May 1999

LAKE ROOSEVELT MONITORING DATA COLLECTION PROGRAM

Annual Report 1997

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LAKE ROOSEVELT MONITORING/DATA COLLECTION PROGRAM

1997 ANNUAL REPORT

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May 1999

This report contains preliminary data and conclusions that may be subject to change. This report may be cited in publications, but the manuscript status (Annual Report) must be noted.

EXECUTIVE SUMMARY

The Lake Roosevelt Monitoring / Data Collection Program is the result of a merger between two projects, the Lake Roosevelt Monitoring Program (BPA No. 8806300) and the Lake Roosevelt Data Collection Project (BPA No. 9404300). These projects were merged in 1996 to continue work historically completed under the separate projects. The project will develop a model to predict biological responses to reservoir operations and evaluate the effects of releasing hatchery origin kokanee salmon and rainbow trout on the fishery.

Primary production in Lake Roosevelt was investigated for the first time as part of this program during 1997. Thirty individual periphyton taxa were identified from Lake Roosevelt between August and October. Diatoms comprised 96 % of the periphyton density, and 88 % of the periphyton biomass observed. Periphyton colonization rates at Seven Bays and Spring Canyon were significantly higher than those at Gifford and Porcupine Bay however, colonization rates declined throughout the observed period at all sites. Results of our study indicate that periphyton growth / colonization in Lake Roosevelt may be inhibited during drawdown and benefited during refill conditions in the Lake. Phytoplankton surveys were conducted in Lake Roosevelt from May through December, 1997, with 51 taxa identified. Phytoplankton densities were highest from May through June, corresponding with increased chlorophyll *a* levels. Volumetrically, unicellular flagellates and diatoms (both of which are important in the diet of zooplankton) dominated phytoplankton collections throughout our sampling period.

Zooplankton collections from Lake Roosevelt exhibited a dicyclic population peak (July and September) during 1997, unlike previous years. The population however maintained its historic diversity with 17 species of Cladocera and five species of Copepoda identified during 1997 surveys. The large number of species including a large range of sizes of zooplankton sampled during 1997 suggests that the population is not being substantially cropped by planktivorous fishes stocked into Lake Roosevelt. Reservoir mean temperature within the growing season was found to best predict total zooplankton density ($r^2 = 0.70$) and biomass ($r^2 = 0.60$) in Lake Roosevelt during 1997. Attempts to model the effects of other environmental variables (chlorophyll *a*, secchi depth, daily WRT, daily temperature, and reservoir inflow, outflow, and elevation) on zooplankton were generally unsuccessful, with individual variables generally accounting for less than 5 percent of the variance in zooplankton densities or biomass.

The program also evaluates success of various stocking strategies to increase fish harvest while maximizing the return of spawning kokanee to egg collection facilities. Stocking of rainbow trout and kokanee salmon into Lake Roosevelt began from the Spokane Tribal Hatchery in 1991 and the Sherman Creek Hatchery in 1992. Approximately 2.5 million kokanee salmon and 400,000 rainbow trout have been released annually since both hatcheries went on line. We estimated that anglers made 146,264 trips to Lake Roosevelt during 1997 with an economic value of $5,841,784. Tag return data suggested excessive entrainment occurred in 1997, with 97 percent (146 of 151) of tag recoveries from rainbow trout coming from below Grand Coulee Dam. Estimated harvest of kokanee salmon (588 fish) in 1997 declined relative to 1996 (1,265), and in particular, relative to 1995 (32,353 fish). Estimated harvest of rainbow trout from Lake Roosevelt declined dramatically in 1997 (5,366 fish) relative to 1996 (127,025 fish). High entrainment, decreased fishing pressure due to drawdown, and decreased sensitivity of creel analysis during periods of low fishing pressure may have contributed to reduced harvest estimates of kokanee salmon and rainbow trout during 1997. In contrast, our estimated 1997 harvest of smallmouth bass (2,331) each increased dramatically relative to 1996 (79). Our harvest estimate for walleye during 1997 (87,515) was reduced relative to 1996 (104,055) however, the estimated number of walleye caught during 1997 (147,316) was the highest since 1993.

Creel data indicates that hatchery reared rainbow trout contribute substantially to the Lake Roosevelt fishery and in 1997, 100 percent of the rainbow trout observed in the creel were of hatchery origin. Analysis of historical tagging data indicates that hydro-operations can have a substantial influence on entrainment rates of rainbow trout from Lake Roosevelt. Water retention times below approximately 30 days lead to substantial entrainment of rainbow trout from Lake Roosevelt, and rainbow trout are entrained at greater rates during reservoir drawdown than during other operations, regardless of water retention times in the reservoir. Walleye are an important component of the fishery in Lake Roosevelt as well. However, catch and harvest estimates of walleye vary across years probably as a result of variable year class strength and/or recruitment from year to year. Variations in walleye recruitment are probably due to a combination of factors including annual hydro-operations, fishing pressure, and spawning success.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

The Lake Roosevelt Monitoring / Data Collection Program 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 due to overlapping support staff and data requirements. The Lake Roosevelt Monitoring / Data Collection Program continues work historically completed under the separate projects and will develop a biological rule curve for Lake Roosevelt.

1.1 Project History

The Lake Roosevelt Monitoring Program began July 1988. The primary objective was to determine stocking strategies of hatchery origin kokanee salmon (*Oncorhynchus nerka*) and rainbow trout (*Oncorhynchus mykiss*) that maximized angler harvest and return of kokanee salmon to egg collection facilities. In addition, the project collected baseline data to evaluate effects of stocking kokanee salmon and rainbow trout on the ecosystem and assessed the effectiveness of kokanee salmon hatcheries and rainbow trout enhancement strategies. Tasks of the Monitoring Program were to conduct a year round reservoir wide creel survey, sample the fishery during spring, summer and fall via electrofishing and gillnet surveys, and collect information on diet, growth, and age composition of various fish species in Lake Roosevelt. Data was also analyzed to determine food availability and utilization, and angler use information (e.g. harvest).

The Lake Roosevelt Data Collection Project began in July, 1991 as part of the Bonneville Power Administration (BPA), Bureau of Reclamation (BOR), and U.S. Army Corps of Engineer's (USACE) System Operation Review process. This process sought to develop an operational scenario for the Federal Columbia River Hydropower System which minimized impacts to all stakeholders of the Columbia River. The objective of the Data Collection Project was to develop a biological model for Lake Roosevelt that will predict biological responses to different reservoir operation strategies. 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, downstream and anadromous fisheries). Major components of the Lake Roosevelt model will be: 1) quantification of entrainment and other impacts to phytoplankton, zooplankton and fish caused by reservoir drawdowns and low water retention times; 2) seasonal quantification, distribution and use information for fish food organisms in the reservoir; and 3) examination of variations in fish growth and its relation to reservoir operations, prey abundance and prey utilization.

Previous annual reports for the Lake Roosevelt Data Collection Project include Griffith et al. (1995), Griffith and McDowell (1996), Voeller (1996), Shields and Underwood (1996 and 1997), and Cichosz et al. (1998). Previous reports for the Lake Roosevelt Monitoring Program include Peone et al. (1990), Griffith and Scholz (1991), Griffith et al. (1995), Underwood and Shields (1996), Underwood et al. (1996 and 1997) and Cichosz et al. (1998).

1.2 History of Kokanee Salmon and Rainbow Trout Stocking

From 1988 to 1990, kokanee salmon reared at the Ford Hatchery by the Washington Department of Fish and Wildlife (WDFW) were stocked into Lake Roosevelt. Approximately 750,000 and 100,000 kokanee salmon fry were stocked into Sherman Creek and the Spokane River at Little Falls Dam, respectively, each year between May and July. Rainbow trout fry were provided to the Lake Roosevelt Net Pen Program by the Spokane Hatchery (WDFW) from 1986 to 1990. The number of rainbow trout provided by the Spokane Hatchery began at 50,000 and increased to 276,500 by 1990. Rainbow trout were stocked in net pens during October and held until May or June when they were released as yearlings. The Net Pen Program was operated by the Lake Roosevelt Development Association, a nonprofit volunteer group.

The Spokane Tribal Hatchery went on line in 1990 as a full production facility and began stocking kokanee salmon and rainbow trout into Lake Roosevelt in 1991. The Sherman Creek Hatchery is a part time rearing facility operated by the WDFW near Kettle Falls, Washington which began rearing and releasing kokanee salmon in 1992. Construction and operation of these hatcheries was funded by the Bonneville Power Administration as partial mitigation for the loss of anadromous salmon and steelhead following the construction of Grand Coulee Dam in 1939. The dam was not equipped with a fish ladder and permanently blocked the migration of anadromous salmon and steelhead to areas above the dam.

The Sherman Creek Hatchery is the primary egg collection facility for kokanee salmon stocked into Lake Roosevelt, and collected eggs are transferred to the Spokane Tribal Hatchery for incubation and rearing. Initial egg stocks were obtained from the Lake Whatcom Hatchery near Bellingham, WA (operated by WDFW), and due to limited adult returns in Lake Roosevelt, kokanee salmon eggs continue to be supplemented by the Lake Whatcom Hatchery. A portion of the kokanee salmon reared in the Spokane Tribal Hatchery are transferred to Sherman Creek Hatchery in early spring for imprinting and later released. The hatcheries original production goals were 8 million kokanee salmon fry for release into Lake Roosevelt and 500,000 rainbow trout fry for the Lake Roosevelt Net Pen Program. However, due to a limited water supply at the Spokane Tribal Hatchery, approximately 2.5 million kokanee salmon and 250,000 rainbow trout fry have been released annually.

