Water Quality, Benthic Macroinvertebrate, and Fish Community Monitoring in the Lost River Sub-basin, Oregon and California, 1999.

Annual Report 1999

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Table of Contents

Executive Summary

The Lost River, characterized as an interior or closed drainage basin, is primarily controlled by releases from Clear Lake Reservoir and is a highly altered system. The Lost River flows through areas of intensive agriculture production and irrigable land associated with the U.S. Bureau of Reclamation's Klamath Project. Stream corridor and in-stream habitat conditions have been impacted by dam construction, channel modifications, water diversions, wetland drainage, agriculture activities, and cattle grazing. The presence of two endangered fish species, the Lost River sucker, *Deltistes luxatus*, and shortnose sucker, *Chasmistes brevirostris*, has focused attention on research, monitoring, and restoration efforts in the Lost River sub-basin.

Currently, the Lost River does not meet Oregon water quality standards for bacteria, chlorophyll-a, dissolved oxygen, and water temperature. In 2001 the Oregon Department of Environmental Quality (ODEQ) will initiate a Total Maximum Daily Load (TMDL) process to ensure that designated beneficial uses in the Lost River sub-basin are met. The TMDL process is initiated by the ODEQ in water quality impaired streams that have been placed on the State's 303 (d) list.

In 1999, the U.S. Geological Survey, Biological Resources Division (BRD) and the U.S. Bureau of Reclamation monitored water quality and sampled macroinvertebrate and fish populations in the Lost River. Data were collected to provide background information on this system. In the event that large-scale restoration efforts are initiated in the Lost River, these data may help to evaluate the effectiveness of these efforts and help direct management activities towards meeting water quality goals in the Lost River sub-basin.

This report is organized into three sections. The first section summarizes the results of water quality monitoring that was conducted from May – October, 1999. Additional water quality sampling is currently ongoing (into 2000) and will be reported separately. Macroinvertebrate sampling was conducted from August – October, 1999 and was intended to measure community composition, structure, and function in association with large-scale geomorphologic factors as well as site-specific environmental conditions. Sampling of the fish community was conducted from June – October, 1999 and was intended to describe community structure as well as determine the distribution of suckers within the system.

Suggested Citation Format

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Chapter 1

Water Quality Monitoring in the Lost River Sub-Basin Below Malone Dam, Oregon May 1999-October 1999

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Introduction

The Lost River, controlled by releases from Clear Lake and Gerber Reservoir, flows through areas of intensive agricultural production and irrigable land associated with the Bureau of Reclamation's Klamath Project. Over the past century, the Lost River has been modified by dam construction, channelization, water diversions, wetland drainage, agricultural activities, grazing, and urban development. These activities have direct and indirect effects upon water quantity and quality. Two endangered species, Lost River sucker (*Deltistes luxatus*) and shortnose sucker (*Chasmistes brevirostris*), and three species of special concern, Klamath largescale sucker (*Catostomus snyderi*), redband trout (*Oncorhynchus mykiss*), and blue chub (*Gila bicolor*) exist in the Lost River Watershed.

Currently, the Lost River does not meet Oregon State water quality standards for bacteria, chlorophyll-a, dissolved oxygen, and water temperature. In 2001 the Oregon Department of Environmental Quality (ODEQ) will initiate a Total Maximum Daily Load (TMDL) process to ensure that designated beneficial uses in the Lost River sub-basin are met. The TMDL process is initiated by the ODEQ in water quality impaired streams that have been placed on the State's 303(d) list. As of 1998, beneficial uses designated for the Lost River between river mile 5 and river mile 65 and the Lost River diversion channel include public domestic water supply, private domestic water supply, industrial water supply, irrigation, livestock watering, resident fish and aquatic life, wildlife and hunting, fishing, boating, water contact recreation, and aesthetic quality.

Objectives

In May, 1999 the Bureau of Reclamation, Klamath Basin Area Office, began conducting water quality sampling once every two weeks at 13 sites along the course of the Lost River. The purpose of this sampling is to provide baseline information on selected water quality parameters on both a seasonal and spatial scale. Water quality sampling is proposed to continue through May, 2001 and will compliment biological monitoring conducted in 1999 (See Kohler et al. this report).

Study Area

The Lost River is part of the upper Klamath River watershed of northern California and southern Oregon located in Modoc and Siskiyou counties, California, and Klamath County, Oregon (Figure 1.). The Lost River sub-basin is characterized as an interior or closed drainage basin with a watershed area covering approximately 7,754 km^2. Surrounding habitat consists of sagebrush/juniper, agricultural, and urban areas. Originating in the mountains east of Clear Lake Reservoir in Modoc County, California, the Lost River flows to Tule Lake Sump a distance of approximately 120 km. Headwater tributaries are Willow and Boles Creek, with Willow Creek contributing the majority of inflow into Clear Lake Reservoir. Significant tributaries on the mainstem Lost River include the East Branch of the Lost River, Miller Creek, and Buck Creek. Other inflows to the Lost River include springs, drains and water diverted from the Klamath River. Water quality stations below Wilson Reservoir receive water from Upper Klamath Lake and the Klamath River during the May-October period. Samples collected during the present study are taken from Malone Dam downstream to immediately upstream of Tule Lake. Location and surrounding land use of sample sites are described in Table 1. All sample locations except Miller Creek are located on the mainstem Lost River or on tributaries of the Lost River. Miller Creek at North Canal is located several miles from the Lost River and contains water that is primarily used for irrigation purposes. The North Canal does not directly enter the Lost River so water quality parameters collected at this site are not considered to be direct contributors to water quality in the Lost River.

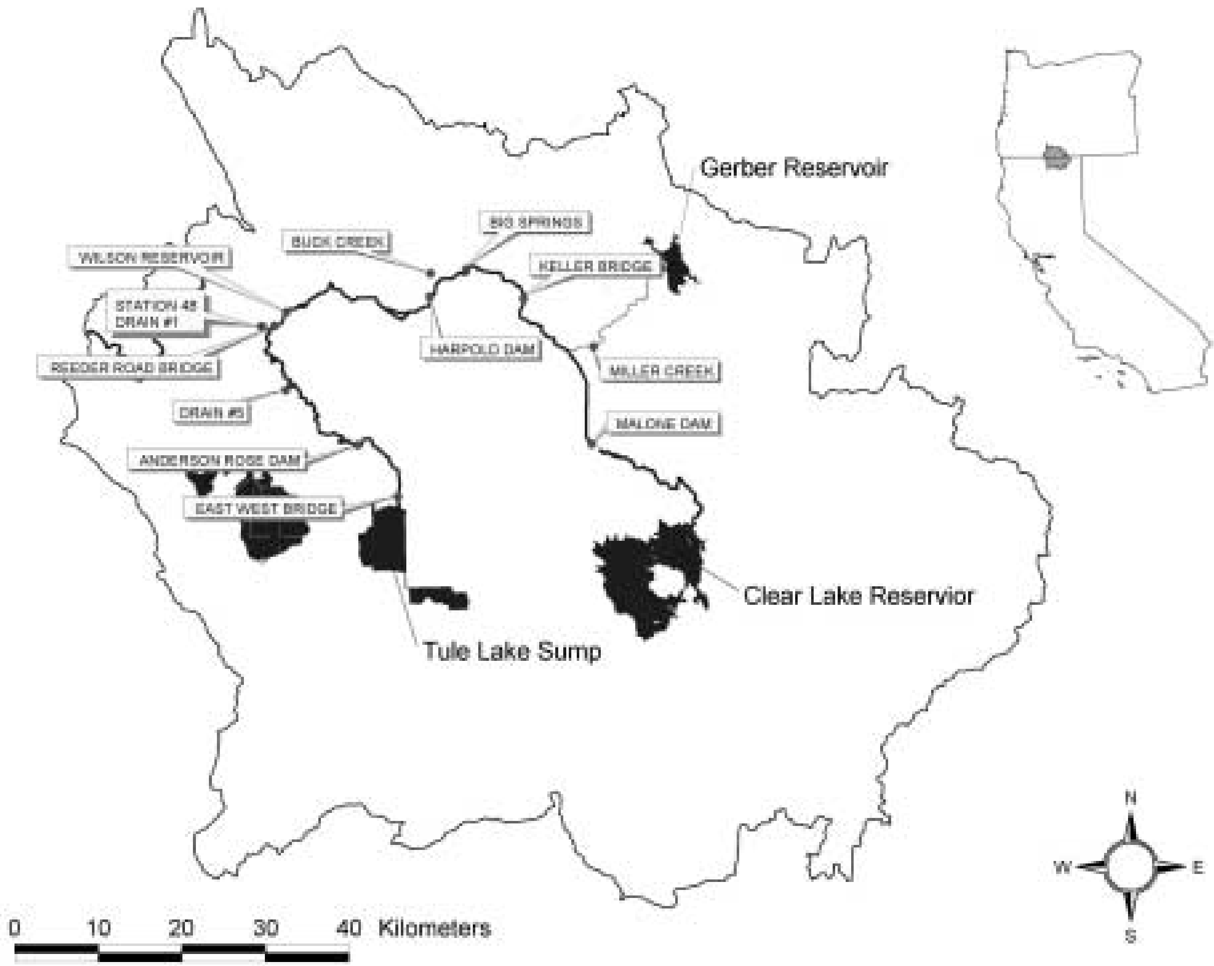

Figure 1. Map of Lost River sub-basin with water quality monitoring sites, 1999.

Table 1. Lost River sub-basin sampling site name, location, and description.

Site Name	River Mile	Mainstem/Tributary	Site Descriptions
Malone Dam	~64	Mainstem	Considered as a baseline water quality entering the Lost River system. Upstream uses include reservoir storage, open range, and timber harvest. Surrounding upland habitat includes juniper/sagebrush with the river channel confined to a high gradient, rocky canyon.
Miller Creek	~56	Tributary	Sample site is located in a canal that diverts 100% of flow released from the bottom of Gerber Reservoir into Miller Creek. Water is used for irrigation purposes with a small amount spilling into the Lost River.
Keller Bridge	~49	Mainstem	Located at the northern end of Langell Valley, this site is surrounded by intensive agriculture lands and dairy farms.
Big Springs	~44	Tributary	A large fresh water spring within the town limits of Bonanza.
Buck Creek	~41	Tributary	A channelized creek used as water conveyance for irrigation purposes. Surrounded by intensive agriculture mostly in hay and alfalfa production, including pasture for cattle and sheep.
Harpold Dam	~40	Mainstem	Located at the upstream end of Poe Valley. Largely surrounded by agricultural lands.
Wilson Reservoir	~19	Mainstem	An impoundment located downstream of Poe Valley. Influenced to some degree by water diverted from Upper Klamath Lake. Water from the reservoir is diverted into the Lost River diversion channel.
Wilson Bridge (Reeder Rd)	~17	Mainstem	Located downstream of Wilson reservoir dam. At most times of the year this site has negligible flows.
Station 48	~16	Tributary	Used to convey water from the Lost River diversion channel into the Lost River. Water in the diversion channel originates from the Lost River and/or the Klamath River. Flow is normally present only during irrigation season.
# 1 Drain	~16	Tributary	A drain that covers southwest Klamath Falls. Influenced by agricultural, industrial, and domestic land uses including sewage treatment plant effluent.
# 5 Drain	~9	Tributary	A drain that predominately covers agricultural lands west of the Lost River.
Anderson-Rose Reservoir	~8	Mainstem	Located at the northern end of historical Tule Lake area surrounded by intensive agriculture lands.
East-West Bridge	~1	Mainstem	Located immediately upstream of the mouth of Tule Lake sump 1A.

Water Quality Parameters

A variety of water quality parameters were routinely measured as part of the sampling protocol. Dissolved oxygen, conductivity, temperature, and pH were collected *in situ* using a Hydrolab H_20 unit. Turbidity was measured using a Hach 2100P turbidimeter. Caltest Analytical Laboratory analyzed the water samples for nutrients, alkalinity, and chlorophyll-a according to EPA method guidelines and laboratory standard operating procedures (Caltest QAM-006, April, 1998). Specific collection, preservation, calibration, analytic, and quality assurance/quality control procedures can be found in the Appendix (Quality Assurance Project Plan for Water Quality Monitoring on the Lost River between Malone Reservoir, Oregon and Tule Lake, California (BOR 1999)).

Table 2. Selected water quality parameters collected in the Lost River sub-basin, May-October 1999.

Parameters Evaluated	Physical/Inorganic/Biological	Reported In
Temperature	Physical	Degrees Celcius- °C
Dissolved Oxygen	Physical	Milligrams per liter- mg/L
pH	Physical	Standard Units
Conductivity	Physical	Microsiemens per centimeter- *u*S/cm
Turbidity	Physical	Nephlometric Turbidity Unit- NTU
Discharge (Flow)	Physical	Cubic Feet Per Second- CFS
Total Kjeldahl Nitrogen	Inorganic	Milligrams per liter- mg/L
Ammonia-N	Inorganic	Milligrams per liter- mg/L
Nitrate-Nitrite-N	Inorganic	Milligrams per liter- mg/L
Total Phosphorus	Inorganic	Milligrams per liter- mg/L
Orthophosphate	Inorganic	Milligrams per liter- mg/L
Total Alkalinity ($CaCo_3$)	Inorganic	Milligrams per liter- mg/L
Chlorophyll-a	Biological	Micrograms per Liter- *u*g/L

Results and Discussion

Biweekly Monitoring

Samples were collected twice-monthly beginning in May, 1999. The following discussion focuses on major trends observed for each parameter over the May-October, 1999 sampling period.

Physical Measurements

Temperature

As stated by the Oregon Department of Environmental Quality in Oregon's final 1998 water quality limited streams (those appearing on the 303(d) list), the summer temperature criteria for the Lost River was established to maintain the protection of resident warm-water fish and aquatic life. This beneficial use states that "there shall be no measurable increase in temperature in Oregon waters when dissolved oxygen (DO) levels are within .5 mg/L or 10 percent of the water column or intergravel DO criterion for a given stream reach or sub-basin" (ODEQ 1998). In the Lost River and tributaries, instantaneous temperature measurements collected with bi-weekly grab samples display a range of 6.13 degrees Celsius at Buck Creek to 23.25 degrees Celsius at Anderson-Rose Dam. It should be noted that instantaneous temperature measurements do not capture the variability in water temperatures due to ambient temperature extremes and are of limited use in assessing water quality criteria. Continuously recording temperature data loggers are now in place throughout the Lost River sub-basin and will provide a more detailed picture of temperature profiles on a seasonal as well as daily basis.

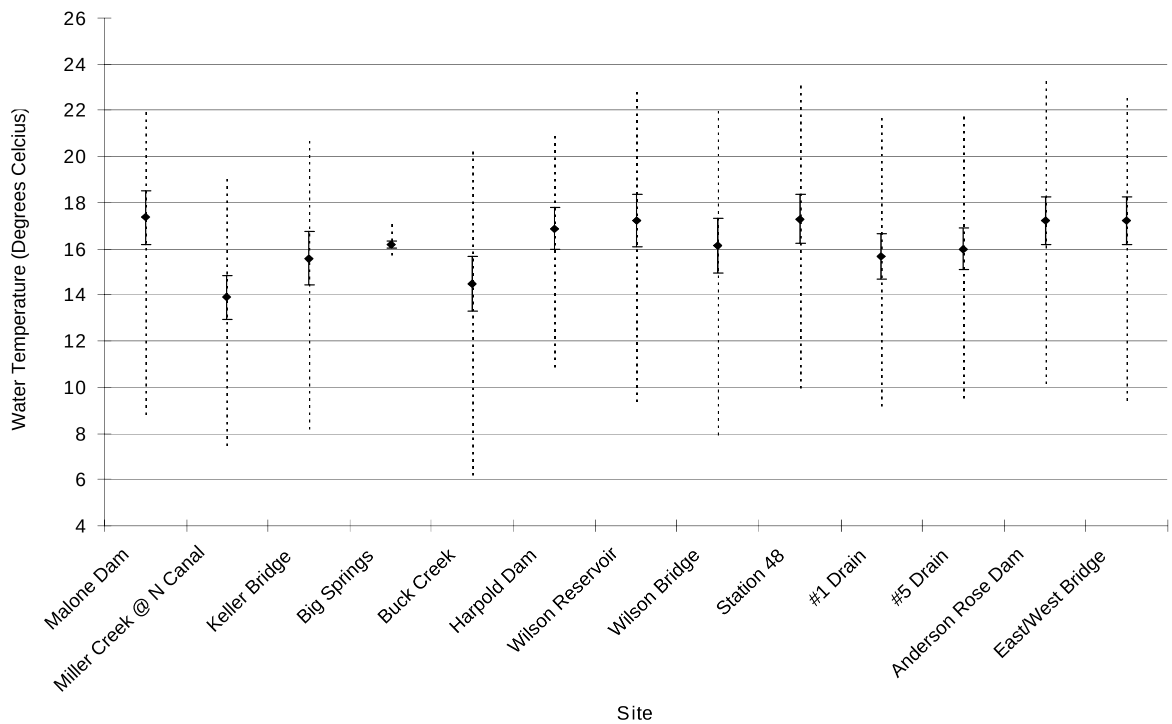

Figure 2. Summary of mean (*N* =13) water temperature values, by site, from bi-weekly water quality sampling in the Lost River sub-basin, May-October 1999. Mean values are presented as diamonds, (±) standard error of the mean by error bars, with dotted lines representing the range of water temperature measures.

Dissolved Oxygen

Instantaneous dissolved oxygen measurements ranged from 0.73 mg/L at Wilson Bridge to 10.67 mg/L at Big Springs and Buck Creek. Dissolved oxygen values varied widely at individual sites, presumably due to temperature variations, photosynthetic activities, plant respiration, and biological decomposition of organic material by aerobic bacteria and other microorganisms. Dissolved oxygen values below the Oregon State standard of 5.5 mg/L were measured at all sites except Miller Creek (North Canal). Generally, these were sites where dissolved oxygen was measured in the morning when plant respiration has presumably lowered dissolved oxygen content in the water column. Dissolved oxygen measurements were collected at 1.0 m depth, or at the bottom if the depth was less than 1.0 m. Lower dissolved oxygen concentrations than those recorded from May-October, 1999 have been measured in previous years, particularly at reservoir sites. For example, nearly anoxic conditions (<0.50 mg/L) were recorded 12 times near the bottom of Wilson Reservoir from 1993-1998.

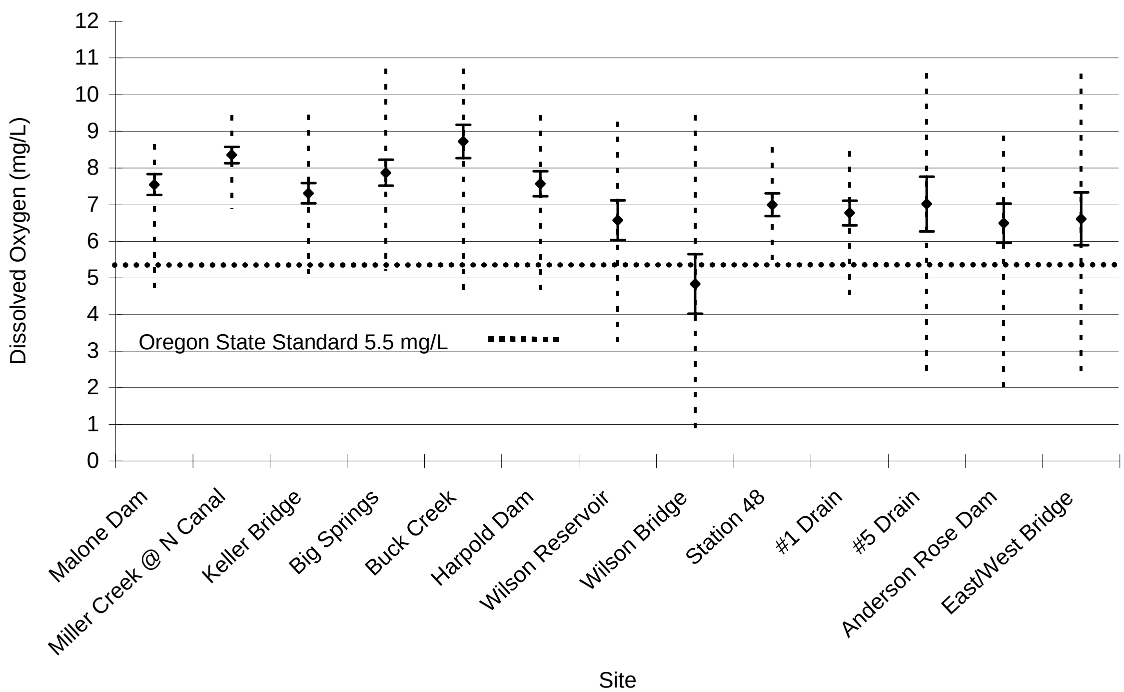

Figure 3. Summary of mean (*N* =13) dissolved oxygen values, by site, from bi-weekly water quality sampling in the Lost River sub-basin, May-October 1999. Mean values are presented as diamonds, (±) standard error of the mean by error bars, with dotted lines representing the range of dissolved oxygen measures.

pH

Measurements of pH ranged from 6.85 at Wilson Bridge to 9.18 at Station 48 and varied considerably at individual sites, presumably due to high primary productivity rates. Measurements collected towards the end of the day reflect photosynthetically elevated pH values while lower pH values are associated with measurements collected earlier in the day. Sample collection times at individual sites varied over the course of the May-October sampling period so that sites were not sampled at the same time of day throughout the season. Presently, no pH standards are set for the Lost River sub-basin.

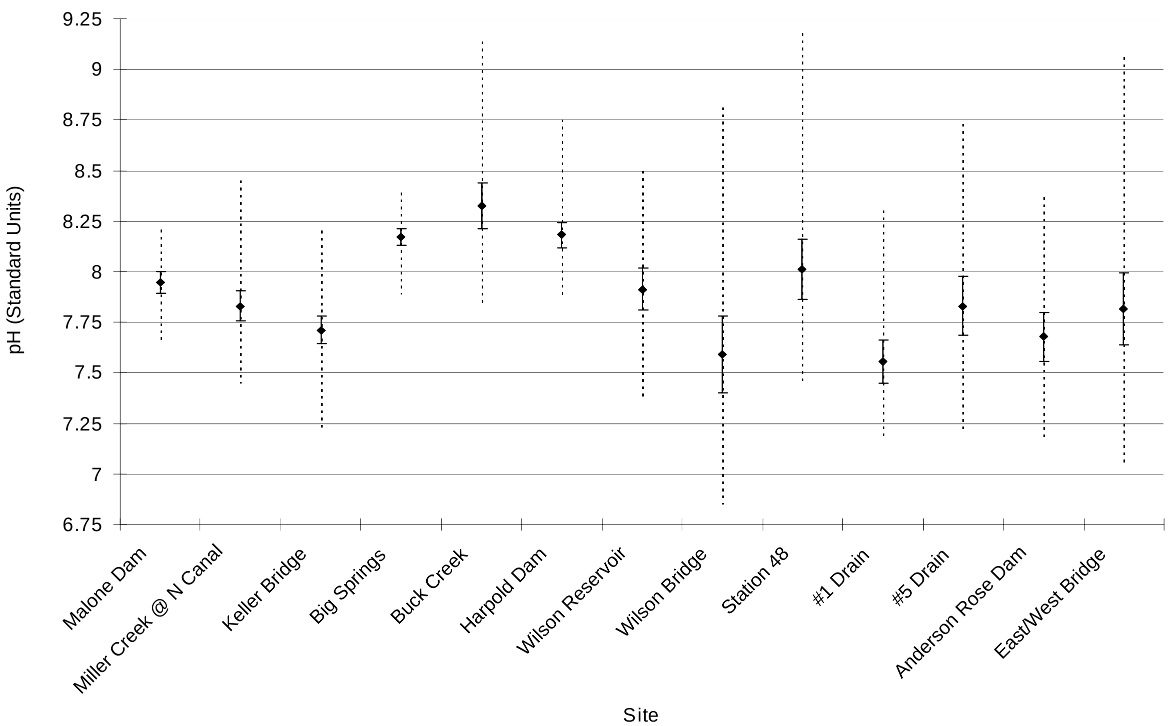

Figure 4. Summary of mean (*N* =13) pH values, by site, from bi-weekly water quality sampling in the Lost River sub-basin, May-October 1999. Mean values are presented as diamonds, (±) standard error of the mean by error bars, with dotted lines representing the range of pH measures.

Conductivity

Conductivity units, measured in *u*S/cm, ranged from 61 at Miller Creek (North Canal) to 831 at Buck Creek. Fresh surface waters in Oregon generally range from 20 to 500 *u*S/cm (ODEQ 1996). High measurements recorded in Buck Creek are presumably due to parent geology or increased dissolved ions entering the stream from agricultural activities.

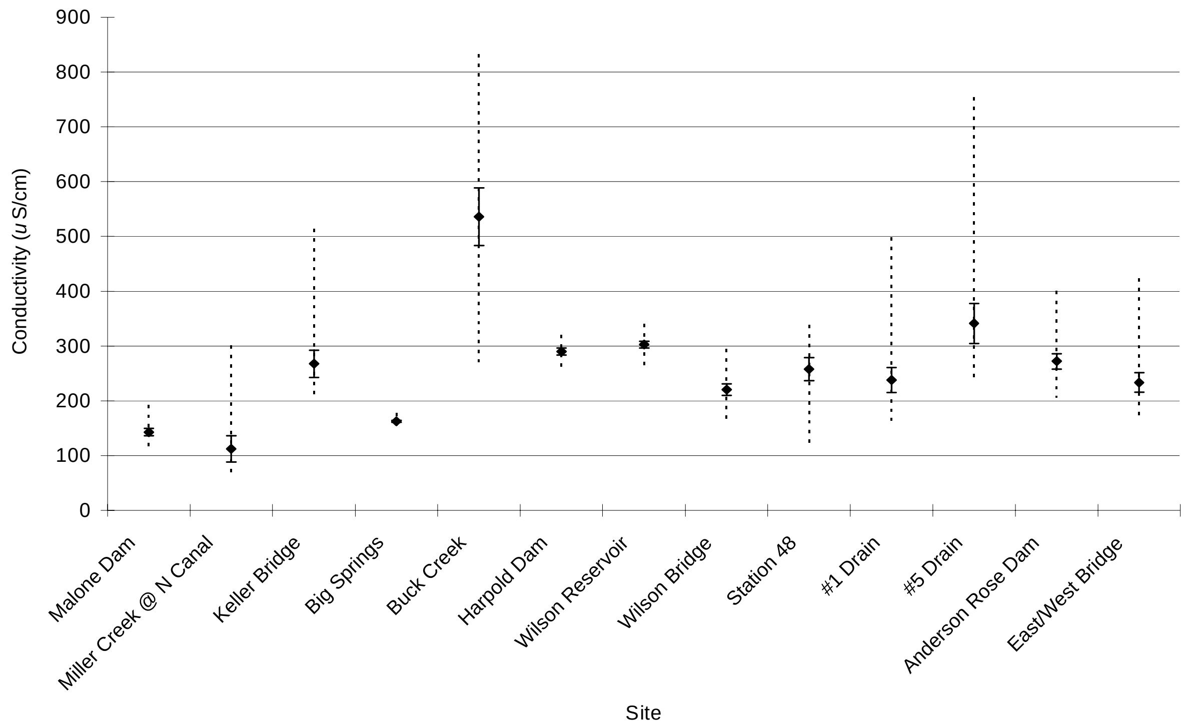

Figure 5. Summary of mean (N =13) conductivity values, by site, from bi-weekly water quality sampling in the Lost River sub-basin, May-October 1999. Mean values are presented as diamonds, (±) standard error of the mean by error bars, with dotted lines representing the range of conductivity measures.

Turbidity

Turbidity measurements ranged from 0.2 NTU at Big Springs to 108.0 NTU at Malone Dam. Below Malone Dam, a site with consistently high turbidity measurements, no apparent trend in turbidity is noted (Figure 6). Malone Dam is located approximately 16 kilometers downstream of Clear Lake Reservoir, a large, shallow body of water with fine clay particles frequently suspended in the water column by wind events. Elevated turbidity measurements at Malone Dam are presumably influenced by Clear lake Reservoir.

