T/F/W Ecoregion Bioassessment Pilot Project

by

Robert W. Plotnikoff
Hank L. Dietrich

Environmental Investigations and Laboratory Services
Surface Water Investigations Section
Washington State Department of Ecology
Olympia, WA 98504-6814

Interim Report
June 1991

TABLE OF CONTENTS

	Page
LIST OF TABLES	ii
LIST OF FIGURES	iii
ACKNOWLEDGEMENTS	iv
INTRODUCTION	1
Phase I-Project Development	1
PRELIMINARY RESULTS	2
Habitat Survey	2
Refinements to Site Selection and Habitat Surveys	3
Site Descriptions	3
Benthic Macroinvertebrates	8
Water Quality	8
SUMMARY	10
LITERATURE CITED	19

LIST OF TABLES

Title		Page
Table 1.	Score ranges for habitat assessment of reference streams in the Puget Lowland, Cascades, and Columbia Basin ecoregions (Fall 1990)	5
Table 2.	Score ranges for habitat assessment of reference streams in the Puget Lowland, Cascades and Columbia Basin ecoregions (Winter 1991)	6

LIST OF FIGURES

Title		Page
Figure 1.	Location and identification of sites surveyed in the Ecoregion Bioassessment Pilot Project	4
Figure 2.	Mean number of benthic macroinvertebrates per square meter of riffle/run in reference streams of the Cascades and Columbia Basin ecoregions (Nov. 1990)	9
Figure 3.	Principal component analysis including the standardized loadings for each water quality parameter surveyed at sites within the Puget Lowland, Cascades, and Columbia Basin ecoregions (Nov. 1990-Mar. 1991)	11
Figure 4.	Box plots for conductivity, hardness, and alkalinity in the Puget Lowland, Cascades, and Columbia Basin Ecoregions (Nov. 1990- Mar. 1991)	12
Figure 5.	Box plots for nitrate+nitrite nitrogen and total persulfate nitrogen in the Puget Lowland, Cascades, and Columbia Basin ecoregions (Nov. 1990-Mar. 1991)	13
Figure 6.	Box plots for pH and total phosphorus in the Puget Lowland, Cascades, and Columbia Basin ecoregions (Nov. 1990-Mar. 1991)	14
Figure 7.	Mean monthly values for conductivity, hardness, and alkalinity in the Puget Lowland, Cascades, and Columbia Basin ecoregions (Nov. 1990-Mar. 1991)	15
Figure 8.	Mean monthly concentrations for nitrate+nitrite nitrogen in the Puget Lowland, Cascades, and Columbia Basin ecoregions (Nov. 1990-Mar. 1991)	16
Figure 9.	Mean monthly values for pH and total phosphorus in the Puget Lowland, Cascades, and Columbia Basin ecoregions (Nov. 1990-Mar. 1991)	17

ACKNOWLEDGEMENTS

The Timber/Fish/Wildlife Program funded this project for the purposes of better defining forest harvest impacts on aquatic life. We wish to express our appreciation to the T/F/W-Water Quality Steering Committee (Robert Bilby-Chair) for persevering in development of this project. The following personnel from the Surface Water Investigations Section in the Department of Ecology provided invaluable field assistance: Betsy Dickes, Randy Coots, Joe Joy, Keith Seiders, Roger Willms, Craig Graber, and Robert Cusimano.

INTRODUCTION

Support of aquatic life is a commonly designated beneficial use of aquatic resources and an important reason for maintaining a high degree of water quality. Historically, chemical analysis of water column samples have been the primary means of assessing aquatic conditions, however, this has not always been adequate. Techniques to assess the biological community can be better measures of overall conditions. The use of bioassessment as a resource management tool provides a broader view of aquatic conditions by including the evaluation of living organisms. Bioassessment has experienced increasing popularity with a number of states and is endorsed by the United States Environmental Protection Agency (1987). Its current use in Washington State has been limited by a lack of regional biological information.

Bioassessment can be conducted with a variety of aquatic organisms, but the use of benthic macroinvertebrates is the most attractive approach. Benthic macroinvertebrates are dependent on habitat quality (Minshall, 1984) and are especially well suited for nonpoint pollution assessment. These organisms integrate water quality conditions over time and space and thus indicate overall stream conditions. A combination of biological, chemical, and physical water quality information enhances the knowledge of dynamic instream processes (Vannote *et al.*, 1980; Newbold *et al.*, 1981; Ohio EPA, 1988).

Establishment of a bioassessment program requires the identification of the nominal condition of aquatic life in an ecoregion (Odum *et al.*, 1979). This defines a "reference" condition that will enable comparisons within and between ecoregions. The condition of a site is determined by using a combination of macroinvertebrate community metrics, habitat assessments, land use assessments, and the identification of probable point and nonpoint pollution sources. Bioassessment is useful in long-term trend monitoring and in site specific surveys.

Phase I-Project Development

Washington State includes an extreme range of conditions within eight ecoregion types (Omernick and Gallant, 1986). Bioassessment has been implemented in three of these ecoregions. The ecoregions in which sampling has taken place are Puget Lowland (Region 2), Cascades (Region 4), and Columbia Basin (Region 10). The Cascades and Puget Lowland ecoregions typically contain forested lands. The Columbia Basin is predominantly covered by sagebrush and grasses, with forested areas located on the fringe.

The objectives for the Ecoregion Bioassessment pilot project are as follows:

1. To characterize the benthic macroinvertebrate community in generally unimpacted third and fourth order streams of three ecoregions in Washington State (Puget Lowland, Cascades, Columbia Basin).

2. To define the benthic macroinvertebrate reference condition in each ecoregion during different seasons.

3. To develop a general methods protocol for conducting ecoregion bioassessment surveys in Washington State.

A biomonitoring network covering some of Washington's key drainages will be a valuable tool to use in evaluating the long term goals of preservation and improvement of existing water quality. Coordination of methods and sampling techniques with agencies including the United States Geological Survey (USGS), adherents to the Timber/Fish/Wildlife (TFW) agreement, and local and tribal governments has been initiated.

The Ecoregion Bioassessment Pilot Project began in November of 1990 and is scheduled to run through October 1991. The following interim report includes preliminary findings and describes project progress to date. A draft report of the one-year pilot project will be available in March 1992. The final report will be completed by June 1992.

PRELIMINARY RESULTS

Specific information regarding methodology for the habitat survey, benthic macroinvertebrate collection, and water quality collection can be found in Plotnikoff (1990).

Habitat Survey

Habitat evaluation was conducted at each reference site on a seasonal basis which coincided with the benthic macroinvertebrate surveys. Reference site locations are displayed in Figure 1. We used the EPA rapid bioassessment protocol habitat evaluation method to score nine descriptors of habitat condition (Plafkin *et al.*, 1989). Score ranges were prepared representing each ecoregion for Fall and Winter (Tables 1 and 2). A total score of 135 points represents excellent habitat condition.

The total score ranges were noticeably different among the ecoregions during each of the seasons. The Fall 1990 score ranges indicated that the Columbia Basin reference stations attained the best habitat condition (Table 1). The Cascades and the Puget Lowland ecoregions followed in the order of declining habitat condition. The Winter 1991 habitat evaluation scored the Puget Lowland ecoregion reference sites highest, with ranges from the Columbia Basin and the Cascades ecoregions following in declining order (Table 2). The Puget Lowland ecoregion was primarily disturbed by embeddedness and scouring resulting from large quantities of precipitation in Fall 1990 (Table 1). The Cascades ecoregion streams experienced loss of habitat due to low discharges in Winter 1991, as was indicated by flow velocity/depth scores in Table 2.