1.3 Description of Study Area

Lake Roosevelt is a mainstem Columbia River impoundment formed by the construction of Grand Coulee Dam in 1939 (Figure 1.1). Filled in 1941, the reservoir inundates 33,490 hectares at a full pool elevation of 393 m above mean sea level. It has a maximum width of 3.4 km and a maximum depth of 122 m (Stober *et al*. 1981). 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.

1.4 1997 Study Objectives

Objectives of the Lake Roosevelt Monitoring/Data Collection Project for 1997 were:

1. Monitor environmental parameters including pH, temperature, dissolved oxygen, percent dissolved oxygen saturation, conductivity, turbidity, total dissolved gas, total dissolved solids, oxidative reductive potential chlorophyll *a* and secchi disk at eleven locations within Lake Roosevelt;

2. Investigate seasonal primary and secondary trophic level interactions by determining phytoplankton speciation, density and bio-volume and zooplankton speciation, density and biomass at eleven locations within Lake Roosevelt;

3. Assess impacts of the August drawdown on primary production in Lake Roosevelt through periphyton investigations.

4. Assess entrainment and growth rates of tagged rainbow trout;

5. Estimate angler pressure and harvest, average size of fish harvested and economic value of the fishery;

6. Estimate the relative abundance of fishes in Lake Roosevelt;

7. Conduct dietary analysis on all fish species collected from Lake Roosevelt to assess relative importance of prey items and dietary overlap;

8. Back calculate length at age of various fish species collected from Lake Roosevelt;

9. Compare and contrast data collected during 1997 with previous years to identify changes in lake conditions or the fishery;

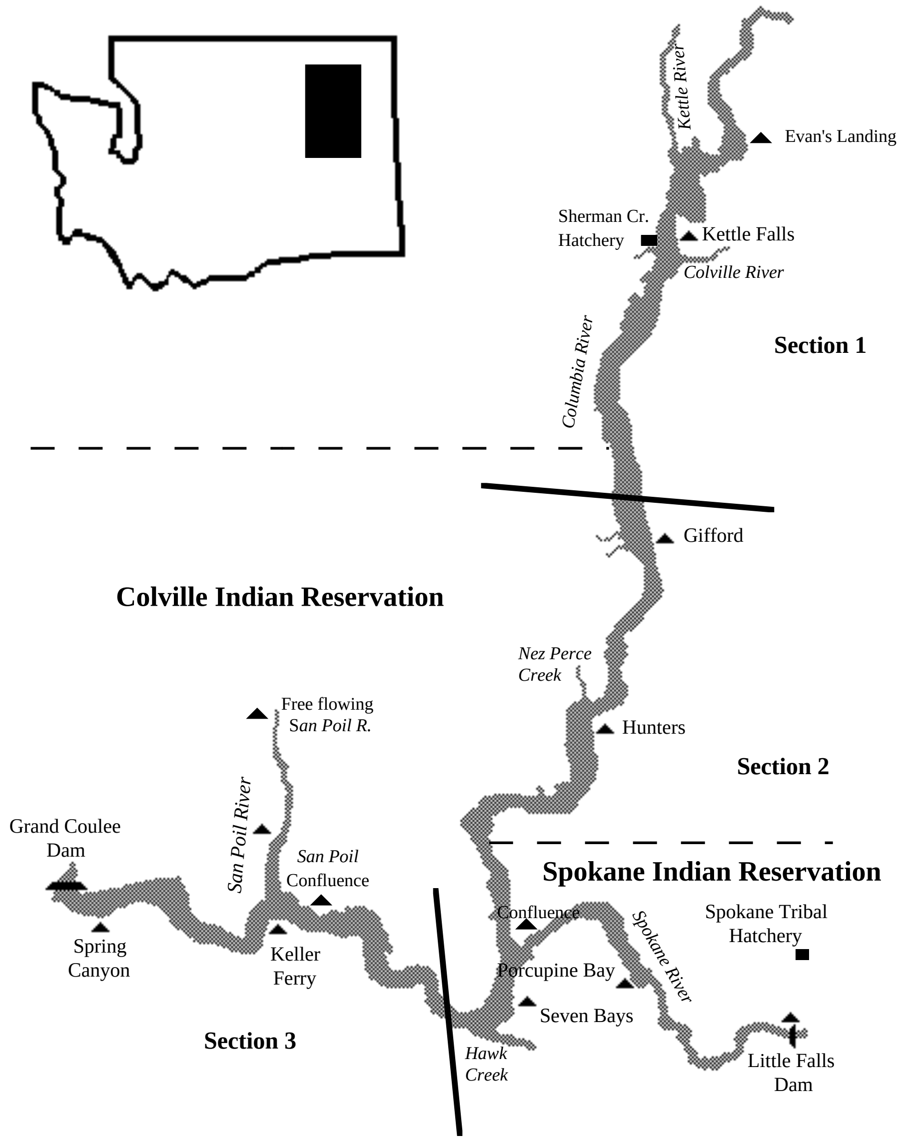


Figure 1.1 Map of Lake Roosevelt, Washington showing standard sampling locations (▲) and sections used for creel surveys and data analysis.

2.0 MATERIALS AND METHODS

2.1 Reservoir Limnology

Water temperature, pH, dissolved oxygen, conductivity, and oxidation - reduction potential were recorded at eleven sites in the reservoir using a Hydrolab Surveyor II (January through April). Purchase of a Hydrolab Surveyor 4 enabled us to expand our water quality surveys from May through December to include percent dissolved oxygen saturation, total dissolved gas, turbidity and total dissolved solids. Water quality data were collected mid-channel at 3 m intervals to a depth of 33 m near Evans Landing (Location 0), Kettle Falls (Location 1), Gifford (Location 2), Hunters (Location 3), Porcupine Bay (Location 4), the Confluence of the Spokane and Columbia Rivers (Location Confluence), Seven Bays (Location 6), Keller Ferry (Location 7), immediately above the confluence of the San Poil and Columbia rivers (Location 8A), San Poil River (Location 8) and Spring Canyon (Location 9; Figure 1.1). Secchi disk readings were taken in conjunction with Hydrolab measurements at each site. Water quality measurements were collected twice per month from March through October, and once during each other month. Collection of water quality data continues investigations which began in 1991.

Water retention times were calculated from daily midnight reservoir elevations (ft) and total outflows in thousand cubic feet per second per day (kcfs). Reservoir elevation and total outflow values were obtained from summary reports for Grand Coulee Dam prepared by the USACE Reservoir Control Center in Portland. Reservoir elevation was converted to volume of water stored (kcfsd) using a reservoir water storage table (USACE 1981), and daily water retention time was then calculated as reservoir volume divided by outflow.

2.2 Primary Production

To examine spatial and temporal trends in primary production within Lake Roosevelt, phytoplankton and chlorophyll *a* surveys were conducted within the euphotic zone from May through December, 1997. Phytoplankton were sampled at eleven standardized locations (Figure 1.1) twice per month from May through October and once per month in November and December. The euphotic zone was defined as the upper portion of the water column extending to a depth where one percent of the ambient light penetrates (Goldman and Horne 1983). Euphotic zone depth was determined for each site / date sampled using a Kahl Scientific Instruments Model 268WD305 underwater irradiameter.

Phytoplankton samples were collected using an integrated sampling tube to collect a column of water from the surface to the bottom of the euphotic zone. Phytoplankton samples were preserved with Lugol's solution and shipped to the Water Research Center at Eastern Washington University for speciation, enumeration and estimation of bio-volumes.

Chlorophyll *a* measurements were recorded at eleven standardized locations twice per month from May through October and once per month in November and December. A Turner Designs Model 10-AU field fluorometer was used to measure Chlorophyll *a* levels. Chlorophyll *a* levels at each site / date sampled were recorded at three depths within the euphotic zone; 0.5 m below the surface, the mid point of the euphotic zone, and 0.5 m above the bottom of the euphotic zone.

Periphyton monitoring was conducted in Lake Roosevelt from mid August through early October, 1997. Periphyton were allowed to colonize glass microscope slides suspended at depths of five and fifteen feet below the surface in embayments near Gifford, Porcupine Bay, Seven Bays, and Spring Canyon. Five separate colonization periods were examined including three periods of 2 – 3 weeks each, one period of approximately 5 weeks (mid August through mid September), and one period of approximately 7 weeks (early August through early October). Slides were collected following each colonization period and sent to the Water Research Center at Eastern Washington University for speciation, enumeration, and bio-volume estimation.

2.3 Zooplankton

Zooplankton were collected from each standard sampling location twice per month from May through October, and once in each other month with the exception of November during 1997 (Figure 1.1). Zooplankton were collected with a Wisconsin vertical tow plankton net with 80 μm mesh and a radius of 14.5 cm. Triplicate tows were made from a depth of 33 m to the surface at each location within Lake Roosevelt. In cases where depths were less than 33 m, zooplankton tows were done from 1 m above the substrate to the lake surface. Unlike previous years of this study, no zooplankton collections were conducted at Rufus Woods (below Grand Coulee Dam) during 1997. Organisms collected in each tow were preserved in individual bottles containing 10 ml of 37% formaldehyde, 0.5 g of sugar (Rigler 1978), and 1.0 ml of saturated eosin-y ethanol stain.

