Lake Roosevelt Fisheries Evaluation Program

Limnological and Fisheries Monitoring

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Lake Roosevelt Fisheries Evaluation Program

Limnological and Fisheries Monitoring

Annual Report January 1999 – December 1999

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Executive Summary

Lake Roosevelt is a large reservoir (243 km long with 334.9 km² surface area) on the upper Columbia River. Grand Coulee Dam holds Lake Roosevelt and is operated for multiple uses including power production, flood control, irrigation, and recreation. There is a mitigation and sport fishery in Lake Roosevelt important to the region. Monitoring of the fishery and ecosystem within the reservoir were conducted in 1999 to assist in balancing the management of the reservoir for multiple uses.

Precipitation accumulation was 107 % of normal in the basin above Grand Coulee Dam. This resulted in outflows at Grand Coulee Dam that were 23 % above the 15 year average (1983-1998). The annual (1999) inflow, outflow, and water retention time in Lake Roosevelt were 130.7 kcfs, 127.4 kcfs and 32.1 days respectively. The higher river flows contributed to an annual mean total dissolved gas saturation of 110 %. Total dissolved gas surpassed the 110 % standard established by Washington state, 51 % of the year at the monitoring station near the U.S./Canadian border, and 37 % of the year at Grand Coulee Dam forebay.

Most of the dissolved nitrogen in Lake Roosevelt was present in the NO₃⁻ form where the annual average was 0.119 mg/L across all locations. Phosphorus in Lake Roosevelt was relatively scarce with an annual average total phosphorus (TP) concentration of 0.006 mg/L across all locations. Annual average total nitrogen and TP ratios (36:1) reflect the limiting nature of phosphorus in Lake Roosevelt. Carlson's trophic state index places Lake Roosevelt in the meso-oligotrophic range (overall annual mean TSI=34).

Mean phytoplankton chlorophyll *a* concentrations over the entire year were low at 1.9 mg/m³. Annual phytoplankton densities and biovolumes averaged 147 organisms/ml and 0.046 mm³/L respectively. Phytoplankton density and biovolume peaked in the summer. Phytoplankton average density and biovolume was significantly greater at Porcupine Bay than most other sampling locations.

Inflow to Lake Roosevelt was positively correlated with phytoplankton density. This was in part, driven by increased nutrients available to phytoplankton for assimilation. Since phosphorus is limiting, increasing inflow brings particulates with adhering phosphorus that supply phytoplankton growth. Total phosphorus was negatively correlated with water

retention time, which also supports this assertion. Reduced inflow can lessen phosphorus available to phytoplankton reducing total primary production available to higher trophic levels alternately; holding the water in Lake Roosevelt can reduce entrainment of zooplankton and fish. Further, investigation is needed to balance the benefits of flow yet reduce the entrainment of sport fish.

Littoral production is limited by changing reservoir elevation. Although limited by the hydraulics of the reservoir, the littoral zone has shown increased productivity. The trophic state index (TSI) that uses phytoplankton chlorophyll *a*, Secchi disk depth, and total phosphorus values to estimate trophic status was used to compare littoral and pelagic zones. Littoral TSI values (37) were significantly higher than pelagic TSI values (33) during 1999. Increased TSI values at littoral sites was due to reduced Secchi depths and no TP determination in the littoral. Additionally, zooplankton showed significantly greater densities and biomass at the shore sampling sites when compared with pelagic sites.

There were 16 species of zooplankton observed in Lake Roosevelt. Copepods were most abundant, accounting for 80.5 % (annual mean 1,111.2 organisms/m³) of total pelagic zooplankton density. *Daphnia* and other Cladocera contributed 17.4 % (annual mean 280.8 organisms/m³) and 2.0 % (annual mean 21.7 organisms/m³) of overall zooplankton density respectively. Mean overall zooplankton densities were lowest in the winter and highest in summer and fall, values ranged from 43.5 organisms/m³ (January) to 961.5 organisms/m³ (September). Mean total pelagic zooplankton densities were lowest in the upper reach (Evan's Landing 42.1 organisms/m³) and highest in the lower reach (Sanpoil River Confluence 897.7 organisms/m³) of the reservoir.

Zooplankton lengths ranged from 0.4 to 10.4 mm in Lake Roosevelt. *Daphnia* exhibited the greatest annual mean lengths (1.18 mm), followed by other Cladocera (0.55 mm), and Copepoda (0.43 mm). Annual mean lengths were greatest in the middle and lower reaches (Spokane River Confluence 0.65 mm) and smallest in the upper reach (Evan's Landing 0.34 mm) of the reservoir.

Zooplankton biomass was dominated by *Daphnia* at 62.5 % (annual mean biomass 3,579.2 µg/m³) of the total pelagic biomass. Copepoda contributed 35.8 % of the total pelagic

zooplankton biomass (annual mean biomass 1,757.4 $\mu\text{g}/\text{m}^3$). Other Cladocera accounted for the remaining 1.7 % of the total pelagic zooplankton biomass (annual mean biomass 64.8 $\mu\text{g}/\text{m}^3$). Similar to zooplankton densities, mean total biomass was lowest in the winter/spring and highest in September (3,377.3 $\mu\text{g}/\text{m}^3$). Mean total pelagic biomass was greatest in the lower reach (1,924.0 $\mu\text{g}/\text{m}^3$) and lowest in the upper reach (47.4 $\mu\text{g}/\text{m}^3$) of the reservoir. There was a strong ($r^2=0.948$) direct relationship observed between temperature and total pelagic mean zooplankton biomass.

Fisheries surveys indicated a reduction in catch-per-unit-effort of all fish species except brown trout in 1999 compared to 1998. The two most abundant fish species, large scale suckers and walleye exhibited the greatest reductions. The CPUE decreased for largescale suckers from 44.59 to 6.22 fish/hr and walleye decreased from 55.01 to 6.68 fish/hr.

Hatchery rainbow trout growth was slightly lower in 1999 than in previous years, but still higher compared to local lakes. Hatchery kokanee growth was stable when compared to previous years in Lake Roosevelt. Walleye growth was also stable compared with previous years, and was similar to growth observed in other local lakes and reservoirs with walleye present.

Walleye fed primarily on Cottidae (16.56%) and Salmonidae (17.94 %) families. Walleye diet was more diverse in previous years. High diet overlap occurred between pelagic fish species, which fed primarily on zooplankton. These instances of high diet overlap may result in interspecific competition when zooplankton densities are compromised by reservoir operations. High diet overlap also occurred between piscivorous fish. Competition likely resulted from low densities of small prey fish available in the reservoir.

Tagging studies from 1999 were similar to results from previous years, in that high water years increase the number of tags collected below Grand Coulee Dam, while low waters years decrease entrainment. Phalon Lake rainbow trout marked and released in the Kettle Falls area were only recaptured in the northern section of the reservoir, suggesting that this locally adapted stock tends to stay in local areas without migrating downstream like the coastal stock rainbow trout tend to do.

Analysis of the creel survey data indicated that the Lake Roosevelt fishery brought in \$6.12 million to the local economy in 1999. An estimated 230,513 angling trips were made to Lake Roosevelt, in 1999, the highest use observed for the reservoir since 1995. Kokanee harvest was down from the previous year (n=1,730), however half of the fish were estimated to be of hatchery origin. Rainbow trout harvest estimates were similar to the previous year (232,019). Fish of hatchery origin dominated in both the kokanee and rainbow trout harvest. Estimated walleye harvest in 1999 was greater than estimated harvest in 1998 (n=236,738). Closure of the Spokane Arm to fishing during the walleye spawning season, ultimately protects them from over harvest during a very sensitive time in their life history, during which they congregate in large numbers.

Lake Roosevelt is a dynamic system altered with large drawdowns, limited habitat, and abundant non-native fish species. The reservoir fishery is an important economic stimulus for regional businesses and deserves the utmost attention.

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Table of Contents

EXECUTIVE SUMMARY	2
ACKNOWLEDGMENTS	6
TABLE OF CONTENTS.....	7
LIST OF TABLES.....	9
LIST OF FIGURES	16
PROJECT HISTORY	19
INTRODUCTION	21
LIMNOLOGY	21
FISHERY	22
STUDY OBJECTIVES 1999.....	22
<i>Limnology</i>	22
<i>Fishery</i>	23
<i>Additional objectives (sub-contracted to other agencies)</i>	23
METHODS	24
DESCRIPTION OF STUDY AREA.....	24
LIMNOLOGY	25
<i>Reservoir Operations</i>	25
<i>Reservoir Water Quality</i>	25
<i>Primary Production</i>	28
<i>Zooplankton</i>	31
FISHERY	35
<i>Fisheries Surveys</i>	35
<i>Age and Growth</i>	37
<i>Feeding Habits</i>	38
<i>Tagging Studies</i>	40
<i>Creel Survey</i>	40
RESULTS	50
LIMNOLOGY	50
<i>Surface Hydrology</i>	50
<i>Total Dissolved Gas</i>	51
<i>Physical and Chemical Characteristics</i>	57
<i>Macro Nutrients</i>	63
<i>Trophic Status</i>	65
<i>Phytoplankton Chlorophyll a</i>	67
<i>Attached Algae</i>	69
<i>Phytoplankton Abundance and Biovolume</i>	72
<i>Zooplankton Species Identified</i>	79

<i>Pelagic Zooplankton Densities</i>	80
<i>Zooplankton Lengths</i>	86
<i>Zooplankton Biomass</i>	91
<i>Daphnia Biomass</i>	95
<i>Copepoda Biomass</i>	100
<i>Other Cladocera Biomass</i>	104
<i>Shore vs Pelagic Zooplankton Comparisons</i>	108
FISHERY	113
<i>Fisheries Surveys</i>	113
<i>Age and Growth</i>	120
<i>Feeding Habits</i>	126
<i>Tagging Studies</i>	129
<i>Creel Surveys</i>	132
DISCUSSION	141
LIMNOLOGY	141
FISHERY	150
<i>Fisheries Surveys</i>	150
<i>Age and Growth</i>	157
<i>Feeding Habits</i>	162
<i>Tagging Studies</i>	164
<i>Creel Survey</i>	168
RECOMMENDATIONS	171
LIMNOLOGY	171
FISHERY	171
LITERATURE CITED	172
APPENDICES	180
APPENDIX A. FISH DIET ANALYSIS TABLES.	181
APPENDIX B. CREEL SURVEY TABLES.	213

List of Tables

Table 1.	Limnology sampling dates and corresponding round numbers on Lake Roosevelt (1999).....	27
Table 2.	Sampling locations during 1999 on Lake Roosevelt and limnologic parameters sampled.....	29
Table 3.	Report limits and methods for selected analytes.	31
Table 4.	Slope (b) and intercept (ln a) values used to estimate dry weights for 1999 Lake Roosevelt zooplankton samples.....	34
Table 5.	Number of floy tagged fish released into Lake Roosevelt, 1999.	40
Table 6.	Names and numerical code of boat launch and rove sites for creel surveys per section sampled, 1999.....	42
Table 7.	Monthly and annual hydrologic characteristics at Grand Coulee Dam and Lake Roosevelt, WA (1999).	51
Table 8.	Total dissolved gas (%) descriptive statistics by month for all Spokane Tribe sampling locations in 1999.	53
Table 9.	Total dissolved gas (%) descriptive statistics for all Spokane Tribe sampling locations and USACOE water quality, sampling stations in 1999.	54
Table 10.	Descriptive statistics from water quality samples, including macro nutrients across all locations in Lake Roosevelt, WA (1999).	64
Table 11.	Trophic state indices calculated from phytoplankton chlorophyll <i>a</i> , Secchi disk depths, and TP concentrations in Lake Roosevelt, WA (1999).....	65
Table 12.	Trophic state indices calculated from phytoplankton chlorophyll <i>a</i> , Secchi disk depths, and TP concentrations at pelagic locations on Lake Roosevelt, WA (1999).....	66
Table 13.	Mean monthly chlorophyll <i>a</i> concentrations, standard deviations, sample size, and statistical differences based on Scheffe's S ($p < 0.05$).	68
Table 14.	Mean phytoplankton chlorophyll <i>a</i> concentrations and other descriptive statistics by location on Lake Roosevelt (1999).	69
Table 15.	Attached algae taxa list, relative density, and relative biovolume in Lake Roosevelt (1999).	70
Table 16.	Descriptive statistics for attached algae biovolume (mm^3/cm^2) at four locations in Lake Roosevelt, WA (1999).	71
Table 17.	Descriptive statistics for attached algae chlorophyll <i>a</i> production by sampling location, incubation time and incubation depth in Lake Roosevelt (1999).	72

Table 18.	Phytoplankton taxa list, relative density, and relative biovolume in Lake Roosevelt (1999).....	74
Table 19.	Monthly descriptive statistics for phytoplankton densities in Lake Roosevelt (1999).....	75
Table 20.	Monthly descriptive statistics for phytoplankton biovolumes in Lake Roosevelt, WA (1999).....	77
Table 21.	Zooplankton species found in Lake Roosevelt, WA (1999).....	79
Table 22.	Mean pelagic zooplankton densities (organisms/m ³) by taxonomic group and sample date collected in Lake Roosevelt, WA. Data includes all sites sampled in 1999.	81
Table 23.	Monthly mean densities (organisms/m ³) of <i>Daphnia</i> , Other Cladocera, Copepoda, and pelagic zooplankton for the five traditional index stations (Gifford, Porcupine Bay, Seven Bays, Keller Ferry, and Spring Canyon) on Lake Roosevelt, WA in 1999.....	84
Table 24.	Annual mean lengths, standard deviation of the mean, number of individuals measured, and the range in lengths for all species of zooplankton observed in Lake Roosevelt, WA (1999). Pelagic zooplankton and taxonomic group mean lengths, standard deviations, organisms measured, and ranges are also included.	87
Table 25.	Mean zooplankton length from pelagic sampling at each location and reach from Lake Roosevelt, WA (1999).....	89
Table 26.	Total biomass, percent biomass, and percent density contributed by taxonomic group in Lake Roosevelt, WA (1999).....	91
Table 27.	Mean pelagic zooplankton biomass (µg/m ³) and taxonomic group biomass across locations in Lake Roosevelt, WA (1999). Parentheses indicate taxonomic group percentage of zooplankton biomass at given location.	94
Table 28.	Mean zooplankton biomass (µg/m ³) across months and locations in Lake Roosevelt, WA (1999).....	96
Table 29.	Mean monthly <i>Daphnia</i> biomass (µg/m ³) Lake Roosevelt WA (1999).....	97
Table 30.	Mean monthly Copepoda biomass (µg/m ³) across locations in Lake Roosevelt (1999).....	101
Table 31.	Mean monthly other Cladocera biomass (µg/m ³) across locations in Lake Roosevelt, WA (1999).....	105
Table 32.	Annual mean zooplankton density (organism/m ³) at selected locations from pelagic and shore zones in Lake Roosevelt (1999).	108

Table 33.	Annual mean zooplankton biomass ($\mu\text{g}/\text{m}^3$) at four index locations from pelagic and shore zones in Lake Roosevelt, WA (1999).	110
Table 34.	The family, species, and scientific name of all fish species collected in Lake Roosevelt, WA via electrofishing, gillnetting, angling, and beach seining (1999).	114
Table 35.	Summary of relative abundance (R.A.), mean total length (mm, $\pm$ standard deviation), and mean weight (grams $\pm$ standard deviation) for fish collected via boat electrofishing, gill nets, beach seines, and the test fishery (1999) Lake Roosevelt, WA.....	115
Table 36.	Number (n), relative abundance (% RA), catch-per-unit-effort (CPUE), and size range (mm) for fish captured via boat electrofishing in Lake Roosevelt, WA (1999). (effort = 40.69 hrs.).....	116
Table 37.	Number (n), relative abundance (% RA), catch-per-unit-effort (CPUE), and size range (mm) for fish captured via horizontal gill nets in Lake Roosevelt, WA (1999) (effort = 1,554.06 hrs).....	118
Table 38.	Number (n), relative abundance (% RA), catch-per-unit-effort (CPUE), and size range (mm) for fish captured via vertical gill nets in Lake Roosevelt, WA (1999) (effort = 657.05 hrs).....	118
Table 39.	Relative abundance (% RA), catch-per-unit-effort (CPUE), and size range (mm) for fish captured via beach seining in Lake Roosevelt, WA (1999).....	119
Table 40.	Number (n), relative abundance (%), catch-per-unit-effort (CPUE in fish/hour), mean total length ($\pm$ standard deviation, mm), mean weight ($\pm$ standard deviation, g) and range of total length (TL) of fish captured during the annual test fishery in Lake Roosevelt, WA (1999). Mean lengths and weights were only calculated from kokanee salmon (n = 14) and rainbow trout (n = 117) that were harvested (total rod hours = 333.3 hours).....	119
Table 41.	Number (n), relative abundance (% RA), total length (TL) range and mean ($\pm$ standard deviation), and weight range and mean ($\pm$ standard deviation) of hatchery and wild kokanee salmon and rainbow trout collected, combining all sampling, gears except the test fishery in Lake Roosevelt, WA (1999).....	119
Table 42.	Condition factor ($\pm$ standard deviation) of fish captured in Lake Roosevelt, WA using all sampling gear types, 1999.....	121
Table 43.	Back calculated total lengths (mm) ($\pm$ standard deviation) of kokanee collected from Lake Roosevelt, WA (1999).	122
Table 44.	Back calculated total lengths (mm) ($\pm$ standard deviation) of rainbow trout collected from Lake Roosevelt, WA (1999).....	122
Table 45.	Back calculated total lengths (mm) ($\pm$ standard deviation) of brown trout collected from Lake Roosevelt, WA (1999).....	122

Table 46.	Back calculated total lengths (mm) ($\pm$ standard deviation) of eastern brook trout collected from Lake Roosevelt, WA (1999).....	122
Table 47.	Back calculated total lengths (mm) ($\pm$ standard deviation) of lake whitefish collected from Lake Roosevelt, WA (1999).....	123
Table 48.	Back calculated total lengths (mm) ($\pm$ standard deviation) of mountain whitefish collected from Lake Roosevelt, WA (1999).....	123
Table 49.	Back calculated total lengths (mm) ($\pm$ standard deviation) of smallmouth bass collected from Lake Roosevelt, WA (1999).....	124
Table 50.	Back calculated total lengths (mm) ($\pm$ standard deviation) of walleye collected in 1999.	124
Table 51.	Back calculated total lengths (mm) ($\pm$ standard deviation) of yellow perch collected from Lake Roosevelt, WA (1999).....	125
Table 52.	Back calculated total lengths (mm) ($\pm$ standard deviation) of northern pikeminnow collected from Lake Roosevelt, WA (1999).....	125
Table 53.	Relative importance values of prey items in the diet of kokanee salmon, rainbow trout, walleye, and smallmouth bass collected in Lake Roosevelt, WA (1999).	127
Table 54.	Diet overlap of various fish species collected in Lake Roosevelt, WA (1999). Bold values represent high diet overlaps (≥ 0.70).	129
Table 55.	The number (n) and percent (%) of the tag recoveries from rainbow trout in 1999 by release year.	131
Table 56.	Number (n) and percent (%) of rainbow trout tag recoveries by release location and tag recovery location in Lake Roosevelt (FDR), WA (1999).....	131
Table 57.	The mean total length growth (mm/day), mean weight growth (g/day) and mean number of days in the fishery ($\pm$ standard deviation) between date of release and date of capture, by release location and stock of recaptured rainbow trout in Lake Roosevelt, WA (1999).....	132
Table 58.	Total monthly angler pressure estimates in hours ($\pm$ 95% confidence intervals), by creel section on Lake Roosevelt, WA from December 1998 through October 1999.	134
Table 59.	Angler trip estimates by section based on angler hours (pressure estimates) and average trip length (hrs) for Lake Roosevelt, WA from December 1998 through October 1999.	135
Table 60.	Harvest per unit effort (HPUE) by species and section from December 1998 through October 1999 at Lake Roosevelt, WA. HPUE reflects the number of fish kept per angler hour.	136

Table 61.	Catch-per-unit-effort (CPUE) by species and section from December 1998 through October 1999 at Lake Roosevelt, WA. CPUE reflects the number of fish kept and released per angler hour.	136
Table 62.	Number of fish observed during creel surveys (n) and estimated number of fish harvested ($\pm$ 95% confidence intervals) at Lake Roosevelt, WA from December 1998 through October 1999.	136
Table 63.	Number of fish captured (n) and estimated number of fish captured (harvested and released) ($\pm$ 95% confidence intervals) for Lake Roosevelt, WA from December 1998 through October 1999.	137
Table 64.	Mean length (mm) and weight (grams) and standard deviation (SD) of fish captured in each section of Lake Roosevelt, WA (1999).	137
Table 65.	Percent of anglers unsatisfied and satisfied with their fishing trip by quarter and per section at Lake Roosevelt, WA (1999).	138
Table 66.	Percent of anglers targeting various fish species by quarter and section at Lake Roosevelt, WA (1999).	139
Table 67.	Origin of residence, number, and percent of anglers utilizing the fishery per section at Lake Roosevelt, WA (1999).	140
Table 68.	Mean <i>Daphnia</i> spp. biomass ($\mu\text{g}/\text{m}^3$) collected from five index locations in Lake Roosevelt, WA (1991-1999).	149
Table 69.	Catch-per-unit-effort (fish/hr) of fish collected via boat electrofishing in Lake Roosevelt, WA (1993-1999).	154
Table 70.	Catch-per-unit-effort (fish/hr) for fish collected via gill net surveys in Lake Roosevelt, WA (1993-1999).	155
Table 71.	Summary of the relative abundance (%) of fish species collected via boat electrofishing in Lake Roosevelt, WA (1989-1999).	156
Table 72.	Summary of the relative abundance (%) of fish species collected via horizontal and vertical gill netting in Lake Roosevelt, WA (1989-1999).	157
Table 73.	Comparison of Salmonidae condition factors (C.F.) and standard deviation (SD) of fish collected at Lake Roosevelt, WA since 1997, and from other lakes and reservoirs in eastern Washington.	159
Table 74.	Comparison of game fish and non-game fish condition factors (C.F.) and standard deviation (SD) of fish collected at Lake Roosevelt, WA since 1997, and from other lakes and reservoirs in eastern Washington.	160
Table 75.	Comparison of mean back-calculated total lengths (mm) at annulus formation between an average from 16 lakes and rivers in the United States and British Columbia (average) and Lake Roosevelt (FDR), WA.	161

Table 76.	Relative importance values of fish prey items in the diet of walleye collected in Lake Roosevelt, WA (1997-1999).....	164
Table 77.	Number of marked hatchery rainbow trout and kokanee salmon released into Lake Roosevelt, WA (1996-1999).....	166
Table 78.	Total number of fish tagged by year and tag returns by release year in Lake Roosevelt, WA and below Grand Coulee Dam (GCD). Parentheses denote tags recovered below GCD.	167
Table 79.	Economic value of the fishery and number of kokanee salmon, rainbow trout, and walleye harvested in Lake Roosevelt, WA (1990-1999).....	169
Table 80.	Percent by dry weight, percent by number, frequency of occurrence, and relative importance values of diet categories for black crappie and bridgelip sucker collected in Lake Roosevelt, WA (1999).	181
Table 81.	Percent by dry weight, percent by number, frequency of occurrence, and relative importance values of diet categories for eastern brook trout and brown trout collected in Lake Roosevelt, WA (1999).	185
Table 82.	Percent by dry weight, percent by number, frequency of occurrence, and relative importance values of diet categories for burbot and kokanee salmon collected in Lake Roosevelt, WA (1999).....	189
Table 83.	Percent by dry weight, percent by number, frequency of occurrence, and relative importance values of diet categories for longnose sucker and largescale sucker collected in Lake Roosevelt, WA (1999).	193
Table 84.	Percent by dry weight, percent by number, frequency of occurrence, and relative importance values of diet categories for lake whitefish and mountain whitefish collected in Lake Roosevelt, WA (1999).	197
Table 85.	Percent by dry weight, percent by number, frequency of occurrence, and relative importance values of diet categories for northern pikeminnow and rainbow trout collected in Lake Roosevelt, WA (1999).	201
Table 86.	Percent by dry weight, percent by number, frequency of occurrence, and relative importance values of diet categories for smallmouth bass and tench collected in Lake Roosevelt, WA (1999).....	205
Table 87.	Percent by dry weight, percent by number, frequency of occurrence, and relative importance values of diet categories for walleye and yellow perch collected in Lake Roosevelt, WA (1999).....	209
Table 88.	Corrected mean boat angler hours per strata in the upper section (1) of Lake Roosevelt, WA (1999).....	213
Table 89.	Corrected mean boat angler hours per strata in the middle section (2) of Lake Roosevelt, WA (1999).....	214

Table 90.	Corrected mean boat angler hours per strata in the lower section (1) of Lake Roosevelt, WA (1999).	215
Table 91.	Pressure estimates calculated per month per strata in the upper section (1) of Lake Roosevelt, WA (1999).	216
Table 92.	Pressure estimates calculated per month per strata in the middle section (2) of Lake Roosevelt, WA (1999).	219
Table 93.	Pressure estimates calculated per month per strata in the lower section (3) of Lake Roosevelt, WA (1999).	222

List of Figures

Figure 1.	Limnology sampling stations on Lake Roosevelt (1999).....	26
Figure 2.	Boxplot components as calculated by Statview 5.0.1.....	27
Figure 3.	Boat electrofishing, gill net, and rainbow trout and kokanee net pen locations in Lake Roosevelt, 1999.	36
Figure 4.	Daily water retention time, outflow, and reservoir elevation (Grand Coulee Dam forebay) for Lake Roosevelt, WA (1999).....	52
Figure 5.	Scatter plot of TDG (%) data from USACOE water quality sampling stations and monthly means with error bars (± 1 standard deviation) from the Spokane Tribe of Indians (STOI) Lake Roosevelt sampling in 1999.....	55
Figure 6.	Scatter plot of TDG (%) data from the Spokane Tribe Lake Roosevelt sampling and USACOE water quality stations in 1999.	56
Figure 7.	Box plots of temperature ($^{\circ}\text{C}$) and dissolved oxygen (mg/L) data split by sampling location averaged over the entire year and by month averaged over all sampling locations on Lake Roosevelt during 1999.....	58
Figure 8.	Box plots of total dissolved solids (mg/L) and specific conductivity ($\mu\text{S}/\text{cm}$) data split by sampling location averaged over the entire year and by month averaged over all sampling locations on Lake Roosevelt, WA (1999).....	59
Figure 9.	Box plots of pH and oxidation-reduction (redox) potential (mV) data split by sampling location averaged over the entire year and by month averaged over all sampling locations on Lake Roosevelt during 1999.....	60
Figure 10.	Box plots of annual mean Secchi disk depths (m) and euphotic zone depths (m) for all sampling locations in Lake Roosevelt, WA (1999), and monthly mean Secchi disk depths (m) and euphotic zone depths (m) combined across all sampling locations.	61
Figure 11.	Box plots of surface irradiance ($\mu\text{W}/\text{cm}^2\cdot\text{nm}$) split by sampling location averaged over the entire year and by month averaged over all sampling locations on Lake Roosevelt, WA (1999).....	62
Figure 12.	Box plots of turbidity (NTU) split by sampling location averaged over the entire year and by month averaged over all sampling locations on Lake Roosevelt, WA (1999).....	63
Figure 13.	Box plots of trophic state indices calculated from phytoplankton chlorophyll <i>a</i> , Secchi disk depths, and total P concentrations across all locations on Lake Roosevelt, WA (1999).....	66
Figure 14.	Box plots of mean trophic state index split by pelagic and littoral zones, across all locations on Lake Roosevelt, WA (1999).....	67

Figure 15.	Mean monthly phytoplankton chlorophyll <i>a</i> concentrations and monthly sample size in Lake Roosevelt, WA (1999).	68
Figure 16.	Seasonal variation of mean monthly phytoplankton density in Lake Roosevelt, WA (1999).	76
Figure 17.	Seasonal variation in mean monthly density for major phytoplankton groups in Lake Roosevelt, WA (1999).	78
Figure 18.	Seasonal variation in mean monthly biovolume for phytoplankton groups taken from Lake Roosevelt, WA (1999).	78
Figure 19.	Mean pelagic zooplankton densities (a) and mean pelagic zooplankton densities by taxonomic group (b) in lake Roosevelt, WA (1999). Includes all sampling locations.	82
Figure 20.	Mean pelagic zooplankton densities for all sample locations in Lake Roosevelt, WA (1999).	83
Figure 21.	Mean pelagic zooplankton densities (a) and mean pelagic zooplankton densities by taxonomic group (b) in lake Roosevelt, WA (1999). Includes index sampling locations only.	85
Figure 22.	Seasonal variation of zooplankton mean length and mean length by taxonomic group in Lake Roosevelt, WA (1999).	88
Figure 23.	Mean pelagic zooplankton length and mean abundance by taxonomic group for locations sampled in Lake Roosevelt, WA (1999).	90
Figure 24.	Mean pelagic zooplankton biomass (a) and mean pelagic zooplankton densities by taxonomic group (b) in lake Roosevelt, WA (1999). Includes all sampling locations.	92
Figure 25.	Overall annual mean zooplankton biomass across locations in Lake Roosevelt, WA (1999).	93
Figure 26.	Mean monthly biomass for <i>Daphnia</i> species in Lake Roosevelt, WA (1999).	99
Figure 27.	Mean monthly Copepoda species biomass on Lake Roosevelt (1999).	103
Figure 28.	Mean monthly other Cladocera biomass in Lake Roosevelt, WA (1999).	107
Figure 29.	Annual mean zooplankton density at selected index locations from pelagic and shore zones in Lake Roosevelt, WA (1999).	108
Figure 30.	Mean zooplankton densities across four index locations with shore and pelagic zones on Lake Roosevelt, WA (1999).	109
Figure 31.	Annual mean zooplankton density for major groups collected from shore and pelagic zones in Lake Roosevelt, WA (1999). Data combined across four index locations.	110

Figure 32.	Annual mean zooplankton biomass at index locations from pelagic and shore zones in Lake Roosevelt, WA (1999).....	111
Figure 33.	Mean zooplankton biomass across all sampling locations within shore and pelagic zones in Lake Roosevelt, WA (1999).	112
Figure 34.	Annual mean zooplankton biomass within shore and pelagic zones for major groups in Lake Roosevelt (1999).....	113
Figure 35.	Mean phytoplankton density (organisms/ μ L) regressed upon mean inflow (kcfs). Phytoplankton means are from sampling rounds in 1999 across all sampling locations while mean inflow to Grand Coulee Dam was from the 30 day mean prior to the sampling round.....	141
Figure 36.	Mean total phosphorus (mg/L) regressed upon mean water retention time (days). Mean total phosphorus calculated from sampling rounds in 1999 across all sampling locations on Lake Roosevelt, WA and mean water retention time from 30 day mean prior to sampling round.	143
Figure 37.	Mean zooplankton biomass and mean phytoplankton density by round across all pelagic sampling locations on Lake Roosevelt, WA (1999).	144
Figure 38.	Mean $\ln$ zooplankton biomass (μ g/ m^3) regressed upon mean water temperature ($^{\circ}$ C) taken at Grand Coulee forebay 30 days prior to day of sampling. Mean zooplankton biomass calculated from sampling rounds in 1999 across all sampling locations.	148
Figure 39.	Length to age of walleye collected in Lake Roosevelt, WA (1980-1999). See Table 75 for references.	162
Figure 40.	Percent tag recoveries collected below Grand Coulee Dam compared to monthly mean water residence time in Lake Roosevelt, (1990-1999).	166
Figure 41.	Estimated harvest of rainbow trout, kokanee salmon, and walleye between 1990 and 1999 in Lake Roosevelt, WA.....	170
Figure 42.	Lake Roosevelt, WA elevation (ft above sea level) compared to annual harvest of kokanee salmon and rainbow trout.	170

Project History

The construction of Grand Coulee Dam in 1939 permanently blocked waters historically utilized for reproduction and rearing by anadromous fish species. Grand Coulee was constructed without a fish ladder, which eliminated steelhead (*Onchorhynchus mykiss*), chinook salmon (*O. tshawyastica*), coho salmon (*O. kisutch*) and sockeye salmon (*O. nerka*) from returning to approximately 1,835 km (1,140 miles) of natal streams and tributaries found in the upper Columbia River Drainage in the United States and Canada (Mullan 1985, 1987 and Mullan et al. 1993).

The Pacific Northwest Electric Power Planning and Conservation Act of 1980 gave the Bonneville Power Administration (BPA), the authority and responsibility to use its legal and financial resources, “to protect, mitigate, and enhance fish and wildlife to the extent affected by the development and operation of any hydroelectric project of the Columbia River and its tributaries. This is to be done in a manner consistent with the program adopted by the Northwest Power Planning Council (NWPPC), and the purposes of the Act” (NWPPC, 1987).

With the phrase “protect, mitigate and enhance,” Congress signaled its intent that the NWPPC’s fish and wildlife program should do more than avoid future hydroelectric damage to the basin’s fish and wildlife. The program must also counter past damage, work toward rebuilding those fish and wildlife populations that have been harmed by the hydropower system, protect the Columbia Basin’s fish and wildlife resources, and mitigate for harm caused by decades of hydroelectric development and operations. By law, this program is limited to measures that deal with impacts created by the development, operation and management of hydroelectric facilities on the Columbia River and its tributaries. However, off-site enhancement projects are used to address the effects of the hydropower system on fish and wildlife (NWPPC 1987).

Resident game fish populations have been established in Franklin D. Roosevelt Lake, the reservoir behind Grand Coulee Dam, since the extirpation of anadromous fish species. The resident game fish populations are now responsible for attracting a large percentage of the recreational visits to the region. An increase in popularity has placed Lake Roosevelt fifth

amongst the most visited State and Federal parks in Washington (Washington State Data Book, 1991). Increased use of the reservoir prompted amplified efforts to enhance the Native American subsistence fishery and the resident sport fishery in 1984 with hatchery supplementation of rainbow trout (*O. mykiss*) and kokanee salmon (*O. nerka*). This was followed by the formation of the Spokane Tribal Lake Roosevelt Monitoring Project (LRMP) in 1988 and later by formation of the Lake Roosevelt Data Collection Project in 1991.

The Lake Roosevelt Data Collection Project began in July 1991 as part of the BPA, Bureau of Reclamation, and U.S. Army Corps of Engineers' System Operation Review process. This process sought to develop an operational scenario for the federal Columbia River hydropower system to maximize the in-reservoir fisheries with minimal impacts to all other stakeholders in the management of the Columbia River.

The Lake Roosevelt Monitoring / Data Collection Program (LRMP) is the result of a merger between the Lake Roosevelt Monitoring Program (BPA No. 8806300) and the Lake Roosevelt Data Collection Project (BPA No. 9404300). These projects were merged in 1996 forming the Lake Roosevelt Monitoring Program (LRMP), which continues the work historically completed under the separate projects.

The LRMP has two main goals. The first is to develop a biological model for Lake Roosevelt that will predict in-reservoir biological responses to a range of water management operational scenarios, and to develop fisheries and reservoir management strategies accordingly. The model will allow identification of lake operations that minimize impacts on lake biota while addressing the needs of other interests (e.g. flood control, hydropower generation, irrigation, and downstream resident and anadromous fisheries). Major components of the model will include: 1) quantification of entrainment and other impacts to phytoplankton, zooplankton and fish caused by reservoir drawdowns and low water retention times; 2) quantification of seasonal distributions, standing crop, and habitat use of fish food organisms (i.e. zooplankton and juvenile fish species) in the reservoir; 3) examination of variations in fish growth and abundance in relation to reservoir operations, prey abundance and predator/prey relationships; and 4) quantification of habitat alterations due to hydro-operations.

The second goal of the LRMP is to evaluate the impacts of hatchery kokanee salmon and rainbow trout on the ecosystem and to determine stocking strategies that maximize angler harvest and return of adult kokanee salmon to egg collection facilities. Major tasks of the hatchery evaluation portion of the project include conducting a year round reservoir wide creel survey, sampling the fishery during spring, summer and fall via electro-fishing and gillnet surveys, and collecting information on diet, growth, and age composition of various fish species in Lake Roosevelt.

Introduction

Limnology

In 1980, primary production values revealed the trophic status of the reservoir to be mesotrophic to slightly eutrophic (Stober et al. 1981). However, recent data indicate Lake Roosevelt has become more oligotrophic (RAASC 1999, Wierenga et al. 1997, Wilson et al. 1996). Recent reductions in industrial effluents into the Columbia River, mainly from the British Columbia based Cominco, Ltd. lead-zinc smelter and fertilizer plant, along with the Celgar Pulp Co. mill, are believed to have significantly reduced reservoir nutrient loading (Sheehan and Lamb 1987, Johnson et al. 1988, Kenyon and Glover 1994). Reduction in reservoir nutrient loading is thought to have changed the trophic status, impart through declines in phytoplankton abundance. Since zooplankton rely on phytoplankton as a food source the reduction in pelagic primary production is of concern.

Long term monitoring by the LRMP and others has underlined the importance of zooplankton communities in supporting viable populations of resident sport fish within the reservoir (Beckman et al. 1985; Peone et al. 1990; Cichosz et al. 1997; Cichosz et al. 1999). The zooplankton community of Lake Roosevelt forms a critical link between phytoplankton and secondary consumers. In particular, cladoceran zooplankton comprise a substantial portion of the diets of many Lake Roosevelt fishes including: kokanee salmon, rainbow trout, mountain whitefish (*Prosopium williamsoni*), lake whitefish (*Coregonus clupeaformis*), largescale sucker (*Catostomus macrocheilus*), smallmouth bass (*Micropterus dolomieu*), walleye (*Stizostedion vitreum*) and yellow perch (*Perca flavescens*; Beckman et

al. 1985, Cichosz et al. 1999). Monitoring zooplankton populations in Lake Roosevelt assists in determining biomass available to fish, and are necessary for the modeling efforts.

Fishery

Monitoring of the Lake Roosevelt fishery began in July 1988 (Peone et al. 1990). The monitoring program is a cooperative effort between the Spokane Tribe of Indians, Colville Confederated Tribes, Washington Department of Fish and Wildlife, and Eastern Washington University. Fishery surveys were conducted to collect information on relative abundance, growth and condition, dietary items and overlap focused on inter-and-intra specific competition, identifying predator-prey relationships, and harvest of sport fish.

The Lake Roosevelt fishery has brought in 5.3 to 20.7 million dollars annually to the local economy since artificial production began in the late 1980's (Spotts et al. 2002). Anglers have harvested up to an estimated 32,353 kokanee salmon and 499,460 rainbow trout annually in Lake Roosevelt since monitoring began (Cichosz et al. 1999). A self-sustaining walleye population is managed in conjunction with the salmonid fishery to maximize sport fishing opportunities. Long-term monitoring of the fishery has allowed managers to adjust regulations to maintain the integrity of the fishery while maximizing harvest.

Study Objectives 1999

Limnology

- 1) Analyze surface hydrology data for Lake Roosevelt.
- 2) Collect limnological data from Lake Roosevelt including temperature, dissolved oxygen, conductivity, turbidity, pH, redox potentials, and total dissolved gas.
- 3) Collect primary production data, including speciation, abundance, and chlorophyll *a* for phytoplankton and attached algae from Lake Roosevelt.
- 4) Collect zooplankton biomass, density, and length data from Lake Roosevelt. Examine trophic status, zooplankton and their interaction between shore and pelagic sampling sites.
- 5) Examine interactions between parameters to improve understanding of the reservoir ecosystem within 1999, and between years to monitor temporal changes.
- 6) Maintain complete databases to be used in the development of the ecological model of Lake Roosevelt.

Fishery

- 1) Estimate the relative abundance and catch-per-unit-effort of fishes in Lake Roosevelt through electrofishing, gill net, and beach seine surveys to evaluate species population trends.
- 2) Back calculate length at age of selected fish species collected from Lake Roosevelt to assess annual growth rates by year class.
- 3) Assess ecological impacts, relative importance of predator/prey relationships, and dietary overlap for the majority of fish species in Lake Roosevelt.
- 4) Estimate annual angler pressure and harvest, mean size of harvested fish, and conduct comparative assessments through rove-access creel surveys.
- 5) Compare and contrast historical and current fishery and limnological data to evaluate the reservoir ecosystem stability.
- 6) Evaluate the performance of hatchery stocks of kokanee salmon and rainbow trout as they contribute to the fishery.

Additional objectives (sub-contracted to other agencies)

- 1) Evaluation of hatchery kokanee returns to egg collection facilities (Eastern Washington University) (McLellan et al. 2001).
- 2) Evaluation of limiting factors for stocked kokanee and rainbow trout in Lake Roosevelt (Washington Department of Fish and Wildlife) (Baldwin et al. 2002, and Baldwin et al. 2003, in press).
- 3) Assessment of Lake Roosevelt habitat (Colville Confederated Tribe)

Previous annual reports for the Lake Roosevelt Data Collection Project include, Shields and Underwood (1996a and b), Cichosz et al. (1997; combined 1996 Annual Report for the Lake Roosevelt Monitoring and Data Collection Programs), Cichosz et al. (1999), Shields et al. (2002), and Spotts et al. (2002). Previous reports for the Lake Roosevelt Monitoring Program include Peone et al. (1990), Griffith and Scholz (1991), Griffith et al. (1995), Griffith and McDowell (1996), Voeller (1996) Underwood et al. (1996a and b), and Cichosz et al. (1997; combined 1996 Annual Report for the Lake Roosevelt Monitoring and Data Collection Programs).

Methods

Description of Study Area

Lake Roosevelt is a mainstem Columbia River impoundment formed by the completion of Grand Coulee Dam in 1941 (Figure 1). The reservoir, at a full pool elevation of 393 m (1290 ft) inundates 33,490 hectares (82,691 acres) with a storage capacity of $1.16 \times 10^{10} \text{ m}^3$ (9.41×10^{10} acre-ft) and a maximum depth of 122 meters (400 ft) (Nigro et al. 1981). Lake Roosevelt is the largest reservoir in Washington, the sixth largest reservoir in the U.S., and one of the largest artificial lakes in the world (Johnson et al. 1991). Grand Coulee Dam is the largest producer of hydropower in the United States and the third largest in the world, generating \$462 million in power in 1994 (Grand Coulee Dam Information Center 1998). Grand Coulee Dam is a Bureau of Reclamation storage project operated primarily for power, flood control, and irrigation with secondary operations for recreation, fish, and wildlife.

The Lake Roosevelt watershed drains a wide range of ecological habitat types including the steppe-shrub desert of central Washington, the agricultural/urban areas of the Spokane and Colville River valleys, the ponderosa pine (*Pinus ponderosa*) forests of the inter-mountain plateau, and the western snow pack of the Rocky Mountains (Wilson 1996). Major tributaries to Lake Roosevelt include the Columbia, Spokane, and Kettle Rivers, which contribute an average of 89, 7, and 3 percent of the inflow volumes to the lake respectively (Stober et al. 1981).

Flood control operations at Grand Coulee Dam annually reduce reservoir water elevation by up to 24 m between January and June to create room for peak spring flows. Spring drawdown events decrease the volume of the reservoir by an average of 55 % and its surface area by 45 % annually (Beckman et al. 1985). Full pool elevation (393 m) is usually achieved by early July, coinciding with the Fourth of July weekend (Nigro et al. 1981). More recently, Lake Roosevelt has experienced an August drawdown of three-meters to facilitate anadromous fish migration through the lower Columbia and Snake Rivers.

Limnology

Reservoir Operations

Water retention time was calculated from daily midnight forebay elevations (ft) and total outflows in thousand cubic feet per second per day (kcfs). Reservoir elevation and total outflow data generated by the USACOE were obtained via the “DART River Environment” website (USACOE 2003). Reservoir elevation was converted to volume of water stored (kcfsd) using a reservoir water storage table (USACOE 1981), and daily water retention time was calculated as reservoir volume divided by outflow.

Reservoir Water Quality

Physical and chemical measurements of water temperature, dissolved oxygen, conductivity, pH, oxidation–reduction (redox) potential, turbidity, total dissolved solids, percent oxygen saturation, and total dissolved gas were recorded from the pelagic and littoral zone using a Hydrolab Surveyor 4 in 1999. The Hydrolab was maintained and calibrated as recommend by the manufacturer. However, there were some instrument malfunctions and field protocol issues described in the results section of this report.

Lake Roosevelt was sampled during 18 rounds throughout 1999 (Table 1). Nineteen different locations were sampled (Table 2; Figure 1). All locations listed in Table 2 were sampled the entire year except for the Little Falls Dam locations (April–December) and the Colville River bridge location (August). Hydrolab data were collected from the surface to a depth of 33 m in 3 m intervals. Additional Hydrolab measurements were taken from 40 m to 90 m at 10 m intervals at Keller Ferry and Spring Canyon to characterize the profundal zones of the lower reservoir. To assess differences between pelagic and littoral habitats, sampling was conducted at 10 locations with near shore and mid channel sites (Table 2).

Lake Roosevelt

Figure 1. Limnology sampling stations on Lake Roosevelt (1999).

Table 1. Limnology sampling dates and corresponding round numbers on Lake Roosevelt (1999).