Refinements to Site Selection and Habitat Surveys

The current use of the EPA Rapid Bioassessment Protocol qualitative scoring system for habitat survey appears to be of limited value in interpreting site specific water quality and biological observations. Other contiguous States (Oregon and Idaho) have expressed the same concern and are represented along with Washington in a work group dealing with changes to the currently used RBPs. The changes include quantification of habitat parameters on an annual basis at each of the reference sites in a monitoring program. The parameters selected for use address any unique conditions normally present in the ecoregions of the Pacific Northwest.

A second work group was formed in order to address the concept of sub-regions within an ecoregion. The sub-region concept is the next logical step in defining continuity on a spatial scale and provides a greater degree of resolution in order to minimize differences when considering replicate sites within a region. A variety of entities were involved in this work group including the following: Bureau of Land Management, US Forest Service, Idaho Department of Health and Welfare, Washington Department of Ecology, EPA-Environmental Research Laboratory, EPA Region X, Oregon Department of Environmental Quality, and The Center for Streamside Studies at the University of Washington.

Site Descriptions

The following narratives describe some of the visual observations made at a single reference site from each ecoregion. Similar narratives are being produced for the remaining reference sites surveyed in this project.

Bingham Creek - (Puget Lowlands Ecoregion)

The Bingham Creek site is located within second growth timber on commercial forest lands. The sample station is around 200 meters above mean sea level in elevation. Upstream drainage basin area is approximately four square miles. The basin terminates in the surrounding hills, two miles upstream from the sampling site. Maximum elevation within the Bingham Creek drainage basin is 800 meters. Second growth forest has been cut recently in the vicinity of the reference station reach.

Stream substrate within the sample reach contains cobble, gravel, and silty areas. Large diameter woody debris is present along and within the stream. Conditions during water quality and benthic macroinvertebrate sampling in May were characterized by minimal surface flow.

Forests in the vicinity of the sample station have a closed canopy and are dominated by Douglas fir (*Pseudotsuga menziesii*) which are one to two feet diameter. Larger well rotted stumps are visible above the forest floor. Other tree species observed include western hemlock (*Tsuga heterophylla*), big-leaf maple (*Acer macrophyllum*), red alder (*Alnus rubra*), and black cottonwood (*Populus trichocarpa*). Tall shrubs include osoberry (*Oemleria cerasiformis*) and vine maple (*Acer circinatum*). Lower shrubs include Oregon grape (*Berberis nervosa*), salal

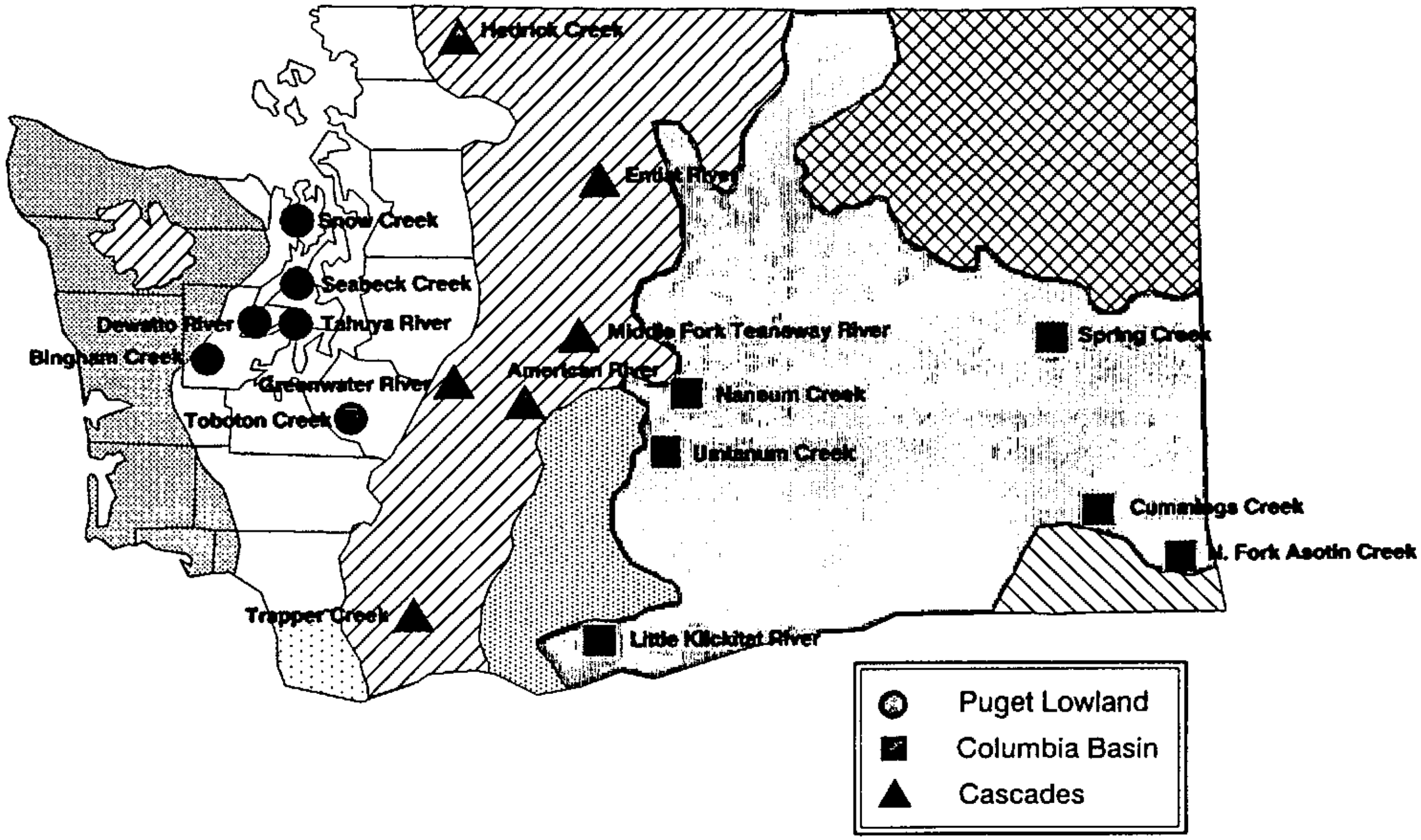


Figure 1. Location and identification of sites surveyed in the Ecoregion Bioassessment Pilot Project.

Table 1. Score ranges for habitat assessment of reference streams in the Puget Lowland, Cascades, and Columbia Basin ecoregions (Fall 1990).

Parameter	Puget Lowland	Cascades ----Score Ranges----	Columbia Basin
Substrate/ cover	11-17	18-20	17-20
Embeddedness	12-18	14-20	16-20
Flow velocity/ depth	15-20	16-20	16-20
Channel alteration	9-14	13-15	15
Scouring and deposition	9-12	11-15	10-15
Pool/riffles, run/bend ratio	14-15	13-15	14-15
Bank stability	8-10	8-10	8-10
Bank vegetative stability	8-10	9-10	8-10
Streamside cover	8-10	7-8	7-9
Totals:	104-121	117-128	118-132

Table 2. Score ranges for habitat assessment of reference streams in the Puget Lowland, Cascades, and Columbia Basin ecoregions (Winter 1991).

Parameter	Puget Lowland	Cascades ----Score Ranges----	Columbia Basin
Substrate/ cover	15-20	11-18	14-19
Embeddedness	8-18	8-17	11-16
Flow velocity/ depth	13-19	6-17	10-18
Channel alteration	10-15	7-15	7-14
Scouring and deposition	7-11	3-12	5-11
Pool/riffles, run/bend ratio	8-15	8-13	5-14
Bank stability	8-10	5-10	5-9
Bank vegetative stability	9-10	4-9	7-10
Streamside cover	8-10	6-8	5-9
Totals:	95-118	74-112	86-115

(*Gaultheria shallon*), baldhip rose (*Rosa gymnocarpa*), red huckleberry (*Vaccinium parvifolium*), and salmonberry (*Rubus spectabilis*). Herbs include sword-fern (*Polystichum munitum*), false lily-of-the-valley (*Maianthemum dilatatum*), bleeding heart (*Dicentra formosa*), and pig-a-back-plant (*Tolmiea menziesii*).

