Hynes, 1970). Also, the number of sediment-intolerant taxa was significantly higher in the samples collected from the high-elevation sites (p = 0.05, figure 11). These results emphasize the need to keep samples collected at different elevations and different ecoregions separated and highlight the importance of properly classifying sites before developing a BIBI (Karr and Chu, 1997).

Low-Elevation, Large Stream Sites

A total of 24 low-elevation, large stream sites were sampled in 1995 (8 high LMI and 8 medium LMI sites and 8 test sites), and 20 sites were sampled in 1996 (6 high LMI, 7 medium LMI sites, and 7 test sites). The reduction in sites from 1995 to 1996 was due to extreme low-flow conditions in 1996. As was the case with small streams, replicate samples with fewer than 100 individuals were excluded. This resulted in 12 sites (6 high LMI, 6 medium LMI) for 1995 and 10 sites (7 medium LMI, 3 high LMI) for 1996 BIBI development. Under ideal circumstances, a BIBI should be developed with sites ranging from low LMI to high LMI. A wide range of sites makes it easier to identify which metrics respond to land management influences as well as help to establish metric scoring criteria. The lack of low LMI sites in the low-elevation, large streams limited the range of sites typically needed to successfully develop a BIBI. In addition, none of the metric graphics examined in both 1995 and 1996 successfully separated the medium and high LMI sites (Appendixes E and F). Therefore, a BIBI score for low-elevation, large streams was not calculated. Macroinvertebrate communities are often more difficult to characterize in larger streams (Allan, 1995), partially due to a greater heterogeneity in habitat conditions (Downes and others, 1993) as well as to sampling difficulties. Quite often, samples from larger streams are collected in safe or convenient locations rather than scientifically appropriate locations. These factors can result in inaccurate taxon estimates or increased variability. There may be other influences on the biological integrity of the benthic communities in large streams of the Cedar River Watershed than those examined in this study that include both anthropogenic and natural factors.

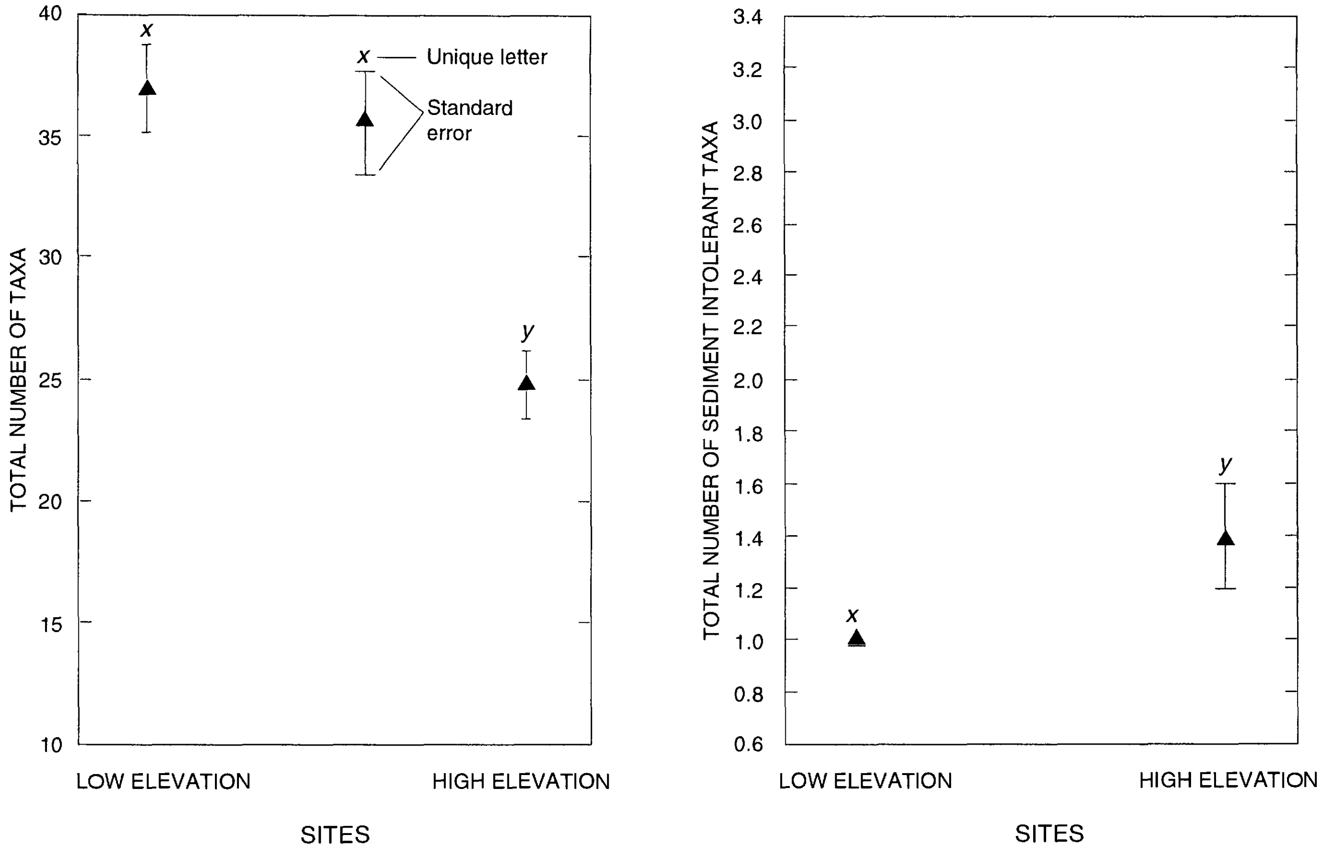


Figure 11. Mean value of total number of taxa and sediment intolerant taxa by year and elevation for 1996 sampling sites. Bars represent 1 standard error around the mean. Means with unique letters (*x*, *y*) are significantly different at p=0.05 within years.

Pool Samples Compared With Riffle Samples

Invertebrate communities found in riffles and pools are typically different. To fully characterize a stream, samples from both pools and riffles should be collected. However, time and funding often prevent such an extensive collection effort. Given that most of the BIBI studies in the Northwest have been performed on riffle samples, it was decided to use riffle samples for this study. The possibility that macroinvertebrate samples collected in pools might yield different results was evaluated by collecting pool and riffle samples from five sites in 1995. Metric values calculated for pools and riffles were statistically compared using a Wilcoxon's signed-ranks test (Sokal and Rohlf, 1981). The sampling sites and metric values used in the analysis are in table 12. Generally, metric values for riffle samples were higher than those for pool samples. Of the 15 metrics examined, 6 metric values were found to be significantly higher in the riffle samples: total abundance, percent tolerant taxa, total taxa, Ephemeroptera taxa, Trichoptera taxa, and clinger taxa (figure 12). These results do not conclusively suggest that pool samples would not be valuable for the development of a BIBI or for further use in monitoring. However, riffle samples did have a significantly higher number of taxa than the pool samples, as well as other metric values.

Table 12. Mean metrics values for 1995 pool and riffle samples by site

	Creek name and river mile									
	Rock 0.0	Rock 0.0	Rock 3.7	Rock 3.7	Boulder 0.5	Boulder 0.5	Rack 0.0	Rack 0.0	Rex 0.8	Rex 0.8
Map site number	11	11	12	12	2	2	31	31	42	42
Sample type	Riffle	Pool	Riffle	Pool	Riffle	Pool	Riffle	Pool	Riffle	Pool
Total abundance	364.6	112	134.7	78.7	126.7	2	6	2	243	48
Percent scrapers	16.4	28.0	36.9	25.5	66.2	0	37.5	0	44.6	18.8
Percent predators	4.1	5.0	14.9	15.9	5.6	0	12.5	0	7.7	0
Percent dominant taxa (3 taxa)	60.7	59.0	49.2	44.2	59.4	100	72.2	100	53.1	47.92
Percent total tolerant	38.9	13.0	24.9	9.5	1.2	0	5.5	0	5.4	0
Percent sediment tolerant	0	0	0.6	4.3	3.7	0	0	0	7.1	2.1
Total taxa	23.0	16.7	26.0	24.3	19.0	2	4.7	1.0	28.0	15.0
Ephemeroptera taxa	7.3	5.0	8.7	5.3	5.7	2	0.7	0	7.7	5.0
Plecoptera taxa	2.7	1.7	5.0	5.3	4.0	0	1.0	0	4.7	1.0
Trichoptera taxa	5.7	4.0	6.0	5.7	5.0	0	1.3	1.0	8.0	4.0
Intolerant taxa	2.3	0.7	4.7	6.0	4.7	0	2.0	1.0	3.3	3.0
Sediment intolerant taxa	1.7	1.3	1.7	3.0	2.3	0	0.7	0	3.3	1.0
Long lived taxa	0.7	0.3	1.7	1.0	0	0	0	0	0	0
Pteronarcys sp.	0	0	0.7	0	0	0.8	0	1.0	0	0
Clinger taxa	15.6	11.0	16.7	10.7	14.0	2.0	2.2	2.0	17.6	7.9

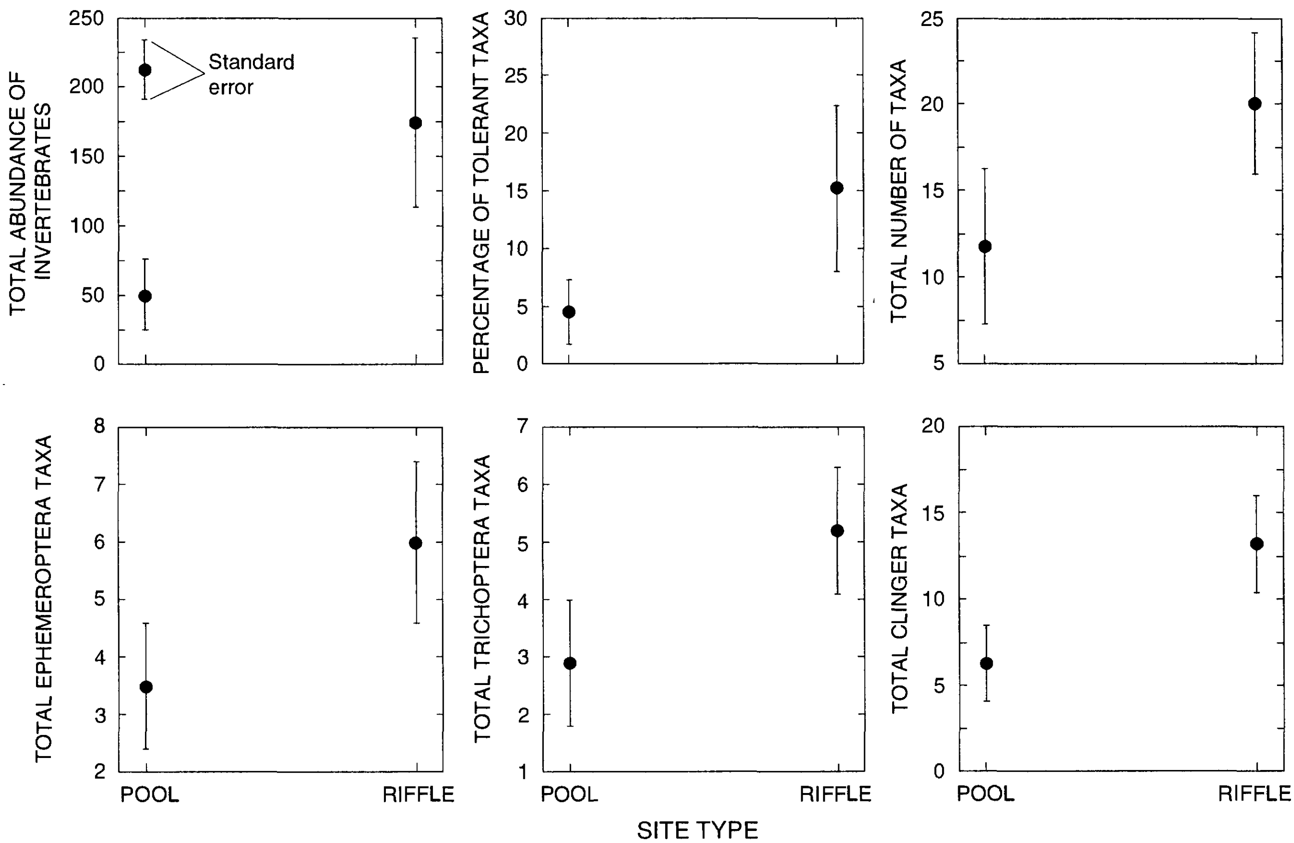


Figure 12. A comparison of mean metric values for riffle and pool samples collected at the same sites in the Cedar River Watershed. In all cases, riffle metric values were significantly higher than pool samples, at p=0.05.

Habitat Data Analysis and Results

To determine the relationship between some of the habitat variables and the BIBI scores at the high and low-elevation, small stream sites, a preliminary analysis was performed using stepwise regression procedures (Kachigan, 1986) on 1996 data and 1995 and 1996 data combined for the high- and low-elevation sites, respectively. One habitat variable, percent embeddedness (the degree to which rocks are embedded in fine material), at the high-elevation sites was significantly correlated with BIBI scores ($r^2 = 0.71$, $p = 0.04$). As the percent embeddedness increased, the BIBI scores decreased. For the low-elevation sites, the percentage of sand at a site was found to be related to the BIBI scores ($r^2 = 0.52$, $p=0.003$). The percentage of sand at a site was also negatively correlated with BIBI scores. The habitat variables that were correlated to the BIBI scores for both high and low elevation sites were substrate related.

SUMMARY AND CONCLUSIONS

As part of the City of Seattle's Cedar River Aquatic System Monitoring Plan, a benthic index of biological integrity (BIBI) analysis was performed for the upper Cedar River watershed. The use of biological indices or multimetrics for the assessment of aquatic system has increased over the last ten years (Gerritsen, 1995). Additive metrics such as the BIBI have the unique ability to simplify multiple measure of biological information into a single measure of biological integrity. It has been suggested that such a measure may improve the ability of managers to make informed decisions regarding aquatic system management (Fore and others, 1996; Gerritsen, 1995).

A BIBI was created for low-elevation, small streams using only two metrics, total taxa and sediment intolerant taxa, that were found to be effective at differentiating sites with different land management influence. Such a limited number of metrics used to create the BIBI limits its ability to be used on other similar sized streams within the watershed. Fore and others (1996) suggest that multiple metrics are critical to a useful BIBI because they increase the probability of successfully identifying the biological integrity of a site. The limited number of metrics identified for the low-elevation, small stream sites could be due to the high variability in metric values between replicate samples, the high variability in metric values between years and the limited number of sites, as well as individual invertebrates found at each site. A great deal of care should be taken if this BIBI were used to evaluate similar streams, given its limited number of metrics. The small range of possible BIBI scores increases the likelihood that a new site being evaluated using this BIBI might be misclassified, depending on the year sampled. There was also variability in the BIBI scores between years for some of the low-elevation, small stream sites. An effective BIBI should not be sensitive to natural annual variability (Fore and others, 1996). But a complete separation of natural and human effects in a BIBI is unrealistic because human disturbance exacerbates naturally occurring disturbance (Schlosser, 1990). BIBI scores may represent natural as well as human disturbance. To be able to use this two-metric BIBI to evaluate another low-elevation, small stream site within the Cedar River watershed, it would be helpful to collect invertebrates from additional high and low LMI sites to be able to accurately evaluate the test score.

A BIBI was created for high elevation-small streams sampled in 1996, using metrics that were found effective at differentiating between LMI's. The eight-metric BIBI for high elevation-small streams was found to be statistically significant. Like the low-elevation, small stream BIBI, a great deal of care must be taken if this BIBI were to be used to evaluate other streams in the watershed. The high-elevation BIBI was generated with only 4 sites, and there was a high degree of variability within replicate samples and between years. In many cases, samples had so few invertebrate individuals they had to be deleted from the analysis. Future monitoring efforts in this watershed would benefit from increasing the area sampled for each replicate so that more individuals are collected.

The number of total taxa and sediment-intolerant taxa were found to be statistically different between the high elevation and the low elevation-small stream sites. The difference between the high- and low-elevation, small stream BIBI's emphasizes the fact that distinct macroinvertebrate populations occur in the different ecoregions in the Cedar River Watershed and the need to carefully select and characterize sites.

The mean metric values that were calculated for riffle sampling sites were significantly higher than the metrics calculated for pool sampling sites. Riffle samples also had a significantly higher number of taxa and other metrics, compared with pool samples. The higher metric values and greater number of taxa improves the resolution of a BIBI and therefore makes it more effective. By focusing the sampling effort on the riffle samples in the Cedar River Watershed, a more robust BIBI was calculated.

The results of the initial BIBI analysis for the upper Cedar River Watershed were mixed. While it was possible to identify a series of metrics capable of differentiating sites over a range of land management influences in smaller streams, it was not possible to do so for larger streams and rivers. It is unclear why the metrics examined were unable to detect any site differences for the larger rivers. It is possible that three replicate samples per site were inadequate to capture the range of variability found at larger river sites. Larger rivers tend to have a greater degree of habitat heterogeneity (Downes and others, 1993; Allan, 1995). This heterogeneity within reaches can create patches with unique community composition. In order to measure the entire community, additional sample locations or replicates may be needed, or a more selective sampling site selection protocol could be implemented. Another reason that the metrics examined could not differentiate between larger stream sites could be the fact that the macroinvertebrates at these sites are unaffected by the land management influences examined in this study. It is possible that naturally occurring physical processes could be influencing invertebrate communities at these sites to a greater degree than land management influences. Additional studies designed to examine the relationship between macroinvertebrate communities and physical measures may help address the natural influences on community dynamics of the larger river sites.

Habitat data was collected along with samples of macroinvertebrates, but the data were not incorporated into the development of the BIBI. Habitat data collected at the BIBI sites can be found in Appendixes G through K. Some of these variables were used in a preliminary assessment of the relationship between the habitat variables and the BIBI scores for low- and high-elevation, small streams for 1995 and 1996 data combined. The habitat variables found to be the best predictors of the BIBI scores were percent sand for the low-elevation, small stream sites and percent embeddedness for the higher elevation-small stream sites. Both variables are related to the quality of the substrate utilized by benthic invertebrates. To better determine if substrate is the most influential factor in the health of the benthic communities in the Cedar River Watershed, a more extensive quantitative habitat analysis may be necessary.

The BIBI is only one tool in assessing macroinvertebrate communities and how they are influenced by land management practices. Other macroinvertebrate community assessment tools that may be useful to water management agencies would be (1) a multivariate assessment that would include all habitat, water quality, and LMI data, to determine the driving forces on community composition; (2) a predictive model for determining macroinvertebrate communities for different site types, such as the use of the River Invertebrate Prediction and Classification System (Wright, 1995), or (3) using indicator species to predict possible anthropogenic effects.

Other aspects of the monitoring plan including the hydrology module (Seattle Public Utilities, 1998) will help explain differences in the benthic communities between sites and between years. The BIBI developed from the data collected in 1995 and 1996 should not be used alone to assess land management influences on macroinvertebrate communities, but it can be used in addition to other monitoring in the Cedar River Watershed.

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APPENDIXES

Appendix A. Partial site list of 1995 invertebrate abundance data for the Cedar River Watershed aquatic system monitoring plan

[Data for all sites can be found on the U.S. Geological Survey home page at http://wa.water.usgs.gov/; RS, riffle sample; >, greater than; <, less than; sp, species]

			Stream					
			Bear Creek	Bear Creek	Bear Creek	Boulder Creek	Boulder Creek	Boulder Creek
Figure code			1	1	1	2	2	3
River mile			1.6	1.6	1.6	0.5	0.5	1.1
Replicate number			RS1	RS2	RS3	RS1	RS2	RS3
Date			10-27-95	10-27-95	10-27-95	10-26-95	10-26-95	10-26-95
Elevation			>3,000	>3,000	>3,000	<3,000	<3,000	<3,000
Stream order			1–3	1–3	1–3	4–6	4–6	4–6
Order	Family	Taxon	Bear Creek	Bear Creek	Bear Creek	Boulder Creek	Boulder Creek	Boulder Creek
Coleoptera		Coleoptera	0	0	0	0	0	0
Coleoptera	Curculionidae	Curculionidae	0	0	0	0	0	0
Coleoptera	Dytiscidae	*Oreodytes* sp.	0	0	0	0	0	0
Coleoptera	Elmidae	*Cleptelmis* sp.	0	0	0	0	0	0
Coleoptera	Elmidae	Elmidae	0	0	0	0	0	0
Coleoptera	Elmidae	*Heterlimnius* sp.	0	0	0	0	1	0
Coleoptera	Elmidae	*Lara* sp.	0	0	0	0	0	0
Coleoptera	Elmidae	*Narpus* sp.	0	0	0	0	0	0
Coleoptera	Elmidae	*Optioservus* sp.	0	0	0	0	0	0
Coleoptera	Elmidae	*Zaitzevia* sp.	0	0	0	0	0	0
Coleoptera	Hydraenidae	*Hydraena* sp.	0	0	0	0	0	0
Coleoptera	Psephenidae	*Acneus* sp.	0	0	0	0	0	0
Diptera	Athericidae	*Atherix* sp.	0	0	0	0	0	0
Diptera	Blephariceridae	Blephariceridae	0	0	0	0	0	0

Appendix B. Partial site list of 1996 invertebrate abundance data for the Cedar River Watershed aquatic system monitoring plan

[Data for all sites can be found on the U.S. Geological Survey home page at http://wa.water.usgs.gov/; RS, riffle sample; >, greater than; <, less than; sp, species]

			Stream				
			Bear Creek	Bear Creek	Bear Creek	Boulder Creek	Boulder Creek
Figure code			1	1	1	3	3
Site id			BEA1.6	BEA1.6	BEA1.6	BOU1.1	BOU1.1
Replicate number			RS 1	RS 2	RS 3	RS 1	RS 2
Date			09-11-96	09-11-96	09-11-96	09-28-96	09-28-96
Elevation			>3,000	>3,000	>3,000	<3,000	<3,000
Stream order			1–3	1–3	1–3	4–6	4–6
Order	Family	Taxon	Bear Creek	Bear Creek	Bear Creek	Boulder Creek	Boulder Creek
Bivalva	Sphaeriidae	Sphaeriidae	0	0	0	0	0
Coleoptera	Dytiscidae	Dytiscidae	0	0	0	0	0
Coleoptera	Dytiscidae	*Hydrovatus* sp.	0	0	0	0	0
Coleoptera	Dytiscidae	*Oreodytes* sp.	0	0	0	0	0
Coleoptera	Elmidae	Elmidae	0	0	0	0	0
Coleoptera	Elmidae	*Heterlimnius* sp.	0	0	0	0	2
Coleoptera	Elmidae	*Lara* sp.	0	0	0	0	0
Coleoptera	Elmidae	*Narpus* sp.	0	0	0	0	0
Coleoptera	Elmidae	*Optioservus* sp.	0	0	0	0	0
Coleoptera	Elmidae	*Zaitzevia* sp.	0	0	0	0	0
Coleoptera	Psephenidae	*Acneus* sp.	0	0	0	0	0

Appendix C. Partial site list of 1995 metric data for sites in the Cedar River Watershed

[Data for all sites can be found on the U.S. Geological Survey home page at http://wa.water.usgs.gov/; RS, riffle sample; PS, pool sample; >, greater than; <, less than]

	Stream											
	Bear Creek	Bear Creek	Bear Creek	Boulder Creek	Boulder Creek	Boulder Creek	Boulder Creek	Boulder Creek	Boulder Creek	Boulder Creek	Boulder Creek	Boulder Creek
Site identification number	BEA 1.6	BEA 1.6	BEA 1.6	BOU 0.5	BOU 0.5	BOU 0.5	BOU 0.5	BOU 1.1	BOU 1.1	BOU 1.1	BOU 3.1	BOU 3.1
Replicate number	RS1	RS2	RS3	RS1	RS2	RS3	PS1	RS1	RS2	RS3	RS1	RS3
Date	10-27-95	10-27-95	10-27-95	10-26-95	10-26-95	10-26-95	10-26-95	10-26-95	10-26-95	10-26-95	10-13-95	10-13-95
Elevation	>3,000	>3,000	>3,000	<3,000	<3,000	<3,000	<3,000	<3,000	<3,000	<3,0100	>3,000	>3,f000
Stream order	1-3	1-3	1-3	4-6	4-6	4-6	4-6	4-6	4-6	4-6	1-3	1-3
Total Abundance	250	31	34	308	30	42	2	34	91	120	2	1
Scraper, percentage	58	84	71	50	80	69	0	76	66	79	0	0
Predators, percentage	17	13	18	5	0	12	0	6	13	6	0	0
Dominant taxa (3 taxa), percentage	54	71	59	49	70	60	100	62	58	71	100	100
Total tolerant, percentage	1	0	0	4	0	0	0	6	4	2	0	0
Sediment tolerant, percentage	1	0	0	2	7	2	0	6	1	4	0	0
Total taxa	33	8	10	36	10	11	2	12	17	18	1	1
Ephemeroptera taxa	6	3	3	10	4	3	2	3	4	5	0	0
Plecoptera taxa	10	3	2	11	0	1	0	3	4	4	0	0
Trichoptera taxa	10	2	4	8	3	4	0	4	5	4	1	1
Intolerant taxa	14	4	3	10	2	2	0	3	5	3	1	1
Sediment intolerant taxa	5	2	2	3	2	2	0	2	3	3	0	0
Long-lived taxa	1	0	0	0	0	0	0	1	0	0	0	0
Pteronarcys sp.	0	0	0	0	0	0	0	0	0	0	0	0
Clinger taxa	21	7	8	25	9	9	1	9	13	12	1	1