Round	Sampling Dates	Round	Sampling Dates
1	Jan. 19, & 21-22	10	Jul. 26-28
2	Feb. 16, & 18-19	11	Aug. 9-10
3	Mar. 22-24	12	Aug. 24-27
4	Apr. 20-22	13	Sep. 7-9
5	May 1-5	14	Sep. 21-23
6	May 17-19	15	Oct. 12-15
7	Jun. 7-9	16	Oct. 25-27, & Nov. 2
8	Jun. 30 & Jul. 1-2	17	Nov. 15-16, & 18
9	Jul. 12-14	18	Dec. 13-16

Figure 2. Boxplot components as calculated by Statview 5.0.1.

Euphotic zone depths were estimated using a Kahl Scientific Instruments Model 268WD305 underwater irradiator. Euphotic zone depths were defined as the portion of the water column extending from the surface to a depth where one percent of ambient surface light penetrates (Goldman and Horne 1994). Hydrolab and other limnology data were represented in box plots created by Statview 5.0.1 (Figure 2). Statistical analysis of limnology data included analysis of variance (ANOVA) with significance tests based on F distributions. Analyses of variances were supplemented by pairwise comparisons between means to assess differences between groupings (RVLS 2003). Pairwise comparisons included Fisher's

protected least squared difference (Fisher PLSD) and Scheffe's statistic (Scheffe S). Pairwise comparisons and ANOVA's were computed using Statview 5.0.1. Statistical test assumptions (homogeneity of variance and normal distribution) were checked and data were transformed ($\log_{10}$) in some cases to better meet assumptions (RVLS 2003). Simple linear regression on selected limnology data was performed to examine the relationship between a dependent and independent variable.

Primary Production

Spatial and temporal trends in primary producers within Lake Roosevelt were investigated by conducting phytoplankton and attached algae studies within the euphotic zone.

Phytoplankton samples were collected at eleven pelagic locations (Table 2) except for littoral chlorophyll *a* samples at Hawk Creek. Phytoplankton samples were collected using an integrated sampling tube to extract a column of water from the surface to the bottom of the euphotic zone. Phytoplankton samples were processed at Eastern Washington University, Water Research Center in Cheney, WA. Analysis included speciation, enumeration, and estimation of biovolumes. These samples were preserved with Lugol's solution. Statistical analysis of phytoplankton data was conducted using same methods outlined in the limnology data analysis.

Phytoplankton chlorophyll *a* measurements were conducted at eleven locations Lake Roosevelt (Table 2). Phytoplankton chlorophyll *a* concentrations were determined using a Turner Designs Model 10-AU field fluorometer calibrated monthly to laboratory determined (EWU spectrophotometrically) chlorophyll *a* concentrations. Phytoplankton chlorophyll *a* samples were taken from three depths within the euphotic zone at a given location: 0.5 m below the surface; the mid point of the euphotic zone; and 0.5 m above the bottom of the euphotic zone. Some equipment difficulties were experienced with the fluorometer early in 1999 from January to May. Calibration coefficients were adjusted for the January to May chlorophyll *a* samples.

Attached algae colonization rates were monitored on artificial growing substrates beginning in August and continuing until late October in embayment/littoral habitats near

Table 2. Sampling locations during 1999 on Lake Roosevelt and limnologic parameters sampled.

Location Name	Location #	River km From Mouth	Hydrolab Profiles	Water Quality	Zooplankton Density	Phytoplankton Density & Biovolume	Phytoplankton Chlorophyll <i>a</i>	Attached algae Density & Biovolume	Attached algae Chlorophyll <i>a</i>
Columbia River									
Evan's Landing	0.0	1143	P	S	P & L	P	P		
Kettle Falls	1.0	1128	P & L	S	P & L	P	P		
<u>Gifford</u>	2.0	1085	P & L	S	P & L	P	P	L	L
Hunters	3.0	1064	P & L	S	P & L	P	P		
Spokane R. Confluence	5.5	1028	P & L	S	P & L	P	P		
<u>Seven Bays</u>	6.0	1024	P & L	S	P & L	P	P	L	L
Sanpoil R. Confluence	8.5	992	P & L	S	P & L	P	P		
<u>Keller Ferry</u>	7.0	989	P & L	S	P & L	P	P		
<u>Spring Canyon</u>	9.0	965	P & L	S	P & L	P	P	L	L
Spokane River									
Little Falls Above Dam	5.6	47.5	L						
Little Falls Fish Trap			L						
Raceway	5.4	47.5							
Little Falls Spillway	5.3	47.5	L						
Little Falls Turbine	5.2	47.5	L						
Little Falls Boat Launch	5.1	41.8	L						
<u>Porcupine Bay</u>	4.0	18.5	P & L	S		P	P	L	L
Sanpoil River									
Free Flowing Sanpoil R.	8.8	12.9	L						
Sanpoil R.	8.0	3.6	P & L	S		P	P		
Other									
Hawk Creek	6.5	1.2	L				L		
Blue Creek	4.0	18.5						L	L
Colville R. Bridge	1.1	1.6	L						
P=pelagic L=littoral S=surface <u>Index Station</u>									

Gifford, Porcupine Bay, Seven Bays and Spring Canyon (Table 2). Attached algae was allowed to colonize glass microscope slides anchored at depths of 1.5 m (5 ft) and 4.6 m (15 ft) below the reservoir surface at the beginning of the incubation period. There were five colonization periods examined, which included two, four, six, nine, and eleven week time increments. Slides were collected and frozen following each colonization period and sent to Eastern Washington University's, Water Research Center for speciation, enumeration, biovolume estimation, and chlorophyll *a* concentration determination. Statistical analysis of attached algae data was conducted using same methods outlined in limnology data analysis.

Marconutrients and other chemical constituents were determined from surface water at eleven locations (Table 2). Samples were collected in acid washed bottles, and sent to the EPA certified Spokane Tribal laboratory in Spokane WA for analysis. Water samples were taken mid channel at sampling locations. Chemical constituents were analyzed using standard methodologies (Table 3) listed in the National Environmental Methods Index or NEMI (EPA and USGS 2003). Some chemical concentrations were at reporting limits (the smallest measured concentration of a substance that can be reliably measured by using a given analytical method) and theoretical concentrations were substituted. Theoretical concentrations were determined by dividing the report limit in half (RAASC 1999 and USGS 1999). Trophic status was assessed using Secchi disk depths, chlorophyll *a* concentrations, and total phosphorus concentrations entered into Carlson's trophic state index (Carlson 1977, Carlson and Simpson 1996). Statistical analysis of trophic state index was conducted using same methods outlined in limnology data analysis. The equations used in the trophic state index were as follows:

$$\text{TSI Secchi Disk} = 60 - 14.41 \ln (\text{Secchi Disk in m})$$

$$\text{TSI Chlorophyll } a = 9.81 \ln (\text{Chlorophyll } a \text{ in mg/m}^3) + 30.6$$

$$\text{TSI Total P} = 14.42 \ln (\text{Total P in mg/m}^3) + 4.15$$

$$\text{TSI Overall} = (\text{TSI Secchi disk} + \text{TSI Chlorophyll } a + \text{TSI Total P}) / n$$

$$n = \text{total number of TSI observations}$$

Table 3. Report limits and methods for selected analytes.

Analyte	Method (NEMI)	Report Limit
N as NO ₃ ⁻	300.0	<0.01 (mg/L)
N as NO ₂ ⁻	300.0	<0.01 & <0.005 (mg/L)
N as NH ₃	350.3	<0.05 (mg/L)
Ortho P	300.0	<0.01 (mg/L)
Total P	200.7	<0.005 (mg/L)
Si	200.7	<0.02 (mg/L)
Alkalinity	310.1	<1.0 (mg/L)
Hardness as CaCO ₃ & MgCO ₃	200.7	<0.02 (mg/L)
Total Suspended Solids	160.2	<4.0 & <2.0 (mg/L)
Turbidity	180.1	<0.5 NTU

Zooplankton

Zooplankton were sampled at nine locations and collected during 18 rounds in 1999 (Table 2). Three vertical Wisconsin zooplankton tows were taken in the pelagic zone of each sampling location from a depth of 33 m to surface (when possible). In cases where sampling location depths were less than 33 m, zooplankton tows were taken from 1 m above the bottom to the lake surface. All zooplankton samples collected in 1999 were obtained using a 20 cm diameter, 80 µm mesh Wisconsin plankton net fitted with a high efficiency sampling collar (Aquatic Resource Incorporated).

Zooplankton analysis in Lake Roosevelt was expanded beyond the pelagic zone to include embayment/littoral (Shore) habitat sampling and analysis of vertical zooplankton distributions. Shore zooplankton samples were taken from four index locations in conjunction with pelagic samples. Shore/pelagic comparative zooplankton sampling involved collection of two 17 m vertical Wisconsin tows at both pelagic and shore sites. When the depth was shallower than 17 m, tows were taken from 1 m above the bottom. Statistical analysis of zooplankton data was conducted using same methods outlined in limnology data analysis.

Assuming 100% filtering efficiency, each 33 m tow filtered approximately 1,036 liters of reservoir water and 17 m tows filtered 518 liters. When tow depth was taken from 1 m off the bottom, the depth was noted and the filtered volume was calculated during zooplankton processing. Zooplankton collected from each tow were rinsed onto a 63 µm

mesh screen (to remove excess water) and flash killed for one minute in 95% ethanol to ensure maximum egg retention. Collected organisms were then rinsed into a 60 ml polyethylene sample bottle using 70% ethanol for preservation.

In the laboratory, zooplankton samples were sorted, counted, and identified to species or lowest practical taxon using taxonomic keys by Brooks (1957), Edmondson (1959), Pennak (1989) and Thorp and Covitch (1991). In cases where organism densities were too high to count directly, sub-samples were taken using a Motodo 1.5 liter plankton splitter. High-density zooplankton samples were split until approximately 100 organisms of the most prevalent species remained in the sub-sample. Organism lengths were taken from the first 20 individuals of each species using a Leica MZ-8 dissecting microscope fitted with an optical micrometer. Upon obtaining 20 length measurements by species, all remaining individuals were counted. Organism lengths for Branchiopoda (i.e. *Daphnia* and other cladocera) were taken from the anterior most region of the head to the posterior base of the carapace. Organism lengths for copepod taxa were taken from the anterior most region of the head to the base of the caudal ramus.

Zooplankton length, density, biomass, number of eggs per female and organism sex ratios (where applicable) were calculated for individual tows and the results of replicate tows were combined to derive average values by location and date. The average number of eggs per female was calculated for each tow by counting the total number of eggs by species and dividing this value by the number of females observed for the species. Zooplankton densities were calculated through the incorporation of two equations. First, the volume of water sampled by the plankton net was calculated according to the equation:

$$V = \pi r^2 h$$

Where:

- V = volume of water sampled (liters);
- π = pi (3.14);
- r = radius of the sample net (cm); and
- h = depth of the sample (m).

Second, the number of zooplankton per cubic meter of water sampled was calculated using the equation:

$$D = ((TC \times SF) / V) \times 1000$$

Where:

- D = organism density (#/m³);
- TC = total organisms measured and counted;
- SF = the split fraction of original sample analyzed; and
- V = volume of water sampled (liters).

Zooplankton biomass was determined for each species using the length to dry weight regressions of Dumont et al. (1975) and Bottrell et al. (1976) as summarized by Downing and Rigler (1984; Table 4). Dry weight estimates for observed zooplankton species were calculated using the equation:

$$W = e^{a + b \ln(L)}$$

Where:

- W = dry weight estimate (μg) for each species;
- a = the slope intercept constant;
- b = the slope constant of the regression line; and
- L = length measurement (μm) for each individual.

Table 4. Slope (b) and intercept (ln a) values used to estimate dry weights for 1999 Lake Roosevelt zooplankton samples.

ZOOPLANKTON SPECIES	ln a	b
CLADOCERA		
<i>Daphnia pulex</i> ^a	1.59	2.77
<i>Daphnia retrocurva</i> ^a	1.4322	3.129
<i>Daphnia galeata mendotae</i> ^a	1.51	2.56
<i>Daphnia thorata</i> ^a	1.51	2.56
Juvenile <i>Daphnia</i> ^b	2.45	2.67
<i>Ceriodaphnia quadrangula</i> ^a	2.5623	3.338
<i>Bosmina longirostris</i> ^a	3.28	3.13
<i>Sida crystalina</i> ^a	2.0539	2.189
<i>Alona quadrangularis</i> ^a	2.8713	3.079
<i>Diaphanosoma brachyrum</i> ^a	1.6242	3.0468
<i>Diaphanosoma birgei</i> ^a	1.6242	3.0468
<i>Leptodora kindtii</i> ^a	-0.822	2.670
<i>Polyphemus pediculus</i> ^a	2.7792	2.152
<i>Chydorus sphaericus</i> ^a	4.543	3.636
COPEPODA		
<i>Epischura nevadensis</i> ^c	0.0077	2.33
<i>Leptodiaptomus ashlandi</i> ^c	0.0077	2.33
<i>Diacyclops bicuspidatus thomasi</i> ^c	1.10	2.59
<i>Mesocyclops edax</i> ^c	1.10	2.59
Calanoid/cyclopoid nauplii ^c	1.10	1.89

References: ^a = Downing and Rigler, 1984; ^b = Bottrell et al., 1976 and ^c = Dumont et al., 1975.

Fishery

Fisheries Surveys

Fishery surveys were conducted at ten index stations in the reservoir, which included: Evans, Kettle Falls, Gifford, Hunters, Porcupine Bay, Little Falls Dam, Seven Bays, Sanpoil River, Keller Ferry, and Spring Canyon (Figure 2). Fishery data was collected at each index station over 24 hour intervals.

Fish surveys were conducted three times annually (May, July, and October). Boat electrofishing surveys were performed in littoral areas of Lake Roosevelt and its tributaries. Ten minute transects were surveyed along 0.5 km of shoreline using SR-180 and SR-23 electrofishing boats (Smith Root, Inc., Vancouver, WA; Reynolds 1983, Novotany and Prigel 1974). Voltage was adjusted to produce a pulsating DC current of approximately 5 amperes. Fish were collected using dip nets and placed into live wells on the boat for examination and data collection. A minimum of six transects were sampled at each index station.

Gill net surveys were performed in pelagic zones with benthic horizontal and vertical gill nets (Hubert 1983). Four gillnets were set at each index station including 2-3 horizontal gillnets, and 1-2 vertical gill nets dependent upon site morphology. Horizontal gill nets were set on the lake bottom, and were 61 m in length and 3.7 m deep. Each horizontal net consisted of four 15.2 m panels with square mesh sizes of 1.3 cm, 2.5 cm, 3.8 cm and 5.1 cm. Vertical gill nets were 3.0 m wide, extended to a maximum depth of 61 m, and had a uniform 5.1 cm square mesh size. Gill nets were set in early afternoon and pulled the next morning.

Beach seine hauls were conducted during July at thirteen locations (37 hauls) and in October at two locations (6 hauls) with 1 to 3 hauls per location. Beach seine mesh size was 3 mm and the dimensions were 2 m × 30 m.

Fish were identified to species using the taxonomic key of Wydoski and Whitney (1979). Each fish was measured to the nearest millimeter (mm) total length and weighed to the nearest gram using a spring scale. Sex and origin (hatchery or wild) were determined when possible. Mean length and weight were calculated for each species collected. Relative abundance and catch-per-unit-effort (CPUE) were calculated seasonally for each gear type (Anderson and Neumann 1996).

Figure 3. Boat electrofishing, gill net, and rainbow trout and kokanee net pen locations in Lake Roosevelt, 1999.

The heads of hatchery kokanee were removed, placed in individually numbered bags and frozen. Heads were sent to Eastern Washington University's, Fisheries Research Center for coded wire tag extraction and analyses.

Age and Growth

In the field, scales were taken from appropriate locations for each species (Jearld 1983) and placed in coin envelopes labeled with species, fish number, length, weight, location, and date. In the laboratory, scales were removed from the envelope and placed between two microscope slides. Slides were then placed in a Realist Vantage 5, Model 3315 microfiche reader. Scale images were projected onto the screen and a non-regenerated, uniform scale was selected to determine age and back calculate length at age. Age was determined by counting the number of annuli (Jearld 1983). For back calculations, the annulus distance was measured from the origin of the scale to the last circuli of each respective annulus. Each measurement was made under constant magnification to the nearest millimeter.

The direct proportional method was used to back calculate the length of the fish at the formation of each annulus (Devries and Frie 1996). The direct proportional method was used instead of the Fraser Lee method to maintain consistency with the methods used in previous Lake Roosevelt reports.

Back-calculations were computed using the formula:

$$L_i = \left(\frac{S_i}{S_c} \right) L_c$$

Where:

- L_i = back calculated length of fish (mm) when the i th increment was formed;
- L_c = length of fish (mm) at capture;
- S_c = radius of hard part at capture; and
- S_i = radius of hard part at the i th increment.

Condition factors were determined for each fish to serve as an indicator of fish condition (Hile 1970, Everhart and Youngs 1981). Condition factor describes how a fish adds weight in relation to incremental changes in length. The relationship is shown by the formula:

$$K_{TL} = \left(\frac{w}{l^3} \right) 10^5$$

Where:

K_{TL} = condition factor;
 w = weight of fish (g); and
 l = total length of fish (mm).

Feeding Habits

Fish stomachs were collected opportunistically from kokanee salmon, rainbow trout, eastern brook trout, brown trout, lake whitefish, mountain whitefish, walleye, yellow perch, black crappie (*Pomoxis nigromaculatus*), smallmouth bass, bridgelip sucker (*Catostomus columbianus*), longnose sucker (*Catostomus catostomus*), largescale sucker, burbot (*Lota lota*), northern pikeminnow (*Ptychocheilus oregonensis*), and tench (*Tinca tinca*) at each index station. Creel clerks obtained additional kokanee stomachs from anglers throughout the year. Stomachs were collected by making an incision into the body cavity, cutting the esophagus, and pinching the pyloric sphincter. The esophagus was clamped to keep prey items from being expelled and the stomach was placed in 10% formalin.

In the laboratory, stomachs were transferred to a 70% isopropyl alcohol solution. Contents were identified to Order or Family when possible using the taxonomic keys of Brooks (1957), Ward and Whipple (1966), Borror et al. (1976), Ruttner-Kolisko (1974), Edmonds et al. (1976), Wiggins (1977), Pennak (1978, 1989), and Merritt and Cummins (1984). Food organisms were identified using a Nikon SMZ-1B dissecting microscope equipped with a fiber optics illumination system and 5 mm ocular micrometer.

Prey items were enumerated and weighed by drying sorted stomach contents in an oven at 105° for 24 hours on a stainless steel wire screen. Sub samples of zooplankton were taken using a petri dish with a molded grid. Eight squares were counted, and counts were extrapolated to represent the entire sample. Contents were weighed on a Sartorius Model H51 analytical balance to the nearest 0.0001 g (Weber 1973, APHA 1993).

Number, dry weight, and frequency of occurrence were calculated for each prey item (Bowen 1996). Relative importance index values were used to compensate for numerical estimate biases that tend to over-emphasize small prey groups consumed in large numbers and weight

estimate biases that overemphasize large prey items consumed in small numbers. The relative importance index was calculated using the formula (George and Hadley 1979; Bowen 1996):

$$Ri_a = \frac{100Ai_a}{\sum_{a=1}^n Ai_a}$$

Where:

- Ri_a = relative importance of food item a;
- Ai_a = absolute importance of food item a; and
- n = number of different food types.

Relative importance values range from zero to 100% with prey items near zero being relatively less important than those prey items near one hundred percent.

Diet overlap was calculated to determine forage utilization and the degree to which interspecific competition exists in Lake Roosevelt. Fish diet overlaps were computed by using the overlap formula of Morisita (1959) as modified by Horn (1966). Overlap values were based upon indices obtained from Ri_a calculations. Overlap index was expressed in the equation:

$$C_x = \frac{2 \sum_{i=1}^n (P_{xi} \times P_{yi})}{\sum_{i=1}^n P_{xi}^2 + \sum_{i=1}^n P_{yi}^2}$$

Where:

- C_x = overlap coefficient;
- n = number of food categories;
- P_{xi} = proportion of food category (i) in the diet of species x;
- and
- P_{yi} = proportion of food category (i) in the diet of species y.

Overlap coefficients were computed using Ri_a values in the equation for the variables P_{xi} and P_{yi} . Overlap coefficients range from 0 (no overlap) to 1 (complete overlap). Values of less than 0.3 are considered low and values greater than 0.7 indicate high overlap (Peterson and Martin-Robichaud 1982). High diet overlap indices may indicate competition if food items utilized by the species are limited (MacArthur 1968), or there may be an abundant food supply and therefore competition does not exist.

Tagging Studies

Sub-samples of hatchery reared rainbow trout and kokanee salmon were marked with T-anchor type Floy[®] tags as part of a tagging study to evaluate fish performance. Spokane stock rainbow trout (coastal strain, *Oncorhynchus mykiss irideus*) were marked and released in April from Kettle Falls and Seven Bays net pens (Table 5). Phalon Lake stock redband rainbow trout (*O. m. gairdneri*), native to Kettle River tributaries, were released in October from net pens Kettle Falls. Kokanee salmon were released in June for Kettle Falls (Table 5).

Posters with tag return information were posted at access points throughout the reservoir. Tags were recovered from anglers via creel clerks or were reported by phone or mail. Anglers asked to provide date of capture, location, species, length and weight when possible. Data was used to evaluate movement within and out of the reservoir and growth.

Table 5. Number of floy tagged fish released into Lake Roosevelt, 1999.

Release Location and stock	Release Date	Number released
Kettle Falls		
Rainbow trout (Spokane stock)	4/27-28/99	9,977
Rainbow trout (Phalon Lake stock)	10/26/99	9,142
Kokanee (Lake Whatcom stock)	6/28/99	9,621
Seven Bays		
Rainbow trout (Spokane stock)	4/99	9,995
Totals		38,735

Creel Survey

A two-stage probability sampling scheme using a roving-access design was used to determine annual fishing pressure, catch-per-unit-effort (CPUE), and sport fish harvest by species on Lake Roosevelt (Pollock et al. 1994, Malvestuto 1986). Creel surveys were a cooperative effort between the Spokane Tribe, Colville Confederated Tribe, and the Washington Department of Fish and Wildlife. The lake was split into three sections; upper, middle and lower, with each agency responsible for a section. Creel surveys were conducted at Spokane and Colville tribal campgrounds and National Park Service boat launches for a total of 27 survey locations (Table 6).

The creel surveys are reported for the time period December 1998 through October 1999. Quarters were split into December 1998 through February 1999 (winter), March through May 1999 (spring), June through August 1999 (summer), and September through October all). December 1998 was included in the analysis to allow for a continuous winter quarter instead of a broken winter quarter. To reduce costs, creel surveys were not conducted in any section during November (historically a low pressure month) or April (the mid spring month), and October in the upper section.

Schedules were constructed by dividing each month into weekday and weekend/holiday stratum and days were stratified into a.m. (sunrise to 12:00) and p.m. (12:00 to sunset) time periods. Eighteen weekdays and four weekend/holidays were randomly selected to schedule roving progressive pressure counts with half of the surveys conducted during the a.m. and the other half conducted during the p.m. (Pollock et al. 1994). The remaining a.m. or p.m. time slots over the 21 day time period were used to conduct five hour access point surveys. The schedules were developed monthly by randomly selecting day, time (am/pm), and location of access point surveys. Rove surveys were conducted during the opposite time period of the access point surveys. Schedules were randomly constructed and independent by section.

During roving progressive pressure counts, creel clerks recorded the number of boat trailers and shore anglers at access points in their section. Many shoreline anglers do not fish at boat launches. Consequently, locations frequently visited by anglers were added as sites for the rove, but not as access areas to sit at. The creel clerk reached the access points by road. If the clerk was ahead of schedule, they interviewed the shoreline anglers that were close to the road. An interview took less than five minutes, and enabled the clerk to gather important catch and trip length data.

Access point surveys were only conducted at boat launches (Table 6). During each access point survey, creel clerks interviewed anglers to collect the following information: angler type, hours fished, completed trip, satisfaction, zip code of residence, target species, and number of fish harvested and released. Harvested fish were identified to species, measured for total length (mm), weighed (g), and examined for floy tags, fin clips, and physical markings such as eroded pectoral and pelvic fins, and stubbed dorsal fins. Physical marks were used to differentiate rainbow trout of net-pen/hatchery origin from wild fish. Scale

samples were collected from representative kokanee, rainbow trout, and walleye. Heads were taken from fin clipped kokanee for coded wire tag analyses. Additionally, non-anglers were interviewed to correct for recreational boaters vs. anglers.

Table 6. Names and numerical code of boat launch and rove sites for creel surveys per section sampled, 1999.

Section 1 (Upper)	Section 2 (Middle)	Section 3 (Lower)
<u>Boat launch sites</u>		
Gifford Campground	Little Falls ¹	Keller Marina
Bradbury Beach	Porcupine Bay ¹	Keller Park ²
Kettle Falls Marina	Fort Spokane ¹	Spring Canyon
Marcus Island	Hunters	
Evans	Seven Bays Marina	
<u>Rove Sites</u>		
China Bend	Hunters	Keller Ferry Marina
North Gorge	Columbia Campground	Keller Ferry (South)
Marcus Island	Fort Spokane ¹	Keller Ferry (North) ²
Bradbury Beach	A- Frame ¹	Keller Park ²
13 Daisy	Porcupine Bay ¹	Sanpoil River ²
Gifford Campground	Docks ¹	Swawilla Basin
	Sand Bar ¹	Spring Canyon
	Little Falls Launch ¹	Crescent Bay
	Little Falls Dam ¹	Coulee Dam
	Seven Bays Marina	
	Hawk Creek	

¹ Spokane River sites

² Sanpoil River sites

Between 1990 and 1993, air flights (one flight per stratum) were scheduled to coincide with monthly roving pressure counts. The creel clerks recorded the number of boat trailers and shore anglers in their section while concurrently the surveyor in the airplane recorded the number of boats on the water and the number of shore anglers. This information was used to

compute a correction factor for the number of boats on the water versus the number of boat trailers at access points. The correction factor for boat trailers versus boats on the water was determined between 1990 and 1993, averaged among years and then applied to 1999. Limitation of funds negated our ability to conduct regularly scheduled air flights. See Cichosz et al. (1999) for flight correction factors.

The number of boats on the reservoir was determined for the stratum weekday/weekend, section and month by completing the following calculation:

$$T_b = (C_{bt})(CF_b)$$

Where:

T_b = number of boats on the water for each stratum per month;

C_{bt} = mean boat trailer count from pressure counts for each stratum per month (total # of boats/ # of days sampled;

and

CF_b = boat trailer correction factor for each stratum per month.

The number of boats fishing for the strata weekday/weekend, section and month was calculated by using the formula:

$$B_f = (T_b)(\%B_f)$$

Where:

B_f = number of boats fishing for each stratum per month;

T_b = number of boats on the water for each stratum per month; and

$\%B_f$ = percent of boats fishing for each stratum per month (number is in decimal form).

The adjusted mean number of boat anglers per day for the strata weekday/weekend, section and month was estimated using the formula:

$$X_d = (Ad)(B_f)$$

Where:

X_d = adjusted mean number of anglers per boat per day for each stratum per month;

Ad = mean number of anglers per boat from effort counts for each stratum per month; and

B_f = number of boats fishing for each stratum per month.

The above calculations used to estimate the instantaneous number of boat anglers were estimated separately by section then summed to obtain a full lake estimate.

The number of hours available for fishing (sunrise to sunset) was estimated using the following formula:

$$N_s = (D_s)(H_d)$$

Where:

N_s = number of hours per weekend, weekday per month;

D_s = number of days per month a weekday or weekend; and

H_d = average number of hours per day for each stratum per month.

The number of hours sampled for each stratum per month was estimated using the formula:

$$n = \sum_{i=1}^{D_s} (H_{ci})$$

Where:

n = number of hours sampled for each stratum per month;

D_s = number of days per month within each stratum; and

H_{ci} = mean number of hours creel per day for each stratum per month.

The number of shore anglers per day for each stratum per month was estimated using the formula:

$$X_d = \sum_{i=1}^{P_d} (S_{pi})$$

Where:

X_d = mean number of shore anglers per day for each stratum per month from pressure counts;

P_d = Number of days that pressure counts were conducted for each stratum per month; and

S_{pi} = total number of shore anglers counted during pressure counts for each stratum per month.

The mean number of anglers (boat or shore) for each stratum per month was estimated using the formula:

$$X_s = (X_d)(D_s)$$

Where:

X_s = mean number of anglers for each stratum per month;

X_d = mean number of anglers for each stratum per day; and

D_s = number of days per month within the stratum.

The standard deviation of anglers (boat or shore) for each stratum per month was estimated using the formula:

$$S_s = (S_d)(D_s)$$

Where:

S_s = standard deviation of anglers for each stratum per month;

S_d = standard deviation of anglers per day for each stratum per month; and

D_s = number of days per month for each stratum per month.

The mean number of angler hours per angler for each stratum was estimated using the formula:

$$H_a = \left(\frac{T_h}{A_i} \right)$$

Where:

H_a = mean number of angler hours per angler for each stratum per month;

T_h = total hours spent fishing for each stratum per month;
and

A_i = total number of anglers interviewed for each stratum per month.

Pressure (hours fished) was estimated for day stratum (week day or weekend/holiday) for boat and shore anglers for each month by section by the formula:

$$PE_s = \left(\frac{N_s}{n} \right) (X_s)(H_a)$$

Where:

PE_s = pressure estimate for each stratum per month;

N_s = number of hours for each stratum per month;

n = number of hours sampled for each stratum per month;

X_s = mean number of anglers for each stratum per month;
and

H_a = mean number of angler hours per angler for each stratum per month.

The variance of the pressure (hours fished) estimate for each stratum per month was calculated by:

$$VPE_s = \left(\frac{N_s}{n} \right) S_s^2$$

Where:

VPE_s = variance of pressure estimate for each stratum per month;

N_s = number of hours for each stratum per month;

n = number of hours sampled for each stratum per month;
and

S_s = standard deviation of mean number of angler hours for each stratum per month.

Ninety-five percent confidence intervals for each stratum per month were calculated by:

$$C.I. = PE \pm \sqrt{(VPE_s)1.96}$$

Where: C.I. = 95% confidence intervals for each stratum per month;

PE = pressure estimate for each stratum per month; and

VPE_s = variance of the pressure estimate for each stratum per month.

Monthly angler pressure and 95% C.I. were determined by calculating weekend/weekday and boat/shore anglers per month by section. If data gaps existed in any strata, the annual averages were used to fill the gaps. Annual angler pressure and 95% C.I. estimates were calculated by summing monthly angler pressure estimates and variances, which were used to calculate a 95% C.I. estimate for each section. Each section was then added together to estimate reservoir wide pressure.

Studies by Malvestuto et al. (1978), Fletcher (1988) and, Malvestuto (1996) have shown that CPUE values calculated independently from complete and incomplete trip data are not statistically different. Therefore, complete and incomplete angler trips were used to compute

CPUE for fish species in each stratum. CPUE was calculated independently for fish captured (kept and released) and fish harvested (kept) for each stratum for the month by the formula:

$$CPUE = \left(\frac{F}{T_h} \right)$$

Where:

CPUE = Catch per unit effort of a particular fish species for each stratum per month;

F = number of fish captured (harvested) for each stratum per month; and

T_h = total hours spent fishing for each stratum per month.

Monthly CPUE of a particular fish species was calculated by dividing the total catch for the entire month (all stratum) by the total angler hours (all stratum) for each section. Annual CPUE values of a particular fish species were calculated by dividing the total catch for the year by the total number of angler hours for the year.

Harvest of fish species was determined for each stratum per month by the formula:

$$\text{Harvest} = (H_{cpue})(PE_s)$$

Where:

Harvest = harvest of a particular fish species for each stratum per month;

H_{cpue} = number of fish harvested of a particular fish species for each stratum per month for each stratum per month; and

PE_s = pressure (hours fished estimate for each stratum per month).

Monthly harvest estimates for a particular fish species by stratum were combined to calculate a total monthly harvest estimate by section. Monthly harvest estimates were combined to calculate annual estimates for each fish species by section. Section harvest estimates were added by month to obtain reservoir wide harvest.

Data compiled by the U.S. Fish and Wildlife Service in 1996 determined that the average inland fishery angler spent \$25.00 per trip (USFWS 1998). To calculate current dollar amount spent by anglers per trip, the 1996 cost per fishing trip was adjusted for inflation using the consumer price index inflation calculator, which adjusted \$25.00 in 1996 to \$26.55 in 1999 (USDL 2003).

The adjusted dollar value was multiplied by total number of angler trips in 1999 to provide an estimate of the economic value of the fishery. The number of angler trips per month was determined by dividing the total number of angler hours per month by the average length of a completed fishing trip for the month. Annual angler trips were calculated by summing monthly angler trip values.

Results

Limnology

Surface Hydrology

Precipitation during the 1999 water year in the Columbia River basin was, on average, 94.6 % of normal. Precipitation in the sub-basin above Grand Coulee Dam was slightly higher at 96.4 % of normal. Precipitation accumulation in the entire Columbia River basin was on average 109 % of normal while precipitation accumulation in the basin above Grand Coulee was 107 % of normal. Snow packs during water year 1999 were higher than normal, which contributed to higher than normal river flows in the Columbia River basin and at Grand Coulee Dam (USACOE 1999).

Columbia River flows at the Dalles were 120 % of the 15-year average (1983-1998), while outflows at Grand Coulee Dam were 123 % (USACOE 1999, USGS 2003). Outflows in 1999 were generally higher in early summer and lower in late summer/fall (Figure 4). The annual mean outflow at Grand Coulee Dam was 127.4 (kcfs) during 1999 (Table 7). Outflows at Grand Coulee were highest in July with a mean of 150.5 (kcfs) and lowest in October with a mean of 85.7 (kcfs).

Reservoir elevation varied over 1999 with low elevations occurring early in the year to prepare for storage of upstream spring runoff. All elevation measurements occurred at the forebay of Grand Coulee Dam forebay where the 1999 mean elevation was 1268.2 ft above sea-level (ft ASL). Typical full pool elevation is 1290 ft ASL. The highest mean monthly elevation was reached in August at 1288.6 ft ASL and the lowest mean monthly elevation occurred in May at 1220.9 ft ASL (Table 7). Forebay elevation was below the mean elevation a total of 154 days. The most extended periods of littoral desiccation occurred during the months of February, March, April, and May. Forebay elevations were below the mean elevation for the entirety of those months. On average, forebay elevation was below the mean elevation by 6, 13, 36, and 47 ft during the months of February, March, April, and May, respectively. In the first half of 1999 daily elevation change (mean from midnight forebay elevations) averaged 0.86 ft/day and in the last half, daily elevation change averaged

0.41 ft/day. The highest daily elevation change occurred in June at 1.45 ft/day and the lowest daily elevation change occurred in August at 0.28 ft/day (Table 7; Figure 4).

Water retention time varied through the year and reflected the change in elevation and flows as the reservoir was prepared for spring runoff (Table 7; Figure 4). The average water retention time was 32.1 (days) in Lake Roosevelt during 1999. The lowest water retention time occurred in May 17.8 days while the reservoir was being lowered to accommodate the spring runoff. The highest water retention time occurred in October 53.9 days when flows were lowest.

Table 7. Monthly and annual hydrologic characteristics at Grand Coulee Dam and Lake Roosevelt, WA (1999).

Month	Inflow (kcfs)	Outflow (kcfs)	Spill (kcfsd)	Forebay Elevation (ft-ASL)	Storage Capacity (kcfsd)	Water Retention Time (d)	Mean Elevation Change (ft/d)	Days Below Mean Elevation
Jan	113.2	129.1	0.00	1269.6	3819.7	30.3	0.623	16
Feb	137.3	135.6	0.00	1262.0	3546.1	27.6	0.486	28
Mar	108.8	127.9	0.00	1254.5	3295.3	26.1	0.626	31
Apr	110.3	127.7	0.00	1232.2	2612.1	21.3	0.883	30
May	156.1	132.3	0.00	1220.9	2305.0	17.8	1.148	31
Jun	203.3	144.9	0.03	1264.4	3649.6	26.0	1.453	18
Jul	164.9	150.5	0.10	1288.4	4537.7	30.6	0.358	0
Aug	151.9	147.3	0.15	1288.6	4545.2	31.2	0.277	0
Sep	106.5	103.4	0.10	1285.4	4418.4	44.1	0.397	0
Oct	91.2	85.7	0.00	1285.9	4438.4	53.9	0.352	0
Nov	99.4	102.6	0.00	1286.0	4441.4	45.3	0.490	0
Dec	126.8	141.8	0.00	1279.5	4187.9	30.2	0.619	0
Annual Mean	130.7	127.4	0.03	1268.2	3819.0	32.1	0.643	Sum = 154

Total Dissolved Gas

Due to equipment malfunctions during 1999, total dissolved gas (TDG) measurements were suspect. Specifically, problems with the Hydrolab TDG sensor and barometric pressure gage were encountered. The TDG sensor was periodically non-functional during sampling in February, May, November, and December. Barometric pressure readings were unusually high in June, July, and October.

Figure 4. Daily water retention time, outflow, and reservoir elevation (Grand Coulee Dam forebay) for Lake Roosevelt, WA (1999).

To validate 1999 sampling, this data was compared to TDG data collected at Grand Coulee forebay and the US / Canada Border on the Columbia River by the USACOE. The lowest monthly mean TDG level occurred in December (103 %), while the high was observed in March (117 %; Table 8). Standard deviation within a month was not consistent from month to month, indicating possible sampling problems (Figure 5). The standard deviation for January TDG data was 5.2 %, while March was 0.9 % (Table 8). There were significant differences between measurements from month to month (Scheffe's S, $p < 0.05$). However, in light of the erratic standard deviations and other issues, the meaning of those statistical differences is in question.

Table 8. Total dissolved gas (%) descriptive statistics by month for all Spokane Tribe sampling locations in 1999.

Month	B.P. (mmHg)	TDG (mmHg)	TDG (%)	TDG (%) Sd. Dev.	Temp (°C)	% D.O.	D.O. (mg/L)	% N Sat.
Jan	725.8	771.2	106.3	5.2	3.7	56.3	6.8	120.6
Mar	719.1	841.5	117.0	0.9	4.7	91.0	11.7	123.6
Apr	723.2	825.4	114.1	1.5	7.2	95.2	11.5	119.3
May	725.0	765.1	105.5	3.7	9.0	99.2	11.4	107.7
Jun	715.7	780.0	109.2	8.6	13.6	111.5	11.0	111.0
Jul	724.1	823.4	113.7	0.5	16.3	64.0	6.1	128.5
Aug	722.9	823.9	114.0	1.3	18.4	104.4	9.0	120.7
Sep	736.9	825.1	112.0	1.9	17.2	99.3	8.8	119.4
Oct	745.5	825.9	110.8	2.0	13.8	91.9	8.7	119.6
Nov	730.1	825.9	113.1	1.1	10.5	92.4	9.5	121.3
Dec	734.9	761.3	103.6	11.3	6.8	92.5	10.4	108.6
Annual Mean	728.4	807.1	110.9	5.8	12.9	92.7	9.3	118.1

Between sampling locations, the highest annual mean TDG measurement on the mainstem was recorded at Hunters (112 %). The lowest annual mean was recorded at the Spokane River Confluence at 109 % (Table 9). However, there were no statistical differences between locations sampled by the Spokane Tribe in 1999 (Tukey's HSD, $p > 0.05$). Standard deviation for location data was more uniform than monthly data.

Table 9. Total dissolved gas (%) descriptive statistics for all Spokane Tribe sampling locations and USACOE water quality, sampling stations in 1999.

Location	Mean (%)	St. Dev.	n	Min	Max
Canada Border (USACOE)	112.2	8.1	358	100.6	148.6
Evan's Landing	111.1	3.9	141	100.6	117.2
Kettle Falls	110.6	4.1	274	101.0	117.1
Gifford	110.8	4.2	286	99.4	117.4
Hunters	111.8	4.0	286	99.7	117.8
Porcupine Bay	109.9	8.2	272	86.6	118.7
Little Falls, Boat Launch	109.9	7.1	15	88.5	115.8
Little Falls, Turbines	110.0	7.3	15	88.5	116.2
Little Falls, Spill Way	109.9	7.2	15	89.0	115.1
Little Falls, Fish Trap	111.4	4.2	9	103.8	114.7
Little Falls, Above Dam	110.3	7.3	15	89.1	117.1
Spokane River Confluence	109.8	6.9	300	89.2	118.2
Seven Bays	110.1	7.1	293	88.8	129.5
Hawk Creek	109.5	6.9	196	88.5	118.3
Keller Ferry	111.7	5.6	300	97.0	126.3
Sanpoil River	111.5	5.3	299	94.1	125.0
Sanpoil River Confluence	111.4	4.8	300	96.7	120.1
Free Flowing Sanpoil River	112.1	5.4	17	103.2	125.0
Spring Canyon	111.7	6.1	301	97.4	128.2
Grand Coulee Forebay (USACOE)	107.4	6.5	354	96.1	125.7

Total dissolved gas was consistently higher at the US/Canada border on a monthly basis in 1999. Total dissolved gas was significantly higher at the US/Canada border over the entire year (Scheffe's S, $p < 0.0001$). The border station is closer to gas loading by upstream dams and as the water travels downstream, supersaturated gas will come out of solution as it equilibrates with the atmosphere (Weitkamp 2000). Monthly TDG extremes at the US/Canada border occurred during February (105 %) and June (122 %). Monthly TDG extremes at Grand Coulee forebay occurred in November (100 %) and August (116 %) in 1999. Generally, TDG was lower in the winter and higher in the early summer at both the US/Canada border and the Grand Coulee forebay (Figure 5; Figure 6).

During 1999, TDG as measured by the Spokane Tribe, exceeded the state and federal water quality standard of 110 % saturation nearly 70 % of the time (Figure 6). These TDG measurements were below the standard mainly during the spring. At the US/Canada border,

mean daily TDG exceeded the standard 51 % of the year. The saturation standard was exceeded for much of May, June, July and August at the US/Canada border. At Grand Coulee's forebay, mean daily TDG exceeded the standard for 37 % of the year, primarily between May and August of 1999.

Figure 5. Scatter plot of TDG (%) data from USACOE water quality sampling stations and monthly means with error bars (± 1 standard deviation) from the Spokane Tribe of Indians (STOI) Lake Roosevelt sampling in 1999.

Figure 6. Scatter plot of TDG (%) data from the Spokane Tribe Lake Roosevelt sampling and USACOE water quality stations in 1999.

Physical and Chemical Characteristics

Monthly mean water temperature was highest in August (17.9 °C) and lowest in January (3.7 °C) during 1999 in Lake Roosevelt. Temperature rose steadily from winter until late summer then began decreasing in the fall (Figure 7). Water temperature varied significantly by sampling location (Fisher's PLSD, $p < 0.05$). Average annual temperature at Porcupine Bay (12.7 °C) was greater than Hunters (11.7 °C), Gifford (11.7 °C), and Kettle Falls (11.6 °C). Average annual temperature at Kettle Falls (11.6 °C) was less than Spring Canyon (12.5 °C) and the Sanpoil River (12.6 °C). Average annual temperature at Gifford (11.7 °C) was less than Spring Canyon (12.6 °C) and Porcupine Bay (12.7 °C).

Temperatures were higher near Grand Coulee Dam, in the Spokane River, and in the Sanpoil River. Pelagic site thermal stratification (1 °C Δ /m) was only observed at Seven Bays and Porcupine Bay on July 7. Thermal stratification at both locations was gone by the next sampling round, 20 days later. Stratification was weak at both locations. The magnitude of change between depths was 1.1 °C/m at Seven Bays and 1.5 °C/m at Porcupine Bay. Both of these temperature gradients occurred from 3 m to the surface.

Dissolved oxygen concentrations in January (6.98 mg/L) and July (6.28 mg/L) were lower than what would be expected under typical conditions (Figure 7). With a mean temperature of 3.7 °C and reservoir elevation of 1269.6 ft ASL in January, dissolved oxygen at 100 % saturation would have a concentration of 12.6 mg/L (APHA 1995). In June the mean temperature and reservoir elevation were 15.7 °C and 1288.4 ft ASL and dissolved oxygen at 100 % saturation would have a concentration of 9.48 mg/L (APHA 1995). January and July dissolved oxygen concentrations likely would have been near the estimates. Disregarding January and July means, the lowest mean dissolved oxygen concentration was observed in October (8.65 mg/L), while the highest was in March (11.68 mg/L). Mean annual dissolved oxygen content at Porcupine Bay (8.23 mg/L) was significantly less than annual means observed at all other pelagic sampling locations (Scheffe's S, $p \leq 0.002$).

Mean monthly total dissolved solids (TDS) ranged from 66.9 mg/L in July to 90.1 mg/L in

Figure 7. Box plots of temperature (°C) and dissolved oxygen (mg/L) data split by sampling location averaged over the entire year and by month averaged over all sampling locations on Lake Roosevelt during 1999.