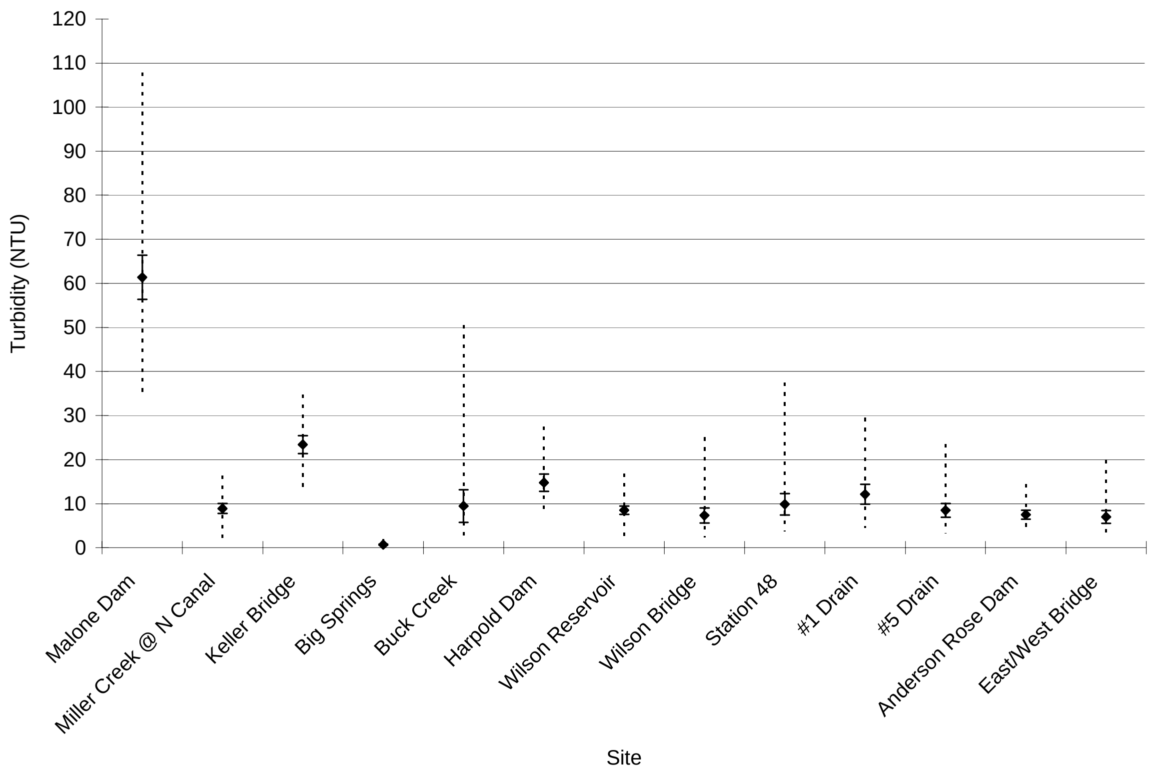

Figure 6. Summary of mean (*N* =13) turbidity values, by site, from bi-weekly water quality sampling in the Lost River sub-basin, May-October 1999. Mean values are presented as diamonds, (±) standard error of the mean by error bars, with dotted lines representing the range of turbidity measures.

Discharge

Discharge measurements in cubic feet per second were collected in conjunction with bi-weekly grab samples. Some flow measurements are missing due to high water situations where it was deemed unsafe to measure flow or where excessive macrophyte growth made automated flow measurements inaccurate. Occasionally, time and personnel constraints prohibited the measurement of flow data at sites where continuous discharge measurements are unavailable, contributing to missing flow data.

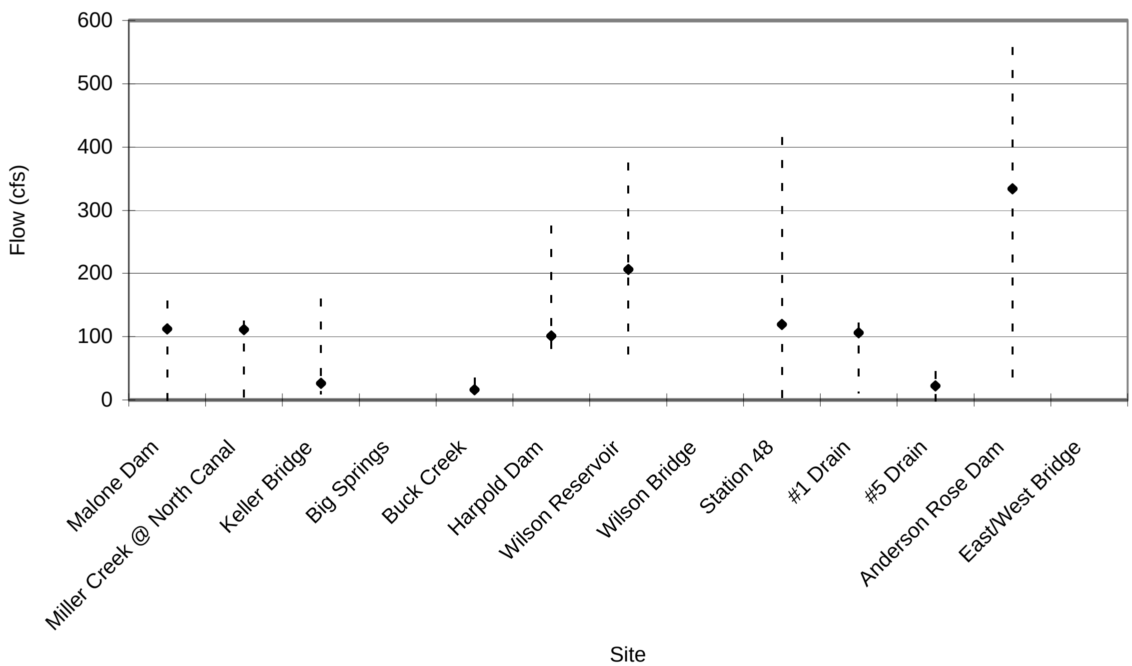

Figure 7. Summary of flow (cfs) measurements collected at Lost River sub-basin water quality monitoring sites, May-Ocober, 1999. Median values are presented as diamonds with dotted lines representing ranges. Sites without flow measurements are presented for reference.

Nutrients

Total Nitrogen

Total Kjeldahl nitrogen concentrations ranged from below detection limits (<0.3 mg/L) at Big Springs to 2.4 mg/L at #5 Drain and #1 Drain. Total nitrogen values generally increased in the mainstem Lost River moving downstream. According to Dodds, Smith, and Zander, 1997, a periphyton-dominated stream that has low water velocity is considered eutrophic if total nitrogen concentrations are > 0.3 mg/L.

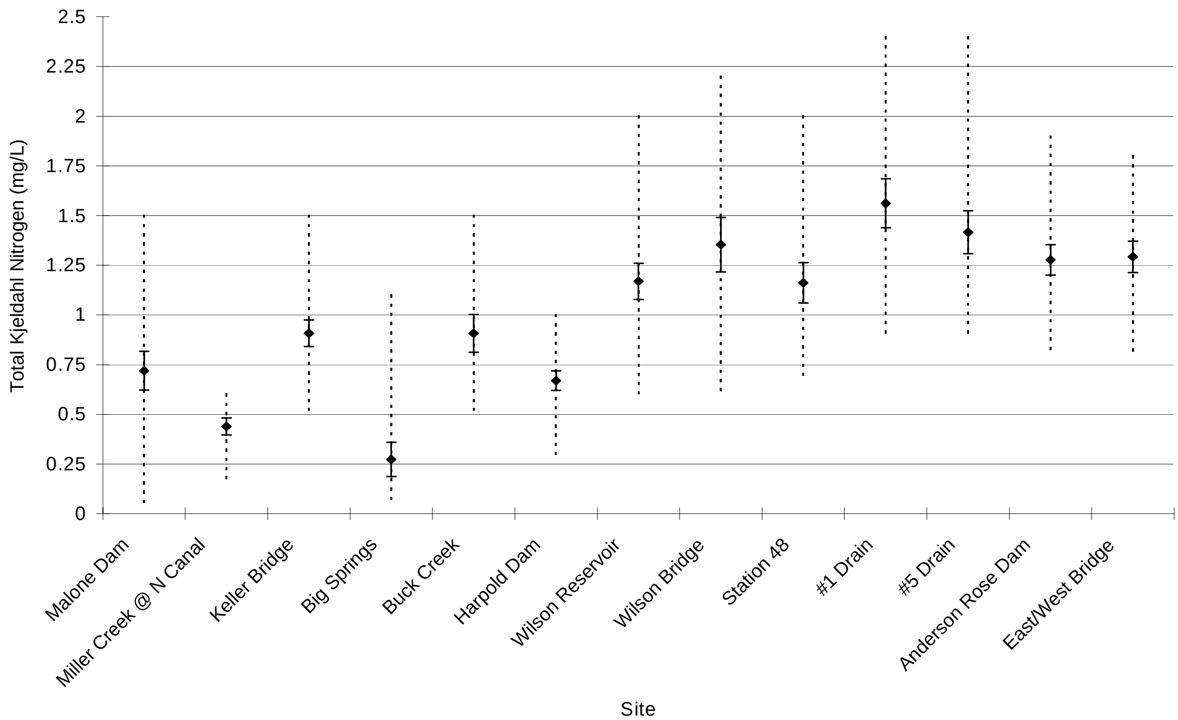

Figure 8. Summary of mean (*N* =13) TKN values, by site, from bi-weekly water quality sampling in the Lost River sub-basin, May-October 1999. Mean values are presented as diamonds, (±) standard error of the mean by error bars, with dotted lines representing the range of TKN measures. For graphical and statistical analysis, parameter concentrations that were below detection limits were assigned a value representing 50% of the lower detection limit.

Ammonia-Nitrogen

Ammonia-N concentrations ranged from below detection limits (<0.1 mg/L) at all sites except Station 48 and #1 Drain to 1.0 mg/L at #1 Drain. No apparent trend in concentration values exists from Malone Dam to Harpold Dam. However, ammonia-N concentrations below Harpold Dam were higher than upstream sites.

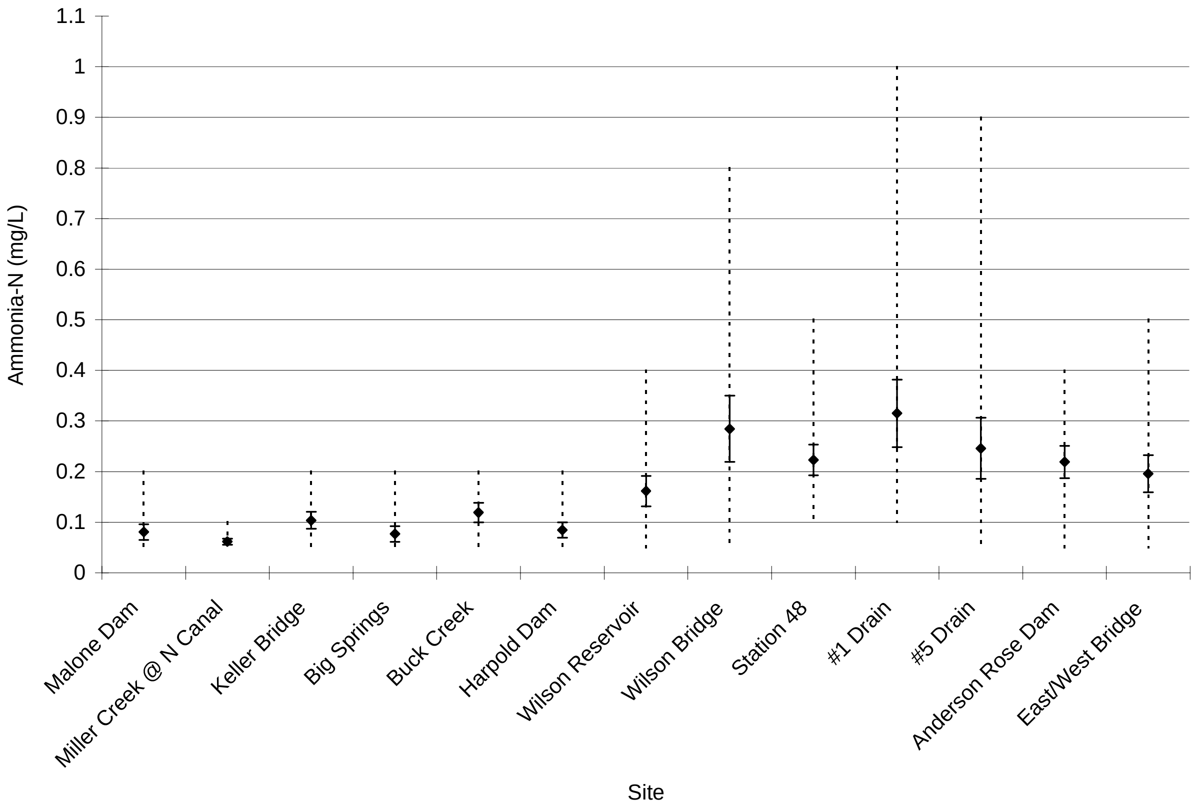

Figure 9. Summary of mean (*N* =13) ammonia-N values, by site, from bi-weekly water quality sampling in the Lost River sub-basin, May-October 1999. Mean values are presented as diamonds, (±) standard error of the mean by error bars, with dotted lines representing the range of ammonia-N measures. For graphical and statistical analysis, parameter concentrations that were below detection limits were assigned a value representing 50% of the lower detection limit.

Nitrate-Nitrite-Nitrogen

Nitrate-Nitrite-N concentrations ranged from below detection limits (<0.04 mg/L) at Malone Dam, Miller Creek, Keller Bridge, Wilson reservoir, Wilson Bridge, Station 48, and East/West Bridge to 4.5 mg/L at Buck Creek. No apparent trend in concentration values can be seen during the May-October sampling period (Figure 9).

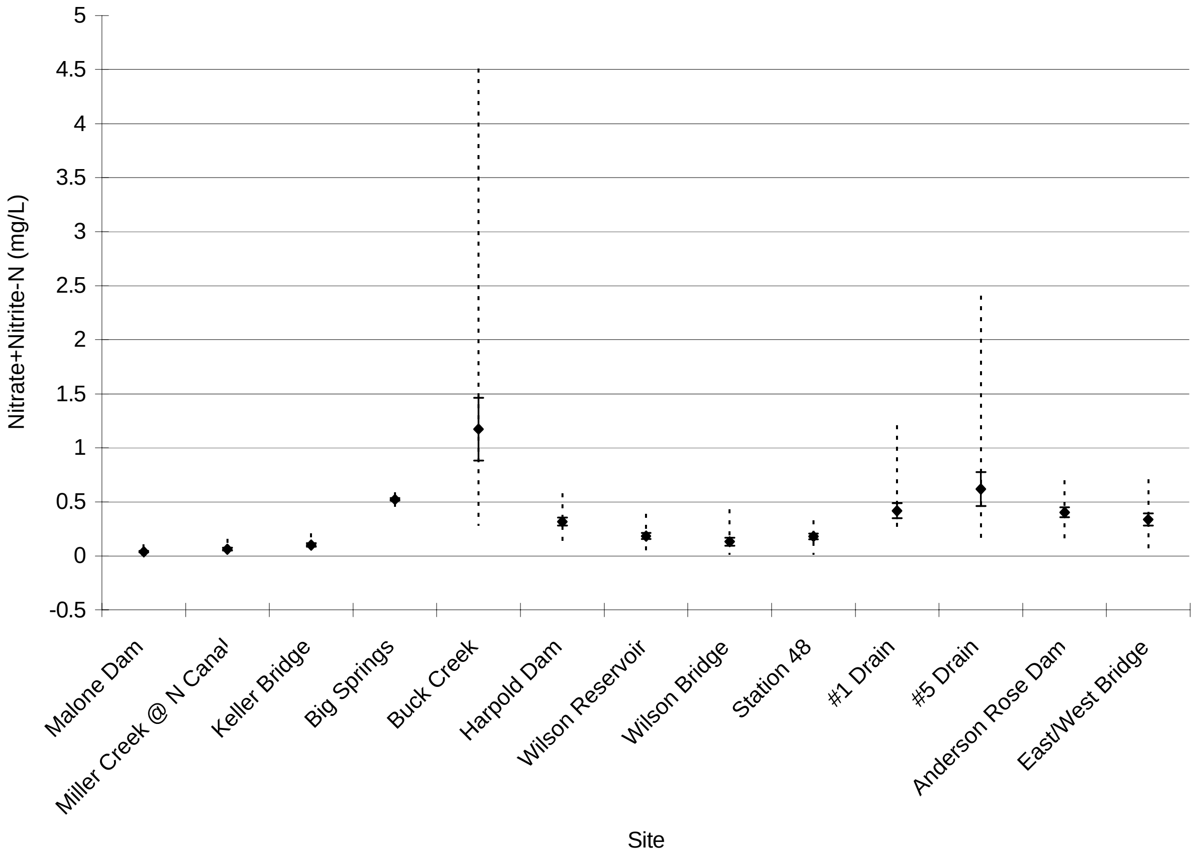

Figure 10. Summary of mean (*N* =13) nitrate-nitrite-N values, by site, from bi-weekly water quality sampling in the Lost River sub-basin, May-October 1999. Mean values are presented as diamonds, (±) standard error of the mean by error bars, with dotted lines representing the range of nitrate-nitrite-N measures. For graphical and statistical analysis, parameter concentrations that were below detection limits were assigned a value representing 50% of the lower detection limit.

Total Phosphorus

Total phosphorus values ranged from below detection limits (<0.1 mg/L) at Miller Creek, Keller Bridge, Big Springs, and Harpold Dam to 0.6 mg/L at Buck Creek, Wilson Bridge, #1 Drain, and #5 Drain. Total phosphorus values generally increased moving downstream. Total phosphorus concentrations in the Lost River sub-basin below Malone Dam are indicative of a highly eutrophic system. For reference, in freshwater lakes the following total phosphorus concentrations tend to correspond to the given trophic state: 0.005-0.010 mg/L oligotrophic, 0.010-0.030 mg/L mesotrophic, 0.030-0.100 mg/L eutrophic (Wetzel 1983). According to Wetzel, and assuming comparability to lake trophic status, most Lost River sites can be placed in the hyper-eutrophic category (>0.1 mg/L). In 1997, Dods, Smith, and Zander outlined a trophic state guideline for periphyton-dominated streams that have low water velocity. By their estimates, streams with these characteristics are considered eutrophic if total phosphorus is >0.02 mg/L.

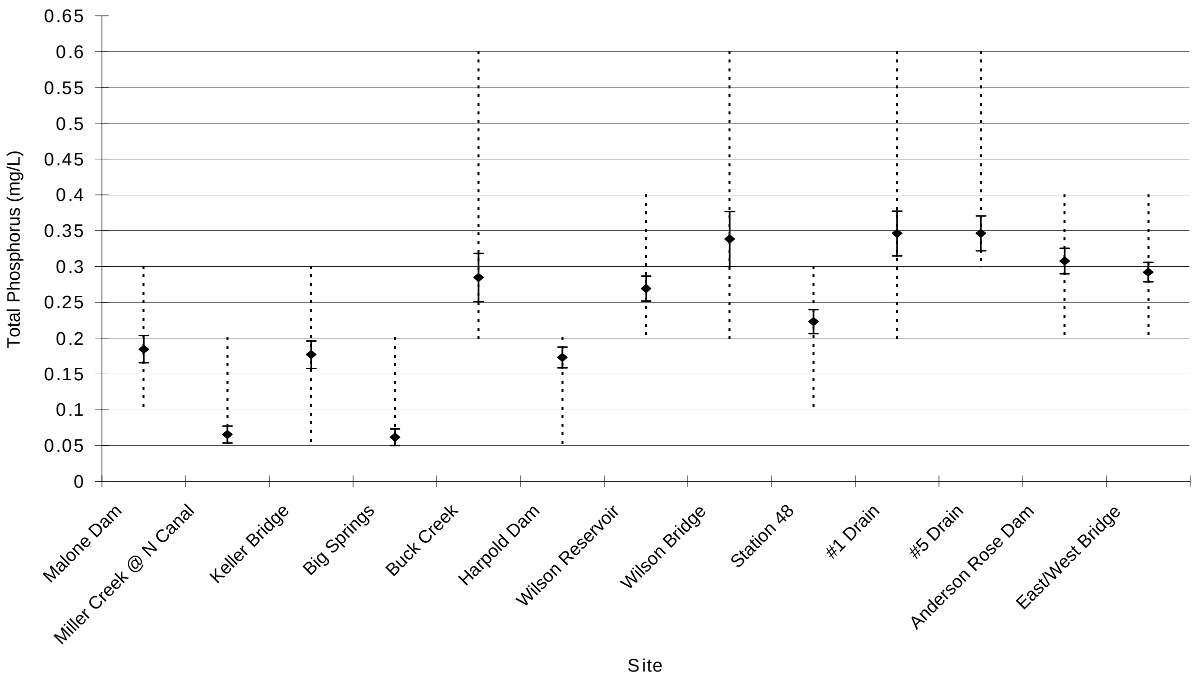

Figure 11. Summary of mean (*N* =13) total phosphorus values, by site, from bi-weekly water quality sampling in the Lost River sub-basin, May-October 1999. Mean values are presented as diamonds, (±) standard error of the mean by error bars, with dotted lines representing the range of total phosphorus measures. For graphical and statistical analysis, parameter concentrations that were below detection limits were assigned a value representing 50% of the lower detection limit.

Orthophosphate

Orthophosphate showed a similar trend to total phosphorus values with concentrations generally increasing at downstream sites. Concentration values ranged from below detection limits (<0.1 mg/L) at all sites except #1 Drain, #5 Drain, and Anderson Rose Dam to 0.6 mg/L at #5 Drain.

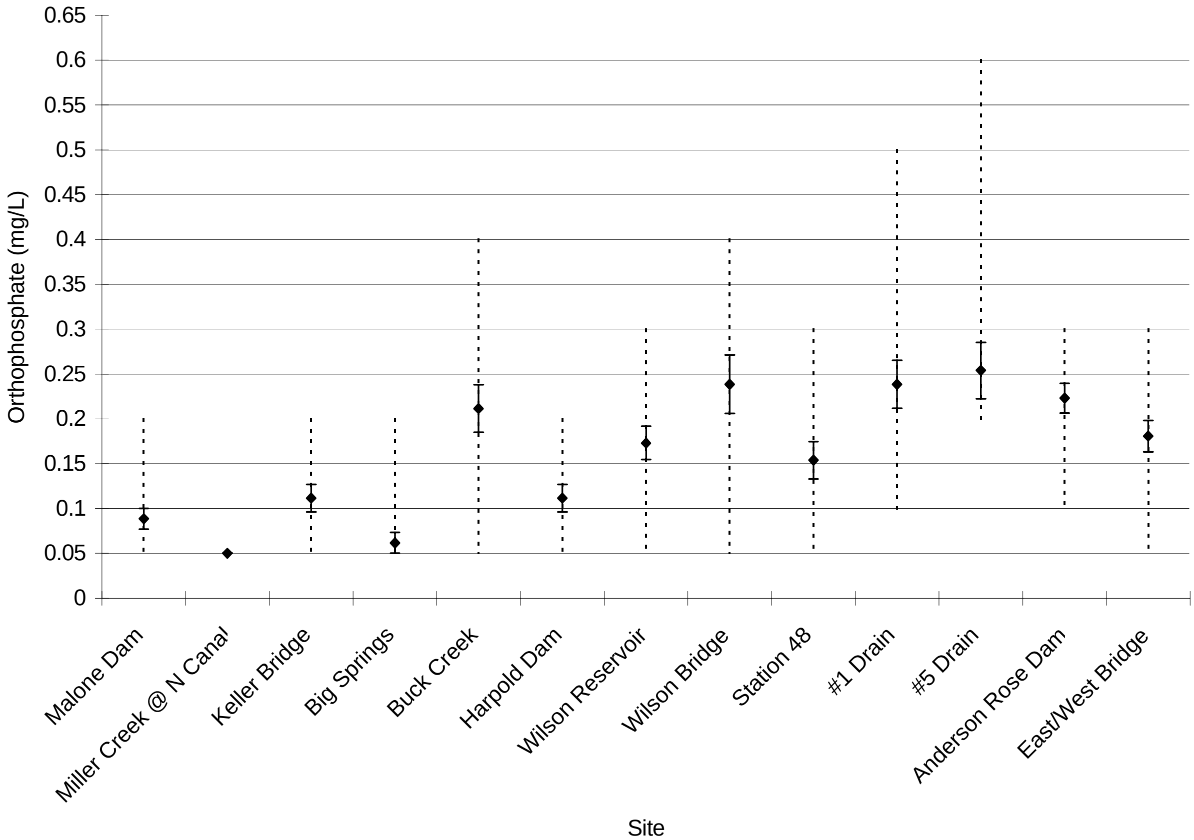

Figure 12. Summary of mean (*N* =13) orthophosphate values, by site, from bi-weekly water quality sampling in the Lost River sub-basin, May-October 1999. Mean values are presented as diamonds, (±) standard error of the mean by error bars, with dotted lines representing the range of orthophosphate measures. For graphical and statistical analysis, parameter concentrations that were below detection limits were assigned a value representing 50% of the lower detection limit.

Total Alkalinity

Total alkalinity values ranged from 40 mg/L at Miller Creek to 320 mg/L at Buck Creek. No apparent trend in concentration values can be seen for the May-October sampling period (Figure 13).

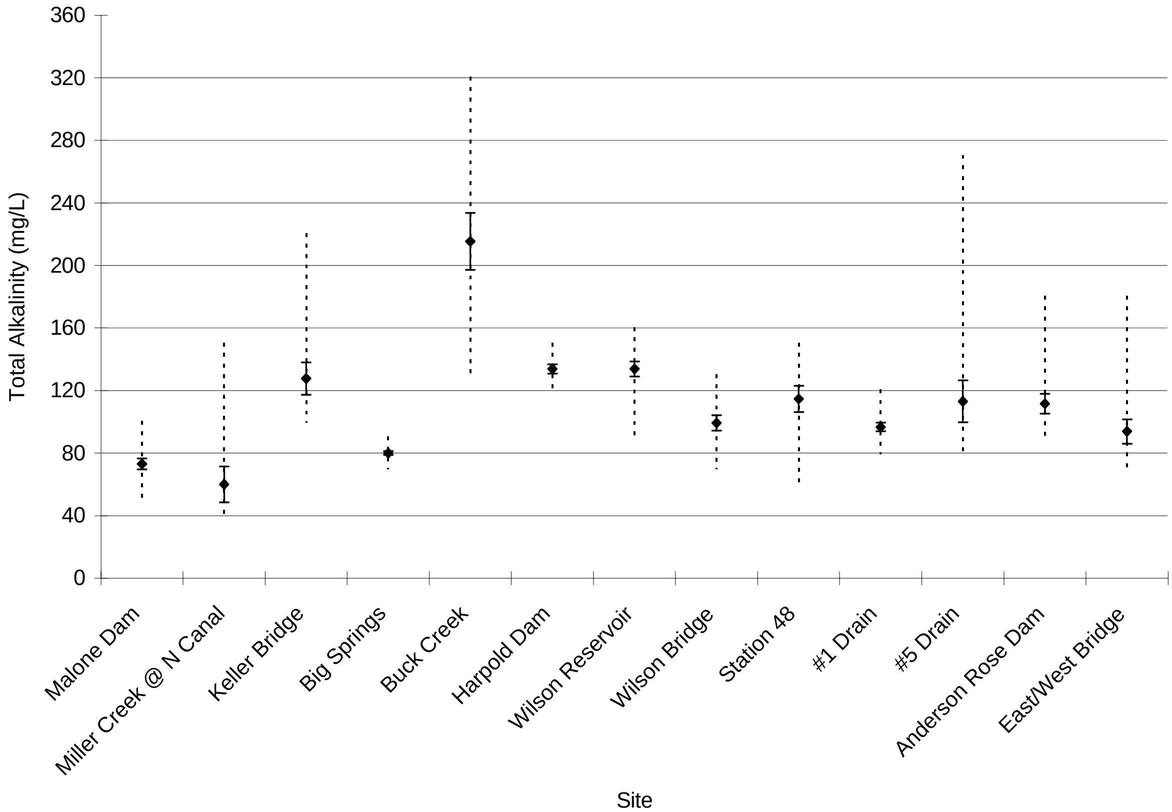

Figure 13. Summary of mean (*N* =13) total alkalinity values, by site, from bi-weekly water quality sampling in the Lost River sub-basin, May-October 1999. Mean values are presented as diamonds, (±) standard error of the mean by error bars, with dotted lines representing the range of total alkalinity measures. For graphical and statistical analysis, parameter concentrations that were below detection limits were assigned a value representing 50% of the lower detection limit.