Zooplankton were identified to species or lowest practical taxon using taxonomic keys by Brooks (1957), Edmondson (1959), Pennak (1989), Ruttner-Kolisko (1974), Stemberger (1979) and Thorp and Covitch (1991). A Nikon SMZ-10 dissecting microscope, a compound Nikon Optiphot phase contrast microscope, and/or a Leica MZ-8 compound microscope were used to identify zooplankton. In cases where sample densities were high, three 6 ml sub-samples were drawn from the original sample to count zooplankton.

Zooplankton densities were calculated for each individual tow and the results of the three tows were averaged to arrive at a single location density. Zooplankton density (# organisms/ m^3) was calculated as:

$$D = \frac{\left(\frac{T_c}{S_n} * \frac{SV}{SSV}\right)}{V} * 1000$$

where:	D	=	density (# organisms/ m^3);
	T_c	=	total number counted of each species.
	S_n	=	number of sub-samples;
	SV	=	volume of preserved sample (ml);
	SSV	=	sub-sample volume (ml);
	V	=	volume sampled with plankton net (l).

To estimate biomass of predominant zooplankton taxa, dry weight was estimated as a linear function (ln transformed) of zooplankton length using parameters derived by Dumont et al. (1975), Bottrell et al. (1976), and Downing and Rigler (1984; Table 2.1). Mean length of plankton species was determined by measuring randomly chosen groups of up to twenty individuals from the top of the head to the base of the carapace, excluding the tail spine or setae. Average zooplankton biomass was then calculated as:

$$B = (\ln w)(D)$$

where:	B	=	biomass ($\mu g/m^3$);
	ln w	=	log of the dry weight estimate by species (μg); and
	D	=	density (# organisms/m^3).

2.4 Tagging Studies

Tagging studies were conducted on Lake Roosevelt using age one net-pen reared rainbow trout and hatchery reared kokanee salmon. Fish were randomly netted out of pens or raceways, measured to the nearest millimeter and tagged with individually numbered floy tags into the posterior base of the dorsal fin. Orange and blue tags were used to tag rainbow trout and kokanee salmon, respectively, in 1997. Carbon dioxide was used to anesthetize rainbow trout prior to handling (Post 1979). Kokanee salmon were

Table 2.1 Slope (*b*) and intercept (ln *a*) values used to estimate zooplankton dry weight. *

ZOOPLANKTON SPECIES	ln *a*	*b*
CLADOCERA		
D. schødleri	2.30	3.10
D. pulex	1.4663	3.1932
D. retrocurva	1.4322	3.129
D. galeata mendotae	1.51	2.56
D. thorata	1.51	2.56
Juvenile *Daphnia*	2.45	2.67
Ceriodaphnia reticulata	2.83	3.15
Bosmina longirostris	2.7116	2.5294
Bosmina coregoni	2.7839	2.505
Sida crystalina	2.0539	2.189
Alona quadrangularis	2.8713	3.079
Diaphanosoma brachyurum	1.6242	3.0468
Leptodora kindtii	-0.822	2.670
Chydorus sphaericus	4.5430	3.636
Scapholebris mucronata	2.8713	3.079
COPEPODA		
Epischura nevadensis	1.467	2.4741
Leptodiaptomus ashlandi	1.2431	2.2634
Mesocyclops edax	1.6602	3.968
Calanoid/cyclopoid copepodites	0.6977	0.469
Calanoid/cyclopoid nauplii	0.6977	0.469

* From Downing and Rigler, 1984.

anesthetized with either carbon dioxide (Post 1979), MS-222 (Wedemeyer 1970), or clove oil (Soto and Burhanuddin 1995) prior to handling. The use of various anesthetics for kokanee salmon allowed the Sherman Creek Hatchery Manager to observe differential effects and mortality rates associated with each. Once measured and tagged, rainbow trout were allowed to recuperate for up to 30 minutes prior to being returned to the net pens. Kokanee salmon were returned immediately to hatchery raceways following tagging.

To maximize angler tag returns, informational posters describing the Monitoring Program's tagging studies were distributed throughout Lake Roosevelt and Rufus Woods Reservoir at locations frequented by anglers. These posters gave a visual description of floy tags and requested that anglers return tags with the following recapture information: recapture date, location, fish length and fish weight. Anglers returning tag information were sent a letter informing them of the fish release date, location, and length at release. The angler was also provided with a brief summary of the tagging program.

Tag return data was used to estimate growth rates of rainbow trout and kokanee salmon within Lake Roosevelt. Tag returns were also used to estimate entrainment rates of these species from Lake Roosevelt.

2.5 Creel Design and Procedures

A two-stage probability sampling scheme was used to determine annual fishing pressure, catch-per-unit-effort (CPUE), and sport fish harvest by species on Lake Roosevelt (Lambou 1961;1966, Malvestuto 1983). Creel surveys were conducted at 48 locations including the Spokane and Colville Tribal campgrounds and National Park Service boat launches throughout Lake Roosevelt.

Three creel clerks interviewed anglers at access points along Lake Roosevelt. The lake was divided into three sections (upper, middle and lower), and one creel clerk was permanently assigned to each section. Creel clerks were scheduled approximately 22 days per month to make roving instantaneous pressure and effort counts at access points within their section.

Schedules were constructed by dividing each month into weekday and weekend/holiday stratum and days were stratified into a.m. and p.m. time periods. Schedules for roving instantaneous pressure counts were randomly selected on approximately eighteen weekdays and four weekend/holidays, with half of the surveys conducted during a.m. hours and the other half conducted during p.m. hours. The remaining a.m. or p.m. time slots were used to conduct five hour access point surveys. Creel schedules were developed monthly by randomly selecting the time, day, survey type (roving instantaneous pressure count or access point survey) and, if an access type of survey, the location. Roving instantaneous pressure counts and access point survey schedules differed among creel clerks both spatially and temporally.

During access point surveys, creel clerks collected the following data from each angler interviewed: angler type (boat or shore), hours fished, complete / incomplete trip, satisfaction, zip code of origin, target species, and number of fish kept or released. Fish harvested were identified to species, measured (mm), weighed (g) and examined for floy tags, fin clips, and physical marks. Physical marks such as eroded pectoral and pelvic fins, and stubbed dorsal fins were used to differentiate wild from net-pen or hatchery origin rainbow trout. Scale samples were collected by creel clerks from representative kokanee salmon, rainbow trout, and walleye, and stomach samples were collected from kokanee salmon whenever possible. Heads were taken from adipose clipped (hatchery origin) kokanee salmon for coded wire tag (CWT) analysis. Additionally, incoming boaters (angler or non angler) were surveyed to determine the number of boats angling and the number of anglers per boat.

During roving instantaneous pressure counts, creel clerks traveled by road and recorded the number of boat trailers and shore anglers at the access points in their section. No angler interviews were performed during roving instantaneous pressure counts.

Data collected from December 1996 through November 1997 were used for 1997 creel analyses. Quarters were established based on historic weather trends and angler use of the fishery as December (1996) through February (1997; winter), March through May (spring), June through August (summer), and September through November (fall). December 1996 was included in the 1997 creel analyses to allow examination of a continuous rather than a broken (e.g. Jan., Feb. and Dec., 1997) winter quarter. If no anglers were surveyed during any month within any stratum (but boat trailers were counted at access points) quarterly averages were used to estimate angler catch, effort, and pressure for that month/stratum.

During 1997, four air flights (two weekday and two weekend) were scheduled each month to coincide with roving instantaneous pressure counts. Creel clerks recorded the number of boat trailers and shore anglers in their section while a surveyor in the airplane concurrently recorded the number of boats on the water and the number of shore anglers. A correction factor for the number of boats on the water versus the number of boat trailers at access points was determined by dividing the number of boats observed (based on aerial surveys) by the number of trailers observed (based on roving ground surveys).

The number of boats on the reservoir in each stratum (weekday / weekend), section and month was determined by multiplying the mean number of boat trailers counted by the correction factor. The number of boats fishing in each stratum, section and month was calculated by multiplying the number of boats on the water by the percentage of boats fishing based on access point surveys.

The adjusted mean number of boat anglers per day for each stratum, section and month was estimated as the mean number of anglers per boat (from access point surveys) multiplied by the number of boats fishing in each stratum, section and month. The instantaneous number of boat anglers was estimated separately by section and summed to obtain a full lake estimate.

The mean daily number of shore anglers in each stratum and month was estimated as the total number of shore anglers recorded during pressure counts divided by the number of pressure counts conducted. The total number of anglers (boat or shore) during each stratum and month was estimated by multiplying the mean number of anglers for each stratum per day by the number of days in each strata and month.

The mean time spent angling per angler for each stratum was estimated as the total number of hours spent fishing divided by the number of anglers interviewed in any month. The number of hours available for fishing (sunrise to sunset) by stratum and month was calculated as the number of weekend or weekday days per month multiplied by the mean number of hours per day for each stratum and month.

Pressure (hours fished) was estimated for each stratum, section and month for both boat and shore anglers as:

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

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.