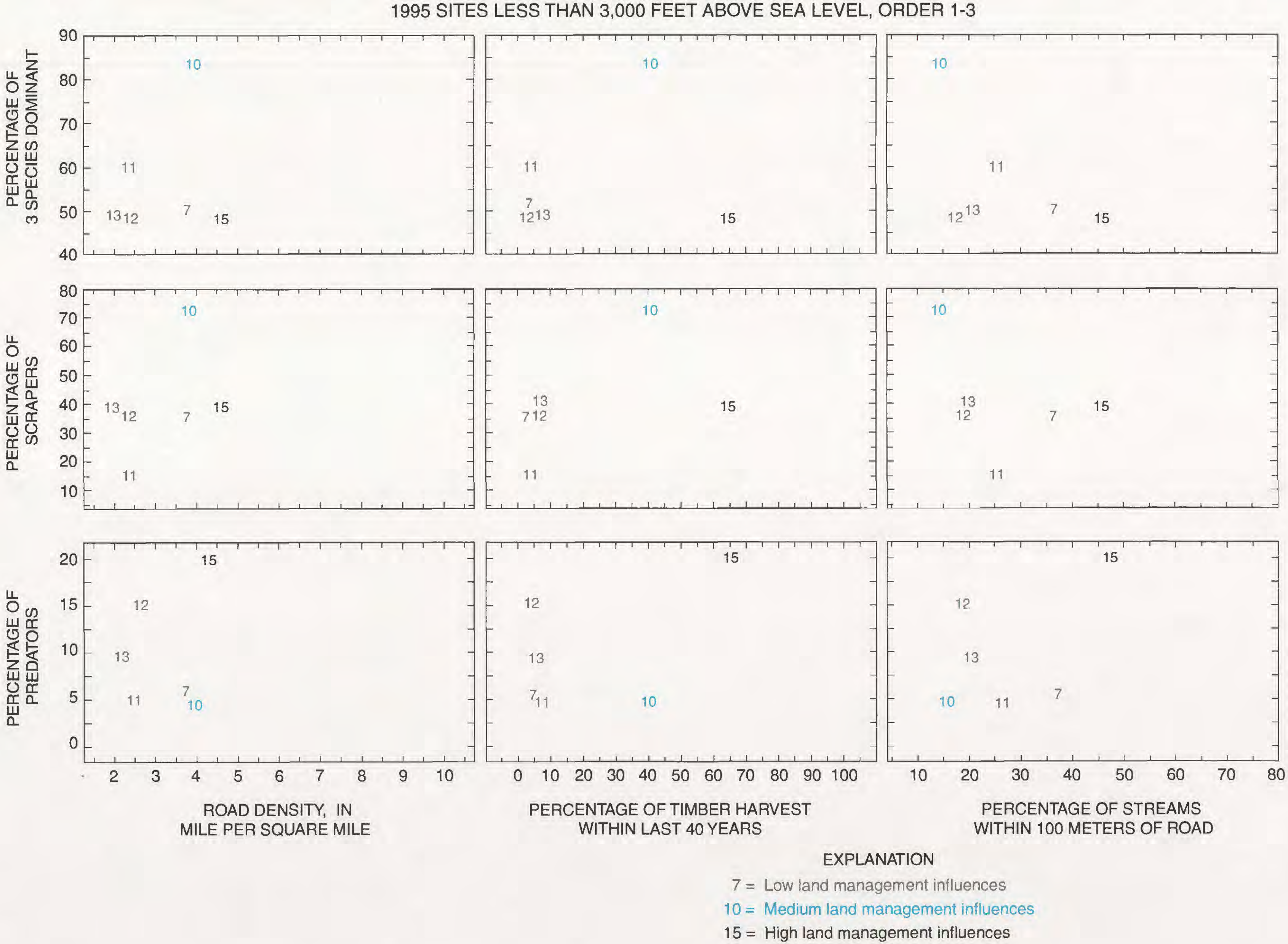
Appendix D. Partial site list of 1996 metric data for sites in the Cedar River Watershed

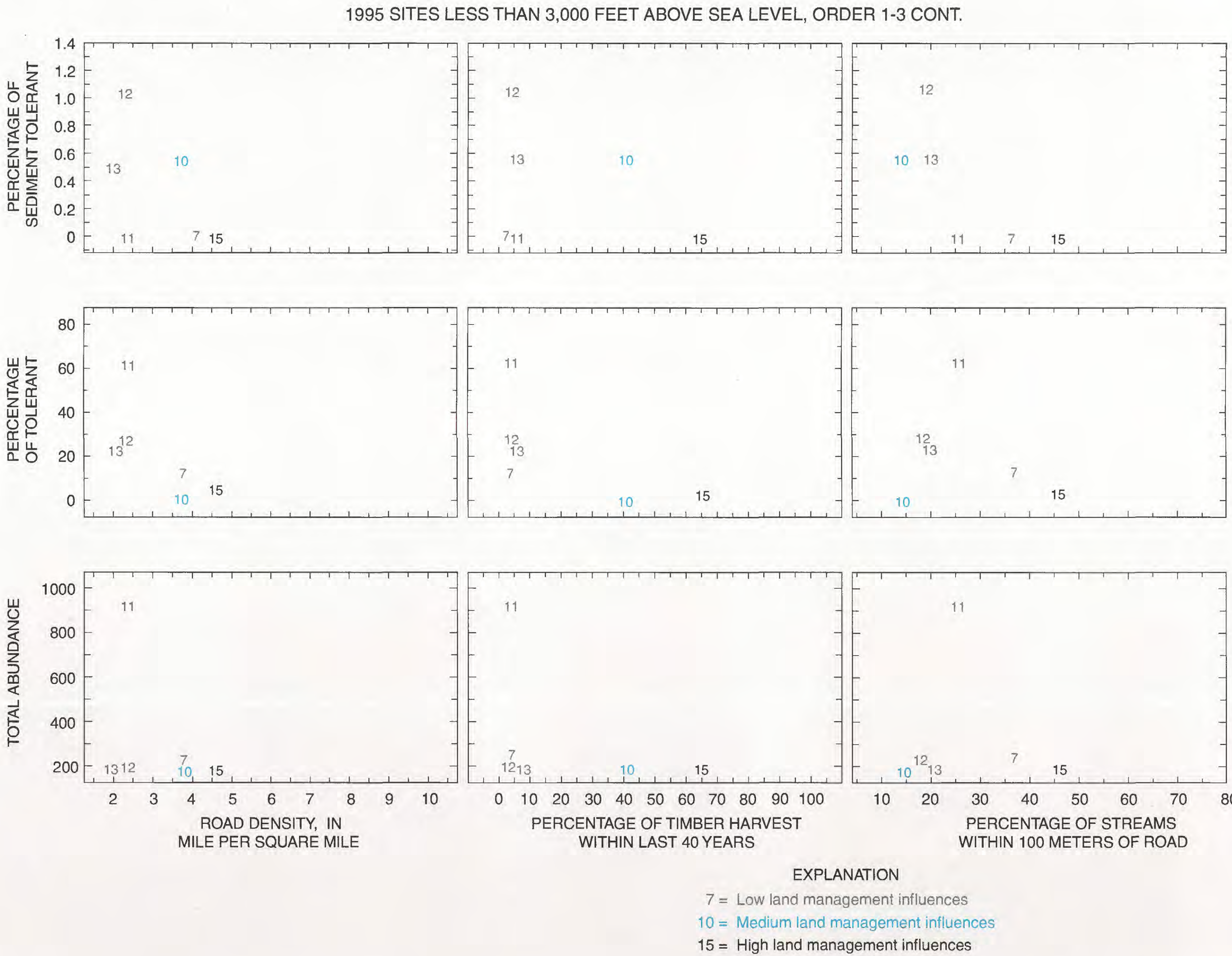
[Data for all sites can be found on the U.S. Geological Survey home page at http://wa.water.usgs.gov/; RS, riffle sample; PS, pool sample; >, greater than; <, less than]

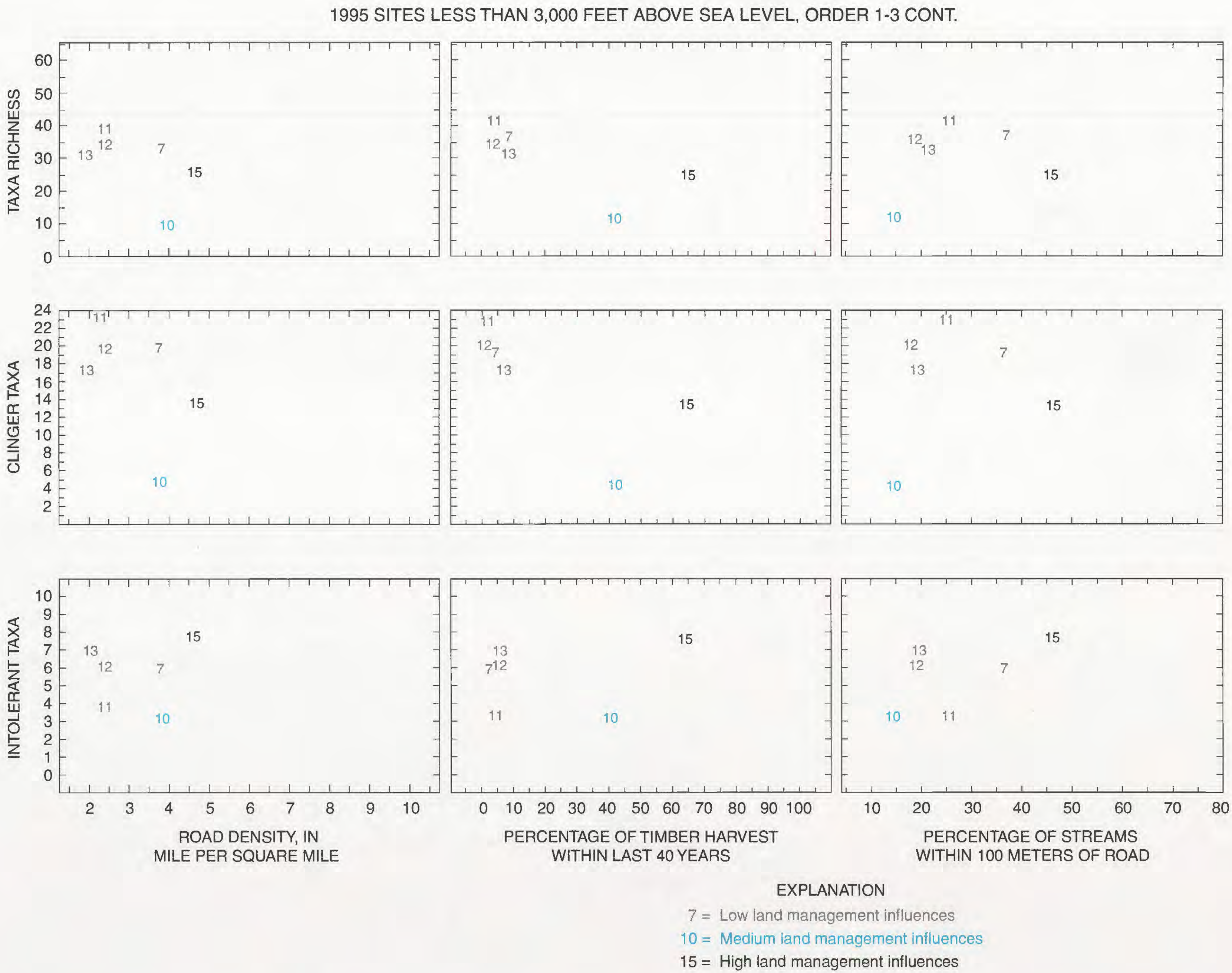
	Stream											
	Bear Creek	Bear Creek	Bear Creek	Boulder Creek	Boulder Creek	Boulder Creek	Boulder Creek	Boulder Creek	Boulder Creek	Boulder Creek	Boulder Creek	Boulder Creek
Site id	BEA 1.6	BEA 1.6	BEA 1.6	BOU 1.1	BOU 1.1	BOU 1.1	BOU 3.1	BOU 3.1	BOU 3.1	BOU 3.2	BOU 3.2	BOU 3.2
Replicate number	RS 1	RS 2	RS 3	RS 1	RS 2	RS 3	RS 1	RS 2	RS 3	RS 1	RS 2	RS 3
Date	09-11-96	09-11-96	09-11-96	09-28-96	09-28-96	09-28-96	09-04-96	09-04-96	09-04-96	09-04-96	09-04-96	09-04-96
Elevation	>3,000	>3,000	>3,000	<3,000	<3,000	<3,000	>3,000	>3,000	>3,000	>3,000	>3,000	>3,000
Stream order	1-3	1-3	1-3	4-6	4-6	4-6	1-3	1-3	1-3	1-3	1-3	1-3
Total abundance	101	67	115	214	112	129	4	200	7	181	1118	261
Scrapers, percentage	44	46	34	20	7	3	0	9	14	6	2	2
Predators, percentage	18	15	27	25	16	10	0	8	14	4	7	2
Dominant taxa (3 taxa), percentage	50	46	31	36	43	53	100	61	71	57	62	68
Tolerant taxa, percentage	0	0	0	7	36	7	0	2	0	0	7	1
Sediment tolerant taxa, percentage	0	0	3	0	0	0	0	0	0	0	1	0
Total taxa	21	23	30	37	22	25	1	24	5	15	37	16
Ephemeroptera taxa	4	5	5	9	6	4	0	7	2	1	6	2
Plecoptera taxa	8	6	9	7	7	4	0	5	1	2	8	2
Trichoptera taxa	7	6	9	8	1	4	1	7	1	5	9	4
Intolerant taxa	5	3	7	1	1	0	1	3	0	2	4	1
Long-lived taxa	3	1	3	2	2	0	0	2	0	0	1	0
Sediment intolerant taxa	2	0	1	0	0	0	0	0	0	1	0	0
Pteronarcys sp.	1	0	0	0	0	0	0	0	0	0	1	0
Clinger taxa	12	11	15	17	10	10	1	14	3	7	18	7

Appendix E. 1995 metric values for sites less than 3,000 feet above sea level, stream order 1 to 3, and sites less than 3,000 feet above sea level, stream order 4 to 6 by land management influence

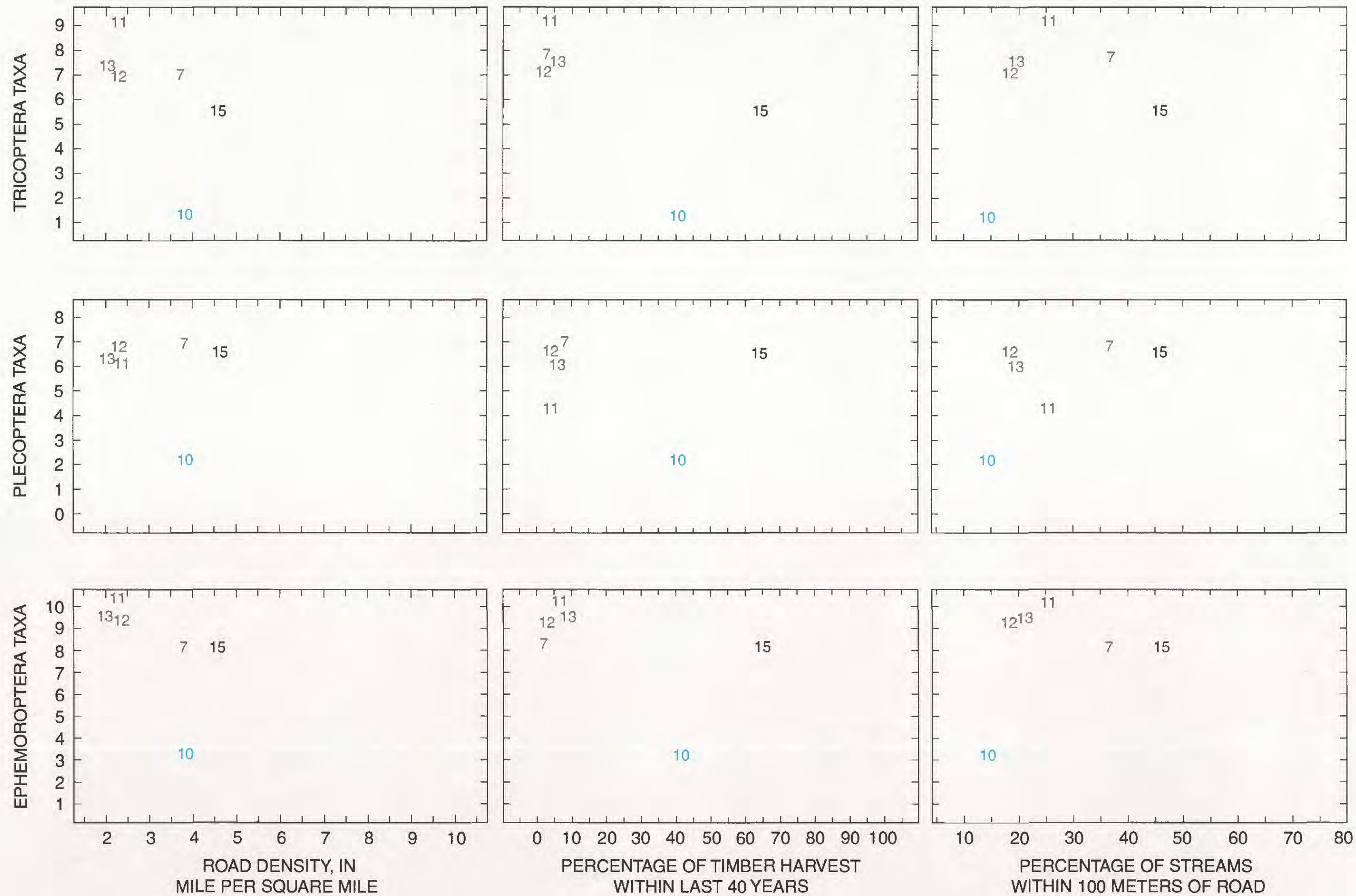
Appendix E. 1995 metric values for sites less that 3,000 feet above sea level, stream order 1 to 3, and sites less than 3,000 feet above sea level, stream order 4 to 6 by land management influence (see table 1 for site number identification).




1995 SITES LESS THAN 3,000 FEET ABOVE SEA LEVEL, ORDER 1-3 CONT.
PERCENTAGE OF SEDIMENT TOLERANT
PERCENTAGE OF TOLERANT
TOTAL ABUNDANCE
ROAD DENSITY, IN MILE PER SQUARE MILE
PERCENTAGE OF TIMBER HARVEST WITHIN LAST 40 YEARS
PERCENTAGE OF STREAMS WITHIN 100 METERS OF ROAD
EXPLANATION
7 = Low land management influences
10 = Medium land management influences
15 = High land management influences


1995 SITES LESS THAN 3,000 FEET ABOVE SEA LEVEL, ORDER 1-3 CONT.
TAXA RICHNESS
CLINGER TAXA
INTOLERANT TAXA
ROAD DENSITY, IN MILE PER SQUARE MILE
PERCENTAGE OF TIMBER HARVEST WITHIN LAST 40 YEARS
PERCENTAGE OF STREAMS WITHIN 100 METERS OF ROAD
EXPLANATION
7 = Low land management influences
10 = Medium land management influences
15 = High land management influences

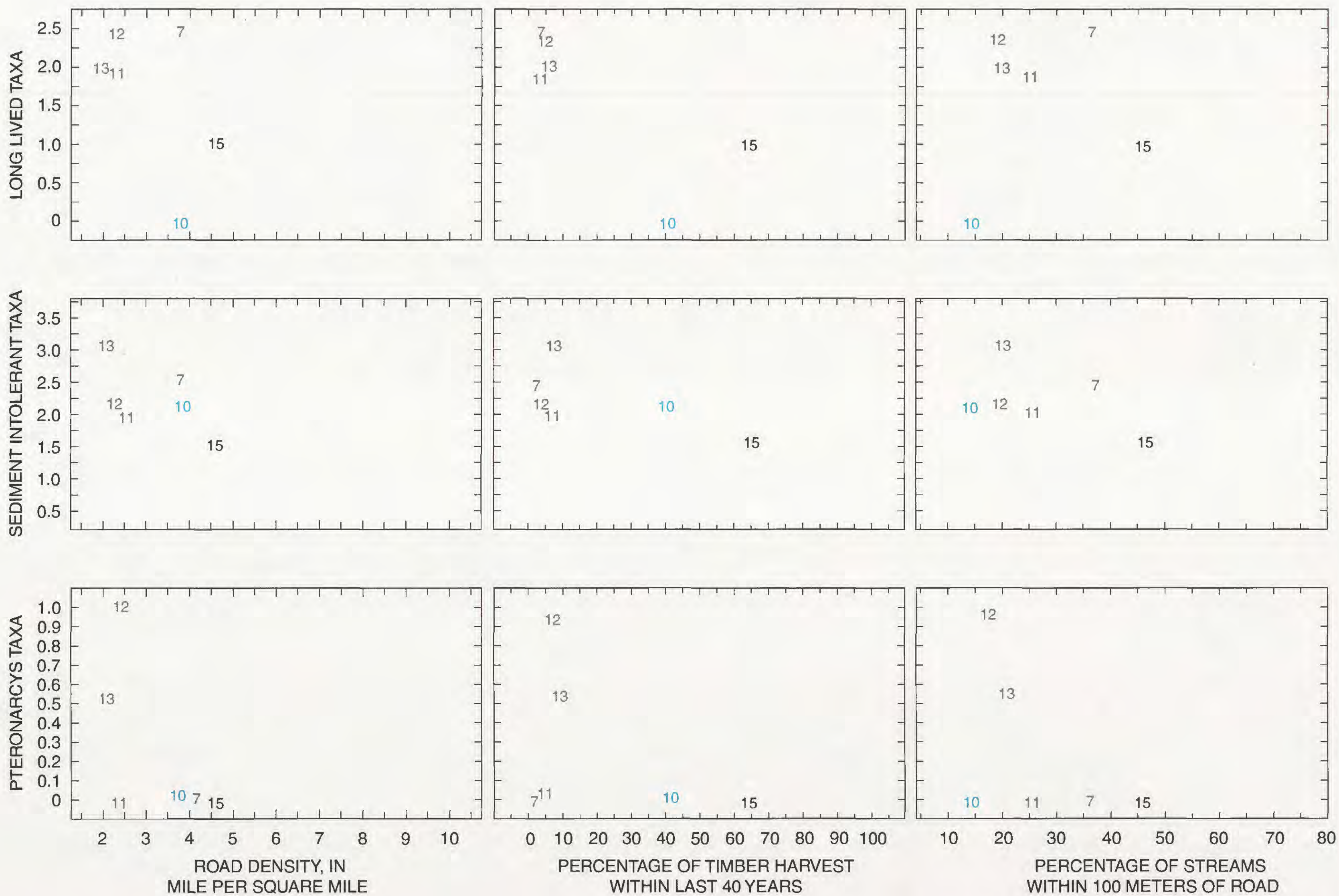
1995 SITES LESS THAN 3,000 FEET ABOVE SEA LEVEL, ORDER 1-3 CONT.