January (Figure 8). Annually, TDS varied the most at Porcupine Bay (129.0 mg/L to 10.0 mg/L) resulting in an annual standard deviation of 27.1 mg/L, while the annual standard deviation across all other pelagic sites was 8.0 mg/L. Specific conductance numbers had the same relative distribution as TDS since they are measured from the same *Hydrolab* sensor. Mean annual conductivity averaged across all locations was lowest in July (104.6 $\mu\text{S}/\text{cm}$) and highest in January (141.0 $\mu\text{S}/\text{cm}$) averaged across all sites (Figure 8). Porcupine Bay had the greatest annual variation in conductivity with a standard deviation of 41.6 $\mu\text{S}/\text{cm}$ (Figure 8).

Figure 8. Box plots of total dissolved solids (mg/L) and specific conductivity (µS/cm) data split by sampling location averaged over the entire year and by month averaged over all sampling locations on Lake Roosevelt, WA (1999).

Mean monthly hydrogen ion concentration (pH) ranged annually from 7.1 in January to 8.8 in July (Figure 9). Mean annual pH was significantly lower at Porcupine Bay (7.8) than Evan's Landing (8.1), Gifford (8.2), Hunters (8.2), and Keller Ferry (8.0) (Scheffe's, $p \leq 0.0251$). Additionally, mean annual pH was significantly lower at Spring Canyon (8.0) than Hunters (8.2), and Gifford (8.2) (Scheffe's, $p \leq 0.0444$).

Oxidation/reduction (redox) potentials measured in Lake Roosevelt were suspiciously low from July (82.3 mV) until November (14.6 mV) (Figure 9). Considering that dissolved oxygen saturation ranged from 98.9 % to 104.0 % during that time period, except in July (64.7 %), it is likely there was an equipment malfunction. In general,

Figure 9. Box plots of pH and oxidation-reduction (redox) potential (mV) data split by sampling location averaged over the entire year and by month averaged over all sampling locations on Lake Roosevelt during 1999.

mean annual redox potentials were lower in the upper reservoir and with increasing proximity to Grand Coulee Dam. Mean annual redox potential at Evan's Landing and Spring Canyon were 94.6 mV and 162.3 mV respectively. However, the means by location are suspiciously low as well (Figure 9), considering current redox potentials in Lake Roosevelt averaged 327 mV across all locations in 2003 (LRFEP unpublished data 2003). Deoxygenation that could lead to low water column redox potentials during late fall and winter is unlikely since, Lake Roosevelt is well mixed at that time.

Mean monthly Secchi disk depths ranged from 2.6 m in May to 8.8 m in November (Figure 10). Comparisons between locations indicate that mean annual Secchi disk depth at Spring Canyon (7.2 m) was significantly greater than depths observed at Evan's Landing (5.3 m),

Figure 10. Box plots of annual mean Secchi disk depths (m) and euphotic zone depths (m) for all sampling locations in Lake Roosevelt, WA (1999), and monthly mean Secchi disk depths (m) and euphotic zone depths (m) combined across all sampling locations.

Gifford (5.1 m), Hunters (5.3 m), and Kettle Falls (5.0 m) (Fisher's PLSD, $p \leq 0.0385$). Mean annual Secchi depths were also significantly greater at the Sanpoil River

Confluence (6.9 m) than Kettle Falls (5.0 m) and Porcupine Bay (4.8 m; Fisher's PLSD, $p \leq 0.0451$). Secchi disk depths confirm euphotic zone depths assessed with an irradiator. Monthly mean euphotic zone depths across all sites ranged from 6.8 m in April to 15.9 m in November. Mean annual euphotic zone depths ranged from 9.47 m at Porcupine Bay to 12.2 m at Spring Canyon (Figure 10). Porcupine Bay and Spring Canyon were the only locations with significantly different euphotic zone depths (Fisher's PLSD, $p = 0.0437$).

Mean monthly incidental irradiance at the water surface peaked in July (79.3 $\mu\text{W}/\text{cm}^2 \cdot \text{nm}$) and was lowest in January (9.6 $\mu\text{W}/\text{cm}^2 \cdot \text{nm}$; Figure 11). Mean monthly turbidity values ranged from 0.129 NTU in July to 3.906 NTU in January (Figure 12). However, this was after several turbidity values were removed from the data set because they were unreasonably high. The values removed were all from a depth of zero meters and ranged from 59.4 NTU to 576.8 NTU. The high surface turbidity values were likely the result of an air bubble interfering with the turbidity sensor.

Figure 11. Box plots of surface irradiance ($\mu\text{W}/\text{cm}^2 \cdot \text{nm}$) split by sampling location averaged over the entire year and by month averaged over all sampling locations on Lake Roosevelt, WA (1999).

Figure 12. Box plots of turbidity (NTU) split by sampling location averaged over the entire year and by month averaged over all sampling locations on Lake Roosevelt, WA (1999).

Macro Nutrients

Different forms of nitrogen and phosphorus important to primary producers in Lake Roosevelt were measured in 1999. Nitrogen in Lake Roosevelt was largely in the most oxidized form NO_3^- (Table 10). Nitrogen in the form of NO_3^- averaged 0.119 mg/L across all locations. Nitrate levels were highest at Porcupine Bay, exhibiting an annual average of 0.435 mg/L and peaking in December (0.767 mg/L). Nitrogen as NO_2^- was often at or near the report limit. Nitrite averaged 0.004 mg/L during 1999 across all sampling locations (Table 10). Ammonia (NH_3) was also observed in low concentrations during 1999 (Table 10). All NH_3 concentrations were measured at the report limit of 0.025 mg/L (theoretical concentrations for NH_3 were not calculated). Total nitrogen (TN) was calculated by adding all N fractions. Since organic N was not measured at the laboratory, TN was underestimated. Total N averaged 0.148 mg/L across all locations during 1999.

Total phosphorus (TP) was at or near the report limit (0.005 mg/L) for most Lake Roosevelt samples in 1999. Mean annual TP across all locations was 0.006 mg/L (Table 10). Mean TP was greatest at Porcupine Bay (0.011 mg/L), particularly during the spring (March TP 0.030 mg/L). Ortho-phosphate was measured, but was always in concentrations below the report limit of 0.010 mg/L. In a natural system, ortho-

phosphate will always be a fraction of TP. Since TP averaged 0.006 mg/L overall, ortho-phosphate was very likely well below the 0.010 mg/L report limit.

Nitrogen and phosphorus ratios were calculated to assess potential limiting factors to primary production. Total N divided by TP was used for ratio calculations. Total N to TP ratios averaged 35.9:1 in 1999 (Table 10). Mean TN to TP ratios were highest on the Spokane Arm at Porcupine Bay (79.5:1). Ratios there were highest during November (288.8:1). Total N to TP ratios were lowest in the Sanpoil River averaging 24.3:1 in 1999. Again, since organic N was not measured and was missing from the TN calculation, TN and TP ratios were likely underestimated. With greater TN values, the ratios would indicate even stronger phosphorus limitation.

Another potential limiting nutrient to primary production in Lake Roosevelt was silica (Si). Diatoms (Bacillariophyceae) comprised the greatest percentage of the phytoplankton and attached algae communities, with respective relative densities of 37 % and 96 % in 1999. Silicon is a major component of diatom frustules. Silicon concentrations averaged 2.9 mg/L in 1999 across all sampling locations. Mean Si concentrations were highest at Porcupine Bay and lowest at Evan's Landing, with annual means of 4.9 mg/L and 2.3 mg/L respectively. Annual Si concentrations at Porcupine Bay were significantly greater than all other locations (Scheffe's S, $p < 0.0001$).

Table 10. Descriptive statistics from water quality samples, including macro nutrients across all locations in Lake Roosevelt, WA (1999).

Variable	Mean	St. Dev.	Min	Max	n
NO ₃ ⁻ (mg/L)	0.119	0.133	0.014	0.767	163
NO ₂ ⁻ (mg/L)	0.004	0.004	0.003	0.045	163
NH ₃ (mg/L)	0.025	0.000	0.025	0.025	163
TN (mg/L)	0.148	0.134	0.042	0.794	163
TP (mg/L)	0.006	0.005	0.003	0.034	152
TN:TP	35.9	35.5	3.0	288.8	152
Si (mg/L)	2.9	1.1	1.5	6.9	163
Alkalinity (mg/L)	60.1	13.3	23.6	160.0	163
Hardness (mg/L)	58.4	9.0	26.0	87.7	163
TSS Final (mg/L)	3.2	5.6	1.0	67.0	163
Turbidity (NTU)	1.7	2.0	0.2	15.4	163

Trophic Status

Determining trophic status is important in providing information about the Lake Roosevelt ecosystem and fishery. The annual mean TSI calculated from phytoplankton chlorophyll *a*, Secchi disk depths, and total phosphorus concentrations was 33.6 (Table 11). Porcupine Bay had the highest mean annual pelagic TSI (35.5; Table 12).

Conversely, Keller Ferry (31.2) had the lowest annual mean pelagic TSI. The mean TSI at Porcupine Bay was significantly greater than at Gifford (32.2), Hunters (31.8), Keller Ferry, and Spring Canyon (31.8; Fisher's PLSD, $p < 0.05$).

Table 11. Trophic state indices calculated from phytoplankton chlorophyll *a*, Secchi disk depths, and TP concentrations in Lake Roosevelt, WA (1999).

Variable	Mean	St. Dev.	Min	Max	n
TSI (Phyto. Chlorophyll <i>a</i>)	33.9	9.0	0.2	52.0	394
TSI (Secchi)	36.9	8.6	23.6	70.0	321
TSI (Total Phosphorus)	25.8	9.4	17.4	55.0	152
TSI (Overall)	33.6	9.7	0.2	70.0	867

During 1999, monthly TSI averages within the pelagic zone were highest during May (39.2) and lowest during November (23.9). Trophic state indices calculated from Secchi depths across both pelagic and littoral zones raised the index, especially during the spring. The TSI calculations were highest in spring, primarily as a result of reduced Secchi depths, and higher phytoplankton chlorophyll *a* concentrations. TSI values were lowest due to total phosphorus concentrations. Respective annual mean Secchi depth, phytoplankton chlorophyll *a*, and TP concentrations were 36.9, 33.9, and 25.8 (Figure 13). Mean annual littoral trophic state indices (36.5) were significantly greater than those found for the pelagic zone (32.9; Scheffe's S, $p < 0.0001$; Figure 14). It should be noted that TP was not sampled in littoral areas and was therefore not included in littoral TSI calculations. Excluding TP values from the pelagic TSI raised the mean to 34.9. Additionally, littoral chlorophyll *a* was collected at Hawk Creek only, not throughout the reservoir as it was for the pelagic zones.

Table 12. Trophic state indices calculated from phytoplankton chlorophyll *a*, Secchi disk depths, and TP concentrations at pelagic locations on Lake Roosevelt, WA (1999).

Location	Mean	St. Dev.	Min	Max	n
Evan's Landing	32.7	8.4	17.4	54.2	65
Gifford	32.2	11.4	0.2	68.6	67
Hunters	31.8	10.2	2.5	50.0	66
Keller Ferry	31.2	11.3	0.2	54.2	69
Kettle Falls	32.6	10.3	0.2	55.0	69
Porcupine Bay	35.5	12.4	0.2	60.0	72
SanPoil R Confluence	34.9	7.2	17.4	50.0	52
SanPoil R	35.1	10.0	17.4	60.0	67
Seven Bays	32.3	8.0	17.4	46.8	65
Spokane R Confluence	33.0	8.6	0.2	44.2	52
Spring Canyon	31.8	7.4	17.4	43.9	68

Figure 13. Box plots of trophic state indices calculated from phytoplankton chlorophyll *a*, Secchi disk depths, and total P concentrations across all locations on Lake Roosevelt, WA (1999).

Figure 14. Box plots of mean trophic state index split by pelagic and littoral zones, across all locations on Lake Roosevelt, WA (1999).

Phytoplankton Chlorophyll *a*

Phytoplankton chlorophyll *a* concentrations taken from the euphotic zone in Lake Roosevelt during 1999 were highest in April (2.94 mg/m³) and May (3.35 mg/m³), and lowest in September (1.01 mg/m³) and November (0.70 mg/m³; Figure 15). During the first six sampling rounds of the year, problems were experienced in calibrating the fluorometer. Chlorophyll *a* concentrations generated by the fluorometer during that period were either unusually variable or inaccurate. Significantly higher differences in phytoplankton chlorophyll *a* were detected during the spring, and remained variable throughout the year (Table 13). April and May chlorophyll *a* concentrations (log₁₀ transformed) were both significantly higher than July, August, and September (Scheffe's S, $p < 0.05$; Table 13). Phytoplankton chlorophyll *a* peaked a month earlier than phytoplankton density and biovolume, which further questions the validity of these results.

Table 13. Mean monthly chlorophyll *a* concentrations, standard deviations, sample size, and statistical differences based on Scheffe's S ($p < 0.05$).

Month	Mean Chlorophyll <i>a</i> (mg/m ³)	St. Dev.	n	Significant Difference ($p < 0.05$)
Jan	1.52	0.37	36	
Feb	1.67	0.38	36	
Mar	1.52	0.59	36	
Apr	2.94	0.88	36	> Jul, Aug, & Sep
May	3.35	1.56	61	> Jul, Aug, & Sep
Jun	2.44	1.33	16	
Jul	1.26	1.55	76	< Aug & May
Aug	1.10	0.64	46	< Aug & May
Sep	1.01	0.71	15	< Aug & May
Oct	1.84	0.93	34	
Nov	0.70	na	1	
Dec	1.48	na	1

Figure 15. Mean monthly phytoplankton chlorophyll *a* concentrations and monthly sample size in Lake Roosevelt, WA (1999).

All multiple comparisons of phytoplankton chlorophyll *a* across sites were non-significant ($\log_{10}$ transformation; $P > 0.05$). Differences for between location comparisons were insignificant. Differences between the Sanpoil River and Keller Ferry exhibited the

smallest p value (Scheffe's S, $p=0.9060$). Sample size between locations was more uniform than between months. However, standard deviation for location comparisons was greater than between month comparisons (Table 13; Table 14). Mean chlorophyll *a* concentrations by location were highest at the Sanpoil River (2.709 mg/m^3) and moderate at Keller Ferry (1.851 mg/m^3) (Table 14). Hawk Creek was the only littoral sampling location for chlorophyll *a*, yet no significant differences were observed between pelagic locations. There were also no significant differences at different depths within the euphotic zone across the entire reservoir (Scheffe's S, $p>0.05$).

Table 14. Mean phytoplankton chlorophyll *a* concentrations and other descriptive statistics by location on Lake Roosevelt (1999).

Location Name	Mean Chlorophyll <i>a</i> (mg/m^3)	St. Dev.	Min	Max	n
Evan's Landing	1.67	0.872	0.525	3.582	31
Kettle Falls	1.666	1.081	0.01	4.269	35
Gifford	1.809	0.964	0.005	3.801	33
Hunters	1.79	1.118	0.057	4.204	32
Porcupine Bay	2.079	1.435	0.005	5.49	38
Spokane R. Confluence	1.533	0.915	0.005	3.838	30
Seven Bays	1.686	0.991	0.389	4.259	32
Hawk Creek	1.97	1.409	0.391	5.084	27
Keller Ferry	1.851	1.478	0.005	4.626	35
Sanpoil R.	2.709	2.382	0.484	8.879	35
Sanpoil R. Confluence	2.098	1.331	0.375	4.59	31
Spring Canyon	1.758	1.139	0.458	3.875	35
Overall	1.892	1.348	0.005	8.879	394

Attached Algae

Attached algae was collected from glass slides incubated in Lake Roosevelt embayments during the summer at Gifford, Porcupine Bay, Seven Bays, and Spring Canyon in 1999. Attached algae relative density was dominated by the Bacillariophyceae (diatoms; 95.9 %), followed by the Chlorophyceae (green algae; 4.0 %), and finally the Cyanophyceae (cyanobacteria; 0.1 %). Twenty-two different species of attached algae were identified in Lake Roosevelt in 1999 (Table 15). By species, the Bacillariophyceae dominated the relative densities and biovolumes of the attached algae. In fact, the three most abundant species, *Achnanthes* sp., *Synedra* sp., and *Amphora* sp., comprising 66.3 %, 7.7 %, and

5.5 % of the total density respectively, were diatoms. Similarly, the three species with the greatest biovolume included *Melosira varians*, *Amphora sp.*, and *Amphipleura sp.* were also diatoms. Of the total biovolume, they comprised 23.7 %, 21.0 %, and 10.8 % respectively (Table 15).

Table 15. Attached algae taxa list, relative density, and relative biovolume in Lake Roosevelt (1999).

Division, Class, <i>Species</i>	% of Total Density	% of Total Volume
Chlorophyta		
Chlorophyceae	4.0	16.3
<i>Cladophora sp.</i>	2.1	5.6
<i>Cosmarium sp.</i>	0.0	0.1
<i>Mougeotia sp.</i>	1.8	10.6
<i>Pediastrum boryanum</i>	0.0	0.0
<i>Scenedesmus bujuga</i>	0.1	0.0
Chrysophyta		
Bacillariophyceae	95.9	83.5
<i>Achnanthes sp.</i>	66.3	10.8
<i>Amphipleura sp.</i>	0.1	0.3
<i>Amphora sp.</i>	5.5	21.0
<i>Asterionella formosa</i>	0.0	0.0
<i>Cocconeis sp.</i>	0.5	3.9
<i>Cymbella sp.</i>	0.0	0.0
<i>Fragilaria crotonensis</i>	0.4	0.4
<i>Fragilaria sp.</i>	6.1	6.6
<i>Gomphonema sp.</i>	3.2	8.4
<i>Melosira distans</i>	0.0	0.2
<i>Melosira varians</i>	2.9	23.7
<i>Navicula sp.</i>	2.7	2.7
<i>Pinnularia sp.</i>	0.0	2.2
<i>Synedra sp.</i>	7.7	0.9
<i>Tabellaria sp.</i>	0.3	2.6
Cyanophyta		
Cyanophyceae	0.1	0.1
<i>Oscillatoria sp.</i>	0.1	0.1

Attached algae biovolume and density values were $\log_{10}$ transformed to test for significance across incubation depth, incubation time, and sampling location. Results

indicated there were significant differences in attached algae biovolume between locations. Mean biovolume at Spring Canyon ($0.042 \text{ mm}^3/\text{cm}^2$) was significantly greater than Seven Bays ($0.011 \text{ mm}^3/\text{cm}^2$) and Porcupine Bay ($0.016 \text{ mm}^3/\text{cm}^2$; Scheffe's S, $p < 0.05$). Generally, attached algae biovolume increased from upstream to downstream sampling locations (Table 16). There were no significant differences between the incubation depths of 1.5 m and 4.6 m for either density or biovolume (Scheffe's S, $p > 0.05$). However, the p-value for the difference in attached algae density between incubation depths was nearly significant indicating there may be a depth effect (Scheffe's S, $p = 0.0627$). There were also no significant differences in attached algae density or biovolume between the incubation times of two, four, six, nine, and eleven week periods (Scheffe's S, $p > 0.05$).

Table 16. Descriptive statistics for attached algae biovolume (mm^3/cm^2) at four locations in Lake Roosevelt, WA (1999).

Location	Mean	St. Dev.	Min	Max	n
Gifford	0.015	0.021	0.000	0.114	96
Porcupine Bay	0.016	0.030	0.000	0.245	83
Seven Bays	0.011	0.019	0.000	0.117	84
Spring Canyon	0.042	0.071	0.000	0.300	18
Overall	0.016	0.030	0.000	0.300	281

Attached algae chlorophyll *a* were $\log_{10}$ transformed and examined across incubation depth, incubation time, and sampling location. There were significant differences in attached algae chlorophyll *a* concentrations between incubation times (Scheffe's S, $p > 0.05$). The two week incubation period was significantly lower than the six, nine, and eleven week periods for attached algae chlorophyll *a* accrual. Mean attached algae chlorophyll *a* across all locations was $13.34 \text{ mg}/\text{m}^2$ with a standard deviation of $9.93 \text{ mg}/\text{m}^2$. Mean chlorophyll *a* production across all locations and incubation periods was $0.324 \text{ mg}/\text{m}^2/\text{day}$ and the standard deviation was $0.246 \text{ mg}/\text{m}^2/\text{day}$ (Table 17).

Table 17. Descriptive statistics for attached algae chlorophyll *a* production by sampling location, incubation time and incubation depth in Lake Roosevelt (1999).

Chlorophyll <i>a</i> Prod. (mg/m²/day)	Mean	St. Dev.	Min	Max	n
Gifford	0.29	0.24	0.03	0.87	10
Porcupine Bay	0.34	0.28	0.10	1.00	10
Seven Bay	0.30	0.25	0.04	0.92	10
Spring Canyon	0.54	0.12	0.46	0.62	2
2 Week Incubation	0.33	0.31	0.03	0.87	8
4 Week Incubation	0.41	0.26	0.24	0.92	6
6 Week Incubation	0.44	0.32	0.13	1.00	6
9 Week Incubation	0.24	0.13	0.10	0.40	6
11 Week Incubation	0.21	0.10	0.05	0.31	6
1.5 depth (m)	0.36	0.27	0.04	1.00	16
4.6 depth (m)	0.29	0.23	0.03	0.92	16
Overall	0.32	0.25	0.03	1.00	32

Phytoplankton Abundance and Biovolume

Fourty one species of phytoplankton from six classes were identified from Lake Roosevelt in 1999 (Table 18). The Bacillariophyceae (diatoms) were most diverse, represented by 17 species, followed by the Chlorophyceae (green algae) with 13 species. Bacillariophyceae had the greatest relative density (36.6 %), followed by Cryptophyceae (unicellular flagellates; 25.2 %) (Table 18). By genus, *Rhodomonas sp.* (21.6 %), *Asterionella sp.* (18.1 %), and *Chlamydomonas sp.* (13.8 %) had the highest relative densities. Relative biovolume was greatest in the Bacillariophyceae (60.4 %), followed by the Cryptophyceae (23.5 %) (Table 18). By genus, *Asterionella sp.* (30.8 %), *Cryptomonas sp.* (13.3 %), and *Rhodomonas sp.* (10.2 %) had the greatest total relative biovolumes. Mean phytoplankton density and biovolume was 147 organisms/ml and 0.046 mm³/L respectively. The total sample size for both density and biovolume was 1951, with standard deviations of 254 organisms/ml and 0.123 mm³/L respectively.

Phytoplankton density in Lake Roosevelt varied monthly during 1999. Density numbers from 1999 were transformed by log₁₀ before conducting ANOVA's. Mean densities in June (249 organism/ml) and July (190 organism/ml) were significantly greater than

December mean density (82 organism/ml; Figure 16; Scheffe's S, $p < 0.05$). Mean density in July was also significantly greater than the mean density in January (96 organism/ml), March (116 organism/ml), and October (117 organism/ml). In June, mean density was 249 organisms/ml while the total mean density was 1168 organism/ml. The lowest monthly mean occurred in December (82 organisms/ml). Mean density peaked in April and again in June (Figure 16). This signified the spring and summer bloom, which is typical in some temperate reservoirs (Horne and Goldman 1994).

Density for each major group peaked during the following months: Dinophyceae (dinoflagellates) peaked in July (5 organisms/ml); Chrysophyceae (golden-brown algae) also peaked in July (83 organisms/ml); Cyanophyceae (cyanobacteria) peaked sharply in August (275 organisms/ml); Bacillariophyceae peaked sharply in June (356 organisms/ml); Chlorophyceae remained relatively constant over the year however maximum density occurred in September (220 organisms/ml); Cryptophyceae peaked in June (320 organisms/ml); and Microplankton peaked in April (407 organisms/ml; (Figure 17).

Table 18. Phytoplankton taxa list, relative density, and relative biovolume in Lake Roosevelt (1999).

Division	Class	Species	% Density	% Volume
Chlorophyta				
	Chlorophyceae		16.2	8.4
		<i>Ankistrodesmus falcatus</i>	1.4	0.0
		<i>Carteria sp.</i>	0.1	0.0
		<i>Chlamydomonas sp.</i>	13.8	8.0
		<i>Eudorina elegans</i>	0.0	0.0
		<i>Mougeotia sp.</i>	0.0	0.1
		<i>Oocystis sp.</i>	0.0	0.0
		<i>Pediastrum boryanum</i>	0.0	0.0
		<i>Scenedesmus bijuga</i>	0.2	0.1
		<i>Scenedesmus dimorphus</i>	0.1	0.0
		<i>Scenedesmus quadricauda</i>	0.3	0.1
		<i>Schroederia setigera</i>	0.2	0.1
		<i>Spondylosium sp.</i>	0.0	0.0
		<i>Tetraedron minimum</i>	0.0	0.0
Chrysophyta				
	Bacillariophyceae		36.6	60.4
		<i>Achnanthes sp.</i>	0.1	0.0
		<i>Amphora sp.</i>	0.0	0.1
		<i>Asterionella formosa</i>	18.1	30.8
		<i>Cyclotella sp.</i>	0.4	1.9
		<i>Cymbella sp.</i>	0.0	0.0
		<i>Fragilaria crotonensis</i>	3.7	7.9
		<i>Fragilaria sp.</i>	0.2	0.3
		<i>Gomphonema sp.</i>	0.0	0.0
		<i>Melosira distans</i>	0.4	1.0
		<i>Melosira granulata</i>	0.0	0.0
		<i>Melosira herzogii</i>	0.4	1.3
		<i>Melosira italica</i>	1.1	3.8
		<i>Melosira varians</i>	0.1	1.4
		<i>Navicula sp.</i>	0.1	0.1
		<i>Rhizosolenia sp.</i>	2.8	7.8
		<i>Synedra sp.</i>	8.9	1.6
		<i>Tabellaria sp.</i>	0.3	2.3
Chrysophyta				
	Chrysophyceae		2.6	3.6
		<i>Dinobryon bavaricum</i>	0.2	0.2
		<i>Dinobryon sertularia</i>	2.1	1.7
		<i>Mallomonas pseudocoronata</i>	0.0	0.1
		<i>Mallomonas sp.</i>	0.3	1.6

Table 18. Phytoplankton taxa list continued.

Division	Class	Species	% Density	% Volume
Cryptophyta				
	Cryptophyceae		25.2	23.5
		<i>Cryptomonas sp.</i>	3.6	13.3
		<i>Rhodomonas sp.</i>	21.6	10.2
Cyanophyta				
	Cyanophyceae		3.6	1.0
		<i>Anabaena sp.</i>	0.2	0.1
		<i>Gloeocapsa sp.</i>	0.0	0.0
		<i>Oscillatoria limnetica</i>	1.5	0.4
		<i>Oscillatoria sp.</i>	1.8	0.5
Pyrrhophyta				
	Dinophyceae		0.0	0.4
		<i>Ceratium hirundinella</i>	0.0	0.4
Microplankton			15.8	2.9

Table 19. Monthly descriptive statistics for phytoplankton densities in Lake Roosevelt (1999).

Density (organisms / ml)	Mean	St. Dev.	Min	Max	n	Significant Difference (p < 0.05)
Jan	96	116	5	431	106	< Jul
Feb	112	140	5	552	90	
Mar	116	222	5	1901	102	< Jul
Apr	160	211	5	1341	142	
May	129	152	5	1252	292	
Jun	249	565	5	7045	218	> Dec
Jul	190	247	5	2535	255	> Jan, Mar, & Oct
Aug	149	176	5	1069	208	
Sep	133	152	0	672	178	
Oct	117	143	0	718	190	< Jul
Nov	98	119	5	448	76	
Dec	82	89	5	293	94	< Jun & Jul
Overall	147	254	0	7045	1951	-

Mean phytoplankton density by location was significantly greater at Porcupine Bay (208 organisms/ml) than all other locations (137 organisms/ml), except Gifford and the Spokane River Confluence (Fisher's PLSD, $p < 0.0292$). The lowest mean density by location was observed at the Sanpoil River Confluence (123 organisms/ml).

Biovolumes varied significantly by month in Lake Roosevelt during 1999. Biovolume values were $\log_{10}$ transformed for ANOVA's. Mean monthly phytoplankton biovolume across all location was greater in July ($0.066 \text{ mm}^3/\text{L}$) than January ($0.019 \text{ mm}^3/\text{L}$) and December ($0.024 \text{ mm}^3/\text{L}$; Scheffe's S, $p < 0.05$; Table 20). The mean biovolume in January was also significantly lower than mean biovolume observed in June ($0.098 \text{ mm}^3/\text{L}$; Scheffe's S, $p < 0.05$; Table 20). Standard deviations (0.3-0.018) and sample sizes (76-292) varied by month considerably. Similar to patterns observed for density, mean total biovolume peaked in April ($0.227 \text{ mm}^3/\text{L}$) and again in July ($0.411 \text{ mm}^3/\text{L}$) (Figure 18).

Figure 16. Seasonal variation of mean monthly phytoplankton density in Lake Roosevelt, WA (1999).

Between location comparisons of biovolume also exhibited patterns similar to what was observed for density. Mean biovolume at Porcupine Bay was significantly greater than all other locations, except the Spokane River Confluence (Fisher's PLDS, $p > 0.0376$). Mean biovolume at Porcupine Bay was $0.077 \text{ mm}^3/\text{L}$ while the mean across all other locations, excluding the Spokane River Confluence, was $0.042 \text{ mm}^3/\text{L}$.

Table 20. Monthly descriptive statistics for phytoplankton biovolumes in Lake Roosevelt, WA (1999).

Volume (mm³/L)	Mean	St. Dev.	Min	Max	n	Significant Difference ($p < 0.05$)
Jan	0.019	0.018	0	0.08	106	< Jun & Jul
Feb	0.027	0.043	0	0.28	90	
Mar	0.027	0.042	0	0.28	102	
Apr	0.051	0.079	0	0.48	142	
May	0.034	0.041	0	0.21	292	
Jun	0.098	0.3	0	3.78	218	> Jan
Jul	0.066	0.138	0	1.53	255	> Jan & Dec
Aug	0.045	0.06	0	0.39	208	
Sep	0.039	0.048	0	0.42	178	
Oct	0.036	0.072	0	0.81	190	
Nov	0.022	0.026	0	0.16	76	
Dec	0.024	0.039	0	0.3	94	< Jul
Overall	0.046	0.123	0	3.78	1951	-

Figure 17. Seasonal variation in mean monthly density for major phytoplankton groups in Lake Roosevelt, WA (1999).

Figure 18. Seasonal variation in mean monthly biovolume for phytoplankton groups taken from Lake Roosevelt, WA (1999).

Zooplankton Species Identified

Sixteen species of zooplankton were identified from Lake Roosevelt in 1999, twelve were from the order Branchiopoda and four from the sub-order Copepoda (Table 21). The most dominant families observed in 1999 were Daphniidae, Bosminidae, Diaptomidae, and Cyclopidae.

Table 21. Zooplankton species found in Lake Roosevelt, WA (1999).

Phylum Arthropoid	Phylum Arthropoid
Sub-class Crustacea	Sub-class Copepoda
Order Branchiopoda	Sub-order Calanoida
Family Daphniidae	Family Diaptomidae
<i>Ceriodaphnia quadrangula</i>	<i>Leptodiaptomus ashlandi</i>
<i>Daphnia galeata</i>	Family Temoridae
<i>Daphnia pulex</i>	<i>Epischura nevadensis</i>
<i>Daphnia retrocurva</i>	Sub-order Cyclopoida
<i>Daphnia thorata</i>	Family Cyclopoidae
Family Chydoridae	<i>Diacyclops bicuspidatus thomasi</i>
<i>Alona quadrangularis</i>	<i>Mesocyclops edax</i>
<i>Chydorus sphaericus</i>	
Family Sididae	
<i>Diaphanosoma bergei</i>	
<i>Diaphanosoma brachyurum</i>	
<i>Sida crystallina</i>	
Family Bosminidae	
<i>Bosmina longirostris</i>	
Family Leptodoriidae	
<i>Leptodora kindtii</i>	

Consistent with previous years, taxonomically related zooplankton species were grouped into categories for certain analyses as follows: *Daphnia pulex*, *Daphnia retrocurva*, *Daphnia thorata*, *Daphnia galeata mendotae*, and juvenile *Daphnia* were grouped as “*Daphnia* spp.”; *Alona quadrangularis*, *Bosmina longirostris*, *Ceriodaphnia quadrangula*, *Diaphanosoma brachyurum*, *Diaphanosoma birgei*, *Diaphanosoma brachyurum*, *Leptodora kindtii*, *Chydorus sphaericus*, and *Sida crystallina* were grouped as “other Cladocera,”; *Leptodiaptomus ashlandi*, *Diacyclops bicuspidatus thomasi*,

Mesocyclops edax, *Epischura nevadensis*, juvenile calanoid copepods, and nauplii (juvenile copepoda) were grouped as copepoda.

Pelagic Zooplankton Densities

Copepoda were the most abundant zooplankton taxon collected from Lake Roosevelt 1999, accounting for 80.5 % of the annual pelagic zooplankton density. *Daphnia* spp. were the second most abundant taxon, accounting for 17.4 % of the annual pelagic zooplankton density. Other Cladocera were the least abundant taxon, comprising 2.0 % of the overall zooplankton density. High copepod densities were driven primarily by large numbers of nauplii and *Diacyclops bicuspidatus thomasi*, which comprised 51.8 % and 19.6 % of the overall zooplankton density in Lake Roosevelt.

Mean overall zooplankton densities in 1999 were low (<64.1 organisms/m³) January through March, dramatically increased from May through July (192.9–851.3 organisms/m³), decreased in early August (625.7 organisms/m³) before peaking in late September (961.5 organisms/m³; Table 22; Figure 19a). Mean overall zooplankton abundance declined sharply in mid-October, before rebounding by late October (Table 22; Figure 19a). In mid-December, mean overall zooplankton abundance decreased to 94.8 organisms/m³ (Table 22; Figure 19a).

Timing of peak pelagic zooplankton abundances varied slightly across taxonomic groups in 1999. Copepoda densities were nearly identical to the shifts observed in the overall zooplankton abundances across time, while *Daphnia* were characterized by a small peak in mid-July, followed by decreases through early-September (Table 22; Figure 19b). *Daphnia* exhibited the greatest abundances later in the year than what is commonly observed in Lake Roosevelt. *Daphnia* abundance first peaked in September and reached their highest densities in late October (Table 22; Figure 19b).

Table 22. Mean pelagic zooplankton densities (organisms/m³) by taxonomic group and sample date collected in Lake Roosevelt, WA. Data includes all sites sampled in 1999.

Approximate Sample Date¹	<i>Daphnia</i>	Other Cladocera	Copepoda	Overall Zooplankton
19 Jan	10.3	0.5	127.1	43.5
18 Feb	2.8	0.5	193.5	62.5
23 Mar	21.1	0.4	182.8	64.1
21 April	3.9	2.7	330.3	107.3
4 May	9.7	5.1	591.2	192.9
18 May	15.0	7.8	533.0	176.9
8 June	45.1	25.9	930.2	318.9
1 July	185.1	50.5	1,484.4	543.5
13 July	387.9	48.9	1,579.8	628.4
27 July	259.4	52.8	2,385.2	851.3
9 Aug	163.5	27.5	1,791.0	625.7
25 Aug	791.5	36.4	1,773.5	795.0
8 Sept	589.9	11.6	1,967.1	791.5
22 Sept	743.6	11.5	2,369.9	961.5
13 Oct	485.9	36.1	901.2	434.0
26 Oct	960.4	35.0	1,257.1	676.2
16 Nov	274.8	32.6	1,402.5	534.6
14 Dec	105.1	5.3	201.2	94.8
Total	280.8	21.7	1,111.2	439.0

¹ Date depicts second day of sampling in each round.

Figure 19. Mean pelagic zooplankton densities (a) and mean pelagic zooplankton densities by taxonomic group (b) in lake Roosevelt, WA (1999). Includes all sampling locations.

Mean pelagic zooplankton abundance was lowest at the northernmost locations in Lake Roosevelt, and generally increased going downstream towards Grand Coulee Dam (Figure 20). Evan's Landing (42.1 organisms/m³) and Kettle Falls (42.3 organisms/m³) exhibited the lowest densities, whereas, the greatest mean pelagic zooplankton abundance was observed at the Sanpoil River Confluence (892.7 organisms/m³; Figure 20). The Sanpoil River location mean pelagic zooplankton density (658.3 organisms/m³) was similar to what was observed at Spring Canyon (650.1 organisms/m³), while Porcupine Bay (509.1 organisms/m³) was similar to densities observed at adjacent mainstem locations, the Spokane River Confluence (502.9 organisms/m³) and Seven Bays (454.6 organisms/m³) the next downstream location.

Figure 20. Mean pelagic zooplankton densities for all sample locations in Lake Roosevelt, WA (1999).

Beginning in 1991, reservoir mean zooplankton abundance was calculated as an average of densities observed at five index stations (Gifford, Porcupine Bay, Seven Bays, Keller Ferry, and Spring Canyon). While additional zooplankton sampling locations have been added since 1995, between year comparisons of zooplankton density are made using the five location average in order to preserve comparability across years.

Mean pelagic zooplankton abundance from the index locations exhibited a pattern similar to observed densities over time for all sampling locations in 1999. Mean zooplankton abundance was low from January through March (<91.6 organisms/m³), then increased

throughout the spring and summer, and before peaking in September (1,131.6 organisms/m³; Table 23; Figure 21a). Mean pelagic zooplankton densities gradually decreased over the winter (Table 23; Figure 21a).

Daphnia abundance from the traditional Lake Roosevelt index locations was very low from January through May and increased through September, when *Daphnia* peaked at 710.9 organisms/m³ (Table 23; Figure 21b). October through December *Daphnia* abundances decreased from 671.7 organisms/m³ to 153.5 organisms/m³ (Table 23). Similarly, mean monthly Copepoda density generally increased from January (149.3 organisms/m³) to the maximum value in September, (2,935.2 organisms/m³; Table 23; Figure 21b). March exhibited the only exception, yielding a decrease of 66.6 organisms/m³ in copepod abundance from the previous month. Other Cladocera abundances were low throughout 1999. The lowest density was observed in January (0.5 organisms/m³) and peak density was observed in June (51.7 organisms/m³; Table 23; Figure 21b).

Table 23. Monthly mean densities (organisms/m³) of *Daphnia*, Other Cladocera, Copepoda, and pelagic zooplankton for the five traditional index stations (Gifford, Porcupine Bay, Seven Bays, Keller Ferry, and Spring Canyon) on Lake Roosevelt, WA in 1999.

Month	<i>Daphnia</i>	Other Cladocera	Copepoda	Overall Zooplankton
Jan	8.4	0.5	149.3	50.0
Feb	1.7	0.7	285.6	91.6
Mar	0.2	0.7	219.0	70.0
Apr	3.6	0.8	465.8	149.5
May	2.9	6.7	752.2	242.9
Jun	48.7	51.7	1,210.5	419.6
Jul	221.7	45.9	1,933.7	694.5
Aug	559.7	29.0	1,934.1	779.9
Sep	710.9	9.2	2,935.2	1,131.6
Oct	671.7	35.2	1,537.5	686.8
Nov	306.9	24.5	1,597.1	601.9
Dec	153.5	6.9	316.1	145.3

Figure 21. Mean pelagic zooplankton densities (a) and mean pelagic zooplankton densities by taxonomic group (b) in lake Roosevelt, WA (1999). Includes index sampling locations only.

Zooplankton Lengths

Of the sixteen species of zooplankton collected in Lake Roosevelt during 1999, three species had annual mean lengths less than 0.5 mm, eight species had annual mean lengths of 0.5 to 1.0 mm, and five species had annual mean lengths of 1.0 mm or greater (Table 24). *Leptodora kindti*, the largest zooplankter found in Lake Roosevelt, was the only species that exceeded 2.0 mm annual mean length (Table 24). Of the total number of zooplankton measured in 1999 (n=27,386), 35.2 % were smaller than 0.5 mm, 23.2 % were 0.5 mm to 1.0 mm in length, 33.0 % were 1.0 to 2.0 mm in length, and 8.6 % were 2.0 mm or greater in length. Copepoda composed the majority of the < 0.5 mm (73.0 %) and the 0.5 to 1.0 mm (91.5 %) categories. *Daphnia* (52.1 %) and Copepoda (46.9 %) comprised nearly equal portions of the 1.0 to 2.0 mm category, and zooplankton greater than 2.0 mm were primarily comprised of *Daphnia* (87.8 %).

Overall, *Daphnia* comprised the group with the greatest annual mean length (1.18 mm), while the Copepoda were the shortest group (0.43 mm; Table 24). Other Cladocera, the group that contains both the smallest zooplankter in Lake Roosevelt (*Chydorus sphaericus* at 0.27 mm) and the largest (*Leptodora kindti* at 3.58 mm), were only slightly larger than the Copepoda in annual mean length (Table 24). Comparisons of mean length over time indicate that *Daphnia* maintained the greatest mean length throughout the year, while mean length of the other Cladocera and Copepoda remained similar most of the year (Figure 22). However, large differences between groups were observed in July, September, and November (Figure 22). On all three occasions, the differences in mean length were characterized by much larger other Cladocera compared with the copepods (Figure 22).

Table 24. Annual mean lengths, standard deviation of the mean, number of individuals measured, and the range in lengths for all species of zooplankton observed in Lake Roosevelt, WA (1999). Pelagic zooplankton and taxonomic group mean lengths, standard deviations, organisms measured, and ranges are also included.

	Mean Length (mm)	Standard Deviation	Number	Observed Range
<i>Daphnia</i>				
<i>Daphnia galeata</i>	1.11	0.46	745	0.40 - 2.91
<i>Daphnia pulex</i>	1.29	0.55	3,013	0.45 - 3.15
<i>Daphnia retrocurva</i>	1.16	0.45	581	0.38 - 2.43
<i>Daphnia thorata</i>	1.71	0.36	62	0.85 - 2.69
Juvenile <i>Daphnia</i>	0.39	0.07	369	0.15 - 0.58
<i>Daphnia</i>	1.18	0.56	4,770	0.15 - 3.15
Other Cladocera				
<i>Alona quadrangularis</i>	0.55	0.18	66	0.15 - 0.96
<i>Bosmina longirostris</i>	0.33	0.09	861	0.04 - 0.67
<i>Ceriodaphnia quadrangula</i>	0.46	0.21	7	0.34 - 0.91
<i>Chydorus sphaericus</i>	0.27	0.07	101	0.17 - 0.46
<i>Diaphanosoma birgei</i>	0.69	0.20	2	0.55 - 0.83
<i>Diaphanosoma brachyurum</i>	0.94	0.37	47	0.38 - 2.12
<i>Leptodora kindtii</i>	3.58	2.37	60	0.32 - 10.40
<i>Sida crystalline</i>	0.86	0.44	40	0.19 - 2.12
Other Cladocera	0.55	0.91	1,184	0.04 - 10.40
Copepoda				
<i>Diacyclops bicuspidatus thomasi</i>	0.68	0.26	6,987	0.22 - 1.78
<i>Epischura nevadensis</i>	0.73	0.44	485	0.28 - 2.38
<i>Leptodiaptomus ashlandi</i>	0.74	0.29	3,195	0.24 - 2.39
<i>Mesocyclops edax</i>	0.91	0.32	78	0.22 - 1.64
Juvenile Calanoid	0.60	0.39	9	0.27 - 1.56
Nauplii	0.16	0.06	10,678	0.08 - 1.65
Copepoda	0.43	0.34	21,432	0.08 - 2.39
Overall Zooplankton	0.57	0.51	27,386	0.4 - 10.40

Figure 22 Seasonal variation of zooplankton mean length and mean length by taxonomic group in Lake Roosevelt, WA (1999).

Comparisons amongst locations sampled in Lake Roosevelt in 1999 indicate that mean length of pelagic zooplankton was smallest at Evan's Landing (0.34 mm), and greatest at the Spokane River Confluence (0.65 mm; Figure 23; Table 25). Between Evan's Landing and the Spokane River Confluence, mean pelagic zooplankton lengths increased with distance downriver. Mean pelagic zooplankton lengths decreased from the Spokane River Confluence to Keller Ferry (0.56 mm), increased at the Sanpoil River Confluence (0.62 mm), and decreased slightly at Spring Canyon (0.59 mm; Figure 23; Table 25). Mean zooplankton length was 0.61 mm at Porcupine Bay and 0.64 mm at the Sanpoil River location (Figure 23; Table 25).

Table 25. Mean zooplankton length from pelagic sampling at each location and reach from Lake Roosevelt, WA (1999).

Location	Reach	Mean Length (mm)	Standard Deviation
Evans Landing	Mainstem - Upper	0.34	0.35
Kettle Falls	Mainstem - Upper	0.355	0.331
Gifford	Mainstem - Upper	0.437	0.388
Hunters	Mainstem - Mid	0.483	0.459
Spokane River Confluence	Mainstem - Mid	0.65	0.616
Seven Bays	Mainstem - Mid	0.597	0.566
Keller Ferry	Mainstem - Lower	0.562	0.457
Sanpoil River Confluence	Mainstem - Lower	0.619	0.492
Spring Canyon	Mainstem - Lower	0.594	0.499
Porcupine Bay	Spokane Arm	0.606	0.551
Sanpoil River	Sanpoil Arm	0.639	0.514
Total		0.568	0.509

Figure 23. Mean pelagic zooplankton length and mean abundance by taxonomic group for locations sampled in Lake Roosevelt, WA (1999).