Monthly angler pressure and 95% confidence intervals were determined for boat and shore anglers by strata, month, and section. If data gaps existed in any strata the quarterly averages were used to fill the gaps. Annual angler pressure and 95% C.I. estimates were calculated by summing monthly estimates for each section. Sectional pressure estimates were summed to estimate the reservoir wide annual fishing pressure exerted.

Studies by Fletcher (1988) and Malvestuto et al. (1978) have shown that catch per unit of effort (CPUE) values calculated independently from complete and incomplete trip data are not statistically different. We assume that the same would hold true in estimating harvest per unit of effort (HPUE). Therefore, complete and incomplete angler trips were used to compute CPUE and HPUE for fish species in each stratum.

Monthly CPUE (or HPUE) of a particular fish species was calculated by dividing the total catch (or harvest) for the month by the total angler hours for each section. Annual CPUE (or HPUE) values of a particular fish species were calculated by dividing the total catch (or harvest) for the year by the total annual angler hours exerted.

Total harvest of individual fish species by stratum and month was determined as HPUE multiplied by the pressure estimate for that stratum and month. Monthly harvest estimates by strata for each taxa were combined to estimate total monthly harvest by section. Monthly harvest estimates were combined to calculate annual estimates for each fish species by section, and section harvest estimates were summed to obtain annual harvest estimates.

Data compiled by the U.S. Fish and Wildlife Service showed that a typical angler in inland waters of Washington State spent $26.00 per fishing trip in 1985 (USFWS 1989). To approximate the current amount spent by anglers in Lake Roosevelt, the 1985 cost per fishing trip was adjusted for inflation using the regional consumer price index (CPI):

$$D_{97} = \left(\frac{D_{85} x C_{97}}{C_{85}} \right)$$

where:

D_{97} = dollar value per fishing trip for the Lake Roosevelt fishery in 1997;
C_{85} = regional CPI for 1985;
C_{97} = regional CPI for 1997; and
D_{85} = dollar value per fishing trip for the Lake Roosevelt fishery in 1985 ($26.00).

The number of angler trips to Lake Roosevelt in 1997 was estimated by dividing the estimated number of angler hours fished by the mean trip length for each section and month. 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 that month. Annual angler trips were calculated by summing monthly angler trip values across all sections. The 1997 dollar value was multiplied by total number of angler trips in 1997 to provide an estimate of the economic value of the fishery.

2.6 Fisheries Surveys and Relative Abundance

Fish were collected from ten index stations in Lake Roosevelt during 1997 (Figure 1.1) to determine their relative abundance. Principle target species included kokanee salmon, rainbow trout, and walleye, although it was assumed that all fish were collected in proportion to their relative abundance in the lake.

Relative abundance surveys were performed in littoral areas and tributaries by electrofishing 10 minute transects according to procedures outlined by Reynolds (1983) and 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. Four to six 10 minute transects were electrofished at each sample station on each date sampled.

Additional relative abundance surveys were performed in pelagic zones using gillnet methodologies described by Hubert (1983). Four gillnets were set at each site and included 2-3 horizontal gillnets and 1-2 vertical gillnets dependent upon site morphology. Horizontal gillnets 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 bar mesh sizes of 1.3 cm, 2.5 cm, 3.8 cm and 5.1 cm. Vertical gillnets were 3.0 m wide, extended to a maximum depth of 61 m, and had a uniform 5.1 cm bar mesh size. Gillnets were set in early afternoon (approximately 14:00) and pulled the next morning (approximately 10:00).

All fish captured were identified to species according to *The Inland Fishes of Washington* (Wydoski and Whitney 1979) and measured to the nearest millimeter (total length). Scale samples were taken from a representative sample of each species collected to backcalculate age and growth. All fish were weighed to the nearest gram using spring scales. The heads of kokanee salmon were removed and sent to the Fisheries Research Center at Eastern Washington University, where coded wire tags were dissected out and examined.

2.7 Age, Back Calculations and Condition Factor

In the field, scales were taken from appropriate locations for each species (Jearld 1983) and placed in envelopes labeled with fish species, length, weight, location and date for later analysis. In the laboratory, back-calculation measurements and age class of each fish were determined simultaneously. Scales were placed between two microscope slides and examined using a Realist Vantage 5, Model 3315 microfiche reader. A single, non-regenerated, uniform scale was selected to determine age and obtain measurements to back calculate length at age. Age was determined by counting the number of annuli (Jearld 1983). For back calculations, the annulus distance was measured along a constant axis 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.

Lee's back-calculation method was used to determine the length of the fish at the formation of each annulus (Carlander 1950, 1981; Hile 1970). However, due to a small number of samples, fish length at scale formation was assumed to be zero.

Back-calculated length at age was calculated as:

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

where:

L_i = length of fish (in mm) at each annulus formation;
a = intercept of the body-scale regression line (assumed 0);
L_c = length of fish (in mm) at time of capture;
S_c = distance (in mm) from the focus to the edge of the scale; and
S_i = scale measurement to each annulus.

A condition factor describing how a fish adds weight in relation to incremental changes in length was determined for each fish (Hile 1970, Everhart and Youngs 1981). 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).

2.8 Feeding Habits

Fish stomachs were collected from up to ten individuals of each fish species per index station and season. Additional kokanee salmon stomachs were obtained by creel clerks from anglers throughout the year. Stomachs from representative sizes of fish were collected by making an incision into the body cavity, pinching the pyloric sphincter, and removing the stomach using a scissors. Stomachs were preserved in 10% formalin.

In the laboratory, stomachs were transferred to a 70% isopropyl alcohol solution. Contents were identified and enumerated by taxa using taxonomic keys by Brooks (1957), Edmondson (1959), Ward and Whipple (1966), Borror et al. (1976), Ruttner-Kolisko (1974), Edmonds et al. (1976), Wiggins (1977), Merritt and Cummins (1984), Pennak (1989), and Thorp and Covich (1991).

Dry weights were obtained by drying sorted stomach contents in an oven at 105° C for 24 hours on a stainless steel wire screen and weighing them on a Sartorius Model H51 analytical balance to the nearest 0.0001 g (Weber 1973, APHA 1976). Dry weight values were combined for each age class, and annual means and standard deviations were calculated by species and age class.

Index of relative importance (IRI) 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 (Bowen 1983). The IRI (George and Hadley 1979) was calculated using the formula:

$$Rl_a = \frac{100 Al_a}{\sum_{a=1}^{n} Al_a}$$

where: Rl_a = relative importance of food item a;

Al_a = absolute importance of food item a (*i.e.*, frequency of occurrence + numerical frequency + weight frequency of food item a); and

n = number of different food types.

Relative importance values range from 0 to 100%, with prey items having higher values representing items more important in the fish diet.

Diet overlap was calculated to determine the degree to which inter species competition may exist in Lake Roosevelt. Fish diet overlaps were computed by using the overlap formula of Morisita (1959) as modified by Horn (1966) where:

$$C_x = \frac{2\sum_{i=1}^{n}\left(P_{xi} x P_{yi}\right)}{\sum_{i=1}^{n} P_{xi} 2 + \sum_{i=1}^{n} p_{yi} 2}$$

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 range from 0 (no overlap) to 1 (complete overlap) and were based on indices obtained from IRI calculations. 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 only if food items utilized by both species are limited (MacArthur 1968).

3.0 RESULTS

3.1 Reservoir Operations

During the 1997 water year, precipitation in the Columbia River Basin above Grand Coulee Dam was approximately 135% of normal, resulting in an increased influence of flood control strategies in determining reservoir operations. Mean monthly lake elevations in Lake Roosevelt during 1997 began at 1,273.0 feet above mean sea level in January, declined to 1,220.8 feet in April, and refilled to near full pool (1,290 feet) by July (Table 3.1 and Figure 3.1). For the remainder of the year, reservoir elevations were held relatively stable within twelve feet of full pool (Figure 3.1). Mean annual reservoir elevation in 1997 was 1,266.3 feet above mean sea level (Table 3.1). Mean monthly outflows at Coulee Dam during 1997 ranged from 92.3 kcfs (November) to 258.1 kcfs (June) with an annual mean of 147.8 kcfs (Table 3.1). During 1997, spill over Grand Coulee Dam was substantial in May (24.6 kcfsd) and June (57.0 kcfsd). Mean monthly spill was less than 10 kcfsd in all other months, and the mean annual spill was 8.6 kcfsd (Table 3.1). Mean monthly inflows during 1997 ranged from 94.1 kcfs in November to 360.9 kcfs in May, with a yearly mean of 151.6 kcfs (Table 3.1). Mean monthly water retention times ranged from 10.8 days in May to 46.5 days in September (Table 3.1). Average water retention times in Lake Roosevelt remained below 30 days from February through July (Table 3.1). The maximum estimated daily water retention time for 1997 was 82.0 days on September 6, and the minimum was 8.8 days on April 30 (Figure 3.1).

3.2 Water Quality

3.2.1 Total Dissolved Gas

Our observations of total dissolved gas (TDG) saturation levels were not normally distributed nor did we see homogeneous variances across locations or depths in 1997. Kruskal-Wallis (nonparametric) tests were therefore utilized to examine spatial and temporal differences in TDG saturation during 1997. When spatial or temporal differences were noted, Bonferroni-Dunn procedures (multiple pairwise comparisons) were utilized to further define differences in TDG levels.