EXPLANATION

7 = Low land management influences
10 = Medium land management influences
15 = High land management influences

1995 SITES LESS THAN 3,000 FEET ABOVE SEA LEVEL, ORDER 1-3 CONT.



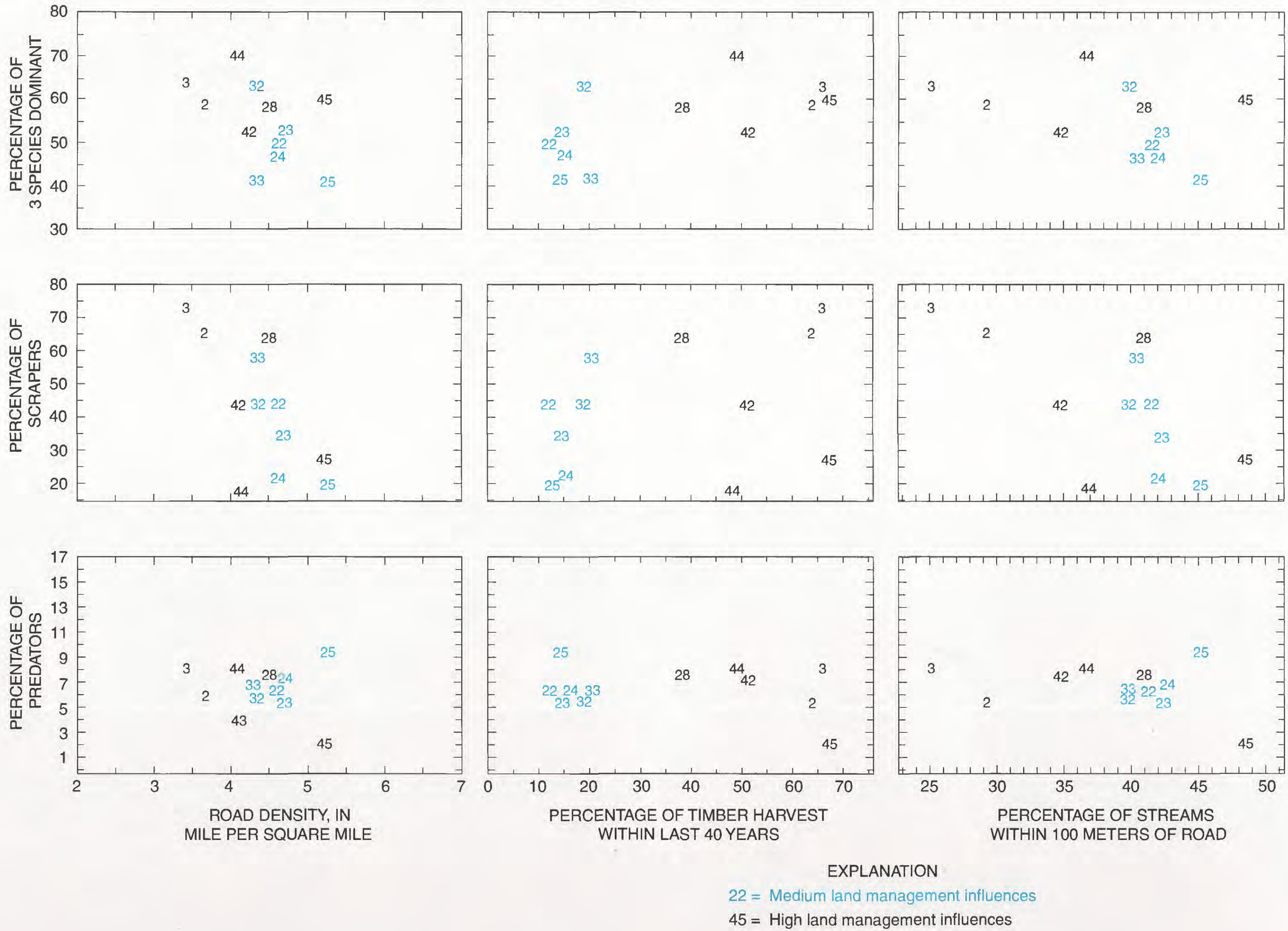
EXPLANATION

7 = Low land management influences

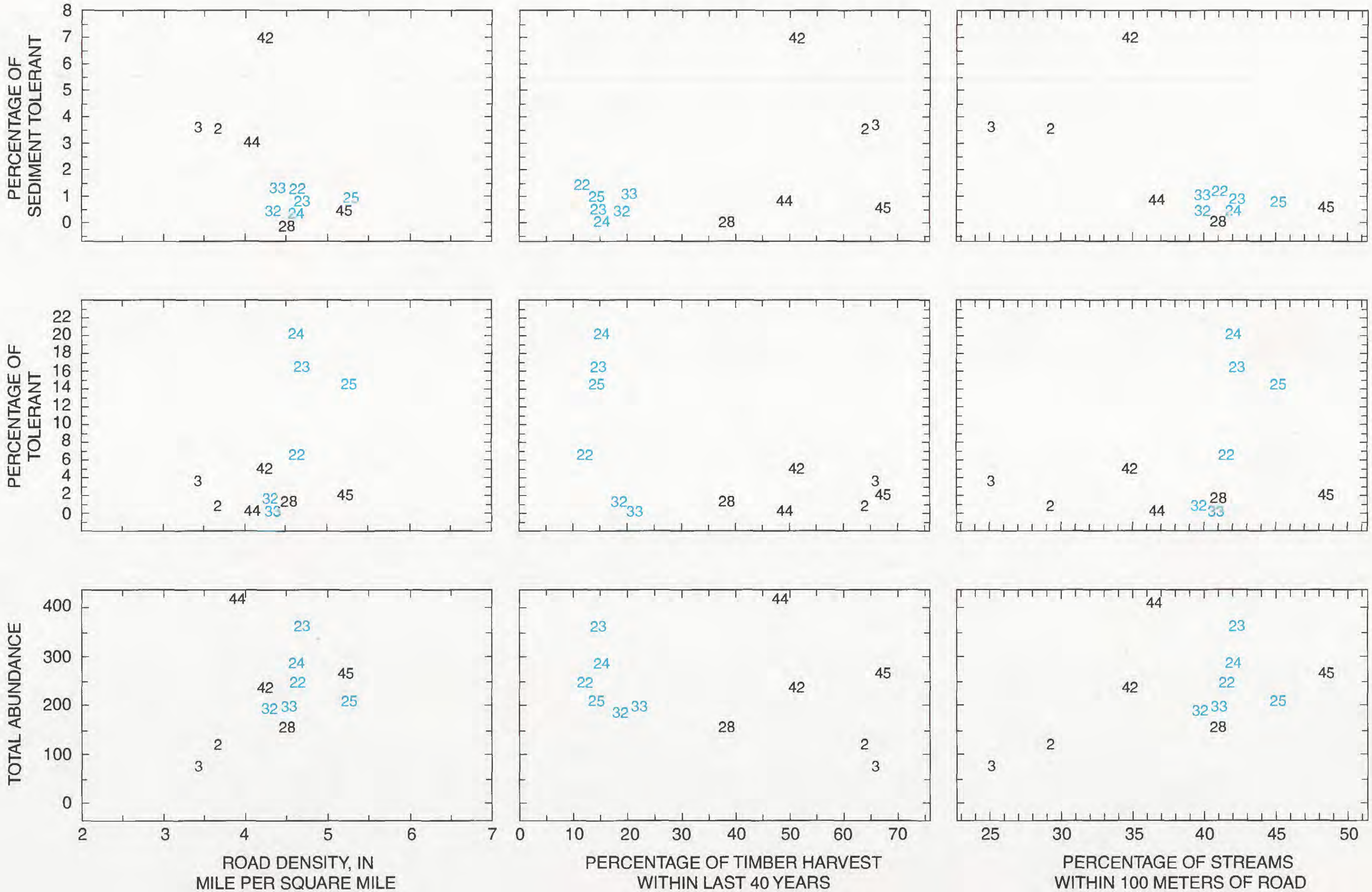
10 = Medium land management influences

15 = High land management influences

1995 SITES LESS THAN 3,000 FEET ABOVE SEA LEVEL, ORDER 4-6 CONT.



1995 SITES LESS THAN 3,000 FEET ABOVE SEA LEVEL, ORDER 4-6 CONT.

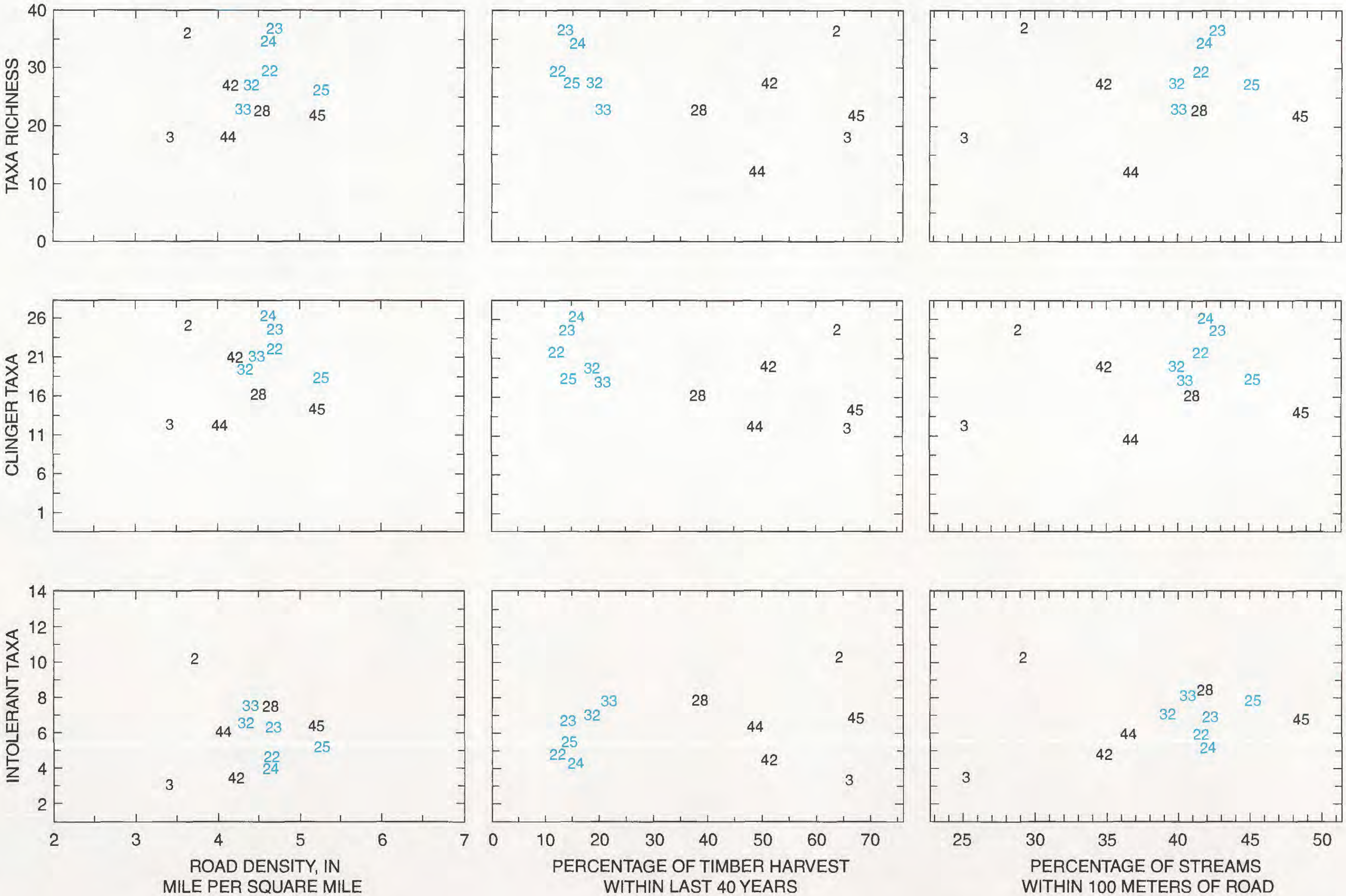


EXPLANATION

22 = Medium land management influences

45 = High land management influences

1995 SITES LESS THAN 3,000 FEET ABOVE SEA LEVEL, ORDER 4-6 CONT.

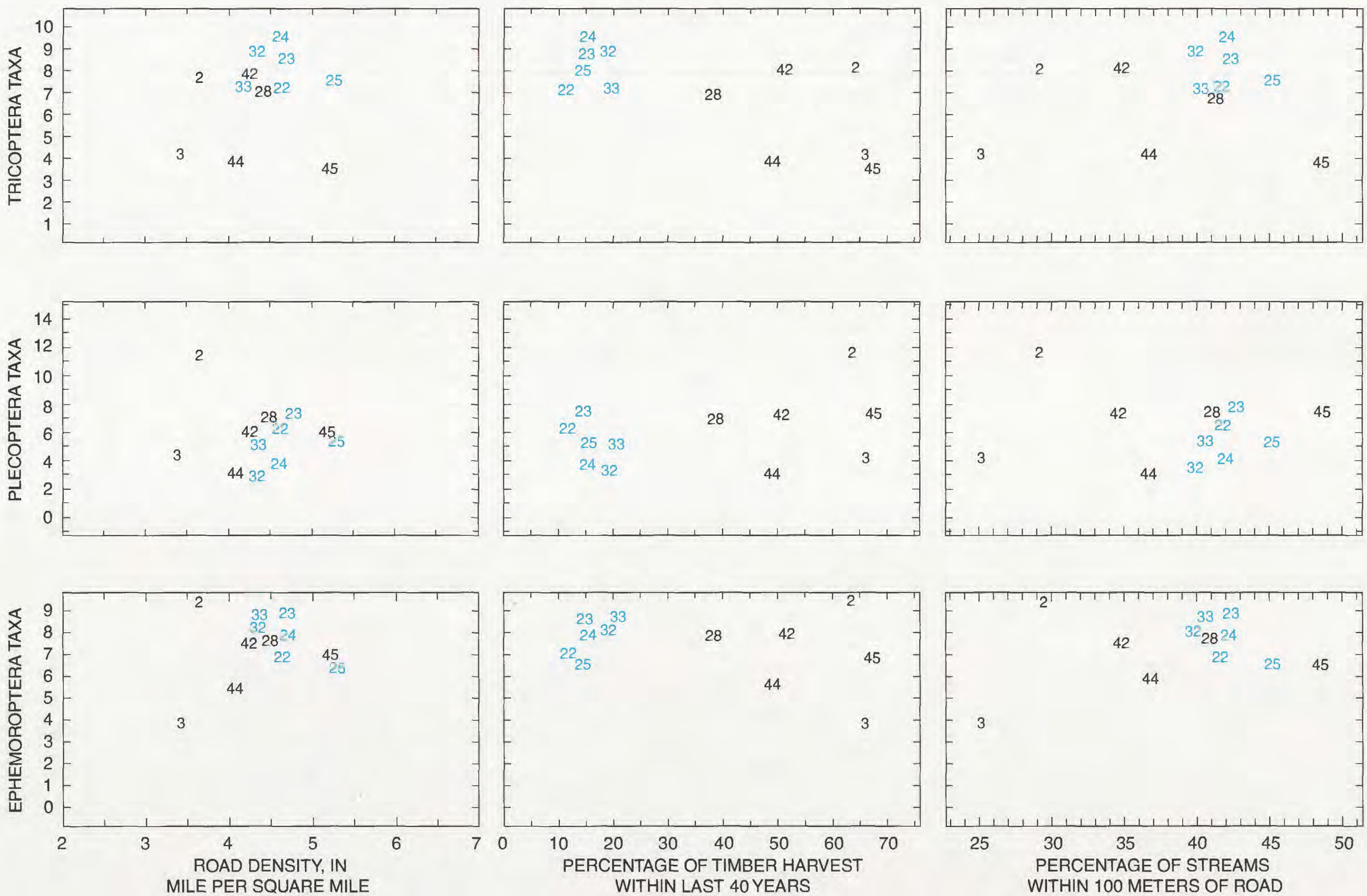


EXPLANATION

22 = Medium land management influences

45 = High land management influences

1995 SITES LESS THAN 3,000 FEET ABOVE SEA LEVEL, ORDER 4-6 CONT.



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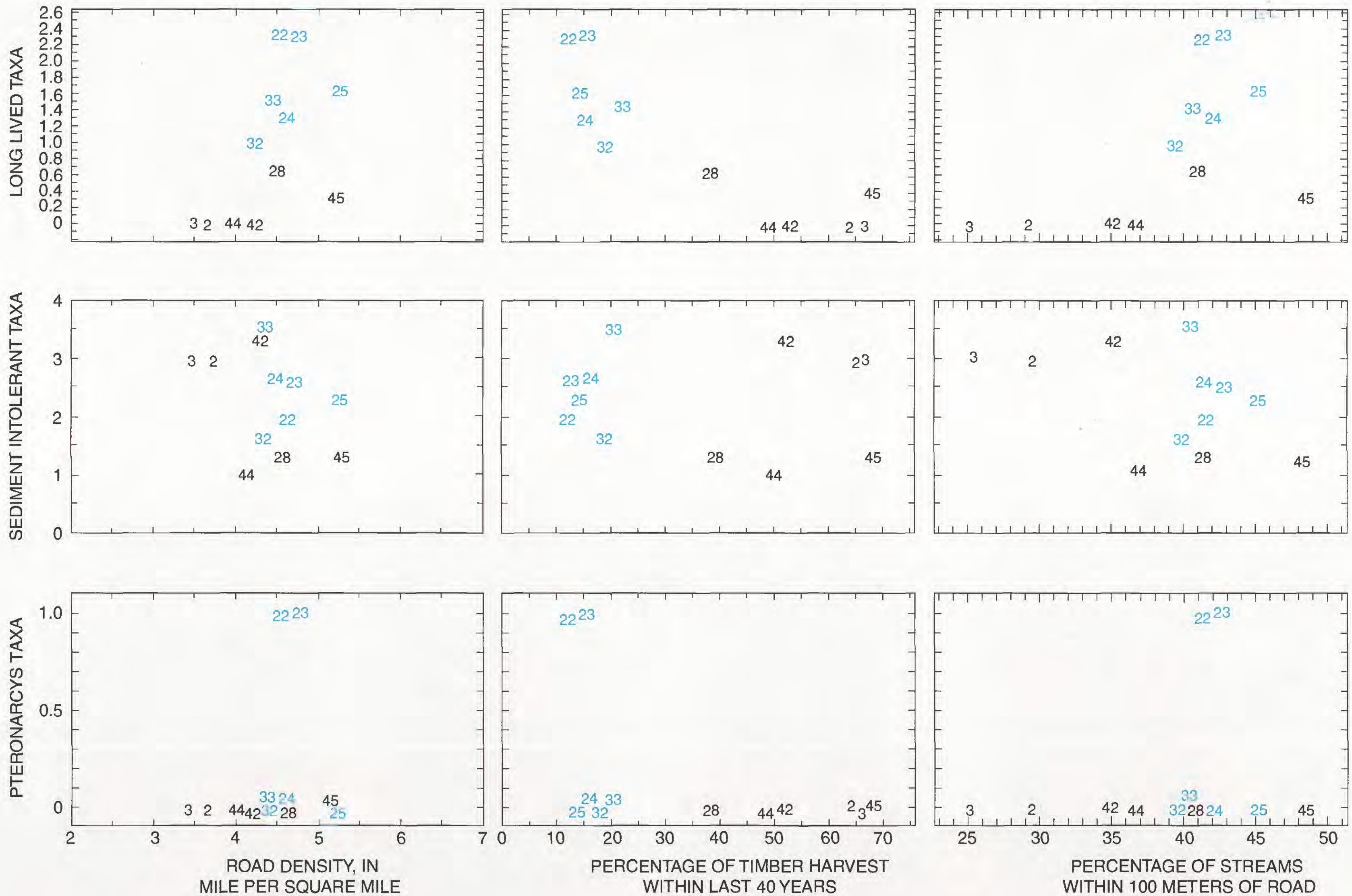
22 = Medium land management influences

45 = High land management influences

1995 SITES LESS THAN 3,000 FEET ABOVE SEA LEVEL, ORDER 4-6 CONT.



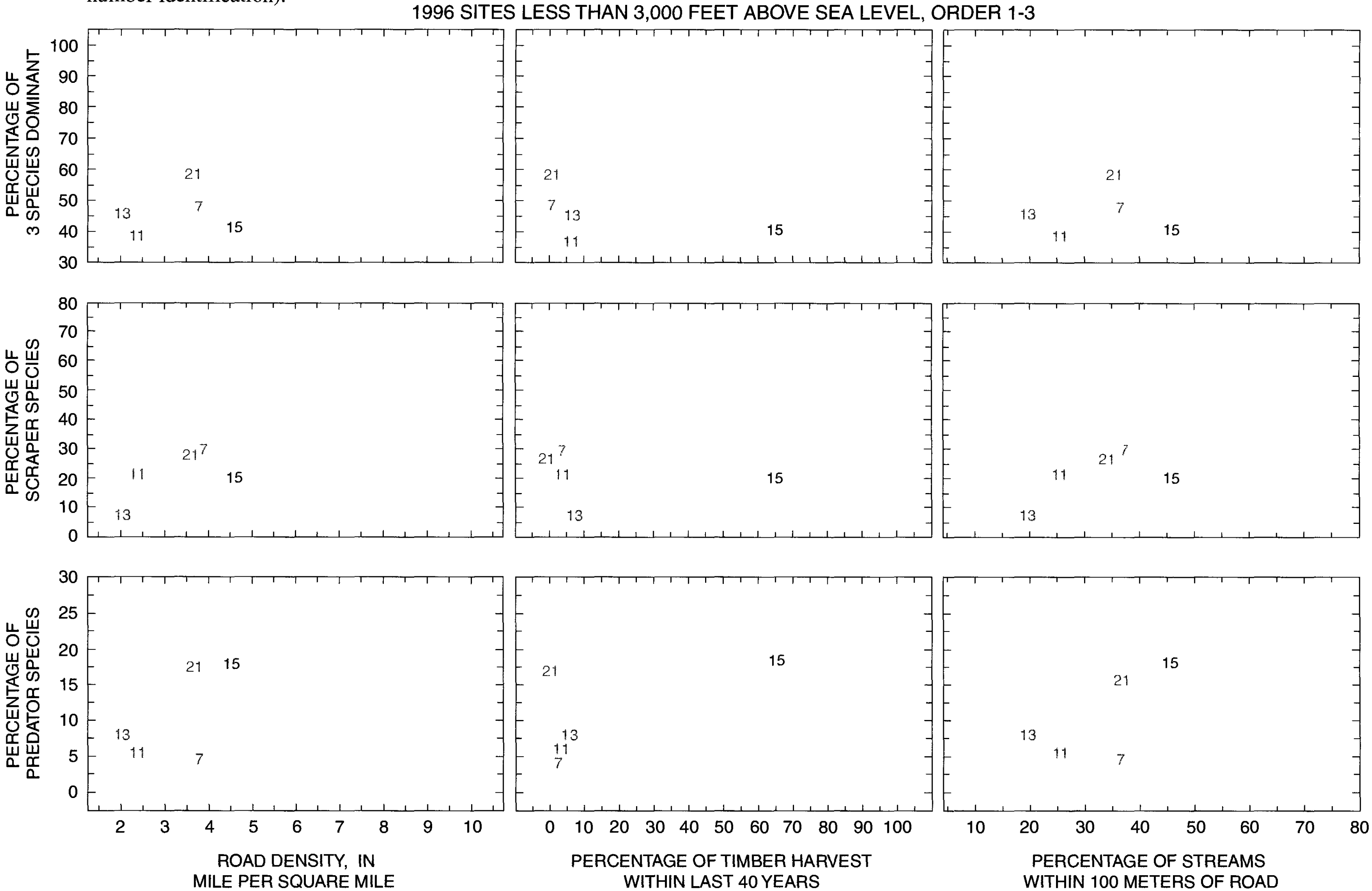
EXPLANATION

22 = Medium land management influences

45 = High land management influences

Appendix F. 1996 metric values for sites less than 3,000 feet above sea level, stream order 1 to 3, sites less than 3,000 feet above sea level, stream order 4 to 6, and sites greater than 3,000 feet above sea level, stream order 1 to 3 by land management influence

Appendix F. 1996 metric values for sites less than 3,000 feet above sea level, stream order 1 to 3, sites less than 3,000 feet above sea level, stream order 4 to 6, and sites greater than 3,000 feet above sea level, stream order 1 to 3 by land management influence (see table 1 for site number identification).