Chlorophyll-a

Chlorophyll-a values ranged from below detection limits (<5.0 *u*g/L) at all sites to 110 *u*g/L at #1 Drain. Concentrations remained relatively constant from Malone Dam to Harpold Dam, however, below Harpold Dam chlorophyll-a values were higher. Water diverted from Upper Klamath Lake enters the Lost River through canals and drains at Wilson Reservoir. Upper Klamath Lake is a hypereutrophic system (Goldman and Horne 1983) with large summertime blooms of *Aphanizomenon flos-aquae*. Water diverted from Upper Klamath Lake is presumably influencing chlorophyll-a values at and below Wilson Reservoir. As seen in Figure 13, chlorophyll-a values (ranges) exceeded the Oregon State water quality criteria of 15 *u*g/L at all sites except Big Springs and Miller Creek at North Canal.

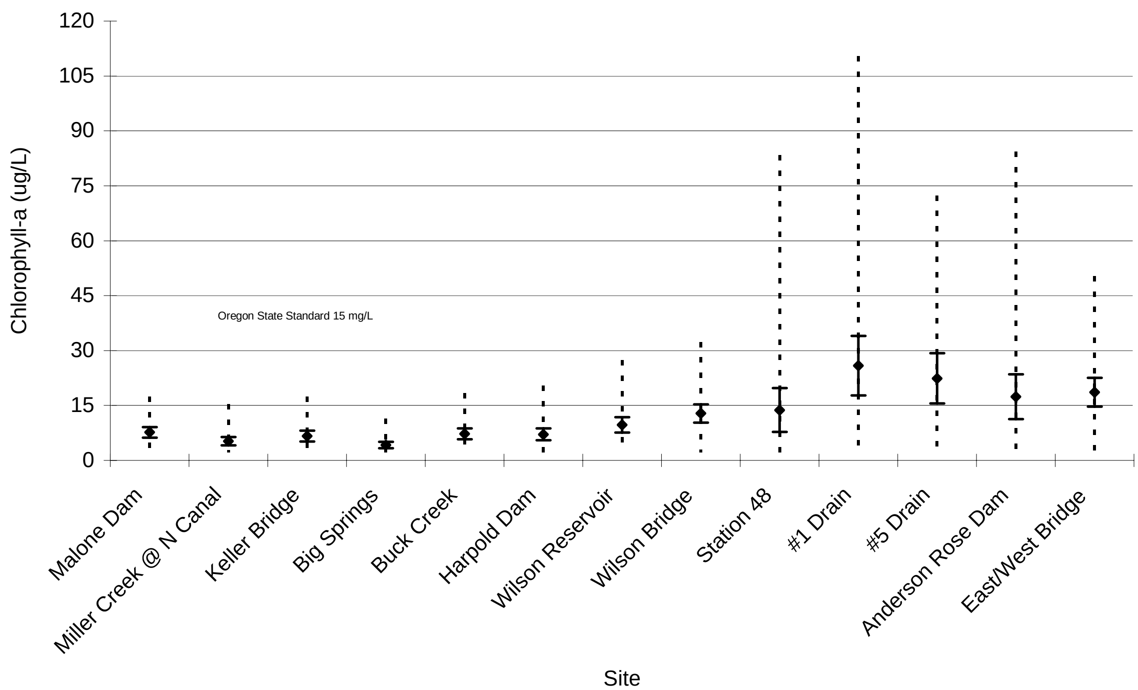

Figure 14. Summary of mean (*N* =13) chlorophyll-a values, by site, from bi-weekly water quality sampling in the Lost River sub-basin, May-October 1999. Mean values are presented as diamonds, (±) standard error of the mean by error bars, with dotted lines representing the range of chlorophyll-a measures. For graphical and statistical analysis, parameter concentrations that were below detection limits were assigned a value representing 50% of the lower detection limit.

Loading Estimate Rankings

Total Kjeldahl nitrogen and total phosphorus loading estimates were calculated for Lost River sub-basin sites using the Mid-Interval Technique for non-continuous data (EPA 1990). To calculate loading estimates, manually collected and automated flow data is combined with concentration data "to calculate an instantaneous loading which is then assumed to characterize the tributary transport over a certain time interval associated with that sample" (EPA 1990). The time interval used for each site is equivalent to one-half the time interval between a specific sample date and the previous sampling date, plus one-half the time interval between the specific sample date and the following sample date. Instantaneous loading values for each site were multiplied by the time interval associated with that site, giving a total load for the time period associated with that sample. The total loads were summed and ranked for each site over the May-October sampling period.

It should be noted that loading estimates generated from intermittent sampling must be used cautiously, as storm events may or may not be represented. Because nonpoint source loading is very dependent on storm events, loading calculations using non-continuous data may overestimate or underestimate true nutrient loading (EPA 1990).

Further, a lack of complete flow data associated with each sample site and date contributes to uncertainty in loading estimates. At three sites; Big Springs, Wilson Bridge, and East/West Bridge, no flow data was available. Tables 2 and 3 are intended to represent relative rankings of sites based on the Mid-Interval Technique for non-continuous data, not actual loading estimates. However, ranking sites based on the above loading estimate method provides valuable assessment and baseline monitoring information that can be used for trend analysis and to identify problem areas.

Table 2. Ranking of Lost River sub-basin sites based on total phosphorus loading estimates, May-October, 1999. Values represent a ranking of sites from highest nutrient loading estimates (Anderson Rose Dam) to lowest (Miller Creek). N/A indicates missing flow data.

Site	5/12	5/27	6/9	6/23	7/8	7/22	8/4	8/18	8/31	9/15	9/29	10/13	10/28	Average	Ranking
Anderson Rose Reservoir	1	1	1	1	1	1	1	1	1	2	1	2	2	1.23	Highest
Wilson Reservoir	2	3	2	3	3	3	3	3	2	1	2	1	1	2.23	
Station 48	4	2	3	2	2	2	2	2	3	4	9	6	4	3.46	
Harpold Dam	N/A	N/A	N/A	N/A	N/A	N/A	6	N/A	4	3	3	3	3	3.67	
#1 Drain	3	4	4	4	4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	3.80	
Malone Dam	N/A	5	N/A	N/A	5	4	4	4	5	5	N/A	8	N/A	5.00	
Keller Bridge	N/A	N/A	N/A	N/A	N/A	N/A	5	5	N/A	N/A	4	5	6	5.00	
#5 Drain	6	7	6	6	7	5	7	7	6	6	7	4	5	6.08	
Buck Creek	5	6	7	7	8	7	9	8	7	8	8	7	7	7.23	
Miller Creek	7	8	8	8	6	6	8	6	8	7	N/A	9	N/A	7.36	Lowest
Big Springs	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
East/West Bridge	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Wilson Bridge	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table 3. Ranking of Lost River sub-basin sites based on total Kjeldahl nitrogen loading estimates, May-October, 1999. Values represent a ranking of sites from highest nutrient loading estimates (Anderson Rose Dam) to lowest (Buck Creek). N/A indicates missing flow data.

Site	5/12	5/27	6/9	6/23	7/8	7/22	8/4	8/18	8/31	9/15	9/29	10/13	10/28	Average	Ranking
Anderson Rose Reservoir	1	1	1	1	1	1	1	1	2	2	2	2	2	1.38	Highest
Wilson Reservoir	2	3	2	3	4	3	3	3	1	1	1	1	1	2.15	
Station 48	4	2	3	2	2	2	2	2	3	3	9	6	3	3.31	
#1 Drain	3	4	4	4	3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	3.60	
Harpold Dam	N/A	N/A	N/A	N/A	N/A	N/A	7	N/A	4	4	3	3	4	4.17	
Keller Bridge	N/A	N/A	N/A	N/A	N/A	N/A	4	6	N/A	N/A	4	4	5	4.60	
Malone Dam	N/A	5	8	5	5	4	5	5	5	5	6	8	N/A	5.55	
#5 Drain	6	8	5	7	7	6	8	4	7	6	7	5	6	6.31	
Miller Creek	7	6	6	6	6	5	6	7	6	7	5	9	N/A	6.33	
Buck Creek	5	7	7	8	8	7	9	8	8	8	8	7	7	7.46	Lowest
Big Springs	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
East/West Bridge	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Wilson Bridge	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Conclusions and Recommendations

Results from the May-October sampling period of the Lost River sub-basin monitoring project indicate impairment of Lost River sub-basin water quality. Measured parameters, specifically dissolved oxygen and chlorophyll-a, did not meet Oregon State water quality standards at a number of sites. Additionally, nutrient concentrations indicate highly eutrophic conditions with widely fluctuating dissolved oxygen and pH values. Currently, water quality conditions in the Lost River sub-basin may compromise beneficial uses as outlined by the Oregon State Department of Environmental Quality for the Lost River.

Biweekly sampling provides important baseline data that will be useful in assessing current conditions, tracking water quality trends, and identifying areas of concern. Additional sampling efforts that would complement the current monitoring program include automated storm event sampling with continuous discharge measurements, depth integrated sampling at reservoir sites, and continuous hydrolab data at selected sites. With these data, quantitative loading estimates could be calculated and incorporated into the TMDL process.

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Chapter 2

Benthic Macroinvertebrate Biomonitoring in the Lost River Sub-basin, Oregon and California, 1999.

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Executive Summary

We sampled benthic macroinvertebrates monthly from August-October 1999 as part of a bioassessment of the Lost River sub-basin, with additional samples taken from the Sprague, Sycan, and Williamson rivers (Klamath Basin, Oregon).

The Lost River, characterized as an interior or closed drainage basin, is primarily controlled by releases from Clear Lake Reservoir and represents a highly altered system flowing through areas of intensive agricultural production and irrigable land associated with the Bureau of Reclamation's Klamath Project. Stream corridor and in-stream habitat conditions have been highly impacted by dam construction, channel modifications, water diversions, wetland drainage, agricultural activities, and cattle grazing. The presence of two endangered fish species, the Lost River (*Deltistes luxatus*) and shortnose (*Chasmistes brevirostris*) sucker has focused attention on research, monitoring, and restoration efforts in the Lost River sub-basin.

We examined differences in macroinvertebrate community composition, structure, and function in association with large-scale geomorphologic factors as well as site-specific environmental conditions. We collected macroinvertebrates from least impacted communities in the Sprague, Sycan, and Williamson rivers, however, differences in watershed characteristics such as gradient, vegetation, and elevation make direct comparisons to the Lost River sub-basin inappropriate. Because no suitable reference community exists for the Lost River sub-basin, collected data and community metric evaluation represent baseline conditions.

Evaluation of community metrics in the Lost River sub-basin below Malone dam is characterized by low taxonomic richness values, high community tolerance values associated with a predominance of tolerant taxa, and a complete absence of intolerant taxa. This situation is typical of organically enriched streams with impaired physical habitat features. Additionally, functional feeding group percent composition indicates a high percent composition of the collector functional feeding group and an absence of the shredder functional feeding group. This indicates that the dominant food component available to macroinvertebrates in the Lost River system is fine particulate organic matter, with little available course particulate organic matter derived from allochthonous riparian vegetation inputs.

These data, in addition to concurrent studies evaluating chemical, physical, and fish community components will provide a useful means to effectively monitor restoration efforts and help direct management plans toward meeting water quality goals in the Lost River sub-basin.

Introduction

Freshwater ecosystems are currently undergoing alarming rates of change in response to human-induced perturbations. In western North America, large scale land-use activities and their associated impacts upon fluvial aquatic systems has led to growing concern for long-term ecological effects (Naiman 1992, Conquest et al. 1993). Floodplain development, timber harvest, road building, mining, and agricultural practices have been primary forces behind changes in land use, with resulting alterations in hydrologic cycles, vegetation cover, and terrestrial-aquatic linkages (Allan 1995). Degraded water quality and a decline in the ecological integrity of aquatic systems are now commonplace wherever significant human developments have occurred (Rosenberg and Resh 1993). Consequently, public concern over deteriorating water quality resulted in federal intervention and legislation of the Federal Water Pollution Control Act of 1972 and the Clean Water Act of 1977; both with objectives to "restore and maintain the chemical, physical, and biological integrity of the nation's waters" (Karr et al. 1986). Section 101 of the Federal Clean Water Act mandates the development of water quality management programs that evaluate, monitor, maintain, and restore aquatic resources.

In order to achieve this goal, federal and state agencies focused restoration efforts on chemical and physical water quality parameters with the assumption that improved biological quality would follow. However, despite these efforts, the biological integrity of water resources has continued to decline (Karr and Dudley 1981). Because the dynamic interactions (chemical, physical, and biological) that constitute an aquatic ecosystem were not adequately addressed through the use of chemical and physical parameters alone, increased efforts to incorporate biological parameters into water quality assessments were made. This has resulted in a more holistic evaluation of the ecological integrity of our aquatic systems (Plafkin et al. 1989, Hayslip 1993, Loeb and Spacie 1994).

Biological monitoring uses fish, algae, protozoans, and aquatic macroinvertebrates to assess the environmental health and biotic integrity of aquatic ecosystems. Biotic integrity is defined as "a balanced, integrated, adaptive community of organisms having species composition, diversity, and functional organization comparable to that of natural habitat of the region" (Frey 1977, Karr and Dudley 1981). Biomonitoring relies on the premise that biological organisms are diagnostic in determining water quality and reflect overall ecological integrity. Biomonitoring techniques use biological organisms as a detector and their response as a measure to determine and evaluate environmental conditions (Hayslip 1993). Organism assemblages that make up an aquatic community comprise those individuals that can "endure, tolerate, compete, reproduce, and persist within a given habitat" (Weber 1973). Because aquatic organisms are exposed to a range of environmental conditions, water quality is reflected in the distribution, abundance, and condition of aquatic organisms (Weber 1973). Therefore, the organisms that inhabit an aquatic ecosystem can serve as fundamental sensors that respond to natural and human-induced perturbations affecting aquatic systems (Loeb and Spacie 1994). Additionally, biological organisms integrate the effects of various stresses over time, thereby providing an encompassing measure of their aggregate impact upon aquatic systems (Plafkin et al. 1989).

Some advantages to using benthic macroinvertebrates to examine water quality are that they (Platts et al. 1983, Plafkin et al. 1989, Dates and Bryne 1997):

1) Respond to changes in the physical, chemical, and biological environment.
2) Act as continuous monitors of environmental quality; integrating and responding to a multitude of environmental impacts.
3) Exhibit a complex life cycle of one or more years with sensitive stages that quickly respond to stress while the overall community responds more slowly.
4) Are relatively abundant, have limited migration patterns or a sessile mode of life, and are easily collected and identified by trained monitors.
5) Act as a primary food source for many recreationally and commercially important fish, forming a vital link in the food chain between aquatic plants, algae, and the upper trophic levels of the food chain.
6) Sampling is relatively easy, requires limited personnel and inexpensive gear, and has limited effects on the resident biota.
7) Are commonly used by State water quality agencies.

Through analysis of community composition, structure, and function, researchers can apply multiple, community based metrics that relate the response of the stream biota's condition to watershed level management activities, both past and present (Klemm et al. 1990).

The Lost River study is designed to investigate water quality issues using benthic macroinvertebrate biomonitoring techniques. Effects of numerous irrigation diversions and returns, impoundments, agriculture, grazing, and urban development within the watershed have altered natural hydrologic functions and produced significant cumulative impacts. Recent concerns regarding nutrient loading and temperatures have focused research efforts on water quality parameters. Information resulting from a macroinvertebrate bioassessment will be used to complement past, present, and future efforts aimed at evaluating water quality issues in the area.

In 1999, the United States Geological Survey, Biological Resources Division (BRD) in conjunction with the United States Bureau of Reclamation (BOR) initiated a monitoring effort in the Lost River sub-basin to determine water quality, physical habitat, and fish community conditions. Results from water quality sampling and fish community structure have yet to be finalized (USGS-BRD unpublished data, BOR unpublished data). Analysis of benthic macroinvertebrate community components will directly compliment water quality and fish community sampling currently being collected by BRD and BOR.

Through analysis of benthic macroinvertebrate community composition, structure, and function, the ecological integrity of the Lost River system will be better understood. Most importantly, the synthesis of chemical, physical, and biological monitoring will reinforce and complement overall water quality assessments and provide valuable information when making future management decisions. Since very little benthic macroinvertebrate biomonitoring data has been collected within the Klamath Basin, the initial study will be used to refine techniques and allow for more thorough investigation in the future. Because macroinvertebrate communities have been shown to respond predictably to environmental variables within specific geographical areas, present baseline data and future studies can be used to monitor Lost River sub-basin stream conditions over time (Richards et al. 1993). Specific objectives of our sampling are to: 1) provide baseline biomonitoring information useful to agencies and groups making management decisions within the Klamath Basin, 2) compliment current research efforts focused in the Lost River sub-basin, 3) provide a means to effectively monitor water quality trends and detect impacts to biotic/habitat integrity throughout the Lost River based on a multi-metric analysis of macroinvertebrate community composition, structure, and function, and 4) employ methods that are efficient (yield rapid and cost-effective collection of data), allow for replication, and incorporate measures that respond to different levels of impact. Ultimately, biomonitoring and associated water quality studies may provide an important effectiveness monitoring tool for restoration efforts and help direct resources toward specific causal factors responsible for stream degradation.

Study Area

The Lost River lies within the Klamath Basin southeast of Upper Klamath Lake (UKL), Oregon and represents a highly altered stream system with both lotic and lentic properties throughout its course from Clear Lake Reservoir to Tule Lake National Wildlife Refuge (Figure 1). Land-use activities and in-stream habitat modifications have largely homogenized riverine habitat while other areas are best described as impounded, lentic habitat units backed up by a series of dams. The Lost River is part of the upper Klamath River watershed of northern California and southern Oregon located in Modoc and Siskiyou counties, California, and Klamath County, Oregon and is characterized as an interior or closed drainage basin with a watershed area covering approximately 7,754 km^2. The Lost River originates in the mountains east of Clear Lake Reservoir in Modoc County, California, and flows to Tule Lake Sump a distance of approximately 120 km. Headwater tributaries are Willow and Boles Creek, with Willow Creek contributing the majority of inflow into Clear Lake Reservoir. Other tributaries include the East Branch of the Lost River, Miller Creek, and Buck Creek. Numerous inflows, diversions, and drains below Wilson reservoir are also worth noting due to their effect upon the system. The Lost River is largely regulated by releases from Clear Lake Reservoir and represents a highly altered system flowing through areas of intensive agricultural production and irrigable land associated with the Bureau of Reclamation's Klamath Project.

We sampled additional sites in the Sprague, Sycan, and Williamson rivers (Figure 2). The Sprague River sub-basin is located in the Klamath River watershed northwest of UKL and encompasses a drainage basin area of approximately 4,167 km^2. The Williamson River sub-basin is also within the Klamath River watershed north of UKL and encompasses a drainage basin area of approximately 3,725 km^2. Forestry and agricultural practices characterize land-use in the Sprague and Williamson River sub-basins. The Lost, Sprague, and Williamson River sub-basins are within the eastern Cascades slopes and foothills ecoregion (Omernik 1995).

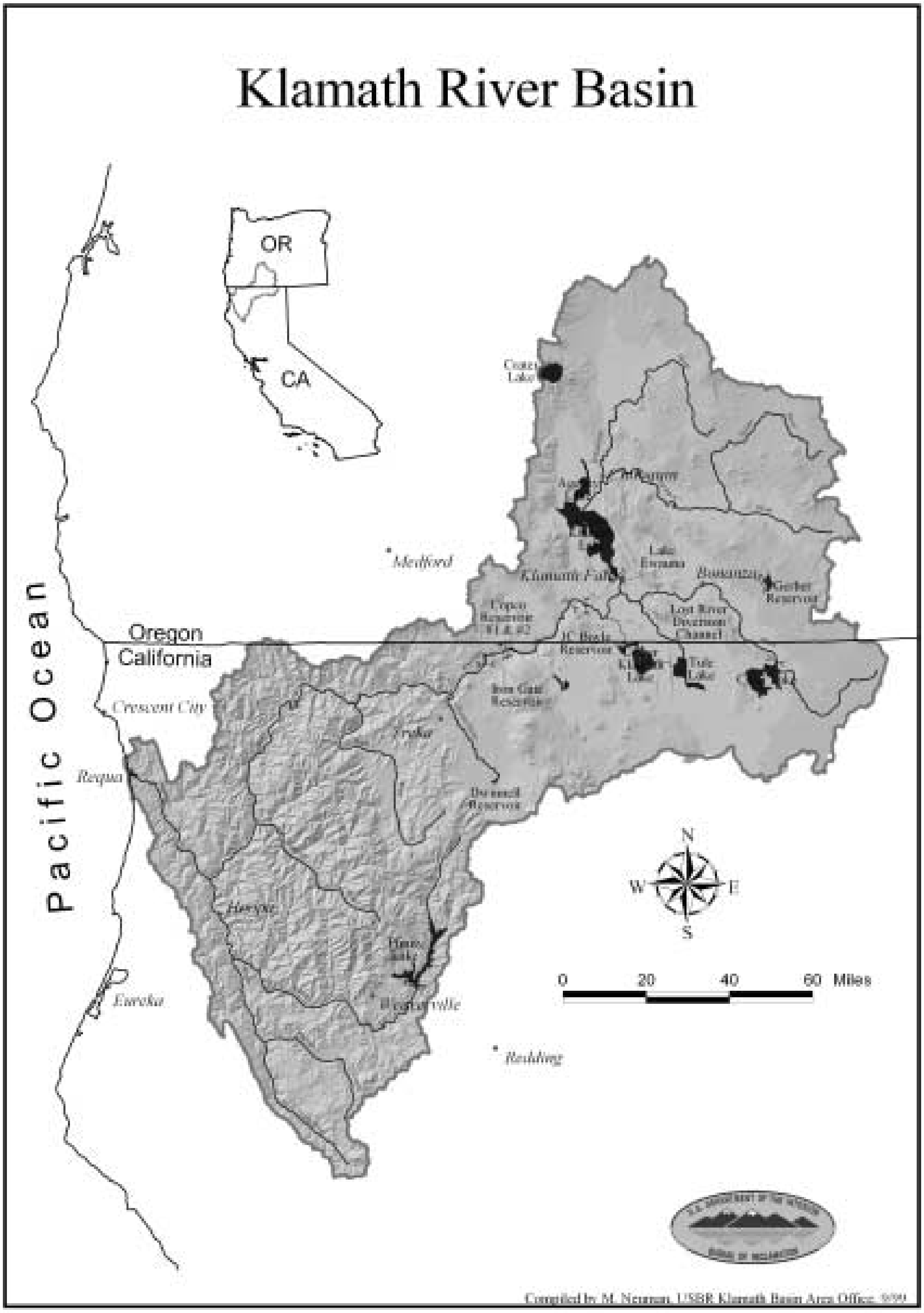


Figure 1. Map of Klamath River watershed.

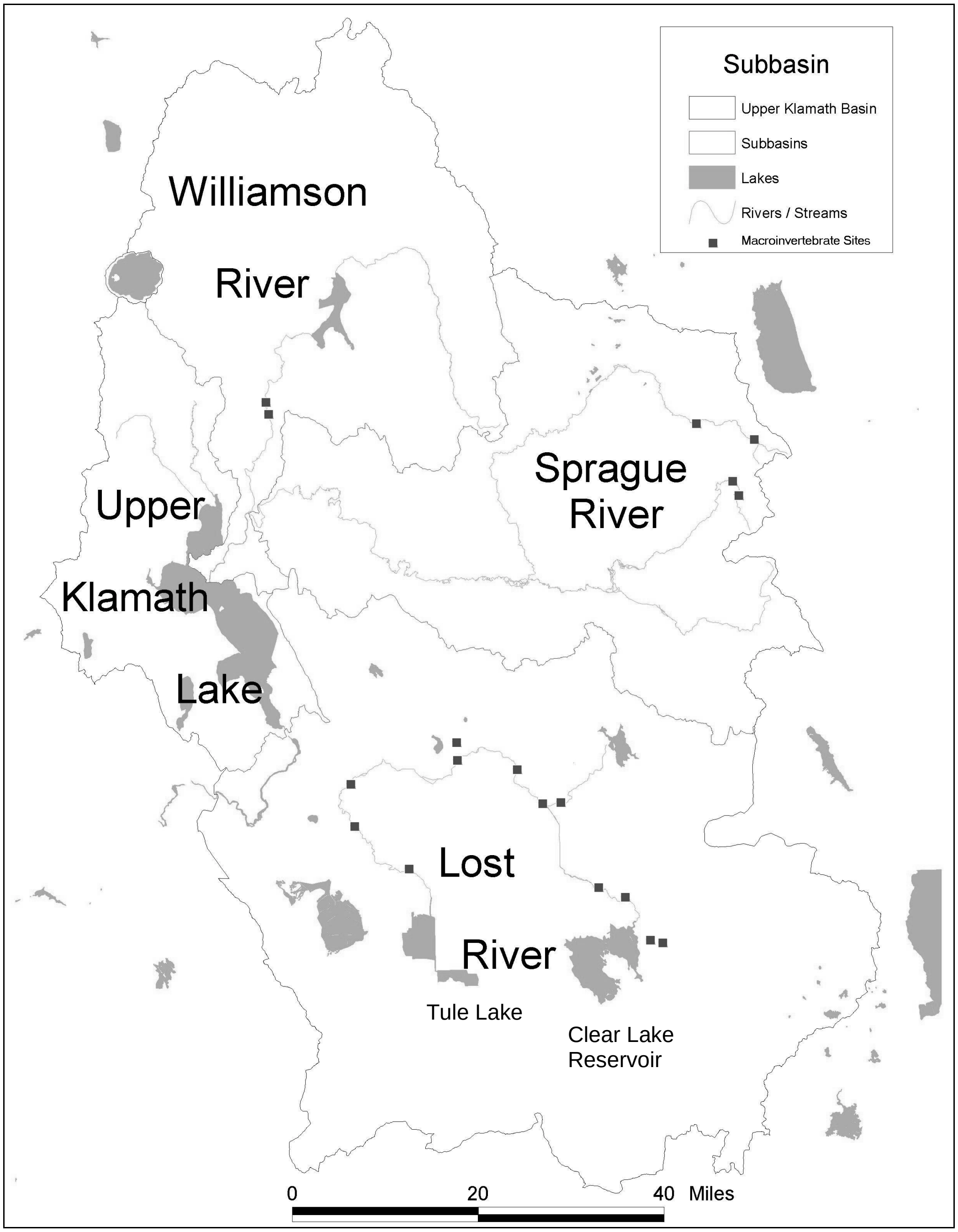


Figure 2. Map of Sprague, Sycan, Williamson, and Lost River watersheds with macroinvertebrate sampling stations.