Monitoring conducted during 1997 showed both spatial and temporal differences in TDG saturation levels in Lake Roosevelt. Overall, TDG saturation levels ranged from 101 to 139 percent saturation during 1997 (Figure 3.2) with a mean saturation level of 112 percent (Table 3.2). Approximately one half of the TDG observations during our 1997

Table 3.1 **Monthly and annual means for reservoir inflow, outflow, spill, reservoir elevation, storage capacity, and water retention time for Lake Roosevelt in 1997.**

Month	Inflow (kcfs)	Outflow (kcfs)	Spill (kcfsd)	Reservoir Elevation (Ft)	Storage Capacity (kcfsd)	Water Retention Time (Days)
January	129.4	141.6	1.4	1,273.0	3,931.8	30.3
February	119.4	142.4	1.2	1253.7	3256.8	23.3
March	121.2	129.2	5.5	1,239.4	2803.4	23.4
April	137.1	152.7	8.2	1,220.8	2,291.9	15.9
May	360.9	218.4	24.6	1,223.4	2,379.5	10.8
June	304.7	258.1	57.0	1,275.3	4027.1	16.1
July	182.2	169.2	4.7	1,287.7	4,498.2	27.1
August	133.2	135.3	0.3	1,285.8	4,422.2	33.2
September	108.4	97.5	0.1	1,284.4	4,368.0	46.5
October	109.9	107.3	0.0	1,283.9	4,344.2	42.4
November	94.1	92.3	0.0	1,243.7	4,301.9	45.9
December	114.2	127.8	0.0	1,280.3	4,209.2	33.5
Mean 1997	**151.6**	**147.8**	**8.6**	**1,266.3**	**3,752.2**	**29.2**

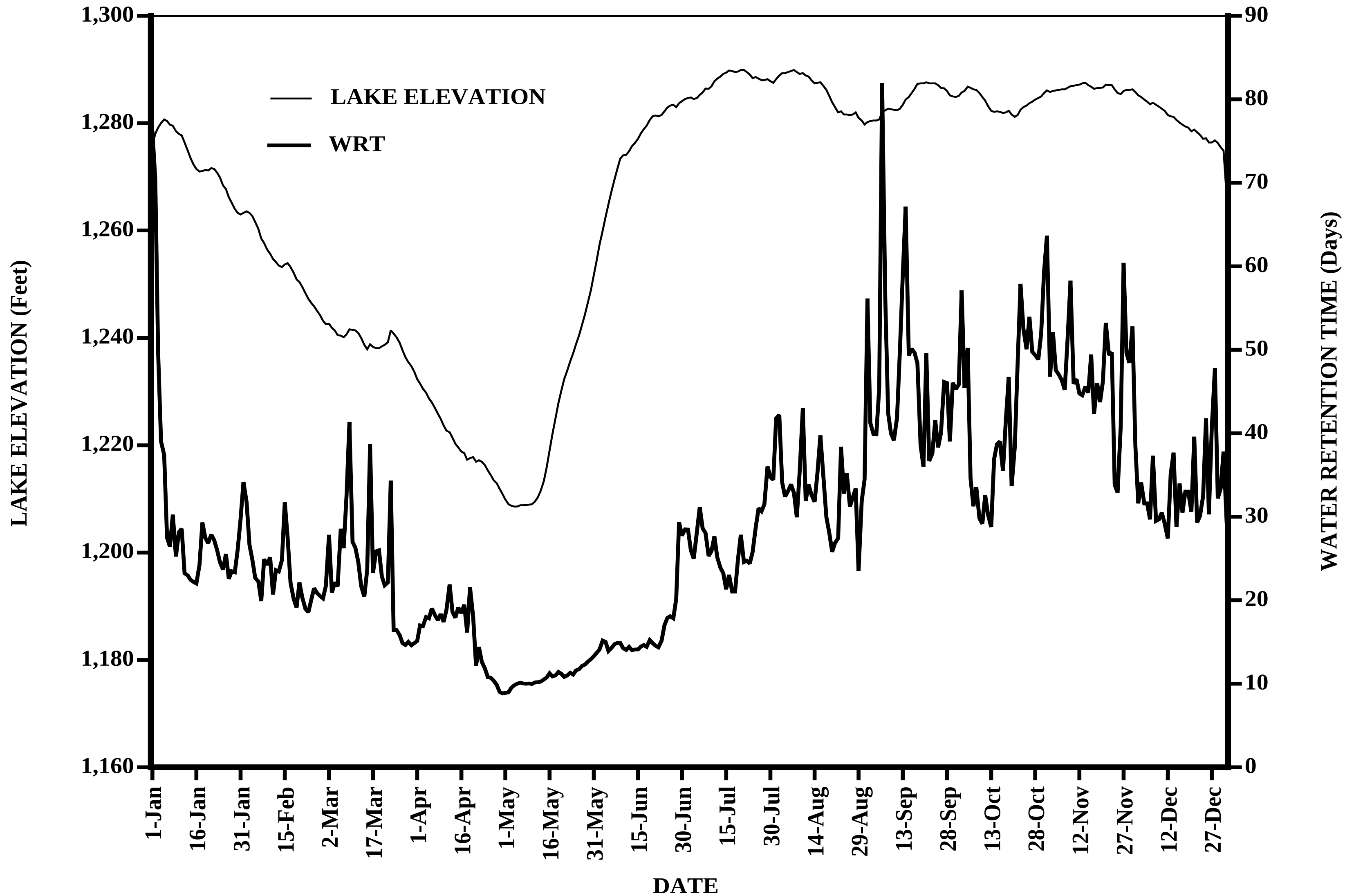


Figure 3.1 Daily water retention times and daily lake elevations for Lake Roosevelt during 1997.

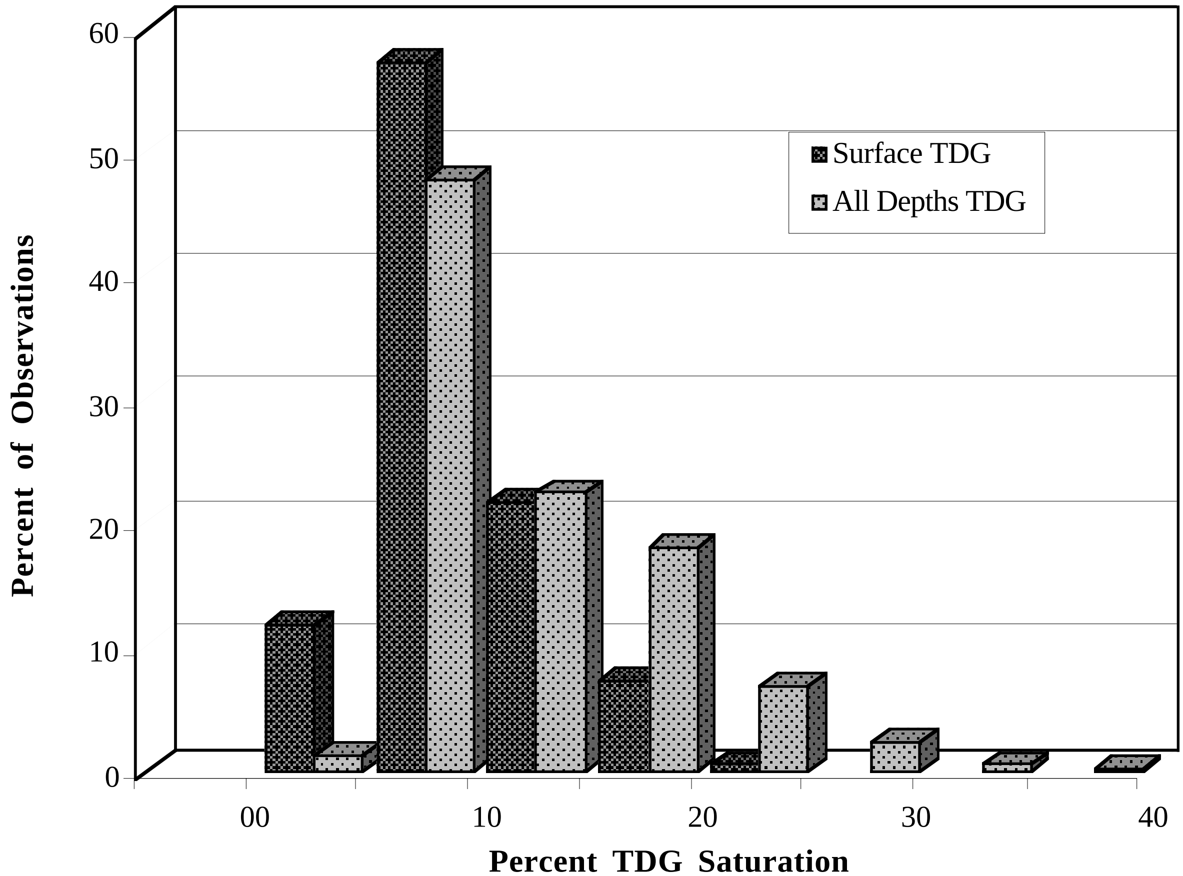


Figure 3.2 Distribution of total dissolved gas (TDG) observations in Lake Roosevelt during 1997.

Table 3.2 Minimum, maximum, and mean TDG saturation levels observed in each reach defined in Lake Roosevelt with regard to TDG concentrations.