Hedrick Creek (Cascades Ecoregion)

Hedrick Creek lies northwest of Mt. Baker in the Mt. Baker-Snoqualmie National Forest and is one of a series of steep, narrow creek basins bisecting the northeast-facing slopes of Slide Mountain. The sampling station's elevation is 300 meters above mean sea level. The drainage basin area upstream is approximately two square miles. Two miles upstream from the sampling site, Hedrick Creek reaches the higher points of the basin at an elevation of 1500 meters. The creek enters the North Fork of the Nooksack River a short distance downstream from the sample reach.

Hedrick Creek is the northernmost Cascade reference stream evaluated in this pilot project. Stream substrate is primarily comprised of cobbles and boulders. Destabilized banks, loss of streamside vegetation, and channel revisions occurred during winter runoff in Hedrick Creek prior to January 1991 surface water sampling. Portions of the slopes along the lower end of the sample reach were undercut exposing a twenty-five foot denuded bank. Recently fallen trees cover the stream bed at the midpoint of the sample reach.

Upland areas near the Hedrick Creek site contain closed canopy second growth western hemlock forests with dominants one to two feet in diameter. Other tree species common in the vicinity include red alder, big-leaf maple, and willows (*Salix* sp.). Vine maple as well as salmonberry and devil's club (*Oplopanax horridum*) in low areas were noted in the shrub layer near the creek. Common herbs include lady-fern (*Athyrium filix-femina*), sword-fern, and pig-a-back-plant.

Cummings Creek (Columbia Basin Ecoregion)

Cummings Creek is a tributary of the Tucannon River. The sample site is located on Department of Wildlife land at around 700 meters in elevation. Cummings Creek extends about eight miles upstream beyond the reference reach. It drains a narrow north by northwest -south by southeast oriented valley. Upstream of the sample reach are about 18 square miles of land within the drainage basin. The Blue Mountains and Umatilla National Forest lie to the south of the reach.

Streamside vegetation is mostly deciduous, and the creek substrate contains considerable organic material. Cobble and gravel are present as well. The stream channel appears stable, without recent signs of erosion. It is likely grazing occurs at points along this stream reach, although there is little evidence of recent grazing activity.

Upland areas contain open Ponderosa pine (*Pinus ponderosa*) forests with some fire scars. Shrub thickets along the creek included mallow ninebark (*Physocarpus malvaceus*), snowberry (*Symphoricarpos* sp.) and alder (*Alnus* sp.). Horsetails (*Equisetum* sp.) and grasses grow along the stream riparian zone.

Benthic Macroinvertebrates

Complete sample sets have been collected for Fall, Winter, and Spring of 1990-1991. Benthic macroinvertebrates for the Fall season are now being identified. Winter and Spring samples are being transferred from field preservative (10% formaldehyde) to laboratory preservative (75% ethanol).

Standardized Methodology

Washington and Oregon bioassessment personnel are attempting to standardize macroinvertebrate field collection and laboratory analysis methodology. Washington shares five ecoregions with Oregon which provides an opportunity for information sharing. This concept will ultimately eliminate high costs associated with larger scale integrated monitoring approaches. The methodologies currently being used by each state are very similar. The only evaluation in field collection technique will be the use of the D-frame kick net in contrast to the square-meter kick net.

Ecoregion Abundance

Preliminary results of laboratory macroinvertebrate sorting provided information regarding abundance in the Cascades and Columbia Basin ecoregions for the November 1990 (Fall) survey (Figure 2). The Cascades reference sites provided highly variable abundance information in comparison to Columbia Basin results. Community abundance in montane regions can be highly variable due to increased disturbance frequencies from flooding and erosion. These disturbances typically increase embeddedness and remove useable habitat for indigenous, sensitive taxa that could potentially be present in high elevation and high gradient streams (Quinn and Hickey, 1990). The qualitative habitat assessment agreed with this explanation in that embeddedness was generally more of a problem in the Cascades (Table 1). Individual embeddedness scores for each reference site in the Cascades ($x=16$) had a tendency to be lower than those sites scored in the Columbia Basin ($x=18$). The analysis of community structure and function will provide much more information on continuities in the Cascades reference sites.

Water Quality

We collected water quality data on a monthly basis from November 1990 through June 1991. Only water quality data from November 1990 through March 1991 have been analyzed for this interim report due to laboratory analysis lag time.

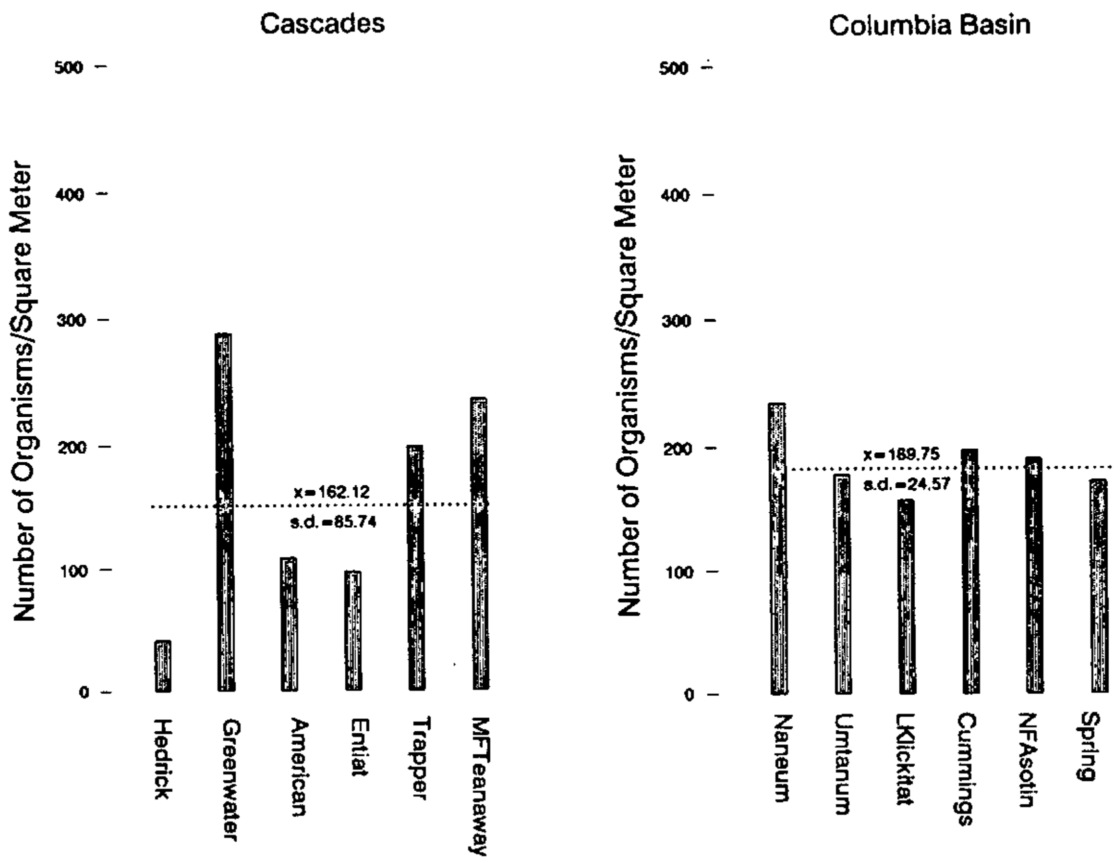


Figure 2. Mean number of benthic macroinvertebrates per square meter of riffle/run in reference streams of the Cascades and Columbia Basin ecoregions (Nov. 1990).