Methods

Ecoregional and Watershed Characteristics

Macroinvertebrate community composition and structure has been shown to respond to physical and environmental variables within specific geographic regions called ecoregions (Richards et al., 1993). Therefore, we examined sites in relation to ecoregional and watershed level conditions. An ecoregion is defined as an area of relative homogeneity, defined by similarities of vegetation, landform, geology, hydrology, climate, and land use (Hayslip, 1993). All our sites were located within the eastern Cascades slopes and foothills ecoregion (Omernik 1995). However, differences in land-use, elevation, drainage basin area, vegetation, and gradient at the watershed level preclude direct comparison of all sites. Sampling stations in the Sprague, Sycan, and Williamson rivers will be treated separately from Lost River sub-basin sites. Ecoregional, watershed, and stream reach variables were determined using ARCINFO GIS coverages of the Klamath Basin (Table 1).

Eighteen sites within the Lost River sub-basin and the upper Klamath River basin were selected for sampling by stratifying streams based on past and present water quality monitoring sites, ecoregional considerations, stream gradient and valley morphology, and instream habitat types. By stratifying habitat types, meaningful comparisons between macroinvertebrate communities can be made. In order to facilitate comparisons between sites, macroinvertebrate sampling procedures were standardized and data were collected and analyzed using methods appropriate for riffle habitat types. Wherever possible, sample collection closely followed Oregon Department of Environmental Quality protocols for in-stream biomonitoring of water quality (ODEQ 1998).

<u>Macroinvertebrate Sampling</u>

Samples were collected in August, September, and October. Macroinvertebrate sampling was conducted with a Hess stream bottom sampler ($0.1m^2$) using a nylon organdy net (500 micrometer pore size). Other sites were sampled with a D-frame kick net (500 micrometer pore size) when depth constraints due to discharge fluctuations prohibited sampling with a Hess sampler.

Table 1. Watershed characteristics for macroinvertebrate sampling stations in the Sprague, Sycan, Williamson, and Lost River sub-basins, 1999.

Site No.	Site Name	Site Abbr.	Sub-watershed	Dominant Land use/Ownership	DominantVegetation Type	~ Upstream Drainage Area (km^2)	Altitude (m)	Gradient (%)
1	North Fork Sprague River @ Lee Thomas Campground	NFSR@LTC	Sprague River	Forestry/USFS	Mixed Conifer	45	1901	7.0
2	North Fork Sprague River @ Lee Thomas Crossing	NFSR@LTX	Sprague River	Forestry/USFS	Mixed Conifer	63	1886	4.5
3	Sycan River above bridge on 3380 and Hwy 28 (upstream site)	SRUP	Sycan River	Forestry/USFS	Mixed Conifer	31	2003	8.5
4	Sycan River above bridge on Hwy 28 (downstream site)	SRDWN	Sycan River	Forestry/USFS	Mixed Conifer	151	1727	3.0
5	Williamson River near Solomon Butte (upstream site)	WRUP	Williamson River	Grazing-Agriculture/Private	Mixed Conifer	3490	1367	5.0
6	Williamson River near Solomon Butte (downstream site)	WRDWN	Williamson River	Grazing-Agriculture/Private	Mixed Conifer	3494	1362	9.0
7	Willow Creek above USBOR Gaging Station (upstream site)	WCUP	Willow Creek	Forestry/USBLM	Juniper/Soft Shrub	1220	1374	8.5
8	Willow Creek @ USBOR Gaging Station (downstream site)	WCDWN	Willow Creek	Forestry/USBLM	Juniper/Soft Shrub	1224	1371	7.0
9	Lost River @ Rock Creek	LR@RC	Lost River	Forestry/USBLM	Juniper/Soft Shrub	2445	1346	2.5
10	Lost River above Malone Bridge	LRMB	Lost River	Forestry/USBLM	Juniper/Soft Shrub	2472	1268	9.0
11	Lost River @ Miller Creek Confluence	LR@MC	Lost River	Agriculture-grazing/Private	Green Grass/Forb	3365	1256	5.0
12	Miller Creek @ USBOR Improved Channel	MC	Lost River	Agriculture-grazing/Private	Green Grass/Forb	655	1257	2.5
13	Lost River @ Keller Bridge	LR@KB	Lost River	Agriculture-grazing/Private	Green Grass/Forb	3458	1255	.75
14	Buck Creek @ Burgdorf Road	BC	Lost River	Agriculture-grazing/Private	Green Grass/Forb	267	1254	1.0
15	Lost River @ Harpold	LR@H	Lost River	Agriculture-grazing/Private	Green Grass/Forb	3977	1251	2
16	Lost River @ Station 48	LR@ST48	Lost River	Agriculture-grazing/Private	Green Grass/Forb	4353	1244	1
17	# 5 Drain @ Wong Road	#5DR	Lost River	Agriculture-grazing/Private	Green Grass/Forb	No Data	1242	.55
18	Lost River @ Wooden Bridge	LR@WB	Lost River	Agriculture-grazing/Private	Green Grass/Forb	4505	1230	1.25

We collected macroinvertebrate samples from wadable, riffle habitat types. Riffles were selected for sampling because: 1) In Pacific Northwest streams, macroinvertebrate diversity and abundance are highest in riffle habitat units; 2) Many quantitative sampling devices appropriate for lotic macroinvertebrates easily sample riffles; 3) When quantitatively examining aspects of community composition, structure, and function, the high variability found among macroinvertebrate communities in relation to physical habitat variables presents significant confounding factors (Plafkin et al. 1989). Therefore, to reduce these factors, only riffle habitat units were sampled using similar methods and effort.

We collected three samples from randomly chosen riffle areas using a random number table. The random number table had four digits, the first two numbers identified a longitudinal location from the downstream end of the habitat unit while the second two digits located a cross section width from the bank for a precise, random sampling location. The sampling device, a Hess stream bottom sampler or d-frame kick net, was then placed at each location starting downstream and proceeding upstream. Sampled stream bottom substrate was disturbed to a depth of approximately 10 centimeters for approximately three minutes for each sample. We then placed all three samples (composite) in a labeled plastic container. The composite sample was then preserved with 90% ethanol for sorting, sub-sampling, and laboratory identification. Preserved macroinvertebrate samples were identified by Aquatic Biology Associates, Inc.[1] in Corvallis, Oregon. Levels of identification varied by taxonomic group (Table 2).

Multimetric Data Analysis and Evaluation

The ecological integrity of stream conditions was evaluated using a multi-metric analysis (Table 3). Metrics are measures of community composition, structure, and function based on single or multiple taxa and are used to measure community attributes such as species richness, evenness, relative abundance, pollution tolerance, and functional feeding group structure. For example, regionally based tolerance values provide a measure of biotic integrity for each sampling site according to the invertebrate communities tolerance or intolerance to certain forms of pollution (eg., organic enrichment). Other metrics, such as species richness, will reflect habitat and water quality conditions based on the diversity of the invertebrate assemblage found at each site. Community composition measures (relative abundance, diversity, evenness, etc.) describe community structure and function, further reflecting water quality and habitat conditions.

[1] Mention of brand names or company does not constitute endorsement by the U.S. Geological Survey

Table 2. Level of macroinvertebrate taxonomic identification for samples collected in the Sprague, Sycan, Williamson, and Lost River sub-basin August-October, 1999.

Taxon	Order	Family	Sub-family	Genus	Species
Amphipoda				x	x
Arachnida	x				
Coleoptera				x	x
Elmidae				x	x
Diptera				x	x
Chironomidae				x	x
Ephemeroptera				x	x
Plecoptera				x	x
Trichoptera				x	x
Gastropoda		x			
Hemiptera				x	x
Lepidoptera				x	x
Megaloptera				x	x
Odonata				x	x
Oligochaeta	x				
Ostracoda	x				
Pelecypoda	x				
Turbellaria	x				

Table 3. Summary of selected macroinvertebrate metrics for samples collected in the Sprague, Sycan, Williamson, and Lost River sub-basin August-October, 1999.

Primary Metrics

Metric	Description	Category
Total Abundance	An estimate of the # of organisms relative to the sample area	Abundance
Total Taxa Richness	Number of taxonomic units in the sample	Diversity
EPT Taxa Richness	Number of taxonomic groups in the sample belonging to the insect orders Ephemeroptera, Plecoptera, and Trichoptera	Diversity
Percent Contribution of Dominant Taxon	Percent of the number of individuals in the sample belonging to the most abundant taxon	Evenness
Community Tolerance	An average of the tolerance values of all individuals in the sample	Pollution Index

Positive Indicators

Metric	Description	Category
Predator Richness	Number of taxonomic units in the sample that are classified as predators	Functional Feeding Group
Scraper Richness	Number of taxonomic units in the sample that are classified as scrapers	Functional Feeding Group
Shredder Richness	Number of taxonomic units in the sample that are classified as shredders	Functional Feeding Group
Xylophage Richness	Number of taxonomic units in the sample that are classified as wood eaters	Functional Feeding Group
% Intolerant Taxa	Percent composition of taxa identified that are known to be very sensitive to stream disturbance	Indicator
Intolerant Taxa Richness	Number of taxonomic units that are intolerant to stream disturbance	Indicator
Positive Habitat Indicators	# of Taxa indicative of high habitat/water quality- high, moderate, low	Indicator
Long-Lived Taxa Richness	Richness of long-lived taxa present in the sample	Indicator
Class 0 Taxa Richness	Taxonomic richness of highly intolerant taxa	Indicator

Negative Indicators

Metric	Description	Category
% Collector	% composition of collector functional feeding group (FFG)	Composition
% Parasite	% composition of parasite FFG	Composition
% Oligocheata	% composition of Oligocheata	Composition
% Leech	% composition of leeches	Composition
% Tolerant Molluscs	% composition of tolerant molluscs	Composition
% Tolerant Crustaceae	% composition of tolerant crustaceae	Composition
% Tolerant Odonates	% composition of tolerant Odonates	Composition
% Tolerant Ephemeroptera	% composition of tolerant Ephemeropterans	Composition
% Tolerant Trichopterans	% composition of tolerant Trichopterans	Composition
% Tolerant Coleopterans	% composition of tolerant Coleopterans	Composition
% Tolerant Dipterans	% composition of tolerant Dipterans	Composition
% Total Tolerant	% of sample comprised of tolerant taxa	Composition
Tolerant Taxa Richness	Taxonomic richness of tolerant organisms	Diversity
% Simuliidae	% of sample comprised of simuliidae	Composition
% Chironomidae	% of sample comprised of chironomidae	Composition

Additional Metrics

Metric	Description	Category
Shannon-Weiner H'	Measures mean diversity as affected by both richness and species composition (eveness)	Diversity
Brillouin H	A diversity measure often applied when data comprises an entire population	Diversity
Simpson D	Measures diversity but is not independent of sample size	Diversity
Eveness	Examines the eveness of species composition	Diversity
Voltinism	Describes life cycle characteristics	Life History

Water Quality and Physical Parameters

At each sampling site, water quality profiles were taken for selected parameters (temperature ^{0}C, Conductivity *u*S/cm, pH standard units, and dissolved oxygen mg/l) using hydroloab multi-parameter probes. Hydrolabs were calibrated prior to each sampling event. In addition, chemical water quality measurements were collected biweekly throughout the sampling period by U.S. Bureau of Reclamation personnel. These measured parameters included total alkalinity, nitrate-nitrite nitrogen, ammonia nitrogen, ortho-phosphate, total phosphorus, total Kjeldahl nitrogen, turbidity (Hach turbidimeter), and chlorophyll a. Sampling procedures for the collection of water samples followed ODEQ protocols and analytical methods followed EPA guidelines (EPA 1991). Discharge was measured using a Marsh-McBirney® portable water current meter. We calculated flow by measuring velocity and depth at one-foot intervals across a measured channel cross-section.

We quantified substrate particle size distributions at each riffle sampling station using a modified Wolman pebble count (Wolman 1954). At least 100 particles were randomly collected, measured, and placed in substrate classes at each riffle. We considered particles <2.0mm fines, >2mm<64mm gravels, >64mm<256mm cobbles, and >256mm boulders.

Results

Water Quality

We collected hydrolab data and flow measurements at all sites during each sampling event (Appendix A). Water temperatures at the Sprague, Sycan, and Williamson River sites were generally lower than Lost River sub-basin sites. Water temperatures (^{o}C) ranged from 5.0-14.4 in the Sprague and Sycan River sites, 13.3-19.5 in the Williamson River sites, and 12.2-26.1 in the Lost River sub-basin sites. Dissolved oxygen concentrations (mg/l) in the Sprague, Sycan, and Williamson river sites were less variable than Lost River sub-basin sites. Dissolved oxygen ranged from 8.60-10.95 in the Sprague and Sycan River sites, 6.21-8.38 in the Williamson River sites, and 1.30-14.20 in the Lost River sub-basin sites. Conductivity values (*u*S/cm) were highest at Lost River sub-basin sites. Conductivity ranged from 37-51 in the Sprague and Sycan River sites, 96-120 in the Williamson River sites, and 139-599 in the Lost River sub-basin sites. Standard units of pH were generally highest at Lost River sub-basin sites and ranged from 7.0-8.3 in the Sprague and Sycan River sites, 7.2-7.5 in the Williamson River sites, and 7.1-9.1 in the Lost River.

BRD and BOR collected additional water quality data for selected sites in the Lost River sub-basin as part of a water quality assessment. August-October, 1999 data is presented as a component to our study (Appendix A). Eight locations from Malone Dam to Anderson Rose Dam were chosen to reflect water quality conditions at macroinvertebrate sampling stations. Chlorophyll a, orthophosphorus (OP), total phosphorus (TP), total Kjehldahl nitrogen (TKN), and ammonia (NH_3) values generally increased from upriver to downriver at Lost River sub-basin sites.

Substrate Particle Size Distribution

We estimated particle size distributions for each macroinvertebrate sampling station using a modified Wolman pebble count (Wolman 1954). Because stream gradient influences particle size distributions, no direct comparisons between sites exhibiting significantly different reach level gradients should be made. The dominant particle size class in the Sprague, Sycan, and Williamson rivers was gravel (Figure 3). Lost River sub-basin sites were more variable. Above Malone Dam, gravel and cobble were dominant, while below Malone Dam all sites except Harpold had >34 % fines (<2mm) indicating significant deposition of fine particles in riffle habitat units (Figures 3-4).

Figure 3. Substrate Particle size distributions as estimated by Wolman Pebble Counts for Sprague, Sycan, Williamson, and Lover River sub-basin sites (above Malone Dam), 1999.

Figure 4. Substrate particle size distributions as estimated by Wolman Pebble Counts for Lost River sub-basin macroinvertebrate sampling sites, 1999.

Macroinvertebrate Community Metrics

We analyzed macroinvertebrate community data using a multimetric approach. All metric values were assigned by Aquatic Biology Assoiciates (Wisseman 1996). Selected metrics are discussed herein. We refer readers to Tables 3-8 for a complete list of metric and index values.

Total Abundance (m^2)

Macroinvertebrate abundance was variable both temporally and spatially for all sites. This variability was particularly pronounced in Lost River sub-basin sites. Mean abundance and standard deviation (SD) for all sites ranged from 2,501(2,352) at Buck Creek to 37,507(27,519) at Miller Creek (Figure 5(A)). Variability associated with Lost River sites may be a result of organic enrichment and unstable substrate characteristics.

Total and EPT Taxonomic Richness

Taxonomic richness (total and EPT) values were highest at Sprague and Sycan River sites and lowest at Lost River sub-basin sites (Figures 5(B) and 6(A)). Total taxonomic richness ranged from 12 at the Lost River (Wooden Bridge) to 51 at the North Fork of the Sprague River (Lee Thomas Crossing). EPT taxonomic richness ranged from 0 at the Lost River (#5 Drain) to 26 at the North Fork of the Sprague River (Lee Thomas Campground and Lee Thomas Crossing). Values at Williamson River sites ranged from 20-29 for total taxonomic richness and 6-9 for EPT taxonomic richness. Low taxonomic richness values associated with the Williamson River seem to be related to site specific substrate characteristics and are not thought to be representative of the Williamson River as a whole. In the Lost River sub-basin, total and EPT taxonomic richness values generally decreased downstream of Willow Creek. EPT richness values were generally 4 times higher at Sprague and Sycan River sites compared to those found in the Lost River sub-basin.

Shannon H' ($\log_2$)

Shannon H' diversity values generally decreased from Willow Creek headwater sites to downstream sites in the Lost River sub-basin (Figure 6(B)). Diversity values were highest at Willow Creek above the BOR gaging station (4.72) and lowest at the Lost River confluence with Miller Creek (2.28). Lost River sub-basin sites above Malone Dam (Willow Creek sites, Lost River at Rock Creek, and Lost River above Malone bridge) had a range of 3.44-4.72. Sites below Malone Dam had a range from 1.91-3.80. Diversity values for the Sprague and Sycan River macroinvertebrate communities ranged from 3.00-4.58. Williamson River sites had a range of 2.13-3.47.

Community Tolerance Value

Community tolerance values (CTV) indicate that a high percentage of Lost River sub-basin macroinvertebrates are tolerant of high temperatures, organic enrichment, and soft sediment and values ranged from 4.65-6.13. In comparison, Sprague and Sycan River CTV ranged from 3.37-5.77 indicating the presence of more intolerant taxa at these sites. Williamson River CTV ranged from 6.13-7.25. Again, the Williamson River sites are not thought to be representative due to site-specific conditions. CTV of macroinvertebrate assemblages in the Sprague, Sycan, and Williamson rivers and Lost River sub-basin sites show an inverse relationship to Shannon H' values (Figure 6(B)).

Percent Composition of Intolerant Taxa

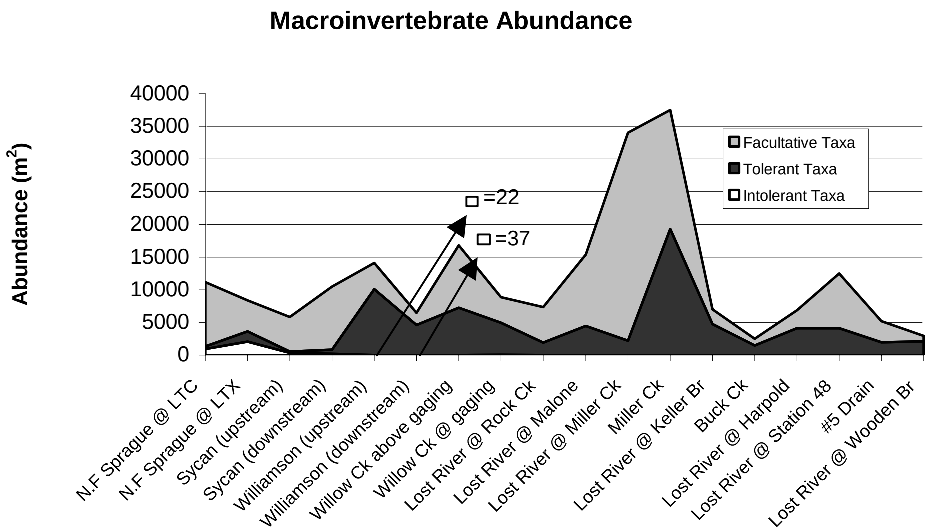
Percent composition of intolerant taxa is an indicator of good water quality and habitat conditions (Figures 7-9). Only two Lost River sub-basin sites, Willow Creek above and at the BOR gaging station, contained intolerant taxa. Mean percent composition and standard deviation of intolerant taxa at Willow Creek was 0.13 (0.22) and 0.42 (0.42) respectively. No sites below Clear Lake Reservoir contained intolerant taxa. Sprague and Sycan River sites contained intolerant taxa. Mean percent composition and standard deviation (SD) of intolerant taxa for the Sprague River at Lee Thomas Campground and Lee Thomas Crossing was 8.36 (6.41) and 24.57 (4.26), respectively. At the Sycan River upstream and downstream sites, mean percent composition of intolerant taxa was 5.79 (7.54) and 1.92 (.79). No intolerant taxa were sampled at the Williamson River sites.

Functional Feeding Group Percent Composition

Percent composition of functional feeding groups is presented in Figures 10-12. The collector-gatherer functional feeding group dominated all sites except Lost River @ Harpold and Lost River @ Wooden Bridge. Scrapers dominated these sites. Interestingly, these sites were the only Lost River sampling stations with > 30% cobble substrate compositions.

Ratio of Shredder Functional Feeding Group to Total Organisms

Macroinvertebrates classified in the shredder functional feeding group (FFG) represent organisms that utilize course particulate organic matter (CPOM) and associated bacterial and fungal colonizers as a food source. Shredder presence and or absence is an indicator of riparian condition. Macroinvertebrates classified in the shredder FFG (Wisseman, 1996) occurred at Sprague, Sycan, and Williamson River sites (Figure 13(B)). The ratio of shredder FFG to total organisms ranged from 0.0-0.03 at the Sprague River, 0.0-0.05 at Sycan River sites, and 0.0-0.01 at Williamson River sites. No shredders were found in Lost River sub-basin sites, indicating a lack of allochthonous inputs from riparian areas.



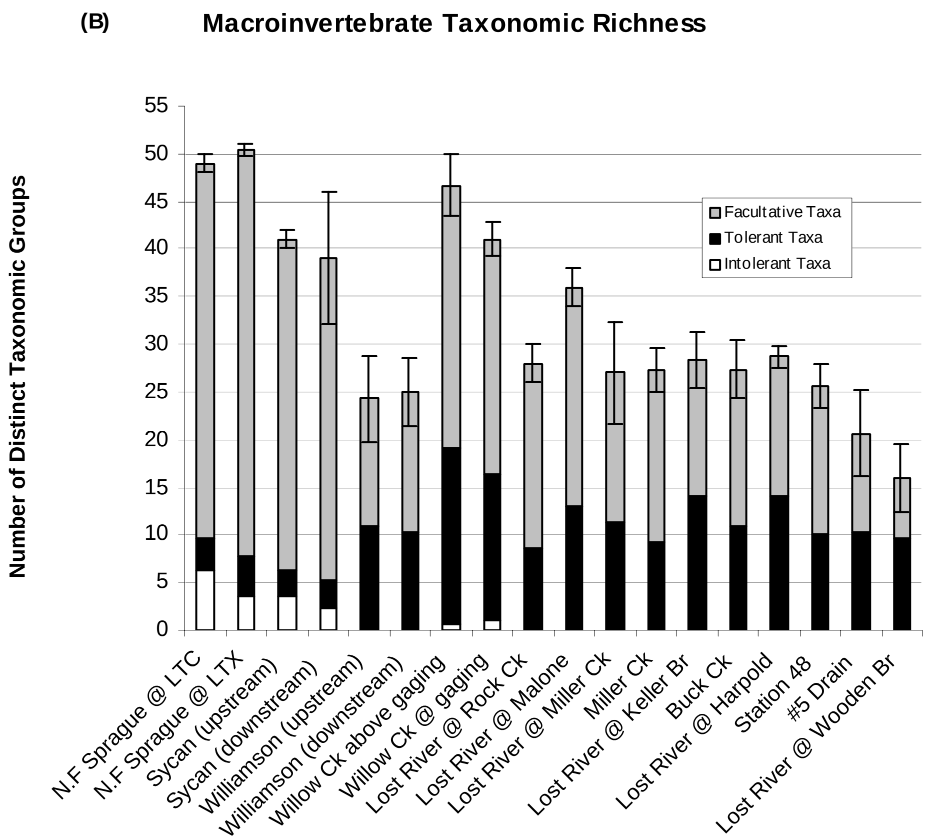
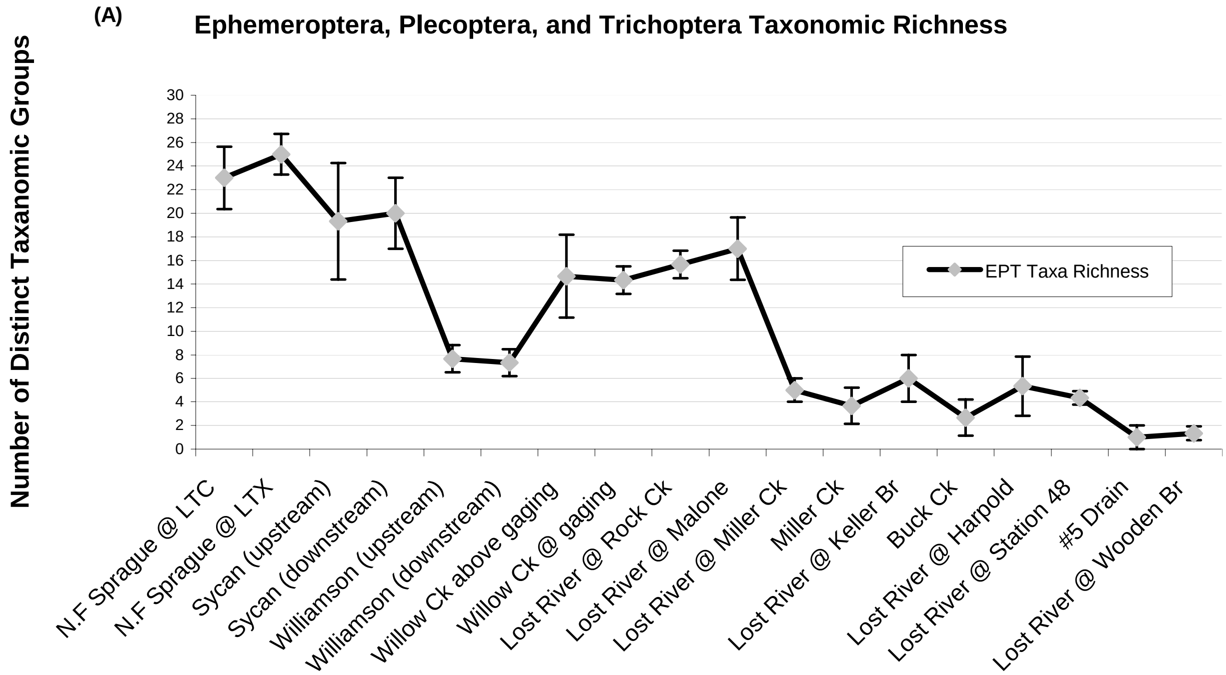


Figure 5. Macroinvertebrate abundance (A) and taxonomic richness (B) for August-October, 1999 sampling period showing percent composition of facultative, tolerant and intolerant taxa. Error bars represent (±) one standard deviation.



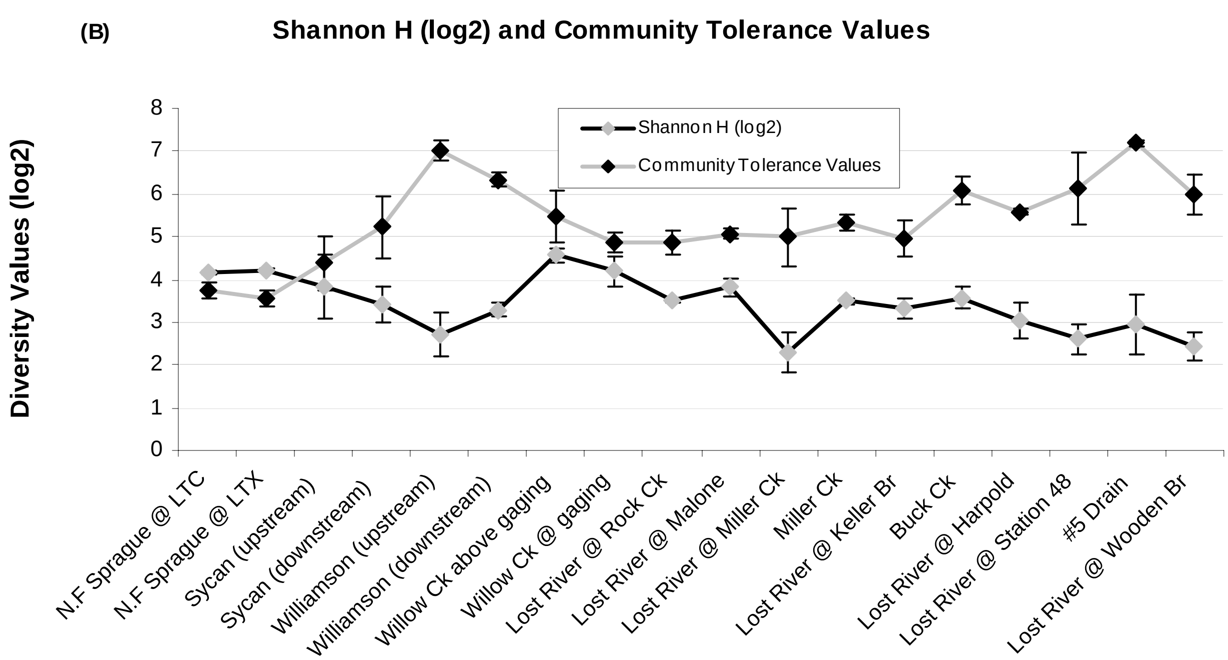


Figure 6. Mean EPT taxonomic richness (A) for macroinvertebrate samples collected in the Sprague, Sycan, Williamson, and Lost River sub-basins August-October, 1999. Mean Shannon H' diversity index values (B) for macroinvertebrate samples collected in the Sprague, Sycan, Williamson, and Lost River sub-basins August-October, 1999. Error bars represent (±) one standard deviation.