Reach	Location(s) included*	Minimum TDG %	Maximum TDG %	Mean TDG %
Upper Mainstem	0,1,2	101.3	139.1	114.0
Middle Mainstem	3,5, 6	103.1	124.0	112.4
Lower Mainstem	7,8,8A, 9	102.9	132.0	111.2
Spokane River	4	101.9	116.1	109.7
			Overall Mean	**112.3**

* See Figure 1.1 for monitoring locations.

Table 3.3 Differences in monthly mean TDG concentrations observed in Lake Roosevelt during 1997. Significance is based on Kruskal-Wallis statistics.

Month	Mean % TDG Saturation	Significant ($p<0.05$) Differences
May (M)	117.1	> J, A,S,O,N,D
June (J)	115.0	> S,O,N,D
July (JY)	116.2	> A,S,O,N,D
August (A)	114.7	> S,O,N,D
September (S)	109.8	> O
October (O)	108.5	
November (N)	108.9	
December (D)	108.1	

monitoring exceeded maximum state and federal guidelines (110% saturation) for surface water quality (Figure 3.2). Surface TDG levels ranged from 101 to 120.5 percent saturation (mean; 109%) in Lake Roosevelt during 1997 (Figure 3.2).

3.2.1.1 Spatial Trends

Spatially, differences in TDG levels were noted by both reach and depth in Lake Roosevelt during 1997. Four significantly different reaches ($p < 0.01$)were defined in Lake Roosevelt with regard to TDG concentrations during 1997; the Spokane River arm (Porcupine Bay) and the upper (Evans Landing, Kettle Falls, Gifford), middle (Hunters, Confluence, Seven Bays), and lower (Keller Ferry, San Poil / Columbia Confluence, San Poil River Arm, Spring Canyon) portions of the mainstem Columbia River (Table 3.2). Mean TDG levels differed between the upper (114.0 % saturation), middle (112.4 % saturation), and lower (111.2 % saturation) mainstem Columbia River portions of Lake Roosevelt, declining from upstream to downstream reaches (Table 3.2). The Spokane River arm exhibited significantly lower mean TDG levels (109.7 % saturation) than the mainstem Columbia River reaches during 1997 (Table 3.2).

Saturation levels of TDG in Lake Roosevelt increased with depth in all reaches, and differences between reaches generally increased with depth (Figure 3.3). Total dissolved gas levels were significantly ($p < 0.05$) less in waters near the reservoir surface (<6 m) than in deeper (>24 m) waters. Mean surface TDG saturation levels varied by approximately one percent between reaches at the surface of Lake Roosevelt (Table 3.3). In contrast, TDG saturation levels varied by approximately five percent between reaches at depths of 15 m or greater (Figure 3.3).

3.2.1.2 Temporal Trends

Total dissolved gas levels in Lake Roosevelt differed significantly between months during 1997 ($p < 0.001$). Observed monthly mean TDG levels in Lake Roosevelt were highest during May (117.1%) and July (116.2%), and the mean TDG level in May was significantly ($p < 0.05$) greater than all months except July (Table 3.3). The highest individual level of TDG supersaturation observed in Lake Roosevelt during our 1997 surveys was 139%, and was noted during June. The lowest monthly mean TDG levels were observed in October (108.5%), November (108.9%), and December (108.1%) and no significant differences were noted between these three months (Table 3.3).

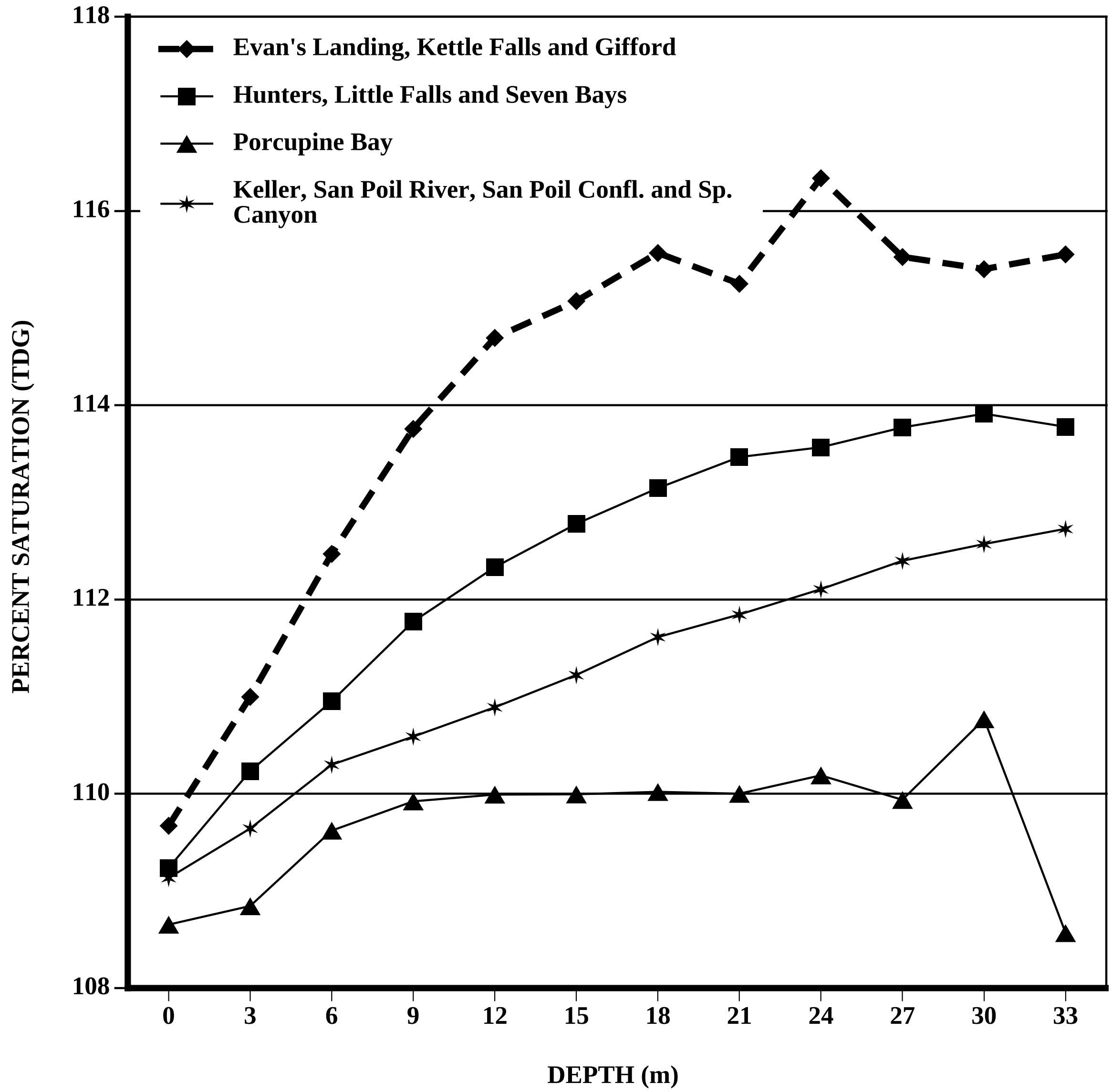


Figure 3.3 **Mean TDG saturation levels by depth and reach in Lake Roosevelt during 1997.**

3.2.2 Additional Limnological Parameters

Temperatures recorded from 12 m deep in Lake Roosevelt (to avoid surface variations and to best represent vertical profile means) during 1997 ranged from 1.6 ^{o}C at Seven Bays in February to 20.9 ^{o}C at Spring Canyon in August. Temperatures exceeded 10 ^{o}C in May at Porcupine Bay, Confluence, and Seven Bays. In contrast, no temperatures above 10 ^{o}C were recorded at other sampling locations until June. Evans Landing, Kettle Falls, Gifford, Hunters, and Seven Bays cooled to below 10 ^{o}C by November, whereas other locations did not fall below 10 ^{o}C until December.

Dissolved oxygen levels recorded during 1997 ranged from 3.9 mg/L at Hunters in September to 25.5 mg/L at Keller Ferry in March. Dissolved oxygen levels recorded from all stations exceeded 15 mg/L from January through March, and 10 mg/L through June. With few exceptions, dissolved oxygen levels ranged between 5 and 12 mg/L from July through November, and between 10 and 14 mg/L in December. Dissolved oxygen saturation levels (%DO) were monitored from May through December in 1997, and ranged from 43.2% saturation at Hunters in September to 154.0% saturation at Hunters in July. Dissolved oxygen was supersaturated (> 100% DO) from May through July at most depths at all locations in 1997.

Conductivity values in Lake Roosevelt during 1997 ranged from 0.059 mmhos/cm at Porcupine Bay in May to 1.078 mmhos/cm at Seven Bays in September. Conductivity values recorded in 1997 were highly correlated ($r = 0.998$) with observed levels of total dissolved solids (TDS). Monitoring of TDS began in June, and observed TDS levels ranged from 46.0 mg/L at San Poil in August to 700 mg/L at Seven Bays in September.

Turbidity in Lake Roosevelt was monitored in the field from May through December, 1997. Observed turbidity levels were highest at Seven Bays (821.5 NTU) and Confluence (193.0 NTU) in September and at San Poil in June (157.7 NTU). The remainder of our turbidity observations in Lake Roosevelt during 1997 were relatively low, only rarely exceeding 10 NTU.