Zooplankton Biomass

Pelagic zooplankton biomass was low during the winter and early spring (January-May) in Lake Roosevelt during 1999. Beginning in June of 1999, overall zooplankton biomass increased peaking in September at 3,377.3 $\mu\text{g}/\text{m}^3$ (Figure 24a). October through December exhibited progressively lower overall zooplankton biomass. *Daphnia* biomass for the 11 sampling stations examined in 1999 exhibited shifts nearly identical to what was observed for pelagic zooplankton biomass. *Daphnia* biomass was low from January through May, then increased from June to September, and peaked in October (9,011.3 $\mu\text{g}/\text{m}^3$; Figure 24b). Copepoda biomass exhibited a similar pattern observed for overall zooplankton. Copepoda biomass was low from January through May, then increased from June to September, before decreasing in October. Copepoda biomass increased again in November, and decreased in December. Other Cladocera biomass levels were low throughout the year and were predominantly confined to summer and fall months. Peak values were observed in July (181.8 $\mu\text{g}/\text{m}^3$), but no consistent changes over time were noticed.

Daphnia accounted for 62.5 % of the overall zooplankton biomass observed in Lake Roosevelt, compared with 17.4 % of the total abundance (Table 26). In contrast, copepods contributed 35.8 % of the overall zooplankton biomass and 80.5 % of the total abundance. Other Cladocera contributed 1.7 % of the biomass and 2.0 % of the abundance (Table 26).

Table 26. Total biomass, percent biomass, and percent density contributed by taxonomic group in Lake Roosevelt, WA (1999).

	Total Biomass ($\mu\text{g}/\text{m}^3$)	Percent Biomass	Percent Density
Copepods	2,435,747.9	35.8 %	80.5 %
<i>Daphnia</i>	4,252,129.4	62.5 %	17.4 %
Other Cladocera	115,503.7	1.7 %	2.0 %
Overall zooplankton	6,803,381.0

Figure 24. Mean pelagic zooplankton biomass (a) and mean pelagic zooplankton densities by taxonomic group (b) in lake Roosevelt, WA (1999). Includes all sampling locations.

Just five species comprised 92.2 % of the pelagic zooplankton biomass in Lake Roosevelt in 1999; *D. pulex* (49.5 %), *D. b. thomasi* (19.6 %), *L. ashlandi* (11.8 %), *D. galeata* (6.4 %),

and *D. retrocurva* (4.9 %). The remaining eleven species, juvenile calanoids, and nauplii comprised the other 7.8 % the pelagic zooplankton biomass.

Generally, mean overall pelagic zooplankton biomass levels increased moving downstream towards Grand Coulee Dam. Exceptions occurred at the Spokane and Sanpoil River Confluence locations (Figure 25). The greatest mean pelagic zooplankton biomass was observed at the Sanpoil River Confluence (1,924.0 $\mu\text{g}/\text{m}^3$), followed by the Spokane River Confluence (1,771.4 $\mu\text{g}/\text{m}^3$; Table 27). The lowest mean pelagic zooplankton biomass was observed at Kettle Falls (41.3 $\mu\text{g}/\text{m}^3$; Table 27). *Daphnia* mean biomass was greatest at the Spokane River Confluence (5,121.7 $\mu\text{g}/\text{m}^3$), followed by the Sanpoil River Confluence (4,159.5 $\mu\text{g}/\text{m}^3$; Table 27). *Daphnia* mean biomass was lowest for Kettle Falls (60.2 $\mu\text{g}/\text{m}^3$). Copepoda biomass was greatest at the Sanpoil River Confluence, and lowest at Kettle Falls (60.2 $\mu\text{g}/\text{m}^3$; Table 27). Other cladocera biomass was low for all locations compared with the other groups examined in Lake Roosevelt in 1999. The greatest other Cladocera mean biomass was observed at the Seven Bays (193.9 $\mu\text{g}/\text{m}^3$), while the lowest was observed at Evan's Landing (11.6 $\mu\text{g}/\text{m}^3$; Table 27).

Figure 25. Overall annual mean zooplankton biomass across locations in Lake Roosevelt, WA (1999).

Table 27. Mean pelagic zooplankton biomass ($\mu\text{g}/\text{m}^3$) and taxonomic group biomass across locations in Lake Roosevelt, WA (1999). Parentheses indicate taxonomic group percentage of zooplankton biomass at given location.

	Copepoda	<i>Daphnia</i>	Other Cladocera	Overall Zooplankton
Evans Landing	81.0 (54.4)	61.7 (35.6)	11.6 (10.0)	47.4
Kettle Falls	60.2 (46.3)	60.2 (39.7)	14.1 (13.9)	41.3
Gifford	127.3 (23.9)	437.6 (70.3)	24.0 (5.8)	169.7
Hunters	416.8 (42.7)	594.8 (52.2)	38.7 (5.1)	310.7
Spokane R. Confluence	950.6 (17.1)	5,121.7 (78.9)	176.3 (4.1)	1,771.4
Seven Bays	1,098.4 (26.8)	3,207.4 (67.1)	193.9 (6.1)	1,303.6
Keller Ferry	1,745.7 (38.0)	3,160.8 (59.0)	107.4 (3.0)	1,461.4
Sanpoil R. Confluence	2,315.0 (38.3)	4,159.5 (59.0)	129.7 (2.8)	1,924.0
Spring Canyon	1,742.1 (40.6)	2,800.8 (55.9)	118.7 (3.6)	1,366.7
Porcupine Bay	997.0 (27.7)	2,998.9 (71.3)	27.9 (1.0)	1,146.5
SanPoil River	1,321.4 (36.6)	2,608.8 (62.0)	40.0 (1.4)	1,148.3
Reservoir Mean	1,757.4	3,579.2	64.8	971.9

Zooplankton biomass was consistently low ($< 500 \mu\text{g}/\text{m}^3$) at all locations from January through March except at the Sanpoil River, which exhibited a small increase in biomass in March ($590.3 \mu\text{g}/\text{m}^3$; Table 28). June was characterized by moderate increases in pelagic zooplankton biomass at the mid and lower mainstem locations, as well as in the Spokane Arm and the Sanpoil Arm (Table 28). Zooplankton biomass levels remained low ($<200 \mu\text{g}/\text{m}^3$) in June at the upper locations, where a decrease in zooplankton biomass was observed for all locations except Evan's Landing, where peak pelagic zooplankton biomass for that location occurred ($144.8 \mu\text{g}/\text{m}^3$; Table 28). July and August were also characterized by increases in zooplankton biomass across most locations, with peak biomass levels observed in August for Kettle Falls ($90.6 \mu\text{g}/\text{m}^3$) and the Sanpoil River ($2,838.9 \mu\text{g}/\text{m}^3$; Table 28). Zooplankton biomass peaked at Seven Bays ($4,233.5 \mu\text{g}/\text{m}^3$), Keller Ferry ($4,384.3 \mu\text{g}/\text{m}^3$), the Sanpoil River Confluence ($4,173.5 \mu\text{g}/\text{m}^3$), and Spring Canyon ($5,143.8 \mu\text{g}/\text{m}^3$) in September, while biomass peaked at Gifford ($934.9 \mu\text{g}/\text{m}^3$), Hunters ($935.8 \mu\text{g}/\text{m}^3$), Porcupine Bay ($2,988.3 \text{ mg}/\text{m}^3$), and the Spokane River Confluence ($5,998.1 \mu\text{g}/\text{m}^3$) in October (Table 28). Keller and Sanpoil River Confluence exhibited increased mean zooplankton biomass in November and increases at Spring Canyon in December (Table 28).

Daphnia Biomass

Reservoir wide mean *Daphnia* biomass collected in 1999 from 11 sampling locations on Lake Roosevelt was $3,579.2 \mu\text{g}/\text{m}^3$. The highest annual mean total *Daphnia* biomass values were recorded at the Spokane River Confluence ($5,121.7 \mu\text{g}/\text{m}^3$; Table 29). The maximum monthly mean *Daphnia* biomass was observed in October ($9,011.3 \mu\text{g}/\text{m}^3$), and the minimum was observed in February ($21.8 \mu\text{g}/\text{m}^3$; Table 29). The greatest biomass observed in Lake Roosevelt in 1999 occurred at the Spokane River Confluence in October ($48,566.1 \mu\text{g}/\text{m}^3$; Table 29).

Table 28. Mean zooplankton biomass ($\mu\text{g}/\text{m}^3$) across months and locations in Lake Roosevelt, WA (1999).

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Evans Landing	14.6	5.9	7.5	62.5	59.6	144.8	80.0	69.4	25.9	22.0	20.8	2.3	47.4
Kettle Falls	20.7	6.1	6.1	17.3	74.9	58.1	29.8	90.6	61.0	39.7	4.6	9.0	41.3
Gifford	5.2	1.7	3.9	36.5	65.8	23.0	167.3	101.9	62.7	934.9	147.7	3.7	169.7
Hunters	7.3	6.4	3.7	35.2	132.9	46.3	187.0	856.1	432.9	935.8	213.5	3.3	310.7
Porcupine Bay	9.4	184.9	48.4	36.4	114.5	478.0	502.3	2,288.6	2,660.4	2,988.3	2,041.4	252.3	1,146.5
Spokane R. Confl.	15.5	11.6	14.3	64.4	115.6	988.2	4,745.4	950.0	2,060.2	5,998.1	1,914.8	149.5	1,771.4
Seven Bays	8.1	9.5	7.0	123.9	90.7	292.2	1,059.3	1,498.1	4,233.5	3,419.6	2,103.6	25.3	1,303.6
Keller Ferry	195.1	9.4	8.0	44.8	252.2	323.8	2,066.9	4,156.3	4,384.3	1,052.2	1,454.6	122.4	1,461.4
Sanpoil River	294.0	89.9	590.3	78.6	448.7	2,192.4	2,006.7	2,838.9	1,679.7	479.5	232.5	93.0	1,148.3
Sanpoil R. Confl.	13.8	5.2	22.3	28.0	139.2	2,163.2	3,905.8	3,707.2	4,173.5	1,009.0	2,840.1	1,527.8	1,924.0
Spring Canyon	144.6	20.1	15.3	46.3	319.6	802.4	3,186.2	1,215.5	5,143.8	536.8	231.4	1,734.1	1,366.7
Mean	65.4	57.7	89.2	83.3	281.1	1185.5	2041.3	2632.7	3377.3	3043.9	1847.1	535.5	1561.8

Table 29. Mean monthly *Daphnia* biomass ($\mu\text{g}/\text{m}^3$) Lake Roosevelt WA (1999).

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Mean
Evan's Landing	2.0	0.0	0.0	0.0	0.0	220.5	91.8	137.4	12.4	46.4	0.0	0.0	61.7
Kettle Falls	0.0	0.0	0.0	0.0	74.2	41.6	10.0	199.6	95.4	59.1	7.5	0.0	60.2
Gifford	0.0	0.0	0.5	0.0	0.0	0.0	230.2	243.0	188.0	5,324.5	513.5	9.5	437.6
Hunters	0.0	0.0	0.0	1.1	47.5	3.4	162.3	2,238.9	1,167.2	2,722.5	657.3	15.9	594.8
Porcupine Bay	0.0	0.0	0.0	5.1	0.0	432.0	1,301.2	12,643.6	11,737.2	22,705.0	7,488.8	1,724.0	2,998.9
Spokane R. Confl.	24.1	0.0	18.7	0.0	25.7	4,405.7	11,291.0	3,281.9	9,111.5	48,566.1	13,065.6	380.3	5,121.7
Seven Bays	15.4	0.0	0.0	51.3	5.7	580.1	2,447.3	5,929.0	8,954.0	14,843.4	11,191.2	82.9	3,207.4
Keller Ferry	462.0	0.0	0.0	40.3	31.6	341.2	5,854.7	13,821.9	10,920.0	995.5	2,766.9	910.7	3,160.8
Sanpoil River	569.3	186.4	1,606.1	287.4	1,864.4	6,215.6	10,350.5	8,404.2	8,599.6	930.4	1,418.6	50.6	2,608.8
Sanpoil R. Confl.	47.5	0.6	3.9	0.0	12.2	724.0	12,632.2	15,128.5	19,121.2	2,420.1	8,483.0	4,348.6	4,159.5
Spring Canyon	383.4	52.8	0.9	0.0	102.6	508.3	6,422.2	4,541.5	17,884.1	511.7	962.0	10,795.0	2,800.8
Mean	136.7	21.8	148.2	35.0	196.7	1,482.2	3,926.2	6,051.8	7,981.0	9,011.3	4,232.2	1,665.2	3,579.2

January through May were characterized by very low biomass levels at several locations, including several instances where *Daphnia* biomass was zero. February through April, *Daphnia* biomass was zero at more than half of the locations sampled, while in January, *Daphnia* biomass was observed at only 7 of 11 locations. *Daphnia* biomass at most mid and upper mainstem locations and the Sanpoil and Spokane Arms increased dramatically in June, while the lower mainstem locations were generally characterized by decreased or unchanged levels. Evan's Landing (upper mainstem), where *Daphnia* biomass increased from 0.0 to 220.5 $\mu\text{g}/\text{m}^3$, and Hunters (mid mainstem), where *Daphnia* biomass decreased by 44.1 $\mu\text{g}/\text{m}^3$ were the only exceptions (Table 29). In July, mean *Daphnia* biomass levels increased at all locations except Evan's Landing and Kettle Falls. Mean *Daphnia* biomass at the mid and upper mainstem and Sanpoil and Spokane Arms remained high ($>1,000 \mu\text{g}/\text{m}^3$) through September, before dropping sharply at Keller Ferry, the Sanpoil River, the Sanpoil River Confluence, and Spring Canyon in October. The remaining locations declined in November. Mean *Daphnia* biomass at the upper mainstem locations generally remained low from August through November ($<550 \mu\text{g}/\text{m}^3$), except at Gifford in October, when *Daphnia* biomass increased by over 300 % (Table 29). December was characterized by further reductions in mean *Daphnia* biomass at all locations except Spring Canyon, which exhibited a greater than 10-fold increase (Table 29).

Daphnia pulex comprised 79.2 % of the annual reservoir wide *Daphnia* biomass in 1999, followed by *D. galeata* (10.3 %), *D. retrocurva* (7.8 %), *D. thorata* (2.1 %), and juvenile *Daphnia* (0.7 %). *Daphnia* biomass was low from January through May, and consisted almost entirely of *D. pulex*. *Daphnia pulex* continued to dominate the *Daphnia* biomass throughout the year in 1999, with dramatic increases from June through October, when *D. pulex* peaked (47,841.8 $\mu\text{g}/\text{m}^3$), before decreasing in November and December (Figure 26). *Daphnia galeata* biomass was observed at very low levels in January and April ($< 3 \mu\text{g}/\text{m}^3$), before increasing from June through August, when *D. galeata* biomass peaked at 7,904.8 $\mu\text{g}/\text{m}^3$; Figure 26). *Daphnia galeata* biomass was also present throughout the rest of the year, but at decreasing levels (Figure 26). *Daphnia thorata* contributed to the May *Daphnia* biomass (32.5 $\mu\text{g}/\text{m}^3$; Figure 26), and exhibited two peaks; one in August (1,352.6 $\mu\text{g}/\text{m}^3$)

Figure 26. Mean monthly biomass for *Daphnia* species in Lake Roosevelt, WA (1999).

and one in October ($1,997.4 \mu\text{g}/\text{m}^3$; Figure 26). *Daphnia retrocurva* appeared in June and peaked in July ($6,750 \mu\text{g}/\text{m}^3$), before decreasing in August (Figure 26). *Daphnia retrocurva* biomass exhibited a small spike in September, before progressively decreasing to zero by December (Figure 26).

Copepoda Biomass

Annual reservoir wide mean copepod biomass was $1,757.4 \mu\text{g}/\text{m}^3$ reservoir wide in 1999 (Table 30). Annual mean copepod biomass ranged from $60.2 \mu\text{g}/\text{m}^3$ at Kettle Falls to $2,315.0 \mu\text{g}/\text{m}^3$ at the Sanpoil River confluence (Table 30). Low annual mean copepod biomass values ($\leq 127.3 \mu\text{g}/\text{m}^3$) were observed at the three upper mainstem locations (Evan's Landing, Kettle Falls, and Gifford), while the three lower mainstem locations (Sanpoil River confluence, Keller Ferry, and Spring Canyon) were characterized by greater biomass values ($>1,742.1 \mu\text{g}/\text{m}^3$; Table 30). Mid-reach mainstem locations exhibited intermediate mean copepod biomass values ranging from $416.8 \mu\text{g}/\text{m}^3$ at Hunters to $1,098.4 \mu\text{g}/\text{m}^3$ at Seven Bays (Table 30). Copepod biomass at Porcupine Bay was similar to observed biomass values at adjacent mainstem locations, while the copepod biomass values at the Sanpoil River location were lower than those seen at adjacent mainstem locations (Table 30).

The minimum monthly mean copepod biomass value was observed in January ($85.9 \mu\text{g}/\text{m}^3$), and the maximum in September ($3,658.5 \mu\text{g}/\text{m}^3$; Table 30), 1999. Mean copepod biomass values were less than $228.7 \mu\text{g}/\text{m}^3$ from January through April and increased from $701.6 \mu\text{g}/\text{m}^3$ in May to $3,658.5 \mu\text{g}/\text{m}^3$ in September. In October and December, mean copepod biomass decreased, but mean copepod biomass increased in November (Table 30). Mean copepod biomass remained low at the upper mainstem Columbia locations ($<500 \mu\text{g}/\text{m}^3$) throughout the year, while the lower mainstem Columbia River locations were low in the winter and spring, and increased during the summer and fall (Table 30). The greatest mean copepod biomass values were found at the Sanpoil River Confluence in November ($12,136.7 \mu\text{g}/\text{m}^3$), whereas the lowest were seen at Evan's Landing in December ($1.2 \mu\text{g}/\text{m}^3$; Table 30).

Table 30. Mean monthly Copepoda biomass ($\mu\text{g}/\text{m}^3$) across locations in Lake Roosevelt (1999).

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Mean
Evan's Landing	35.5	21.3	22.9	145.0	151.6	172.5	123.1	137.3	54.9	6.5	16.1	1.2	81.0
Kettle Falls	24.1	33.9	13.5	55.2	148.1	138.2	105.3	134.3	42.3	18.2	4.5	24.6	60.2
Gifford	34.3	42.6	25.2	175.7	233.5	185.3	423.7	390.5	123.3	471.9	18.5	8.1	127.3
Hunters	65.6	51.6	38.1	186.0	397.6	163.4	331.4	1,836.0	787.5	676.4	8.2	6.4	416.8
Porcupine Bay	110.6	831.9	282.6	305.1	901.3	1,061.7	1,496.6	4,234.1	3,115.4	1,943.4	3,291.5	474.8	997.0
Spokane R. Confl.	21.0	104.2	31.0	313.5	274.5	1,915.2	2,707.2	3,474.1	3,135.2	4,321.1	377.3	31.2	950.6
Seven Bays	35.0	127.8	71.2	439.1	677.6	1,172.1	1,821.3	2,604.4	4,555.5	2,440.0	102.3	89.6	1,098.4
Keller Ferry	52.7	62.0	94.6	312.8	1,456.1	2,306.8	3,938.0	5,226.7	8,259.5	2,769.6	3,606.2	174.9	1,745.7
Sanpoil River	402.3	335.7	834.3	126.6	1,484.3	5,299.3	9,251.9	6,132.2	5,190.7	972.3	586.4	302.1	1,321.4
Sanpoil R. Confl.	62.5	56.7	115.6	197.3	683.5	5,318.7	7,576.4	5,151.6	8,846.8	3,473.8	12,136.7	349.2	2,315.0
Spring Canyon	101.6	113.9	129.5	259.1	1,309.4	3,927.9	8,349.8	3,996.4	6,132.4	2,105.4	1,359.0	1,244.7	1,742.1
Mean	85.9	161.9	150.8	228.7	701.6	2,370.2	2,816.6	3,028.9	3,658.5	1,745.3	1,955.1	246.0	1,757.4

Diacyclops bicuspidatus thomasi accounted for 54.8 % of the annual reservoir-wide copepoda biomass in 1999, followed by *L. ashlandi* (33.0 %), (6.4 %), *E. nevadensis* (4.6 %), and *M. edax* (1.1 %). Juvenile Calanoids (0.1 %) and nauplii (6.4 %) comprised the remaining 6.5 % of the copepod biomass in Lake Roosevelt in 1999. Biomass for all copepod species was low from January through April (Figure 27). In May, *D. b. thomasi* exhibited a small increase, followed by a much more dramatic increase in June, when *D. b. thomasi* biomass peaked ($13,693.1 \mu\text{g}/\text{m}^3$; Figure 27). The summer and fall characterized by a gradual decline in *D. b. thomasi* (Figure 27). *Leptodiaptomus ashlandi* biomass did not show a notable increase until July ($4,983.9 \mu\text{g}/\text{m}^3$), and continued to increase before peaking in September, ($12,789.9 \mu\text{g}/\text{m}^3$; Figure 27). *Mesocyclops edax* and *E. nevadensis* biomass remained low throughout the year ($\leq 1,047.1 \mu\text{g}/\text{m}^3$), peaking in September ($356.9 \mu\text{g}/\text{m}^3$) and August ($1047.1 \mu\text{g}/\text{m}^3$) respectively (Figure 27). Nauplii biomass remained relatively constant throughout the year, increasing slightly over the summer months, when most copepods reproduce (Figure 27).

Figure 27. Mean monthly Copepoda species biomass on Lake Roosevelt (1999).

Other Cladocera Biomass

Other Cladocera annual reservoir-wide mean biomass was $64.8 \mu\text{g}/\text{m}^3$ in Lake Roosevelt in 1999 (Table 31). Other Cladocera biomass ranged from $11.6 \mu\text{g}/\text{m}^3$ at Evan's Landing to $193.9 \mu\text{g}/\text{m}^3$ at Seven Bays (Table 31). Low biomass values were observed for other Cladocera at the upper mainstem Columbia River locations, Hunters, Porcupine Bay, and the Sanpoil River ($\leq 40.0 \mu\text{g}/\text{m}^3$; Table 31). At Seven Bays, Keller Ferry, Spring Canyon, and the Spokane and Sanpoil River Confluences, other Cladocera biomass values were only slightly greater, ranging from 107.4 to $193.9 \mu\text{g}/\text{m}^3$ (Table 31).

The maximum monthly mean biomass for other Cladocera was observed in July ($181.8 \mu\text{g}/\text{m}^3$) and the minimum in February ($0.4 \mu\text{g}/\text{m}^3$; Table 31). Monthly mean biomass levels for other Cladocera were low from January through May ($<10.3 \mu\text{g}/\text{m}^3$), and increased in June and July. Other Cladocera biomass declined in August, increased in September, and exhibited another small decline in October, prior to reaching a second peak in November ($173.1 \mu\text{g}/\text{m}^3$; Table 31). In December, other Cladocera biomass decreased to levels observed earlier in the year ($<10 \mu\text{g}/\text{m}^3$; Table 31). However, increases were noted at locations that exhibited zero other Cladocera mean biomass in November. Mean other Cladocera biomass levels were low ($<100 \mu\text{g}/\text{m}^3$) for the upper mainstem Columbia River locations (Evan's Landing, Kettle Falls, and Gifford) throughout the year (Table 31). The mid-reach mainstem locations intermittently exhibited only slightly greater biomass levels ($>100 \mu\text{g}/\text{m}^3$), including Hunters in October, the Spokane River Confluence in July and October, and Seven Bays in July, September, and November (Table 31). Other Cladocera biomass levels exceeded $100 \text{ mg}/\text{m}^3$ at Keller Ferry in September, the Sanpoil River Confluence in July, September, and November, and at Spring Canyon in June and July (Table 31). Porcupine Bay, on Spokane Arm had other Cladocera biomass means similar to nearby mainstem locations, and only exceeded $100 \mu\text{g}/\text{m}^3$ in June. The Sanpoil River location had lower other Cladocera biomass means than nearby mainstem locations, and only exhibited a biomass in excess of $100 \text{ mg}/\text{m}^3$ in July (Table 31).

Table 31. Mean monthly other Cladocera biomass ($\mu\text{g}/\text{m}^3$) across locations in Lake Roosevelt, WA (1999).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Mean
Evan's Landing	0.5	1.5	0.2	0.7	1.2	15.7	8.1	22.3	11.8	12.8	23.2	3.1	11.6
Kettle Falls	14.3	0.0	0.0	10.3	3.9	2.9	6.4	22.1	22.1	48.6	0.0	0.7	14.1
Gifford	0.0	0.0	0.1	2.9	3.7	12.6	29.0	21.8	4.6	94.6	10.2	0.3	24.0
Hunters	3.1	0.3	0.2	3.6	2.3	0.4	92.9	30.7	49.6	115.5	0.0	1.2	38.7
Porcupine Bay	1.3	1.9	20.5	2.1	2.0	129.5	54.1	87.4	0.0	5.4	0.0	20.5	27.9
Spokane R. Confl.	0.0	0.3	0.0	0.3	3.7	86.8	599.3	74.2	56.0	413.7	1.5	2.7	176.3
Seven Bays	0.0	0.0	0.0	0.0	2.2	37.0	359.6	44.6	204.9	50.1	1,546.9	10.4	193.9
Keller Ferry	0.0	0.0	0.0	0.0	15.3	21.1	93.1	44.7	415.4	36.8	73.7	14.5	107.4
Sanpoil River	0.0	0.6	0.0	7.1	14.8	58.7	136.0	35.8	5.9	8.9	17.1	1.9	40.0
Sanpoil R. Confl.	0.0	0.1	0.0	1.0	15.1	87.1	466.6	47.8	130.6	34.5	220.5	22.3	129.7
Spring Canyon	2.7	0.0	0.0	0.0	49.4	161.6	449.8	64.6	83.7	11.0	10.6	3.9	118.7
Mean	2.0	0.4	1.9	2.5	10.3	66.4	181.8	45.1	89.5	75.6	173.1	7.4	64.8

Leptodora kindtii accounted for 60.3 % of the annual reservoir-wide other Cladocera biomass in 1999, followed by *B. longirostris* (24.6 %), *D. brachyurum* (7.8 %), *S. crystallina* (3.1 %), *A. quadrangularis* (2.6 %), *C. sphaericus* (1.3 %), *D. bergei* (0.3 %), and *C. quadrangula* (0.1 %). Biomass for all other Cladoceran species was low from January through May, and remained low ($<100 \mu\text{g}/\text{m}^3$) throughout the year for all species except *B. longirostris*, *D. brachyurum*, and *L. kindtii* (Figure 28). *Bosmina longirostris* mean biomass increased in May and peaked in June ($341.1 \mu\text{g}/\text{m}^3$), before steadily declining from July through September (Figure 28). October and November exhibited similar *B. longirostris* biomass levels, which were 5 times greater than observed September values. December *B. longirostris* mean biomass decreased to $45.1 \mu\text{g}/\text{m}^3$ (Figure 28). *Diaphanosoma brachyurum* biomass means were less than $100 \mu\text{g}/\text{m}^3$ for all months except July, when biomass peaked at $232.1 \mu\text{g}/\text{m}^3$ (Figure 28). *Leptodora kindtii* had the greatest mean biomass compared with the other species in the group in July, September, October, and November, with peak biomass occurring in November ($1,250.0 \mu\text{g}/\text{m}^3$; Figure 28). The minimum mean biomass for *L. kindtii* ($0.0 \mu\text{g}/\text{m}^3$) occurred from January through April, and in December.

Figure 28. Mean monthly other Cladocera biomass in Lake Roosevelt, WA (1999).

Shore vs Pelagic Zooplankton Comparisons

Comparisons of zooplankton collected at paired shore-pelagic sites for four index locations indicate that mean zooplankton abundance was greater at shore sites compared with pelagic sites for Porcupine Bay, Seven Bays, and Spring Canyon (Scheffe's S, $p < 0.001$; Table 32; Figure 29). The only exception was at Gifford where pelagic densities were greater than shore densities (Scheffe's S, $p < 0.001$; Table 32; Figure 29).

Table 32. Annual mean zooplankton density (organism/m³) at selected locations from pelagic and shore zones in Lake Roosevelt (1999).

Index Locations	Pelagic	Shore
Gifford	226.6	168.0
Porcupine Bay	762.4	1009.8
Seven Bays	454.6	913.6
Spring Canyon	677.4	856.6

Figure 29. Annual mean zooplankton density at selected index locations from pelagic and shore zones in Lake Roosevelt, WA (1999).

Pelagic and shore zooplankton densities compiled across the four index locations followed similar trends in 1999. Low abundances were observed from January through April, with pelagic samples (<160.1 organisms/ m^3) generally contributing a slightly greater portion than shore samples (<131.4 organisms/ m^3 ; Figure 30). Beginning in May, overall zooplankton abundances increased, but shore samples began to represent a greater portion of the overall abundance (Figure 30). In June, pelagic zooplankton abundance (442.4 organisms/ m^3) increased only slightly over May densities (379.8 organisms/ m^3), while shore mean zooplankton increased dramatically, reaching a peak density of $1,422.5$ organisms/ m^3 (Figure 30). Shore zooplankton abundance remained high through July and August, decreasing steadily through the end of the year (Figure 30). January, February, April, and November produced shore zooplankton abundances (336.8 organisms/ m^3) that were less than pelagic abundances (355.7 organisms/ m^3 ; Figure 30).

Figure 30. Mean zooplankton densities across four index locations with shore and pelagic zones on Lake Roosevelt, WA (1999).

Overall, the Copepoda was the most abundant group found in both pelagic ($1,334.4$ organisms/ m^3) and shore ($1,859.7$ organisms/ m^3) samples taken at the four index locations in Lake Roosevelt during 1999 (Figure 31). Copepods collected at shore locations comprised 45.4 %, and pelagic copepods comprised 33.1 % of the zooplankton biomass. Pelagic *Daphnia* (369.4 organisms/ m^3) comprised 7.9 % of the zooplankton biomass, while *Daphnia* (551.8

organisms/m³) collected near shore comprised 11.5 % (Figure 31). Other Cladocera (26.1 organisms/m³) collected at pelagic locations comprised 0.8 % of the zooplankton biomass, while other cladocerans collected near shore (39.5 organisms/m³) comprised the remaining 1.2 % (Figure 31).

Figure 31. Annual mean zooplankton density for major groups collected from shore and pelagic zones in Lake Roosevelt, WA (1999). Data combined across four index locations.

Mean zooplankton biomass was greater at shore sites compared with pelagic sites for all index locations examined in Lake Roosevelt (Table 33; Figure 32). Shore densities were significantly greater at only three locations in 1999; Porcupine Bay, Seven Bays, and Spring Canyon (Fisher's PLSD, $p < 0.001$).

Table 33. Annual mean zooplankton biomass ($\mu\text{g}/\text{m}^3$) at four index locations from pelagic and shore zones in Lake Roosevelt, WA (1999).

Index Locations	Pelagic	Shore
Gifford	235.4	401.0
Porcupine Bay	3599.1	7741.3
Seven Bays	1716.1	3181.0
Spring Canyon	2165.7	4218.4

Figure 32. Annual mean zooplankton biomass at index locations from pelagic and shore zones in Lake Roosevelt, WA (1999).

Zooplankton biomass values were low January through April for both pelagic and shore sites. Pelagic biomass generally contributed a slightly greater portion than the shore samples in January (84.8 and 60.2 $\mu\text{g}/\text{m}^3$ for pelagic and shore respectively) and February (61.0 and 26.6 $\mu\text{g}/\text{m}^3$ for pelagic and shore respectively), while shore samples contributed the greater portion in March (28.2 and 78.2 $\mu\text{g}/\text{m}^3$ for pelagic and shore respectively) and April (146.2 and 200.4 $\mu\text{g}/\text{m}^3$ for pelagic and shore respectively; Figure 33). Beginning in May, overall zooplankton biomass increased, with pelagic samples representing a greater portion of the overall biomass (412.4 and 363.8 $\mu\text{g}/\text{m}^3$ for pelagic and shore respectively; Figure 33). In June, pelagic zooplankton biomass (903.5 $\mu\text{g}/\text{m}^3$) increased only slightly over May pelagic biomass values, while shore mean zooplankton biomass increased dramatically (2,977.0 $\mu\text{g}/\text{m}^3$; Figure 33). Both pelagic and shore zooplankton biomass rose sharply in July (2,743.6 and 6,457.7 $\mu\text{g}/\text{m}^3$ pelagic and shore respectively; Figure 33). In August, pelagic zooplankton biomass continued to increase (3,634.6 $\mu\text{g}/\text{m}^3$), while shore biomass exhibited a slight decline (5,792.9 $\mu\text{g}/\text{m}^3$).

Biomass values for both shore and pelagic zooplankton (3,983.4 $\mu\text{g}/\text{m}^3$ and 6,966.5 $\mu\text{g}/\text{m}^3$ respectively) peaked in September (Figure 33). Both shore and pelagic zooplankton biomass levels declined in October, with pelagic levels decreasing dramatically to 2134.2 $\mu\text{g}/\text{m}^3$, while shore declined more moderately to 6,086.1 $\mu\text{g}/\text{m}^3$ (Figure 33). November shore zooplankton biomass levels decreased dramatically (1,599.5 $\mu\text{g}/\text{m}^3$), while pelagic biomass levels were only slightly lower (1,451.1 $\mu\text{g}/\text{m}^3$). Both pelagic and shore zooplankton biomass decreased in December, with greater biomass levels exhibited at pelagic sites (1,027.0 $\mu\text{g}/\text{m}^3$) compared with shore sites (883.1 $\mu\text{g}/\text{m}^3$; Figure 33).

Figure 33. Mean zooplankton biomass across all sampling locations within shore and pelagic zones in Lake Roosevelt, WA (1999).

Overall, *Daphnia* had the greatest biomass for both pelagic (4,532.2 $\mu\text{g}/\text{m}^3$) and shore (10,078.5 $\mu\text{g}/\text{m}^3$) sites taken at the four index locations in Lake Roosevelt in 1999 (Figure 34), with shore daphnids comprising 47.2 %, and pelagic daphnids comprising 21.6 % of the zooplankton biomass. Pelagic Copepoda (1,971.6 $\mu\text{g}/\text{m}^3$) comprised 10.9 % of the zooplankton biomass, while shore copepods (2,919.5 $\mu\text{g}/\text{m}^3$) comprised 15.9 % (Figure 34). Pelagic other Cladocera

(165.3 $\mu\text{g}/\text{m}^3$) comprised 1.2 % of the zooplankton biomass, while shore other cladocerans (461.7 $\mu\text{g}/\text{m}^3$) comprised the remaining 3.2 % (Figure 34).

Figure 34. Annual mean zooplankton biomass within shore and pelagic zones for major groups in Lake Roosevelt (1999).

Fishery

Fisheries Surveys

A total of 2,091 fish representing 20 species from 8 families were collected in Lake Roosevelt in 1999, using all sampling techniques (electrofishing, gill nets, seine hauls, and angling (Table 34). The most abundant species captured was rainbow trout (19.42%), followed by walleye (18.56%), lake whitefish (13.34%), largescale suckers (12.20%) and kokanee salmon (Table 35).

Electrofishing surveys conducted in 1999 consisted of 222 sampling events and a total of 40.69 hours of effort. The sampling yielded 1,093 fish representing 18 species from 6 families (Table 36). The overall CPUE for electrofishing was 26.86 fish/hour. Walleye was the most abundant species collected by boat electrofishing, representing 24.9% of the total catch, followed by largescale sucker (23.1%), rainbow trout (21.3%), and kokanee salmon (10.9%). The species composition collected by electrofishing varied seasonally in Lake Roosevelt (9.18%, Table 36). In the spring, walleye were captured most frequently followed by rainbow trout and largescale

sucker. In the summer, largescale sucker were the most abundant followed by walleye and smallmouth bass. In the fall, rainbow trout were the most frequently caught species followed by kokanee salmon and largescale sucker. Electrofishing CPUE during 1999 was highest in the fall followed by summer and spring (Table 36).

Gill net surveys in 1999 yielded 582 fish representing 15 species from 8 families (Table 37 and Table 38). Horizontal gill nets were set on 74 occasions, capturing 561 fish in 1,554.06 hours of effort. Vertical gill nets were set on 31 occasions, yielding 21 fish in 657.05 hours of effort. Horizontal gill net and vertical gill net CPUE was 0.36 and 0.03 fish/hour, respectively. Horizontal gill net sampling had the highest CPUE in July (Table 37), whereas vertical gill net CPUE was highest in October (Table 38). Lake whitefish (43.9%) were the most abundant species collected in horizontal gill net sampling followed by walleye, burbot, and longnose sucker (Table 37). Catch composition of horizontal gill nets varied by season in Lake Roosevelt. Lake whitefish, longnose sucker, burbot, and walleye were the most abundant species, respectively, in both spring and summer.

Table 34. The family, species, and scientific name of all fish species collected in Lake Roosevelt, WA via electrofishing, gillnetting, angling, and beach seining (1999).

Family	Species	Scientific Name
Acipenseridae	White sturgeon	<i>Acipenser transmontanus</i>
Cyprinidae	Carp	<i>Cyprinus carpio</i>
	Northern pikeminnow	<i>Ptychocheilus oregonensis</i>
	Tench	<i>Tinca tinca</i>
Catostomidae	Longnose sucker	<i>Catostomus catostomus</i>
	Bridgelip sucker	<i>Catostomus columbianus</i>
	Largescale sucker	<i>Catostomus macrocheilus</i>
Salmonidae	Lake whitefish	<i>Coregonus clupeaformis</i>
	Rainbow trout	<i>Oncorhynchus mykiss</i>
	Kokanee Salmon	<i>Oncorhynchus nerka</i>
	Chinook salmon	<i>Oncorhynchus tshawytscha</i>
	Mountain whitefish	<i>Prosopium williamsoni</i>
	Brown trout	<i>Salmo trutta</i>
	Eastern Brook trout	<i>Salvelinus fontinalis</i>
Gadidae	Burbot	<i>Lota lota</i>
Cottidae	Sculpin	<i>Cottus</i> spp.
Centrarchidae	Smallmouth bass	<i>Micropterus dolomieu</i>
	Black crappie	<i>Pomoxis nigromaculatus</i>
Percidae	Yellow perch	<i>Perca flavescens</i>
	Walleye	<i>Stizostedion vitreum</i>

Table 35. Summary of relative abundance (R.A.), mean total length (mm, $\pm$ standard deviation), and mean weight (grams $\pm$ standard deviation) for fish collected via boat electrofishing, gill nets, beach seines, and the test fishery (1999) Lake Roosevelt, WA.

Species	n	% R.A.	Mean TL	Mean weight
Black crappie	2	0.10	144 $\pm$ 28.28	55 $\pm$ 21.2
Bridgelip sucker	2	0.10	259 $\pm$ 46.67	210 $\pm$ 127.3
Brown trout	24	1.15	373 $\pm$ 74.06	698 $\pm$ 481.7
Burbot	110	5.26	496 $\pm$ 61.73	713 $\pm$ 359.0
Carp	4	0.19	269 $\pm$ 79.59	278 $\pm$ 111.6
Chinook	2	0.10	375 $\pm$ 5.66	450 $\pm$ 56.6
Eastern brook trout	22	1.05	282 $\pm$ 57.38	271 $\pm$ 167.2
Kokanee salmon	192	9.18	337 $\pm$ 82.80	401 $\pm$ 330.9
Lake whitefish	279	13.34	410 $\pm$ 112.15	1,129 $\pm$ 586.9
Largescale sucker	255	12.20	508 $\pm$ 69.31	1,554 $\pm$ 468.3
Longnose sucker	80	3.83	339 $\pm$ 78.72	626 $\pm$ 457.4
Mountain whitefish	14	0.67	439 $\pm$ 79.12	1,171 $\pm$ 800.8
Northern pikeminnow	14	0.67	409 $\pm$ 113.48	983 $\pm$ 680.3
Rainbow trout	406	19.42	376 $\pm$ 92.39	499 $\pm$ 380.3
Sculpin spp.	73	3.49	14 $\pm$ 12.80	16* $\pm$ 0
Smallmouth bass	111	5.31	204 $\pm$ 79.69	183 $\pm$ 165.0
Tench	2	0.10	298 $\pm$ 24.75	404 $\pm$ 118.1
Unidentified sucker fry	62	2.97	11 $\pm$ 0.99	- $\pm$ -
Unidentified fry	26	1.24	5 $\pm$ 0	- $\pm$ -
Walleye	388	18.56	311 $\pm$ 83.74	315 $\pm$ 306.2
White sturgeon	1	0.05	632 $\pm$ 0	2,250 $\pm$ 0
Yellow perch	22	1.05	203 $\pm$ 49.41	134 $\pm$ 136.9
Grand Total	2,091	100.00	343.79 $\pm$ 154.77	751 $\pm$ 643.2

Table 36. Number (n), relative abundance (% RA), catch-per-unit-effort (CPUE), and size range (mm) for fish captured via boat electrofishing in Lake Roosevelt, WA (1999). (effort = 40.69 hrs.)

Species	May			July			October			Annual Totals			
	n	%RA	CPUE	n	%RA	CPUE	n	%RA	CPUE	n	%RA	CPUE	Size Range
Black crappie	0	0.0	0.00	1	0.3	0.07	0	0.0	0.00	1	0.1	0.02	124
Bridgelip sucker	1	0.3	0.07	1	0.3	0.07	0	0.0	0.00	2	0.2	0.05	226-292
Eastern brook trout	0	0.0	0.00	0	0.0	0.00	22	5.4	1.76	22	2.0	0.54	150-369
Brown trout	0	0.0	0.00	15	3.8	1.09	9	2.2	0.72	24	2.2	0.59	247-520
Burbot	4	1.4	0.28	9	2.3	0.65	21	5.1	1.68	34	3.1	0.84	418-610
Chinook salmon	1	0.3	0.07	0	0.0	0.00	0	0.0	0.00	1	0.1	0.02	371
Carp	4	1.4	0.28	0	0.0	0.00	0	0.0	0.00	4	0.4	0.10	207-383
Kokanee salmon	4	1.4	0.28	13	3.3	0.95	102	24.8	8.16	119	10.9	2.92	146-526
Longnose sucker	6	2.1	0.42	7	1.8	0.51	1	0.2	0.08	14	1.3	0.34	160-452
Largescale sucker	43	14.9	2.98	135	34.3	9.82	75	18.2	6.00	253	23.1	6.22	85-693
Lake whitefish	8	2.8	0.55	1	0.3	0.07	6	1.5	0.48	15	1.4	0.37	215-589
Mountain whitefish	1	0.3	0.07	0	0.0	0.00	4	1.0	0.32	5	0.5	0.12	365-425
Northern pike minnow	3	1.0	0.21	2	0.5	0.15	3	0.7	0.24	8	0.7	0.20	216-550
Rainbow trout	87	30.2	6.02	22	5.6	1.60	124	30.2	9.92	233	21.3	5.73	151-568
Smallmouth bass	18	6.3	1.25	53	13.5	3.85	5	1.2	0.40	76	7.0	1.87	116-430
Tench	1	0.3	0.07	1	0.3	0.07	0	0.0	0.00	2	0.2	0.05	280-315
Walleye	105	36.5	7.27	132	33.5	9.60	35	8.5	2.80	272	24.9	6.68	126-565
Yellow perch	2	0.7	0.14	2	0.5	0.15	4	1.0	0.32	8	0.7	0.20	132-211
Totals	288	100	19.94	394	100	28.65	411	100	33	1,093	100	26.86	85-693

Walleye were the most frequently caught species in fall horizontal gillnet sampling followed by lake whitefish, smallmouth bass and burbot (Table 37). A single white sturgeon (*Acipenser transmontanus*) was captured in October horizontal gill net surveys near Evan's Landing measuring 632 mm and weighing 2,250 g. Walleye (33.3%) were the most abundant species collected by vertical gillnets, followed by kokanee salmon, lake whitefish, and smallmouth bass (Table 38). CPUE was highest in fall (0.04 fish/hour) followed by spring and summer (Table 38).

The mean annual CPUE for beach seine surveys was 4.44 fish/haul. July beach seine surveys yielded 191 fish for a CPUE of 5.16 fish/haul. October surveys included 6 hauls yielding no fish. Sculpins (*Cottus sp.*) were the most abundant species collected in beach seine surveys in 1999, followed by unidentified sucker fry and other unidentified fry (Table 39).