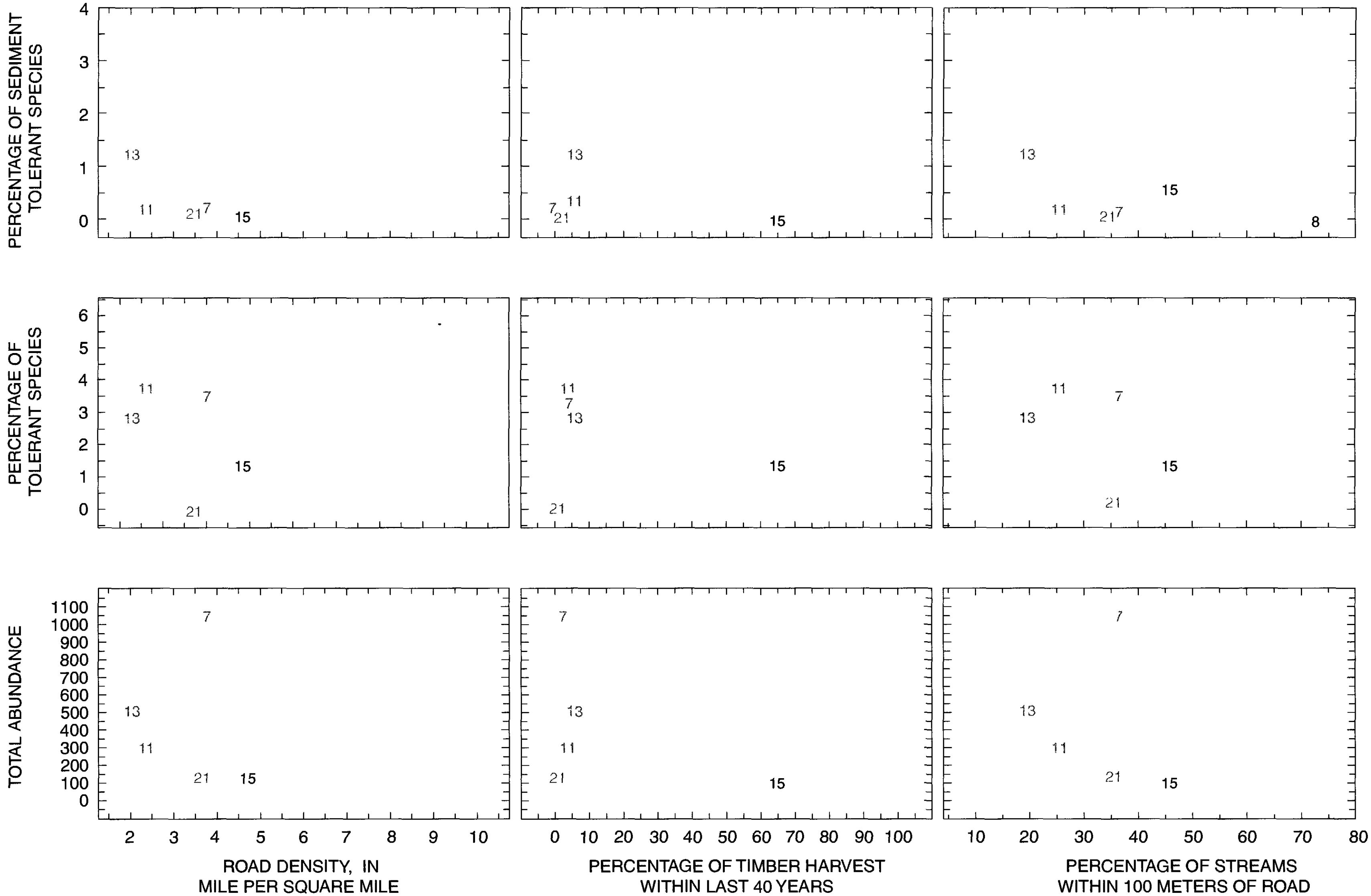
EXPLANATION

7 = Low land management influences

21 = Medium land management influences

15 = High land management influences

1996 SITES LESS THAN 3,000 FEET ABOVE SEA LEVEL, ORDER 1-3 CONT.



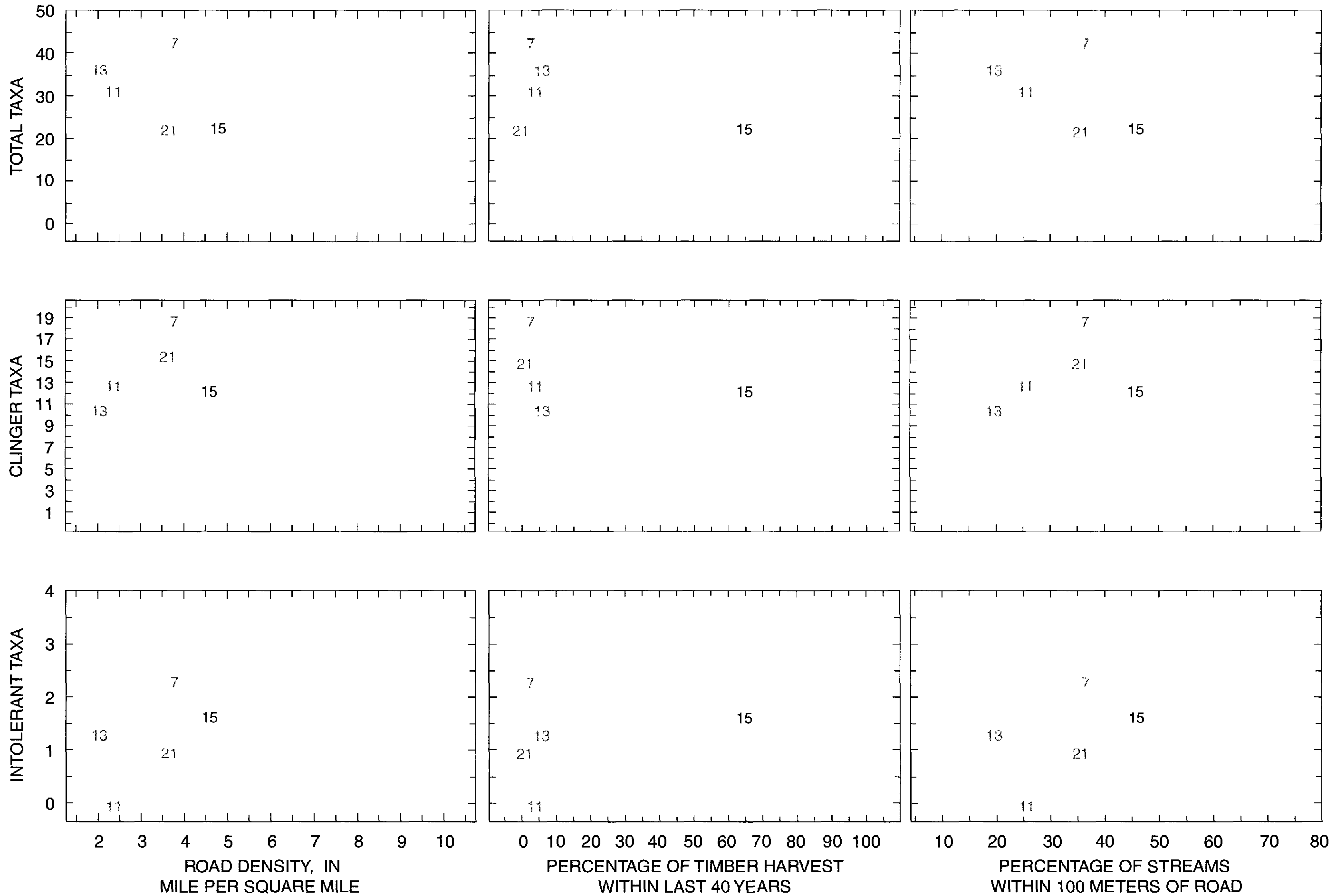
EXPLANATION

7 = Low land management influences

21 = Medium land management influences

15 = High land management influences

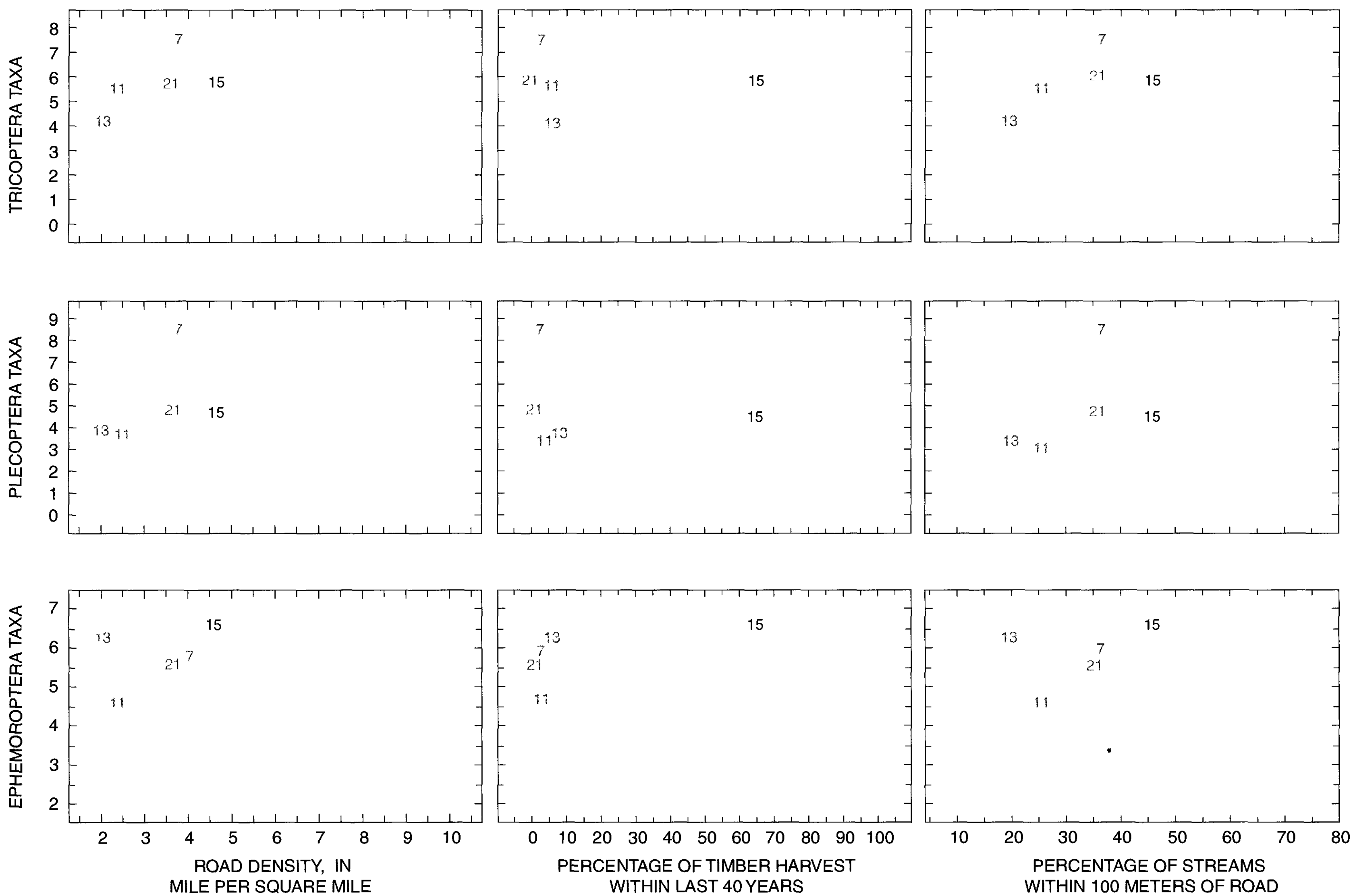
1996 SITES LESS THAN 3,000 FEET ABOVE SEA LEVEL, ORDER 1-3 CONT.



EXPLANATION

7 = Low land management influences
21 = Medium land management influences
15 = High land management influences

1996 SITES LESS THAN 3,000 FEET ABOVE SEA LEVEL, ORDER 1-3 CONT.



EXPLANATION

7 = Low land management influences

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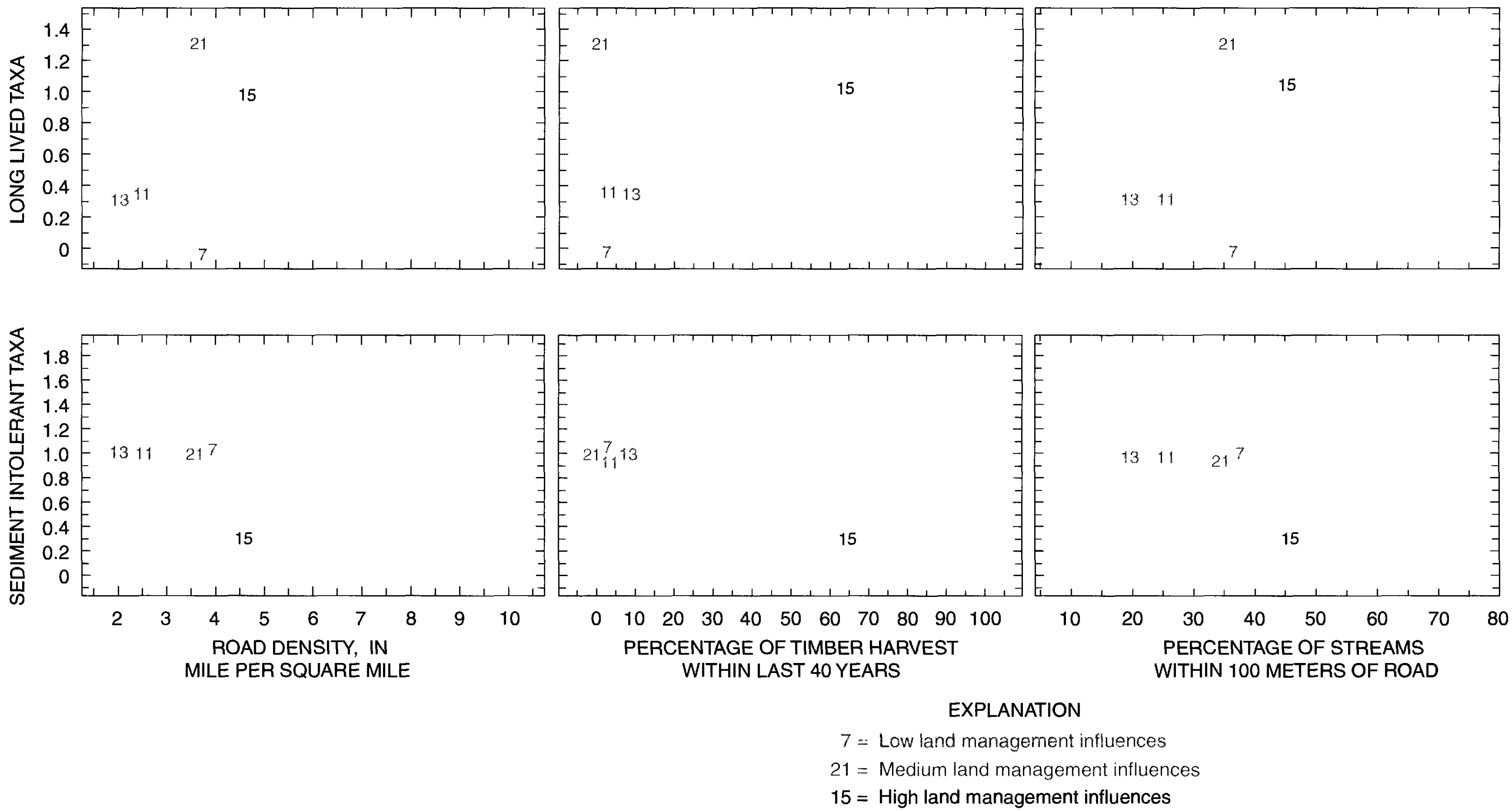
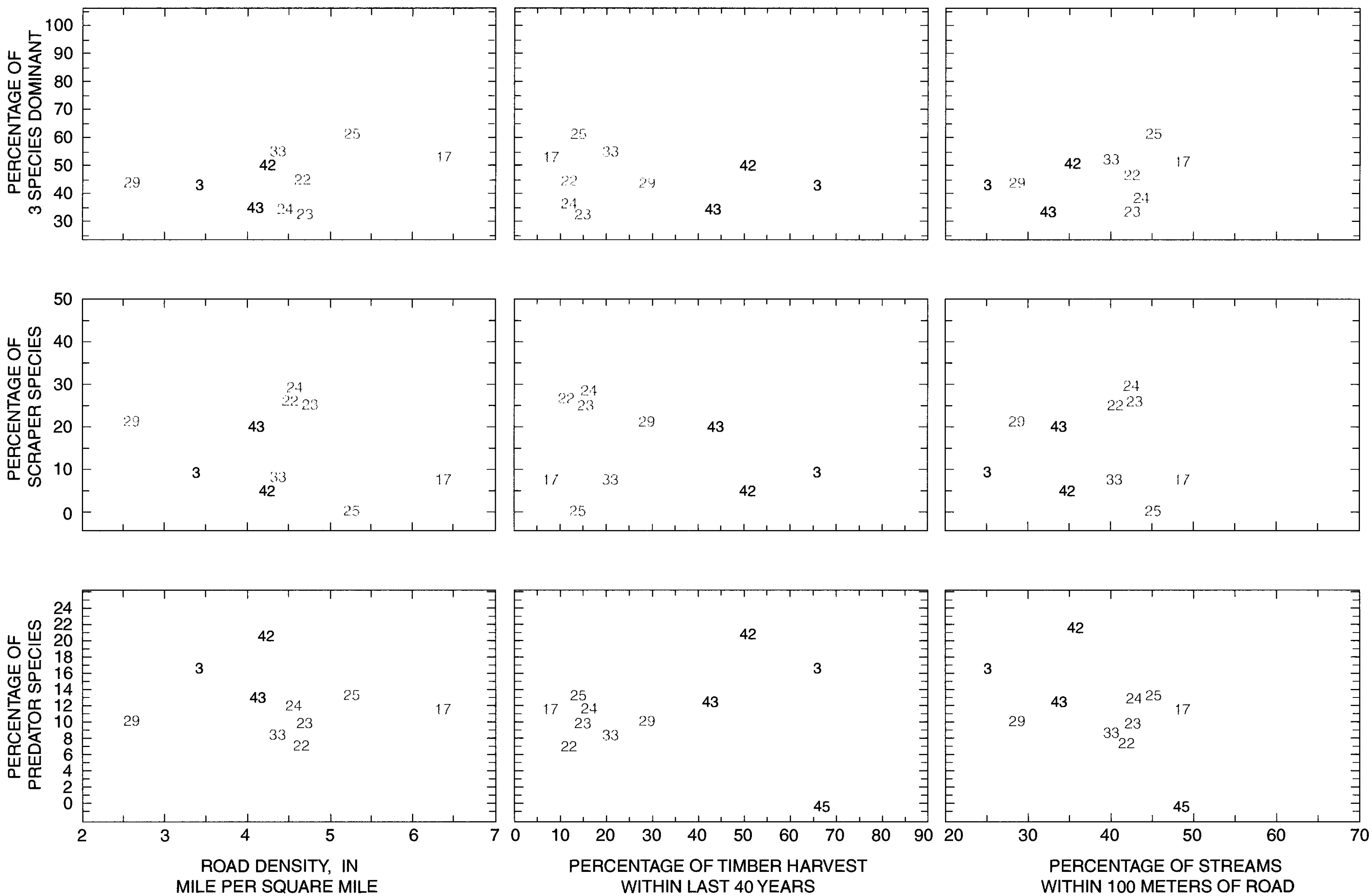
1996 SITES LESS THAN 3,000 FEET ABOVE SEA LEVEL, ORDER 1-3 CONT.