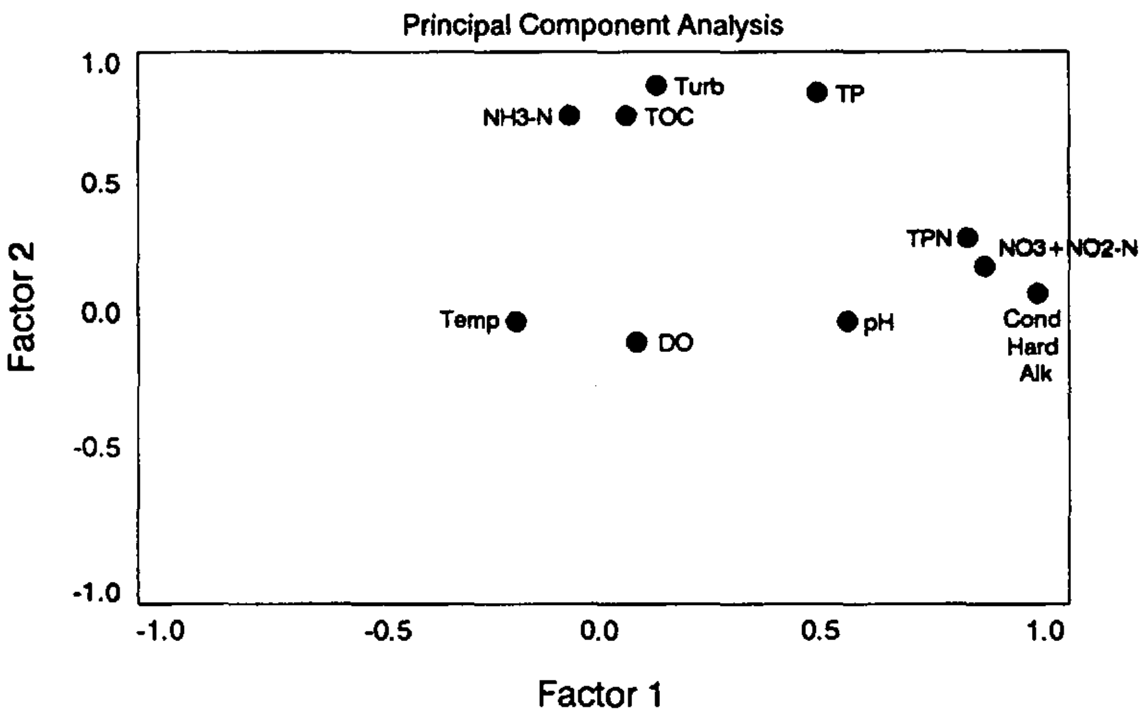
Defining water quality parameters unique to an ecoregion was accomplished by using a statistical ordination technique known as principal components analysis (PCA). The results of the ordination for physico-chemical surface water information are displayed in Figure 3. Factor 1 is the component which describes the largest variance in the data set and thus best delineates differences among ecoregions. Four different parameter clusters were identified along the first component and are exemplified by the "standardized" rotated loadings in Figure 3. The loadings describe the amount of variance accounted for by each parameter and have been grouped according to their numerical similarity. Negative loading values are anomalies associated with the ordination process and do not retain any significance in interpretation.

The first group of parameters explaining most of the variance in the water quality data set are conductivity, total hardness, and alkalinity. Distribution of observations for these parameters by ecoregion is displayed in three notched box plots (Figure 4). The Columbia Basin is significantly different from the Cascades and Puget Lowland for each of these parameters as illustrated by the non-overlap of the 95% confidence intervals (indicated by the notches on each of the box plots). The second grouping of data describe nitrate+nitrite nitrogen and total persulfate nitrogen (Figure 5). Significant differences exist between nitrate+nitrite nitrogen concentrations in the Puget Lowland and the other ecoregions. Total phosphorus and pH were included in the third group of variables defined by the first principal component. Columbia Basin total phosphorus concentrations and pH values were significantly larger than either of Puget Lowland and Cascades observations (Figure 6).

Line graphs were constructed depicting mean concentrations and values for the previously described water quality parameters. A comparison between mean monthly values for each ecoregion and the distribution of data within an ecoregion (box plots) indicated seasonal influences. Consistently higher values for conductivity, total hardness, and alkalinity were typical of the Columbia Basin ecoregion and not influenced by seasonality (Figure 7). Nitrate+nitrite nitrogen and total persulfate nitrogen were not as clearly differentiated among the ecoregions and were considered to be influenced by seasonal changes (Figure 8). The distribution of nitrogen was much broader and may best be analyzed by determining seasonal means. Total phosphorus and pH were predominantly greater for most of the months sampled (Figure 9). Inherent qualities of the Columbia Basin soils and geologic formations influence these two parameters in a consistent manner.

SUMMARY

The scope of this bioassessment effort was focused on identifying impacts to aquatic systems resulting from forest practices. The incorporation of biological monitoring with physical and chemical water quality measurements may provide a more comprehensive view of forest harvest impacts.



Rotated Loadings

	Factor 1	Factor 2
Cond	0.980	0.072
Hard	0.979	0.048
Alk	0.960	0.016
NO3/ NO2-N	0.844	0.201
TPN	0.813	0.306
pH	0.536	0.073
Turb	0.084	0.862
TP	0.418	0.751
TOC	0.064	0.731
NH3-N	-0.071	0.720
Temp	-0.279	-0.086
DO	0.083	-0.017

Figure 3. Principal component analysis including the standardized loadings for each water quality parameter surveyed at sites within the Puget Lowland, Cascades, and Columbia Basin ecoregions (Nov. 1990-Mar. 1991).