During the annual January test fishery, 225 fish were captured from 333.33 rod hours of effort (Table 40). Rainbow trout (n = 164) and kokanee salmon (n = 61) were the only two species represented, accounting for 72.9 and 27.1% of the catch respectively. Total CPUE was 0.18 and 0.49 fish/rod hour for kokanee salmon and rainbow trout respectively (Table 40). Length and weight data were only collected on harvested kokanee salmon (n=14) and rainbow trout (n=117). The mean total length and standard deviation of kokanee salmon was 412mm (± 57.6), ranging from 286 to 474 mm. The mean length and standard deviation of rainbow trout was 382.3 mm (± 22.9), ranging from 333 to 472 mm. The majority (95.1 %) of the kokanee caught were not marked to represent hatchery origin, whereas all of the rainbow trout captured were of hatchery origin

All surveys combined, the longest fish captured was a burbot measuring 721 mm and the heaviest fish was a lake whitefish weighing 2,750 grams. Excluding the test fishery, surveys determined that 74.8% of the kokanee (n = 131) captured were of hatchery origin (Table 41). Alternatively, 74.8 % of the rainbow trout (n = 242) collected were wild in origin (Table 41). The mean length (430 mm) and weight (946 g) of wild kokanee salmon was greater than those of hatchery kokanee salmon (305mm and 327g, respectively). Wild rainbow trout were longer (mean TL = 386 mm) than hatchery origin fish (mean TL = 345mm), but weighed less (mean wt 386g) than hatchery origin fish (mean wt =537g, Table 41).

Table 37. Number (n), relative abundance (% RA), catch-per-unit-effort (CPUE), and size range (mm) for fish captured via horizontal gill nets in Lake Roosevelt, WA (1999) (effort = 1,554.06 hrs).

Species	May			July			October			Annual Total			Size Range
	n	%RA	CPUE	n	%RA	CPUE	n	%RA	CPUE	n	%RA	CPUE	
Black crappie	0	0.0	0.00	0	0.0	0.00	1	0.5	0.00	1	0.2	0.00	164
Burbot	25	21.2	0.05	32	12.9	0.06	19	9.7	0.04	76	13.5	0.05	390-721
Kokanee salmon	0	0.0	0.00	6	2.4	0.01	1	0.5	0.00	7	1.2	0.00	232-462
Longnose sucker	26	21.2	0.05	32	12.9	0.06	7	3.6	0.01	65	11.4	0.04	203-478
Largescale sucker	0	0.0	0.00	1	0.4	0.00	1	0.5	0.00	2	0.4	0.00	328-495
Lake whitefish	44	37.3	0.09	144	58.1	0.26	58	29.7	0.11	246	43.9	0.16	200-600
Mountain whitefish	7	5.9	0.01	1	0.4	0.00	1	0.5	0.00	9	1.6	0.01	279-580
Northern pike minnow	0	0.0	0.00	1	0.4	0.00	4	2.1	0.01	5	0.9	0.00	255-516
Rainbow trout	0	0.0	0.00	3	1.2	0.01	2	1.0	0.00	5	0.9	0.00	211-444
Sculpin spp.	0	0.0	0.00	0	0.0	0.00	1	0.5	0.00	1	0.2	0.00	104
Smallmouth bass	0	0.0	0.00	0	0.0	0.00	21	10.8	0.04	21	3.7	0.01	182-314
Walleye	11	9.3	0.02	27	10.9	0.05	70	35.9	0.13	108	19.3	0.07	225-510
White sturgeon	0	0.0	0.00	0	0.0	0.00	1	0.5	0.00	1	0.2	0.00	632
Yellow perch	5	4.2	0.01	1	0.4	0.00	8	4.1	0.02	14	2.5	0.01	111-340
Totals	118	100	0.25	248	100	0.45	195	100	0.37	561	100	0.36	104-721

Table 38. Number (n), relative abundance (% RA), catch-per-unit-effort (CPUE), and size range (mm) for fish captured via vertical gill nets in Lake Roosevelt, WA (1999) (effort = 657.05 hrs).

Species	May			July			October			Annual totals			
	n	% RA	CPUE	n	% RA	CPUE	n	% RA	CPUE	n	% RA	CPUE	Size Range
Chinook salmon	1	25	0.01	0	0.0	0.00	0	0.0	0.00	1	4.8	0.00	379
Kokanee salmon	1	25	0.01	0	0.0	0.00	4	36.4	0.02	5	23.8	0.01	274-488
Longnose sucker	0	0	0.00	0	0.0	0.00	1	9.1	0.00	1	4.8	0.00	311
Lake whitefish	1	25	0.01	1	16.7	0.00	1	9.1	0.00	3	14.3	0.00	210-350
Northern pike minnow	0	0	0.00	1	16.7	0.00	0	0.0	0.00	1	4.8	0.00	270
Rainbow trout	0	0	0.00	1	16.7	0.00	0	0.0	0.00	1	4.8	0.00	278
Smallmouth bass	0	0	0.00	0	0.0	0.00	2	18.2	0.01	2	9.5	0.00	250-257
Walleye	1	25	0.01	3	50.0	0.01	3	27.3	0.01	7	33.3	0.01	222-377
Totals	4	100	0.03	6	100	0.02	11	100	0.04	21	100	0.03	210-488

Table 39. Relative abundance (% RA), catch-per-unit-effort (CPUE), and size range (mm) for fish captured via beach seining in Lake Roosevelt, WA (1999).

Species	July (Effort = 37 hauls)			October (Effort = 6 hauls)			Grand Totals		
	n	% RA	CPUE	n	% RA	CPUE	n	CPUE	Size Range
Lake whitefish	15	7.9	0.41	0	0	0	15	0.35	32-72
Rainbow trout	3	1.6	0.08	0	0	0	3	0.07	50-65
Sculpin spp.	72	37.7	1.95	0	0	0	72	1.67	9-52
Smallmouth bass	12	6.3	0.32	0	0	0	12	0.28	10
Unidentified fry	26	13.6	0.70	0	0	0	26	0.60	5
Unidentified sucker fry	62	32.5	1.68	0	0	0	62	1.44	10-12
Walleye	1	0.5	0.03	0	0	0	1	0.02	30
Totals	191	100	5.16	0	100	0	191	4.44	5-72

Table 40. Number (n), relative abundance (%), catch-per-unit-effort (CPUE in fish/hour), mean total length ($\pm$ standard deviation, mm), mean weight ($\pm$ standard deviation, g) and range of total length(TL) of fish captured during the annual test fishery in Lake Roosevelt, WA (1999). Mean lengths and weights were only calculated from kokanee salmon (n = 14) and rainbow trout (n = 117) that were harvested (total rod hours = 333.3 hours).

Species	n	% RA	CPUE	Mean TL	Mean wt	TL (mm)
Kokanee salmon	61 ¹	27.1	0.18	411.8 $\pm$ 57.6	707.1 $\pm$ 406.2	286-474
Rainbow trout	164	72.9	0.49	382.3 $\pm$ 22.9	567 $\pm$ 139.7	333-472
Totals	225	100	0.68	385.9$\pm$30.4	583.8$\pm$194.2	286-474

¹ Three kokanee were of hatchery origin.

Table 41. Number (n), relative abundance (% RA), total length (TL) range and mean ($\pm$ standard deviation), and weight range and mean ($\pm$ standard deviation) of hatchery and wild kokanee salmon and rainbow trout collected, combining all sampling, gears except the test fishery in Lake Roosevelt, WA (1999).

Species	Origin	n	%RA	TL	Mean TL	Wt.	Mean Wt.
Kokanee salmon	Hatchery	98	74.8	146-503	305 $\pm$ 61.5	20-1250	327 $\pm$ 238.5
	Wild	33	25.2	284-526	430 $\pm$ 65.3	200-1500	946 $\pm$ 422.3
	Total	131	100	146-526	337 $\pm$ 82.8	20-1500	401 $\pm$ 330.9
Rainbow trout	Hatchery	60	24.8	182-460	345 $\pm$ 73.6	60-1750	537 $\pm$ 349.8
	Wild	181	74.8	50-568	386 $\pm$ 96.1	30-1816	386 $\pm$ 449.9
	Total	242¹	100	50-568	376 $\pm$ 92.4	30-1816	499 $\pm$ 380.3

¹The origin of one rainbow trout was unknown but was included in the total mean length and weight calculations.

Age and Growth

Condition factors were calculated for each species collected when lengths and weights were taken (Table 42). For salmonids, a condition factor around 1.00 is considered average (Carlander 1969). Wild kokanee salmon had a slightly higher condition factor (1.13 ± 0.19) compared to hatchery kokanee (1.08 ± 0.26). Hatchery rainbow trout had a slightly higher condition factor (1.13 ± 0.27) compared to wild rainbow trout (1.00 ± 0.25). Walleye and smallmouth bass had condition factors of $0.81 (\pm 0.17)$ and $1.34 (\pm 0.16)$ respectively.

Back-calculated lengths at the formation of each annulus were calculated for 11 species of fish. Six species from the Salmonidae family were analyzed. Hatchery and wild kokanee were combined for age analysis because origin was not distinguished during analysis. A total of 30 kokanee scales were analyzed and ages ranged from one to three (Table 43). Hatchery and wild rainbow trout were also combined because origin was not distinguished during analysis. A total of 159 rainbow trout scales were analyzed with ages ranging from one to five (Table 44). A total of 19 brown trout scales were analyzed with ages ranging from one to six (Table 45). Nine eastern brook trout scales were analyzed with ages between one and two (Table 46). Sixteen lake whitefish were analyzed with ages ranging from one to nine (Table 47), and five mountain whitefish with ages ranging from one to seven (Table 48).

Only one species from the Centrarchidae family was collected for age analysis. Smallmouth bass scales were analyzed from 60 fish with ages ranging from one to seven (Table 49). Two species of Percidae were collected for age analysis. A total of 371 walleye scales were analyzed with ages ranging from one to five (Table 50), and nine yellow perch with ages ranging from one to five (Table 51). One species from the Cyprinidae family was collected for age analysis. Scales from seven northern pikeminnow scales were analyzed with ages ranging from one to eleven (Table 52).

Table 42. Condition factor ($\pm$ standard deviation) of fish captured in Lake Roosevelt, WA using all sampling gear types, 1999.

Species	n	Condition factor (S.D.)
Black crappie	2	1.84 $\pm$ 0.36
Bridgelip sucker	2	1.12 $\pm$ 0.12
Eastern brook trout	17	1.02 $\pm$ 0.26
Brown trout	20	1.14 $\pm$ 0.40
Burbot	110	0.56 $\pm$ 0.12
Chinook	2	0.85 $\pm$ 0.07
Cottidae	1	1.42 $\pm$ 0.00
Carp	4	1.58 $\pm$ 0.57
Kokanee salmon - hatchery	67	1.08 $\pm$ 0.26
Kokanee salmon - wild	9	1.13 $\pm$ 0.19
Longnose sucker	80	1.29 $\pm$ 0.33
Largescale sucker	255	1.14 $\pm$ 0.18
Lake whitefish	264	1.27 $\pm$ 0.23
Mountain whitefish	14	1.16 $\pm$ 0.33
Northern pikeminnow	14	1.12 $\pm$ 0.29
Rainbow trout - hatchery	59	1.13 $\pm$ 0.27
Rainbow trout - wild	20	1.00 $\pm$ 0.25
Smallmouth bass	99	1.34 $\pm$ 0.16
Tench	2	1.51 $\pm$ 0.07
Walleye	388	0.81 $\pm$ 0.17
White sturgeon	1	0.89 $\pm$ 0.00
Yellow perch	22	1.24 $\pm$ 0.22
Grand Total	1,452	

Table 43. Back calculated total lengths (mm) ($\pm$ standard deviation) of kokanee collected from Lake Roosevelt, WA (1999).

Cohort	n	Back calculated total length at annulus formation		
		1	2	3
1998	8	139 (31)		
1997	14	142 (49)	257 (89)	
1996	8	136 (49)	245 (80)	332 (86)
Grand mean	30	140 (44)	235 (85)	332 (86)
Annual growth		140 (44)	113 (55)	87 (30)

Table 44. Back calculated total lengths (mm) ($\pm$ standard deviation) of rainbow trout collected from Lake Roosevelt, WA (1999).

Cohort	n	Back calculated total length at annulus formation				
		1	2	3	4	5
1998	22	156 (63)				
1997	87	160 (37)	293 (52)			
1996	39	129 (42)	220 (52)	326 (53)		
1995	4	128 (21)	193 (31)	268 (24)	349 (40)	
1994	7	126 (27)	179 (12)	242 (27)	319 (41)	367 (49)
Grand mean	159	149 (44)	264 (64)	310 (58)	330 (41)	367 (49)
Annual growth		149 (44)	116 (47)	97 (53)	79 (24)	48 (14)

Table 45. Back calculated total lengths (mm) ($\pm$ standard deviation) of brown trout collected from Lake Roosevelt, WA (1999).

Cohort	n	Back calculated total length at annulus formation					
		1	2	3	4	5	6
1998	2	195 (135)					
1997	1	229 (0)	330 (0)				
1996	6	123 (50)	192 (65)	276 (74)			
1995	6	152 (59)	217 (79)	296 (98)	355 (109)		
1994	3	101 (43)	179 (40)	248 (45)	320 (49)	402 (78)	
1993	1	88 (0)	158 (0)	235 (0)	315 (0)	381 (0)	425 (0)
Grand mean	19	141 (64)	205 (70)	275 (76)	340 (86)	397 (64)	425 (0)
Annual growth		141 (64)	69 (33)	79 (28)	65 (14)	78 (27)	44 (0)

Table 46. Back calculated total lengths (mm) ($\pm$ standard deviation) of eastern brook trout collected from Lake Roosevelt, WA (1999).

Cohort	n	Back calculated total length at annulus formation	
		1	2
1998	7	176 (50)	
1997	2	141 (3)	250 (40)
Grand mean	9	168 (46)	250 (40)
Annual growth		168 (46)	109 (43)

Table 47. Back calculated total lengths (mm) ($\pm$ standard deviation) of lake whitefish collected from Lake Roosevelt, WA (1999).

Cohort	n	Back calculated total length at annulus formation								
		1	2	3	4	5	6	7	8	9
1998	1	165 (0)								
1997	1	128 (0)	176 (0)							
1996	1	118 (0)	218 (0)	268 (0)						
1995	2	94 (13)	167 (14)	314 (50)	374 (34)					
1994	7	76 (24)	144 (40)	249 (77)	348 (73)	406 (63)				
1993	0									
1992	1	31 (0)	92(0)	220(0)	287(0)	461(0)	473(0)	485(0)		
1990	2	87 (11)	135 (14)	169 (4)	242 (12)	326 (86)	398 (66)	451 (91)	477 (61)	
1989	1	79 (0)	156 (0)	184 (0)	260 (0)	360 (0)	411 (0)	439 (0)	490 (0)	513 (0)
Grand mean	16	88 (33)	150 (38)	241 (70)	324 (71)	393 (69)	420 (52)	456 (56)	481 (44)	513 (0)
Annual growth		88 (33)	67 (22)	93 (53)	85 (50)	77 (47)	51 (30)	37 (25)	35 (25)	23 (0)

Table 48. Back calculated total lengths (mm) ($\pm$ standard deviation) of mountain whitefish collected from Lake Roosevelt, WA (1999).

Cohort	n	Back calculated total length at annulus formation						
		1	2	3	4	5	6	7
1998	0							
1997	0							
1996	1	185 (0)	238 (0)	302 (0)				
1995	1	168 (0)	240 (0)	297 (0)	336 (0)			
1994	0							
1993	2	54 (38)	150 (70)	218 (62)	329 (27)	385 (56)	418 (57)	
1992	1	95 (0)	118 (0)	189 (0)	247 (0)	277 (0)	335 (0)	392 (0)
Grand mean	5	111 (65)	179 (66)	245 (60)	310(45)	349 (74)	391 (63)	392 (0)
Annual growth		111 (65)	68 (62)	65 (7)	80 (42)	47 (25)	41 (14)	57 (0)

Table 49. Back calculated total lengths (mm) ($\pm$ standard deviation) of smallmouth bass collected from Lake Roosevelt, WA (1999).

Cohort	n	Back calculated total length at annulus formation						
		1	2	3	4	5	6	7
1998	11	101 (42)						
1997	20	84 (27)	166 (34)					
1996	17	69 (30)	135 (47)	206 (60)				
1995	7	60(21)	108 (28)	155 (30)	200 (39)			
1994	3	69 (22)	113 (21)	165 (16)	201 (30)	233 (39)		
1993	1	61 (0)	84 (0)	104 (0)	123 (0)	149 (0)	173 (0)	
1992	1	100 (0)	141 (0)	202 (0)	284 (0)	319 (0)	358 (0)	402 (0)
Grand mean	60	79 (32)	141 (43)	186 (55)	201 (47)	233 (66)	266 (131)	402 (0)
Annual growth		79 (32)	67 (35)	61 (33)	44 (21)	31 (11)	31 (11)	136 (0)

Table 50. Back calculated total lengths (mm) ($\pm$ standard deviation) of walleye collected in 1999.

Cohort	n	Back calculated total length at annulus formation				
		1	2	3	4	5
1998	62	146 (43)				
1997	83	140 (28)	253 (45)			
1996	148	135 (29)	237 (39)	313 (43)		
1995	40	129 (28)	237 (45)	314 (43)	381 (42)	
1994	28	124 (32)	207 (48)	282 (57)	341 (60)	403 (69)
Grand mean	361	137 (32)	239 (44)	309 (46)	364 (58)	403 (69)
Annual growth	137 (32)	104 (35)	76 (32)	63 (25)	62 (33)	

Table 51. Back calculated total lengths (mm) ($\pm$ standard deviation) of yellow perch collected from Lake Roosevelt, WA (1999).

Cohort	n	Back calculated total length at annulus formation				
		1	2	3	4	5
1998	2	116 (55)				
1997	2	38 (0)	86 (11)			
1996	2	107 (25)	156 (13)	215 (5)		
1995	1	26 (0)	63 (0)	121 (0)	155 (0)	
1994	2	48 (1)	87 (19)	111 (29)	168 (8)	186 (7)
Grand mean	9	62 (46)	91 (45)	155 (57)	163 (9)	186 (7)
Annual growth		62 (46)	41 (15)	45 (20)	49 (20)	18 (1)

Table 52. Back calculated total lengths (mm) ($\pm$ standard deviation) of northern pikeminnow collected from Lake Roosevelt, WA (1999).

	n	Back calculated total length at annulus formation										
		1	2	3	4	5	6	7	8	9	10	11
1998	0											
1997	1	117 (0)	165 (0)									
1996	2	62 (37)	135 (112)	207 (105)								
1995	1	178 (0)	225 (0)	283 (0)	290 (0)							
1994	0											
1993	1	113 (0)	141 (0)	263 (0)	320 (0)	367 (0)	423 (0)					
1992	1	81 (0)	114 (0)	211 (0)	265 (0)	314 (0)	357 (0)	379 (0)				
1991	0											
1990	0											
1989	0											
1988	1	72 (0)	106 (0)	130 (0)	192 (0)	281 (0)	318 (0)	329 (0)	380 (0)	394 (0)	397 (0)	414 (0)
Grand mean	7	98 (45)	146 (61)	217 (71)	267 (55)	321 (43)	366 (53)	354 (36)	380 (0)	394 (0)	397 (0)	414 (0)
Annual growth		98 (45)	48 (36)	74 (34)	45 (25)	62 (24)	46 (10)	16 (8)	51 (0)	14 (0)	3	17

Feeding Habits

Stomachs were collected from 697 fish, representing 16 species from 6 families. Of the 697 stomachs collected in 1999 for analysis, 157 were empty. Cladocera (34.63 %) had the highest relative importance (Ri_a) among identified prey items across all fish species, followed by Osteichthyes (11.52 %) and Diptera (9.89 %). The diet category identified as Other, consisting of detritus, plant seeds, invertebrate eggs, and unidentifiable organic matter, comprised 20.89 % of the relative importance. Across all species, Osteichthyes comprised the highest percent of the diet by dry weight (21.84 %), followed by Cladocera (13.5 %). Cladocera were consumed in the highest numbers, making up 96.0 % of the total items consumed. The percent by weight, percent by number, frequency of occurrence, and Ri_a for each species were summarized in Appendix A.

The four main sport fish species identified in Lake Roosevelt are kokanee salmon, rainbow trout, walleye, and smallmouth bass. Kokanee salmon fed almost exclusively on Cladocera and Diptera, with Ri_a values of 74.4 and 14.0 % respectively (Table 53). The most important food item in the diet of rainbow trout was also Cladocera, which comprised nearly half of the relative importance. Diptera, Osteichthyes and Hemiptera contributed equally to the rainbow trout diet with Ri_a values of 7.9, 7.6, and 7.2 % respectively. The most important food item of walleye was Osteichthyes, with a Ri_a value of 52.8 %. Cladocera was also important in the diet of walleye with a Ri_a value of 23.9 %. Cladocera, Osteichthyes, and Diptera were the most important food items in the diet of smallmouth bass with Ri_a values of 25.2, 22.6, and 14.4 % respectively.

The highest diet overlap occurred between kokanee salmon and rainbow trout (0.90). High diet overlap values (≥ 0.70) were observed between the following species: eastern brook trout with kokanee salmon, brown trout, rainbow trout and smallmouth bass; rainbow trout with kokanee salmon and lake whitefish; tench with bridgelip sucker, longnose sucker and northern pikeminnow; largescale sucker with bridgelip sucker, longnose sucker, and lake whitefish (Table 54). Species that did not have a high diet overlap with any other species included black crappie, burbot, mountain whitefish, walleye, and yellow perch (Table 54).

Table 53. Relative importance values of prey items in the diet of kokanee salmon, rainbow trout, walleye, and smallmouth bass collected in Lake Roosevelt, WA (1999).

Prey Category	Family	Kokanee	Rainbow trout	Walleye	Smallmouth bass
Osteichthyes	Catostomidae	0.00	0.00	0.35	2.41
	Centrarchidae	0.00	0.00	0.24	0.00
	Cottidae	0.00	0.32	16.56	10.16
	Cyprinidae	0.00	0.00	2.01	0.65
	Gadidae	0.00	0.00	0.25	0.00
	Ictaluridae	0.00	0.30	0.00	0.00
	Salmonidae	0.00	0.00	17.94	0.00
	Unidentified non-salmonidae	0.00	1.88	11.06	7.73
	Unidentified Osteichthyes	0.00	5.06	4.39	1.65
Amphipoda	Gammaridae	0.94	0.13	0.20	0.00
	Unidentified Amphipoda	0.00	0.59	0.40	0.00
Arachnoidea spp.	Unidentified Arachnoidea	0.47	2.09	0.00	0.50
Cladocera/Copepoda	Daphnidae	53.88	43.26	0.00	9.35
	Leptodoridae	0.00	0.00	15.08	0.00
	Unidentified Cladocera/Copepoda	20.56	3.93	8.77	15.81
Coleoptera	Carabidae	0.00	0.13	0.00	0.00
	Chrysomelidae	0.00	0.22	0.00	0.00
	Curculionidae	0.00	0.14	0.00	0.00
	Elmidae	0.00	0.51	0.00	0.00
	Hydrophilidae	0.00	0.27	0.00	0.00
	Melyridae	0.00	0.27	0.00	0.00
	Staphylinidae	0.00	0.13	0.00	0.00
	Salpingidae	0.00	0.14	0.00	0.00
	Unidentified Coleoptera	0.00	0.21	0.00	0.00
Decopoda	Astacidae	0.58	2.32	0.00	14.42
Diptera	Chironomidae larvae	1.41	3.21	4.82	3.62
	Chironomidae pupae	12.20	4.13	4.66	1.46
	Dixidae	0.00	0.14	0.19	0.48
	Simuliidae	0.47	0.40	0.20	0.00
	Tabanidae	0.00	0.00	0.00	0.00
	Unidentified Diptera	0.00	0.00	0.00	0.00
Ephemeroptera	Baetidae	0.00	0.94	1.29	1.97
	Ephemerellidae	0.00	0.14	0.00	0.49
	Heptageniidae	0.00	0.00	0.19	0.49
Hemiptera	Belostomatidae	0.00	0.38	0.00	0.00
	Corixidae	0.94	2.83	0.00	4.26
	Gelastocoridae	0.00	0.54	0.00	0.00
	Gerridae	0.00	0.13	0.00	0.00
	Macroveliidae	0.00	0.14	0.00	0.00
	Mesoveliidae	0.00	0.51	0.00	0.00
	Naucoridae	0.00	0.28	0.00	0.00
	Ochteridae	0.00	0.16	0.00	0.00
	Saldidae	0.00	0.87	0.00	0.00
	Veliidae	0.00	0.14	0.00	0.00
	Unidentified Hemiptera	0.00	0.14	0.00	0.00
Homoptera	Unidentified Homoptera	0.00	0.14	0.00	0.00
Lepidoptera	Unidentified Lepidoptera	0.00	0.00	0.00	0.00

Table 53. Continued.

Prey Category	Family	Kokanee	Rainbow trout	Walleye	Smallmouth bass
Odonata	Aeshnidae	0.00	0.14	0.21	2.30
	Unidentified Odonata	0.00	0.00	0.19	0.00
Trichoptera	Brachycentridae	0.00	0.40	0.00	0.00
	Coenagrionidae	0.00	0.00	0.00	0.00
	Glossomatidae	0.00	0.00	0.00	0.00
	Helicopsychidae	0.00	0.00	0.00	0.00
	Hydropsychidae	0.00	0.00	0.00	0.00
	Hydroptilidae	0.00	0.00	0.00	0.00
	Limnephilidae	0.00	0.82	0.56	0.00
	Nemouridae	0.00	0.00	0.00	0.00
	Unidentified Trichoptera	0.00	0.00	0.76	1.01
Plecoptera	Chloroperlidae	0.00	0.00	0.00	0.00
	Peltoperlidae	0.00	0.13	0.00	0.00
	Perlidae	0.00	0.00	0.19	0.48
	Perlodidae	0.00	0.14	0.38	1.03
	Pteronarcyidae	0.00	0.00	0.00	0.48
	Rhyacophilidae	0.00	0.00	0.00	0.49
	Unidentified Plecoptera	0.00	0.00	0.43	0.00
Gastropoda	Lymnaeidae	0.00	0.54	0.00	0.49
	Physidae	0.00	1.52	0.00	0.00
	Planorbidae	0.00	0.46	0.00	0.00
	Unidentified Gastropoda	0.00	0.00	0.00	0.00
Pelecypoda	Sphaeriidae	0.00	0.00	0.00	0.00
	Unidentified Pelecypoda	0.00	0.13	0.00	0.00
Annelida	Hirudinea	0.00	0.00	0.20	0.00
	Oligocheata	0.00	0.00	0.00	0.00
	Unidentified Annelida	0.00	0.41	0.00	1.56
Nematoda	Unidentified Nematoda	0.00	0.00	0.00	0.00
Tricladida	Planariidae	0.00	0.28	0.00	0.00
Arthropoda	Unidentified Arthropoda	2.60	4.84	1.12	4.68
Other	Terrestrial	0.94	5.59	1.36	4.75
	Other	5.01	7.48	6.00	7.28

Table 54. Diet overlap of various fish species collected in Lake Roosevelt, WA (1999). Bold values represent high diet overlaps (≥ 0.70).

Species	n	Diet Overlap																
Black crappie	1	-																
Bridgelip sucker	3	0.00	-															
Eastern brook trout	16	0.05	0.24	-														
Eastern Brown trout	18	0.29	0.37	0.72	-													
Burbot	20	0.00	0.47	0.35	0.57	-												
Kokanee Salmon	59	0.18	0.08	0.71	0.41	0.05	-											
Longnose sucker	10	0.09	0.87	0.25	0.43	0.46	0.11	-										
Largescale sucker	164	0.05	0.75	0.63	0.56	0.42	0.60	0.78	-									
Lake whitefish	13	0.08	0.01	0.22	0.12	0.03	0.24	0.02	0.73	-								
Mountain whitefish	5	0.47	0.47	0.24	0.64	0.32	0.18	0.50	0.41	0.38	-							
Northern pikeminnow	4	0.00	0.60	0.43	0.52	0.50	0.06	0.57	0.44	0.35	0.46	-						
Rainbow trout	169	0.07	0.19	0.77	0.51	0.18	0.90	0.20	0.69	0.72	0.19	0.15	-					
Smallmouth bass	49	0.03	0.26	0.76	0.65	0.66	0.42	0.26	0.47	0.65	0.22	0.35	0.45	-				
Tench	1	0.00	0.76	0.20	0.29	0.39	0.08	0.75	0.58	0.34	0.46	0.73	0.15	0.19	-			
Walleye	161	0.08	0.20	0.44	0.48	0.43	0.12	0.20	0.21	0.28	0.23	0.38	0.11	0.49	0.18	-		
Yellow perch	4	0.55	0.14	0.34	0.66	0.24	0.16	0.20	0.12	0.22	0.67	0.53	0.11	0.25	0.23	0.50	-	
			Black crappie	Bridgelip sucker	Eastern brook trout	Brown trout	Burbot	Kokanee	Longnose sucker	Largescale sucker	Lake whitefish	Mountain whitefish	Northern pikeminnow	Rainbow trout	Smallmouth bass	Tench	Walleye	Yellow perch

Tagging Studies

A total of 309 tags were recovered in 1999 (Table 55). Most of the tags recovered (n=220) came from fish released in 1998 (Table 55). Recoveries were nearly equal between fish released at Kettle Falls (n=119) and Seven Bays (n=101). Tags recovered from 1996, 1997, and 1999 fish releases made up 2, <1, and 27 %, respectively, of the total tags recovered in 1998 (Table 55). Tags recovered from 1996 rainbow trout releases comprised 0.02 % of tagged fish released from Kettle Falls and 0.08 % of the fish tagged and released at Seven Bays. Only one tag was recovered from 1997 fish releases, representing 0.01 % of the tagged fish from the Seven Bays release group. No tags were recovered from the 1997 Kettle Falls release. The tags recovered from 1998 equaled 1.19 % of the Kettle Falls tagged fish

and 1.01 % of the Seven Bays tagged fish. Tags were recovered from 0.24 % of the rainbow trout tagged and released from Kettle Falls in 1999. Tags were recovered from 0.45 % of fish tagged and released at Seven Bays in 1999.

Tags were recovered from 164 fish, consisting of 145 Spokane stock rainbow trout, and 19 Phalon Lake stock rainbow trout, that were released from Kettle Falls, of which 75 % were recovered downstream of the release site and 16 % were recovered downstream of Grand Coulee Dam. The longest distance between the release site and the tag recovery site was just over 1,100 km, from Kettle Falls to Rice Island, near the mouth of the Columbia River, where 6 tag recoveries were made. Tag recoveries from Rufus Woods Reservoir, below Grand Coulee Dam, accounted for 10 % of the recoveries made from fish released at Kettle Falls. A total of 26 tags were recovered at Kettle Falls from fish that were also released there, representing 15.9 % of the tag recoveries from Kettle Falls released fish (Table 56). All of the Phalon Lake stock tag recoveries were collected from Kettle Falls, accounting for 73.1 % of the tags recovered at Kettle Falls from fish released at Kettle Falls. Phalon Lake stock tag recoveries accounted for 0.21 % of the Phalon Lake stock tagged fish and Spokane stock recoveries represented 0.26 % of the Spokane stock tagged fish released from Kettle Falls. No tags were recovered from the 9,621 kokanee salmon tagged and released from Kettle Falls in 1999 (Table 56).

Tags were recovered from 145 fish that were released from Seven Bays, 45 % of which were recovered downstream of the release location and 14 % were recovered below Grand Coulee Dam (Table 56). Three tags were recovered at Porcupine Bay and one at Fort Spokane in the Spokane Arm of Lake Roosevelt (Table 56). No tags were recovered from fish released at Seven Bays above the confluence of the Spokane River. Recoveries from Spokane stock rainbow trout released at Seven Bays represented 0.37 % of the fish tagged.

The mean ($\pm$ standard deviation) number of days spent in the reservoir after release, across both release locations and both rainbow trout stocks, was 292.1($\pm$ 163.7) days (Table 57). The mean ($\pm$ standard deviation) time difference between release and capture for fish released from Kettle Falls (275.6 $\pm$ 139.2) was lower than that of fish released from Seven Bays (310.8 $\pm$ 186.3; Table 57). The mean ($\pm$ standard deviation) time difference between

release and capture for Phalon Lake stock rainbow trout (65.7 ± 22.7) resulted in the reduced value (Table 57). The mean ($\pm$ standard deviation) time difference between release and capture of Spokane stock rainbow trout released from Kettle Falls was 321.4 (± 84.4) days, which was higher than the Spokane stock fish released from Seven Bays (310.8 ± 186.3 ; Table 57).

Growth was evaluated as mean growth per day between the date of release and date of capture for total length (mm) and weight (g) when possible. The mean growth in total length ($\pm$ standard deviation) across both release locations for both Spokane and Phalon Lake stocks ($n = 189$) was $0.0046 (\pm 0.0017)$ mm/day (Table 57). The mean growth in weight ($\pm$ standard deviation) across both release locations for both stocks ($n = 96$) was $0.0175 (\pm 0.0141)$ g/day (Table 57). The mean growth in total length ($\pm$ standard deviation) was greater for fish released at Kettle Falls (0.0047 ± 0.0017 mm/day; $n = 105$) than for fish released at Seven Bays (0.0045 ± 0.0017 ; $n = 84$), despite the slow growth observed for Phalon Lake stock rainbow trout (Table 57). Phalon Lake stock rainbow trout ($n = 10$), released at Kettle Falls, showed lower mean total length growth (0.0009 ± 0.0004 mm/day) than Spokane stock rainbow trout released at Kettle Falls (0.0051 ± 0.0012 mm/day) and Seven Bays (Table 57). The mean growth in weight was also greater for fish released from Kettle Falls (0.0183 ± 0.0126 g/day) than for fish released at Seven Bays (0.0165 ± 0.0158 g/day; Table 57). Phalon Lake fish were not weighed upon recapture to avoid any additional stress placed on the fish, before release back into the fishery.

Table 55. The number (n) and percent (%) of the tag recoveries from rainbow trout in 1999 by release year.

Year of Release	n	%
1996	6	2
1997	1	<1
1998	220	71
1999	82	27
Totals	309	100

Table 56. Number (n) and percent (%) of rainbow trout tag recoveries by release location and tag recovery location in Lake Roosevelt (FDR), WA (1999).

Tag Recovery Location	Release Location							
	Kettle Falls				Seven Bays		Total	
	Phalon Lake stock		Spokane stock		Spokane stock			
	n	%	n	%	n	%	n	%
Kettle Falls	19	73	7	27	0	0	26	8
Gifford	0	0	2	1	0	0	2	1
Hunters	0	0	7	4	0	0	7	2
Porcupine Bay	0	0	0	0	3	2	3	1
Fort Spokane	0	0	0	0	1	1	1	0
Seven Bays	0	0	50	30	57	39	107	35
Keller Ferry	0	0	18	11	32	22	50	16
Sanpoil River	0	0	2	1	1	1	3	1
Spring Canyon	0	0	19	12	24	17	43	14
Unknown FDR	0	0	14	9	11	8	25	8
Below GCD ¹	0	0	26	16	16	11	42	14
Totals	19		145		145		309	

¹ GCD=Grand Coulee Dam

Table 57. The mean total length growth (mm/day), mean weight growth (g/day) and mean number of days in the fishery ($\pm$ standard deviation) between date of release and date of capture, by release location and stock of recaptured rainbow trout in Lake Roosevelt, WA (1999).

Location and Stock	Growth (TL)		Growth (wt)		Days in Fishery	
Kettle Falls						
Spokane stock	0.0051	0.0012	0.0183	0.0126	321.4	84.4
Phalon Lake stock	0.0009	0.0004	-		65.7	22.7
Kettle Falls Totals	0.0047	0.0017	-		275.6	139.2
Seven Bays						
Spokane stock	0.0045	0.0017	0.0165	0.0158	310.8	186.3
Grand Totals	0.0046	0.0017	0.0175	0.0141	292.1	163.7

Creel Surveys

Total annual pressure (10 months) was estimated to be 1,038,104 ($\pm$ 47,581 95 %C.I.) angler hours (Table 58). The highest estimated fishing pressure occurred in the middle section (562,874 $\pm$ 23,558 95 % C.I.) (Hawk Creek to Hunters including the Spokane River Arm), followed by the lower section (Grand Coulee Dam to Keller Ferry including the Sanpoil River Arm), and the lowest occurred in the upper section 119,002 ($\pm$ 1,629 95 %C.I.) (Gifford to Evans). Pressure estimates and all calculations made were summarized in Appendix B.

Estimates from annual mean trip length and pressure indicated that anglers averaged 4.5 hours per trip and made 230,513 fishing trips to Lake Roosevelt during the study period (Table 59). An estimated 81,517 trips were made in the lower section, 135,632 in the middle section and 23,753 in the upper section (Table 59). Reservoir wide, the greatest number of trips were made in June in the middle section (50,103 angler trips).

Six species of fish were captured and harvested as recorded by creel at Lake Roosevelt in 1999, kokanee salmon, rainbow trout, walleye, smallmouth bass, yellow perch, and chinook salmon with an estimated annual harvest of 389,164 ($\pm 95\%$ CI 16,546) fish and a total catch of 603,685 ($\pm 95\%$ CI 29,085) fish (Table 60, Table 61, Table 62, Table 63). Rainbow trout and walleye were the most abundant fish harvested and captured, with the greatest number of rainbow trout harvested in the lower section ($129,272 \pm 7,126$) and the greatest number of walleye harvested in the middle section ($125,586 \pm 4,055$; Table 62). Walleye were the most abundant fish captured in the upper section ($57,749 \pm 1,529$; Table 63). Harvest and catch were similar for all species except smallmouth bass. No smallmouth bass were harvested in the lower section, however an estimated 124,033 ($\pm 8,468$) were captured. Monthly harvest and catch for each species were summarized in Appendix B.

Reservoir wide, 935 fish were measured for total length. Rainbow trout averaged 362 mm and 716 g, and decreased mean size from the upper to lower sections (370, 368, and 360 mm TL respectively). Walleye averaged 266 mm and 422 g reservoir wide and decreased with size from the upper to lower sections (373, 366, and 270 mm TL respectively). Only two kokanee were observed during the creel survey, of which one was of wild origin captured in the lower section (420 mm and 1,200 g), and one in the middle section of hatchery origin (295 mm and 325 g; Table 64). Release location of hatchery kokanee could not be determined because it did not have a coded wire tag.

The majority of the 330 anglers that responded to the question of satisfaction with their angling trip were satisfied (58.18 %), compared to unsatisfied (41.82 %). Seasonally, anglers were unsatisfied in the winter (59.46 %), and satisfied during the spring (76.23 %), summer (63.04 %), and fall (58.18 %; Table 65).

Of the 1,140 anglers that answered the question regarding target species, 74.56 % were targeting rainbow trout (Table 66). Seasonally, anglers targeted rainbow trout during the winter (92.3 %), spring (86.3 %), and fall (56.6 %), switching to walleye during the summer (57.8 %; Table 66).

Anglers from different counties utilized each section of the reservoir. All anglers interviewed in the upper section resided in either Stevens (81.35 %) or Spokane Counties (15.08 %). Anglers were interviewed from 11 different counties in the middle section; primarily Spokane (48.03 %), Stevens (26.25 %), and Lincoln (13.65 %) Counties. The lower section had the most diverse use. Anglers interviewed resided in 24 different counties; primarily Grant (41.72 %), Okanogan (19.22 %), and Ferry (13.90 %) Counties. Twelve counties from the western side of the state were combined to form the Westside category, which accounted for 13.90 % of the anglers (Table 67). Based on an estimate of 230,513 angler trips to Lake Roosevelt, at \$26.55 per trip, the estimated economic value of the Lake Roosevelt fishery in 1999 was \$6,120,120 in 1999.

Table 58. Total monthly angler pressure estimates in hours ($\pm$ 95% confidence intervals), by creel section on Lake Roosevelt, WA from December 1998 through October 1999.

Month	Section			Total
	Upper (1)	Middle (2)	Lower (3)	
December	2,559 $\pm$ 111	11,036 $\pm$ 1,288	1,889 $\pm$ 282	15,484 $\pm$ 1,681
January	2,163 $\pm$ 185	28,404 $\pm$ 2,893	5,598 $\pm$ 816	36,165 $\pm$ 3,894
February	1,813 $\pm$ 94	20,802 $\pm$ 1,538	7,279 $\pm$ 749	29,894 $\pm$ 2,381
March	2,851 $\pm$ 116	15,478 $\pm$ 1,447	11,887 $\pm$ 1,362	30,216 $\pm$ 2,925
April	x	x	x	x
May	541 $\pm$ 0	2,490 $\pm$ 182	9,029 $\pm$ 1,090	12,060 $\pm$ 1,272
June	51,543 $\pm$ 1,316	215,944 $\pm$ 7,028	35,587 $\pm$ 2,560	303,074 $\pm$ 10,904
July	17,928 $\pm$ 561	29,358 $\pm$ 1,028	96,107 $\pm$ 6,638	143,393 $\pm$ 8,227
August	27,828 $\pm$ 651	36,935 $\pm$ 719	127,439 $\pm$ 8,637	192,202 $\pm$ 10,007
September	11,775 $\pm$ 339	102,267 $\pm$ 2,854	54,209 $\pm$ 191	168,251 $\pm$ 3,384
October	x	100,162 $\pm$ 4,580	7,204 $\pm$ 69	107,366 $\pm$ 4,649
Total	119,002 $\pm$ 1,629	562,874 $\pm$ 23,558	356,228 $\pm$ 22,394	1,038,104 $\pm$ 47,581

An x denotes no creel surveys performed

Table 59. Angler trip estimates by section based on angler hours (pressure estimates) and average trip length (hrs) for Lake Roosevelt, WA from December 1998 through October 1999.

Month	Section	Mean Trip Length	Angler hours	No. Angler Trips
December	Upper (1)	4.54	2,559	564
	Middle (2)	4.10	11,036	2,692
	Lower (3)	4.95	1,889	382
January	Upper (1)	4.22	2,163	513
	Middle (2)	4.33	28,404	6,560
	Lower (3)	4.12	5,598	1,359
February	Upper (1)	5.49	1,813	330
	Middle (2)	3.82	20,802	5,446
	Lower (3)	4.25	7,279	1,713
March	Upper (1)	6.07	2,851	470
	Middle (2)	3.42	15,478	4,526
	Lower (3)	4.71	11,887	2,524
May	Upper (1)	4.86	541	111
	Middle (2)	4.16	2,490	599
	Lower (3)	4.60	9,029	1,963
June	Upper (1)	5.34	51,543	9,652
	Middle (2)	4.31	215,944	50,103
	Lower (3)	3.84	35,587	9,267
July	Upper (1)	4.89	17,928	3,666
	Middle (2)	4.83	29,358	6,078
	Lower (3)	4.57	96,107	21,030
August	Upper (1)	4.94	27,828	5,633
	Middle (2)	4.16	36,935	8,879
	Lower (3)	4.79	127,439	26,605
September	Upper (1)	4.79	11,775	2,458
	Middle (2)	4.83	102,267	21,173
	Lower (3)	3.83	54,209	14,154
October	Upper (1)	x	x	x
	Middle (2)	3.77	100,162	1,911
	Lower (3)	4.07	7,204	29,239
Section	Upper (1)	5.01	119,002	23,753
Totals	Middle (2)	4.15	562,874	135,632
	Lower (3)	4.37	356,228	81,517
Annual Estimates		4.50	1,038,104	230,513

An x denotes no creel survey performed

Table 60. Harvest per unit effort (HPUE) by species and section from December 1998 through October 1999 at Lake Roosevelt, WA. HPUE reflects the number of fish kept per angler hour.

Species	Upper	Middle	Lower	Total
Kokanee salmon	0.000	0.001	0.001	0.002
Rainbow trout	0.026	0.130	0.361	0.517
Walleye	0.300	0.112	0.021	0.433
Smallmouth bass	0.001	0.001	0.000	0.002
Yellow perch	0.002	0.000	0.000	0.002
Chinook salmon	0.001	0.000	0.000	0.001
Annual HPUE	0.329	0.244	0.383	0.956

Table 61. Catch-per-unit-effort (CPUE) by species and section from December 1998 through October 1999 at Lake Roosevelt, WA. CPUE reflects the number of fish kept and released per angler hour.

Species	Upper	Middle	Lower	Total
Kokanee salmon	0.000	0.001	0.001	0.002
Rainbow trout	0.026	0.133	0.370	0.529
Walleye	0.466	0.116	0.027	0.609
Smallmouth bass	0.002	0.002	0.132	0.136
Yellow perch	0.004	0.000	0.003	0.007
Chinook salmon	0.003	0.000	0.000	0.003
Annual CPUE	0.498	0.252	0.533	1.283

Table 62. Number of fish observed during creel surveys (n) and estimated number of fish harvested ($\pm$ 95% confidence intervals) at Lake Roosevelt, WA from December 1998 through October 1999.