1996 SITES LESS THAN 3,000 FEET ABOVE SEA LEVEL, ORDER 4-6 CONT.

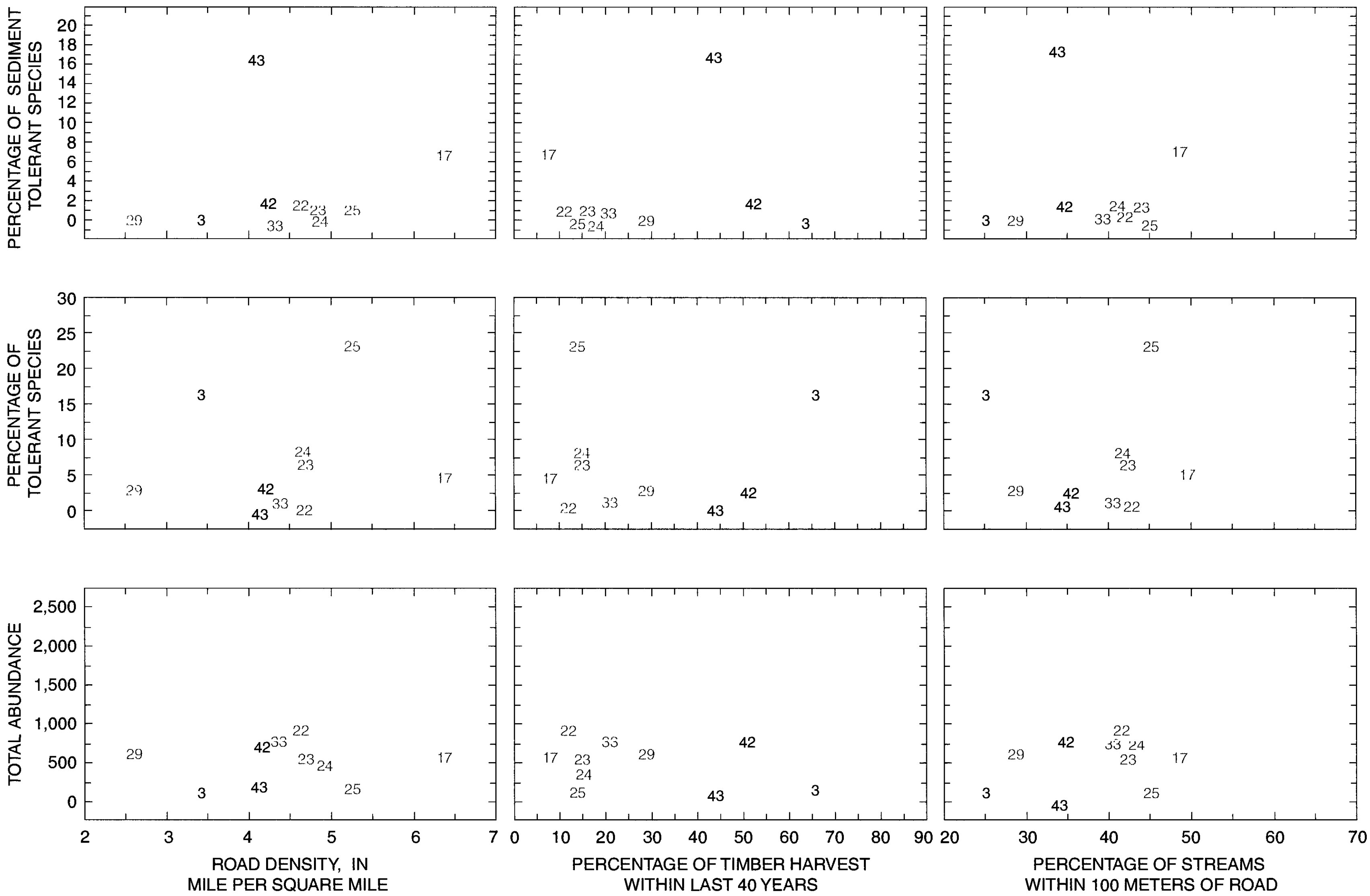


EXPLANATION

22 = Medium land management influences

42 = **High land management influences**

1996 SITES LESS THAN 3,000 FEET ABOVE SEA LEVEL, ORDER 4-6 CONT.

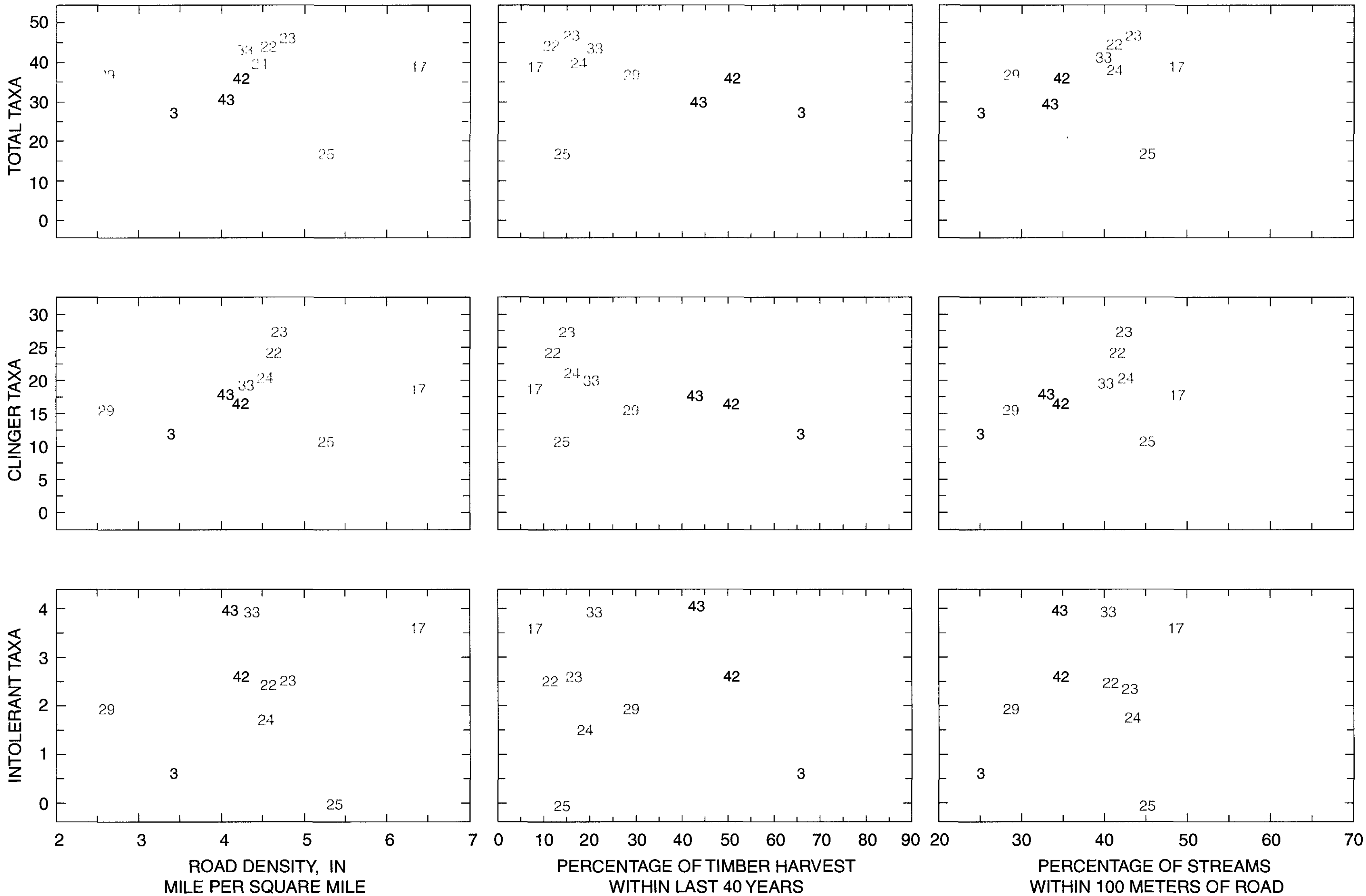


EXPLANATION

22 = Medium land management influences

42 = High land management influences

1996 SITES LESS THAN 3,000 FEET ABOVE SEA LEVEL, ORDER 4-6 CONT.

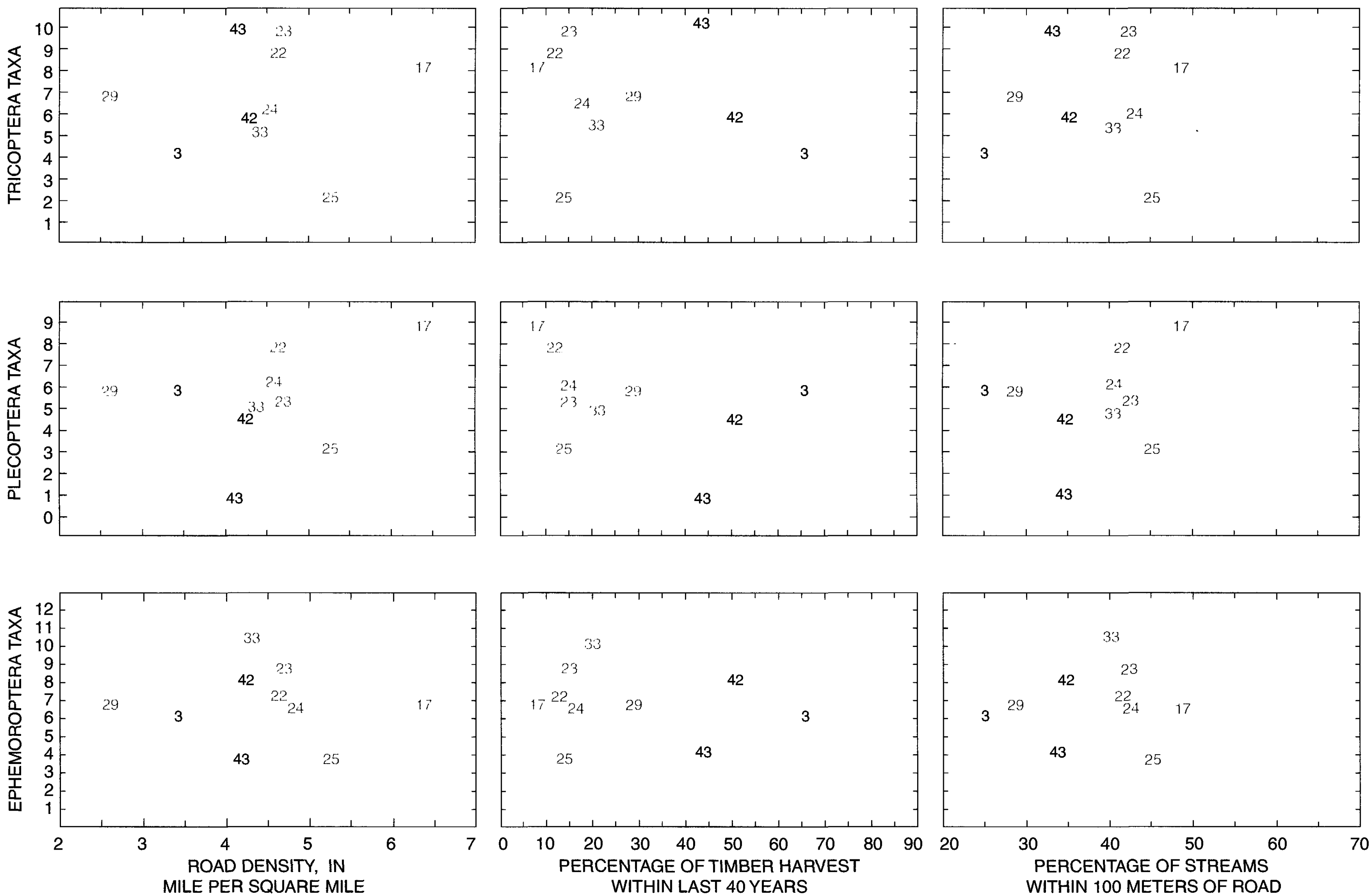


EXPLANATION

22 = Medium land management influences

42 = High land management influences

1996 SITES LESS THAN 3,000 FEET ABOVE SEA LEVEL, ORDER 4-6 CONT.

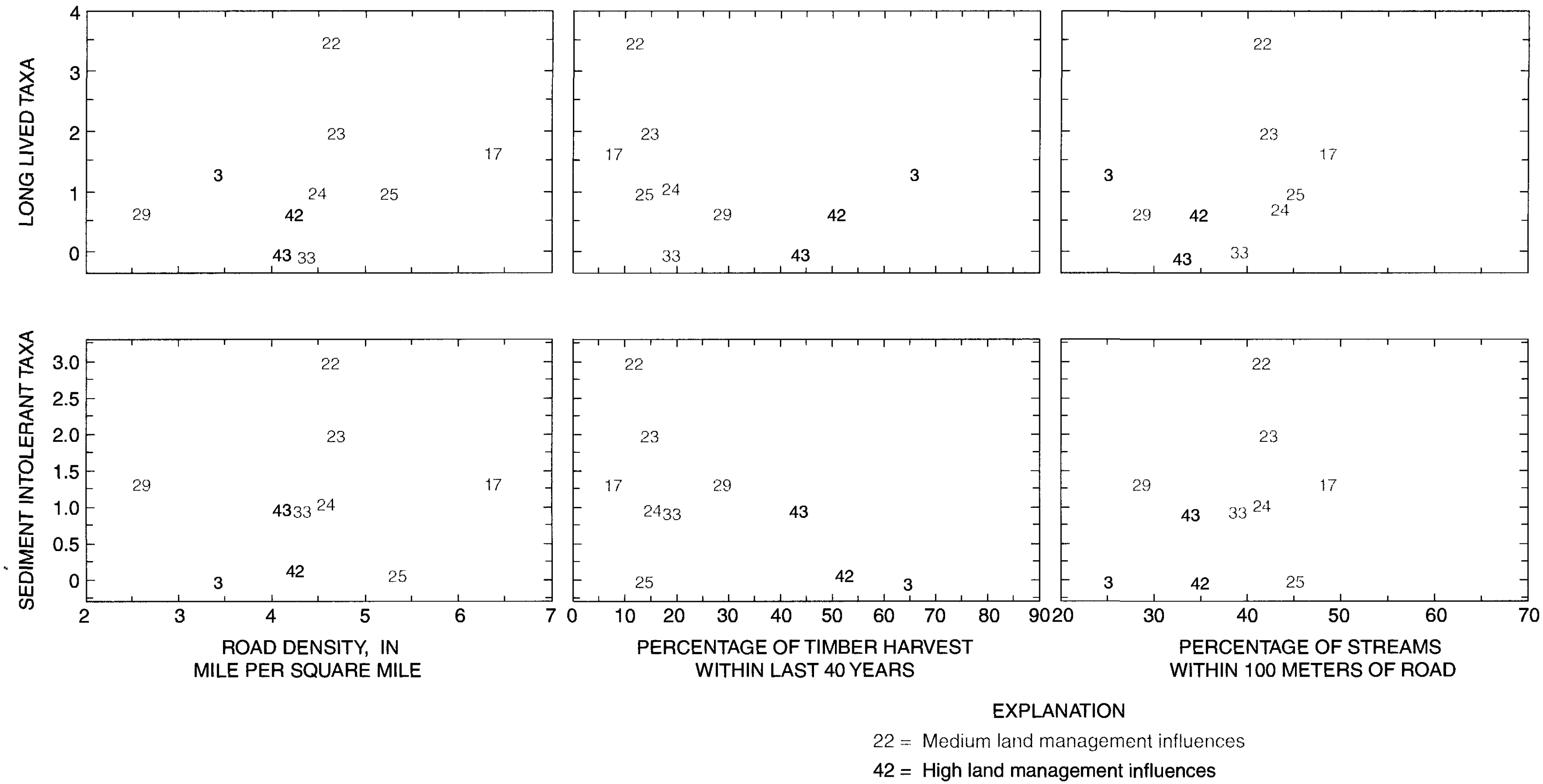


EXPLANATION

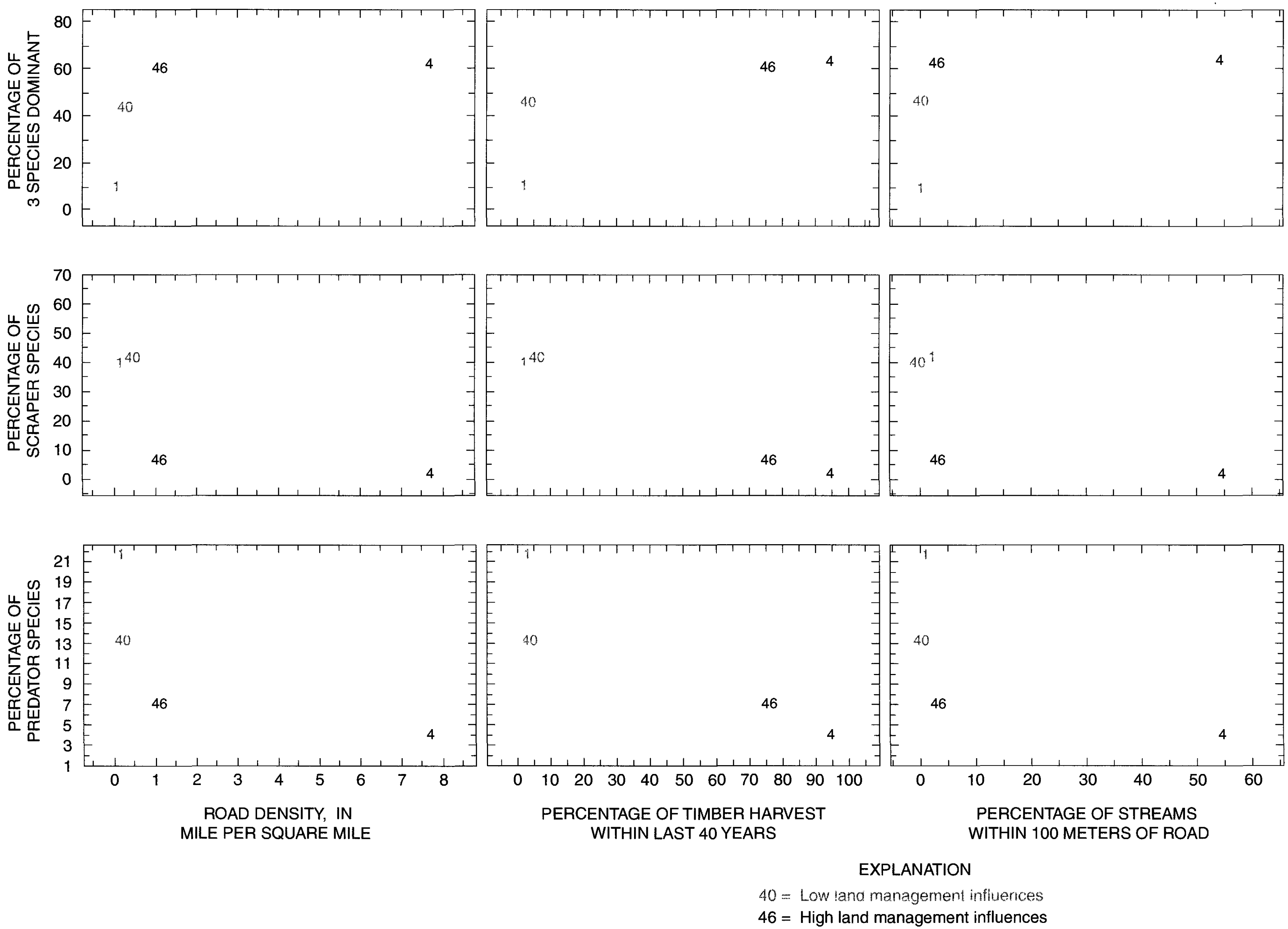
22 = Medium land management influences

42 = High land management influences

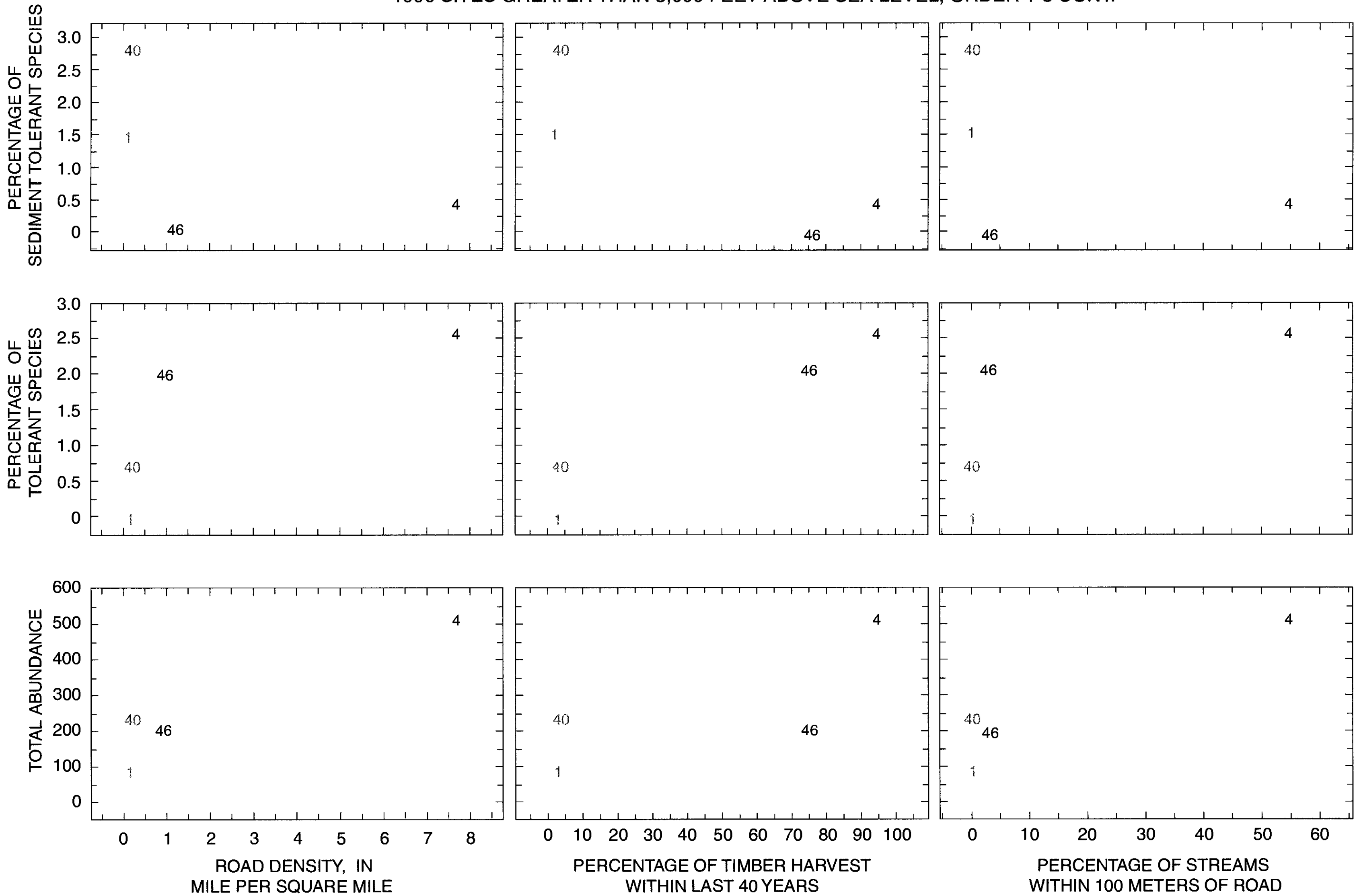
1996 SITES LESS THAN 3,000 FEET ABOVE SEA LEVEL, ORDER 4-6 CONT.



1996 SITES GREATER THAN 3,000 FEET ABOVE SEA LEVEL, ORDER 1-3 CONT.

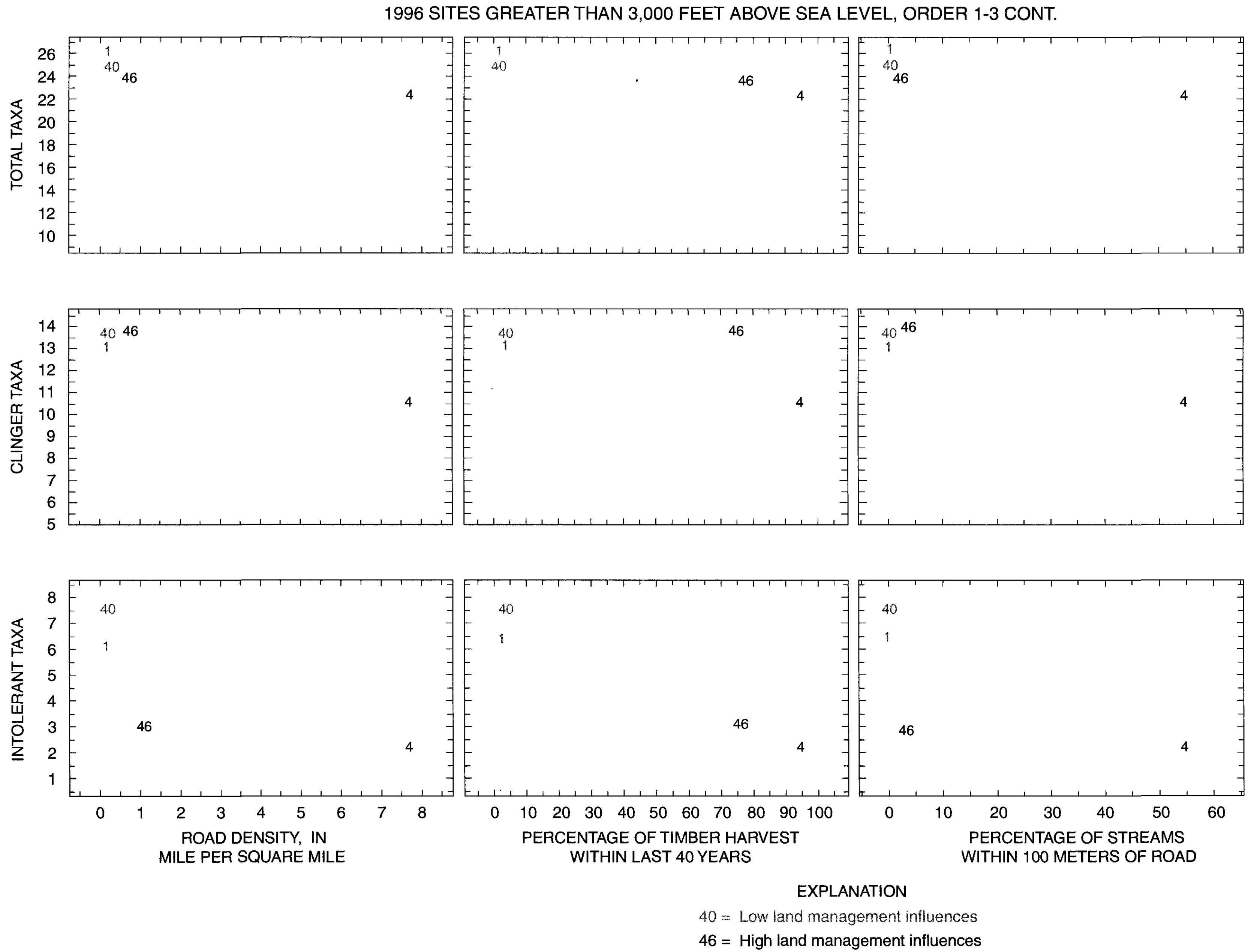


1996 SITES GREATER THAN 3,000 FEET ABOVE SEA LEVEL, ORDER 1-3 CONT.

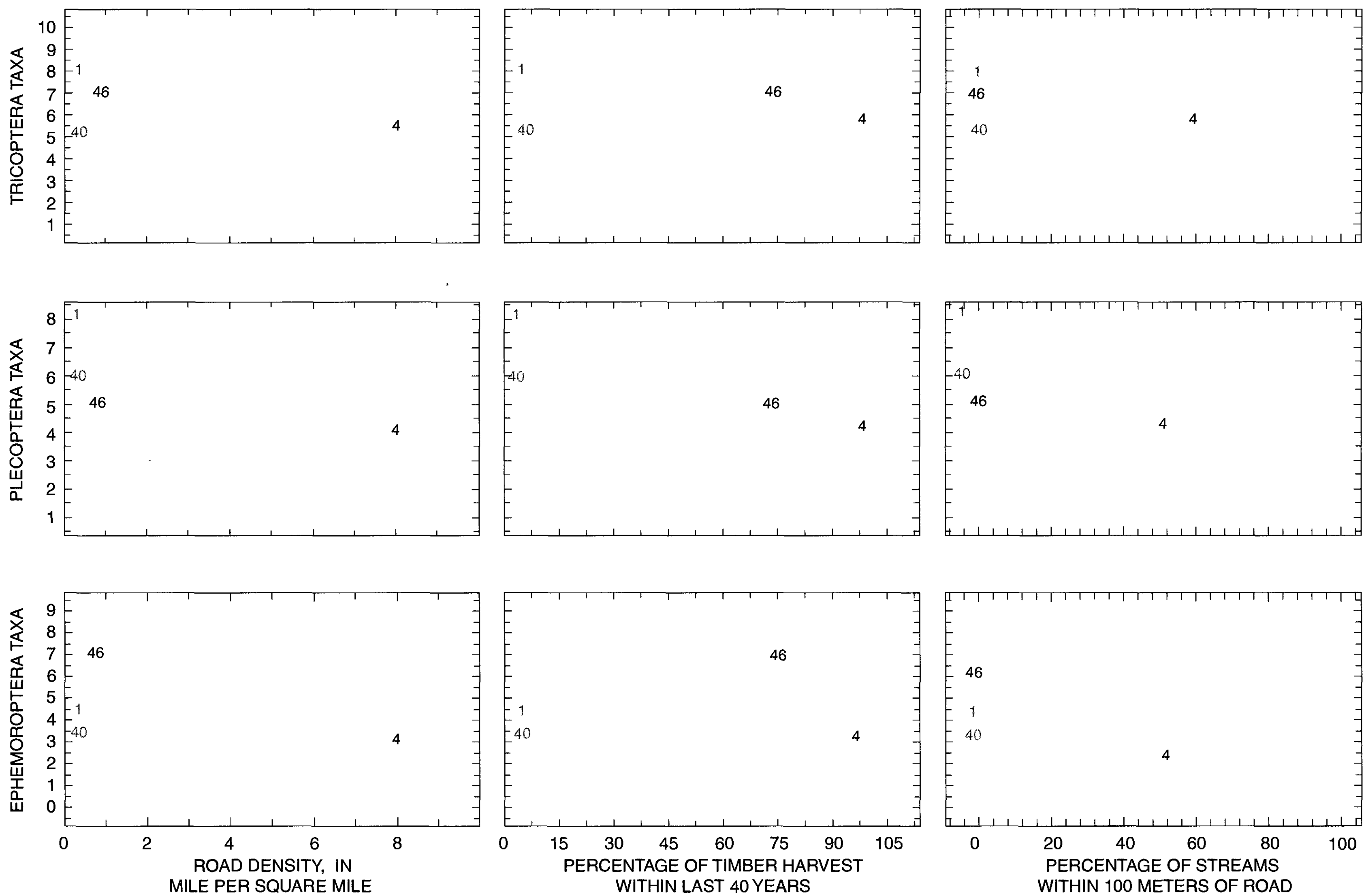


EXPLANATION

40 = Low land management influences
46 = High land management influences


1996 SITES GREATER THAN 3,000 FEET ABOVE SEA LEVEL, ORDER 1-3 CONT.
TOTAL TAXA
CLINGER TAXA
INTOLERANT TAXA
ROAD DENSITY, IN MILE PER SQUARE MILE
PERCENTAGE OF TIMBER HARVEST WITHIN LAST 40 YEARS
PERCENTAGE OF STREAMS WITHIN 100 METERS OF ROAD
EXPLANATION
40 = Low land management influences
46 = High land management influences

1996 SITES GREATER THAN 3,000 FEET ABOVE SEA LEVEL, ORDER 1-3 CONT.

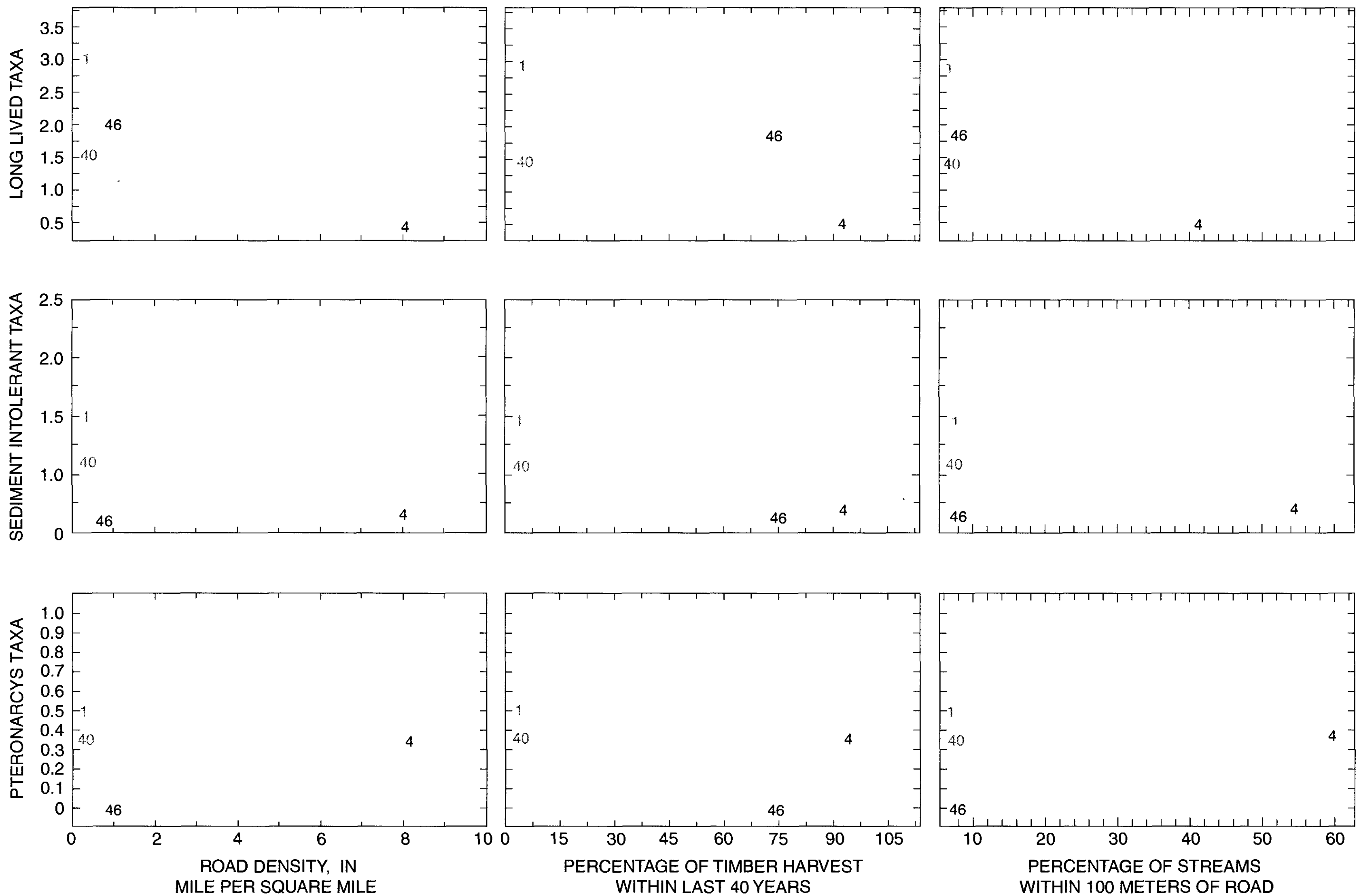


EXPLANATION

40 = Low land management influences

46 = High land management influences

1996 SITES GREATER THAN 3,000 FEET ABOVE SEA LEVEL, ORDER 1-3 CONT.



EXPLANATION

40 = Low land management influences

46 = High land management influences

Appendix G. Percentage of cover at benthic index of biological integrity (BIBI) sites in the Cedar River Watershed