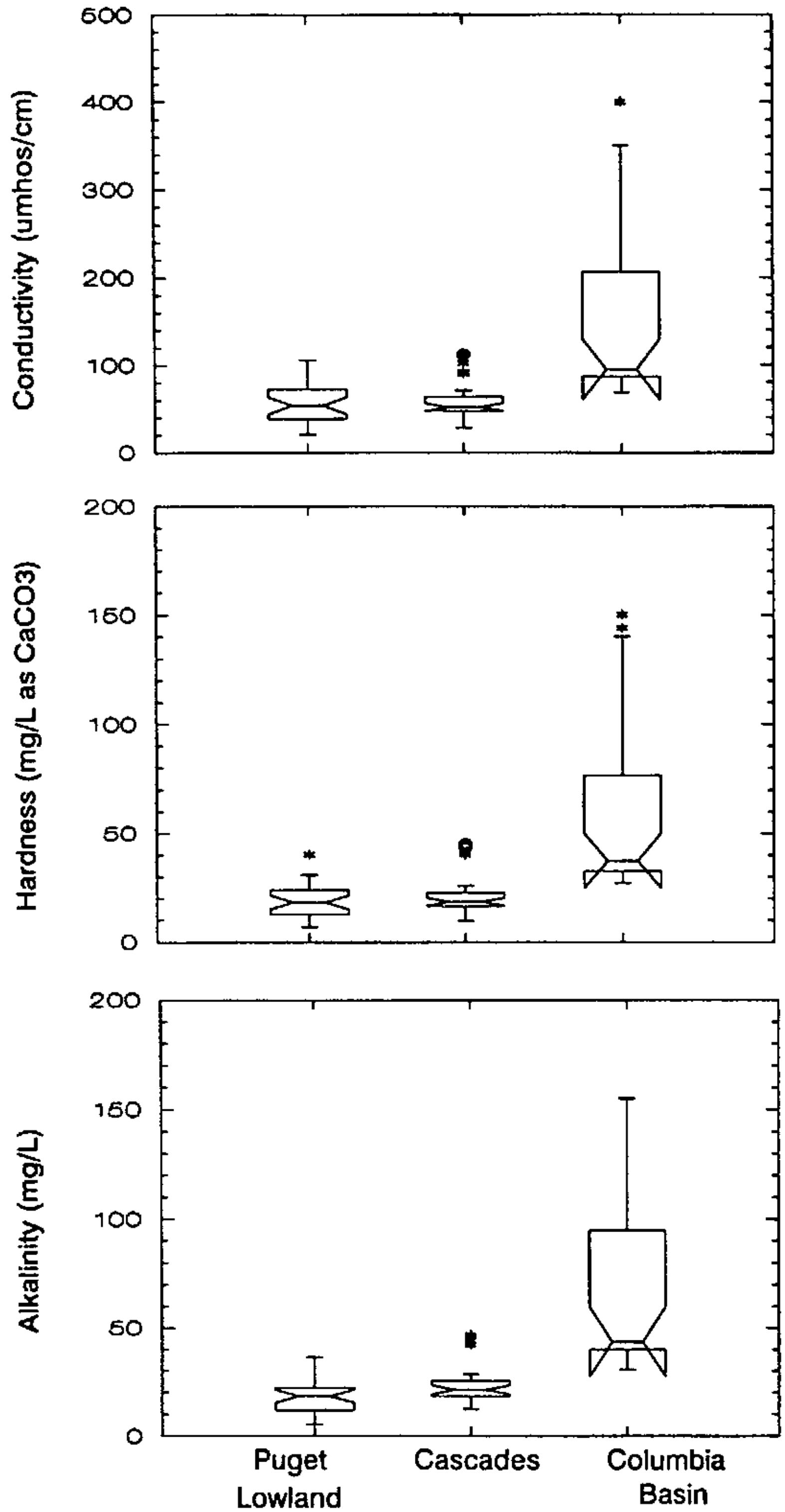


Figure 4. Box plots for conductivity, hardness, and alkalinity in the Puget Lowland, Cascades, and Columbia Basin ecoregions (Nov. 1990-Mar. 1991).

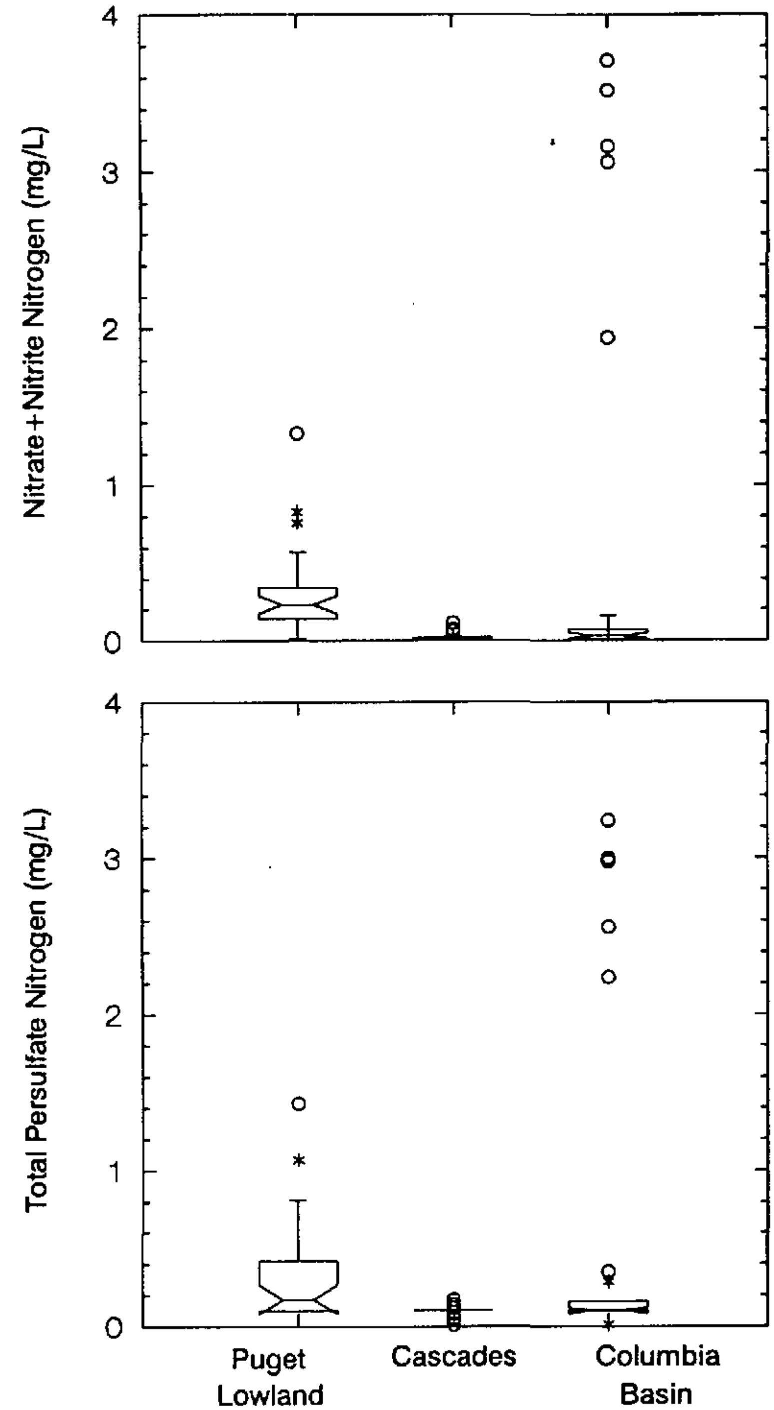


Figure 5. Box plots for nitrate+nitrite nitrogen and total persulfate nitrogen in the Puget Lowland, Cascades, and Columbia Basin ecoregions (Nov. 1990-Mar. 1991).