Species	n	Upper	n	Middle	n	Lower	n	Total
Kokanee salmon	0	0 $\pm$ 0	1	1,683 $\pm$ 48	1	47 $\pm$ 7	2	1,730 $\pm$ 55
Rainbow trout	29	2,037 $\pm$ 62	92	65,806 $\pm$ 3,317	387	129,272 $\pm$ 7,126	508	197,115 $\pm$ 10,505
Walleye	340	57,749 $\pm$ 1,529	79	125,586 $\pm$ 4,055	23	4,955 $\pm$ 356	442	188,290 $\pm$ 5,940
Smallmouth bass	1	13 $\pm$ 1	1	1,583 $\pm$ 52	0	0 $\pm$ 0	2	1,596 $\pm$ 53
Yellow perch	1	334 $\pm$ 9	0	0 $\pm$ 0	0	0 $\pm$ 0	1	334 $\pm$ 9
Chinook salmon	1	99 $\pm$ 3	0	0 $\pm$ 0	0	0 $\pm$ 0	1	99 $\pm$ 3
Annual	372	60,232 $\pm$ 1,603	173	194,658 $\pm$ 7,472	411	134,274 $\pm$ 7,489	956	389,164 $\pm$ 16,564

Table 63. Number of fish captured (n) and estimated number of fish captured (harvested and released) ($\pm$ 95% confidence intervals) for Lake Roosevelt, WA from December 1998 through October 1999.

Species	n	Upper	n	Middle	n	Lower	n	Total
Kokanee salmon	0	0 $\pm$ 0	1	1,683 $\pm$ 48	1	47 $\pm$ 7	2	1,730 $\pm$ 55
Rainbow trout	29	2,037 $\pm$ 62	94	73,535 $\pm$ 3,671	396	156,447 $\pm$ 9,003	519	232,019 $\pm$ 12,736
Walleye	528	99,420 $\pm$ 2,630	82	130,335 $\pm$ 4,210	29	6,983 $\pm$ 507	639	236,738 $\pm$ 7,347
Smallmouth bass	2	112 $\pm$ 3	2	3,166 $\pm$ 103	141	124,033 $\pm$ 8,468	145	127,311 $\pm$ 8,574
Yellow perch	3	533 $\pm$ 14	0	0 $\pm$ 0	3	5,255 $\pm$ 356	6	5,788 $\pm$ 370
Chinook salmon	1	99 $\pm$ 3	0	0 $\pm$ 0	0	0 $\pm$ 0	1	99 $\pm$ 3
Annual	563	102,201 $\pm$ 2,712	179	194,658 $\pm$ 8,032	570	134,274 $\pm$ 18,341	1,312	603,685 $\pm$ 29,085

Table 64. Mean length (mm) and weight (grams) and standard deviation (SD) of fish captured in each section of Lake Roosevelt, WA (1999).

Species	n	Mean TL (SD)	n	Mean Wt (SD)
Upper Section (1)				
Chinook salmon	1	559 (0)	1	1,814 (0)
Rainbow trout	28	370 (318)	20	556 (318)
Smallmouth bass	1	400 (0)	1	1,220 (0)
Walleye	332	373 (134)	331	408 (134)
Yellow perch	1	252 (0)	1	174 (0)
Total (1)	363	373 (180)	354	422 (176)
Middle Section (2)				
Kokanee salmon	1	295 (0)	1	325 (0)
Rainbow trout	92	368 (139)	92	669 (139)
Smallmouth bass	1	235 (0)	1	325 (0)
Walleye	67	366 (465)	37	543 (465)
Total (2)	161	366 (279)	131	628 (279)
Lower Section (3)				
Kokanee salmon	1	420 (0)	1	1,200 (0)
Rainbow trout	387	360 (262)	328	739 (262)
Walleye	23	270 (29)	0	0 (0)
Total (3)	411	355 (263)	329	741 (263)
Reservoir				
Chinook salmon	1	559 (0)	1	1,814 (0)
Kokanee salmon	2	358 (619)	2	763 (619)
Rainbow trout	507	362 (248)	440	716 (248)
Smallmouth bass	2	318 (632)	2	773 (623)
Walleye	422	366 (198)	368	422 (198)
Yellow perch	1	252 (0)	1	174 (0)
Grand Total	935	364 (275)	814	584 (275)

Table 65. Percent of anglers unsatisfied and satisfied with their fishing trip by quarter and per section at Lake Roosevelt, WA (1999).

Quarter	Section	Anglers interviewed	% Unsatisfied	% Satisfied
Winter	Upper (1)	64	64.06	35.94
	Middle (2)	24	75.00	25.00
	Lower (3)	23	30.43	69.57
Winter total		111	59.46	40.54
Spring	Upper (1)	33	42.42	57.58
	Middle (2)	6	66.67	33.33
	Lower (3)	11	63.64	36.36
Spring total		50	50.00	50.00
Summer	Upper (1)	69	11.59	88.41
	Middle (2)	23	17.39	82.61
	Lower (3)	30	56.67	43.33
Summer total		122	23.77	76.23
Fall	Upper (1)	22	54.55	45.45
	Middle (2)	12	8.33	91.67
	Lower (3)	12	33.33	66.67
Fall total		46	36.96	63.04
Grand Total		330	41.52	58.18

Table 66. Percent of anglers targeting various fish species by quarter and section at Lake Roosevelt, WA (1999).

Quarter	Section	Number interviewed	Kokanee	Rainbow trout	Walleye	Chinook	Any
Winter	Upper (1)	126	0.0	93.7	6.4	0.0	0.0
	Middle (2)	205	0.0	96.1	3.9	0.0	0.0
	Lower (3)	163	13.5	86.5	0.0	0.0	0.0
Winter Total		494	4.5	92.3	3.2	0.0	0.0
Spring	Upper (1)	38	0.0	15.8	84.2	0.0	0.0
	Middle (2)	50	0.0	86.0	10.0	0.0	4.0
	Lower (3)	196	0.0	100.0	0.0	0.0	0.0
Spring Total		284	0.0	86.3	13.0	0.0	0.7
Summer	Upper (1)	69	0.0	1.5	97.1	0.0	1.5
	Middle (2)	93	0.0	6.5	91.4	0.0	2.2
	Lower (3)	101	0.0	85.2	0.0	0.0	14.9
Summer Total		263	0.0	35.4	57.8	0.0	6.8
Fall	Upper (1)	22	0.0	9.1	90.9	0.0	0.0
	Middle (2)	45	4.4	57.8	8.9	15.6	13.3
	Lower (3)	32	0.0	87.5	0.0	0.0	12.5
Fall Total		99	2.0	56.6	24.2	7.1	10.1
Grand Total		1,140	2.1	74.6	20.1	0.6	2.6

Table 67. Origin of residence, number, and percent of anglers utilizing the fishery per section at Lake Roosevelt, WA (1999).

County or State	# of anglers interviewed	Percent	County or State	# of anglers interviewed	Percent
Upper (1)			Lower (3)		
Spokane	38	15.08	Adams	2	0.41
Stevens	205	81.35	Benton	8	1.64
Washington	6	2.38	Chelan	12	2.45
Idaho	2	0.79	Ferry	26	5.32
California	1	0.40	Franklin	2	0.41
	252		Grant	204	41.72
			Lincoln	13	2.66
Middle (2)			Okanogan	94	19.22
Adams	1	0.26	Spokane	23	4.70
Ferry	9	2.36	Stevens	7	1.43
Grant	1	0.26	Whitman	3	0.61
King	14	3.67	Yakima	7	1.43
Lincoln	52	13.65	West side ¹	68	13.90
Pend Oreille	4	1.05	Washington	7	1.43
Snohomish	8	2.10	Alabama	1	0.20
Spokane	183	48.03	Alaska	2	0.41
Stevens	100	26.25	California	3	0.61
Whitman	1	0.26	Hawaii	1	0.20
Yakima	5	1.31	Texas	4	0.82
Idaho	1	0.26	British Columbia	2	0.41
Montana	1	0.26		489	
Oregon	1	0.26			
	381				

¹ Westside = 12 counties from the western side of Washington state: Clallam, Clark, Cowlitz, King, Kittitas, Lewis, Pacific, Pierce, Skagit, Snohomish, Thurston, and Whatcom.

Discussion

Limnology

With an impoundment the size of Lake Roosevelt, a large degree of spatial variation can be expected. The reservoir that was once the Columbia River now functions somewhere between a large river and lake. In many reservoirs there is a gradient of conditions moving longitudinally from one end to the other (Kimmel et al. 1990). The gradient of conditions within Lake Roosevelt are largely dominated by the hydrology of the reservoir. The way in which water moves through the reservoir can significantly affect the biota contained therein.

One such example was the direct relationship observed between inflow and phytoplankton density (Figure 35; $r^2=0.657$; $p<0.0001$). Wierenga et al. (1998) suggested that primary production in Lake Roosevelt was “heavily” influenced by inflow. The connection between inflow and phytoplankton density likely lies in the nutrient trapping nature of reservoirs.

Figure 35. Mean phytoplankton density (organisms/ μ L) regressed upon mean inflow (kcfs). Phytoplankton means are from sampling rounds in 1999 across all sampling locations while mean inflow to Grand Coulee Dam was from the 30 day mean prior to the sampling round.

As the transport potential (flow) of water is reduced, particulates associated with nutrients sediment out of the water column. Of particular interest is phosphorus, because frequently in nutrient poor freshwater systems phosphorus, is limiting to primary production (Wetzel 1983).

Nitrogen and phosphorus ratios currently indicate that phosphorus is likely the limiting agent, especially in the summer (mean TN:TP was 36 in 1999). Additionally, since TN was underestimated, ratios must be greater, indicating even stronger phosphorus limitation. Wilson et al. (1996) found that N and P ratios in Lake Roosevelt were frequently above 20 in 1994 and 1995. They also observed higher ratios (>100) in August of 1994. The increased ratios suggest that water column P is depleted by primary producers and not replenished because inflows are reduced in the summer. Interestingly, nitrogen and phosphorus ratios indicated borderline N limitations in the early 1980's, due to P loading from a fertilizer plant's (Cominco) effluent (RAASC 1999). After this P loading was reduced in the early 1990's, N and P ratios have risen (Wilson et al. 1996). Since P is limiting primary production in Lake Roosevelt, knowledge of P behavior in the system is important. In the current study, total phosphorus was found to have a significant inverse relationship with water residence time (Figure 36; $r^2=0.869$). Biggs and Close (1989) found that total P, dissolved reactive P, total Kjeldahl N, and N as NH_4^+ had significant positive correlations with increased flow in several New Zealand rivers.

Trophic status in Lake Roosevelt has shifted in the direction of oligotrophy since the 1980's, following the decline in water column phosphorus (Wilson et al 1996, RAASC 1999, Shields et al. 2002). "Oligotrophication" has only recently been recognized as an issue in some reservoirs. Of particular interest is its potential to reduce fishery carrying capacity (Stockner et al. 2000). Carlson's trophic state index (TSI), calculated from phytoplankton chlorophyll *a*, Secchi disk, and total phosphorus, was > 45 in the 1980's, and by 1995 was < 40 (Wilson et al. 1996). In the current study, TSI calculated from the same parameters was, on average, 34, which places Lake Roosevelt in the meso-oligotrophic range. In 1999, TSI values were highest in the upper reservoir and Spokane Arm as a result of lower Secchi depths during the spring. Higher TSI values during the spring are not necessarily the result of increased phytoplankton production but are likely more related to increased suspended solids loads

accompanying runoff. However, phytoplankton primary productivity has been found to be significantly greater at upper reservoir sites and in the Spokane Arm (Wilson et al. 1996 and Wierenga 1998). Phytoplankton primary productivity was likely higher because more phosphorus adhering to suspended solids was available in upper reservoir and Spokane Arm.

Figure 36. Mean total phosphorus (mg/L) regressed upon mean water retention time (days). Mean total phosphorus calculated from sampling rounds in 1999 across all sampling locations on Lake Roosevelt, WA and mean water retention time from 30 day mean prior to sampling round.

Phytoplankton provide sustenance for zooplankton in Lake Roosevelt. A distinct drop in phytoplankton density occurs while zooplankton densities rise (Figure 37). A reduction in phytoplankton production due to Lake Roosevelt's meso-oligotrophic status could reduce the transfer of energy into higher trophic levels (i.e. zooplankton and zooplanktivores). Rensel and associated (RAASC 1999) stated that if nutrient reductions, and the subsequent trophic status shift, could affect zooplankton and the sport fishery, it would only have been noticed recently. They suggested that the effects of food limitation and competition might be seen in decreasing zooplankton lengths. A comparison of zooplankton lengths over multiple years has not been done yet.

Figure 37. Mean zooplankton biomass and mean phytoplankton density by round across all pelagic sampling locations on Lake Roosevelt, WA (1999).

Considering the reduction of nutrients in the water column, and subsequent shifts towards oligotrophy, the condition of the reservoir's littoral zone should be emphasized. Commonly, these near shore zones provide nursery areas for young fish and are more productive than open waters. Even in Lake Roosevelt where the reservoir elevation was below the mean 42 % of the year in 1999, the littoral TSI values were significantly higher than those in open water. The difference observed between littoral and pelagic TSI should be interpreted with caution. Since, the littoral TSI did not include phosphorus values and only included chlorophyll *a* values from one location (Hawk Creek). The Hawk Creek location is a protected embayment and conditions there are likely different than other littoral areas across the reservoir that are less sheltered. With that being stated, littoral with some degree of protection potentially created conditions conducive to increased primary and secondary production.

In the Colorado River below Glenn Canyon dam where elevation fluctuations are common, embayment/littoral areas had significantly higher numbers of zooplankton (Blinn and Cole 1991). Fluctuations in the Colorado River below Glenn Canyon dam have been found to have negative affects on littoral biota. Angradi and Kubly (1993) observed that after 2 weeks

of exposure, 84 % of attached algae chlorophyll *a* was lost. The implication is a significant reduction in primary production that can reduce habitat and food sources for other littoral organisms. McKinney et al. (1999) observed similar responses in littoral attached algae (75 % loss dry weight) and littoral macroinvertebrates (90 % loss of *Gammarus lacustris* and 72 % loss of chironomid by dry weight) in the Colorado River below Glenn Canyon Dam following three days of exposure.

If the degree of littoral exposure could be limited, the benefit to near shore production and habitat could be considerable. Beckman et al. (1985) suggested the potential benefits of minimizing reservoir fluctuations in Lake Roosevelt.

“In order to change the trophic conditions in Lake Roosevelt from a system driven primarily by nutrients washed into the reservoir from the watershed to one driven by watershed nutrients supplemented by nutrients generated from littoral production, it would be necessary to establish a perennial belt of vegetation around the perimeter of the reservoir” (Beckman et al. 1985).

To do this, reservoir fluctuations would need to be reduced to such a degree that allows for the establishment of some aquatic macrophytes. Aquatic macrophytes provide multi-dimensional habitat to littoral organisms. It has been estimated that submerged aquatic macrophytes can create 10 times the surface area of unvegetated benthic sediments (Horne and Goldman 1994).

Burks et al. (2001) found that zooplankton, in the presence of zooplanktivores, used littoral macrophytes as shelter from predation. Qualitatively, macrophytes have been observed in some embayment habitats of Lake Roosevelt. It is unknown if zooplankton use those areas as refugia. However, zooplankton biomass and densities were sampled in pelagic and shore areas of Lake Roosevelt and results indicated that zooplankton biomass and densities were frequently greater in the near shore areas compared to pelagic areas. This was true for all major taxonomic groups. Pelagic zone zooplankton data was pooled from 17 m and 33 m tows. Differences between 17 m and 33 m pelagic zone zooplankton densities and biomass were insignificant (Fisher's PLSD, $p > 0.05$). On the Rocky Reach reservoir (of the middle Columbia River), zooplankton in the littoral area had significantly higher biomass during

July 2000. However, during other times of the year zooplankton biomass was less in the littoral zone (CCPUD 2001). In the Snake River, another impounded river of the Pacific Northwest, Copepods were found in significantly higher concentrations in littoral areas compared to mid channel (Dragoy 1998).

The movement of zooplankton to littoral areas is not well understood and is contrary to some past literature, but has recently been documented (Burks et al. 2001, 2002). It is typically thought that zooplankters are pelagic organisms and avoid near shore areas because of increased predation (Wetzel 1983). Near shore areas sampled in this study were not entirely “littoral” however. The mean depth from all near shore tows was 17.2 m. Conditions at these shore sampling locations could likely favor increased zooplankton densities and biomass. The annual mean photic zone at these shore locations was 10.5 m, well above the mean tow depth (17.2 m). Since sampling took place during day light hrs zooplankton potentially could have been holding in the darker waters below the photic zone. This is a common behavioral trait in zooplankton to avoid visual predators during daylight hours (Wetzel 1983). However, Beckman et al. (1985) found no significant diel vertical migration in Lake Roosevelt zooplankton. If it is advantageous for zooplankton to migrate to darker depths to avoid predation, it may be possible in these areas. Yet, the water column at all locations is relatively unstable (well mixed) so this may be unlikely.

Another potential benefit to zooplankton inhabiting these near shore areas is a reduced rate of predation. In littoral areas of Lake Roosevelt (1999) zooplanktivores (mainly small and young fish) are in reduced numbers as evident from boat electrofishing and beach seining surveys. Catch per unit effort of native minnows caught by boat electrofishing in littoral areas of Lake Roosevelt was low in 1999 (CPUE 0-0.2; Table 69). Out of 43 beach seine hauls in July and October (1999) only 191 fish (5-72 mm size range) were caught (Table 39). Walleye a top predator, sampled by boat electrofishing had the highest relative abundance in Lake Roosevelt during 1999 (Annual RA% 24.9; Table 36). Walleye in lakes, rivers, and reservoirs have been found to significantly alter prey fish numbers and assemblage (Lyons and Magnuson 1987; McMahon and Bennett 1996). The main prey item of walleye is fish with a subsequent Ri_a value of 52.8 % in Lake Roosevelt during 1999 (Table 53). Young zooplanktivorous fish in near shore areas are likely being heavily preyed upon since the

quality and amount of littoral habitat is limited. Diel horizontal migration to littoral areas by zooplankton has been related to reduced zooplanktivory, as well as increased aquatic macrophytes (Burk et al 2001, 2002).

Coupled with reduced zooplanktivores in near shore areas, resource availability may also support the higher zooplankton densities and biomass observed there. As discussed previously, trophic status in the littoral sampling areas is elevated above that of the open waters. Trophic status in the littoral areas was higher because of phytoplankton chlorophyll *a* at Hawk Creek and Secchi depths across the reservoir. Phytoplankton chlorophyll *a* and Secchi depth serve as surrogates to phytoplankton biomass and nutrients. Increased phytoplankton, biomass due in part to increased nutrients, would be available to zooplankton, potentially increasing biomass and density in littoral areas. In a comparative study of the Colorado River below Glen Canyon dam, zooplankton in backwater and littoral areas were found in densities four times that of the main channel (Blinn and Cole 1991).

In littoral areas assimilation of these resources could be accelerated because temperatures are greater than in pelagic areas. Zooplankton physiology is closely related to ambient temperatures. Cooper and Black (1998) observed a significant positive correlation with zooplankton and temperature in Lake Roosevelt. Mean annual temperature at shore sampling locations was 14.0 °C, while the mean at pelagic locations was 12.2 °C in 1999. Within pelagic sampling areas there was a strong, positive relationship with temperature and transformed (natural logarithm) zooplankton biomass ($r^2=0.948$; Figure 38).

Temperature means were calculated from measurements taken at Grand Coulee Dam forebay over the thirty-day period prior to the zooplankton sampling round. Using temperature from the forebay was reasonable because the highest zooplankton biomass and densities were observed at the lower portion of the reservoir (Figure 25; Figure 20). This accumulation of zooplankton closer to Grand Coulee Dam was consistent with previous work on Lake Roosevelt (Shields et al. 2002). Zooplankton were also found in higher densities and biomass in the Spokane and Sanpoil arms during this study and previous studies (Wilson et al. 1996 and Beckman et al. 1985). The higher zooplankton numbers at these locations is likely related to temperatures as well, since the annual means at Porcupine Bay (13.6 °C) and Sanpoil River (13.2 °C) were higher than the Columbia River mainstem mean (12.9 °C).

Figure 38. Mean ln zooplankton biomass ($\mu\text{g}/\text{m}^3$) regressed upon mean water temperature ($^{\circ}\text{C}$) taken at Grand Coulee forebay 30 days prior to day of sampling. Mean zooplankton biomass calculated from sampling rounds in 1999 across all sampling locations.

Beginning in 1991, reservoir mean zooplankton biomass was calculated as an average of biomass values observed at five index locations (Gifford, Porcupine Bay, Seven Bays, Keller Ferry, and Spring Canyon). Biomass estimates were only computed for *Daphnia* spp. prior to 1997; therefore, between year comparisons of zooplankton biomass were only made for this group. Mean *Daphnia* biomass in 1999 was 2.5 times greater than the mean biomass in 1998 (Table 68). However, this was still considerably lower than previous years.

Zooplankton sampling gear was changed in 1997. It was switched from a horizontal sampler (Clark-Bumpus) to a vertical sampler (Wisconsin net). Comparability between previous years may need to be reassessed.

Table 68. Mean *Daphnia* spp. biomass ($\mu\text{g}/\text{m}^3$) collected from five index locations in Lake Roosevelt, WA (1991-1999).

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Jan	12.80	1,168.00		55,075.00	2,050.00		1,435.20	97.00	172.15
Feb		121.60	518.20	1,350.00	1,985.00		68.00	28.60	10.55
Mar		327.90	61.00	1,625.00	346.70	10.00	58.60	16.20	0.28
Apr	23.40	35.10	56.00	2,950.00	157.50	40.00	200.30		19.33
May	20.50	146.00	2,655.40	475.00	437.50	55.00	58.30	612.40	27.97
Jun	58.00	1,497.10	26,063.30	22,875.00	47,787.50	1,335.00	180.20	1,228.40	413.69
Jul	3,108.00	1,704.40	13,060.70	35,725.00	31,800.00	66,010.00	7,662.80	9,064.70	2,976.50
Aug	3,843.20	7,100.00	81,122.90	147,200.00	71,825.00	39,775.00	60,937.00	3,877.30	7,435.80
Sep	3,467.30	1,830.60	27,992.90	15,400.00	78,425.00	37,150.00	9,244.90	2,753.80	9,936.66
Oct	5,755.50	2,062.22	7,938.50	13,925.00	15,675.00	64,566.70	5,763.80	1,940.80	8,876.03
Nov	7,633.50	2,158.03	6,906.40			11,600.00		1,521.70	4,584.47
Dec	2,066.40		9,907.00			50,035.00	3,763.70	2,504.70	2,704.41
Annual Mean	2,598.90	1,650.10	16,025.60	29,660.00	25,048.90	27,057.70	8,124.80	1,464.30	3,740.95

Fishery

Fisheries Surveys

Electrofishing, gill net, and beach seine surveys were performed to account for the different biases that each gear type possesses and allow for sampling that is more representative of the fish community (Bowen 1996). Electrofishing effort has varied substantially (13.88-118 hours) since 1993 (Table 69). Methodologies of electrofishing and gill net surveys have also been inconsistent since 1993. From 1993 to 1995, surface and benthic horizontal gill sets were used (Underwood and Shields 1996; Underwood et al. 1996a, 1996b). In 1996, vertical gill net sets were added to the sampling regime along with surface and benthic set horizontal gill nets (Cichosz et al. 1997). From 1997 to 1998, surface set horizontal gill nets were eliminated from the sampling techniques, while benthic horizontal gill net and vertical gill net sets were maintained (Cichosz et al. 1999, Spotts et al. 2002). These changes in the sampling strategies may have contributed to the differences observed in CPUE and relative abundance values observed in 1999, when compared to previous years.

Catch-per-unit-effort varied widely from 1993 to 1999 in both electrofishing (2.6-161.6 fish/hr) and gill net (0.008-1.78 fish/hr) surveys (Table 69 and Table 70). Electrofishing CPUE was lowest in 1993 (2.63 fish/hr) and 1994 (3.85 fish/hr), then increased and remained relatively high over the next four years (76.39-161.6 fish/hr), peaking in 1998 (161.6 fish/hr), before decreasing in 1999 to the lowest value in five years (26.86 fish/hr; Table 69). CPUE from electrofishing (26.86 fish/hr) was relatively low in 1999 compared to CPUE from electrofishing (161.6 fish/hr) in 1998 (Table 69). Largescale suckers had the highest electrofishing CPUE from 1996 to 1998, however walleye (6.68 fish/hr) had the highest CPUE in electrofishing surveys in 1999 (Table 69). Walleye (1.20-59.21 fish/hr) and largescale sucker (0.26-55.01 fish/hr) CPUE has been variable over the past ten years and may reflect collection efforts during the spring spawning, when the two species are congregated in high densities in the Spokane Arm of Lake Roosevelt.

Horizontal and vertical gill net surveys in 1999 were combined to allow for comparisons with previous years. Gill net CPUE was lowest in 1993, corresponding to the lowest effort exerted, and may not be representative of the fishery as a whole (Table 70). Gill net CPUE was highest in 1996 (1.78 fish/hr), but decreased more than four fold during the next three years (0.26-0.37

fish/hr; Table 70). Gill net CPUE in 1999 (0.26 fish/hr) decreased more than 25% from 1997 (0.35 fish/hr) and 1998 (0.37 fish/hr). Lake whitefish followed by walleye have exhibited the highest CPUE in gill net surveys since 1995 (Table 70).

Relative abundance of fish species collected in Lake Roosevelt from electrofishing and gill net surveys have experienced some notable changes since 1989 (Table 71 and 71). Forage species in Lake Roosevelt have been low in relative abundance since 1989, with the exception of yellow perch and largescale suckers. Yellow perch dominated the catch composition of electrofishing surveys in 1989 and 1990 but have shown a steady decline since. The inclusion of young-of-year (YOY) fish in boat electrofishing relative abundance calculations during earlier years inflated abundance values of yellow perch and, in turn, reduced the relative abundance of other species (Table 71). Largescale sucker were the most abundant species in electrofishing surveys from 1991 until 1997, after which numbers reduced by nearly half (Table 71).

Salmonid abundance from electrofishing surveys were relatively stable from 1989 to 1997, but showed an increase in 1998 and 1999. Kokanee salmon and rainbow trout, species that are augmented by the artificial production program, have shown the largest increases in electrofishing relative abundance of salmonids. Rainbow trout abundance exhibited an increase of 9 % in 1999 electrofishing surveys, accounting for the highest percent relative abundance (21 %) since 1989 (Table 71). Kokanee salmon relative abundance (11 %) from electrofishing surveys increased 3 % from 1998 and was second highest in the ten years of record (Table 71). Other species that showed less dramatic increases in relative abundance in 1999 electrofishing surveys include brown trout, eastern brook trout, burbot, smallmouth bass, and longnose sucker (Table 71). Walleye have been abundant (7-34 %) in electrofishing surveys since 1989 and became the most abundant species in 1998 and 1999, although a decrease of nearly 25 % was noted in 1999 compared with the previous year (Table 71). Gas bubble disease was observed in high numbers of largescale suckers in 1997 and may have caused increased mortality resulting in their lower relative abundance in 1998 and 1999 (A. Scholz, EWU unpublished data).

Lake whitefish (15-51 %) and walleye (15-48 %) have been the most abundant species in gill net surveys since 1989, except in 1990 when yellow perch (46 %) and lake whitefish were the most abundant (33 %; Table 72). Species that showed a decrease in relative abundance in gill net surveys conducted during 1999 include largescale sucker, rainbow trout, northern pikeminnow,

and yellow perch. Largescale sucker relative abundance has decreased in gill net surveys from 15 % as early as 1994 to less than 1 % in 1999. Species that showed an increase in gill net relative abundance from 1998 were longnose sucker, lake whitefish, kokanee salmon, mountain whitefish, burbot, black crappie, walleye, and sculpin spp. (Table 72). Longnose suckers showed a 6 % increase in gill net surveys, representing their highest percent relative abundance (11 %) since 1989 (Table 72). The increase in longnose sucker relative abundance, and corresponding decrease in largescale sucker relative abundance, may be due to the longnose sucker's preference to inhabit deeper water compared to more littoral orientated largescale suckers (Carl et al. 1967; Wydoski and Whitney 1979). Deepwater habitat may be the least affected by reservoir operations and could serve as a refuge from dissolved gases and walleye predation (MacLean and Magnuson 1977, Weitkamp 2000).

A test fishery performed in 1999 represented the first organized efforts in which angling data was collected according to a specific protocol. All of the rainbow trout collected were of hatchery origin, whereas in electrofishing and gill net surveys, 74.8 % of the rainbow trout collected appeared to be of wild origin. The lack of wild rainbow trout observed could be a result of the timing of the test fishery. Wild rainbow trout spawn in the spring, which may reduce their availability to the January fishery. In this respect, hatchery rainbow trout are a valuable component to the winter fishery in Lake Roosevelt. Unmarked (presumably wild in origin) kokanee salmon accounted for 95.1 % of the kokanee salmon caught in the test fishery. Alternately, only 25.2 % of the kokanee salmon collected in electrofishing and gill net surveys were unmarked. The higher incidence of hatchery kokanee in electrofishing and gill net surveys is a result of fall efforts at or near kokanee collection locations in fall surveys. The majority of hatchery origin kokanee that return to collection sites in Lake Roosevelt are precocious, maturing in their second year of life (McLellan et al. 2000). Because they are released to the fishery in June of their second year and spawn in the fall, many of the kokanee have completed their lifecycle and don't contribute to the winter fishery. Based on the January test fishery, hatchery rainbow trout substantially contributed to the winter fishery in Lake Roosevelt (Table 40). It appears that hatchery kokanee salmon contribute minimally to the winter fishery (Table 40), although their abundance is recognized in surveys utilizing other collection techniques, in the summer and fall (Table 41).

Walleye were introduced into Lake Roosevelt in the 1950's by the U.S. Fish and Wildlife Service (Brown and Williams 1983) and are the primary apex predator in Lake Roosevelt (Beckman et al. 1985, Baldwin et al. 1999). It is evident that walleye have played a part in shaping the fish community structure in Lake Roosevelt. The impacts of top predators on forage fish populations have been documented for many freshwater systems (Forney 1974, Hartman and Margraf 1993, Lyons and Magnuson 1987, Knight and Vondracek 1993, and Vigg et al. 1991). Fish prey depletion is common for introduced fish assemblages in reservoirs where drawdown increases prey fish vulnerability due to habitat loss (McMahon and Bennett 1996). The predation pressure exerted on prey species may multiply during years when year class strength is compromised by hydro-operations. Other than largescale suckers, native forage species have not been observed in large numbers throughout the reservoir since before 1989 and may actually represent an element of the fishery in need of protection and/or restoration.

Lake Roosevelt is a dynamic system that is greatly impacted by the hydro-operations of Grand Coulee Dam, as well as hydro-operations of upstream dams. Entrainment has been attributed to a substantial source of juvenile fish loss in reservoir habitats (Travnichak et al. 1993). Hydro-operations that included extreme drawdowns in 1997 likely resulted in high levels of entrainment of fish from Lake Roosevelt, as evidenced by tagging studies of salmonids in Lake Roosevelt (Figure 40; Table 78). Interactions between native and non-native species has added further complexity the system (ie. competition for food, habitat utilization, and predator prey interactions).

Table 69. Catch-per-unit-effort (fish/hr) of fish collected via boat electrofishing in Lake Roosevelt, WA (1993-1999).

Effort (hrs)	Catch-per-unit-effort for boat electrofishing						
	1993	1994	1995	1996	1997	1998	1999
	13.88	36.3	118	27	34.3	41.5	40.69
White sturgeon	0	0	0	0	0	0	0
Carp	0.03	0.05	1.75	2.18	8.46	2	0.1
Northern pikeminnow	0.22	0.14	1.81	2.04	2.42	1.37	0.2
Tench	0	<0.01	0	0.11	0.06	0.12	0.05
Peamouth	0	0	0	0	0.03	0.02	0
Redside shiner	0	<0.01	0.01	0	0.35	0	0
Longnose sucker	0	0.07	0.21	1.33	0.32	0.82	0.34
Bridgelip sucker	0	<0.01	0.7	2.22	0.32	0.05	0.05
Largescale sucker	1.20	1.37	22.7	45.15	59.21	44.59	6.22
Brown bullhead	<0.01	<0.01	0.05	0	0	0	0
Lake whitefish	<0.01	0.01	0.34	0.59	0.93	0.68	0.37
Rainbow trout	0.24	0.25	3.88	6.92	5.19	19.85	5.73
Kokanee salmon	0.02	0.14	17.01	4.4	1.66	12.54	2.92
Chinook salmon	<0.01	<0.01	0.02	0	0.09	0.07	0.02
Mountain whitefish	<0.01	<0.01	0.08	0.07	0.12	0.17	0.12
Brown trout	0.02	0.01	0.31	2.15	0.47	0.41	0.59
Bull trout	0	<0.01	0.01	0	0	0	0
Eastern Brook trout	<0.01	0.01	0.18	0.96	0.23	1.37	0.54
Burbot	0	0.04	0.26	3.55	4.06	3.04	0.84
Sculpin	0.07	0.63	4.73	1.04	2.07	9.82	0
Smallmouth bass	0.25	0.32	7.96	6.62	9.83	9.04	1.87
Largemouth bass	0	0	0	0	0.03	0.05	0
Black crappie	0	<0.01	0.08	0	0	0.17	0.02
Yellow perch	0.29	0.46	5.45	1.78	3.59	0.17	0.02
Walleye	0.28	0.26	8.74	20.06	13.31	55.01	6.68
Totals	2.63	3.85	76.39	99.04	113	161.6	26.86

Table 70. Catch-per-unit-effort (fish/hr) for fish collected via gill net surveys in Lake Roosevelt, WA (1993-1999).

Effort (hrs)	Catch-per-unit-effort for gill net surveys						
	1993 94.1	1994 642.92	1995 2099	1996 201.2	1997 1689.2	1998 2624.4	1999 2211.11
White sturgeon	0	0	0	0	0	< 0.01	<0.01
Carp	0	<0.01	0.03	0.02	< 0.01	< 0.01	0
Northern pikeminnow	0	<0.01	0.03	0.01	0.01	0.01	<0.01
Tench	0	0	< 0.01	0	0	< 0.01	0
Peamouth	0	0	0	0	< 0.01	0	0
Redside shiner	0	0	0	0	0	0	0
Longnose sucker	0	<0.01	0.03	0.02	0.01	0.02	0.03
Bridgelip sucker	0	0	0.05	< 0.01	< 0.01	0	0
Largescale sucker	<0.01	<0.01	0.06	0.11	0.03	0.01	<0.01
Brown bullhead	0	0	0	<0.01	0	0	0
Lake whitefish	<0.01	<0.01	0.68	0.91	0.13	0.15	0.11
Rainbow trout	< 0.01	<0.01	0.06	0.11	< 0.01	0.02	<0.01
Kokanee salmon	< 0.01	<0.01	0.07	0.08	< 0.01	< 0.01	<0.01
Chinook salmon	0	0	0	0	0	0	<0.01
Mountain whitefish	0	0	< 0.01	0	0	0	<0.01
Brown trout	0	0	< 0.01	0	< 0.01	0	0
Bull trout	0	0	0	0	0	0	0
Brook trout	0	0	0	0	0	0	0
Burbot	0.01	<0.01	0.07	0.18	0.04	0.03	0.03
Sculpin	0	0	0	0	0	0	0
Smallmouth bass	0	<0.01	0.04	0	0.01	0.04	0.01
Largemouth bass	0	0	0	0	0	0	0
Black crappie	0	<0.01	0	0	< 0.01	0	<0.01
Yellow perch	< 0.01	<0.01	0.1	0.05	0.01	0.01	<0.01
Walleye	<0.01	<0.01	0.26	0.26	0.1	0.07	0.05
Totals	<0.01	0.01	1.47	1.78	0.35	0.37	0.26

Table 71. Summary of the relative abundance (%) of fish species collected via boat electrofishing in Lake Roosevelt, WA (1989-1999).

Species	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
White sturgeon	0	0	0	0	0	0	0	0	0	0	0
Chiselmouth	0	<1	0	<1	0	0	0	0	0	0	0
Carp	2	2	<1	2	1	1	2	2	7	1	<1
Peamouth	<1	0	<1	<1	0	0	0	0	<1	<1	0
Northern pikeminnow	4	6	3	2	8	4	2	2	2	<1	<1
Redside shiner	0	<1	0	<1	0	<1	<1	0	<1	0	0
Tench	<1	<1	<1	<1	0	<1	<1	<1	<1	<1	<1
Longnose sucker	<1	2	<1	<1	0	2	<1	1	<1	<1	1
Bridgelip sucker	1	<1	<1	<1	0	<1	<1	2	<1	<1	<1
Largescale sucker	12	19	35	46	46	36	30	44	52	28	23
Unidentified sucker	7	0	0	0	0	0	<1	5	0	0	0
Bullhead	<1	<1	<1	0	<1	<1	<1	0	0	0	0
Lake whitefish	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	1
Cutthroat trout	0	0	0	0	0	0	0	<1	0	0	0
Rainbow trout	6	3	4	6	9	7	5	7	5	12	21
Kokanee salmon	2	<1	<1	3	1	4	22	4	1	8	11
Chinook salmon	<1	<1	<1	<1	<1	<1	<1	0	<1	<1	<1
Mountain whitefish	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Brown trout	<1	<1	<1	<1	1	<1	<1	2	<1	<1	2
Bull trout	<1	<1	0	0	0	<1	<1	0	0	0	0
Eastern Brook trout	<1	<1	<1	1	<1	<1	<1	1	<1	<1	2
Burbot	<1	<1	<1	<1	0	<1	<1	3	4	2	3
Sculpin spp.	2	2	<1	2	3	16	6	1	2	6	0
Pumpkinseed	<1	<1	0	0	0	2	0	0	<1	0	0
Smallmouth bass	1	3	15	7	9	8	10	6	9	6	7
Largemouth bass	<1	<1	<1	<1	0	0	0	0	<1	<1	0
Black crappie	<1	<1	<1	1	0	<1	<1	0	0	<1	<1
Yellow perch	44	48	30	20	11	12	7	2	3	<1	<1
Walleye	16	13	11	8	11	7	11	19	12	34	25

Table 72. Summary of the relative abundance (%) of fish species collected via horizontal and vertical gill netting in Lake Roosevelt, WA (1989-1999).

Species	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
White sturgeon	<1	0	0	0	0	0	0	0	0	<1	<1
Chiselmouth	0	0	0	0	0	0	0	0	0	0	0
Carp	0	1	0	0	0	1	0	1	<1	<1	0
Peamouth	<1	0	0	0	0	0	0	0	<1	0	0
Northern pikeminnow	5	4	5	3	0	2	2	<1	2	2	1
Redside shiner	0	0	0	0	0	0	0	0	0	0	0
Tench	0	0	0	0	0	0	<1	0	0	<1	0
Longnose sucker	1	2	<1	2	0	1	2	1	4	5	11
Bridgelip sucker	1	0	<1	0	0	0	3	<1	<1	0	0
Largescale sucker	15	20	11	6	16	15	4	6	9	3	<1
Unidentified sucker	0	0	0	0	0	0	0	0	0	0	0
Bullhead	<1	0	0	0	0	0	0	<1	0	0	0
Lake whitefish	31	33	23	15	33	40	46	51	37	40	43
Cutthroat trout	0	0	0	0	0	0	0	0	0	0	0
Rainbow trout	2	8	9	14	2	2	4	6	<1	6	<1
Kokanee salmon	<1	2	<1	<1	2	1	5	5	<1	1	2
Chinook salmon	0	0	0	0	0	0	0	0	0	0	0
Mountain whitefish	<1	0	0	0	0	0	<1	0	0	0	2
Brown trout	0	0	0	0	0	0	<1	0	<1	0	0
Bull trout	0	0	0	0	0	0	0	0	0	0	0
Eastern brook trout	0	0	0	0	0	0	0	0	0	0	0
Burbot	<1	<1	1	0	7	4	4	10	13	9	13
Sculpin spp.	0	<1	0	0	0	0	0	0	0	0	<1
Pumpkinseed	0	0	0	0	0	0	0	0	0	0	0
Smallmouth bass	6	3	7	10	0	6	3	0	3	12	4
Largemouth bass	0	0	0	0	0	0	0	0	0	0	0
Black crappie	0	0	0	0	0	<1	0	0	<1	0	<1
Yellow perch	5	46	3	3	5	10	7	3	3	2	2
Walleye	32	21	39	48	35	19	18	15	27	19	20

Age and Growth

Condition factors of salmonids were relatively similar for fish collected since 1997 (Table 73). Hatchery rainbow trout had a higher condition than wild rainbow trout, which is to be expected because wild rainbow trout resemble steelhead and tend to be more slender. Hatchery rainbow trout had similar condition factors to Sprague Lake, and higher conditions compared to hatchery rainbow trout found in Rock Lake, Whitman County and Deer Lake, Stevens County (Table 73). While, hatchery and wild kokanee salmon conditions were not distinguished in 1997 and 1998, wild kokanee salmon had higher conditions compared to the hatchery-reared fish in 1999. Wild

kokanee salmon captured in Lake Roosevelt tend to be larger, with a mean length of 434 mm (17 inches) compared to the hatchery kokanee that averaged 305 mm (12 inches) in TL.

Condition of other game fish and non-game fish appeared stable when compared to previous years (Table 74). Few comparisons exist for local lakes with the exception of walleye. Walleye condition was similar to previous years calculated for Lake Roosevelt, which are similar to values found in Banks Lake (Lincoln County) and Moses Lake (Grant County), but less than values found in Sprague Lake (Lincoln and Adams Counties; Table 74).

Kokanee salmon ages ranged from one to three in 1999 with age three kokanee salmon averaging 332 mm TL (SD 86), which was slightly lower compared to age three kokanee salmon collected in 1998 (404 SD 0; Spotts et al. 2002). Low sample sizes in 1999 ($n = 30$) and 1998 ($n = 34$) may have resulted in the lower mean length. Additionally, the difference in growth could be explained by the combination of hatchery and wild kokanee salmon. Using scales for growth analysis is based on alternating periods of relatively fast growth (spring and summer) and slow growth (fall and winter; Devries and Frie 1996). Hatchery kokanee are raised to post smolts (age 1.5) before they are released in Lake Roosevelt, decreasing the chance that an annuli forming during their first winter, which would skew incremental growth calculations. In the future, hatchery and wild kokanee salmon scales should be separated to eliminate deviation caused by hatchery contribution to analyses.

Rainbow trout ages ranged from one to five in 1999 and one to four in 1998 (Spotts et al. 2002). Age four fish averaged 330 mm (SD 41) in 1999 and 344 mm (SD 28) in 1998. Growth appeared similar between the two years, however wild and hatchery fish were combined. Hatchery rainbow trout are usually transferred to net pens in the late fall (November), which allows them to experience winter water temperatures that decreases their metabolism. However, they are fed well, which could also affect the formation of their winter annuli. Hatchery and wild rainbow trout should be separated for age analysis in the future.

Table 73. Comparison of Salmonidae condition factors (C.F.) and standard deviation (SD) of fish collected at Lake Roosevelt, WA since 1997, and from other lakes and reservoirs in eastern Washington.

Species and Location	n	C.F. (SD)	Species and Location	n	C.F. (SD)
Brown trout			Rainbow trout (hatchery)		
FDR 97	19	1.06 (0.27)	FDR 97	50	1.30 (0.24)
FDR 98	5	1.15 (0.17)	FDR 98	154	1.39 (0.25)
FDR 99	20	1.14 (0.40)	FDR 99	59	1.13 (0.27)
Rock Lake, WA ¹	593	0.89 (0.14)	Rock Lake, WA ¹	266	0.98 (0.20)
Box Canyon Reservoir, WA ²		0.90 (-----)	Sprague Lake, WA ³	86	1.14 (0.16)
			Deer Lake, WA ⁴		1.07 (----)
Chinook			Rainbow trout (wild)		
FDR 97	3	0.85 (0.59)	FDR 97	31	1.16 (0.24)
FDR 98	1	1.05 (0.00)	FDR 98	50	1.25 (0.30)
FDR 99	2	0.85 (0.07)	FDR 99	20	1.00 (0.25)
Eastern brook trout			Mountain whitefish		
FDR 97	7	1.38 (0.18)	FDR 97	4	0.91 (0.14)
FDR 98	7	0.84 (0.11)	FDR 98	18	1.13 (0.20)
FDR 99	17	1.02 (0.26)	FDR 99	14	1.16 (0.33)
Kokanee			Lake whitefish		
FDR 97	39	1.12 (0.34)	FDR 97	214	1.25 (0.20)
FDR 98	359	1.18 (0.15)	FDR 98	418	1.26 (0.27)
FDR 99 hatchery	67	1.08 (0.26)	FDR 99	264	1.27 (0.23)
FDR 99 wild	9	1.13 (0.19)			

¹McLellan 2000.

²Barber et al. 1990

³Taylor 2000

⁴Scholz et al. 1988

Table 74. Comparison of game fish and non-game fish condition factors (C.F.) and standard deviation (SD) of fish collected at Lake Roosevelt, WA since 1997, and from other lakes and reservoirs in eastern Washington.