Stream name	River mile	Map site number	Latitude	Longitude	Date	Center upstream	Center downstream	Center left	Center right	Left bank	Right bank	Average cover
					1995							
Bear Creek	1.6	1	47-19-30	121-36-33	10-27-95	86	88	76	92	88	90	87
Boulder Creek	0.5	2	47-21-58	121-41-35	10-26-95	27	63	0	89	0	100	47
	1.1	3	47-21-37	121-42-11	10-26-95	70	80	80	80	85	100	83
	3.2	4	47-20-09	121-42-14	10-13-95	14	44	37	49	94	53	49
Cedar River	0.0	36	47-22-12	121-37-23	10-06-95	0	0	8	0	16	85	18
	1.0	22	47-23-06	121-57-18	10-17-95	100	80	100	100	95	100	96
	5.0	37	47-20-45	121-33-00	10-06-95	7	33	53	66	74	77	52
	6.9	24	47-23-13	121-51-59	10-20-95	99	98	61	83	0	0	57
	8.8	25	47-24-07	121-50-10	10-21-95	82	77	30	50	4	32	46
	11.5	26	47-25-02	121-47-15	10-19-95	94	75	58	44	1	6	46
Goat Creek	0.1	5	47-19-11	121-31-48	10-27-95	65	60	75	70	90	90	75
Green Point Creek	0.0	6	47-21-08	121-47-10	10-23-95	58	53	69	84	74	90	71
Hotel Creek	0.2	7	No Data	No Data	10-25-95	26	37	19	21	100	100	51
Lost Creek	0.4	8	47-24-26	121-45-21	10-31-95	92	59	85	88	80	85	82
McClellan Creek	0.0	9	47-22-57	121-39-40	10-23-95	70	70	70	70	70	70	70
Middle Fork Taylor	1.0	28	47-21-08	121-47-10	10-31-95	63	48	21	57	35	44	45
	3.0	16	47-21-14	121-44-59	11-01-95	18	56	46	12	9	6	25
North Fork Cedar River	0.7	29	47-19-01	121-30-25	10-05-95	30	5	46	68	62	82	49
	2.4	30	47-19-15	121-28-52	10-04-95	74	25	30	65	38	92	54
North Fork Taylor Creek	1.3	17	47-22-24	121-47-60	11-02-95	34	10	3	6	8	6	11
Pine Creek	0.7	47	47-19-32	121-36-40	10-26-95	75	75	75	75	75	75	75
	0.8	41	47-19-30	121-36-32	10-26-95	90	97	95	97	65	85	88
Rack Creek	0.0	31	47-23-30	121-43-16	10-12-95	92	91	82	94	99	97	93
Rex River	2.2	43	47-21-04	121-39-32	10-25-95	29	52	78	59	89	100	68
	4.2	44	47-20-05	121-37-52	10-26-95	25	25	25	25	45	45	32
	5.7	45	47-18-56	121-37-44	10-25-95	25	25	25	25	25	25	25
Roaring Creek	0.2	10	47-21-42	121-35-24	10-31-95	87	87	89	89	89	91	89
Rock Creek	0.0	11	47-23-36	121-56-49	10-24-95	12	6	10	13	5	28	12
	0.0	11	47-23-36	121-56-49	10-30-95	37	35	18	27	17	19	26
	4.6	13	47-24-36	121-53-55	10-31-95	69	66	79	77	80	80	75
	4.6 (pool)	13	47-24-36	121-53-55	10-31-95	20	34	15	20	24	14	21

Appendix G. Percentage of cover at benthic index of biological integrity (BIBI) sites in the Cedar River Watershed—Continued

Stream name	River mile	Map site number	Latitude	Longitude	Date	Center upstream	Center downstream	Center left	Center right	Left bank	Right bank	Average cover
					1995—Continued							
Seattle Creek	1.8	15	47-19-13	121-33-25	10-27-95	15	100	35	88	0	0	40
South Fork Cedar River	3.0	48	47-19-32	121-36-40	10-03-95	0	8	2	60	5	99	29
Spring Creek	0.6	40	47-18-55	121-28-20	10-04-95	81	71	87	91	82	93	84
Taylor Creek	0.0	32	47-23-26	121-51-05	10-30-95	42	55	23	30	11	21	30
	0.9	33	47-23-01	121-50-28	11-01-95	31	33	32	7	39	2	24
	2.3	34	47-22-21	121-49-36	11-01-95	55	75	40	37	41	46	49
	2.5	35	47-22-09	121-49-35	10-31-95	68	81	83	84	84	93	82
Tinkham Creek	0.3	39	47-19-40	121-28-04	10-02-95	0	0	14	8	36	62	20
Webster Creek	2.1	18	47-26-00	121-54-40	10-26-95	27	12	6	11	4	9	12
	2.8	19	47-26-25	121-54-07	10-30-95	15	11	5	14	7	6	10
Williams Creek	0.2	20	47-23-43	121-51-09	10-30-95	11	41	-1	12	0	18	14
	1.0	21	47-23-43	121-51-09	10-30-95	6	10	6	8	6	4	7
					1996							
Bear Creek	1.6	1	47-19-30	121-36-33	09-11-96	86	88	76	92	88	90	87
Boulder Creek	3.1	46	47-20-10	121-41-56	09-04-96	37	36	59	50	88	71	57
	3.2	4	47-20-09	121-42-14	09-04-96	4	55	100	0	100	0	43
Cedar River	1.0	22	47-23-06	121-57-18	09-05-96	100	80	100	100	95	100	96
	5.2	23	47-23-04	121-53-49	09-05-96	3	5	33	28	88	88	41
	6.9	24	47-23-13	121-51-59	09-05-96	27	25	51	57	97	100	60
	8.8	25	47-24-07	121-50-10	09-05-96	32	22	58	48	88	70	53
	11.5	26	47-25-02	121-47-15	08-21-96	13	6	26	36	63	100	41
	12.1	27	No Data	No Data	08-21-96	13	100	49	82	58	100	67
Goat Creek	0.1	5	47-19-11	121-31-49	09-10-96	10	9	12	5	5	0	7
Lost Creek	0.4	8	47-24-26	121-45-21	09-18-96	92	59	85	88	80	85	82
North Fork Taylor Creek	1.3	17	47-22-24	121-47-60	09-06-96	63	69	73	73	80	73	72
North Fork Cedar River	2.4	30	47-19-15	121-28-52	08-28-96	32	71	61	75	100	100	73
Pine Creek	0.7	47	47-19-32	121-36-40	10-17-96	10	10	10	10	30	70	23
	0.8	41	47-19-30	121-36-32	10-22-96	90	97	95	97	65	85	88
Rex River	2.2	43	47-21-04	121-39-32	09-19-96	29	52	78	59	89	100	68
	4.2	44	47-20-05	121-37-52	09-19-96	73	63	84	90	100	95	84

Appendix G. Percentage of cover at benthic index of biological integrity (BIBI) sites in the Cedar River Watershed—Continued

Stream name	River mile	Map site number	Latitude	Longitude	Date	Center upstream	Center downstream	Center left	Center right	Left bank	Right bank	Average cover
					1996—Continued							
Roaring Creek	0.2	10	47-21-42	121-35-24	09-10-96	87	87	89	89	89	91	89
Rock Creek	4.6	13	47-24-36	121-53-55	09-06-96	31	32	38	11	25	4	24
Seattle Creek	1.8	15	47-19-13	121-33-25	09-10-96	15	100	35	88	0	0	40
South Fork Cedar River	3.0	48	47-19-32	121-36-40	09-10-96	98	100	100	100	94	95	98
Spring Creek	0.6	40	47-18-55	121-28-20	09-12-96	80	77	90	88	89	86	85
Taylor Creek	2.5	35	47-22-09	121-49-35	08-30-96	60	61	54	41	21	100	56
Tinkham Creek	0.3	39	47-19-01	121-30-68	09-17-96	43	22	39	64	85	85	56
Webster Creek	2.1	18	47-26-00	121-54-40	09-16-96	83	69	84	73	85	77	79
	2.8	19	47-26-25	121-54-07	09-16-96	70	73	100	54	95	58	75
Williams Creek	0.2	20	47-23-43	121-51-09	09-24-96	63	56	78	56	87	72	69

Appendix H. Qualitative Habitat Assessment for Benthic Index of Biological Integrity (BIBI) Sites in the Cedar River Watershed

EXPLANATION

Substrate:	Poor, greater than 50 percent; Marginal, 20–50 percent; Sub-optimal, 10–20 percent; Optimal, less than 10 percent.
Instream cover:	Poor, less than 25 percent; Marginal, 25–50 percent; Sub-optimal, 50–75 percent; Optimal, greater than 75 percent.
Embeddedness:	Poor, greater than 75 percent; Marginal, 50–75 percent; Sub-optimal, 25–50 percent; Optimal, 0–25 percent.
Velocity / depth:	Poor, 1 of 4 habitats; Marginal, 2 of 4 habitats; Sub-optimal, 3 of 4 habitats; Optimal, all habitats.
Channel shape:	Poor, inverse trapezoidal; Sub-optimal, rectangular; Optimal, trapezoidal.
Pool / riffle ratio:	Poor, greater than 25; Marginal, 16–25; Sub-optimal, 8–15; Optimal, less than 7.
Bank vegetation:	Poor, less than 50 percent; Marginal, 50–60 percent; Sub-optimal, 70–89 percent; Optimal, greater than 90 percent.
Lower bank stability:	Poor, unstable; Marginal, moderate erosion; Sub-optimal, little erosion; Optimal, stable.
Disruptive pressure:	Poor, high, less than 30 percent; Marginal, obvious, 30–60 percent; Sub-optimal, evident, 60–90 percent; Optimal, minimal.
Zone of influence:	Bank full width: Poor, little or none; Marginal, greater than 1 meter and less than 2 meters; Sub-optimal, greater than 2 meters and less than 4 meters; Optimal, greater than 4 meters
Success and stage:	Poor, seedlings / clearcut; Marginal, pole sampling; Sub-optimal, young; Optimal, old growth.

Appendix H. Qualitative habitat assessment for benthic index of biological integrity sites in the Cedar River Watershed.

[Percent fines is substrate that consists of 6.35millimeter size or smaller. All other measures were made visually by field personnel and not measured. Disruptive pressures is a general visual estimate of evidence of vegetation disruption on stream banks; <, less than; >, more than; %, percent]

Stream name	River mile	Map site number	Latitude	Longitude	Date	Substrate (percentage of fines)	Instream cover
				1995			
Bear Creek	1.6	1	47-19-30	121-36-33	10-27-95	Optimal	Optimal
Boulder Cree	0.5	2	47-21-58	121-41-35	10-26-95	Optimal	No data
	1.1	3	47-21-37	121-42-11	10-26-95	Marginal	No data
	3.2	4	47-20-09	121-42-14	10-13-95	Poor	Marginal
Cedar River	0.0	36	47-22-12	121-37-23	10-06-95	Optimal	Optimal
	1.0	22	47-23-06	121-57-18	10-17-95	Optimal	Poor
	5.0	37	47-20-45	121-33-00	10-06-95	Optimal	Optimal
	6.9	38	47-19-14	121-31-44	10-27-95	Optimal	Poor
	8.8	25	47-24-07	121-50-10	10-21-95	Optimal	Poor
	11.5	26	47-25-02	121-47-15	10-19-95	Optimal	Marginal
Goat Creek	0.1	5	47-19-11	121-31-48	10-27-95	Optimal	Optimal
Lost Creek	0.4	8	47-24-26	121-45-21	10-31-95	Optimal	Optimal
McClellan Creek	0.0	9	47-22-57	121-39-40	10-23-95	Sub-optimal	Sub-optimal
North Fork Cedar River	0.7	29	47-19-01	121-30-25	10-05-95	Optimal	Sub-optimal
	2.4	30	47-19-15	121-28-52	10-04-95	Optimal	Sub-optimal
Pine Creek	0.8	41	47-19-32	121-36-40	10-26-95	Optimal	Optimal
Rack Creek	0.0	31	47-23-30	121-43-16	10-12-95	Optimal	Sub-optimal
Rex River	0.8	42	47-21-36	121-40-44	10-25-95	Optimal	Poor
	2.2	43	47-21-04	121-39-32	10-25-95	Optimal	Poor
	4.2	44	47-20-05	121-37-52	10-26-95	Optimal	Poor
	5.7	45	47-18-56	121-37-44	10-25-95	Optimal	Poor
Roaring Creek	0.2	10	47-21-42	121-35-24	10-31-95	Poor	Poor
Seattle Creek	1.8	15	47-19-13	121-33-25	10-27-95	Optimal	Poor
South Fork Cedar River	3.0	48	47-19-32	121-36-40	10-03-95	Sub-optimal	Sub-optimal
Spring Creek	0.6	40	47-18-55	121-28-20	10-04-95	Optimal	No data
Tinkham Creek	0.3	39	47-19-40	121-28-04	10-02-95	Optimal	Sub-optimal
				1996			
Bear Creek	1.6	1	47-19-30	121-36-33	09-11-96	Optimal	Sub-optimal
Boulder Creek	3.1	46	47-20-10	121-41-56	09-04-96	Sub-optimal	Optimal
	3.2	4	47-20-09	121-42-14	09-04-96	Sub-optimal	Sub-Optimal
Cedar River	1.0	22	47-23-06	121-57-18	09-05-96	Optimal	Poor
	5.2	23	47-23-04	121-53-49	09-05-96	Sub-optimal	Sub-optimal
	6.9	24	47-23-13	121-51-59	09-05-96	Optimal	Optimal
	11.5	26	47-25-02	121-47-15	08-21-96	Optimal	Optimal
	12.1	27	No data	No data	08-21-96	Optimal	Sub-optimal
Goat Creek	0.1	5	47-19-11	121-31-49	09-10-96	Optimal	Poor
Lost Creek	0.4	8	47-24-26	121-45-21	09-18-96	Optimal	Sub-optimal
North Fork Cedar River	2.4	30	47-19-15	121-28-52	08-28-96	Poor	Sub-optimal
North Fork Taylor Creek	1.3	17	47-22-24	121-47-60	09-06-96	Sub-optimal	Marginal
Pine Creek	0.7	47	47-19-32	121-36-40	10-17-96	Sub-optimal	Marginal
	0.8	41	47-19-30	121-36-32	10-22-96	Optimal	Marginal
Rex River	2.2	43	47-21-04	121-39-32	09-19-96	Sub-optimal	Optimal
	4.2	44	47-20-05	121-37-52	09-19-96	Sub-optimal	Optimal
Roaring Creek	0.2	10	47-21-42	121-35-24	09-10-96	Poor	Sub-optimal
Rock Creek	4.6	13	47-24-36	121-53-55	09-06-96	Marginal	Sub-optimal
Seattle Creek	1.8	15	47-19-13	121-33-25	09-10-96	Sub-optimal	Sub-optimal
South Fork Cedar River	3.0	48	47-19-32	121-36-40	09-10-96	Optimal	Poor
Spring Creek	0.6	40	47-18-55	121-28-20	09-12-96	Sub-optimal	Optimal
Taylor Creek	2.5	35	47-22-09	121-49-35	08-30-96	Sub-optimal	Marginal
Tinkham Creek	0.3	39	47-19-01	121-30-68	09-17-96	Optimal	Sub-optimal
Webster Creek	2.8	19	47-26-25	121-54-07	09-16-96	Poor	Sub-optimal
Williams Creek	1.0	21	47-23-43	121-51-09	09-24-96	Sub-optimal	Sub-optimal

Appendix H. Qualitative habitat assessment for benthic index of biological integrity sites in the Cedar River Watershed.—Continued

Stream name	Embeddedness	Velocity / depth	Channel shape
		1995	
Bear Creek	Optimal	Optimal	Optimal
Boulder Creek	Sub-optimal	Marginal	Optimal
	Optimal	Marginal	Sub-optimal
	Poor	Marginal	Optimal
Cedar River	Optimal	Optimal	Optimal
	Optimal	Optimal	Sub-optimal
	Optimal	Sub-optimal	Optimal
	Optimal	Optimal	Sub-optimal
	Optimal	Optimal	Optimal
	Optimal	Sub-optimal	Sub-optimal
Goat Creek	Optimal	Marginal	Sub-optimal
Lost Creek	Optimal	Optimal	Optimal
McClellan Creek	Marginal	Marginal	Sub-optimal
North Fork Cedar River	Marginal	Marginal	Sub-optimal
	Sub-optimal	Marginal	Optimal
Pine Creek	Optimal	Sub-optimal	Optimal
Rack Creek	Marginal	Marginal	Sub-optimal
Rex River	Optimal	Poor	Optimal
	Optimal	Marginal	Sub-optimal
	Poor	Poor	Sub-optimal
	Poor	Poor	Sub-optimal
Roaring Creek	Marginal	Poor	Optimal
Seattle Creek	Sub-optimal	Optimal	Sub-optimal
South Fork Cedar River	Sub-optimal	Marginal	Sub-optimal
Spring Creek	Optimal	Optimal	No data
Tinkham Creek	Optimal	Sub-optimal	Optimal
		1996	
Bear Creek	Optimal	Optimal	Sub-optimal
Boulder Creek	Sub-optimal	Sub-optimal	Sub-optimal
	Marginal	Marginal	Sub-Ooptimal
Cedar River	Optimal	Sub-optimal	Optimal
	No data	Optimal	Optimal
	Optimal	Optimal	Optimal
	Sub-optimal	Optimal	Optimal
	Optimal	Marginal	Sub-optimal
Goat Creek	Poor	Poor	Sub-optimal
Lost Creek	Optimal	Marginal	Optimal
North Fork Cedar River	Poor	Optimal	Optimal
North Fork Taylor Creek	Optimal	Marginal	Optimal
Pine Creek	Optimal	Marginal	Optimal
Rex River	Sub-optimal	Optimal	Sub-optimal
	Marginal	Sub-optimal	Poor
Roaring Creek	Sub-optimal	Sub-optimal	No data
Rock Creek	Sub-optimal	Marginal	Sub-optimal
Seattle Creek	Marginal	Marginal	Sub-optimal
South Fork Cedar River	Optimal	Marginal	Sub-optimal
Spring Creek	Optimal	Optimal	Optimal
Taylor Creek	Optimal	Marginal	Optimal
Tinkham Creek	Optimal	Sub-optimal	Optimal
Webster Creek	Marginal	Marginal	Poor
Williams Creek	Sub-optimal	Marginal	Sub-optimal

Appendix H. Qualitative habitat assessment for benthic index of biological integrity sites in the Cedar River Watershed.—Continued

Stream name	Pool / riffle ratio	Width to depth ratio	Bank vegetation	Lower bank stability
		1995		
Bear Creek	Optimal	Optimal	Optimal	Optimal
Boulder Creek	Optimal	Optimal	Sub-optimal	Marginal
	Marginal	Sub-optimal	Marginal	Poor
	Poor	No data	Sub-optimal	Poor
Cedar River	Optimal	Marginal	Optimal	Sub-optimal
	Poor	Sub-optimal	Optimal	Optimal
	Optimal	No data	Marginal	Marginal
	Poor	Optimal	Optimal	Optimal
	Optimal	Poor	Optimal	Optimal
	Optimal	Marginal	Sub-optimal	Sub-optimal
Goat Creek	Poor	Optimal	Sub-optimal	Optimal
Lost Creek	Poor	Marginal	Optimal	Optimal
McClellan Creek	Marginal	Sub-optimal	Marginal	Poor)
North Fork Cedar River	Sub-optimal	Marginal	Optimal	Marginal
	Marginal	Marginal	Optimal	Optimal
Pine Creek	Marginal	Optimal	Optimal	Sub-optimal
Rack Creek	Optimal	Sub-optimal	Marginal	Poor
Rex River	Optimal	Optimal	Poor	Optimal
	Optimal	Poor	Optimal	Optimal
	Optimal	Sub-optimal	Sub-optimal	Sub-optimal
	Optimal	Marginal	Sub-optimal	Sub-optimal
Roaring Creek	Poor	Sub-optimal	Poor	Poor
Seattle Creek	Marginal	Sub-optimal	Marginal	Marginal
South Fork Cedar River	Marginal	Marginal	Sub-optimal	Marginal
Spring Creek	Marginal	Optimal	Optimal	Optimal
Tinkham Creek	Optimal	Poor	Optimal	Marginal
		1996		
Bear Creek	Optimal	Optimal	Optimal	Sub-optimal
Boulder Creek	Marginal	Sub-optimal	Sub-optimal	Optimal
	Sub-optimal	Marginal	Sub-optimal	Sub-optimal
Cedar River	Marginal	Marginal	Optimal	Sub-optimal
	Sub-optimal	Sub-optimal	Optimal	Optimal
	Sub-optimal	Sub-optimal	Optimal	Optimal
	Optimal	Optimal	Optimal	Optimal
	Poor	Optimal	Sub-optimal	Marginal
Goat Creek	Poor	Poor	Poor	Optimal
Lost Creek	Optimal	Optimal	Optimal	Marginal
North Fork Cedar River	Marginal	Optimal	Optimal	Optimal
North Fork Taylor Creek	Sub-optimal	Marginal	Optimal	Sub-optimal
Pine Creek	Optimal	Optimal	Marginal(	Marginal
	Optimal	Optimal	Poor	Marginal
Rex River	Poor	Poor	Optimal	Optimal
	Sub-optimal	Marginal	Sub-optimal	Optimal
Roaring Creek	Poor	Sub-optimal	Poor	Marginal
Rock Creek	Marginal	Sub-optimal	Optimal	Marginal
Seattle Creek	Poor	Poor	Marginal	Marginal
South Fork Cedar River	Poor	Poor	Marginal	Marginal
Spring Creek	Optimal	Optimal	Sub-optimal	Marginal
Taylor Creek	Sub-optimal	Sub-optimal	Optimal	Marginal
Tinkham Creek	Optimal	Optimal	Optimal	Optimal
Webster Creek	Poor	Sub-optimal	Marginal	Marginal
Williams Creek	Marginal	Marginal	Marginal	Marginal

Appendix H. Qualitative habitat assessment for benthic index of biological integrity sites in the Cedar River Watershed.—Continued

Stream name	Disruptive pressure	Zone of influence	Successional stage
		1995	
Bear Creek	Optimal	Poor	Optimal
Boulder Creek	Marginal	Sub-optimal	Sub-optimal
	Poor	Optimal	Sub-optimal
	Poor	Sub-optimal	Marginal
Cedar River	Sub-optimal	Sub-optimal	Sub-optimal
	Optimal	Poor	Sub-optimal
	Poor	Sub-optimal	Sub-optimal
	Optimal	Poor	Sub-optimal
	Optimal	Optimal	Sub-optimal
	Optimal	Optimal	Sub-optimal
Goat Creek	Optimal	Optimal	Sub-optimal
Lost Creek	Optimal	Poor	Marginal
McClellan Creek	Marginal	Optimal	Sub-optimal
North Fork Cedar River	Sub-optimal	Optimal	Sub-optimal
	Optimal	Marginal	Optimal
Pine Creek	Sub-optimal	Optimal	Optimal
Rack Creek	Marginal	Sub-optimal	Sub-optimal
Rex River	Optimal	Optimal	Poor
	Optimal	Poor	Marginal
	Sub-optimal	Sub-optimal	Sub-optimal
	Sub-optimal	Optimal	Sub-optimal
Roaring Creek	Poor	Poor	Optimal
Seattle Creek	Sub-optimal	Optimal	Poor
South Fork Cedar River	Sub-optimal	Sub-optimal	Marginal
Spring Creek	Optimal	Optimal	Optimal
Tinkham Creek	Marginal	Optimal	Optimal
		1996	
Bear Creek	Optimal	Sub-Optimal	Optimal
Boulder Creek	Sub-optimal	Marginal	Marginal
	Sub-optimal	Poor	Poor
Cedar River	Optimal	Optimal	Sub-optimal
	Optimal	Marginal	Sub-optimal
	Optimal	Sub-optimal	Sub-optimal
	Optimal	Optimal	Sub-optimal
	Marginal	Optimal	Sub-optimal
Goat Creek	Marginal	Optimal	Sub-optimal
Lost Creek	Marginal	Poor	Marginal
North Fork Cedar River	Optimal	Sub-optimal	Sub-optimal
North Fork Taylor Creek	Marginal	Sub-optimal	Sub-optimal
Pine Creek	Marginal	Sub-optimal	Poor
	Poor	Optimal	Poor
Rex River	Optimal	Sub-optimal	Sub-optimal
	Optimal	Sub-optimal	Sub-optimal
Roaring Creek	Poor	Optimal	Sub-optimal
Rock Creek	Sub-optimal	Optimal	Sub-optimal
Seattle Creek	Marginal	Sub-optimal	Marginal
South Fork Cedar River	Marginal	Poor	Poor
Spring Creek	Optimal	Optimal	Optimal
Taylor Creek	Sub-optimal	Sub-optimal	Sub-optimal
Tinkham Creek	Poor	Poor	Marginal
Webster Creek	Marginal	Marginal	Poor
Williams Creek	Marginal	Sub-optimal	Sub-optimal

Appendix I. Reach profile for benthic index of biological integrity (BIBI) sites in the Cedar River Watershed

[Measures in feet unless otherwise stated; --, no data]