Oxidation reduction potential (ORP) and pH were monitored throughout 1997 in Lake Roosevelt, and were strongly negatively correlated ($r = -0.864$; $p < 0.0001$). Observed pH in Lake Roosevelt ranged from 6.20 (Hunters in July) to 11.03 (San Poil Confluence in October) and were highest at most locations in September and October. Oxidation reduction potential ranged from 127 to 1,047 mV at Gifford (September) and Confluence

(March) locations, respectively. Oxidation reduction potentials were generally lowest in September at all monitoring locations.

3.3 Primary Production

3.3.1 Chlorophyll *a*

Chlorophyll *a* concentrations varied between months (ANOVA, $p < 0.001$) during our 1997 sampling in Lake Roosevelt. Monthly mean chlorophyll *a* concentrations were highest in June (3.74 mg/m^3) and July (3.02 mg/m^3), and lowest from October through December (<0.5 mg/m^3; Table 3.4). Pairwise comparisons indicated that monthly mean chlorophyll *a* concentrations increased from May to June, were similar in June and July, and then decreased significantly during the August through December period (Scheffe's S, $p < 0.05$; Table 3.4).

No significant differences in chlorophyll *a* concentrations were noted between sampling locations or depths within the euphotic zone from May through December, 1997 (ANOVA, $p > 0.10$). Mean chlorophyll *a* concentrations in the upper portion of the euphotic zone (1.44 mg/m^3) were however, slightly lower than those in the middle (1.80 mg/m^3) and lower (1.80 mg/m^3) portions of the euphotic zone.

Table 3.4 Differences in monthly mean chlorophyll *a* concentrations observed in Lake Roosevelt during 1997. Significance is based on Scheffe's statistic.

Month	Mean Chlorophyll *a* Concentration	Significant (p<0.05) Differences
May (M)	2.158	< J ; > S, O, N, D
June (J)	3.742	> A, S, O, N, D
July (JY)	3.015	> A, S, O, N, D
August (A)	1.261	
September (S)	0.657	
October (O)	0.440	
November (N)	0.473	
December (D)	0.445	

3.3.2 Periphyton

Thirty individual periphyton taxa were identified from Lake Roosevelt during our 1997 surveys (August through early October), including representatives of three Divisions and four Classes (Table 3.5). Periphyton collections from Lake Roosevelt during 1997 were dominated by diatoms (Bacillariophyceae) at all locations. Diatoms accounted for 96.0 percent of the total periphyton density and 88.3 percent of the total periphyton volume observed during 1997 surveys (Table 3.5). Numerically, *Achnanthes* sp. (Bacillariophyceae) dominated periphyton collections, accounting for 75.5 percent of the total density observed (Table 3.5). *Amphora* sp. (Bacillariophyceae), *Fragilaria* sp. (Bacillariophyceae), and *Mougeotia* sp. (Chlorophyceae) were also important numerically and, respectively, made up 3.8, 3.3, and 3.6 percent of observed periphyton densities (Table 3.5). Periphyton collections were volumetrically dominated by *Achnanthes* sp. (19.3 %), *Melosira varians* (Bacillariophyceae; 18.6%), *Amphora* sp. (12.8%), and *Mougeotia* sp. (10.5%; Table 3.5).

Periphyton colonization rates (mean number of organisms/cm^2/day) differed significantly between sampling depths, locations, and colonization periods during our 1997 surveys (ANOVA; $p < 0.05$). Mean periphyton colonization rates were five times greater at a depth of 5 feet (0.015 organisms/cm^2/day) than at 15 feet (0.003 organisms/cm^2/day), and were significantly less at Gifford and Porcupine Bay (<0.05 organisms/cm^2/day) than at Seven Bays and Spring Canyon (>0.13 organisms/cm^2/day; Scheffe's S, $p < 0.05$). Mean colonization rates of periphyton declined between colonization periods, from 0.017 organisms/cm^2/day during our first colonization period (approximately Aug. 10 – Aug. 28) to 0.013 organisms/cm^2/day during the second colonization period (approximately Aug. 28 – Sept. 17), and 0.004 organisms/cm^2/day during the final colonization period (approximately Sept. 17 – Oct. 2). The mean periphyton colonization rate during period one was significantly greater than that in period three (Scheffe's S; $p < 0.05$), however colonization rates during the third period did not include samples from Spring Canyon where rates were generally high.

Colonization rates of periphyton were not additive across colonization periods during 1997. Mean periphyton colonization rate across colonization periods one and two (combined) was 0.008 organisms/cm^2/day, considerably less than colonization rates noted during either individual colonization period (0.017 and 0.013 organisms/cm^2/day). Similarly, the mean colonization rate across colonization periods one through three was

Table 3.5 Relative abundance of periphyton species observed in Lake Roosevelt during 1997 surveys.

	% of Total Density	% of Total Bio-volume
Division Chlorophyta		
Class Chlorophyceae	**4.0**	**10.8**
Ankistrodesmus falcatus	<1.0	<1.0
Mougeotia sp.	3.6	10.5
Oedogonium sp.	<1.0	<1.0
Scenedesmus bijuga	<1.0	<1.0
Scenedesmus dimorphus	<1.0	<1.0
Scenedesmus quadricauda	<1.0	<1.0
Division Chrysophyta		
Class Bacillariophyceae	**95.9**	**88.3**
Achnanthes sp.	75.5	19.3
Amphipleura sp.	<1.0	<1.0
Amphora sp.	3.8	12.8
Asterionella formosa	<1.0	<1.0
Cocconeis sp.	<1.0	<1.0
Cyclotella sp.	<1.0	<1.0
Cymbella sp.	1.5	4.2
Fragilaria crotonensis	<1.0	1.2
Fragilaria sp.	3.3	7.7
Gomphonema sp.	1.7	4.7
Melosira distans	<1.0	<1.0
Melosira herzogii	<1.0	<1.0
Melosira italica	<1.0	<1.0
Melosira varians	1.7	18.6
Navicula sp.	2.3	6.1
Pinnularia sp.	<1.0	2.3
Rhizosolenia sp.	1.9	<1.0
Stauroneis sp.	<1.0	<1.0
Synedra sp.	2.4	<1.0
Tabellaria sp.	<1.0	<1.0
Class Chrysophyceae	**<1.0**	**<1.0**
Dinobryon bavaricum	<1.0	<1.0
Mallomonas sp.	<1.0	<1.0
Division Cyanophyta		
Class Cyanophyceae	**<1.0**	**<1.0**
Lyngbya sp.	<1.0	<1.0
Oscillatoria sp.	<1.0	<1.0

0.004 organisms/cm^2/day, similar to that observed during our third colonization period (0.004 organisms/cm^2/day), but significantly lower than that observed during period one (Scheffe's S; $p < 0.05$).

3.3.3 Phytoplankton

Fifty one phytoplankton taxa were identified in 1997 collections, including representatives of five Divisions and six Classes (Table 3.6). Phytoplankton densities in Lake Roosevelt during 1997 were highest in June (815 organisms/L), with May and July also having high densities (629 and 707 organisms/L, respectively) relative to other months (Figure 3.4). Phytoplankton densities were less than 500 organisms/L from August (494 organisms/L) through December (359 organisms/L), and declined throughout this period (Figure 3.4).

By density, predominant groups of phytoplankton collected during 1997 were the microplankton, Cryptophyceae (unicellular flagellates), Chlorophyceae (green algae), and Bacillariophyceae (diatoms; Figure 3.4). Microplankton and diatoms exhibited similar temporal trends in density in Lake Roosevelt during 1997 with both groups being greatest in abundance from May through August, and reduced (but relatively consistent) in abundance from September through December (Figure 3.4). Observed densities of the Cryptophyceae were variable from May through December whereas densities of Chlorophyceae remained relatively consistent throughout the sampling period.

Volumetrically, Cryptophyceae and Bacillariophyceae dominated our phytoplankton collections from May through December, 1997 (Figure 3.5). Both groups exhibited the highest observed bio-volumes from May through July, with slightly reduced bio-volumes from August through December.

To investigate substantial changes in either speciation or mean size of phytoplankton, we examined variation in the volume/density ratios of each major group (Figure 3.6). An increase in the volume/density ratio would represent either a relative increase in the abundance of larger individuals of a given species, or a change in species composition with a shift toward larger individuals. Two groups exhibited substantial changes in volume/density ratios during our 1997 monitoring. Bacillariophyceae and Chrysophyceae each had an increase in volume/density ratio during October, declining by December to levels comparable to earlier months (Figure 3.6).

Table 3.6 Phytoplankton taxa identified from Lake Roosevelt during the 1997 study period.

Division Chlorophyta

Class Chlorophyceae

Actinastrum gracilimum
Ankistrodesmus falcatus
Carteria sp.
Chlamydomonas sp.
Chodatella quadriseta
Cosmarium sp.
Crucigenia tetrapedia
Eudorina elegans
Mougeotia sp.
Oocystis sp.
Pandorina morum
Pediastrum duplex
Quadrigula chodatii
Scenedesmus bijuga
Scenedesmus dimorphus
Scenedesmus quadricauda
Schroederia setigera
Schroederia judayi
Spondylosium sp.
Staurastrum paradoxum
Tetraedion minimum

Division Chrysophyta

Class Chrysophyceae

Dinobryon bavaricum
Dinobryon divergens
Dinobryon sertularia
Mallomonas pseudocoronata
Mallomonas sp.