Game fish	n	C.F. (SD)	Non Game Fish	n	C.F. (SD)
Burbot			Northern pikeminnow		
FDR 97	113	0.59 (0.12)	FDR 97	46	1.04 (0.29)
FDR 98	168	0.57 (0.16)	FDR 98	58	1.09 (0.21)
FDR 99	110	0.56 (0.12)	FDR 99	14	1.12 (0.29)
Smallmouth bass			Longnose sucker		
FDR 97	66	1.53 (0.25)	FDR 97	39	1.20 (0.25)
FDR 98	239	1.54 (0.56)	FDR 98	75	1.28 (0.42)
FDR 99	99	1.34 (0.16)	FDR 99	80	1.29 (0.33)
Yellow perch			Largescale sucker		
FDR 97	30	1.26 (0.21)	FDR 97	193	1.11 (0.17)
FDR 98	28	1.43 (0.25)	FDR 98	278	1.08 (0.20)
FDR 99	22	1.24 (0.22)	FDR 99	255	1.14 (0.18)
Walleye			Rock Lake ¹	320	1.17 (0.26)
FDR 90	333	0.88 (----)	Pend Oreille River, WA ²	--	0.99 (---)
FDR 97	554	0.87 (0.17)	Bridgelip sucker		
FDR 98	737	1.00 (0.22)	FDR 97	10	1.28 (0.31)
FDR 99	388	0.81 (0.17)	FDR 98	2	1.07 (0.38)
Sprague Lake, WA ³	655	1.02 (0.47)	FDR 99	2	1.12 (0.12)
Banks Lake, WA ⁴	319	0.89 (0.15)			
Moses Lake, WA ⁵	372	0.90 (0.15)			

¹McLellan 2000.

²Scholz et al. 1988

³Taylor 2000

⁴Polacek, M. WDFW 2002 unpublished data

⁵Burgess, D. WDFW 1999 unpublished data

Walleye growth in Lake Roosevelt was similar until age 3, then slightly decreased during ages 4 and 5 compared to previous years (Table 75). A similar growth study conducted by EWU revealed similar growth patterns to previous years (McLellan 2001; Figure 39). The decrease in growth observed in this year's data set was probably due to small sample sizes in the older age classes, which potentially reduced the accuracy of the older fish calculations. Walleye growth appeared stable in 1999 compared with previous years.

This was the first year scales were used to analyze growth for fish other than the three primary game fish, and sample sizes for most species were very small, and therefore, not used in comparisons with other systems. Other fish included brown trout, eastern brook trout, lake whitefish, mountain whitefish, smallmouth bass, yellow perch and northern pikeminnow. Scales

from suckers (largescale, longnose, and bridgelip suckers) were taken, but not analyzed because preliminary analysis by WDFW comparing opercular clips, scales and fin ray clips indicated scales were not accurate in determining sucker age. WDFW aged largescale suckers up to 28 years old using opercular clips (WDFW, C. Baldwin, unpublished data). Annuli on scales of older fish were not distinguishable in the older ages to properly account for each year. To properly age other long-lived fish, supplemental methods should be considered, such as otoliths, opercular clips, and fin ray clips.

Table 75. Comparison of mean back-calculated total lengths (mm) at annulus formation between an average from 16 lakes and rivers in the United States and British Columbia (average) and Lake Roosevelt (FDR), WA.

Location	n	Mean Total Length (mm) at Annulus Formation												
		1	2	3	4	5	6	7	8	9	10	11	12	13
Average ^a		177	280	368	431	483	530	554	548	675	675	728		
FDR, 1980-83 ^b	3,248	189	307	385	450	515	569	629	668	702	742	740	761	780
FDR, 1988 ^a	369	204	273	348	410	470	532	590	635	688	689			
FDR, 1989 ^b	467	210	282	351	418	493	571	603						
FDR, 1990 ^c	311	184	295	380	439	511	597	651	698	734				
FDR, 1995 ^d	360	121	224	315	380	444	481	539	556	611	695	726		
FDR, 1996 ^e	240	114	223	315	398	458	509	587						
FDR 1997 ^f	314	109	214	307	382	461	531	539	636	674	710			
FDR 1998 ^g	301	129	222	303	392	472	541	609	648					
FDR, 1997 ^h	2,355	172	279	363	424	478	535	617	662					
FDR, 1998 ^h	302	179	290	364	427	481	530	576	616	667	717	748	801	829
FDR, 1999 ^h	171	188	301	375	427	476	518	578	643					
FDR, 1999ⁱ	361	137	239	309	364	403								

^aPeone et al. 1990

^bBeckman et al. 1985

^dUnderwood et al. 1996b

^eCichosz et al. 1997

^fCichosz et al. 1999

^gSpotts et al. 2002

^hMcLellan et al. 2002- adjusted standard intercept of 55 mm used

ⁱCurrent study 2003

Figure 39. Length to age of walleye collected in Lake Roosevelt, WA (1980-1999). See Table 75 for references.

Feeding Habits

Feeding habits in 1999 followed trends similar to those seen in recent years. In most recent years (1997-1999), fish have comprised more than half (52.8 %) of the relative importance of the diet of walleye and cladocerans made up a substantial portion of the remaining prey items (16.42-23.85 %). No identifiable percids were observed in the 1999 analyses. However, an increase in percid relative importance was observed in 1998 compared with the previous year (Spotts et al. 2002). Burbot were first observed in the walleye diet in 1999 accounting for 0.25 % of the relative abundance. The observed changes in the walleye diet could represent changes in the fish community structure of Lake Roosevelt. A decrease in catostomids in the diet appears to coincide with decreasing largescale sucker relative abundance and CPUE, as well as an elevated relative abundance of salmonids. Sculpins have been important in the walleye diet representing 8.00 to 16.56 % of the relative abundance since 1993 (Table 69; Table 70; Table 71; Table 72; Table 76).

Approximately 1 million kokanee salmon and 500,000 rainbow trout are stocked into Lake Roosevelt annually, increasing the abundance of rainbow trout and kokanee salmon in recent years. This has created a forage base that walleye capitalize on, especially when alternative prey species are limited. Baldwin et al. (2002) estimated reservoir wide walleye predation of hatchery kokanee salmon and rainbow trout in 1999 to be as high as 39 % (95 % CI 20-59 %) and 7.9 %

(95 % CI 4.0-11.9%), respectively. The opportunistic feeding habits of walleye are elucidated by the annual variation in the composition of fish prey species observed in their diet.

Cladocera have been the dominant prey item in the diet of kokanee in recent years. Cladocera and Copepoda together accounted for 74.44 % of kokanee salmon diets in 1999. This is similar to what was observed in recent years, where Cladocera and Copepoda comprised 70 % to 97 % of kokanee salmon diets from 1995 to 1998. Cladocera/Copepoda R_{ia} values were reduced by nearly 23 % from 1998 to 1999, but remained the most important food items combined. Diptera have been an important diet item of kokanee salmon in recent years; 14.08 % in 1999, 8.3 % in 1998, and 14.41 % in 1997. An increase in the relative importance of Amphipoda, Diptera, Hemiptera, and Arachnoidea was observed in 1999. This shift in the diet of kokanee may be a result of decreased zooplankton densities that result from hydro-operations, particularly during high runoff years.

Rainbow trout were the most omnivorous of the sport fish species. In 1999, rainbow trout fed on more than 20 food categories identified to order or beyond. Prey items observed in 1999 that were not seen in the diet of rainbow trout in 1997 and 1998 include Decapoda, Homoptera, and Pelecypoda. Trichoptera were observed in 1998 and 1999, but weren't observed in 1997 and Ostracoda have been absent from the rainbow trout diet since 1997. The omnivorous feeding habits of rainbow trout may allow the species to better compete in a system in which the forage base is compromised by constant anthropogenic manipulations.

The occurrence of high interspecific diet overlap (≥ 0.70) increased in 1999 (13), compared to 1998 (9) and 1997 (5). The majority of high overlap occurred primarily between zooplanktivores (kokanee, rainbow trout and lake whitefish). These instances of high diet overlap may result in interspecific competition when zooplankton densities are compromised by reservoir operations. High diet overlap also occurred between omnivorous fish species (brown trout and brook trout), which were not abundant in the reservoir. Inter- and intraspecific competition for limited food resources could contribute to their low abundance in the reservoir, however it is unlikely that omnivorous species in low abundances would limit each other. The low relative abundance of these species is possibly more related to lack of available habitat and suitable water conditions in Lake Roosevelt.

The sucker species (largescale, longnose, and bridgelip) experienced high diet overlap, however the majority of their diets were unidentified material composed of detritus and digested substances. Largescale sucker diets differed from the other two sucker species, in that zooplankton was a large part of their diet (29.26 %; Appendix A). Longnose sucker primarily preyed on Diptera and Trichoptera species while bridgelip suckers preyed primarily on Diptera, Trichoptera, and Ephemeroptera (Appendix A).

Increased diet overlap between species that prefer specific diet items may experience increased competition when food becomes limited. This may be a prelude to future shortcomings of species that rely on specific food sources and are unable to adapt to a changing forage base.

Table 76. Relative importance values of fish prey items in the diet of walleye collected in Lake Roosevelt, WA (1997-1999).

Species	1993	1994	1995	1996	1997	1998	1999
Catostomidae	-	1.43	1.17	3.25	11.49	3.33	0.35
Centrarchidae	-	-	-	-	2.34	0.39	0.24
Cottidae	9.22	8.00	15.62	11.68	11.84	13.47	16.56
Cyprinidae	2.23	-	4.02	1.94	13.48	3.04	2.01
Gadidae	-	-	-	-	-	-	0.25
Percidae	7.99	11.02	16.40	5.35	3.07	8.59	-
Salmonidae	7.77	9.24	11.19	28.31	-	9.85	17.94
Unidentified	18.74	18.98	18.98	26.63	24.64	12.92	15.45

Tagging Studies

Tagging studies have been used to evaluate movement of rainbow trout and kokanee salmon within Lake Roosevelt, and as a tool to monitor entrainment out of the reservoir since 1988. Tag recoveries from below Grand Coulee Dam identify entrainment as a component of fish loss. However, the lack of a concerted tag recovery effort below Grand Coulee Dam limits our ability to quantify the amount of entrainment occurring. More rainbow trout were tagged in 1999 (n=29,114) compared with all other years (Table 77). However, tag recoveries from yearling fish were the lowest since 1990 (Table 78). Further monitoring of this release year will need to be performed to identify the meaning of the low number of recaptures.

All of the Phalon Lake rainbow trout tags were recovered at the same location where they were released from (Kettle Falls), two of which were recovered from walleye stomachs during a predation study conducted by WDFW. The actual amount of movement from the release location is unknown. Anglers utilize the Kettle Falls boat launch to access much of the northern reservoir, as evident from creel surveys. The actual amount of boat travel is unknown, therefore the specific location of capture, as well as fish movement, are difficult to assess. Seventy-five percent of the Spokane stock rainbow trout tags were recovered downstream of their release locations. This may be attributed, in part, to higher densities of zooplankton in the lower reservoir (Figure 20). Phalon Lake rainbow trout were released in the fall, as opposed to the spring when the Spokane stock rainbow trout were released. These data suggest that the use of native upriver stocks, the fall release strategy, or a combination of the two may reduce downriver migration and/or entrainment. Research should be conducted to further evaluate the use of upriver stocks and alternative release strategies of rainbow trout into Lake Roosevelt.

In previous years, entrainment has been negatively correlated to water residence time in Lake Roosevelt (Cichosz et al. 1999). In years that have experienced low mean water residence times, (<30 days for extended periods of time), including 1990, 1991, 1996, 1997, and 1999 tag recoveries below Grand Coulee Dam were elevated (13.6-96.7 %; Figure 40). In normal water years, tag recoveries from below Grand Coulee Dam have been relatively low (1.7-10.2 %; Figure 40). Hydro-operations resulting in low water retention times likely increase entrainment and reduce the potential for recruitment to the creel in Lake Roosevelt.

Slower growth of fish released at Kettle Falls would be expected due to reduced densities of zooplankton in the upper reservoir, the main diet item of rainbow trout, compared to the lower reservoir (Figure 20). Phalon Lake stock rainbow trout did show the lowest growth rates of all release groups, however Spokane stock rainbow trout released at Kettle Falls had higher growth rates than those released at Seven Bays. The slow growth of Phalon Lake stock rainbow trout may be attributed, in part, to the fall release, when zooplankton densities are decreasing (Figure 19). Spokane stock rainbow trout, are released in the spring when zooplankton densities are increasing (Figure 19)

The mean number of days between release and capture of Spokane stock from Kettle Falls and Seven Bays did not differ substantially. The short amount of time that the Phalon Lake rainbow

trout were in the fishery and the limited number of tag returns were not substantial enough to make any qualitative assessments of their performance. These release groups should be evaluated in future years when conclusions can be based on a more complete data set.

Table 77. Number of marked hatchery rainbow trout and kokanee salmon released into Lake Roosevelt, WA (1996-1999).

Release Location	Year Released			
	1996	1997	1998	1999
Kettle Falls				
Rainbow trout (Spokane stock)	4,998	10,000	9,992	9,977
Rainbow trout (Phalon Lake stock)	0	0	0	9,142
Kokanee (Lake Whatcom stock)	0	0	0	9,621
Seven Bays				
Rainbow trout (Spokane stock)	9,950	10,000	9,989	9,995
Totals	14,948	20,000	19,981	38,735

Figure 40. Percent tag recoveries collected below Grand Coulee Dam compared to monthly mean water residence time in Lake Roosevelt, (1990-1999).

Table 78. Total number of fish tagged by year and tag returns by release year in Lake Roosevelt, WA and below Grand Coulee Dam (GCD). Parentheses denote tags recovered below GCD.

Release Year	No. Fish Tagged	Release Year Tag Recoveries	+1 Year	+2 Year	+3 Year	+4 Year	+5 Year	Tags Returned	Tag Recovery Rate (%)	Tag Recovery Below GCD (%)
1988	1,171	77 (0)	16 (0)	1 (0)				94 (0)	8.03	0
1989	1,753	15 (2)	28 (2)	1 (0)	3 (0)		2 (1)	49 (5)	2.80	10.2
1990	4,361	72 (21)	19 (8)	3 (0)	1 (1)	1 (1)		96 (31)	2.20	32.29
1991	4,345	205 (32)	45 (4)	2 (1)	1 (1)			253 (38)	5.82	15.02
1992	20,997	509 (12)	10 (0)					519 (12)	2.47	2.31
1993	21,261	108 (2)	34 (2)	3 (0)				145 (4)	0.68	2.76
1994	26,975	307 (8)	64 (3)	3 (0)	1 (0)			375 (11)	1.39	2.93
1995	12,984	104 (1)	12 (1)	4 (0)				120 (2)	0.92	1.67
1996	14,948	202 (55)	40 (7)					242 (62)	1.62	25.62
1997	20,000	151 (146)						151 (146)	0.75	96.69
1998	19,981	601 (19)					7 (2)	629 (21)	3.15	3.34
1999	29,114	82 (14)	220 (26)	1 (1)	6 (1)			309 (42)	1.06	13.59
Totals	177,890	2,433 (312)	488 (53)	18 (2)	12 (3)	1 (1)	9 (3)	2,982 (374)	1.68	12.54

Creel Survey

In 1999, creel surveys were reduced to 9 months in the northern section and 10 months in the other two sections, as a cost savings measure. Therefore, the economic value and number of fish captured are not based on 12 months, as in all previous years. Additionally, the economic value of the Lake Roosevelt fishery in 1999 was calculated using the most recent report from the U.S. Fish and Wildlife Service that indicated anglers spend an average of \$26.55 per trip (U.S. Fish and Wildlife Service 1998). In all previous years, the economic value was calculated using an adjusted rate from the 1985 Annual Report that indicated anglers spent an average \$26.00 per trip (U.S. Fish and Wildlife Service 1989). The adjusted rate used in 1998 was \$40.68 per trip (Spotts et al. 2002), which is much higher than the value used in this report. Nevertheless, the most recent value of \$26.55 may be an underestimate of the average trip cost because the majority of anglers traveled from Spokane, Stevens or Grant Counties, which after vehicle gas, boat gas, and food may exceed \$26.55 per trip. In the future, to better assess the economic value of the fishery, anglers should be asked how much they spent on their fishing trip. The number of angler trips estimated in 1999 was the highest since 1995, suggesting that the economic value of the fishery also increased.

It should be noted that Lake Roosevelt, as a resource, is likely worth more than the estimated value, because expenses incurred by recreational campers and swimmers at the lake was not included. The percent of people angling ranged from 6 to 67% during July and August in the reservoir. Therefore, recreational boaters and campers are heavily utilizing Lake Roosevelt, and contributing to the economics of Lake Roosevelt and the entire region.

Historically, the number of fish harvested has varied widely over the past nine years (Table 79). Kokanee salmon harvest has varied from 588 to 32,353, rainbow trout harvest varied between 5,356 and 499,293, and walleye harvest has varied from 40,185 to 307,663 (Figure 41). Harvest estimates of salmonids peaked in 1994, and in 1993 for walleye. Salmonid harvest declined to a low in 1997. The low 1997 salmonid harvest was associated with a large drawdown that occurred in the spring, which resulted from reservoir flood control operations in response to the high water year. The resulting low lake elevations left many boat launches dry in the middle and lower reservoir sections, limiting access to Lake Roosevelt (Figure 42; Cichosz et al. 1999).

Harvest estimates for both walleye and rainbow trout increased in 1998 and 1999, but remained low for kokanee salmon.

The number of kokanee salmon and rainbow trout harvested in 1999 was likely underestimated. The majority of anglers targeted rainbow trout in the middle and lower sections. These sections have the longest roves, which decreased the time spent at boat launches interviewing anglers. Driving time was included in the eight-hour workday posing limitations on the amount of creel data that could be collected. Creel survey hours resulted in few completed angler-trips, especially in the summer months, which ultimately reduced the harvest and catch estimates.

Table 79. Economic value of the fishery and number of kokanee salmon, rainbow trout, and walleye harvested in Lake Roosevelt, WA (1990-1999).

Year of Record	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Economic Value Million/Dollars	\$5.30	\$12.80	\$9.70	\$20.70	\$19.20	\$8.70	\$6.90	\$5.80	\$8.00	\$6.12
Angler Trips	171,725	398,408	291,380	594,508	469,998	232,202	176,769	146,264	196,775	230,513
No. Fish Caught										
Kokanee salmon	17,756	31,651	8,146	13,986	16,567	32,353	1,265	588	10,188	1,730
Rainbow trout	81,560	81,529	167,156	402,277	499,460	125,958	76,915	5,356	233,036	232,019
Walleye	116,473	231,813	163,995	337,413	123,612	73,667	142,873	147,316	133,241	236,738
No. Fish Harvested										
Kokanee salmon	17,403	31,651	8,021	13,960	16,567	32,353	1,265	588	9,980	1,730
Rainbow trout	79,683	73,777	140,609	398,943	499,293	122,939	76,782	5,356	226,809	197,115
Walleye	82,284	168,736	118,863	307,663	53,589	40,185	104,055	87,515	119,346	188,290
Mean length (mm)										
Kokanee salmon	391	361	436	486	481	467	438	338	356	358
Rainbow trout	346	348	422	471	473	410	363	395	364	362
Walleye	376	397	361	382	385	370	372	372	352	366

Figure 41. Estimated harvest of rainbow trout, kokanee salmon, and walleye between 1990 and 1999 in Lake Roosevelt, WA.

Figure 42. Lake Roosevelt, WA elevation (ft above sea level) compared to annual harvest of kokanee salmon and rainbow trout.

Recommendations

Lake Roosevelt is a dynamic system complicated by large reservoir drawdowns that reduce pelagic and benthic food resources, reduce water residence times, and entrain fish species. This, coupled with non-native piscivorous predators that prey heavily on hatchery reared rainbow trout and kokanee salmon make managing the fishery a challenging task.

The following recommendations will address the most urgent limiting factors influencing fish production and ecosystem attributes, within the context of multiple water uses.

Limnology

1. Continue to work together with stakeholders to maximize benefits of hydro-operations while minimizing detrimental effects to the Lake Roosevelt ecosystem
2. Maintain current zooplankton and water quality sampling locations and intensity to better relate the effects of reservoir operations on zooplankton production.
3. Examine the influence macronutrients (nitrogen and phosphorus) in the reservoir have on algal primary production and trophic state.
4. Investigate differences in zooplankton and water quality between littoral and pelagic areas of the reservoir.
5. Compare multiple year zooplankton lengths to assess food limitation and predation stress.

Fishery

1. Monitor and evaluate the artificial production program with respect to: entrainment, fish culture, stocking strategies, and stock utilization.
2. Continue standardized fishery surveys to assess long-term changes in the Lake Roosevelt fishery. Including collecting information on relative abundance, feeding habits, and age and growth.
3. Floy tag 30,000 hatchery reared rainbow trout to evaluate the success of the net pen raised fish.
4. Continue monitoring hatchery reared kokanee adult returns to stocking locations through paired release studies.
5. Assess predation, primarily walleye, as a limiting factor to the artificial production program.

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Appendices

Appendix A. Fish diet analysis tables.

Table 80. Percent by dry weight, percent by number, frequency of occurrence, and relative importance values of diet categories for black crappie and bridgelip sucker collected in Lake Roosevelt, WA (1999).

Species Diet Category	Black crappie (n = 1)				Bridgelip sucker (n = 3)			
	% by Weight	% by Number	Frequency of Occurrence	Relative Importance	% by Weight	% by Number	Frequency of Occurrence	Relative Importance
Osteichthyes								
Catostomidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Centrarchidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cottidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cyprinidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gadidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ictaluridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Salmonidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified non-salmonidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified Osteichthyes	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Amphipoda								
Gammaridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified Amphipoda	0.00	0.00	0.00	0.00	0.00	6.98	33.33	8.06
Arachnoidea								
Unidentified Arachnoidea	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cladocera/Copepoda								
Daphnidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Leptodoridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified Cladocera/Copepoda	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Coleoptera								
Carabidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chrysomelidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 80. Continued.

Species Diet Category	Black crappie				Bridgelip sucker			
	% by Weight	% by Number	Frequency of Occurrence	Relative Importance	% by Weight	% by Number	Frequency of Occurrence	Relative Importance
Curculionidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Elmidae	0.00	0.00	0.00	0.00	0.04	4.65	33.33	7.61
Hydrophilidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Melyridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Staphylinidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Salpingidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified Coleoptera	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Decapoda								
Astacidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Diptera								
Chironomidae larvae	0.00	0.00	0.00	0.00	0.01	39.53	33.33	14.58
Chironomidae pupae	100.00	100.00	100.00	100.00	0.00	0.00	0.00	0.00
Dixidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Simuliidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tabanidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ephemeroptera								
Baetidae	0.00	0.00	0.00	0.00	0.01	18.60	33.33	10.39
Ephemerellidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heptageniidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hemiptera								
Belostomatidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Corixidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gelastocoridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gerridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Macroveliidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mesoveliidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Naucoridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 80. Continued.

Species Diet Category	Black crappie				Bridgelip sucker			
	% by Weight	% by Number	Frequency of Occurrence	Relative Importance	% by Weight	% by Number	Frequency of Occurrence	Relative Importance
Ochteridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Saldidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Veliidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified Hemiptera	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Homoptera								
Unidentified Homoptera	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lepidoptera								
Unidentified Lepidoptera	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Odonata								
Aeshnidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified Odonata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Trichoptera								
Brachycentridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Coenagrionidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Glossomatidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Helicopsychidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydropsychidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydroptilidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Limnephilidae	0.00	0.00	0.00	0.00	0.51	25.58	33.33	11.88
Nemouridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified Trichoptera	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Plecoptera								
Chloroperlidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Peltoperlidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Perlidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Perlodidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 80. Continued

Species Diet Category	Black crappie				Bridgelip sucker			
	% by Weight	% by Number	Frequency of Occurrence	Relative Importance	% by Weight	% by Number	Frequency of Occurrence	Relative Importance
Pteronarcyidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rhyacophilidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified Plecoptera	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gastropoda								
Lymnaeidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Physidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Planorbidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified Gastropoda	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pelecypoda								
Sphaeriidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified Pelecypoda	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Annelida								
Hirudinea	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oligocheata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified Annelida	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nematoda								
Unidentified Nematoda	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Planariidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified Arthropoda	0.00	0.00	0.00	0.00	0.09	1.16	33.33	6.92
Terrestrial	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other	0.00	0.00	0.00	0.00	99.34	3.49	100.00	40.56

Table 81. Percent by dry weight, percent by number, frequency of occurrence, and relative importance values of diet categories for eastern brook trout and brown trout collected in Lake Roosevelt, WA (1999).

Species Diet Category	Eastern brook trout (n = 16)				Brown trout (n = 18)			
	% by Weight	% by Number	Frequency of Occurrence	Relative Importance	% by Weight	% by Number	Frequency of Occurrence	Relative Importance
Osteichthyes								
Catostomidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Centrarchidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cottidae	57.95	0.10	6.25	15.13	68.07	0.39	11.11	16.46
Cyprinidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gadidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ictaluridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Salmonidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified non-salmonidae	5.73	0.03	12.50	4.30	9.10	0.06	11.11	4.19
Unidentified Osteichthyes	1.39	0.02	6.25	1.80	0.00	0.00	0.00	0.00
Amphipoda								
Gammaridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified Amphipoda	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Arachnoidea								
Unidentified Arachnoidea	0.00	0.00	0.00	0.00	0.01	0.06	11.11	2.31
Cladocera/Copepoda								
Daphnidae	13.43	56.78	31.25	23.87	0.40	50.82	5.56	11.75
Leptodoridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified Cladocera/Copepoda	6.78	41.92	12.50	14.40	0.00	0.00	0.00	0.00
Coleoptera								
Carabidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chrysomelidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Curculionidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Elmidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 81. Continued

Species Diet Category	Eastern brook trout				Brown trout			
	% by Weight	% by Number	Frequency of Occurrence	Relative Importance	% by Weight	% by Number	Frequency of Occurrence	Relative Importance
Hydrophilidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Melyridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Staphylinidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Salpingidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified Coleoptera	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Decapoda								
Astacidae	0.00	0.00	0.00	0.00	11.44	0.09	16.67	5.83
Diptera								
Chironomidae larvae	0.10	0.07	25.00	5.92	0.04	0.33	27.78	5.83
Chironomidae pupae	0.02	0.03	12.50	2.95	3.54	45.61	27.78	15.92
Dixidae	0.00	0.00	0.00	0.00	0.01	0.09	11.11	2.32
Simuliidae	0.00	0.00	0.00	0.00	0.01	0.06	11.11	2.31
Tabanidae	0.00	0.00	0.00	0.00	0.60	0.06	5.56	1.29
Ephemeroptera								
Baetidae	0.01	0.03	6.25	1.48	0.01	0.06	5.56	1.16
Ephemerellidae	0.00	0.00	0.00	0.00	0.26	1.48	11.11	2.66
Heptageniidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hemiptera								
Belostomatidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Corixidae	6.33	0.72	25.00	7.54	0.14	0.27	16.67	3.53
Gelastocoridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gerridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Macroveliidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mesoveliidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Naucoridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ochteridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Saldidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 81. Continued

Species Diet Category	Eastern brook trout				Brown trout			
	% by Weight	% by Number	Frequency of Occurrence	Relative Importance	% by Weight	% by Number	Frequency of Occurrence	Relative Importance
Veliidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified Hemiptera	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Homoptera								
Unidentified Homoptera	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lepidoptera								
Unidentified Lepidoptera	1.02	0.02	6.25	1.72	0.00	0.00	0.00	0.00
Odonata								
Aeshnidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified Odonata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Trichoptera								
Brachycentridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Coenagrionidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Glossomatidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Helicopsychidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydropsychidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydroptilidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Limnephilidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nemouridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified Trichoptera	0.00	0.00	0.00	0.00	0.01	0.03	5.56	1.16
Plecoptera								
Chloroperlidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Peltoperlidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Perlidae	0.34	0.01	6.25	1.55	0.00	0.00	0.00	0.00
Perlodidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pteronarcyidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rhyacophilidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 81. Continued

Species Diet Category	Eastern brook trout				Brown trout			
	% by Weight	% by Number	Frequency of Occurrence	Relative Importance	% by Weight	% by Number	Frequency of Occurrence	Relative Importance
Unidentified Plecoptera	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gastropoda								
Lymnaeidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Physidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Planorbidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified Gastropoda	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pelecypoda								
Sphaeriidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified Pelecypoda	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Annelida								
Hirudinea	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oligocheata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified Annelida	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nematoda								
Unidentified Nematoda	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Planariidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified Arthropoda	2.75	0.05	25.00	6.54	0.98	0.15	27.78	5.98
Terrestrial	0.50	0.16	25.00	6.04	0.31	0.15	27.78	5.84
Other	3.65	0.05	25.00	6.75	5.05	0.27	50.00	11.45

Table 82. Percent by dry weight, percent by number, frequency of occurrence, and relative importance values of diet categories for burbot and kokanee salmon collected in Lake Roosevelt, WA (1999).

Species Diet Category	Burbot (n=20)				Kokanee Salmon (n=59)			
	% by Weight	% by Number	Frequency of Occurrence	Relative Importance	% by Weight	% by Number	Frequency of Occurrence	Relative Importance
Osteichthyes								
Catostomidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Centrarchidae	0.47	1.09	5.00	1.70	0.00	0.00	0.00	0.00
Cottidae	32.76	1.09	5.00	10.09	0.00	0.00	0.00	0.00
Cyprinidae	6.58	3.26	10.00	5.15	0.00	0.00	0.00	0.00
Gadidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ictaluridae	3.35	1.09	5.00	2.45	0.00	0.00	0.00	0.00
Salmonidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified non-salmonidae	6.76	6.52	20.00	8.64	0.00	0.00	0.00	0.00
Unidentified Osteichthyes	0.18	19.57	10.00	7.73	0.00	0.00	0.00	0.00
Amphipoda								
Gammaridae	0.00	0.00	0.00	0.00	0.03	0.00	3.39	0.94
Unidentified Amphipoda	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Arachnoidea								
Unidentified Arachnoidea	0.00	0.00	0.00	0.00	0.01	0.00	1.69	0.47
Cladocera/Copepoda								
Daphnidae	0.00	0.00	0.00	0.00	62.35	82.22	50.85	53.88
Leptodoridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified Cladocera/Copepoda	0.00	0.00	0.00	0.00	26.84	17.23	30.51	20.56
Coleoptera								
Carabidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chrysomelidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Curculionidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Elmidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 82. Continued

Species Diet Category	Burbot				Kokanee			
	% by Weight	% by Number	Frequency of Occurrence	Relative Importance	% by Weight	% by Number	Frequency of Occurrence	Relative Importance
Hydrophilidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Melyridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Staphylinidae	0.04	1.09	5.00	1.59	0.00	0.00	0.00	0.00
Salpingidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified Coleoptera	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Decapoda								
Astacidae	34.26	6.52	25.00	17.09	0.40	0.00	1.69	0.58
Diptera								
Chironomidae larvae	0.56	27.17	5.00	8.50	0.01	0.01	5.08	1.41
Chironomidae pupae	0.00	0.00	0.00	0.00	8.17	0.50	35.59	12.20
Dixidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Simuliidae	0.00	0.00	0.00	0.00	0.01	0.00	1.69	0.47
Tabanidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ephemeroptera								
Baetidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ephemerellidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heptageniidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hemiptera								
Belostomatidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Corixidae	0.00	0.00	0.00	0.00	0.00	0.02	3.39	0.94
Gelastocoridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gerridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Macroveliidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mesoveliidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Naucoridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ochteridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Saldidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 82. Continued

Species Diet Category	Burbot				Kokanee			
	% by Weight	% by Number	Frequency of Occurrence	Relative Importance	% by Weight	% by Number	Frequency of Occurrence	Relative Importance
Veliidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified Hemiptera	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Homoptera								
Unidentified Homoptera	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lepidoptera								
Unidentified Lepidoptera	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Odonata								
Aeshnidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified Odonata	2.00	6.52	10.00	4.81	0.00	0.00	0.00	0.00
Trichoptera								
Brachycentridae	0.04	1.09	5.00	1.59	0.00	0.00	0.00	0.00
Coenagrionidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Glossomatidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Helicopsychidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydropsychidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydroptilidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Limnephilidae	1.85	1.09	5.00	2.06	0.00	0.00	0.00	0.00
Nemouridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified Trichoptera	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Plecoptera								
Chloroperlidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Peltoperlidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Perlidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Perlodidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pteronarcyidae	2.51	5.43	10.00	4.66	0.00	0.00	0.00	0.00
Rhyacophilidae	0.20	6.52	10.00	4.34	0.00	0.00	0.00	0.00

Table 82. Continued

Species Diet Category	% by Weight	% by Number	Burbot Frequency of Occurrence	Relative Importance	% by Weight	% by Number	Kokanee Frequency of Occurrence	Relative Importance
Unidentified Plecoptera	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gastropoda								
Lymnaeidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Physidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Planorbidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified Gastropoda	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pelecypoda								
Sphaeriidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified Pelecypoda	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Annelida								
Hirudinea	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oligocheata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified Annelida	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nematoda								
Unidentified Nematoda	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Planariidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified Arthropoda	0.03	1.09	5.00	1.59	0.96	0.01	8.47	2.60
Terrestrial	0.12	2.17	10.00	3.19	0.02	0.00	3.39	0.94
Other	8.27	8.70	40.00	14.80	1.20	0.01	16.95	5.01

Table 83. Percent by dry weight, percent by number, frequency of occurrence, and relative importance values of diet categories for longnose sucker and largescale sucker collected in Lake Roosevelt, WA (1999).

Species Diet Category	Longnose sucker (n = 10)				Largescale sucker (n = 164)			
	% by Weight	% by Number	Frequency of Occurrence	Relative Importance	% by Weight	% by Number	Frequency of Occurrence	Relative Importance
Osteichthyes								
Catostomidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Centrarchidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cottidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cyprinidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gadidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ictaluridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Salmonidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified non-salmonidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified Osteichthyes	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Amphipoda								
Gammaridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified Amphipoda	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Arachnoidea								
Unidentified Arachnoidea	0.00	0.00	0.00	0.00	0.00	0.00	2.44	0.50
Cladocera/Copepoda								
Daphnidae	0.00	0.00	0.00	0.00	11.32	75.52	23.17	22.61
Leptodoridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified Cladocera/Copepoda	0.00	0.00	0.00	0.00	2.23	19.78	10.37	6.65
Coleoptera								
Carabidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chrysomelidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Curculionidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Elmidae	0.00	0.00	0.00	0.00	0.03	0.07	10.37	2.15

Table 83. Continued

Species Diet Category	Longnose sucker				Largescale sucker			
	% by Weight	% by Number	Frequency of Occurrence	Relative Importance	% by Weight	% by Number	Frequency of Occurrence	Relative Importance
Hydrophilidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Melyridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Staphylinidae	0.00	0.00	0.00	0.00	0.00	0.00	0.61	0.13
Salpingidae	0.00	0.00	0.00	0.00	0.01	0.01	0.61	0.13
Unidentified Coleoptera	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Decapoda								
Astacidae	0.00	0.00	0.00	0.00	0.01	0.00	0.61	0.13
Diptera								
Chironomidae larvae	0.06	26.27	20.00	11.03	4.00	3.44	20.12	5.66
Chironomidae pupae	0.01	4.24	20.00	5.77	0.02	0.03	15.24	3.14
Dixidae	0.00	0.00	0.00	0.00	0.00	0.00	0.61	0.13
Simuliidae	0.00	9.32	10.00	4.60	0.00	0.00	1.83	0.38
Tabanidae	0.00	0.00	0.00	0.00	0.00	0.00	0.61	0.13
Ephemeroptera								
Baetidae	0.00	0.85	10.00	2.58	0.00	0.00	3.66	0.75
Ephemerellidae	0.00	0.00	0.00	0.00	0.01	0.01	4.88	1.01
Heptageniidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hemiptera								
Belostomatidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Corixidae	0.03	1.69	10.00	2.79	0.03	0.01	4.27	0.88
Gelastocoridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gerridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Macroveliidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mesoveliidae	0.00	0.00	0.00	0.00	0.00	0.00	0.61	0.13
Naucoridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ochteridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Saldidae	0.00	0.00	0.00	0.00	0.00	0.00	0.61	0.13

Table 83. Continued

Species Diet Category	Longnose sucker				Largescale sucker			
	% by Weight	% by Number	Frequency of Occurrence	Relative Importance	% by Weight	% by Number	Frequency of Occurrence	Relative Importance
Veliidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified Hemiptera	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Homoptera								
Unidentified Homoptera	0.00	0.00	0.00	0.00	0.01	0.00	0.61	0.13
Lepidoptera								
Unidentified Lepidoptera	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Odonata								
Aeshnidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified Odonata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Trichoptera								
Brachycentridae	0.10	1.69	20.00	5.19	0.02	0.01	6.10	1.26
Coenagrionidae	0.00	0.00	0.00	0.00	0.00	0.00	0.61	0.13
Glossomatidae	0.00	0.00	0.00	0.00	0.01	0.00	0.61	0.13
Helicopsychidae	1.18	45.76	10.00	13.56	0.33	0.07	7.93	1.71
Hydropsychidae	0.01	0.85	10.00	2.58	0.07	0.08	4.27	0.91
Hydroptilidae	0.00	0.00	0.00	0.00	0.00	0.00	1.22	0.25
Limnephilidae	0.00	0.00	0.00	0.00	0.28	0.10	7.93	1.71
Nemouridae	0.00	0.00	0.00	0.00	0.00	0.01	2.44	0.50
Unidentified Trichoptera	0.00	0.00	0.00	0.00	0.01	0.00	0.61	0.13
Plecoptera								
Chloroperlidae	0.00	0.00	0.00	0.00	0.00	0.00	0.61	0.13
Peltoperlidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Perlidae	0.00	0.00	0.00	0.00	0.00	0.00	0.61	0.13
Perlodidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pteronarcyidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rhyacophilidae	0.00	0.00	0.00	0.00	0.02	0.00	1.83	0.38

Table 83. Continued

Species Diet Category	Longnose sucker				Largescale sucker			
	% by Weight	% by Number	Frequency of Occurrence	Relative Importance	% by Weight	% by Number	Frequency of Occurrence	Relative Importance
Unidentified Plecoptera	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gastropoda								
Lymnaeidae	0.00	0.00	0.00	0.00	3.07	0.38	9.15	2.59
Physidae	0.00	0.00	0.00	0.00	0.03	0.00	1.22	0.26
Planorbidae	0.00	0.00	0.00	0.00	0.44	0.14	14.02	3.00
Unidentified Gastropoda	0.00	0.00	0.00	0.00	0.75	0.00	1.22	0.40
Pelecypoda								
Sphaeriidae	0.00	0.00	0.00	0.00	0.05	0.01	2.44	0.51
Unidentified Pelecypoda	0.00	0.00	0.00	0.00	0.01	0.00	1.83	0.38
Annelida								
Hirudinea	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oligocheata	0.00	0.00	0.00	0.00	0.02	0.02	1.22	0.26
Unidentified Annelida	0.00	0.00	0.00	0.00	0.06	0.00	1.22	0.26
Nematoda								
Unidentified Nematoda	0.00	0.00	0.00	0.00	0.87	0.19	4.88	1.22
Planariidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified Arthropoda	1.55	2.54	30.00	8.12	5.61	0.01	17.07	4.66
Terrestrial	0.00	0.00	0.00	0.00	0.02	0.01	5.49	1.13
Other	97.05	6.78	80.00	43.77	70.67	0.09	90.85	33.21

Table 84. Percent by dry weight, percent by number, frequency of occurrence, and relative importance values of diet categories for lake whitefish and mountain whitefish collected in Lake Roosevelt, WA (1999).

Species Diet Category	Lake whitefish (n = 13)				Mountain whitefish (n = 5)			
	% by Weight	% by Number	Frequency of Occurrence	Relative Importance	% by Weight	% by Number	Frequency of Occurrence	Relative Importance
Catostomidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Centrarchidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cottidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cyprinidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gadidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ictaluridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Salmonidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified non-salmonidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified Osteichthyes	3.13	0.26	7.69	2.09	0.00	0.00	0.00	0.00
Amphipoda								
Gammaridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified Amphipoda	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Arachnoidea								
Unidentified Arachnoidea	0.65	0.24	30.77	5.97	0.00	0.00	0.00	0.00
Cladocera/Copepoda								
Daphnidae	28.76	50.59	30.77	20.75	0.00	0.00	0.00	0.00
Leptodoridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified Cladocera/Copepoda	21.69	44.94	30.77	18.35	0.00	0.00	0.00	0.00
Coleoptera								
Carabidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chrysomelidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Curculionidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Elmidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 84. Continued

Species Diet Category	Lake whitefish				Mountain whitefish			
	% by Weight	% by Number	Frequency of Occurrence	Relative Importance	% by Weight	% by Number	Frequency of Occurrence	Relative Importance
Hydrophilidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Melyridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Staphylinidae	0.00	0.00	0.00	0.00	0.04	0.04	20.00	2.71
Salpingidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified Coleoptera	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Decapoda								
Astacidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Diptera								
Chironomidae larvae	5.85	1.90	46.15	10.16	17.30	30.46	80.00	17.26
Chironomidae pupae	0.44	0.11	23.08	4.45	38.15	63.54	100.00	27.26
Dixidae	0.00	0.00	0.00	0.00	0.00	0.02	20.00	2.71
Simuliidae	0.95	0.27	15.38	3.13	0.04	0.14	40.00	5.43
Tabanidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ephemeroptera								
Baetidae	6.52	1.47	7.69	2.96	0.00	0.00	0.00	0.00
Ephemerellidae	0.00	0.00	0.00	0.00	0.17	0.23	80.00	10.86
Heptageniidae	0.01	0.00	7.69	1.45	0.00	0.00	0.00	0.00
Hemiptera								
Belostomatidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Corixidae	0.17	0.02	7.69	1.49	0.00	0.00	0.00	0.00
Gelastocoridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gerridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Macroveliidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mesoveliidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Naucoridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ochteridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Saldidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 84. Continued

Species Diet Category	Lake whitefish				Mountain whitefish			
	% by Weight	% by Number	Frequency of Occurrence	Relative Importance	% by Weight	% by Number	Frequency of Occurrence	Relative Importance
Veliidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified Hemiptera	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Homoptera								
Unidentified Homoptera	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lepidoptera								
Unidentified Lepidoptera	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Odonata								
Aeshnidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified Odonata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Trichoptera								
Brachycentridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Coenagrionidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Glossomatidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Helicopsychidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydropsychidae	0.10	0.01	15.38	2.92	0.00	0.02	20.00	2.71
Hydroptilidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Limnephilidae	1.08	0.02	15.38	3.11	28.28	5.40	20.00	7.25
Nemouridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified Trichoptera	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Plecoptera								
Chloroperlidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Peltoperlidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Perlidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Perlodidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pteronarcyidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rhyacophilidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 84. Continued

Species Diet Category	Lake whitefish				Mountain whitefish			
	% by Weight	% by Number	Frequency of Occurrence	Relative Importance	% by Weight	% by Number	Frequency of Occurrence	Relative Importance
Unidentified Plecoptera	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gastropoda								
Lymnaeidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Physidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Planorbidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified Gastropoda	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pelecypoda								
Sphaeriidae	0.25	0.01	7.69	1.50	0.00	0.00	0.00	0.00
Unidentified Pelecypoda	1.56	0.09	23.08	4.66	0.00	0.00	0.00	0.00
Annelida								
Hirudinea	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oligocheata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified Annelida	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nematoda								
Unidentified Nematoda	0.02	0.02	7.69	1.46	0.00	0.00	0.00	0.00
Planariidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified Arthropoda	2.47	0.01	15.38	3.36	0.27	0.02	20.00	2.74
Terrestrial	0.36	0.03	7.69	1.52	0.03	0.06	60.00	8.12
Other	25.99	0.01	30.77	10.70	15.71	0.08	80.00	12.94

Table 85. Percent by dry weight, percent by number, frequency of occurrence, and relative importance values of diet categories for northern pikeminnow and rainbow trout collected in Lake Roosevelt, WA (1999).