Stream name	River mile	Map site number	Latitude	Longitude	Date	Transect	Wetted width	Bankfull width	Maximum depth	Percentage of gradient
					1995					
Bear Creek	1.6	1	47-19-30	121-36-33	10-27-95	Riffle sample	13.0	30.0	2.0	0.1
Boulder Creek	0.5	2	47-21-58	121-41-35	10-26-95	Riffle sample	11.0	80.0	6.0	0.0
	1.1	3	47-21-37	121-42-11	10-26-95	Riffle sample	20.0	70.0	6.0	0.1
	3.2	4	47-20-09	121-42-14	10-13-95	Start of segment	21.0	33.0	2.7	0.1
	3.2	4	47-20-09	121-42-14	10-13-95	Riffle sample	13.4	16.0	3.2	0.1
Cedar River	0.0	36	47-22-12	121-37-23	10-06-95	Riffle sample	77.0	150.0	2.9	0.0
	5.0	37	47-20-45	121-33-00	10-06-95	Start of segment	57.0	86.0	4.4	0.0
	5.0	37	47-20-45	121-33-00	10-06-95	End of segment	35.1	83.1	6.1	0.0
	5.0	37	47-20-45	121-33-00	10-06-95	Riffle sample	48.1	60.0	3.9	0.0
	6.9	24	47-23-13	121-51-59	10-20-95	Riffle sample	120.7	120.7	1.8	--
	8.8	25	47-24-07	121-50-10	10-21-95	Riffle sample	83.7	83.7	2.1	0.0
	11.5	26	47-25-02	121-47-15	10-19-95	Start of segment	87.6	87.6	--	--
Goat Creek	0.1	5	47-19-14	121-31-44	10-27-95	Riffle sample	75.0	85.0	1.8	0.1
	0.1	5	47-19-11	121-31-48	10-27-95	Riffle sample	17.0	30.0	6.0	0.2
Green Point Creek	0.0	6	47-21-08	121-47-10	10-23-95	Riffle sample	5.5	38.0	3.2	0.1
Hotel Creek	0.0	7	No Data	No Data	10-25-95	Riffle sample	4.0	7.0	1.3	0.0
Lost Creek	0.4	8	47-24-26	121-45-21	10-31-95	Riffle sample	17.0	17.0	0.5	0.2
McClellan Creek	0.0	9	47-22-57	121-39-40	10-23-95	Riffle sample	11.0	38.0	5.5	0.1
Middle Fork Taylor	1.0	28	47-21-08	121-47-10	10-31-95	Riffle sample	21.5	29.1	2.9	0.1
	3.0	16	47-21-14	121-44-59	11-01-95	Riffle sample	14.9	16.2	2.4	0.0
North Fork Cedar River	0.7	29	47-19-01	121-30-25	10-05-95	Start of segment	31.3	39.1	4.0	0.0
	0.7	29	47-19-01	121-30-25	10-05-95	End of segment	34.6	39.6	5.7	0.0
	0.7	29	47-19-01	121-30-25	10-05-95	Rifflesample	38.3	46.5	4.8	0.0
North Fork Taylor Creek	1.3	17	47-22-24	121-47-60	11-02-95	Riffle sample	15.2	22.5	2.2	0.0
North Fork Cedar River	2.4	30	47-19-15	121-28-52	10-04-95	Start of segment	43.7	47.6	3.5	0.1
	2.4	30	47-19-15	121-28-52	10-04-95	End of segment	30.0	40.0	8.0	0.1
	2.4	30	47-19-15	121-28-52	10-04-95	Riffle sample	46.0	90.0	4.4	0.0
Pine Creek	0.7	47	47-19-32	121-36-40	10-26-95	Riffle sample	12.0	40.0	3.0	0.1

Appendix I. Reach profile for benthic index of biological integrity (BIBI) sites in the Cedar River Watershed—Continued

Stream name	River mile	Map site number	Latitude	Longitude	Date	Transect	Wetted width	Bankfull width	Maximum depth	Percentage of gradient
					1995—Continued					
Rack Creek	0.0	31	47-23-30	121-43-16	10-12-95	Start of segment	18.0	34.3	4.0	0.0
	0.0	31	47-23-30	121-43-16	10-12-95	End of segment	25.2	27.8	5.9	0.0
	0.0	31	47-23-30	121-43-16	10-12-95	Riffle sample	17.5	25.6	3.2	0.0
Rex River	0.8	42	47-21-36	121-40-44	10-25-95	Riffle sample	60.0	300.0	6.0	0.0
	2.2	43	47-21-04	121-39-32	10-25-95	Riffle sample	54.0	65.0	1.5	0.0
	4.2	44	47-20-05	121-37-52	10-26-95	Riffle sample	15.0	24.0	2.5	0.0
	5.7	45	47-18-56	121-37-44	10-25-95	Riffle sample	15.0	21.0	2.5	0.0
Roaring Creek	0.2	10	47-21-42	121-35-24	10-31-95	Riffle sample	4.0	8.0	0.5	0.1
Rock Creek	0.0	11	47-23-36	121-56-49	10-24-95	Riffle sample	19.6	19.6	1.6	0.0
	0.0	11	47-23-36	121-56-49	10-30-95	Riffle sample	18.9	23.8	3.1	0.0
	4.6	13	47-24-36	121-53-55	10-31-95	Riffle sample	13.9	14.2	1.3	0.0
	4.6(pool)	13	47-24-36	121-53-55	10-31-95	Start of segment	15.4	24.7	2.2	0.0
	4.6(pool)	13	47-24-36	121-53-55	10-31-95	End of segment	9.1	18.7	1.5	--
Seattle Creek	1.8	15	47-19-13	121-33-25	10-27-95	Riffle sample	20.0	20.0	1.5	0.0
South Fork Cedar River	3.0	48	47-19-32	121-36-40	10-03-95	Start of segment	21.0	21.0	3.3	0.1
	3.0	48	47-19-32	121-36-40	10-03-95	End of segment	17.1	39.0	5.0	0.1
	3.0	48	47-19-32	121-36-40	10-03-95	Riffle sample	26.2	33.4	4.8	0.1
Spring Creek	0.6	40	47-18-55	121-28-20	10-04-95	Start of segment	12.4	15.6	2.6	0.1
	0.6	40	47-18-55	121-28-20	10-04-95	Midpoint of segment	15.0	20.9	2.4	--
Taylor Creek	0.0	32	47-23-26	121-51-05	10-30-95	Riffle sample	43.4	44.1	2.6	0.0
	0.9	33	47-23-01	121-50-28	11-01-95	Riffle sample	38.5	40.5	2.1	0.0
	2.3	34	47-22-21	121-49-36	11-01-95	Riffle sample	49.9	50.1	1.7	0.0
	2.5	35	47-22-09	121-49-35	10-31-95	Riffle sample	33.6	42.4	2.1	--
Tinkham Creek	0.3	39	47-19-40	121-28-04	10-02-95	Start of segment	23.3	26.0	3.3	0.0
	0.3	39	47-19-40	121-28-04	10-02-95	Riffle sample	31.0	63.0	4.8	0.1
Webster Creek	2.1	18	47-26-00	121-54-40	10-26-95	Riffle sample	14.0	18.2	1.6	0.0
	2.8	19	47-26-25	121-54-07	10-30-95	Riffle sample				0.1
Williams Creek	0.2	20	47-23-43	121-51-09	10-30-95	Riffle sample	12.4	15.1	1.8	0.0
	1.0	21	47-23-43	121-51-09	10-30-95	Riffle sample	6.5	9.8	1.7	0.0

Appendix I. Reach profile for benthic index of biological integrity (BIBI) sites in the Cedar River Watershed—Continued

Stream name	River mile	Map site number	Latitude	Longitude	Date	Transect	Wetted width	Bankfull width	Maximum depth	Percentage of gradient
					1996					
Bear Creek	1.6	1	47-19-30	121-36-33	09-11-96	Start of segment	24.1	34.0	--	0.1
	1.6	1	47-19-30	121-36-33	09-11-96	Riffle sample	19.4	27.0	2.5	0.2
Boulder Creek	3.2	4	47-20-09	121-42-14	09-4-96	Riffle sample	3.0	1.5	3.5	0.1
Cedar River	11.5	26	47-25-02	121-47-15	08-21-96	Start of segment	72.1	99.4	5.8	0.0
	11.5	26	47-25-02	121-47-15	08-21-96	End of segment	71.6	121.7	5.7	0.0
	11.5	26	47-25-02	121-47-15	08-21-96	Riffle sample	83.0	127.0	6.9	0.0
	1.0	22	47-23-06	121-57-18	09-05-96	Riffle sample	121.3	154.6	5.5	0.0
	5.2	23	47-23-04	121-53-49	09-05-96	Riffle sample	114.0	118.0	--	--
	6.9	24	47-23-13	121-51-59	09-05-96	Start of segment	90.5	121.5	8.3	0.0
	6.9	24	47-23-13	121-51-59	09-05-96	Riffle sample	77.0	85.7	6.3	0.0
	8.8	25	47-24-07	121-50-10	09-05-96	Start of segment	127.0	139.0	4.4	0.0
	8.8	25	47-24-07	121-50-10	09-05-96	Riffle sample	71.7	82.6	4.2	--
	12.1	27	--	--	08-21-96	Start of segment	28.5	35.2	2.2	--
	12.1	27	--	--	08-21-96	Midpoint of segment	--	--	--	0.0
	12.1	27	--	--	08-21-96	End of segment	--	--	--	0.0
	12.1	27	--	--	08-21-96	Riffle sample	25.1	4.6	--	0.0
Goat Creek	0.1	5	47-19-11	121-31-49	09-10-96	Midpoint of segment	9.8	23.8	--	0.1
	0.1	5	47-19-11	121-31-49	09-10-96	Riffle sample	8.0	11.0	3.5	0.1
Lost Creek	0.4	8	47-24-26	121-45-21	09-18-96	Start of segment	6.0	11.8	1.8	0.5
	0.4	8	47-24-26	121-45-21	09-18-96	Riffle sample	6.2	8.0	2.0	0.4
North Fork Cedar River	2.4	30	47-19-15	121-28-52	08-28-96	Riffle sample	32.0	82.0	4.1	0.1
North Fork Taylor Creek	1.3	17	47-22-24	121-47-60	09-06-96	Start of segment	16.5	19.3	1.8	0.1
	1.3	17	47-22-24	121-47-60	09-06-96	Midpoint of segment	15.0	18.0	1.0	0.1
	1.3	17	47-22-24	121-47-60	09-06-96	End of segment	5.0	19.4	2.2	0.1
	1.3	17	47-22-24	121-47-60	09-06-96	Riffle sample	15.8	16.8	1.6	0.1
Pine Creek	0.7	47	47-19-32	121-36-40	10-17-96	Riffle sample	20.0	50.0	--	0.2
	0.8	41	47-19-30	121-36-32	10-22-96	Riffle sample	10.0	15.0	--	0.2
Rex River	2.2	43	47-21-04	121-39-32	09-19-96	Start of segment	32.8	40.2	2.9	0.0
	2.2	43	47-21-04	121-39-32	09-19-96	Riffle sample	30.1	38.2	2.6	0.0
	4.2	44	47-20-05	121-37-52	09-19-96	Start of segment	27.0	36.0	2.8	0.0
Roaring Creek	0.2	10	47-21-42	121-35-24	09-10-96	Start of segment	13.4	17.0	1.6	0.2

Appendix I. Reach profile for benthic index of biological integrity (BIBI) sites in the Cedar River Wathershed—Continued

Stream name	River mile	Map site number	Latitude	Longitude	Date	Transect	Wetted width	Bankfull width	Maximum depth	Percentage of gradient
					1996—Continued					
Rock Creek	4.6	13	47-24-36	121-53-55	09-06-96	Start of segment	15.2	16.7	1.1	0.0
	4.6	13	47-24-36	121-53-55	09-06-96	End of segment	12.0	14.0	2.5	0.0
	4.6	13	47-24-36	121-53-55	09-06-96	Rifflesample	12.0	19.6	1.4	0.0
Seattle Creek	1.8	15	47-19-13	121-33-25	09-10-96	Start of segment	6.7	28.9	1.8	0.0
South Fork Cedar River	3.0	48	47-19-32	121-36-40	09-10-96	Start of segment	9.6	15.6	2.0	0.0
	3.0	48	47-19-32	121-36-40	09-10-96	Riffle sample	14.0	20.5	1.7	0.1
Spring Creek	0.6	40	47-18-55	121-28-20	09-12-96	Start of segment	14.5	22.5	2.6	0.2
	0.6	40	47-18-55	121-28-20	09-12-96	End of segment	20.4	24.6	2.4	0.2
	0.6	40	47-18-55	121-28-20	09-12-96	Riffle sample	10.7	25.7	2.5	0.2
Taylor Creek	2.5	35	47-22-09	121-49-35	08-30-96	Start of segment	25.4	39.0	1.3	0.0
	2.5	35	47-22-09	121-49-35	08-30-96	End of segment	32.4	40.8	1.8	0.0
	2.5	35	47-22-09	121-49-35	08-30-96	Riffle sample	19.3	35.4	0.7	0.0
Tinkham Creek	0.3	39	47-19-40	121-28-04	09-17-96	Start of segment	9.0	20.5	2.4	0.1
	0.3	39	47-19-40	121-28-04	09-17-96	Riffle sample	33.4	38.5	1.8	0.1
Webster Creek	2.1	18	47-26-00	121-54-40	09-16-96	Midpoint of segment	14.6	18.0	1.1	0.1
	2.1	18	47-26-00	121-54-40	09-16-96	Riffle sample	18.7	20.7	2.6	0.1
	2.8	19	47-26-25	121-54-07	09-16-96	Start of segment	6.3	9.6	0.8	0.1
	2.8	19	47-26-25	121-54-07	09-16-96	Riffle sample	17.2	17.2	1.2	0.1
Williams Creek	1.0	21	47-23-43	121-51-09	09-24-96	Midpoint of segment	19.1	22.1	1.4	0.1
	1.0	21	47-23-43	121-51-09	09-24-96	Riffle sample	11.7	17.9	1.5	0.1
	1.0	21	47-23-43	121-51-09	09-24-96	Start of segment	7.8	23.9	1.3	0.1

Appendix J. Riparian Vegetation at Benthic Index of Biological Integrity (BIBI) Sites in the Cedar River Watershed

EXPLANATION

Canopy–big and small trees:	1-sparse, 0–10 percent; -moderate, 10–40 percent; 3-heavy, 40–75 percent; 4-very heavy, greater than 75 percent.
Understory–woody shrubs:	1-sparse, 0–10 percent; 2-moderate, 10–40 percent; 3-heavy, 40–75 percent; 4-very heavy, greater than 75 percent.
Ground cover–woody shrubs:	1-sparse, 0–10 percent; 2-moderate, 10–40 percent; 3-heavy, 40–75 percent; 4-very heavy, greater than 75 percent.
Ground cover–barren:	1-sparse, 0–10 percent; 2-moderate, 10–40 percent; 3-heavy, 40–75 percent.

Appendix J. Riparian vegetation at benthic index of biological integrity (BIBI) sites in the Cedar River Watershed

[%, percent]

Stream name	River mile	Map site number	Latitude	Longitude	Date	Canopy vegetation type		Canopy–big trees		Canopy–small trees
						Left bank	Right bank	Left bank	Right bank	Left bank
						1995				
Bear Creek	1.6	1	47-19-30	121-36-33	10-27-95	Coniferous	Mixed	3-Heavy	2-Moderate	1-Sparse
Boulder Creek	0.5	2	47-21-58	121-41-35	10-26-95	Deciduous	Mixed	0-Absent	2-Moderate	2-Moderate
	1.1	3	47-21-37	121-42-11	10-26-95	Deciduous	Deciduous	2-Moderate	2-Moderate	1-Sparse
	3.2	4	47-20-09	121-42-14	10-13-95	Mixed	None	0-Absent	0-Absent	3-Heavy
Cedar River	0.0	36	47-22-12	121-37-23	10-06-95	Deciduous	Deciduous	2-Moderate	2-Moderate	2-Moderate
	1.0	22	47-23-06	121-57-18	10-17-95	Mixed	Deciduous	3-Heavy	1-Sparse	1-Sparse
	5.0	37	47-20-45	121-33-00	10-06-95	Mixed	Mixed	2-Moderate	2-Moderate	3-Heavy
	6.9	38	47-19-14	121-31-44	10-27-95	Coniferous	Mixed	3-Heavy	3-Heavy	2-Moderate
	8.8	25	47-24-07	121-50-10	10-21-95	Mixed	Mixed	4-Very heavy	4-Very heavy	1-Sparse
	11.5	26	47-25-02	121-47-15	10-19-95	Mixed	Mixed	4-Very heavy	4-Very heavy	1-Sparse
Goat Creek	0.1	5	47-19-11	121-31-48	10-27-95	Mixed	Mixed	1-Sparse	1-Sparse	3-Heavy
Green Point Creek	0.0	6	47-21-08	121-47-10	10-23-95	Mixed	Mixed	2-Moderate	2-Moderate	1-Sparse
Hotel Creek	0.2	7	No data	No data	10-25-95	Mixed	Mixed	2-Moderate	2-Moderate	3-Heavy
Lost Creek	0.4	8	47-24-26	121-45-21	10-31-95	Coniferous	Mixed	0-Absent	0-Absent	4-Very heavy)
McClellan Creek	0.0	9	47-22-57	121-39-40	10-23-95	Mixed	Mixed	2-Moderate	2-Moderate	1-Sparse
Middle Fork Taylor	1.0	28	47-21-08	121-47-10	10-31-95	Deciduous	Deciduous	1-Sparse	0-Absent	3-Heavy
	3.0	16	47-21-14	121-44-59	11-01-95	Mixed	Mixed	2-Moderate	4-Very heavy	3-Heavy
North Fork Cedar River	0.0	29	47-19-01	121-30-25	10-05-95	Mixed	Mixed	2-Moderate	1-Sparse	4-Very heavy
North Fork Taylor Creek	1.3	17	47-22-24	121-47-60	11-02-95	Mixed	Mixed	3-Heavy	2-Moderate	4-Very heavy
North Fork Cedar River	3.0	30	47-19-15	121-28-52	10-04-95	Coniferous	Coniferous	2-Moderate	2-Moderate	1-Sparse
Pine Creek	0.7	47	47-19-32	121-36-40	10-26-95	Mixed	No data	3-Heavy	No data	2-Moderate
Rack Creek	0.0	31	47-23-30	121-43-16	10-12-95	Deciduous	Deciduous	1-Sparse	1-Sparse	2-Moderate
Rex River	0.8	42	47-21-36	121-40-44	10-25-95	Deciduous	Deciduous	0-Absent	0-Absent	1-Sparse
	2.2	43	47-21-04	121-39-32	10-25-95	Mixed	Mixed	1-Sparse	1-Sparse	4-Very heavy
	4.2	44	47-20-05	121-37-52	10-26-95	Coniferous	No data	1-Sparse	No data	1-Sparse
	5.7	45	47-18-56	121-37-44	10-25-95	Coniferous	Coniferous	2-Moderate	2-Moderate	1-Sparse
Roaring Creek	0.2	10	47-21-42	121-35-24	10-31-95	Coniferous	None	2-Moderate	0-Absent	1-Sparse
Rock Creek	0.0	11	47-23-36	121-56-49	10-24-95	Deciduous	Mixed	2-Moderate	3-Heavy	1-Sparse
	0.0	11	47-23-36	121-56-49	10-30-95	Mixed	Deciduous	3-Heavy (40-75%)	3-Heavy (40-75%)	2-Moderate
	4.6	13	47-24-36	121-53-55	10-31-95	Mixed	Mixed	1-Sparse (0-10%)	3-Heavy (40-75%)	2-Moderate
	4.6(pool)	13	47-24-36	121-53-55	10-31-95	Mixed	Mixed	1-Sparse (0-10%)	2-Moderate (10-40%)	3-Heavy
Seattle Creek	1.8	15	47-19-13	121-33-25	10-27-95	Mixed	Mixed	0-Absent	0-Absent	1-Sparse
South Fork Cedar River	3.0	48	47-19-32	121-36-40	10-03-95	Mixed	Mixed	3-Heavy	3-Heavy	No data
Spring Creek	0.6	40	47-18-55	121-28-20	10-04-95	Coniferous	No data	4-Very heavy	No data	1-Sparse

Appendix J. Riparian vegetation at benthic index of biological integrity (BIBI) sites in the Cedar River Watershed—Continued

Stream name	River mile	Map site number	Latitude	Longitude	Date	Canopy vegetation type		Canopy–big trees		Canopy–small trees
						Left bank	Right bank	Left bank	Right bank	Left bank
						1995—Continued				
Taylor Creek	0.0	32	47-23-26	121-51-05	10-30-95	Coniferous	Mixed	4-Very heavy	2-Moderate	2-Moderate
	0.9	33	47-23-01	121-50-28	11-01-95	Deciduous	Mixed	2-Moderate	1-Sparse	3-Heavy
	2.3	34	47-22-21	121-49-36	11-01-95	No data	Deciduous	No data	2-Moderate)	No data
	2.5	35	47-22-09	121-49-35	10-31-95	Deciduous	Deciduous	3-Heavy	3-Heavy	1-Sparse
Tinkham Creek	0.0	39	47-19-40	121-28-04	10-02-95	Mixed	Coniferous	2-Moderate	4-Very heavy	3-Heavy
Webster Creek	2.1	18	47-26-00	121-54-40	10-26-95	Mixed	Coniferous	3-Heavy	3-Heavy	2-Moderate
	2.8	19	47-26-25	121-54-07	10-30-95	Mixed	Mixed	4-Very heavy	4-Very heavy	2-Moderate
Williams Creek	0.2	20	47-23-43	121-51-09	10-30-95	Mixed	Mixed	3-Heavy	2-Moderate	2-Moderate
	1.0	21	47-23-43	121-51-09	10-30-95	Mixed	Mixed	3-Heavy	2-Moderate	1-Sparse
						1996				
Bear Creek	1.6	1	47-19-30	121-36-33	09-11-96	Mixed	Mixed	1-Sparse	3-Heavy	3-Heavy
Boulder Creek	3.1	46	47-20-10	121-41-56	09-04-96	Mixed	Mixed	0-Absent	0-Absent	3-Heavy
	3.2	4	47-20-09	121-42-14	09-04-96	Deciduous	Deciduous	0-Absent	0-Absent	2-Moderate
Cedar River	1.0	22	47-23-06	121-57-18	09-05-96	Mixed	Mixed	3-Heavy	3-Heavy	1-Sparse
	5.2	23	47-23-04	121-53-49	09-05-96	Mixed	Mixed	2-Moderate	2-Moderate	2-Moderate
	6.9	24	47-23-13	121-51-59	09-05-96	Mixed	Mixed	3-Heavy	2-Moderate	1-Sparse
	8.8	25	47-24-07	121-50-10	09-05-96	Coniferous	Mixed	3-Heavy	2-Moderate	1-Sparse
	11.5	26	47-25-02	121-47-15	08-21-96	Coniferous	Coniferous	3-Heavy	3-Heavy	3-Heavy
	12.1	27	No data	No data	08-21-96	Deciduous	Deciduous	2-Moderate	2-Moderate	2-Moderate
Goat Creek	0.1	5	47-19-11	121-31-49	09-10-96	Mixed	Mixed	1-Sparse	0-Absent	2-Moderate
Lost Creek	0.4	8	47-24-26	121-45-21	09-18-96	Mixed	Coniferous	0-Absent	0-Absent	3-Heavy
North Fork Cedar River	3.0	30	47-19-15	121-28-52	08-28-96	Deciduous	Mixed	2-Moderate	2-Moderate	1-Sparse
North Fork Taylor Creek	1.3	17	47-22-24	121-47-60	09-06-96	Deciduous	Deciduous	3-Heavy	1-Sparse	1-Sparse
Rex River	2.2	43	47-21-04	121-39-32	09-19-96	Mixed	Deciduous	2-Moderate	2-Moderate	2-Moderate
	4.2	44	47-20-05	121-37-52	09-19-96	Mixed	Mixed	1-Sparse	1-Sparse	4-Very heavy
Roaring Creek	0.2	10	47-21-42	121-35-24	09-10-96	Mixed	Mixed	1-Sparse	2-Moderate	2-Moderate
Rock Creek	4.6	13	47-24-36	121-53-55	09-06-96	Mixed	Mixed	2-Moderate	4-Very heavy	1-Sparse
Seattle Creek	1.8	15	47-19-13	121-33-25	09-10-96	Coniferous	Coniferous	0-Absent	0-Absent	1-Sparse (
South Fork Cedar River	3.0	48	47-19-32	121-36-40	09-10-96	Coniferous	Coniferous	0-Absent	0-Absent	1-Sparse
Taylor Creek	2.5	35	47-22-09	121-49-35	08-30-96	Deciduous	Mixed	No data	1-Sparse	3-Heavy
Tinkham Creek	3.0	39	47-19-01	121-30-68	09-17-96	Mixed	Deciduous	0-Absent	0-Absent	3-Heavy
Spring Creek	0.6	40	47-18-55	121-28-20	09-12-96	Coniferous	Coniferous	3-Heavy	3-Heavy	1-Sparse
Webster Creek	2.1	18	47-26-00	121-54-40	09-16-96	Coniferous	Mixed	2-Moderate	2-Moderate	1-Sparse
	2.8	19	47-26-25	121-54-07	09-16-96	No data	Deciduous	0-Absent	0-Absent	0-Absent
Williams Creek	1.0	21	47-23-43	121-51-09	09-24-96	Mixed	Mixed	2-Moderate	1-Sparse	1-Sparse

Appendix J. Riparian vegetation at benthic index of biological integrity (BIBI) sites in the Cedar River Watershed—Continued