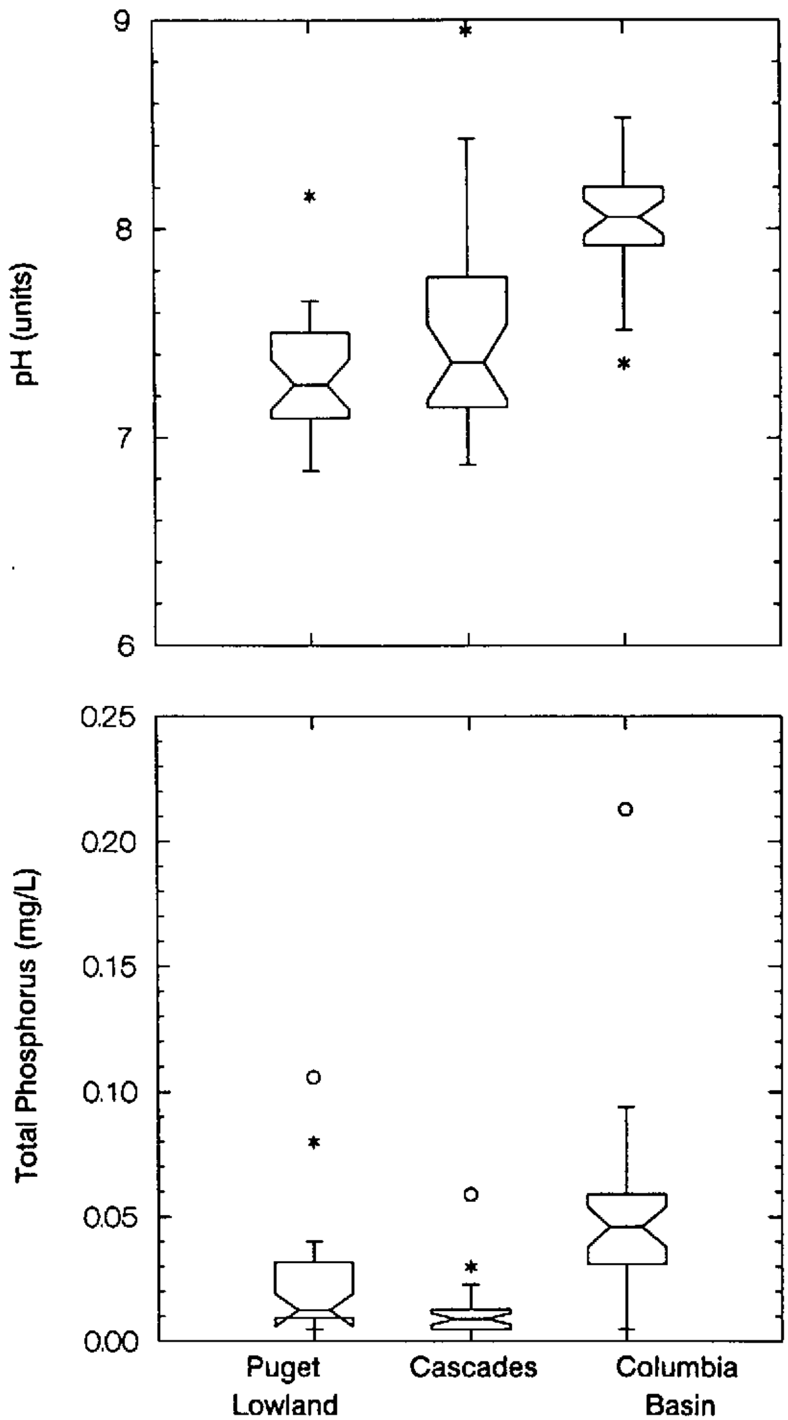


Figure 6. Box plots for pH and total phosphorus in the Puget Lowland, Cascades, and Columbia Basin ecoregions (Nov. 1990-Mar. 1991).

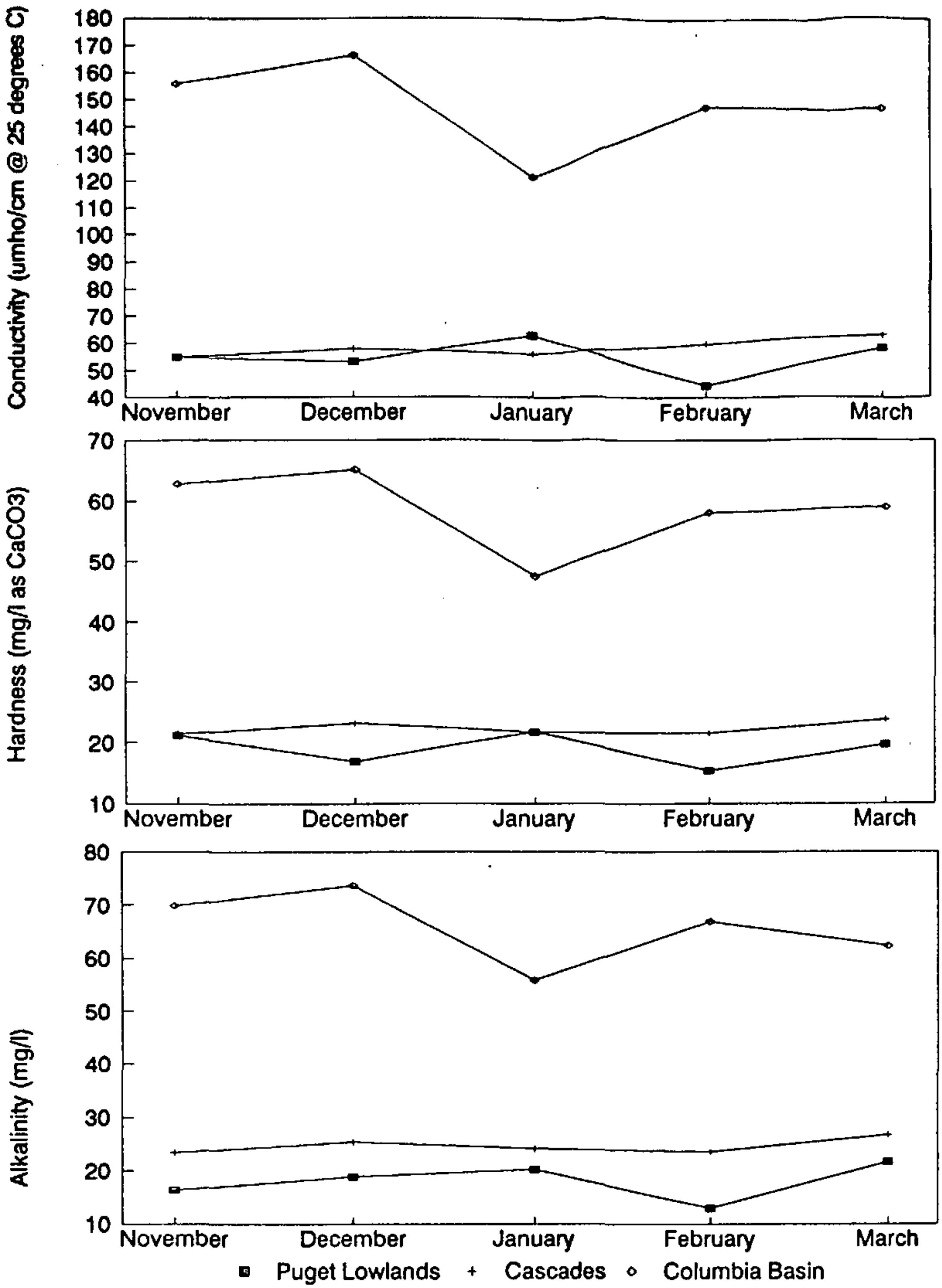


Figure 7. Mean monthly values for conductivity, hardness, and alkalinity in the Puget Lowland, Cascades, and Columbia Basin ecoregions (Nov.1990 - Mar. 1991)