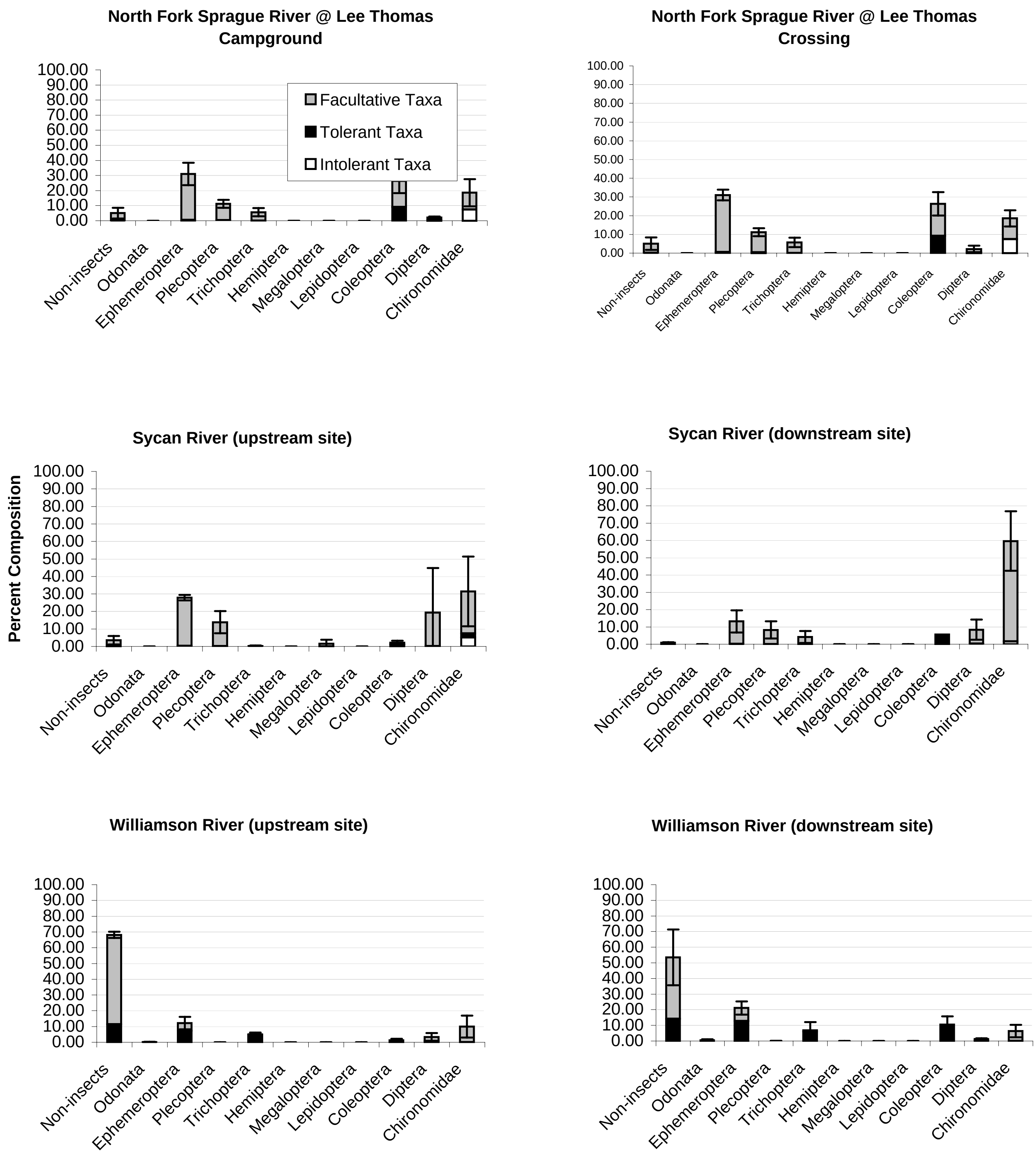


Figure 7. Mean ordinal percent composition at Sprague, Sycan, and Williamson River macroinvertebrate sampling stations August-October, 1999. Error bars represent (±) one standard deviation.

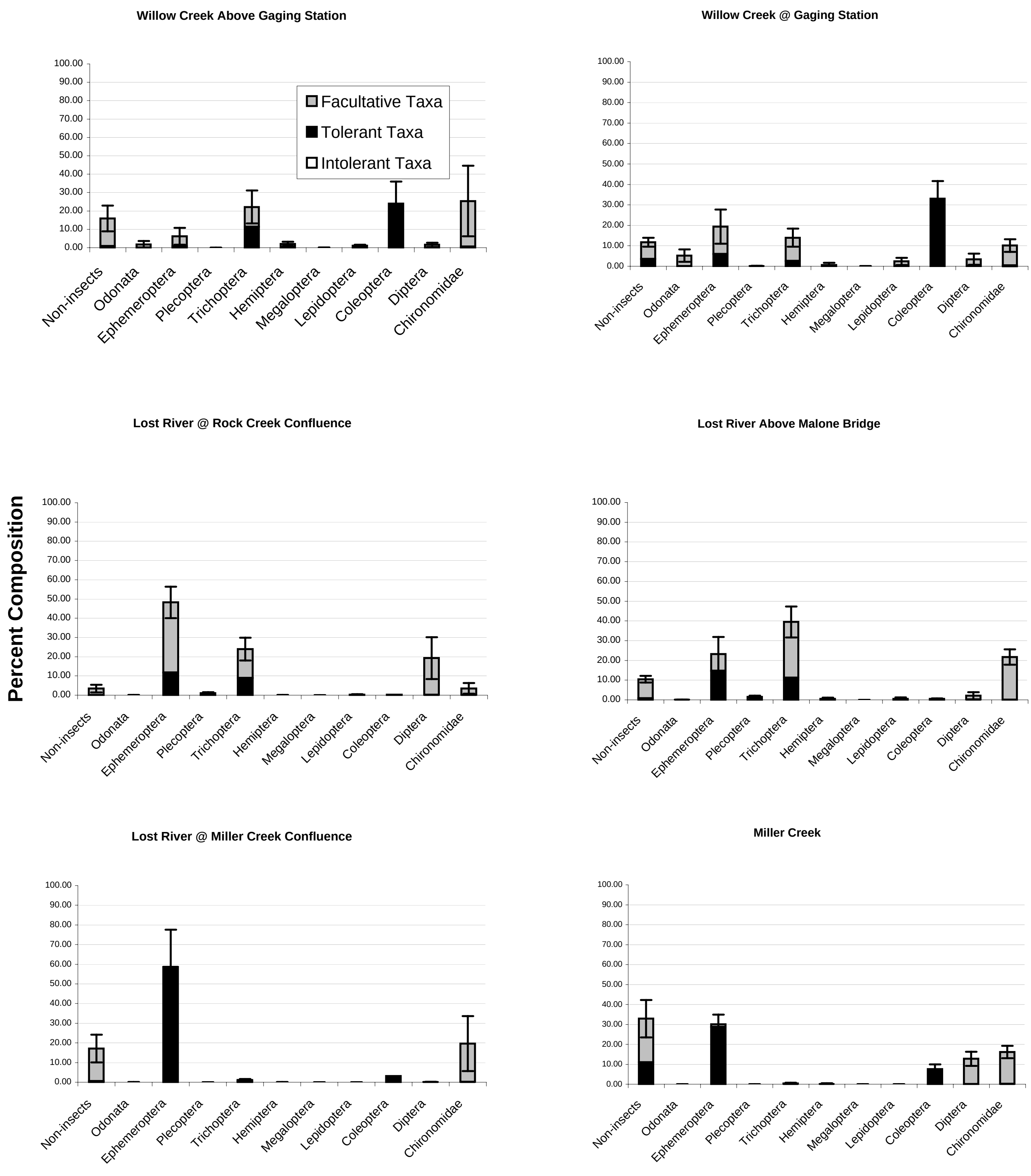


Figure 8. Mean ordinal percent composition at Lost River sub-basin macroinvertebrate sampling stations above Keller Bridge August-October, 1999. Error bars represent (±) one standard deviation.

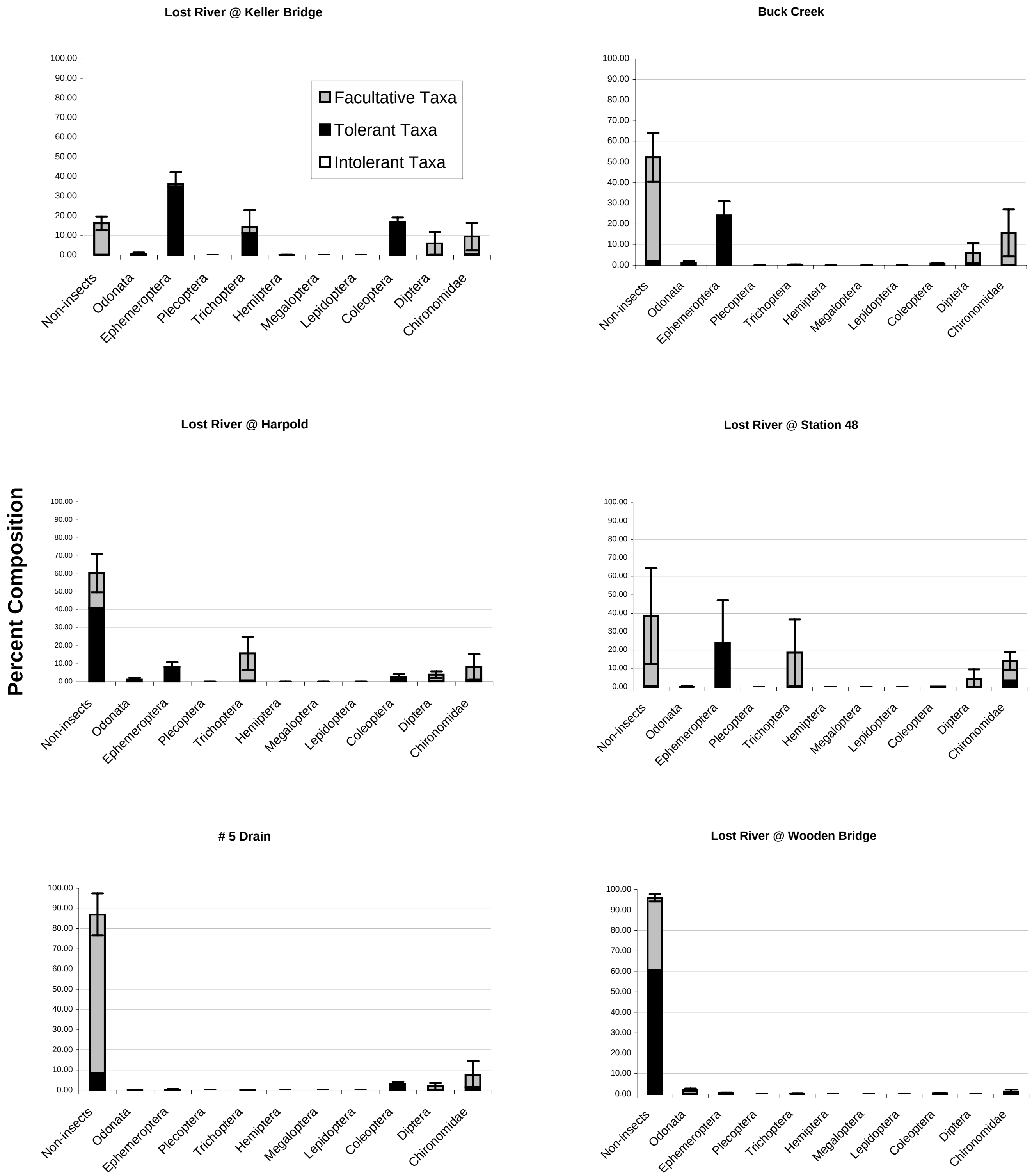


Figure 9. Mean ordinal percent composition at Lost River sub-basin macroinvertebrate sampling stations below Keller Bridge August-October, 1999. Error bars represent (±) one standard deviation.

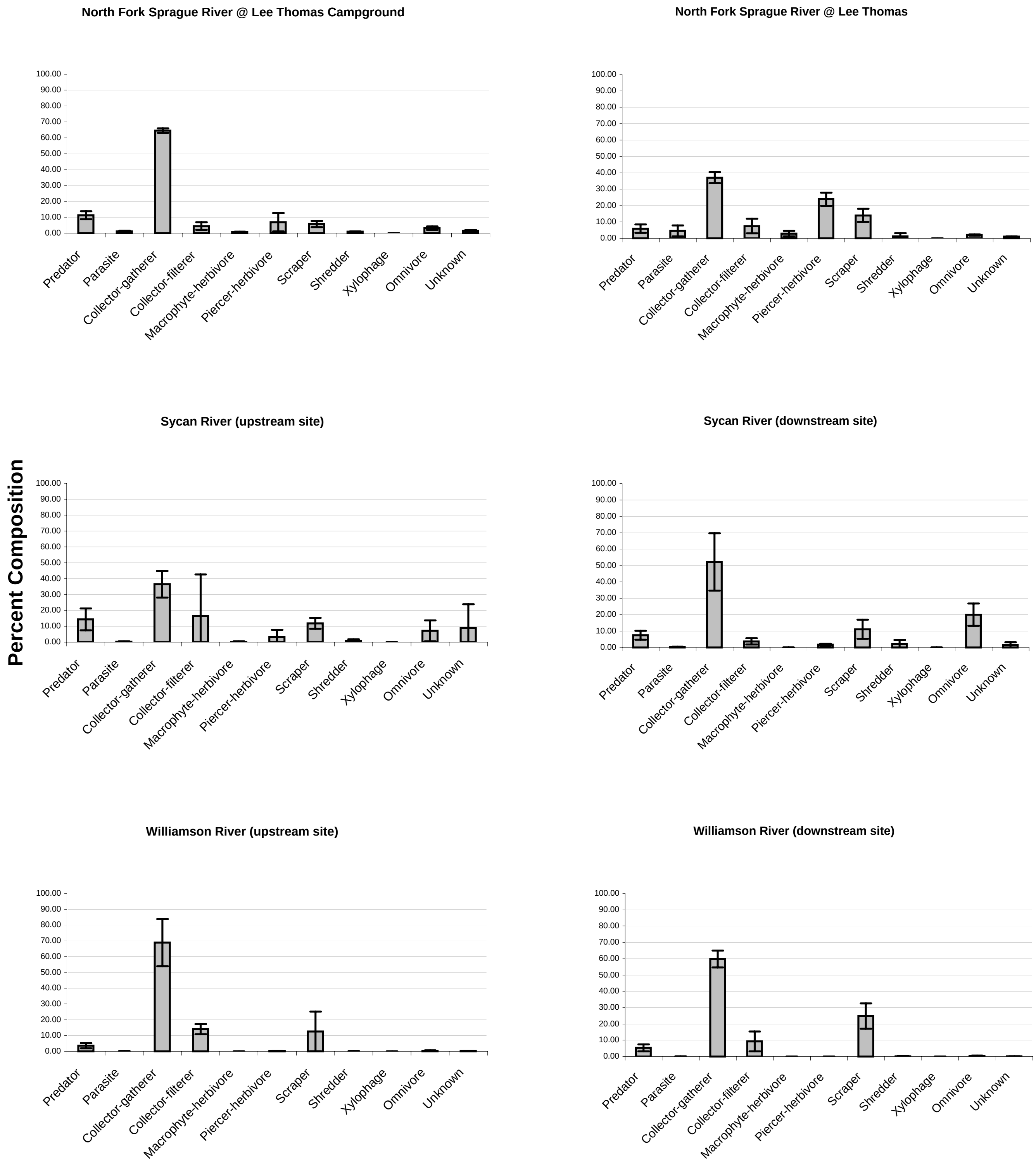


Figure 10. Mean percent composition of functional feeding groups at Sprague, Sycan, and Williamson River sampling stations August-October, 1999. Error bars represent (±) one standard deviation.

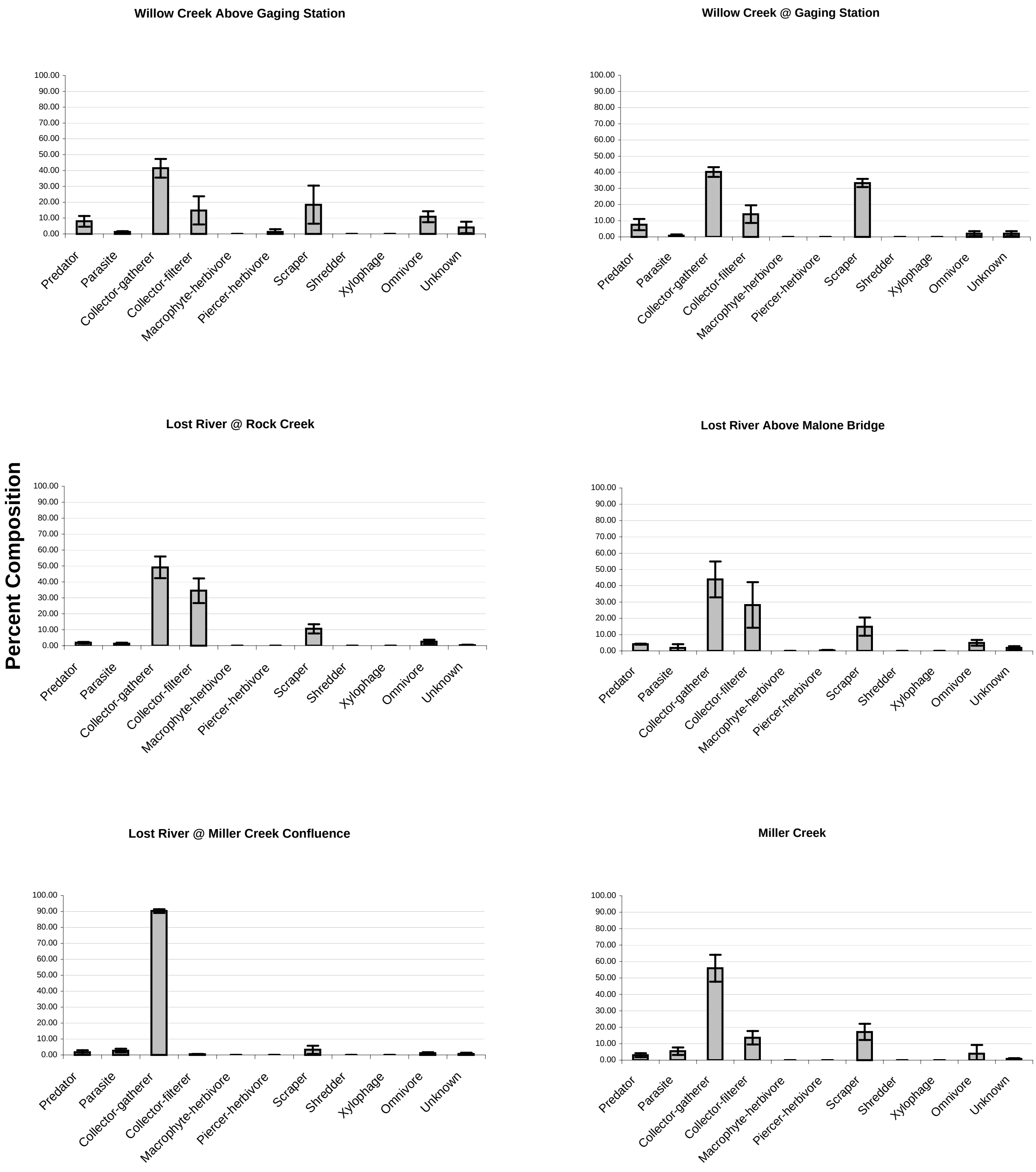


Figure 11. Mean percent composition of functional feeding groups at Lost River sub-basin sampling stations above Keller Bridge August-October, 1999. Error bars represent (±) one standard deviation.

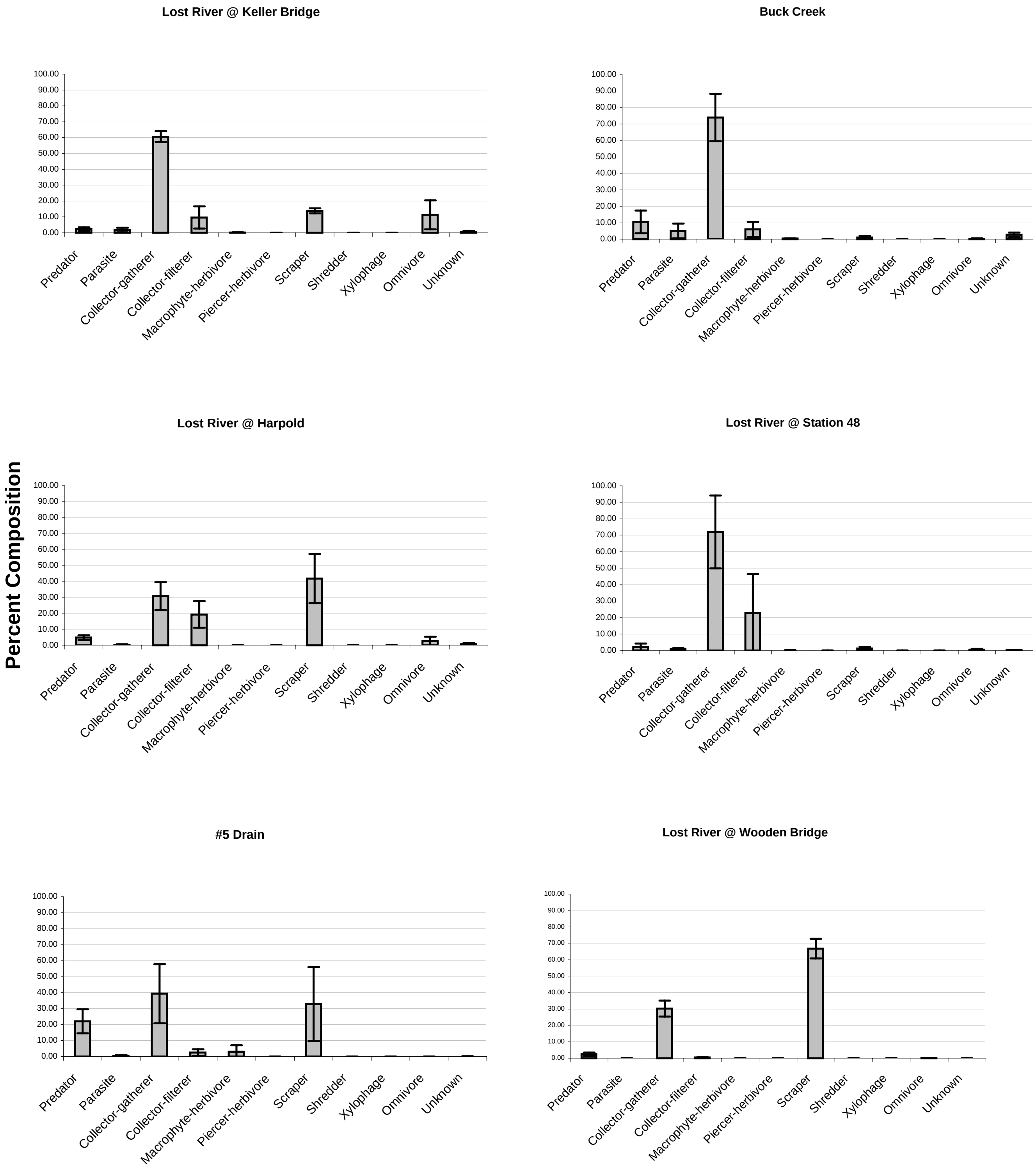
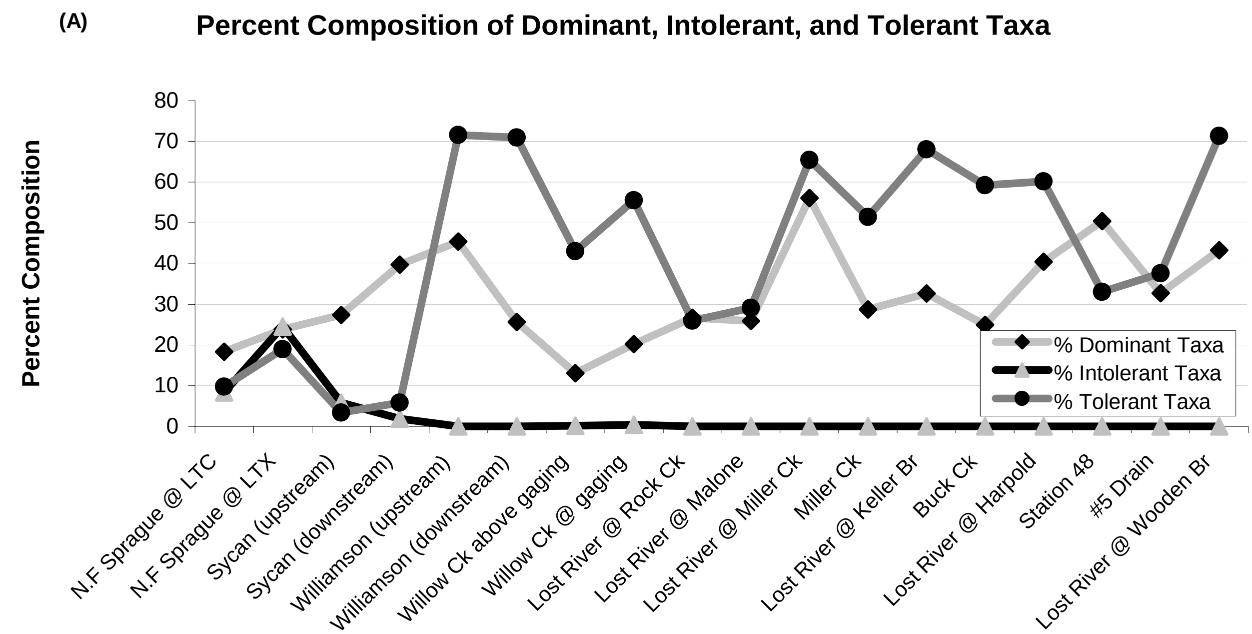
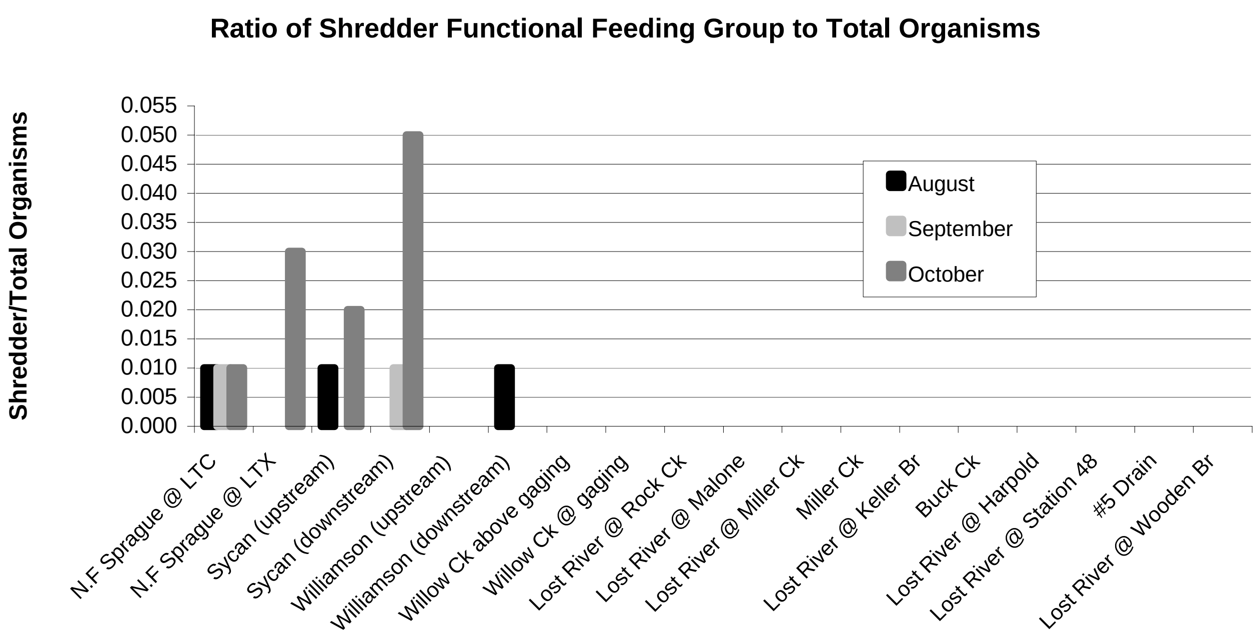


Figure 12. Mean percent composition of functional feeding groups at Lost River sub-basin sampling stations below Keller Bridge August-October, 1999. Error bars represent (±) one standard deviation.