	Canopy–small trees	Understory–vegetation type		Understory–woody shrubs		Understory–non-woody herbs	
Stream name	Right bank	Left bank	Right bank	Left bank	Right bank	Left bank	Right bank
			1995				
Bear Creek	3-Heavy	None	Mixed	0-Absent	1-Sparse	0-Absent	3-Heavy
Boulder Creek	1-Sparse	Coniferous	Mixed	1-Sparse	2-Moderate	2-Moderate	1-Sparse
	1-Sparse	Mixed	Mixed	1-Sparse	1-Sparse	No data	No data
	2-Moderate	Mixed	Mixed	2-Moderate	2-Moderate	2-Moderate	2-Moderate
Cedar River	2-Moderate	Mixed	Mixed	3-heavy	3-Heavy	2-Moderate	2-Moderate
	1-Sparse	Deciduous	Deciduous	3-Heavy	4-Very heavy	1-Sparse	1-Sparse
	2-Moderate	Mixed	Mixed	4-Very heavy	1-Sparse	3-Heavy	2-Moderate
	2-Moderate	Coniferous	Coniferous	1-Sparse	2-Moderate	1-Sparse	1-Sparse
	1-Sparse	Mixed	Mixed	1-Sparse	2-Moderate	1-Sparse	2-Moderate
	1-Sparse	Deciduous	Deciduous	1-Sparse	1-Sparse	2-Moderate	2-Moderate
Goat Creek	3-Heavy	Coniferous	Mixed	2-Moderate	2-Moderate	1-Sparse	1-Sparse
Green Point Creek	1-Sparse	Mixed	Deciduous	1-Sparse	1-Sparse	0-Absent	0-Absent
Hotel Creek	3-Heavy	Deciduous	Deciduous	3-Heavy	3-Heavy	2-Moderate	2-Moderate
Lost Creek	3-Heavy	None	Deciduous	2-Moderate)	2-Moderate	0-Absent	1-Sparse
McClellan Creek	1-Sparse	Coniferous	None	1-Sparse	1-Sparse	No data	No data
Middle Fork Taylor	3-Heavy	Deciduous	Deciduous	3-Heavy	3-Heavy	3-Heavy	3-Heavy
	2-Moderate	Mixed	Mixed	4-Very heavy	3-Heavy	1-Sparse	2-Moderate
North Fork Cedar River	4-Very heavy	Coniferous	Mixed	1-Sparse	2-Moderate	0-Absent	0-Absent
North Fork Taylor Creek	2-Moderate	Deciduous	Mixed	2-Moderate	3-Heavy	3-Heavy	3-Heavy
North Fork Cedar River	1-Sparse	Mixed	Mixed	2-Moderate	2-Moderate	No data	No data
Pine Creek	No data	Mixed	No data	3-Heavy	No data	1-Sparse	No data
Rack Creek	2-Moderate	Deciduous	Deciduous	2-Moderate	2-Moderate	1-Sparse	1-Sparse
Rex River	1-Sparse	Deciduous	Deciduous	1-Sparse	1-Sparse	1-Sparse	1-Sparse
	4-Very heavy	Mixed	Mixed	1-Sparse	1-Sparse	1-Sparse	1-Sparse
	No data	Deciduous	No data	2-Moderate	No data	0-Absent	No data
	1-Sparse	Coniferous	Coniferous	1-Sparse	1-Sparse	1-Sparse	1-Sparse
Roaring Creek	0-Absent	Mixed	None	1-Sparse	0-Absent	1-Sparse	0-Absent
Rock Creek	1-Sparse	Deciduous	Deciduous	2-Moderate	3-Heavy	3-Heavy	1-Sparse
	3-Heavy	Deciduous	Deciduous	2-Moderate	3-Heavy	2-Moderate	2-Moderate
	1-Sparse	Mixed	Deciduous	3-Heavy	3-Heavy	1-Sparse	2-Moderate
	3-Heavy	Mixed	Deciduous	1-Sparse	3-Heavy	1-Sparse	1-Sparse
Seattle Creek	1-Sparse	Mixed	Mixed	1-Sparse	1-Sparse	2-Moderate	2-Moderate
South Fork Cedar River	No data	Mixed	Mixed	3-Heavy	3-Heavy	4-Very heavy	4-Very heavy
Spring Creek	No data	Mixed	No data	4-Very heavy	No data	1-Sparse	No data

Appendix J. Riparian vegetation at benthic index of biological integrity (BIBI) sites in the Cedar River Watershed—Continued

	Canopy–small trees	Understory–vegetation type		Understory–woody shrubs		Understory–non-woody herbs	
Stream name	Right bank	Left bank	Right bank	Left bank	Right bank	Left bank	Right bank
			1995—Continued				
Taylor Creek	2-Moderate	Mixed	Mixed	3-Heavy	4-Very heavy	3-Heavy	1-Sparse
	3-Heavy	Deciduous	Mixed	3-Heavy	4-Very heavy	2-Moderate	2-Moderate
	4-Very heavy	No data	Deciduous	No data	4-Very heavy	No data	1-Sparse
	3-Heavy	Deciduous	Deciduous	3-Heavy	4-Very heavy	2-Moderate	3-Heavy
Trinkham Cree	1-Sparse	Mixed	Coniferous	4-Very heavy	2-Moderate	1-Sparse	No data
Webster Creek	3-Heavy	Mixed	Deciduous	2-Moderate	1-Sparse	1-Sparse	0-Absent
	2-Moderate	Mixed	Mixed	4-Very heavy	4-Very heavy	1-Sparse	1-Sparse
Williams Creek	2-Moderate)	Mixed	Mixed	1-Sparse	2-Moderate	2-Moderate	0-Absent
	3-Heavy	Mixed	Mixed	3-Heavy	1-Sparse	2-Moderate	3-Heavy
			1996				
Bear Creek	1-Sparse	Mixed	Mixed	3-Heavy	2-Moderate	2-Moderate	2-Moderate
Boulder Creek	3-Heavy	Mixed	Mixed	1-Sparse	1-Sparse	1-Sparse	1-Sparse
	0-Absent	Deciduous	Mixed	2-Moderate	1-Sparse	1-Sparse	2-Moderate
Cedar River	1-Sparse	Deciduous	Deciduous	1-Sparse	1-Sparse)	0-Absent	0-Absent
	1-Sparse	None	Deciduous	No data	2-Moderate	No data	1-Sparse
	2-Moderate	Deciduous	Mixed	2-Moderate	1-Sparse	3-Heavy	1-Sparse
	1-Sparse	None	Deciduous	No data	4-Very heavy	No data	1-Sparse
	3-Heavy	Coniferous	Coniferous	3-Heavy	3-Heavy	1-Sparse	1-Sparse
	2-Moderate	Deciduous	Deciduous	3-Heavy	3-Heavy	2-Moderate	2-Moderate
Goat Creek	2-Moderate	Mixed	Mixed	2-Moderate	2-Moderate	2-Moderate	1-Sparse
Lost Creek	2-Moderate	Mixed	Mixed	3-Heavy	4-Very heavy	1-Sparse	2-Moderate
North Fork Cedar River	2-Moderate	Mixed	Deciduous	2-Moderate	2-Moderate	2-Moderate	2-Moderate
North Fork Taylor Creek	3-Heavy	Deciduous	Deciduous	3-Heavy	2-Moderate	1-Sparse	2-Moderate
Rex River	2-Moderate	Mixed	Mixed	2-Moderate	2-Moderate	2-Moderate	2-Moderate)
	4-Very heavy	Mixed	Mixed	4-Very heavy	4-Very heavy	1-Sparse	1-Sparse
Roaring Creek	1-Sparse	Mixed	Mixed	2-Moderate	2-Moderate	1-Sparse	2-Moderate
Rock Creek	0-Absent	Deciduous	Deciduous	3-Heavy	3-Heavy	2-Moderate	2-Moderate
Seattle Creek	1-Sparse	Mixed	Mixed	2-Moderate	2-Moderate	2-Moderate	2-Moderate
South Fork Cedar River	1-Sparse	Deciduous	Deciduous	3-Heavy	3-Heavy	3-Heavy	3-Heavy
Taylor Creek	2-Moderate	Deciduous	Deciduous	3-Heavy	2-Moderate	2-Moderate	3-Heavy
Tinkham Creek	2-Moderate	Mixed	Deciduous	2-Moderate	4-Very heavy	2-Moderate	2-Moderate
Spring Creek	1-Sparse	Mixed	Coniferous	3-Heavy	2-Moderate	1-Sparse	1-Sparse
Webster Creek	0-Absent	Mixed	Mixed	3-Heavy	3-Heavy	2-Moderate	2-Moderate
	1-Sparse	Deciduous	Deciduous	3-Heavy	3-Heavy	2-Moderate	2-Moderate
Williams Creek	3-Heavy	Deciduous	Deciduous	3-Heavy	3-Heavy	2-Moderate	2-Moderate

Appendix J. Riparian vegetation at benthic index of biological integrity (BIBI) sites in the Cedar River Watershed—Continued

	Ground cover–woody shrubs		Ground cover–non-woody herbs		Ground cover–barren	
Stream name	Left bank	Right bank	Left bank	Right bank	Left bank	Right bank
			1995			
Bear Creek	0-Absent	1-Sparse	4-Very heavy	3-Heavy	0-Absent	0-Absent
Boulder Creek	2-Moderate	2-Moderate	2-Moderate	2-Moderate	No data	No data
	2-Moderate	2-Moderate	2-Moderate	2-Moderate	No data	No data
	2-Moderate	2-Moderate	3-Heavy	3-Heavy	1-Sparse	1-Sparse
Cedar River	3-Heavy	3-Heavy	1-Sparse	1-Sparse	No data	No data
	1-Sparse	1-Sparse	1-Sparse	4-Very heavy	3-Heavy	1-Sparse
	2-Moderate	1-Sparse	3-Heavy	1-Sparse	0-Absent	3-Heavy
	1-Sparse	1-Sparse	1-Sparse	2-Moderate	0-Absent	0-Absent
	0-Absent	3-Heavy)	1-Sparse	2-Moderate	2-Moderate	2-Moderate
	1-Sparse	2-Moderate	1-Sparse	1-Sparse	2-Moderate	2-Moderate
Goat Creek	Moderate	2-Moderate	2-Moderate	2-Moderate	No data	No data
Green Point Creek	1-Sparse	1-Sparse	2-Moderate	2-Moderate	0-Absent	0-Absent
Hotel Creek	1-Sparse	1-Sparse	3-Heavy	3-Heavy	1-Sparse	1-Sparse
Lost Creek	3-Heavy	0-Absent	1-Sparse	1-Sparse	1-Sparse	1-Sparse
McClellan Creek	1-Sparse	1-Sparse	3-Heavy	3-Heavy	0-Absent	0-Absent
Middle Fork Taylor	3-Heavy	3-Heavy	3-Heavy	3-Heavy	1-Sparse	1-Sparse
	3-Heavy	2-Moderate	2-Moderate	1-Sparse	2-Moderate	2-Moderate
North Fork Cedar River	2-Moderate	1-Sparse	3-Heavy	3-Heavy	No data	No data
North Fork Taylor Creek	2-Moderate	1-Sparse)	2-Moderate	3-Heavy	1-Sparse	1-Sparse
North Fork Cedar River	3-Heavy	3-Heavy	3-Heavy	3-Heavy	No data	No data
Pine Creek	2-Moderate	No data	2-Moderate	No data	No data	No data
Rack Creek	2-Moderate	2-Moderate)	No data	No data	No data	No data
Rex River	1-Sparse	1-Sparse	1-Sparse	1-Sparse	3-Heavy (40-75%)	3-Heavy (40-75%)
	1-Sparse	1-Sparse	4-Very heavy	4-Very heavy	1-Sparse (0-10%)	1-Sparse (0-10%)
	1-Sparse	No data	1-Sparse	No data	2-Moderate (10-40%)	No data
	2-Moderate	2-Moderate	2-Moderate	2-Moderate	No data	No data
Roaring Creek	1-Sparse	0-Absent	1-Sparse	0-Absent	3-Heavy (40-75%)	0-Absent
Rock Creek	2-Moderate	3-Heavy	2-Moderate	3-Heavy	0-Absent	0-Absent
	1-Sparse	1-Sparse	1-Sparse	2-Moderate	2-Moderate (10-40%)	1-Sparse (0-10%)
	1-Sparse	3-Heavy	2-Moderate	2-Moderate	2-Moderate (10-40%)	1-Sparse (0-10%)
	1-Sparse	1-Sparse	1-Sparse	1-Sparse	3-Heavy (40-75%)	2-Moderate (10-40%)
Seattle Creek	1-Sparse	1-Sparse	4-Very heavy	4-Very heavy	0-Absent	0-Absent
South Fork Cedar River	4-Very heavy	4-Very heavy	2-Moderate	2-Moderate	2-Moderate (10-40%)	2-Moderate (10-40%)
Spring Creek	2-Moderate	No data	3-Heavy	No data	2-Moderate (10-40%)	No data

Appendix J. Riparian vegetation at benthic index of biological integrity (BIBI) sites in the Cedar River Watershed—Continued

	Ground cover–woody shrubs		Ground cover–non-woody herbs		Ground cover–barren	
Stream name	Left bank	Right bank	Left bank	Right bank	Left bank	Right bank
			1995—Continued			
Taylor Creek	3-Heavy	1-Sparse	2-Moderate	3-Heavy	1-Sparse	1-Sparse
	1-Sparse	2-Moderate	3-Heavy	2-Moderate	1-Sparse	0-Absent
	No data	1-Sparse	No data	2-Moderate	No data	2-Moderate
	2-Moderate	2-Moderate	2-Moderate	3-Heavy	2-Moderate	1-Sparse
Tinkham Cree	4-Very heavy	2-Moderate	2-Moderate	1-Sparse	0-Absent	0-Absent
Webster Creek	1-Sparse	1-Sparse	3-Heavy	2-Moderate	1-Sparse	2-Moderate
	4-Very heavy	4-Very heavy	1-Sparse	1-Sparse	1-Sparse	1-Sparse
Williams Creek	2-Moderate	3-Heavy	3-Heavy	1-Sparse	0-Absent	2-Moderate
	2-Moderate	2-Moderate	3-Heavy	2-Moderate	0-Absent	2-Moderate
			1996			
Bear Creek	1-Sparse	1-Sparse	3-Heavy	2-Moderate	1-Sparse	3-Heavy
Boulder Creek	0-Absent	0-Absent	0-Absent	0-Absent	0-Absent	0-Absent
	1-Sparse	1-Sparse	1-Sparse	2-Moderate	1-Sparse	1-Sparse
Cedar River	2-Moderate	2-Moderate	2-Moderate	2-Moderate	1-Sparse	1-Sparse
	2-Moderate	3-Heavy	3-Heavy	3-Heavy	2-Moderate	1-Sparse
	2-Moderate	2-Moderate	3-Heavy	2-Moderate	1-Sparse	2-Moderate
	2-Moderate	4-Very heavy	2-Moderate	2-Moderate	2-Moderate	1-Sparse
	2-Moderate	2-Moderate	2-Moderate	2-Moderate	1-Sparse	1-Sparse
	2-Moderate	2-Moderate	2-Moderate	2-Moderate	2-Moderate	2-Moderate
Goat Creek	1-Sparse	1-Sparse	1-Sparse	1-Sparse	2-Moderate	2-Moderate
Lost Creek	1-Sparse	1-Sparse	4-Very heavy	3-Heavy	1-Sparse	1-Sparse
North Fork Cedar River	3-Heavy	2-Moderate	3-Heavy	2-Moderate	1-Sparse	2-Moderate
North Fork Taylor Creek	1-Sparse	1-Sparse	3-Heavy	3-Heavy	1-Sparse	1-Sparse
Rex River	2-Moderate	2-Moderate	2-Moderate	2-Moderate	1-Sparse	1-Sparse
	1-Sparse	1-Sparse	1-Sparse	2-Moderate	3-Heavy	3-Heavy
Roaming Creek	1-Sparse	1-Sparse	1-Sparse	1-Sparse	3-Heavy	3-Heavy
Rock Creek	2-Moderate	2-Moderate	3-Heavy	3-Heavy	1-Sparse	1-Sparse
Seattle Creek	3-Heavy	3-Heavy	3-Heavy	3-Heavy	1-Sparse	1-Sparse
South Fork Cedar River	0-Absent	0-Absent	2-Moderate	2-Moderate	1-Sparse	1-Sparse
Taylor Creek	2-Moderate	1-Sparse	3-Heavy	3-Heavy	1-Sparse	1-Sparse
Tinkham Creek	3-Heavy	3-Heavy	2-Moderate	2-Moderate	1-Sparse	1-Sparse
Spring Creek	2-Moderate	2-Moderate	3-Heavy	2-Moderate	1-Sparse	2-Moderate
Webster Creek	0-Absent	0-Absent	2-Moderate	2-Moderate	2-Moderate	2-Moderate
	3-Heavy	3-Heavy	1-Sparse	1-Sparse	1-Sparse	1-Sparse

Appendix K. Substrate measures for benthic index of biological integrity (BIBI) sites within the Cedar River Watershed

[mm, millimeter; --, no data collected]

Stream name	River mile	Map site number	Latitude	Longitude	Date	Embedded	Silt - clay muck (Percentage)	Sand (0.06 2 mm) (Percentage)	Fine gravel (2 to 16 mm) (Percentage)	Coarse gravel (16 to 64 mm) (Percentage)	Cobble (64 to 250 mm) (Percentage)	Boulder (250 to 400 mm) (Percentage)	Bedrock (smooth) (Percentage)
						1995							
Bear Creek	1.6	1	47-19-30	121-36-33	10-27-95	5	--	5	5	30	60	--	---
Boulder Creek	0.5	2	47-21-58	121-41-35	10-26-95	73	--	1	4	14	80	0	--
	1.1	3	47-21-37	121-42-11	10-26-95	72	--	14	5	22	13	47	--
Goat Creek	0.1	5	47-19-11	121-31-48	10-27-95	18	--	--	3	5	55	25	12
Green Point Creek	0.0	6	47-21-08	121-47-10	10-23-95	48	--	1	9	20	56	13	--
Hotel Creek	0.2	7	--	--	10-25-95	79	--	4	--	--	--	--	--
Lower Cedar River	1.0	22	47-23-06	121-57-18	10-17-95	10	--	--	--	--	--	--	--
	11.5	26	47-25-02	121-47-15	10-19-95	29	--	10			--	--	--
	6.9	24	47-23-13	121-51-59	10-20-95	25	2	12	--	--	--	--	--
	8.8	25	47-24-07	121-50-10	10-21-95	25	--	6	--	--	--	--	--
Lost Creek	0.4	8	47-24-26	121-45-21	10-31-95	27	--	1	--	8	13	80	--
McClellan Creek	0.0	9	47-22-57	121-39-40	10-23-95	65	--	1	6	9	42	43	--
Middle Fork Taylor	1.0	28	47-21-08	121-47-10	10-31-95	71	--	1	--	--	--	--	--
	3.0	16	47-21-14	121-44-59	11-01-95	46	--	6	--	--	--	--	--
North Fork Cedar River	0.7	29	47-19-01	121-30-25	10-05-95	53	--	7	--	--	--	--	--
Tinkham Creek	0.3	39	47-19-40	121-28-04	10-02-95	0	--	4	93	--	--	--	--
Spring Creek	0.6	40	47-18-55	121-28-20	10-04-95	--	2	21	30	30	--	--	--
North Fork Cedar River	2.4	30	47-19-15	121-28-52	10-04-95	30	--	5	--	--	--	--	--
North Fork Taylor Creek	1.3	17	47-22-24	121-47-60	09-06-96	--	--	22	27	27	25	--	--
Pine Creek	0.7	47	47-19-32	121-36-40	10-26-95	20	--	5	10	10	40	97	--
Rack Creek	0.0	31	47-23-30	121-43-16	10-12-95	67	--	1	1	3	33	63	--
Rex River	0.8	42	47-21-36	121-40-44	10-25-95	50	--	11	15	27	49	--	--
	2.2	43	47-21-04	121-39-32	10-25-95	100	--	--	1	1	1	--	100
	4.2	44	47-20-05	121-37-52	10-26-95	100	--	--	--	--	--	--	100
	5.7	45	47-18-56	121-37-44	10-25-95	100	--	--	--	--	--	--	100
Roaring Creek	0.2	10	47-21-42	121-35-24	10-31-95	58	--	30	40	--	--	--	--
Rock Creek	0.0	11	47-23-36	121-56-49	10-30-95	75	--	7	--	--	--	--	--
	0.0	11	47-23-36	121-56-49	10-24-95	75	0	4	--	--	--	--	--
	4.6	13	47-24-36	121-53-55	10-31-95	29	--	6	--	--	--	--	--
	4.6(pool)	13	47-24-36	121-53-55	10-31-95	29	--	8	--	--	--	--	--
South Fork Cedar River	3.0	48	47-19-32	121-36-40	10-03-95	--	2	34	--	--	95	--	--

Appendix K. Substrate measures for benthic index of biological integrity (BIBI) sites within the Cedar River Watershed—Continued

Stream name	River mile	Map site number	Latitude	Longitude	Date	Embedded	Percentage: Silt - clay muck	Sand (0.06 2 mm)	Fine gravel (2 to 16 mm)	Coarse gravel (16 to 64 mm)	Cobble (64 to 250 mm)	Boulder (250 to 400 mm)	Bedrock (smooth)
Taylor Creek	0.0	32	47-23-26	121-51-05	10-30-95	29	--	3	--	--	--	--	--
	0.9	33	47-23-01	121-50-28	11-01-95	42	--	1	--	--	--	--	--
	2.3	34	47-22-21	121-49-36	11-01-95	46	--	6	--	--	--	--	--
	2.5	35	47-22-09	121-49-35	10-31-95	46	--	3	--	--	--	--	--
Upper Cedar River	0.0	36	47-22-12	121-37-23	10-06-95	23	--	2	3	4	92	--	--
	5.0	37	47-20-45	121-33-00	10-06-95	35	--	--	--	--	--	--	--
	6.9	38	47-19-14	121-31-44	10-27-95	55	--	--	--	10	90	100	--
Webster Creek	2.1	18	47-26-00	121-54-40	10-26-95	21	--	7	--	--	--	--	--
	2.8	19	47-26-25	121-54-07	10-30-95	13	--	6	--	--	--	--	--
Williams Creek	0.2	20	47-23-43	121-51-09	10-30-95	33	--	12	--	--	--	--	--
	1.0	21	47-23-43	121-51-09	10-30-95	46	--	1	--	15	2	3	--
						1996							
Bear Creek	1.6	1	47-19-30	121-36-33	09-11-96	27	--	15	18	8	55	3	--
Boulder Creek	1.1	3	47-21-37	121-42-11	09-04-96	40	--	--	--				--
	3.1	46	47-20-10	121-41-56	09-04-96	--	--	--	--	3	41	56	--
	3.2	4	47-20-09	121-42-14	09-04-96	47	--	10	44	6	8	32	--
Goat Creek	0.1	5	47-19-11	121-31-49	09-10-96	100	--	--	--		--	--	100
Lower Cedar River	1.0	22	47-23-06	121-57-18	09-05-96	25	--	12	25	45	18	--	--
	5.2	23	47-23-04	121-53-49	09-05-96	32	--	35	32	22	12	--	--
	6.9	24	47-23-13	121-51-59	09-05-96	0	--	16	49	25	4	--	--
	8.8	25	47-24-07	121-50-10	09-05-96	0	--	25	15	25	35	--	--
	11.5	26	47-25-02	121-47-15	08-21-96	40	--	3	15	10	37	33	--
	12.1	27	--	--	08-21-96	13	--	10	30	28	14	--	--
Lost Creek	0.4	8	47-24-26	121-45-21	09-18-96	0	2	7	13	--	69	--	--
Tinkham Creek	0.3	39	47-19-01	121-30-68	09-17-96	20	--	3	9	39	79	--	--
Spring Creek	0.6	40	47-18-55	121-28-20	09-12-96	18	--	18	17	23	38	--	--
North Fork Cedar River	2.4	30	47-19-15	121-28-52	08-28-96	--	--	--	--	--	--	--	100
North Fork Taylor Creek	1.3	17	47-22-24	121-47-60	09-06-96	--	--	22	27	27	25	--	--
Pine Creek	0.7	47	47-19-32	121-36-40	10-17-96	0	--	--	2	4	92	--	--
	0.8	41	47-19-30	121-36-32	10-22-96	0	--	--	3	10	85	--	--
Rex River	2.2	43	47-21-04	121-39-32	09-19-96	48	--	25	25	30	10	55	--
	4.2	44	47-20-05	121-37-52	09-19-96	75	--	--	5	15	65	45	--
Roaring Creek	0.2	10	47-21-42	121-35-24	09-10-96	53	--	27	5	30	75	38	--

Appendix K. Substrate measures for benthic index of biological integrity (BIBI) sites within the Cedar River Watershed—Continued

						Percentage							
Stream name	River mile	Map site number	Latitude	Longitude	Date	Embedded	Silt - clay muck	Sand (0.06 2 mm)	Fine gravel (2 to 16 mm)	Coarse gravel (16 to 64 mm)	Cobble (64 to 250 mm)	Boulder (250 to 400 mm)	Bedrock (smooth)
Rock Creek	4.6	13	47-24-36	121-53-55	09-06-96	27	0	18	22	22	38	10	--
Seattle Creek	1.8	15	47-19-13	121-33-25	09-10-96	57	--	25	65	28	25	5	--
South Fork Cedar River	3.0	48	47-19-32	121-36-40	09-10-96	22	--	8	41	33	10	11	--
Taylor Creek	2.5	35	47-22-09	121-49-35	08-30-96	17	--	--	15	30	25	--	--
Webster Creek	2.1	18	47-26-00	121-54-40	09-16-96	5	--	30	21	13	45	30	--
	2.8	19	47-26-25	121-54-07	09-16-96	35	--	3	10	26	45	45	--
Williams Creek	1.0	21	47-23-43	121-51-09	09-24-96	22	0	4	13	22	62	--	--

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