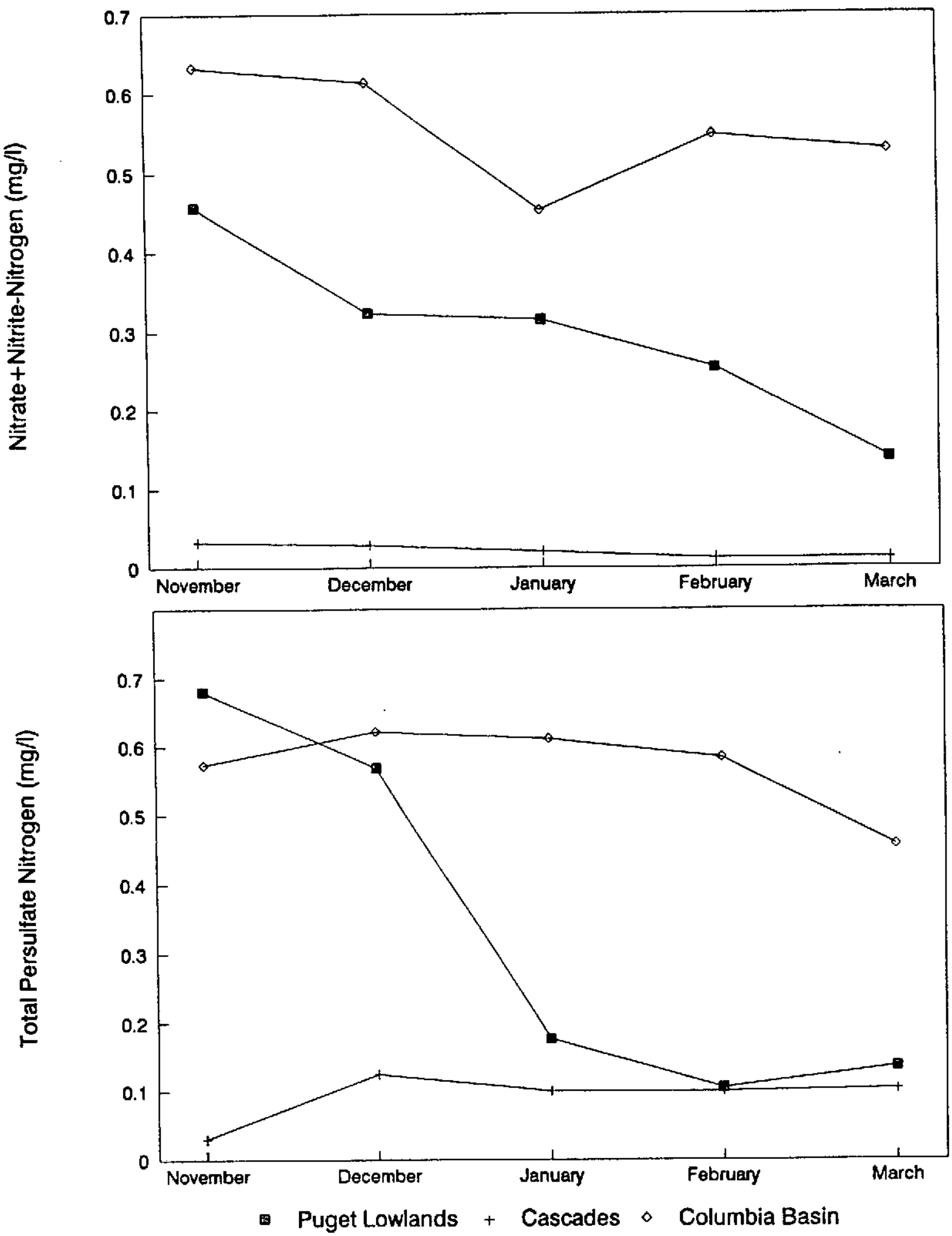


Figure 8. Mean monthly concentrations for nitrate+nitrite nitrogen and total persulfate nitrogen in the Puget Lowland, Cascades, and Columbia Basin ecoregions (Nov. 1990-Mar.1991).

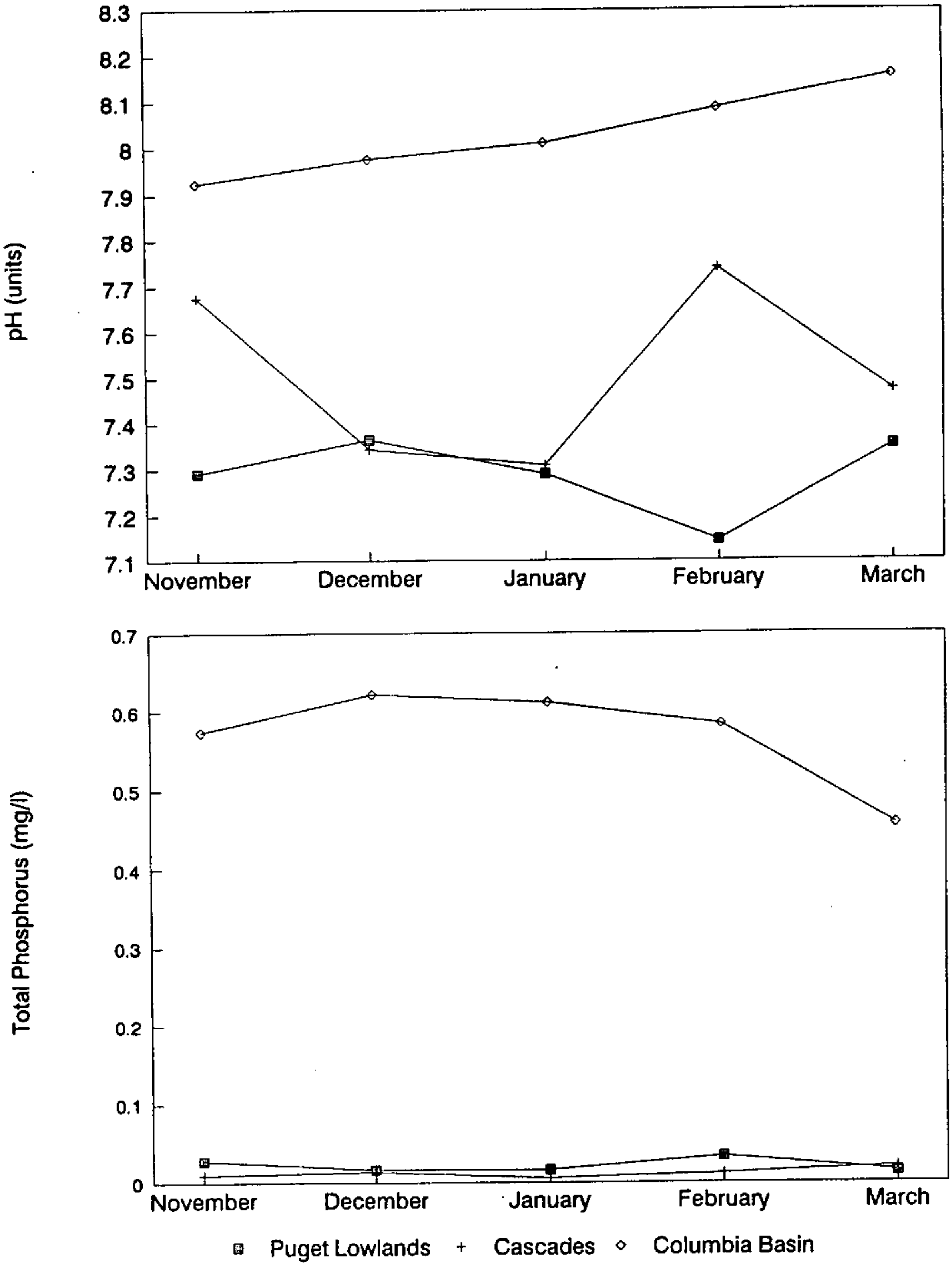


Figure 9. Mean monthly values for pH and total phosphorus in the Puget Lowland, Cascades, and Columbia Basin ecoregions (Nov. 1990-Mar. 1991).

Bioassessment is the next step in constructing a more effective monitoring program of aquatic environments in Washington and is actively used in Oregon and Idaho. The pilot project for ecoregion bioassessment addresses the missing monitoring component of surface water investigations presently conducted in this state. This additional step in our effort to preserve and enhance our freshwater resources will be reflected in better management decisions and fewer problems requiring long-term reclamation of impacted aquatic systems.

The last habitat, surface water, and benthic macroinvertebrate sampling will be conducted in August 1991. Reference information will then be available for each of these categories for one calendar year. Future bioassessment activities should include defining impacted stream conditions due to specific forest practices both on a larger spatial scale as well as within individual basins.

LITERATURE CITED

Environmental Protection Agency. Report of the National Workshop on Instream Biological Monitoring and Criteria. U.S. EPA Office of Water Regulations and Standards. Washington, D.C. 1987, 34 pp.

Minshall, G.W. Aquatic Insect-Substratum Relationships. in The Ecology of Aquatic Insects, V.H. Resh and D.M. Rosenberg (eds.). Praeger Publishers, New York. 1984, 625 pp.

Newbold, J.D., J.W. Elwood, R.V. O'Neill, and W. Van Winkle. Measuring nutrient spiralling in streams. Canadian Journal of Fisheries and Aquatic Sciences 38:860-863. 1981.

Odum, E.P., J.T. Finn, and E.H. Franz. Perturbation theory and the subsidy-stress gradient. Bioscience 29(6): 349-352. 1979.

Ohio EPA. Biological Criteria for the Protection of Aquatic Life: Volume II, Users Manual for Biological Field Assessment of Ohio Surface Waters. State of Ohio EPA, Columbus, Ohio, 1988.

Omernik, J.M. and A.L. Gallant. Ecoregions of the Pacific Northwest. U.S. EPA Doc. EPA/600/3-86/033. 1986. 39 pp.