Species Diet Category	Northern pikeminnow (n = 4)				Rainbow trout (n = 169)			
	% by Weight	% by Number	Frequency of Occurrence	Relative Importance	% by Weight	% by Number	Frequency of Occurrence	Relative Importance
Osteichthyes								
Catostomidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Centrarchidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cottidae	61.32	2.08	25.00	22.10	0.24	0.00	1.18	0.32
Cyprinidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gadidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ictaluridae	0.00	0.00	0.00	0.00	0.72	0.00	0.59	0.30
Salmonidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified non-salmonidae	0.00	0.00	0.00	0.00	5.31	0.00	2.96	1.88
Unidentified Osteichthyes	0.00	0.00	0.00	0.00	19.93	0.00	2.37	5.06
Amphipoda								
Gammaridae	0.00	0.00	0.00	0.00	0.00	0.00	0.59	0.13
Unidentified Amphipoda	0.00	0.00	0.00	0.00	0.23	0.00	2.37	0.59
Arachnoidea								
Unidentified Arachnoidea	0.00	0.00	0.00	0.00	0.32	0.04	8.88	2.09
Cladocera/Copepoda								
Daphnidae	0.00	0.00	0.00	0.00	30.78	91.91	68.05	43.26
Leptodoridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified Cladocera/Copepoda	0.00	0.00	0.00	0.00	1.70	6.76	8.88	3.93
Coleoptera								
Carabidae	0.00	0.00	0.00	0.00	0.00	0.00	0.59	0.13
Chrysomelidae	0.00	0.00	0.00	0.00	0.37	0.00	0.59	0.22
Curculionidae	0.00	0.00	0.00	0.00	0.01	0.00	0.59	0.14
Elmidae	0.00	0.00	0.00	0.00	0.46	0.02	1.78	0.51

Table 85. Continued

Species Diet Category	Northern pikeminnow				Rainbow trout			
	% by Weight	% by Number	Frequency of Occurrence	Relative Importance	% by Weight	% by Number	Frequency of Occurrence	Relative Importance
Hydrophilidae	0.00	0.00	0.00	0.00	0.02	0.00	1.18	0.27
Melyridae	0.00	0.00	0.00	0.00	0.00	0.00	1.18	0.27
Staphylinidae	0.00	0.00	0.00	0.00	0.00	0.00	0.59	0.13
Salpingidae	0.00	0.00	0.00	0.00	0.01	0.00	0.59	0.14
Unidentified Coleoptera	0.00	0.00	0.00	0.00	0.34	0.01	0.59	0.21
Decapoda								
Astacidae	0.00	0.00	0.00	0.00	7.26	0.00	2.96	2.32
Diptera								
Chironomidae larvae	6.45	83.33	50.00	34.95	1.58	0.16	12.43	3.21
Chironomidae pupae	0.00	0.00	0.00	0.00	1.02	0.60	16.57	4.13
Dixidae	0.00	0.00	0.00	0.00	0.03	0.00	0.59	0.14
Simuliidae	0.00	0.00	0.00	0.00	0.01	0.00	1.78	0.40
Tabanidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ephemeroptera								
Baetidae	0.00	0.00	0.00	0.00	0.02	0.00	4.14	0.94
Ephemerellidae	0.00	0.00	0.00	0.00	0.00	0.00	0.59	0.14
Heptageniidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hemiptera								
Belostomatidae	0.00	0.00	0.00	0.00	0.50	0.00	1.18	0.38
Corixidae	0.00	0.00	0.00	0.00	2.24	0.17	10.06	2.83
Gelastocoridae	0.00	0.00	0.00	0.00	1.18	0.01	1.18	0.54
Gerridae	0.00	0.00	0.00	0.00	0.00	0.00	0.59	0.13
Macroveliidae	0.00	0.00	0.00	0.00	0.01	0.00	0.59	0.14
Mesoveliidae	0.00	0.00	0.00	0.00	0.45	0.00	1.78	0.51
Naucoridae	0.00	0.00	0.00	0.00	0.03	0.00	1.18	0.28
Ochteridae	0.00	0.00	0.00	0.00	0.09	0.00	0.59	0.16
Saldidae	0.00	0.00	0.00	0.00	0.26	0.02	3.55	0.87

Table 85. Continued

Species Diet Category	Northern pikeminnow				Rainbow trout			
	% by Weight	% by Number	Frequency of Occurrence	Relative Importance	% by Weight	% by Number	Frequency of Occurrence	Relative Importance
Veliidae	0.00	0.00	0.00	0.00	0.01	0.00	0.59	0.14
Unidentified Hemiptera	0.00	0.00	0.00	0.00	0.02	0.00	0.59	0.14
Homoptera								
Unidentified Homoptera	0.00	0.00	0.00	0.00	0.01	0.00	0.59	0.14
Lepidoptera								
Unidentified Lepidoptera	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Odonata								
Aeshnidae	0.00	0.00	0.00	0.00	0.01	0.00	0.59	0.14
Unidentified Odonata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Trichoptera								
Brachycentridae	0.00	0.00	0.00	0.00	0.01	0.00	1.78	0.40
Coenagrionidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Glossomatidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Helicopsychidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydropsychidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydroptilidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Limnephilidae	0.00	0.00	0.00	0.00	0.06	0.01	3.55	0.82
Nemouridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified Trichoptera	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Plecoptera								
Chloroperlidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Peltoperlidae	0.00	0.00	0.00	0.00	0.00	0.00	0.59	0.13
Perlidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Perlodidae	0.00	0.00	0.00	0.00	0.02	0.00	0.59	0.14
Pteronarcyidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rhyacophilidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 85. Continued

Species Diet Category	Northern pikeminnow				Rainbow trout			
	% by Weight	% by Number	Frequency of Occurrence	Relative Importance	% by Weight	% by Number	Frequency of Occurrence	Relative Importance
Unidentified Plecoptera	1.10	2.08	25.00	7.05	0.00	0.00	0.00	0.00
Gastropoda								
Lymnaeidae	0.00	0.00	0.00	0.00	1.79	0.01	0.59	0.54
Physidae	0.00	0.00	0.00	0.00	3.73	0.02	2.96	1.52
Planorbidae	0.00	0.00	0.00	0.00	0.25	0.01	1.78	0.46
Unidentified Gastropoda	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pelecypoda								
Sphaeriidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified Pelecypoda	0.00	0.00	0.00	0.00	0.00	0.00	0.59	0.13
Annelida								
Hirudinea	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oligocheata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified Annelida	0.00	0.00	0.00	0.00	0.61	0.00	1.18	0.41
Nematoda								
Unidentified Nematoda	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Planariidae	0.00	0.00	0.00	0.00	0.03	0.00	1.18	0.28
Unidentified Arthropoda	13.04	4.17	50.00	16.80	7.05	0.01	13.61	4.84
Terrestrial	0.00	0.00	0.00	0.00	3.75	0.18	20.71	5.59
Other	18.09	8.33	50.00	19.11	7.52	0.04	25.44	7.48

Table 86. Percent by dry weight, percent by number, frequency of occurrence, and relative importance values of diet categories for smallmouth bass and tench collected in Lake Roosevelt, WA (1999).

Species Diet Category	Smallmouth bass (n = 49)				Tench (n = 1)			
	% by Weight	% by Number	Frequency of Occurrence	Relative Importance	% by Weight	% by Number	Frequency of Occurrence	Relative Importance
Osteichthyes								
Catostomidae	6.06	0.20	4.08	2.41	0.00	0.00	0.00	0.00
Centrarchidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cottidae	19.81	1.29	22.45	10.16	0.00	0.00	0.00	0.00
Cyprinidae	0.67	0.07	2.04	0.65	0.00	0.00	0.00	0.00
Gadidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ictaluridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Salmonidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified non-salmonidae	9.58	1.09	22.45	7.73	0.00	0.00	0.00	0.00
Unidentified Osteichthyes	0.49	0.48	6.12	1.65	0.00	0.00	0.00	0.00
Amphipoda								
Gammaridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified Amphipoda	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Arachnoidea								
Unidentified Arachnoidea	0.06	0.03	2.04	0.50	0.00	0.00	0.00	0.00
Cladocera/Copepoda								
Daphnidae	0.31	33.64	6.12	9.35	0.00	0.00	0.00	0.00
Leptodoridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified Cladocera/Copepoda	0.46	57.08	10.20	15.81	0.00	0.00	0.00	0.00
Coleoptera								
Carabidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chrysomelidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Curculionidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Elmidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 86. Continued

Species Diet Category	Smallmouth bass				Tench			
	% by Weight	% by Number	Frequency of Occurrence	Relative Importance	% by Weight	% by Number	Frequency of Occurrence	Relative Importance
Hydrophilidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Melyridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Staphylinidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Salpingidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified Coleoptera	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Decapoda								
Astacidae	47.25	0.27	14.29	14.42	0.00	0.00	0.00	0.00
Diptera								
Chironomidae larvae	0.03	1.19	14.29	3.62	2.28	95.45	100.00	49.43
Chironomidae pupae	0.02	0.14	6.12	1.46	0.00	0.00	0.00	0.00
Dixidae	0.00	0.03	2.04	0.48	0.00	0.00	0.00	0.00
Simuliidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tabanidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ephemeroptera								
Baetidae	0.06	0.20	8.16	1.97	0.00	0.00	0.00	0.00
Ephemerellidae	0.00	0.07	2.04	0.49	0.00	0.00	0.00	0.00
Heptageniidae	0.01	0.03	2.04	0.49	0.00	0.00	0.00	0.00
Hemiptera								
Belostomatidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Corixidae	0.42	1.50	16.33	4.26	0.00	0.00	0.00	0.00
Gelastocoridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gerridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Macroveliidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mesoveliidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Naucoridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ochteridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Saldidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 86. Continued

Species Diet Category	Smallmouth bass				Tench			
	% by Weight	% by Number	Frequency of Occurrence	Relative Importance	% by Weight	% by Number	Frequency of Occurrence	Relative Importance
Veliidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified Hemiptera	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Homoptera								
Unidentified Homoptera	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lepidoptera								
Unidentified Lepidoptera	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Odonata								
Aeshnidae	1.53	0.17	8.16	2.30	0.00	0.00	0.00	0.00
Unidentified Odonata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Trichoptera								
Brachycentridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Coenagrionidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Glossomatidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Helicopsychidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydropsychidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydroptilidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Limnephilidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nemouridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified Trichoptera	0.10	0.14	4.08	1.01	0.00	0.00	0.00	0.00
Plecoptera								
Chloroperlidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Peltoperlidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Perlidae	0.00	0.03	2.04	0.48	0.00	0.00	0.00	0.00
Perlodidae	0.12	0.20	4.08	1.03	0.00	0.00	0.00	0.00
Pteronarcyidae	0.00	0.03	2.04	0.48	0.00	0.00	0.00	0.00
Rhyacophilidae	0.01	0.03	2.04	0.49	0.00	0.00	0.00	0.00

Table 86. Continued

Species Diet Category	Smallmouth bass				Tench			
	% by Weight	% by Number	Frequency of Occurrence	Relative Importance	% by Weight	% by Number	Frequency of Occurrence	Relative Importance
Unidentified Plecoptera	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gastropoda								
Lymnaeidae	0.01	0.03	2.04	0.49	0.00	0.00	0.00	0.00
Physidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Planorbidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified Gastropoda	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pelecypoda								
Sphaeriidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified Pelecypoda	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Annelida								
Hirudinea	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oligocheata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified Annelida	3.96	0.68	2.04	1.56	0.00	0.00	0.00	0.00
Nematoda								
Unidentified Nematoda	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Planariidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified Arthropoda	1.38	0.31	18.37	4.68	0.00	0.00	0.00	0.00
Terrestrial	1.36	0.65	18.37	4.75	0.00	0.00	0.00	0.00
Other	6.31	0.41	24.49	7.28	97.72	4.55	100.00	50.57

Table 87. Percent by dry weight, percent by number, frequency of occurrence, and relative importance values of diet categories for walleye and yellow perch collected in Lake Roosevelt, WA (1999).

Species Diet Category	Walleye (n = 161)				Yellow perch (n = 4)			
	% by Weight	% by Number	Frequency of Occurrence	Relative Importance	% by Weight	% by Number	Frequency of Occurrence	Relative Importance
Osteichthyes								
Catostomidae	0.59	0.03	0.62	0.35	0.00	0.00	0.00	0.00
Centrarchidae	0.11	0.10	0.62	0.24	0.00	0.00	0.00	0.00
Cottidae	30.94	1.91	24.84	16.56	49.91	1.32	25.00	21.78
Cyprinidae	4.38	0.15	2.48	2.01	0.00	0.00	0.00	0.00
Gadidae	0.20	0.05	0.62	0.25	0.00	0.00	0.00	0.00
Ictaluridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Salmonidae	49.24	0.85	12.42	17.94	15.58	1.32	25.00	11.97
Unidentified non-salmonidae	11.50	1.56	25.47	11.06	0.00	0.00	0.00	0.00
Unidentified Osteichthyes	1.23	3.52	10.56	4.39	0.00	0.00	0.00	0.00
Amphipoda								
Gammaridae	0.00	0.08	0.62	0.20	0.00	0.00	0.00	0.00
Unidentified Amphipoda	0.00	0.15	1.24	0.40	0.00	0.00	0.00	0.00
Arachnoidea								
Unidentified Arachnoidea	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cladocera/Copepoda								
Daphnidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Leptodoridae	0.05	49.37	3.11	15.08	0.00	0.00	0.00	0.00
Unidentified Cladocera/Copepoda	0.04	28.66	1.86	8.77	0.00	0.00	0.00	0.00
Coleoptera								
Carabidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chrysomelidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Curculionidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Elmidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 87. Continued.

Species Diet Category	Walleye				Yellow perch			
	% by Weight	% by Number	Frequency of Occurrence	Relative Importance	% by Weight	% by Number	Frequency of Occurrence	Relative Importance
Hydrophilidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Melyridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Staphylinidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Salpingidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified Coleoptera	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Decapoda								
Astacidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Diptera								
Chironomidae larvae	0.30	4.70	11.80	4.82	9.20	23.68	25.00	16.54
Chironomidae pupae	0.19	5.48	10.56	4.66	21.06	69.74	25.00	33.09
Dixidae	0.00	0.05	0.62	0.19	0.00	0.00	0.00	0.00
Simuliidae	0.00	0.08	0.62	0.20	0.00	0.00	0.00	0.00
Tabanidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ephemeroptera								
Baetidae	0.02	1.36	3.11	1.29	0.00	0.00	0.00	0.00
Ephemerellidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heptageniidae	0.00	0.03	0.62	0.19	0.00	0.00	0.00	0.00
Hemiptera								
Belostomatidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Corixidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gelastocoridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gerridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Macroveliidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mesoveliidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Naucoridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ochteridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Saldidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 87. Continued

Species Diet Category	Walleye				Yellow perch			
	% by Weight	% by Number	Frequency of Occurrence	Relative Importance	% by Weight	% by Number	Frequency of Occurrence	Relative Importance
Veliidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified Hemiptera	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Homoptera								
Unidentified Homoptera	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lepidoptera								
Unidentified Lepidoptera	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Odonata								
Aeshnidae	0.09	0.03	0.62	0.21	0.00	0.00	0.00	0.00
Unidentified Odonata	0.00	0.05	0.62	0.19	0.00	0.00	0.00	0.00
Trichoptera								
Brachycentridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Coenagrionidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Glossomatidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Helicopsychidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydropsychidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydroptilidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Limnephilidae	0.02	0.08	1.86	0.56	0.00	0.00	0.00	0.00
Nemouridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified Trichoptera	0.04	0.13	2.48	0.76	0.00	0.00	0.00	0.00
Plecoptera								
Chloroperlidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Peltoperlidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Perlidae	0.01	0.03	0.62	0.19	0.00	0.00	0.00	0.00
Perlodidae	0.02	0.08	1.24	0.38	0.00	0.00	0.00	0.00
Pteronarcyidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rhyacophilidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 87. Continued

Species Diet Category	Walleye				Yellow perch			
	% by Weight	% by Number	Frequency of Occurrence	Relative Importance	% by Weight	% by Number	Frequency of Occurrence	Relative Importance
Unidentified Plecoptera	0.01	0.25	1.24	0.43	0.00	0.00	0.00	0.00
Gastropoda								
Lymnaeidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Physidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Planorbidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified Gastropoda	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pelecypoda								
Sphaeriidae	0.00	0.00	0.00	0.00	0.18	2.63	25.00	7.95
Unidentified Pelecypoda	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Annelida								
Hirudinea	0.06	0.03	0.62	0.20	0.00	0.00	0.00	0.00
Oligocheata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified Annelida	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nematoda								
Unidentified Nematoda	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Planariidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified Arthropod	0.02	0.15	3.73	1.12	4.07	1.32	25.00	8.68
Terrestrial	0.08	0.30	4.35	1.36	0.00	0.00	0.00	0.00
Other	0.86	0.78	19.25	6.00	0.00	0.00	0.00	0.00

Appendix B. Creel survey tables.

Table 88. Corrected mean boat angler hours per strata in the upper section (1) of Lake Roosevelt, WA (1999).

STRATA		Correction factor (Air/ground)	Sum of boats	Sum of days sampled	Mean Boat Trailers for the day	% Boat Fishing	Mean Number Angler/boat	Number Angler/boat S.D.	Corrected mean angler	Corrected X angler S.D.
December	WD	1.539	2	12	0.17	1	3.00	0	0.8	0.0
	WE	2.275	8	8	1.00	1	3.00	0	6.8	0.0
January	WD	1.539	2	15	0.13	1	2.00	0	0.4	0.0
	WE	2.275	2	6	0.33	1	2.00	0	1.5	0.0
February	WD	1.539	4	13	0.31	1	1.50	0.58	0.7	0.3
	WE	2.275	6	7	0.86	1	2.00	0	3.9	0.0
March	WD	1.390	12	16	0.75	1	2.08	0.64	2.2	0.7
	WE	0.974	10	6	1.67	0.21	2.00	0	0.7	0.0
April	WD	1.390	x	x	x	x	x	x	x	x
	WE	0.974	x	x	x	x	x	x	x	x
May	WD	1.390	0	14	0.00	1	2.00	0	0.0	0.0
	WE	0.974	7	8	0.88	1	2.00	0	1.7	0.0
June	WD	0.893	91	16	5.69	1	1.73	0.65	8.8	3.3
	WE	1.261	136	5	27.20	1	1.67	0.58	57.2	19.9
July	WD	0.893	180	13	13.85	0.38	1.91	0.7	9.0	3.3
	WE	1.261	343	8	42.88	0.21	1.50	0.58	17.0	6.6
August	WD	0.893	161	15	10.73	0.23	1.63	0.52	3.6	1.1
	WE	1.261	452	7	64.57	0.33	1.83	0.41	49.3	11.0
September	WD	1.144	73	15	4.87	0.56	1.60	0.55	5.0	1.7
	WE	1.382	54	4	13.50	0.5	1.60	0.55	14.9	5.1
October	WD	1.144	x	x	x	x	x	x	x	x
	WE	1.382	x	x	x	x	x	x	x	x
November	WD	1.144	x	x	x	x	x	x	x	x
	WE	1.382	x	x	x	x	x	x	x	x
Annual	WD	1.242	525	129	4.05	0.80	1.83	0.64	7.3	2.6
Annual	WE	1.473	1018	59	16.99	0.63	1.73	0.46	27.1	7.2
Grand		1.357	1543	188	10.52	0.75	1.80	0.59	19.2	6.3

An x denotes that creel surveys were not performed.

Table 89. Corrected mean boat angler hours per strata in the middle section (2) of Lake Roosevelt, WA (1999).

STRATA		Correction factor (Air/ground)	Sum of boats	Sum of days sampled	Mean Boat Trailers for the day	% Boat Fishing	Mean Number Angler/boat	Number Angler/boat S.D.	Corrected mean angler	Corrected X angler S.D.
December	WD	1.539	21	12	1.75	1	1.5	0.71	4.0	1.9
	WE	2.275	29	7	4.14	1	2.5	0.71	23.6	6.7
January	WD	1.539	28	9	3.11	1	2.13	0.99	10.2	4.7
	WE	2.275	63	6	10.50	1	2.33	1.15	55.7	27.5
February	WD	1.539	24	10	2.40	1	2	0	7.4	0.0
	WE	2.275	74	6	12.33	1	2.33	0.58	65.4	16.3
March	WD	1.390	42	12	3.50	0.97	2.13	0.64	10.1	3.0
	WE	0.974	33	5	6.60	1	2	0	12.9	0.0
April	WD	1.390	x	x	x	x	x	x	x	x
	WE	0.974	x	x	x	x	x	x	x	x
May	WD	1.390	7	10	0.70	1	2.07	0.71	2.0	0.7
	WE	0.974	2	6	0.33	1	2.32	0.68	0.8	0.2
June	WD	0.893	172	8	21.50	0.81	2	0.82	31.1	12.8
	WE	1.261	157	3	52.33	0.95	2.28	0.75	142.9	47.0
July	WD	0.893	651	10	65.10	0.06	2	0	7.0	0.0
	WE	1.261	755	6	125.83	0.07	2.67	0.58	29.7	6.4
August	WD	0.893	794	10	79.40	0.06	2	0	8.5	0.0
	WE	1.261	338	3	112.67	0.07	2	0	19.9	0.0
September	WD	1.144	208	8	26.00	0.88	1.75	0.5	45.8	13.1
	WE	1.382	91	3	30.33	0.54	2.32	0.58	52.5	13.1
October	WD	1.144	70	6	11.67	1	2.6	0.89	34.7	11.9
	WE	1.382	37	2	18.50	1	2.33	0.58	59.6	14.8
November	WD	1.144	x	x	x	x	x	x	x	x
	WE	1.382	x	x	x	x	x	x	x	x
Annual	WD	1.242	2017	95	21.23	0.78	2.07	0.71	42.5	14.6
	WE	1.473	1579	47	33.60	0.67	2.32	0.58	76.8	19.2
Grand		1.357	3596	142	25.32	0.72	2.18	0.71	54.2	17.7

An x denotes that creel surveys were not performed.

Table 90. Corrected mean boat angler hours per strata in the lower section (1) of Lake Roosevelt, WA (1999).

STRATA		Correction factor (Air/ground)	Sum of boats	Sum of days sampled	Mean Boat Trailers for the day	% Boat Fishing	Mean Number Angler/boat	Number Angler/boat S.D.	Corrected mean angler	Corrected X angler S.D.
December	WD	1.539	9	11	0.82	0.92	1.4	0.7	1.6	0.8
	WE	2.275	2	4	0.50	1	2.08	0.86	2.4	1.0
January	WD	1.539	23	9	2.56	1	1.5	0.71	5.9	2.8
	WE	2.275	24	9	2.67	1	2.67	0.58	16.2	3.5
February	WD	1.539	60	11	5.45	1	1	0	8.4	0.0
	WE	2.275	22	7	3.14	1	2.08	0.86	14.9	6.1
March	WD	1.390	83	13	6.38	1	1.4	0.7	12.4	6.2
	WE	0.974	61	8	7.63	1	2.08	0.86	15.4	6.4
April	WD	1.390	x	x	x	x	x	x	x	x
	WE	0.974	x	x	x	x	x	x	x	x
May	WD	1.390	24	9	2.67	1	1.4	0.7	5.2	2.6
	WE	0.974	14	4	3.50	1	2.08	0.86	7.1	2.9
June	WD	0.893	288	14	20.57	1	1	0	18.4	0.0
	WE	1.261	217	8	27.13	1	2	1.15	68.4	39.3
July	WD	0.893	903	12	75.25	0.54	1.4	0.7	50.8	25.4
	WE	1.261	1099	7	157.00	0.67	2.08	0.86	275.9	114.1
August	WD	0.893	1655	13	127.31	0.54	1.75	0.96	107.4	58.9
	WE	1.261	1222	8	152.75	0.67	1.33	0.58	171.6	74.9
September	WD	1.144	304	11	27.64	0.88	1	0	27.8	0.0
	WE	1.382	75	2	37.50	0.56	2	0	58.0	0.0
October	WD	1.144	61	12	5.08	1	1	0	5.8	0.0
	WE	1.382	35	6	5.83	1	3	0	24.2	0.0
November	WD	1.144	x	x	x	x	x	x	x	x
	WE	1.382	x	x	x	x	x	x	x	x
Annual	WD	1.242	3410	115	29.65	0.89	1.40	0.70	45.8	22.9
	WE	1.473	2771	63	43.98	0.84	2.08	0.86	113.7	47.0
Grand		1.357	6181	178	34.72	0.87	1.78	0.85	72.7	34.7

An x denotes that creel surveys were not performed.

Table 91. Pressure estimates calculated per month per strata in the upper section (1) of Lake Roosevelt, WA (1999).

Strata	Hours per day Hd	Days per month Ds	Hours per month Ns	Hours Creeled per month n	Time correction Factor Ns/n	Angler Hours per angler angler Ha	Mean anglers per day Xd	Mean # anglers per month Xs	± angler per day Sd	± anglers per month Ss	Pressure Estimate per month PE	Variance of PE per month VPE	95% C.I. per month CI
DECEMBER													
WEEKDAY													
SHORE	8.40	22	184.80	33.92	5.45	3.00	0.58	12.76	0.90	19.8	209	2,136	91
BOAT	8.40	22	184.80	33.92	5.45	6.07	0.80	17.60	0.00	0.0	582	0	0
WEEKEND													
SHORE	8.40	9	75.60	17.47	4.33	3.00	1.38	12.42	1.77	15.9	161	1,098	65
BOAT	8.40	9	75.60	17.47	4.33	6.07	6.80	61.20	0.00	0.0	1,608	0	0
Total											2,559	3,234	111
JANUARY													
WEEKDAY													
SHORE	8.83	23	203.09	51.37	3.95	4.73	2.93	67.39	1.94	44.6	1,261	7,871	174
BOAT	8.83	23	203.09	51.37	3.95	2.84	0.40	9.20	0.00	0.0	103	0	0
WEEKEND													
SHORE	8.83	8	70.64	17.2	4.11	3.26	4.67	37.36	1.97	15.8	500	1,020	63
BOAT	8.83	8	70.64	17.2	4.11	6.07	1.50	12.00	0.00	0.0	299	0	0
Total											2,163	8,891	185
FEBRUARY													
WEEKDAY													
SHORE	10.25	20	205.00	36.82	5.57	3.67	0.54	10.80	0.78	15.6	221	1,355	72
BOAT	10.25	20	205.00	36.82	5.57	6.06	0.70	14.00	0.30	6.0	472	200	28
WEEKEND													
SHORE	10.25	8	82.00	19.75	4.15	5.09	1.14	9.12	1.68	13.4	193	750	54
BOAT	10.25	8	82.00	19.75	4.15	7.17	3.90	31.20	0.00	0.0	928	0	0
Total											1,813	2,305	94
MARCH													
WEEKDAY													
SHORE	11.97	21	251.37	40.27	6.24	4.22	0.19	3.99	0.54	11.3	105	803	56
BOAT	11.97	21	251.37	40.27	6.24	6.94	2.20	46.20	0.70	14.7	2,001	1,349	72
WEEKEND													
SHORE	11.97	10	119.70	13.42	8.92	4.22	0.50	5.00	1.22	12.2	188	1,328	71
BOAT	11.97	10	119.70	13.42	8.92	8.92	0.70	7.00	0.00	0.0	557	0	0
Total											2,851	3,479	116

Table 91. Continued.

Strata	Hours per day Hd	Days per month Ds	Hours per month Ns	Hours Creed per month n	Time correction Factor Ns/n	Angler Hours per angler angler Ha	Mean anglers per day Xd	Mean # anglers per month Xs	± angler per day Sd	± anglers per month Ss	Pressure Estimate per month PE	Variance of PE per month VPE	95% C.I. per month CI
MAY													
WEEKDAY													
SHORE	15.20	22	334.40	31	10.79	4.22	0.00	0.00	0.00	0.0	0	0	0
BOAT	15.20	22	334.40	31	10.79	6.07	0.00	0.00	0.00	0.0	0	0	0
WEEKEND													
SHORE	15.20	9	136.80	19.02	7.19	4.22	0.00	0.00	0.00	0.0	0	0	0
BOAT	15.20	9	136.80	19.02	7.19	4.92	1.70	15.30	0.00	0.0	541	0	0
Total											541	0	0
JUNE													
WEEKDAY													
SHORE	16.02	21	336.42	53.22	6.32	4.22	0.00	0.00	0.00	0.0	0	0	0
BOAT	16.02	21	336.42	53.22	6.32	6.40	8.80	184.80	3.30	69.3	7,481	30,358	342
WEEKEND													
SHORE	16.02	9	144.18	11	13.11	4.22	0.00	0.00	0.00	0.0	0	0	0
BOAT	16.02	9	144.18	11	13.11	6.53	57.20	514.80	19.90	179.1	44,062	420,439	1,271
Total											51,543	450,798	1,316
JULY													
WEEKDAY													
SHORE	15.67	23	360.41	34.93	10.32	4.22	0.00	0.00	0.00	0.0	0	0	0
BOAT	15.67	23	360.41	34.93	10.32	5.55	9.00	207.00	3.30	75.9	11,856	59,440	478
WEEKEND													
SHORE	15.67	8	125.36	15.63	8.02	4.22	0.00	0.00	0.00	0.0	0	0	0
BOAT	15.67	8	125.36	15.63	8.02	5.57	17.00	136.00	6.60	52.8	6,072	22,360	293
Total											17,928	81,800	561
AUGUST													
WEEKDAY													
SHORE	14.38	21	301.98	43.02	7.02	4.22	0.00	0.00	0.00	0.0	0	0	0
BOAT	14.38	21	301.98	43.02	7.02	5.58	3.60	75.60	1.10	23.1	2,963	3,746	120
WEEKEND													
SHORE	14.38	10	143.80	16.35	8.80	4.22	0.00	0.00	0.00	0.0	0	0	0
BOAT	14.38	10	143.80	16.35	8.80	5.73	49.30	493.00	11.00	110.0	24,865	106,421	639
Total											27,828	110,166	651

Table 91. Continued.

Strata	Hours per day Hd	Days per month Ds	Hours per month Ns	Hours Creeled per month n	Time correction Factor Ns/n	Angler Hours per angler angler Ha	Mean anglers per day Xd	Mean # anglers per month Xs	± angler per day Sd	± anglers per month Ss	Pressure Estimate per month PE	Variance of PE per month VPE	95% C.I. per month CI
SEPTEMBER													
WEEKDAY													
SHORE	12.45	22	273.90	40.1	6.83	4.22	0.00	0.00	0.00	0.0	0	0	0
BOAT	12.45	22	273.90	40.1	6.83	5.44	5.00	110.00	1.70	37.4	4,091	9,554	192
WEEKEND													
SHORE	12.45	8	99.60	8.15	12.22	4.22	0.00	0.00	0.00	0.0	0	0	0
BOAT	12.45	8	99.60	8.15	12.22	5.28	14.90	119.20	5.10	40.8	7,684	20,343	280
Total						4.79					11,775	29,897	339
Annual Totals						5.01					119,002	690,571	1,629

Table 92. Pressure estimates calculated per month per strata in the middle section (2) of Lake Roosevelt, WA (1999).

Strata	Hours per day Hd	Days per month Ds	Hours per month Ns	Hours Creel'd per month n	Time correction Factor Ns/n	Angler Hours per angler Ha	Mean anglers per day Xd	Mean # anglers per month Xs	± angler hrs. per day Sd	± anglers per month Ss	Pressure Estimate per month PE	Variance of PE per month VPE	95% C.I. per month CI
DECEMBER													
WEEKDAY													
SHORE	8.40	22	184.80	39.98	4.62	2.59	11	242.00	6.27	137.9	2,892	87,951	581
BOAT	8.40	22	184.80	39.98	4.62	5.72	4	88.00	1.90	41.8	2,325	8,076	176
WEEKEND													
SHORE	8.40	9	75.60	18.03	4.19	3.00	11.29	101.61	7.99	71.9	1,278	21,682	289
BOAT	8.40	9	75.60	18.03	4.19	5.10	23.6	212.40	6.70	60.3	4,542	15,246	242
Total						4.10					11,036	132,955	1,288
JANUARY													
WEEKDAY													
SHORE	8.83	23	203.09	28.2	7.20	4.27	11.78	270.94	4.63	106.5	8,336	81,669	560
BOAT	8.83	23	203.09	28.2	7.20	4.75	10.2	234.60	4.70	108.1	8,025	84,157	569
WEEKEND													
SHORE	8.83	8	70.64	18.98	3.72	3.21	37.50	300.00	30.82	246.6	3,584	226,256	932
BOAT	8.83	8	70.64	18.98	3.72	5.10	55.7	445.60	27.50	220.0	8,458	180,136	832
Total						4.33					28,404	572,218	2,893
FEBRUARY													
WEEKDAY													
SHORE	10.25	20	205.00	26.58	7.71	3.21	5.50	110.00	4.30	86.0	2,723	57,042	468
BOAT	10.25	20	205.00	26.58	7.71	3.75	7.4	148.00	0.00	0.0	4,280	0	0
WEEKEND													
SHORE	10.25	8	82.00	20.08	4.08	3.21	27.67	221.36	17.48	139.8	2,902	79,857	554
BOAT	10.25	8	82.00	20.08	4.08	5.10	65.4	523.20	16.30	130.4	10,897	69,439	516
Total						3.82					20,802	206,338	1,538
MARCH													
WEEKDAY													
SHORE	11.97	21	251.37	36.93	6.81	2.43	4.92	103.32	4.62	97.0	1,711	64,070	496
BOAT	11.97	21	251.37	36.93	6.81	4.48	10.1	212.10	3.00	63.0	6,471	27,016	322
WEEKEND													
SHORE	11.97	10	119.70	13.53	8.85	1.67	10	100.00	10.79	107.9	1,475	103,000	629
BOAT	11.97	10	119.70	13.53	8.85	5.10	12.9	129.00	0.00	0.0	5,820	0	0
Total						3.42					15,478	194,086	1,447

Table 92. Continued.

	Hours per day	Days per month	Hours per month	Hours Creeled per month	Time correction Factor	Angler Hours per angler	Mean anglers per day	Mean # anglers per month	± angler hrs. per day	± anglers per month	Pressure Estimate per month	Variance of PE per month	95% C.I. per month
Strata	Hd	Ds	Ns	n	Ns/n	Ha	Xd	Xs	Sd	Ss	PE	VPE	CI
MAY													
WEEKDAY													
SHORE	15.20	22	334.40	39.07	8.56	3.21	0.27	5.94	0.65	14.3	163	1,750	82
BOAT	15.20	22	334.40	39.07	8.56	5.10	2.00	44.00	0.70	15.4	1,921	2,030	88
WEEKEND													
SHORE	15.20	9	136.80	12.38	11.05	3.21	0	0.00	0.00	0.0	0	0	0
BOAT	15.20	9	136.80	12.38	11.05	5.10	0.8	7.20	0.20	1.8	406	36	12
Total						4.16					2,490	3,816	182
JUNE													
WEEKDAY													
SHORE	16.02	21	336.42	25.78	13.05	3.18	5.13	107.73	4.52	94.9	4,464	117,575	672
BOAT	16.02	21	336.42	25.78	13.05	5.71	31.1	653.10	12.80	268.8	48,693	942,882	1,903
WEEKEND													
SHORE	16.02	9	144.18	6.02	23.95	3.21	7.00	63.00	4.58	41.2	4,843	40,693	395
BOAT	16.02	9	144.18	6.02	23.95	5.13	142.9	1286.10	47.00	423.0	157,943	4,285,379	4,057
Total						4.31					215,944	5,386,530	7,028
JULY													
WEEKDAY													
SHORE	15.67	23	360.41	25.1	14.36	3.21	2.60	59.80	3.77	86.7	2,756	107,960	644
BOAT	15.67	23	360.41	25.1	14.36	7.50	7	161.00	0.00	0.0	17,338	0	0
WEEKEND													
SHORE	15.67	8	125.36	18.52	6.77	3.21	3.33	26.64	3.01	24.1	579	3,925	123
BOAT	15.67	8	125.36	18.52	6.77	5.40	29.7	237.60	6.40	51.2	8,685	17,744	261
Total						4.83					29,358	129,629	1,028
AUGUST													
WEEKDAY													
SHORE	14.38	21	301.98	23.48	12.86	3.21	2.40	50.40	2.40	50.4	2,081	32,669	354
BOAT	14.38	21	301.98	23.48	12.86	5.10	8.50	178.50	0.00	0.0	11,708	0	0
WEEKEND													
SHORE	14.38	10	143.80	6.77	21.24	3.21	2.33	23.30	4.04	40.4	1,589	34,668	365
BOAT	14.38	10	143.80	6.77	21.24	5.10	19.9	199.00	0.00	0.0	21,557	0	0
Total						4.16					36,935	67,338	719

Table 92. Continued.

Strata	Hours per day Hd	Days per month Ds	Hours per month Ns	Hours Creeled per month n	Time correction Factor Ns/n	Angler Hours per angler Ha	Mean anglers per day Xd	Mean # anglers per month Xs	± angler hrs. per day Sd	± anglers per month Ss	Pressure Estimate per month PE	Variance of PE per month VPE	95% C.I. per month CI
SEPTEMBER													
WEEKDAY													
SHORE	12.45	22	273.90	23.23	11.79	3.21	1.38	30.36	1.92	42.2	1,149	21,037	284
BOAT	12.45	22	273.90	23.23	11.79	6.81	45.8	1007.60	13.10	288.2	80,953	979,334	1,940
WEEKEND													
SHORE	12.45	8	99.60	10.58	9.41	3.21	0.00	0.00	0.00	0.0	0	0	0
BOAT	12.45	8	99.60	10.58	9.41	5.10	52.5	420.00	13.10	104.8	20,165	103,394	630
Total						4.58					102,267	1,103,765	2,854
OCTOBER													
WEEKDAY													
SHORE	12.45	22	273.90	17.13	15.99	3.21	3.83	84.26	8.45	185.9	4,325	552,578	1,457
BOAT	12.45	22	273.90	17.13	15.99	5.10	34.70	763.40	11.90	261.8	62,253	1,095,908	2,052
WEEKEND													
SHORE	12.45	8	99.60	5.13	19.42	3.21	1.50	12.00	0.71	5.7	748	626	49
BOAT	12.45	8	99.60	5.13	19.42	3.55	59.6	476.80	14.80	118.4	32,837	272,173	1,023
Total						3.77					100,162	1,921,285	4,580
Annual Totals							4.15	54.2	17.70		562,874	9,717,961	23,558

Table 93. Pressure estimates calculated per month per strata in the lower section (3) of Lake Roosevelt, WA (1999).

Strata	Hours per day Hd	Days per month Ds	Hours per month Ns	Hours Creeled per month n	Time correction Factor Ns/n	Angler Hours per angler Ha	Mean anglers per day Xd	Mean # anglers per month Xs	± angler hrs. per day Sd	± anglers per month Ss	Pressure Estimate per month PE	Variance of PE VPE	95% C.I. per month CI
DECEMBER													
WEEKDAY													
SHORE	8.40	22	184.80	48.75	3.79	4.71	1	22.00	1.84	40.5	393	6,212	154
BOAT	8.40	22	184.80	48.75	3.79	5.96	1.6	35.20	0.80	17.6	795	1,174	67
WEEKEND													
SHORE	8.40	9	75.60	14.67	5.15	3.18	0.25	2.25	0.50	4.5	37	104	20
BOAT	8.40	9	75.60	14.67	5.15	5.96	2.4	21.60	1.00	9.0	663	417	40
Total											1,889	7,908	282
JANUARY													
WEEKDAY													
SHORE	8.83	23	203.09	34.33	5.92	3.18	1.78	40.94	2.77	63.7	770	24,012	304
BOAT	8.83	23	203.09	34.33	5.92	4.17	5.9	135.70	2.80	64.4	3,345	24,535	307
WEEKEND													
SHORE	8.83	8	70.64	39.67	1.78	3.18	2.44	19.52	6.29	50.3	111	4,509	132
BOAT	8.83	8	70.64	39.67	1.78	5.95	16.2	129.60	3.50	28.0	1,373	1,396	73
Total						4.12					5,598	54,452	816
FEBRUARY													
WEEKDAY													
SHORE	10.25	20	205.00	42.83	4.79	4.58	3.45	69.00	4.20	84.0	1,513	33,773	360
BOAT	10.25	20	205.00	42.83	4.79	5.00	8.40	168.00	0.00	0.0	4,021	0	0
WEEKEND													
SHORE	10.25	8	82.00	36.58	2.24	1.46	5.86	46.88	10.48	83.8	153	15,757	246
BOAT	10.25	8	82.00	36.58	2.24	5.96	14.9	119.20	6.10	48.8	1,593	5,338	143
Total						4.25					7,279	54,868	749
MARCH													
WEEKDAY													
SHORE	11.97	21	251.37	58.38	4.31	2.90	5.77	121.17	5.45	114.5	1,515	56,400	465
BOAT	11.97	21	251.37	58.38	4.31	5.96	12.40	260.40	6.20	130.2	6,682	72,991	530
WEEKEND													
SHORE	11.97	10	119.70	37.08	3.23	4.00	5.63	56.30	4.03	40.3	727	5,243	142
BOAT	11.97	10	119.70	37.08	3.23	5.96	15.4	154.00	6.40	64.0	2,963	13,223	225
Total						4.71					11,887	147,857	1,362

Table 93. Continued.

Strata	Hours per day Hd	Days per month Ds	Hours per month Ns	Hours Creeled per month n	Time correction Factor Ns/n	Angler Hours per angler Ha	Mean anglers per day Xd	Mean # anglers per month Xs	± angler hrs. per day Sd	± anglers per month Ss	Pressure Estimate per month PE	Variance of PE VPE	95% C.I. per month CI
MAY													
WEEKDAY													
SHORE	15.20	22	334.40	57.32	5.83	3.29	5.56	122.32	4.28	94.2	2,350	51,724	446
BOAT	15.20	22	334.40	57.32	5.83	5.96	5.20	114.40	2.60	57.2	3,978	19,088	271
WEEKEND													
SHORE	15.20	9	136.80	25.08	5.45	3.18	4	36.00	6.16	55.4	624	16,765	254
BOAT	15.20	9	136.80	25.08	5.45	5.96	7.1	63.90	2.90	26.1	2,077	3,716	119
Total						4.60					9,029	91,292	1,090
JUNE													
WEEKDAY													
SHORE	16.02	21	336.42	73	4.61	2.75	1.71	35.91	2.05	43.1	455	8,541	181
BOAT	16.02	21	336.42	73	4.61	3.67	18.40	386.40	0.00	0.0	6,535	0	0
WEEKEND													
SHORE	16.02	9	144.18	18.92	7.62	3.00	3.38	30.42	9.55	86.0	695	56,296	465
BOAT	16.02	9	144.18	18.92	7.62	5.95	68.4	615.60	39.30	353.7	27,901	953,354	1,914
Total						3.84					35,587	1,018,190	2,560
JULY													
WEEKDAY													
SHORE	15.67	23	360.41	66.95	5.38	3.18	2.25	51.75	2.09	48.1	886	12,439	219
BOAT	15.67	23	360.41	66.95	5.38	5.96	50.80	1168.40	25.40	584.2	37,487	1,837,255	2,657
WEEKEND													
SHORE	15.67	8	125.36	28.58	4.39	3.18	0.29	2.32	0.49	3.9	32	67	16
BOAT	15.67	8	125.36	28.58	4.39	5.96	275.9	2207.20	114.10	912.8	57,701	3,654,669	3,747
Total						4.57					96,107	5,504,430	6,638
AUGUST													
WEEKDAY													
SHORE	14.38	21	301.98	58.58	5.16	3.18	0.00	0.00	0.00	0.0	0	0	0
BOAT	14.38	21	301.98	58.58	5.16	7.17	107.4	2255.40	58.90	1236.9	83,329	7,886,749	5,504
WEEKEND													
SHORE	14.38	10	143.80	31.58	4.55	3.18	0.00	0.00	0.00	0.0	0	0	0
BOAT	14.38	10	143.80	31.58	4.55	5.65	171.6	1716.00	74.90	749.0	44,109	2,554,526	3,133
Total						4.79					127,439	10,441,275	8,637

Table 93. Continued.

Strata	Hours per day Hd	Days per month Ds	Hours per month Ns	Hours Creeled per month n	Time correction Factor Ns/n	Angler Hours per angler Ha	Mean anglers per day Xd	Mean # anglers per month Xs	± angler hrs. per day Sd	± anglers per month Ss	Pressure Estimate per month PE	Variance of PE VPE	95% C.I. per month CI
SEPTEMBER													
WEEKDAY													
SHORE	12.45	22	273.90	44.58	6.14	0.92	0.64	14.08	1.43	31.5	80	6,081	153
BOAT	12.45	22	273.90	44.58	6.14	4.67	27.8	611.60	0.00	0.0	17,548	0	0
WEEKEND													
SHORE	12.45	8	99.60	8.3	12.00	3.18	0.50	4.00	0.71	5.7	153	387	39
BOAT	12.45	8	99.60	8.3	12.00	6.54	58	464.00	0.00	0.0	36,429	0	0
Total						3.83					54,209	6,468	191
October													
WEEKDAY													
SHORE	12.45	22	273.90	56.42	4.85	3.18	0.25	5.50	0.45	9.9	85	476	43
BOAT	12.45	22	273.90	56.42	4.85	2.75	5.80	127.60	0.00	0.0	1,704	0	0
WEEKEND													
SHORE	12.45	8	99.60	25.75	3.87	3.18	0.50	4.00	0.84	6.7	49	175	26
BOAT	12.45	8	99.60	25.75	3.87	7.17	24.2	193.60	0.00	0.0	5,367	0	0
Total						4.07					7,204	650	69
Annual Totals											356,228	17,327,391	22,394