Figures 13. Pooled percent contribution of dominant, intolerant, and tolerant taxa (A) for macroinvertebrate samples collected in the Sprague, Sycan, Williamson, and Lost River sub-basins August-October, 1999. Ratio of shredder functional feeding group to total organisms (B) for macroinvertebrate samples collected in the Sprague, Sycan, Williamson, and Lost River sub-basins August-October, 1999.

Table 4. Summary of macroinvertebrate community metrics for samples collected in the Sprague and Sycan Rivers August-October, 1999.

	NFK Sprague River @ LTC			NFK Sprague River @ LTX			Sycan River (upstream)			Sycan River (downstream)		
	riffle 8/13/99	riffle 9/9/99	riffle 10/4/99	riffle 8/13/99	riffle 9/9/99	riffle 10/4/99	riffle 8/13/99	riffle 9/9/99	riffle 10/4/99	riffle 8/13/99	riffle 9/9/99	riffle 10/4/99
PRIMARY METRICS												
Total abundance (m2)	9044	13714	10673	7965	8563	8515	8992	4456	4056	11332	8472	11588
Total taxa richness	49	50	48	50	50	51	42	40	41	43	43	31
EPT taxa richness	21	26	22	23	26	26	16	17	25	23	20	17
%Dominant taxa	16.78	23.50	14.66	27.76	19.83	24.01	25.37	46.79	10.02	49.36	42.61	27.20
Community Tolerance	3.57	3.70	3.94	3.60	3.72	3.37	3.96	5.10	4.09	5.71	5.54	4.41
POSITIVE INDICATORS												
Predator richness	6	11	9	9	11	14	5	7	7	6	8	7
Scraper richness	15	15	15	17	17	15	15	14	16	13	11	10
Shredder richness	3	3	4	1	1	4	3	0	5	2	2	3
Xylophage (wood eaters)	0	0	0	0	0	0	0	0	0	0	0	0
% Intolerant taxa	15.73	5.27	4.07	28.43	20.00	25.27	1.68	1.20	14.49	2.72	1.89	1.15
Intolerant taxa richness	7	7	5	2	2	7	4	3	4	3	3	1
+ habitat indicator richness	mod	mod	mod	mod	mod	mod	low	low	low	low	low	low
Long-lived taxa richness	7	8	7	7	5	9	2	5	5	4	3	2
Class 0 taxa richness	0	1	0	0	0	1	1	0	0	0	0	0
NEGATIVE INDICATORS												
%Collector	64.85	70.85	71.00	48.33	47.52	37.70	33.39	77.75	47.62	68.90	60.41	38.31
%Parasite	0.70	0.91	1.71	1.01	7.67	4.87	0.37	0.60	0.00	0.16	0.47	0.38
%Oligochaeta	1.77	0.91	5.30	0.50	0.83	0.54	0.74	1.79	0.99	0.32	0.00	0.77
%Leech	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
%Tolerant molluscs	0.35	0.00	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
%Tolerant crustacea	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Tolerant odonates	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Tolerant mayflies	1.42	0.00	0.00	0.17	0.17	0.00	0.00	0.15	0.00	0.16	0.16	0.00
% Tolerant caddisflies	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.00
% Tolerant beetles	12.54	10.57	4.21	13.88	24.67	17.69	0.74	2.55	0.16	6.09	4.25	6.51
%Tolerant dipterans	0.00	0.00	0.00	0.17	0.00	0.18	6.67	0.00	0.00	0.00	0.16	0.00
% Total tolerant	14.31	10.57	4.37	14.22	24.84	17.87	7.41	2.70	0.06	6.41	4.57	6.51
Tolerant taxa richness	5	2	3	5	3	4	4	3	1	4	4	1
%Simuliidae (blackfly)	0.35	1.28	0.16	8.70	3.00	0.18	0.56	46.79	1.48	0.64	3.46	0.00
%Chironomidae (midge)	28.80	14.57	12.32	33.11	24.83	27.08	45.56	8.67	40.07	68.75	70.28	39.85

Table 5. Summary of macroinvertebrate community metrics for samples collected in the Williamson River and Willow Creek August-October, 1999.

	Williamson River (upstream site)			Williamson River (downstream site)			Willow Creek above gaging station			Willow Creek @ gaging station		
	riffle	riffle	riffle	riffle	riffle	riffle	riffle	riffle	riffle	riffle	riffle	riffle
	8/5/99	9/8/99	9/28/99	8/5/99	9/8/99	9/28/99	8/3/99	9/3/99	10/1/99	8/3/99	9/3/99	10/1/99
PRIMARY METRICS												
Total abundance (m2)	27872	12767	1732	1855	10829	6720	13028	28523	8875	1459	14989	10079
Total taxa richness	24	29	20	26	28	21	43	49	48	42	39	42
EPT taxa richness	7	9	7	8	8	6	11	18	15	13	15	15
%Dominant taxa	63.98	32.78	39.42	22.26	30.44	24.16	8.9	18.56	11.82	18.04	25.17	17.48
Community Tolerance	7.25	6.8	6.95	6.13	6.39	6.43	6.13	4.9	5.37	5.14	4.71	4.79
POSITIVE INDICATORS												
Predator richness	6	5	3	5	7	5	7	5	6	5	6	4
Scraper richness	4	5	4	5	6	5	10	12	11	11	13	13
Shredder richness	0	1	0	0	0	0	0	0	0	0	0	0
Xylophage (wood eaters)	0	0	0	0	0	0	0	0	0	0	0	0
% Intolerant taxa	0	0	0	0	0	0	0	0	0.38	0.91	0.17	0.18
Intolerant taxa richness	0	0	0	0	0	0	0	0	2	1	1	1
+ habitat indicator richness	low	low	low	low	low	low	low	low	low	low	low	low
Long-lived taxa richness	1	2	1	3	3	3	5	5	7	6	4	6
Class 0 taxa richness	0	0	0	0	0	0	0	0	0	0	0	0
NEGATIVE INDICATORS												
%Collector	95.16	67.37	86.51	73.07	62.14	72.13	59.05	64.51	45.27	54.56	56.84	51.33
%Parasite	0.18	0.00	0.00	0.18	0.00	0.00	1.07	1.76	0.75	0.00	0.67	1.62
%Oligochaeta	1.43	7.37	9.23	6.82	6.64	13.94	3.68	5.43	6.57	7.76	4.67	3.06
%Leech	0.54	0.18	0.19	1.08	0.55	0.56	0.00	0.00	0.00	0.00	0.00	0.54
%Tolerant molluscs	0.36	23.57	10.19	1.26	27.31	13.94	1.38	0.18	0.95	0.68	3.83	5.94
%Tolerant crustacea	64.34	33.15	39.61	22.26	30.44	24.35	0.46	0.00	0.19	0.23	0.00	0.18
% Tolerant odonates	0.00	0.37	0.00	0.36	0.00	1.12	0.15	1.05	3.94	4.57	2.50	8.47
% Tolerant mayflies	7.89	4.60	9.23	10.77	11.43	15.80	0.77	0.36	1.13	7.08	2.16	8.65
% Tolerant caddisflies	4.48	6.07	4.04	11.49	3.51	3.35	8.89	4.39	16.33	1.37	4.67	1.44
% Tolerant beetles	0.36	2.21	1.15	16.16	5.72	9.48	10.28	32.24	29.45	27.85	43.01	28.29
%Tolerant dipterans	0.54	1.10	0.58	0.18	0.92	0.74	0.92	0.53	0.00	0.00	0.17	0.00
% Total tolerant	78.51	71.25	64.99	63.56	79.88	69.34	27.91	44.53	56.68	51.83	59.17	55.49
Tolerant taxa richness	12	12	9	9	11	11	19	18	18	14	14	18
%Simuliidae (blackfly)	1.61	1.66	5.58	0.72	0.18	1.12	0.61	1.05	2.81	4.57	5.00	0.36
%Chironomidae (midge)	13.08	14.73	1.92	10.77	4.98	3.16	47.55	15.24	13.32	13.47	7.33	9.55

Table 6. Summary of macroinvertebrate community metrics for samples collected in the Lost River and Miller Creek August-October, 1999.

	Lost River @ Rock Creek			Lost River @ Malone			Lost River @ Miller Creek			Miller Creek		
	riffle 8/4/99	riffle 9/2/99	riffle 9/23/99	riffle 8/4/99	riffle 9/2/99	riffle 9/23/99	riffle 8/5/99	riffle 9/7/99	riffle 9/23/99	riffle 8/5/99	riffle 9/7/99	riffle 9/29/99
PRIMARY METRICS												
Total abundance (m2)	12861	3949	5275	22778	11779	11547	13914	39695	48512	69132	24376	19014
Total taxa richness	26	28	30	34	36	38	25	33	23	26	30	26
EPT taxa richness	15	15	17	18	14	19	5	4	6	4	5	2
%Dominant taxa	25.05	31.74	23.18	19.65	27.35	30.62	36.27	73.32	58.65	24.47	29.51	32.22
Community Tolerance	5.19	4.76	4.65	5.09	5.18	4.93	5.76	4.53	4.67	5.57	5.25	5.22
POSITIVE INDICATORS												
Predator richness	2	4	3	3	5	5	4	6	3	1	3	3
Scraper richness	9	10	13	10	10	11	2	4	5	4	7	5
Shredder richness	0	0	0	0	0	0	0	0	0	0	0	0
Xylophage (wood eaters)	0	0	0	0	0	0	0	0	0	0	0	0
% Intolerant taxa	0	0	0	0	0	0	0	0	0	0	0	0
Intolerant taxa richness	0	0	0	0	0	0	0	0	0	0	0	0
+ habitat indicator richness	low	low	low	low	low	low	low	low	low	low	low	low
Long-lived taxa richness	0	2	2	1	4	4	1	6	4	3	4	4
Class 0 taxa richness	0	0	0	0	0	0	0	0	0	0	0	0
NEGATIVE INDICATORS												
%Collector	81.35	85.18	84.23	68.61	73.88	73.69	92.28	89.44	90.40	77.83	67.38	63.41
%Parasite	0.73	1.97	0.87	0.00	1.20	4.33	1.44	3.86	2.80	3.85	4.55	9.06
%Oligochaeta	2.19	3.13	0.69	8.25	10.58	3.63	17.59	1.51	5.27	15.22	5.83	2.28
%Leech	0.00	0.00	0.00	0.00	0.20	0.00	1.80	0.84	0.32	2.89	1.09	4.03
%Tolerant molluscs	0.00	0.00	0.00	1.06	0.40	0.69	0.36	1.01	0.00	9.25	7.29	16.12
%Tolerant crustacea	0.00	0.33	0.17	0.53	0.00	0.35	2.69	0.84	0.49	2.50	0.55	0.18
% Tolerant odonates	0.00	0.16	0.00	0.00	0.20	0.00	0.00	0.17	0.00	0.00	0.00	0.00
% Tolerant mayflies	2.56	12.83	32.52	19.83	11.38	14.18	39.14	76.84	60.13	24.66	29.51	32.22
% Tolerant caddisflies	10.79	4.27	11.76	15.45	10.78	7.28	0.00	0.34	1.15	0.00	0.36	0.00
% Tolerant beetles	0.18	0.16	0.34	0.18	0.80	0.52	0.18	4.19	5.10	5.01	8.20	9.63
%Tolerant dipterans	0.00	0.00	0.87	0.00	0.00	0.52	0.00	0.34	0.16	0.39	0.00	0.00
% Total tolerant	13.53	18.08	46.35	37.05	26.36	23.88	44.17	84.57	67.51	44.70	47.55	62.18
Tolerant taxa richness	5	8	13	11	13	15	8	15	11	7	12	9
%Simuliidae (blackfly)	14.26	31.74	11.42	0.70	4.19	0.87	0.00	0.00	0.00	11.56	16.76	9.98
%Chironomidae (midge)	6.22	3.62	0.69	24.04	17.17	23.88	34.47	6.71	17.79	15.99	19.31	13.13

Table 7. Summary of macroinvertebrate community metrics for samples collected in the Lost River and Buck Creek August-October, 1999.

	Lost River @ Keller Bridge			**Buck Creek**			**Lost River @ Harpold**		
	riffle 8/5/99	riffle 9/7/99	riffle 9/23/99	riffle 8/5/99	riffle 9/1/99	riffle 9/29/99	riffle 8/5/99	riffle 9/1/99	riffle 9/29/99
PRIMARY METRICS									
Total abundance (m2)	8219	8891	3890	5215	1239	1049	7119	6458	6919
Total taxa richness	30	25	30	28	30	24	28	28	30
EPT taxa richness	4	8	6	1	3	4	3	8	5
%Dominant taxa	29.98	38.89	28.98	30.65	20.70	23.49	33.51	58.48	29.24
Community Tolerance	5.42	4.61	4.83	5.73	6.36	6.19	5.64	5.52	5.60
POSITIVE INDICATORS									
Predator richness	7	4	7	6	5	2	6	4	5
Scraper richness	1	4	4	4	4	2	3	4	4
Shredder richness	0	0	0	0	0	0	0	0	0
Xylophage (wood eaters)	0	0	0	0	0	0	0	0	0
% Intolerant taxa	0	0	0	0	0	0	0	0	0
Intolerant taxa richness	0	0	0	0	0	0	0	0	0
+ habitat indicator richness	low	low	low	low	low	low	low	low	low
Long-lived taxa richness	2	2	4	4	3	1	3	2	3
Class 0 taxa richness	0	0	0	0	0	0	0	0	0
NEGATIVE INDICATORS									
%Collector	81.35	67.61	61.70	70.22	76.90	92.70	50.20	34.74	65.16
%Parasite	3.24	0.37	1.53	8.43	6.72	0.00	0.72	0.00	0.00
%Oligochaeta	6.00	5.74	8.64	9.58	8.06	8.57	12.63	6.19	7.94
%Leech	1.13	0.74	0.51	17.05	7.79	2.22	0.53	2.80	1.08
%Tolerant molluscs	0.16	0.19	0.00	7.85	2.42	11.43	33.69	58.88	30.32
%Tolerant crustacea	6.48	1.85	4.58	5.94	9.95	14.60	1.23	3.79	8.12
% Tolerant odonates	0.32	0.37	1.69	0.19	1.34	1.90	0.18	0.80	2.17
% Tolerant mayflies	32.41	38.70	30.17	30.65	16.94	24.44	5.44	8.59	10.47
% Tolerant caddisflies	0.81	14.63	18.31	0.00	0.00	0.00	0.00	1.20	0.54
% Tolerant beetles	13.94	17.78	18.48	1.14	0.54	0.32	1.76	4.39	1.81
%Tolerant dipterans	0.32	0.00	0.34	0.19	0.00	0.00	1.93	0.40	0.36
% Total tolerant	55.73	74.26	74.25	63.01	59.68	54.91	44.76	80.85	54.87
Tolerant taxa richness	13	13	16	13	12	8	12	15	15
%Simuliidae (blackfly)	12.48	4.26	1.36	11.11	1.88	4.44	1.93	5.59	3.79
%Chironomidae (midge)	17.50	5.93	5.08	4.79	14.52	27.62	16.14	2.59	5.78

Table 8. Summary of macroinvertebrate community metrics for samples collected in the Lost River and # 5 Drain August-October, 1999.

	Lost River @ Station 48			**# 5 Drain**			**Lost River @ Wooden Bridge**		
	riffle 8/6/99	riffle 9/1/99	riffle 9/28/99	riffle 8/5/99	riffle 9/1/99	riffle 9/29/99	riffle 8/5/99	riffle 9/1/99	riffle 9/28/99
PRIMARY METRICS									
Total abundance (m2)	22938	4612	9842	7958	4758	2853	3616	969	4240
Total taxa richness	27	23	27	21	16	25	17	12	19
EPT taxa richness	4	4	5	1	0	2	1	1	2
%Dominant taxa	49.83	62.20	39.30	27.04	51.15	20.04	61.51	35.05	33.21
Community Tolerance	5.66	7.12	5.60	7.15	7.27	7.17	5.46	6.15	6.38
POSITIVE INDICATORS									
Predator richness	3	4	3	2	3	4	1	1	3
Scraper richness	5	1	3	6	3	5	5	3	5
Shredder richness	0	0	0	0	0	0	0	0	0
Xylophage (wood eaters)	0	0	0	0	0	0	0	0	0
% Intolerant taxa	0	0	0	0	0	0	0	0	0
Intolerant taxa richness	0	0	0	0	0	0	0	0	0
+ habitat indicator richness	low	low	low	low	low	low	low	low	low
Long-lived taxa richness	4	0	2	6	3	5	6	3	4
Class 0 taxa richness	0	0	0	0	0	0	0	0	0
NEGATIVE INDICATORS									
%Collector	94.76	93.12	96.49	25.68	60.11	39.47	26.50	29.55	36.07
%Parasite	0.87	1.37	0.92	0.97	0.19	0.19	0.00	0.00	0.00
%Oligochaeta	10.45	62.2	16.42	12.84	51.15	13.81	0.74	8.25	5.18
%Leech	0.52	3.74	0.55	21.79	30.34	15.95	0.00	0.00	0.77
%Tolerant molluscs	0.52	0.00	0.18	12.65	1.53	10.50	69.97	74.91	36.86
%Tolerant crustacea	10.1	0.20	0.37	0.97	0.57	3.50	3.31	5.15	12.47
% Tolerant odonates	0.00	0.39	0.18	0.00	0.00	0.19	1.29	2.41	2.50
% Tolerant mayflies	50.7	10.83	9.41	0.00	0.00	1.16	0.00	0.69	0.58
% Tolerant caddisflies	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.00	0.19
% Tolerant beetles	0.17	0.20	0.37	0.39	0.95	7.98	0.00	0.00	0.77
%Tolerant dipterans	8.53	0.59	1.66	0.58	1.14	2.72	0.37	1.72	0.00
% Total tolerant	70.54	15.95	12.72	36.38	34.53	42.00	75.12	84.88	54.14
Tolerant taxa richness	11	9	10	11	7	13	9	8	12
%Simuliidae (blackfly)	0.35	2.56	10.33	3.50	2.10	0.19	0.00	0.00	0.00
%Chironomidae (midge)	12.20	10.83	19.74	1.95	4.96	15.37	0.55	2.41	0.38

Discussion

An important step in any watershed restoration program is to identify environmental factors that influence the structure and function of stream communities. Combining chemical, physical, and biological data provides researchers and managers with essential information for making natural resource management decisions. With this knowledge, restoration efforts can be focused on causal factors that provide the greatest long-term benefit, thus making wise-use of limited resources. A primary objective of this study was to provide baseline macroinvertebrate community data for the Lost River sub-basin. These data will complement on-going water quality assessments and provide an important tool to monitor the effectiveness of future habitat restoration efforts.

Another objective was the identification of suitable reference conditions for the Lost River sub-basin. Because stream communities are influenced by large-scale geomorphological factors, we examined sites in relation to ecoregional, watershed, and reach level conditions. Without an understanding of how large-scale factors influence the physical-habitat template, it is difficult to identify natural versus anthropogenic influences on stream communities. Unfortunately, rivers flowing through low gradient, unconfined valleys such as the Lost River are generally heavily developed and often exhibit water quality impairments. This necessitates the identification of least-impaired conditions with similar physical characteristics to represent an ecological benchmark for making comparisons between sites. However, sites sampled in the Sprague, Sycan, and Williamson River watersheds are treated separately from Lost River sub-basin sites due to significant watershed and reach level differences in physical characteristics. For this reason, the Sprague, Sycan, and Williamson River sites are not considered to represent comparable reference communities for the Lost River sub-basin. Although not directly comparable, the Sprague and Sycan River sites represent less impaired communities in the upper Klamath River basin. The following discussion will focus on relevant aspects of community composition, structure, and function as presented in the results section of this report, with an emphasis on Lost River sub-basin sites.

Our sites within the Lost River sub-basin exhibit a range of conditions from relatively least-impaired sites above Malone Dam to sites with macroinvertebrate assemblages characteristic of severely impaired water quality and habitat conditions. All sites below Malone Dam display low total and EPT taxonomic richness, highly variable abundance values, and low

Shannon H' diversity values. Macroinvertebrate assemblages at these sites also exhibit a high proportion of tolerant organisms, no intolerant organisms, and a functional feeding group devoid of shredders and dominated by collectors.

Sprague and Sycan River sites had macroinvertebrate assemblages characteristic of mid order, moderate gradient, cold water streams. The presence of intolerant taxa at these headwater sites is an indicator of good water quality and habitat conditions. Macroinvertebrate community metrics, substrate analysis, and hydrolab data provide detailed baseline monitoring data for these sites. In contrast, our Williamson River sites had macroinvertebrate assemblages that indicate poor habitat and water quality conditions when evaluated by community based metrics. However, these sites are not considered to be representative of the Williamson River as a whole. Sites sampled on the Williamson River contained unstable, shifting substrate conditions and macroinvertebrate community composition, structure, and function was most likely influenced by these conditions. Substrate quality at these sites may partially explain metric results that indicate habitat quality impairment. Additional macroinvertebrate sampling throughout the Williamson River watershed is needed to adequately characterize macroinvertebrate community composition, structure, and function.

Macroinvertebrate abundance was variable within and among all sites. However, abundance variability was particularly pronounced in Lost River sub-basin sites. High variability found in the Lost River sub-basin may be a result of organic enrichment creating "boom and bust" communities (Robert Wisseman, personal communication, 2000). Moreover, a high percentage of surface fines in riffle habitat units and the resultant growth of filamentous algae create a more heterogeneous distribution of macroinvertebrates (Meryl Brusven, personal communication, 2000). These factors may explain the highly variable abundance values found in Lost River sub-basin sites.

Another biologically meaningful metric is the percent composition of facultative, tolerant, and intolerant taxa. Species composition and abundance of invertebrate assemblages is a result of differential requirements of specific taxa in relation to environmental conditions present within a given stream (Hawkins et al. 1982). These conditions reflect the ecological integrity of the land-water ecosystem. Therefore, the community composition of facultative, tolerant, and intolerant taxa associated with a given site can provide insight into water quality conditions. Because facultative and tolerant taxa occupy a wide range of water quality and habitat conditions, we feel it is biologically relevant to focus attention on the presence and absence of intolerant taxa, those found only in high water quality and habitat conditions. Only the Sprague and Sycan River and Willow Creek communities contained intolerant taxa. No intolerant taxa were found below Clear Lake Reservoir in the Lost River sub-basin, indicating severely degraded conditions.

A modified Hilsenhoff biotic index, or community tolerance value (CTV), was applied to all macroinvertebrate communities sampled. CTV's generally increased at downstream sites in the Lost River sub-basin. Tolerance values greater than 5.0 often indicate a community tolerant of organic enrichment and hypoxic conditions (Wisseman, personal communication, 1999). Most Lost River sub-basin sites exceed this value. It is important to note that regional variations in the sensitivity of invertebrates to stress may occur (Winget and Mangum, 1979). Because limited macroinvertebrate data collection has occurred in eastern Cascade rivers and streams, refinement of community tolerance values should accompany future biomonitoring efforts to more accurately represent conditions found in this area.

Shannon H' ($\log_2$) diversity values show an inverse relationship to CTV, with a decreasing trend as one moves downstream the Lost River sub-basin. Shannon H' values reach a maximum when taxonomic richness is high and the community is distributed evenly in terms of species composition. Biologically, this is assumed to represent ideal conditions, however, evidence suggest that diversity values based on information theory may be dependent on study design and should be interpreted and compared with caution.

Taxonomic richness, another commonly used macroinvertebrate metric, generally decreases with decreasing water quality and habitat conditions. Again, a decreasing trend in taxonomic richness can be seen in Lost River sub-basin sites from Willow Creek to downstream sites. A similar metric, EPT taxonomic richness, is based on Ephemeroptera (mayfly), Plecoptera (stonefly), and Trichoptera (caddisfly) taxonomic richness. These taxa are generally sensitive to most types of pollution and EPT taxonomic richness will decrease with a decline in water quality and habitat conditions. Lost River sub-basin sites below Malone Dam have very low EPT richness values indicating water quality and habitat impairment.

The percent composition of functional feeding groups can be used to represent the organization of macroinvertebrate assemblages into categories based on feeding behavior. The relative abundance and presence or absence of certain functional feeding groups can provide insights into specific water quality and habitat conditions as well as ecosystem trophic status. Of particular interest to this study is the complete absence of a shredder functional feeding group in lost River sub-basin sites. Shredders feed on coarse particulate organic matter (CPOM), and the bacterial and fungal communities supported thereon, consisting mainly of allochthonous detritus. The absence of a shredder community in the Lost River system seems to be a result of habitat modifications resulting in an almost ubiquitous lack of healthy riparian zones along the stream corridor. Examining macroinvertebrate community assemblages could effectively monitor future restoration efforts aimed at improving riparian conditions in the Lost River and tributaries.

We examined the insect-substrate relationship by quantifying the percentage of surface fines found in riffle sampling units. Substrate quality in lotic environments is an important component of any habitat assessment when evaluating benthic macroinvertebrate communities (Plafkin et al. 1989). As the percentage of fines found in riffle habitat units increases, interstitial space in the hyporheic zone may be limited, thus limiting available habitat for certain invertebrates. Lost River sub-basin sites below Malone Dam, with the exception of our Harpold site, have a very high percentage of surface fines associated with their riffle habitat units. This may be a factor of low gradient and stream velocities present throughout the Lost River sub-basin below Malone Dam. However, since land use practices can modify the character of surficial sediments, we consider percent fines to be an important variable that may be structuring the macroinvertebrate community.

Presented macroinvertebrate data and associated water quality, habitat, and fish community assessments provide valuable information that can be used to help direct management decisions and evaluate the ecological integrity of the Lost River sub-basin. These data are needed to identify factors associated with the biological health of the system and should be used to effectively monitor the success of ongoing and proposed restoration efforts. Our macroinvertebrate community data for the Lost River sub-basin provides important baseline information. Used in combination with associated water quality, habitat, and fish community assessments, these data provide valuable information that can be used to evaluate the ecological integrity of stream ecosystems and used to monitor the effects of habitat restoration efforts.

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Appendix Tables

Water quality and physical measurements

Appendix Table 2-1. Selected water quality data collected in the Lost River sub-basin, 1999.