Plafkin, J.L., M.T. Barbour, K.D. Porter, S.K. Gross, and R.M. Hughes. Rapid Bioassessment Protocols for use in streams and rivers: benthic macroinvertebrates and fish. U.S. EPA Doc. EPA/444/4-89-001. 1989.

Plotnikoff, R.W. 1990. Unimpacted streams as referents in Ecoregion Bioassessment. in Pesticides in Natural Systems: How Can Their Effects Be Monitored? Proceedings of the Conference, December 11th and 12th, 1990. Corvallis, OR, EPA 910/9-91-011. 1990, 107 pp.

Quinn, J.M. and C.W. Hickey. Characterization and classification of benthic invertebrate communities in 88 New Zealand rivers in relation to environmental factors. New Zealand Journal of Marine and Freshwater Research 24: 387-409. 1990.

Vannote, R.L., G.W. Minshall, K.W. Cummins, J.R. Sedell, and C.E. Cushing. The river continuum concept. Canadian Journal of Fisheries and Aquatic Sciences 37: 130-137. 1980.

Addendum

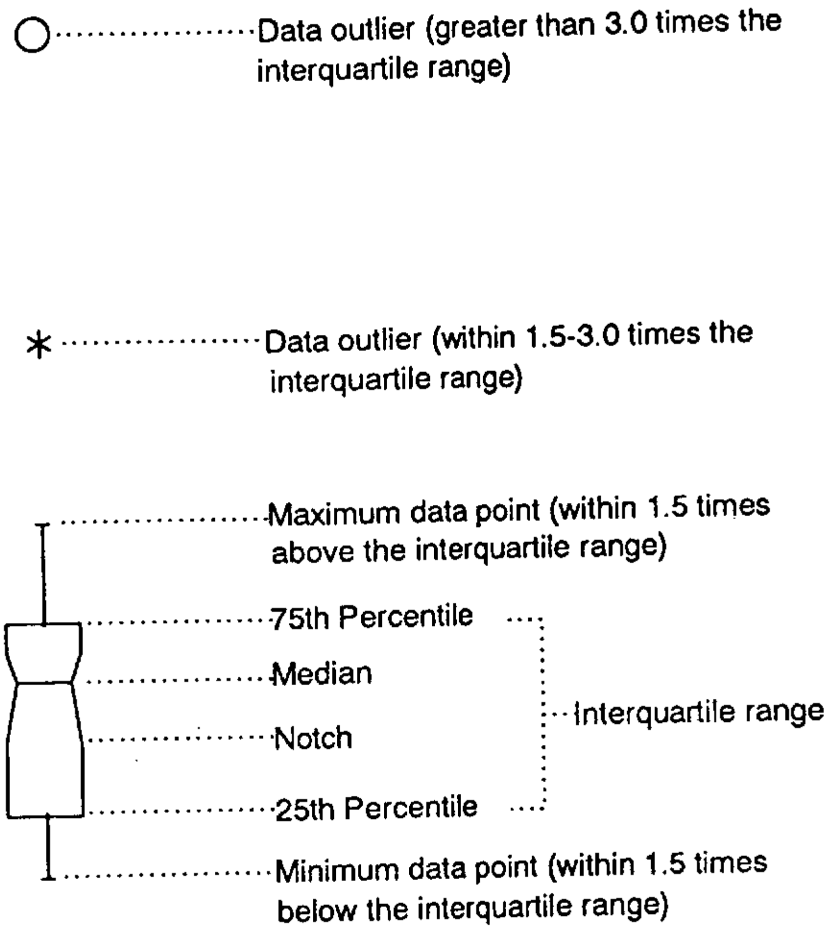
T/F/W Ecoregion Bioassessment Pilot Project

Interim Report
June 1991

1. Box plot description.

2. November 1990 macroinvertebrate abundances including Puget Lowlands (see Figure 2 of the Interim Report).

Box Plot Example



(notches in the box indicate 95% confidence intervals about the median)

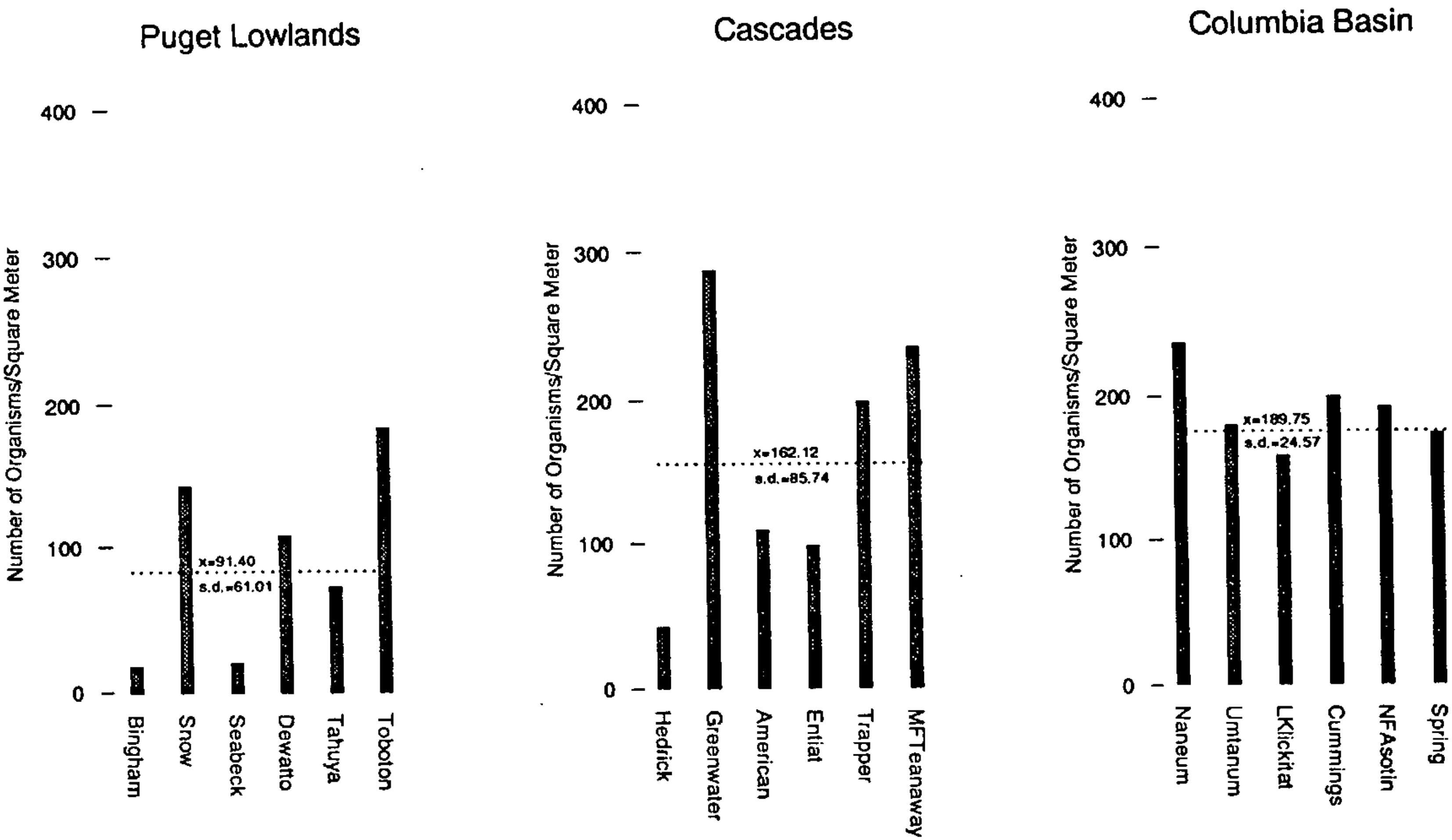


Figure 2. Mean number of benthic macroinvertebrates per square meter of riffle/run in reference streams of the Puget Lowlands, Cascades, and Columbia Basin ecoregions (Nov. 1990).