Date	Site	Time	Chlorophyll A	Total Alkalinity	Ammonia-N	Nitrate-Nitrite-N	Ortho-phosphate	Total Phosphorus	Total Nitrogen	Turbidity-NTU	NTU	NTU
08/04/99	Malone Dam	8:38	8.0	70	<0.1	0.10	0.1	0.2	0.5	56.6	55.3	56.3
08/18/99	Malone Dam	13:27	10.0	70	<0.1	<0.04	0.1	0.3	0.8	58.5	58.4	58.4
08/31/99	Malone Dam	8:17	<5.0	80	<0.1	<0.04	0.2	0.2	0.7	60.6	60.0	60.8
09/15/99	Malone Dam	13:47	<5.0	80	0.1	0.04	0.1	0.2	0.5	55.7	56.8	57.6
09/29/99	Malone Dam	8:15	10.0	70	<0.1	<0.04	0.1	0.2	0.9	69.1	70.3	72.7
10/13/99	Malone Dam	11:19	13.0	90	<0.1	<0.04	0.1	0.3	1.1	107.0	108.0	108.0
10/28/99	Malone Dam	8:15	8.0	100	0.2	0.05	<0.1	0.2	1.5	85.6	83.6	82.0
08/04/99	Miller Creek	9:08	8.0	40	<0.1	0.15	<0.1	<0.1	0.5	9.4	8.2	9.0
08/18/99	Miller Creek	13:03	<5.0	40	<0.1	0.13	<0.1	0.2	0.5	7.2	6.7	7.2
08/31/99	Miller Creek	8:45	<5.0	40	<0.1	<0.04	<0.1	<0.1	0.6	8.9	9.2	8.4
09/15/99	Miller Creek	13:15	6.0	40	<0.1	0.08	<0.1	<0.1	<0.3	6.7	6.6	6.4
09/29/99	Miller Creek	8:52	7.0	40	<0.1	0.05	<0.1	<0.1	0.6	8.7	10.0	9.9
10/13/99	Miller Creek	11:57	<5.0	150	<0.1	<0.04	<0.1	<0.1	<0.3	2.4	2.1	3.1
10/28/99	Miller Creek	8:45	<5.0	150	0.1	0.14	<0.1	<0.1	0.6	2.1	2.1	1.9
08/04/99	Keller Bridge	9:30	6.0	120	<0.1	0.09	0.1	0.2	1.0	18.2	17.9	17.9
08/18/99	Keller Bridge	12:41	<5.0	120	<0.1	0.06	0.1	0.3	0.9	21.0	21.3	21.0
08/31/99	Keller Bridge	9:04	<5.0	110	0.1	<0.04	0.1	0.1	0.8	18.6	18.1	18.4
09/15/99	Keller Bridge	12:55	8.0	120	0.1	0.07	0.1	0.2	0.5	23.4	23.7	23.4
09/29/99	Keller Bridge	9:25	13.0	100	<0.1	0.08	0.1	0.2	1.1	22.8	22.2	21.8
10/13/99	Keller Bridge	13:00	<5.0	220	<0.1	0.18	<0.1	<0.1	0.7	14.6	14.1	13.6
10/28/99	Keller Bridge	9:00	<5.0	190	0.2	0.20	<0.1	<0.1	1.5	13.0	12.5	12.7
08/04/99	Buck Creek	10:06	13.0	140	<0.1	0.84	0.2	0.2	0.5	2.1	3.0	2.2
08/18/99	Buck Creek	11:50	<5.0	130	<0.1	0.29	0.2	0.2	0.6	4.6	6.0	4.7
08/31/99	Buck Creek	9:37	<5.0	230	0.1	0.98	0.3	0.4	0.9	3.1	3.7	3.3
09/15/99	Buck Creek	11:47	12.0	140	<0.1	0.87	<0.1	0.2	0.5	4.0	3.8	3.5
09/29/99	Buck Creek	10:20	5.0	170	<0.1	0.82	0.2	0.2	0.6	3.4	3.6	3.3
10/13/99	Buck Creek	13:48	<5.0	230	<0.1	1.30	0.1	0.2	0.7	2.6	3.2	3.4
10/28/99	Buck Creek	10:10	<5.0	240	0.2	4.50	0.1	0.2	1.3	4.0	4.3	4.5

Appendix Table 2-1 (Continued). Selected water quality data collected in the Lost River sub-basin, 1999.

Date	Site	Time	Chlorophyll A	Total Alkalinity	Ammonia-N	Nitrate-Nitrite-N	Ortho-phosphate	Total Phosphorus	Total Nitrogen	Turbidity-NTU	NTU	NTU
08/04/99	Harpold	10:20	10.0	120	<0.1	0.23	0.1	0.2	0.7	8.8	9.0	9.0
08/18/99	Harpold	11:38	<5.0	130	<0.1	0.41	0.1	0.1	0.7	9.6	9.7	9.5
08/31/99	Harpold	10:18	<5.0	150	<0.1	0.25	0.1	0.2	0.7	8.6	8.4	8.5
09/15/99	Harpold	11:00	8.0	130	<0.1	0.20	0.1	0.2	0.5	11.7	11.8	11.7
09/29/99	Harpold	10:42	12.0	120	<0.1	0.20	0.1	0.2	0.8	14.1	14.6	14.5
10/13/99	Harpold	14:09	<5.0	140	<0.1	0.35	<0.1	<0.1	0.3	8.9	8.4	9.5
10/28/99	Harpold	10:30	<5.0	130	0.1	0.57	<0.1	0.1	0.5	10.0	7.6	7.8
08/04/99	Station 48	11:31	5.0	70	0.3	0.14	0.2	0.3	1.4	3.8	4.1	4.1
08/18/99	Station 48	10:41	<5.0	120	0.2	0.22	0.2	0.2	1.0	4.2	4.0	4.4
08/31/99	Station 48	11:38	<5.0	130	0.3	0.08	0.2	0.3	1.3	3.8	4.8	5.0
09/15/99	Station 48	9:54	<5.0	130	0.2	0.21	0.2	0.3	0.9	6.1	6.5	5.7
09/29/99	Station 48	13:34	11.0	120	0.2	0.26	0.2	0.2	1.1	7.0	7.5	9.5
10/13/99	Station 48	8:22	11.0	130	0.1	0.32	0.2	0.2	0.8	8.2	7.4	8.2
10/28/99	Station 48	12:10	8.0	150	0.2	0.31	<0.1	0.1	1.0	8.7	9.5	9.2
08/04/99	#5 Drain	12:30	8.0	110	0.1	0.47	0.3	0.4	1.2	3.4	3.4	3.6
08/18/99	#5 Drain	9:43	61.0	90	0.3	0.24	0.3	0.4	2.4	22.1	13.2	34.7
08/31/99	#5 Drain	12:49	15.0	100	0.3	0.71	0.2	0.3	1.7	4.2	4.9	4.2
09/15/99	#5 Drain	8:52	17.0	100	0.3	0.50	0.3	0.4	1.5	4.2	8.3	4.8
09/29/99	#5 Drain	13:58	14.0	100	<0.1	0.58	0.2	0.3	1.3	4.9	4.4	5.7
10/13/99	#5 Drain	9:13	13.0	90	0.2	0.76	0.2	0.3	1.2	5.7	4.9	5.3
10/28/99	#5 Drain	12:40	<5.0	270	0.9	2.40	0.6	0.6	1.5	1.4	11.8	1.3
08/04/99	Anderson Rose	12:48	<5.0	90	0.2	0.41	0.2	0.3	1.2	3.8	3.7	3.4
08/18/99	Anderson Rose	9:17	18.0	120	0.3	0.42	0.3	0.4	1.5	6.0	5.4	6.3
08/31/99	Anderson Rose	14:00	10.0	100	0.4	0.56	0.3	0.4	1.4	3.8	3.8	4.2
09/15/99	Anderson Rose	8:57	12.0	110	0.3	0.49	0.3	0.4	1.4	12.8	6.2	8.1
09/29/99	Anderson Rose	14:28	15.0	110	0.1	0.54	0.2	0.3	1.4	4.5	4.4	5.0
10/13/99	Anderson Rose	10:03	14.0	100	0.1	0.53	0.2	0.3	1.2	4.6	4.9	5.0
10/28/99	Anderson Rose	13:05	8.0	180	0.4	0.69	0.2	0.2	1.1	6.9	6.2	6.6

Appendix 2-2. Physical and water quality measurements collected in the Sprague, Sycan, and Lost River sub-basin, 1999.

Site Name	**Date**	**Time**	**Temperature (°C)**	**Dissolved Oxygen (mg/L)**	**Conductivity (*u*S/cm)**	**pH (units)**	**Flow (cfs)**	**Average Velocity (ft/sec.)**
North Fork Sprague River @ Lee Thomas Campground	08-13-99	1036	9.40	9.50	44.00	7.28	15	0.9
	09-09-99	0945	5.00	10.43	43.30	7.72	12	0.8
	10-04-99	1115	5.39	10.55	43.90	7.59	13	0.9
North ForkSprague River @ Lee Thomas Crossing	08-13-99	1116	10.11	9.89	42.70	7.51	17	1.1
	09-09-99	1014	5.51	10.95	43.50	7.62	14	1.0
	10-04-99	1140	5.79	10.62	44.20	7.78	15	1.0
Sycan River (upstream site) @ 3380 and Hwy 28	08-13-99	1254	10.37	9.89	36.60	7.01	14	1.2
	09-09-99	1134	6.69	10.89	42.60	7.51	7	0.8
	10-04-99	1335	6.55	10.44	42.70	7.61	6	0.8
Sycan River (downstream site) @ Hwy 28	08-13-99	1332	14.35	8.60	48.50	7.93	19	1.4
	09-09-99	1209	10.59	10.29	50.70	8.34	12	1.3
	10-04-99	1400	7.98	10.36	50.10	7.90	9	1.0
Williamson River (upstream site) near Solomon Butte	08-05-99	0930	19.59	6.25	117.00	7.52	18	0.8
	09-08-99	1304	17.39	7.86	120.10	7.36	73	1.2
	09-28-99	1400	13.30	8.35	96.50	7.23	73	1.2
Williamson River (downstream site) near Solomon Butte	08-05-99	1000	18.99	6.21	117.00	7.54	18	0.8
	09-08-99	1325	17.67	7.52	120.30	7.34	73	1.2
	09-28-99	1440	13.61	8.38	96.40	7.36	73	1.2
Willow Creek above USBOR Gaging Station	08-03-99	1330	26.10	8.43	212.00	8.49	6	0.5
	09-03-99	1050	15.93	7.25	236.00	8.33	5	0.5
	10-01-99	1350	16.15	11.56	208.00	8.65	11	0.6
Willow Creek below USBOR Gaging Station	08-03-99	1100	21.97	8.03	217.00	8.33	6	0.5
	09-03-99	1000	14.53	7.43	239.00	8.31	5	0.5
	10-01-99	1300	15.17	10.05	208.00	8.60	11	0.6
Lost River @ Rock Creek	08-04-99	1415	24.74	7.46	139.00	8.04	154	1.0
	09-02-99	1055	16.84	7.13	150.00	8.13	103	0.7
	09-23-99	1030	17.09	8.48	158.00	7.91	120	0.8
Lost River above Malone Bridge	08-04-99	1130	22.05	8.32	140.00	8.10	154	1.4
	09-02-99	0945	15.38	7.41	143.20	8.23	103	0.6
	09-23-99	1140	17.48	10.11	152.00	8.41	120	1.0
Lost River @ Miller Creek	08-05-99	1035	18.98	13.26	248.00	8.40	61	1.1
	09-07-99	1100	16.28	8.75	226.00	8.15	50	0.8
	09-23-99	1255	17.96	10.12	230.00	7.99	54	0.9

Appendix 2-2 (Continued). Physical and water quality measurements collected in the Sprague, Sycan, and Lost River sub-basin, 1999.

Site Name	**Date**	**Time**	**Temperature (°C)**	**Dissolved Oxygen (mg/L)**	**Conductivity (*u*S/cm)**	**pH (units)**	**Flow (cfs)**	**Average Velocity (ft/sec.)**
Miller Creek	08-05-99	0933	17.96	10.04	250.00	8.15	9	0.9
	09-07-99	1243	17.69	13.59	293.00	9.05	5	0.5
	09-29-99	1255	14.14	13.82	242.00	8.61	7	0.6
Lost River @ Keller Bridge	08-05-99	1134	20.14	6.19	231.00	7.41	81	0.4
	09-07-99	1400	16.64	6.90	236.00	7.92	131	0.5
	09-23-99	1245	17.00	8.00	251.00	7.49	120	0.6
Buck Creek	08-05-99	1325	19.39	11.67	340.00	8.56	17	0.4
	09-01-99	1515	16.11	9.52	599.00	8.57	15	0.4
	09-29-99	1400	14.72	14.20	409.00	8.74	5	0.1
Lost River @ Harpold	08-05-99	1403	21.64	8.49	253.00	8.41	75	0.5
	09-01-99	1330	16.57	7.54	313.00	8.09	149	0.7
	09-29-99	1040	12.55	8.57	257.00	7.91	232	0.9
Lost River @ Station 48	08-06-99	1315	21.51	6.71	246.00	7.85	283	No Data
	09-01-99	1138	18.76	5.50	288.00	7.46	154	No Data
	09-28-99	1115	14.40	9.25	274.00	7.40	5	No Data
# 5 Drain @ Wong Road	08-05-99	1503	22.82	7.49	191.00	8.12	23	0.4
	09-01-99	1000	14.75	4.67	264.00	7.38	37	0.5
	09-29-99	1630	14.84	13.12	270.00	8.63	22	0.4
Lost River @ Wooden Bridge	08-05-99	1537	23.93	10.80	188.00	8.51	22	0.2
	09-01-99	0918	13.98	1.30	175.00	7.07	23	0.2
	09-28-99	1015	12.19	5.28	253.00	7.28	85	0.8

Chapter 3

Species Composition and Distribution of Fishes in the Lost River, Oregon

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Introduction

The Lost River is a closed drainage basin and originates in Modoc County, California east of Clear Lake Reservoir and flows approximately 120 km to Tule Lake Sump, California. The river is regulated through releases from Clear Lake Reservoir as well as numerous diversions for agriculture. The system is highly degraded due to agricultural activities, extensive cattle grazing, channel modifications, and water diversions (see Kohler et al., (a) this report for further discussion).

Information regarding the fish community structure in the Lost River is limited. Koch and Contreras (1973) and Cantreras (1973) reported on fish community structure based on an intensive 10 day survey in April, 1973, in which sampling was conducted from above Clear Lake downriver into Tule Lake Sump and through the water system into Klamath Straits Drain. Results of this survey indicated that both Lost River *Deltistes luxatus* and shortnose suckers *Chasmistes brevirostris* were found within the system, although shortnose were the predominant sucker species captured below Malone Dam, particularly in Harpold Reservoir. Other dominant species noted in the survey were blue chub *Gila coerulea*, tui chub *G. bicolor*, and bullheads *Ameiurus* spp.

The presence of two endangered fish species, the Lost River sucker and shortnose sucker has focused attention on monitoring and restoration efforts in the Lost River sub-basin. Viable populations of both species have been documented in Clear Lake (Lost River and shortnose suckers) and Gerber (shortnose suckers) reservoirs (Scoppettone et al., 1995; Bureau of Reclamation, unpublished data). However, little information exists regarding the status of Lost River and shortnose suckers in the Lost River.

In 1999, the U.S. Geological Survey, with support from the U.S. Bureau of Reclamation (BOR), conducted a detailed inventory of the Lost River fish community. This report summarizes location and dates sampled as well as the species and size of fish captured with particular emphasis on Lost River and shortnose suckers.

Methods

We partitioned the Lost River into five reaches as defined by the presence of four major diversion dams that exist on the river, Anderson-Rose, Lost River Diversion (Wilson), Harpold, and Malone (Figure 1). Within these reaches, sampling stations were chosen to try to sample representative habitat conditions and to maximize catches of suckers. Access to certain areas was limited due to private land ownership, unsuitable boat launching sites, and the presence of dense submerged aquatic macrophytes preventing the use of motorized boats. In addition to these reaches, we sampled two tributaries to the Lost River, the East Fork of the Lost River below Willow Valley Reservoir and Miller Creek near its confluence with the Lost River.

We used a combination of gear types to sample fish including trammel nets, trap nets, beach and minnow seines, minnow traps, and backpack electrofishing units (Table 1). Trammel nets were the most commonly deployed gear and were 1.8 m tall with two outer panels (30cm bar mesh), an inner panel (3.8 cm bar mesh), a foam core float line, and a lead core bottom line. The length of trammel nets used varied in length from 10 m to 90 m and were generally set perpendicular to shore for 2-5 hours. Trap nets consisted of a 1.2 m high x 30.5 m long lead followed by two 1.2 m x 1.8 m rectangular frames that were held 1 m apart by two PVC pipes. Behind the frames were four 1 m diameter circular hoops spaced at 1 m intervals. Internally, each net had three fykes. Trap nets were used in reservoir areas, generally within 2 km upriver of the dams, and were set perpendicular to shore and fished for 15-24 hours. We also used a beach seine (length 15 m, 3.2 mm bar mesh) and minnow seine (length 3.1 m, 3.2 mm bar mesh) in wadeable near-shore areas. We standardized effort by sampling for 30 minutes with both types of seines. Minnow traps (0.6 m x 0.2 m) were baited with commercial catfish bait or dog food and set in near shore areas (usually in backwater areas) for 24 hours. Backpack electrofishing (Smith-Root model 15-B) was conducted on a limited basis in selected tributaries of the Lost River with voltage, pulse frequency, and pulse width being variable based on water conductivity and habitat conditions.

Adult suckers captured were identified by species and sex, measured to the nearest mm (fork length), inspected for tags (both Passive Integrated Transponder (PIT) and Floy anchor tags), and examined for physical afflictions (e.g., presence of *Lernaea* spp. and lamprey wounds and scars). If a sucker did not have a PIT tag, one was inserted with a hypodermic needle along the ventral surface 1-2 cm anterior to the pelvic girdle. We made no attempt to identify species or sex of juvenile suckers (< 250 mm) captured. Juvenile suckers were either measured to the nearest mm or grouped into length categories. Other fish species captured were identified and measured to the nearest mm, or when many fish were captured grouped in 25 mm categories.

Table 1. Summary of stations sampled, sampling date, gear-type used and relative effort with the various gear types for fish community sampling on the Lost River, OR, 1999.

Sample Reach	**Sample Station**	**Dates Sampled**	**Gear type**						**Totals**
			Electro-fishing	**Minnow Seine**	**Minnow Trap**	**Trap Net**	**Trammel Net**	**Beach Seine**	
Malone	East Fork confluence	7/27			1				1
	Below East Fork confluence	7/7, 27			1	2	5	1	9
	Above Malone Dam	7/8				2			2
	Totals				**2**	**4**	**5**	**1**	**12**
Harpold	Miller Creek confluence	6/24						1	1
	Upstream Keller Bridge	7/1					3		3
	Keller Bridge	7/1					1		1
	1 mile downstream of Keller Bridge	7/1					1	1	2
	Downstream Keller Bridge	7/1, 13					4		4
	Upstream Big Springs	6/29					2	1	3
	Big Springs	6/29, 7/29		1			5	1	7
	Upstream Buck Creek	6/24, 7/29		1			2	1	4
	Buck Creek near mouth	6/15, 17, 21, 30, 7/2			3		8	1	12
	Between Buck Creek and Big Springs	6/11, 6/21					4		4
	Upstream Harpold	6/15, 17, 21			1		4		5
	Above Harpold	6/15, 17, 21			1		5		6
	Totals			**2**	**5**		**39**	**6**	**52**
Lost River Diversion	Below Harpold	6/23					1	1	2
	Lost River Ranch	7/12, 15			3		1	2	6
	Stevenson Park	6/22					5	2	7
	Olene Gap	10/5					4		4
	Upstream Wilson Bridge	6/16, 18, 9/24					9		9
	Between Wilson Bridge and dam	6/16, 25				1	3		4
	Upstream Horseshoe	9/24					3		3
	Above Horseshoe	7/16, 18, 25				1	6		7
	Totals				**3**	**2**	**32**	**5**	**42**

Table 1 (Cont.). Summary of stations sampled, sampling date, gear-type used and relative effort with the various gear types for fish community sampling on the Lost River, OR, 1999.

Sample Reach	Sample Station	Dates Sampled	Gear type: Electro-fishing	Minnow Seine	Minnow Trap	Trap Net	Trammel Net	Beach Seine	Totals
Anderson-Rose	Below Horseshoe	7/22, 23			1		2		3
	Reeder Road Bridge	6/28, 7/8			1		3	2	6
	#1 Drain	7/6, 8			2		3		5
	Upstream Dehlinger Bridge	7/6						1	1
	#5 Drain	7/6					4		4
	Below #5 Drain	7/8					3	1	4
	Totals				**4**		**15**	**4**	**23**
Below Anderson-Rose	Pool below Anderson-Rose Dam						**2**	**2**	**4**
East Branch Lost River	E. Fork Below Willow Dam	7/19	2		1			2	5
	Upstream E. Branch Diversion Dam	7/27			1	1			2
	Totals		**2**		**2**	**1**		**2**	**7**
Miller Creek	Miller Creek	8/11						**1**	**1**
	Grand totals		**2**	**2**	**16**	**7**	**93**	**21**	**141**

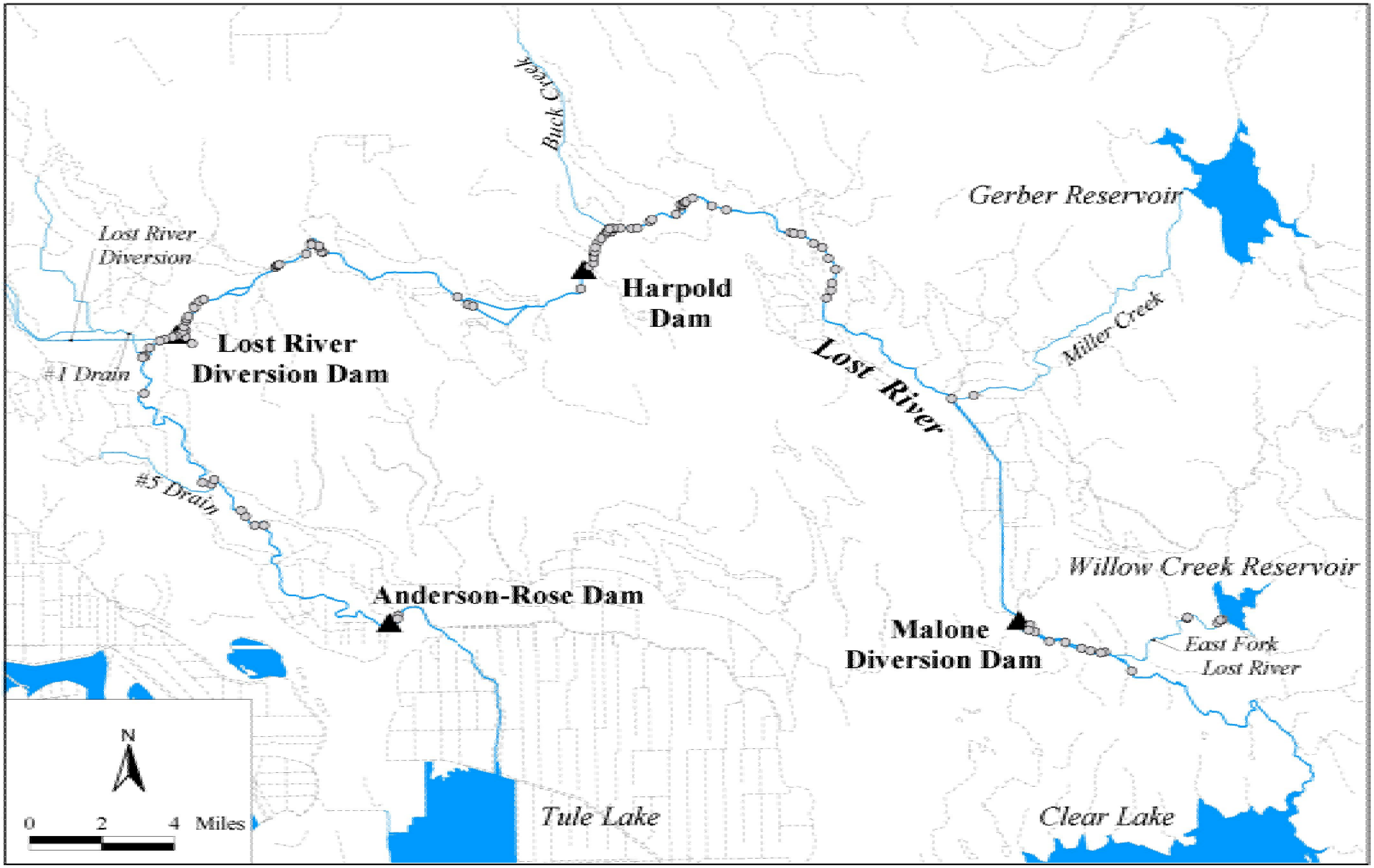

Figure 1. Map of the Lost River system from Clear Lake Reservoir to Tule Lake Wildlife Refuge. Sites sampled for fish community composition and distribution are indicated by shaded circles.

U.S.G.S. Biological Resources Division Klamath Falls, August 2000.

Results and Discussion

We sampled from June 11 to October 5 at 36 stations within the Lost River and selected tributaries (Table 1). The majority of stations sampled were located upriver of Wilson and Harpold dams. We captured a total of 21 different species (Table 2), with fathead minnows *Pimephales promelas* being the predominant species captured in most areas. Other species commonly captured although not in all locations included brown bullheads *Ameiurus nebulasus*, pumpkinseed *Lepomis gibbosus*, Sacramento perch *Archoplites interruptus*, blue chub *Gila coerulea*, tui chub *Gila bicolor*, shortnose sucker and unidentified juvenile suckers.

Distribution of Exotic Species

The fish community structure within the Lost River was dominated by exotic species, most of which are tolerant to degraded habitat conditions. Species composition varied little between reaches sampled, although there were differences in the relative abundance of species captured. We captured young-of-the-year, juveniles, and adults of the commonly occurring species indicating that spawning and recruitment is occurring within the Lost River or its' tributaries (Figure 2). In the Malone reach, Sacramento perch and brown bullhead were the predominant species captured, while in the Harpold reach fathead minnows were the predominant species captured. Within the Wilson reach brown bullhead, pumpkinseed, and fathead minnows were the most commonly captured exotics, and fathead minnows and goldfish *Carassius auratus* dominated the catches in the Anderson-Rose reach. Limited sampling was conducted below Anderson-Rose Dam and tui chubs and fathead minnows were the predominant species captured. The BOR sampled in Tule Lake Sump 1A with trammel nets in April 1999 to capture and implant radio transmitters in adult suckers. Tui and blue chubs dominated catches at most sites sampled (B. Peck, BOR, unpublished data).

Table 2. List of common and scientific names (genus and species) of fishes captured in the Lost River, Oregon from June-October 1999.

Common Name	**Scientific Name**
Shortnose sucker	*Chasmistes brevirostris*
Lost River sucker	*Deltistes luxatus*
Klamath largescale sucker	*Catostomus snyderi*
Tui chub	*Gila bicolor*
Blue chub	*G. coerulea*
Rainbow trout (Redband)	*Oncorhynchus mykiss*
Speckled dace	*Rhinichthys osculus*
Marbled sculpin	*Cottus klamathensis*
Fathead minnow	*Pimephales promelas*
Brown bullhead	*Ameiurus nebulosus*
Black bullhead	*A. melas*
Yellow bullhead	*A. natalis*
Yellow perch	*Perca flavescens*
Black crappie	*Pomoxis nigromaculatus*
White crappie	*P. annularis*
Green sunfish	*Lepomis cyanellus*
Bluegill	*L. macrochirus*
Pumpkinseed	*L. gibbosus*
Largemouth bass	*Micropterus salmoides*
Sacramento perch	*Archoplites interruptus*
Goldfish	*Carassius auratus*

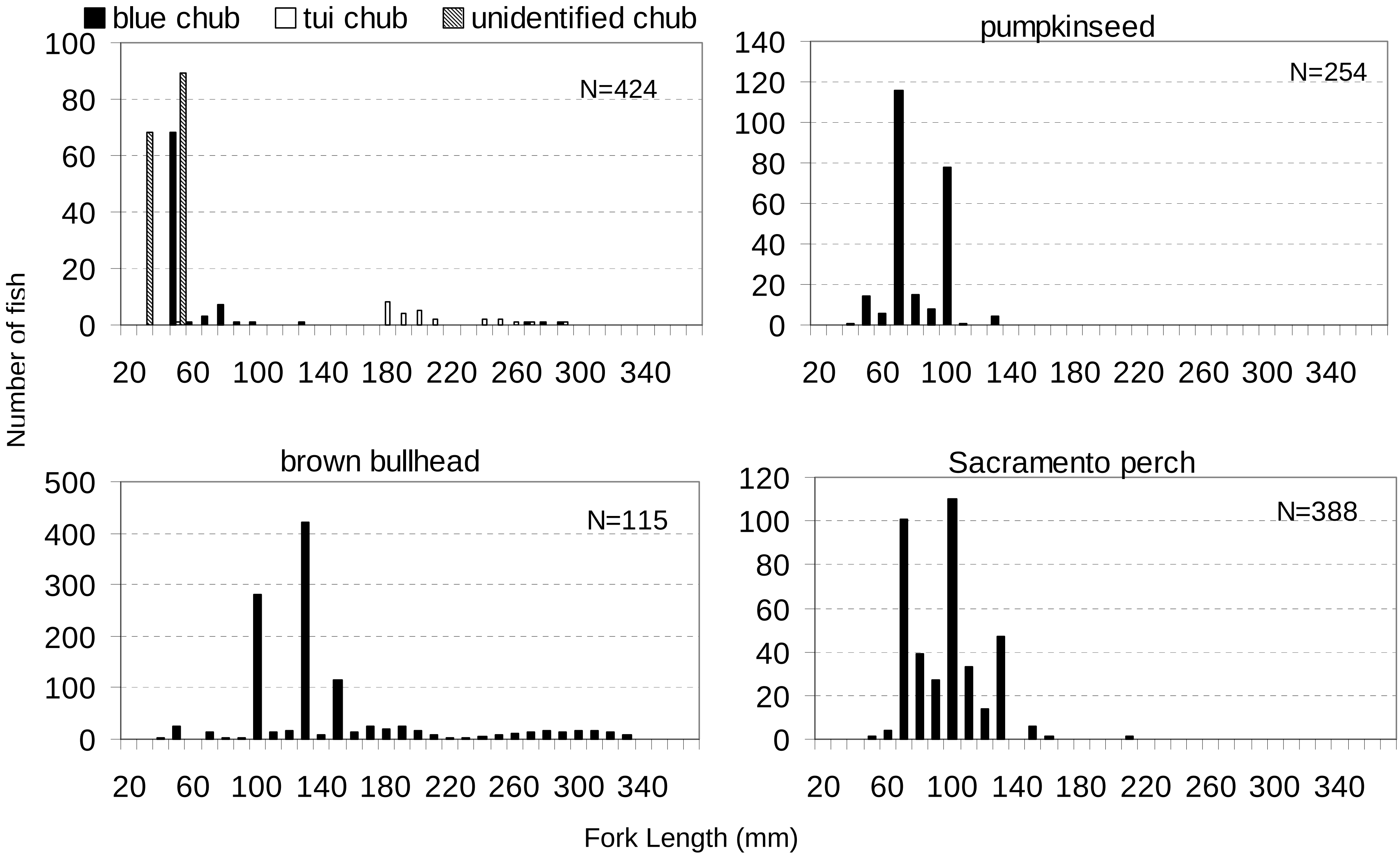

Figure 2. Length frequency distribution of predominant species identified in the Lost River, OR and CA, 1999. Note differences in scale between species.

Distribution of Suckers

Adult suckers were captured throughout the system although the majority of suckers were captured in the Harpold reach (Figure 3). We captured a total of 105 suckers >150 mm. Most suckers (n = 87) were identified as shortnose suckers, although some Klamath largescale suckers (n = 4) and one Lost River sucker were captured. In addition, we captured 12 adult suckers that appeared to have intermediate characteristics of both shortnose and Klamath largescale suckers and one unidentified sucker. The median size of shortnose suckers captured was 431 (range 303 to 518). Based on length frequency distributions it appears that several year classes are represented within the Lost River (Figure 4).

Juvenile suckers (species unknown) were captured throughout the Lost River system (Figure 5). Most juvenile suckers were captured in the Harpold reach near Big Springs, Keller Bridge, and the confluence with or within Miller Creek. Presumably, the majority of these juveniles were produced by adults spawning in Miller Creek (Brian Peck, Bureau of Reclamation, unpublished data). Other potential spawning areas may exist either within the Lost River or other tributaries in this area such as Buck Creek or Rocky Canyon Creek. The occurrence of suckers spawning in Miller Creek may have been attributed to a high flow event (mean 452 cfs) that occurred from February to April, 1999. To date there have only been a few sites within the Lost River system where sucker spawning has been documented including Willow Creek, a tributary to Clear Lake Reservoir (Scoppettone et al., 1995), Miller Creek (Brian Peck, BOR, unpublished data), Barnes Valley Creek, a tributary to Gerber reservoir (BOR unpublished data), and historically suckers spawned at Big Springs (Mark Buettner, BOR personal communication). Below Anderson-Rose Dam adult suckers in spawning condition have been observed although only unfertilized (or dead) eggs were collected (Scoppettone et al. 1995).

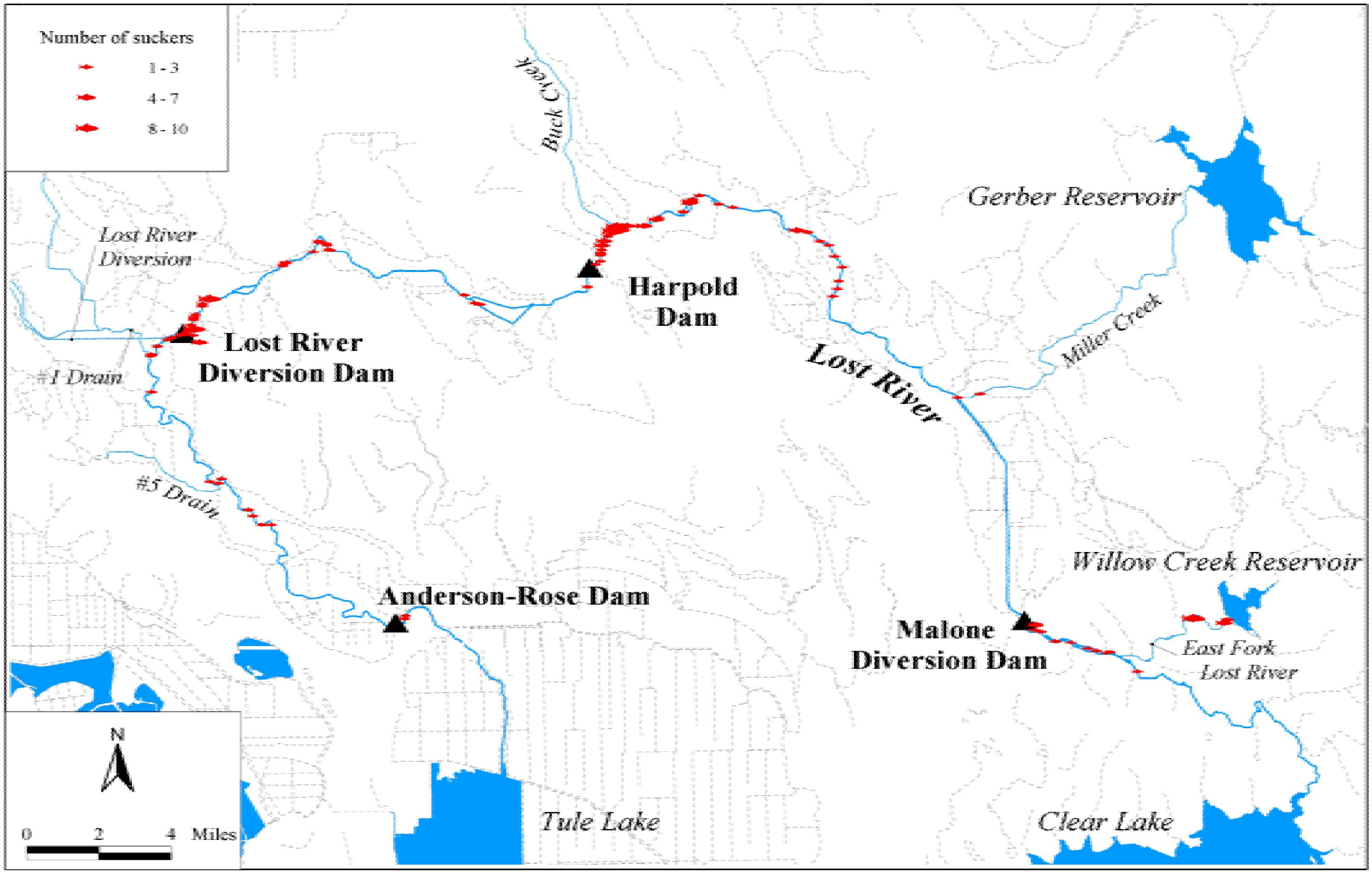

Figure 3. Summary of the location and number of suckers > 150 mm FL captured on the Lost River, OR and CA, 1999.

U.S.G.S. Biological Resources Division Klamath Falls, August 2000.

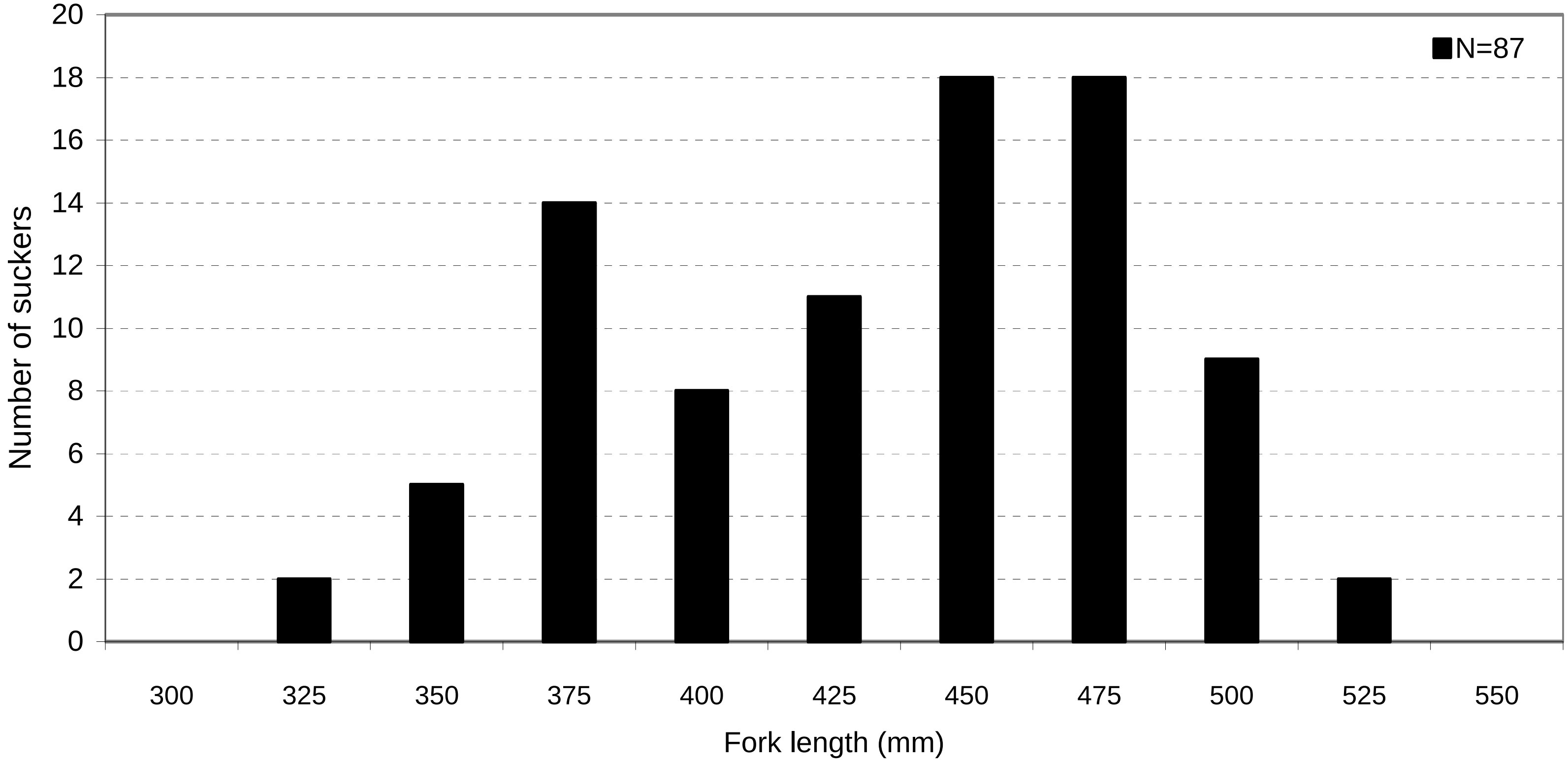

Figure 4. Length frequency distribution of shortnose suckers > 150 mm FL sampled in the Lost River, OR, 1999.

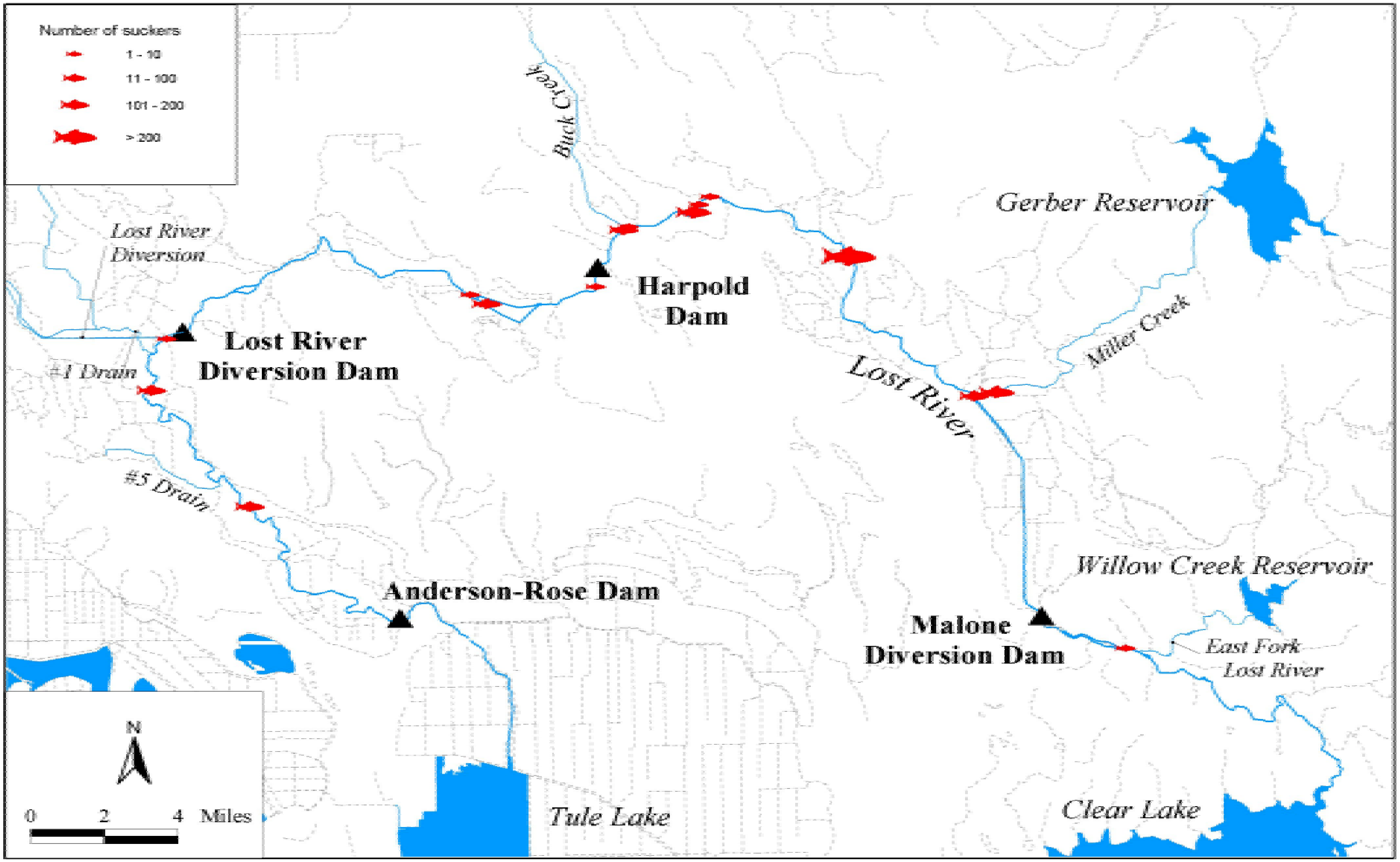

Figure 5. Summary of the location and number of suckers < 150 mm FL captured on the Lost River, OR and CA, 1999.

U.S.G.S. Biological Resources Division Klamath Falls, August 2000.

Comparisons to Previous Sampling

Koch and Cantreras (1973) and Cantreras (1973) reported on the species composition and distribution of fishes collected in the Lost River system. The majority of adult suckers they captured were in the Harpold reach and that some of these fish appeared to be "hybrid" suckers. We also caught the highest number of adult suckers in the Harpold reach, although this area was sampled intensively. We also collected fish that appeared to have intermediate characteristics between shortnose and Klamath largescale suckers. The BOR is currently funding a study examining the morphometric and genetic characteristics of shortnose, Lost River, Klamath largescale, and Klamath smallscale suckers in the basin. Once complete, it may become easier to differentiate between species or determine if hybridization is occurring.

One of the notable differences between our data and those reported by Koch and Cantreras (1973) and Cantreras (1973) was the distribution and predominance of cyprinid fishes and exotic fishes in the system. Cantreras (1973) reported that chubs (both blue and tui chubs) were the dominant fish in the system comprising nearly 75% of the total catch. Specifically, he noted blue chubs were the predominant cyprinid in the upper portion (from Clear Lake Reservoir to Bonanza) of the Lost River system and tui chubs were more predominant in the lower portion (from Bonanza to Tule Lake Refuge) of the system. Chubs were not nearly as abundant in our surveys with blue chubs and tui chubs comprising 0.1%-5.7% and 0-51.1% of total catch within the reaches sampled (Table 3). The highest percent composition of tui chubs occurred below at the station below Anderson-Rose Dam. Blue chubs were more common in the upper part of the system, while tui chubs were more commonly observed in the lower portion of the river, although this trend was not as distinct as reported by Contreras (1973). In Tule Lake Sump 1A, tui chubs predominated the catch of adult cyprinids (B. Peck, BOR unpublished data).

Table 3. Summary of the total number of fish sampled in the Lost River, OR, 1999. Data is presented by sampling reach and includes species captured by gear type and the percent composition of species to total catch.

Malone Reach	Electro-fishing	Minnow	Minnow Seine	Seine	Trammel	Trap Net	Total	Percent Composition
black bullhead						5	5	0.71%
blue chub				1		6	7	0.99%
bluegill				5			5	0.71%
brown bullhead		5		4	6	202	217	30.82%
fathead minnow				6		5	11	1.56%
green sunfish		1				4	5	0.71%
KLS Klamath largescale sucker						1	1	0.14%
largemouth bass				47	2	2	51	7.24%
pumpkinseed			2	14		1	17	2.41%
Sacramento perch		1			1	369	371	52.70%
SNS shortnose sucker					2		2	0.28%
SNSxKLS sucker, hybrid?					3		3	0.43%
unidentified bullhead				2		1	3	0.43%
unidentified sculpin			1				1	0.14%
unidentified sucker						1	1	0.14%
unidentified sunfish				1			1	0.14%
white crappie				3			3	0.43%
Totals	**0**	**7**	**3**	**83**	**14**	**597**	**704**	**100.00%**

Harpold Reach	Electro-fishing	Minnow	Minnow Seine	Seine	Trammel	Trap Net	Total	Percent Composition
blue chub			69		3		72	3.81%
bluegill		2		44			46	2.44%
brown bullhead			1	10	4		15	0.79%
fathead minnow		5	602	549			1156	61.23%
green sunfish		5		2			7	0.37%
largemouth bass			1		8		9	0.48%
marbled sculpin				4			4	0.21%
pumpkinseed		20		10			30	1.59%
rainbow trout/redband					11		11	0.58%
Sacramento perch				1			1	0.05%
SNS shortnose sucker					66		66	3.50%
speckled dace			2	3			5	0.26%
tui chub			2	1	5		8	0.42%
unidentified chub				3			3	0.16%
unidentified sucker			3	451			454	24.05%
yellow perch					1		1	0.05%
Totals	**0**	**32**	**680**	**1078**	**98**	**0**	**1888**	**100.00%**

Table 3 (cont.). Summary of the total number of fish sampled in the Lost River, OR, 1999. Data is presented by sampling reach and includes species captured by gear type and the percent composition of species to total catch.

Horseshoe Reach	Electro-fishing	Minnow	Minnow Seine	Seine	Trammel	Trap Net	Total	Percent Composition
black crappie						14	14	0.90%
blue chub						2	2	0.13%
bluegill			52			13	65	4.16%
brown bullhead				1	102	819	922	59.06%
fathead minnow		1		110			111	7.11%
goldfish					1	8	9	0.58%
largemouth bass					4		4	0.26%
LRS Lost River sucker					1		1	0.06%
marbled sculpin				7			7	0.45%
pumpkinseed			21	6		166	193	12.36%
rainbow trout/redband					1		1	0.06%
Sacramento perch					1	6	7	0.45%
SNS shortnose sucker				1	21		22	1.41%
speckled dace				4			4	0.26%
tui chub					2	19	21	1.35%
unidentified chub				97			97	6.21%
unidentified sucker				51	1		52	3.33%
unidentified sunfish					3		3	0.19%
yellow bullhead						21	21	1.35%
yellow perch				1	3	1	5	0.32%
Totals	**0**	**1**	**73**	**278**	**140**	**1069**	**1561**	**100.00%**

Anderson-Rose Reach	Electro-fishing	Minnow	Minnow Seine	Seine	Trammel	Trap Net	Total	Percent Composition
blue chub				5			5	0.79%
bluegill		3			1		4	0.63%
brown bullhead				1			1	0.16%
fathead minnow			26	352			378	59.53%
goldfish				48			48	7.56%
largemouth bass					6		6	0.94%
pumpkinseed		3		2			5	0.79%
unidentified chub				75			75	11.81%
unidentified sucker				99			99	15.59%
unidentified sunfish				4			4	0.63%
white crappie					6		6	0.94%
yellow perch				4			4	0.63%
Totals	**0**	**6**	**26**	**590**	**13**		**635**	**100.00%**

Table 3 (cont.). Summary of the total number of fish sampled in the Lost River, OR, 1999. Data is presented by sampling reach and includes species captured by gear type and the percent composition of species to total catch.

Below Anderson-Rose Reach	Electro-fishing	Minnow	Minnow Seine	Seine	Trammel	Trap Net	Total	Percent Composition
blue chub				13			13	5.68%
fathead minnow				79			79	34.50%
pumpkinseed				2			2	0.87%
Sacramento perch				8			8	3.49%
tui chub				117			117	51.09%
unidentified chub				4			4	1.75%
yellow perch				6			6	2.62%
Totals	**0**	**0**	**0**	**229**	**0**		**229**	**100.00%**

East Fork Lost River	Electro-fishing	Minnow	Minnow Seine	Seine	Trammel	Trap Net	Total	Percent Composition
bluegill					4		4	10.53%
KLS Klamath largescale sucker	3						3	7.89%
largemouth bass	2					1	3	7.89%
pumpkinseed						7	7	18.42%
Sacramento perch	1						1	2.63%
SNSxKLS sucker, hybrid?						9	9	23.68%
speckled dace	10					1	11	28.95%
Totals	**16**	**0**	**0**	**0**	**4**	**18**	**38**	**100.00%**

Miller Creek	Electro-fishing	Minnow	Minnow Seine	Seine	Trammel	Trap Net	Total	Percent Composition
speckled dace				6			6	4.00%
unidentified sucker				144			144	96.00%
Totals	**0**	**0**	**0**	**150**	**0**	**0**	**150**	**100.00%**

The apparent change in the predominance of chubs in the system is most likely due to competition with exotic species. Cantreras (1973) noted that certain exotics were captured in the Lost River including, bullheads (brown, yellow, and black), largemouth bass *Micropterus salmoides*, pumpkinseed, bluegill *Lepomis macrochirus*, yellow perch *Perca flavescens*, Sacramento perch, white crappie *Pomoxis annularis*, dace (speckled) *Rhinichthys osculus*, and fathead minnows. However, with the exception of bullheads, the abundance of these species was small and scattered throughout the system. Our data indicate that fathead minnows and bullheads were abundant and widely distributed throughout the Lost River and other exotic species such as pumpkinseed, bluegill, largemouth bass, Sacramento perch, black crappie, white crappie, green sunfish, and goldfish well established in most reaches sampled (Table 3). The occurrence of goldfish and green sunfish *Lepomis cyanellus* represent previously unreported exotic species in the Lost River System. The dominance of fathead minnows in the Lost River is similar to accounts of their relative abundance in Upper Klamath Lake where they are the most commonly occurring fish in beach seine and trap net catches (Simon and Markle 1997). Cantreras (1973) reported that fathead minnows were captured only below Anderson-Rose Dam. Simon and Markle (1997) report that fathead minnows were first documented in the Klamath River Basin in 1974. The date at which fathead minnows made it into the Lost River is still unknown although seemingly their introduction into the system has been within the last 30 years. Since being introduced they have proliferated considerably to become the most numerous fish within Upper Klamath Lake and the Lost River.

Conclusions and Recommendations

The Lost River fish community is dominated by habitat tolerant exotic species that appear to have proliferated since the early 1970's. Populations of adult suckers, primarily shortnose, are present within the system with most fish captured in the Harpold reach. Juvenile suckers were captured in several reaches with most juveniles captured in the Harpold reach. This indicates that suckers are spawning within the Lost River or its' tributaries and most likely suckers spawning in Miller Creek produced the juvenile suckers we captured in the Harpold reach. The origin of other juvenile suckers captured below the Harpold reach is unclear. It is possible that spawning may occur in other portions of the system. For example, several adult suckers were captured near the mouth of Buck Creek in June and juvenile suckers were captured within Buck Creek during macroinvertebrate sampling (USGS, unpublished data). It is possible for larval and juvenile suckers to enter the Lost River system (below Harpold Dam) through irrigation canals with water diverted from Upper Klamath Lake. It is also unclear if spawning occurs on a regular basis or is periodic due to limited flows in the system. Electrofishing sampling conducted in Spring 2000 captured only one adult sucker (Klamath largescale x shortnose) in Miller Creek. Stream flows were considerably lower in 2000 as compared to 1999 and likely affected spawning conditions. We suggest investigations be undertaken to examine the extent of sucker spawning within the Lost River system and determine minimal flow requirements for successful spawning and rearing conditions.

The presence of endangered shortnose suckers within the system and the listing of the Lost River on the State of Oregon's 303 (d) list of impaired water bodies list will hopefully increase awareness for this system. The initiation of riparian habitat restoration projects and the establishment of minimal flow criteria would undoubtedly benefit suckers as well as other indigenous species such as redband trout, *Oncorhynchus mykiss* and marbled sculpin, *Cottus klamathensis*. We recommend that periodic surveys be conducted in the Lost River system to assess the status of fish populations (particularly suckers), especially if habitat restoration efforts are initiated on a large scale and/or TMDLs are established for the system.

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