Division Chrysophyta (cont'd)

Class Bacillariophyceae

Achnanthes sp.
Asterionella formosa
Cyclotella sp.
Cymbella sp.
Fragilaria crotonensis
Fragilaria sp.
Gomphonema sp.
Melosira distans
Melosira herzogii
Melosira italica
Navicula sp.
Pinnularia sp.
Rhizosolenia sp.
Stephanodiscus sp.
Synedra sp.
Tabellaria sp.

Division Cryptophyta

Class Cryptophyceae

Cryptomonas sp.
Rhodomonas sp.

Division Cyanophyta

Class Cyanophyceae

Anabaena sp.
Anabaena planctonica
Aphanizomenon flos-aquae
Aphanocapsa
Gleocapsa sp.
Oscillatoria limnetica

Division Pyrrophyta

Class Dinophyceae

Ceratium hirudinella

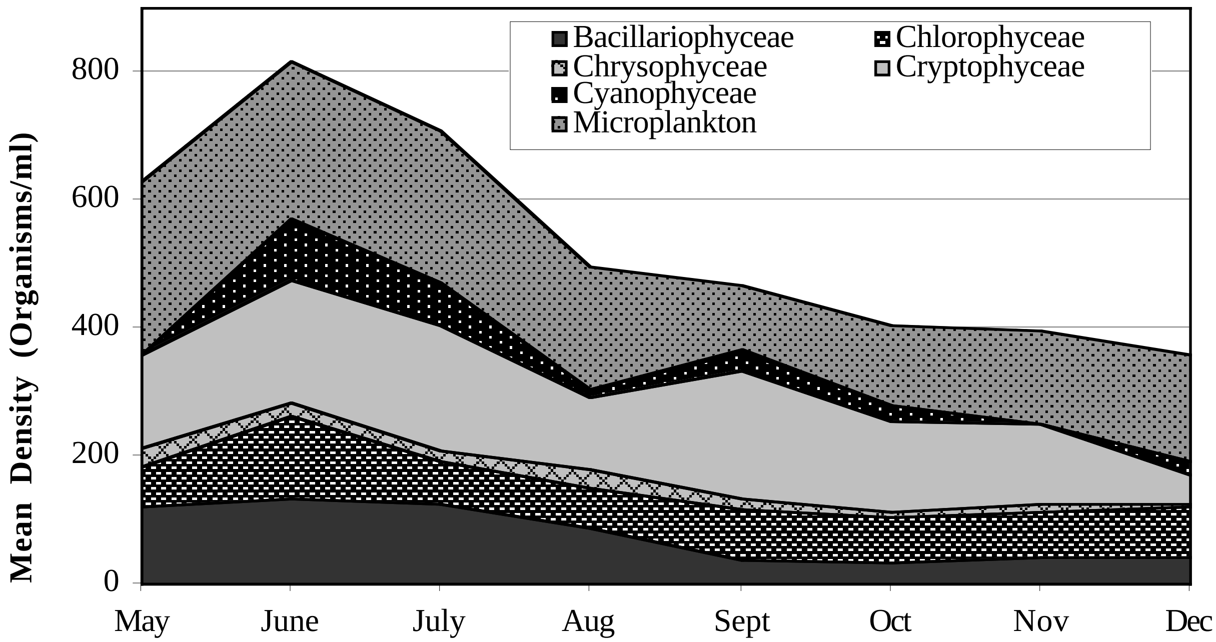


Figure 3.4 Seasonal variation in density of major phytoplankton groups collected from Lake Roosevelt during 1997.

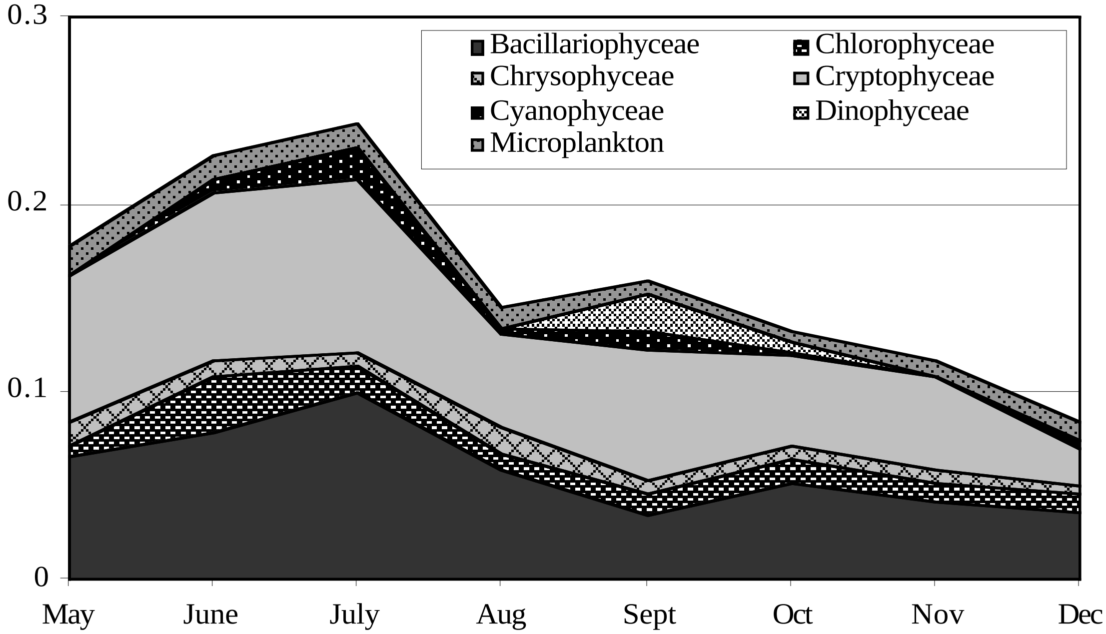


Figure 3.5 Seasonal variation in biovolume of major phytoplankton groups collected from Lake Roosevelt during 1997.

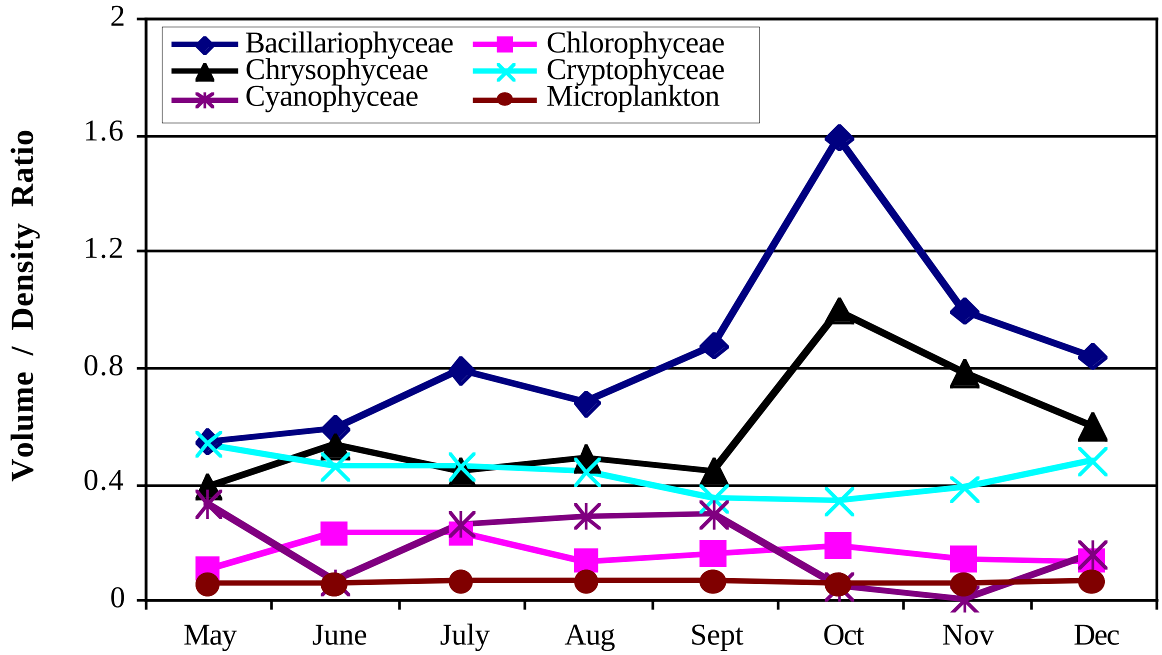


Figure 3.6 Seasonal variation in volume to density ratios for major phytoplankton groups collected from Lake Roosevelt during 1997.

3.4 Zooplankton Densities

3.4.1 Species Identified

In 1997, zooplankton samples collected from Lake Roosevelt were analyzed through a cooperative effort between the Spokane Tribe, EWU and BSA Environmental Services, Inc. This process resulted in identification of 42 zooplankton species from 33 genera. Seventeen species were Cladocera, five species were Copepoda and 22 species were Rotifera (Table 3.7).

Taxonomically related zooplankton species were grouped into categories as follows: *Daphnia pulex*, *Daphnia retrocurva*, *Daphnia schødleri*, *Daphnia thorata* and juvenile *Daphnia* were grouped as "*Daphnia* sp.", while *Alona quadrangularis, Bosmina longirostris, Ceriodaphnia reticulata, Diaphanosoma brachyurum, Leptodora kindti, Leydigia leydigi, Biapertura affinis, Pleuroxus striatus, Chydorus sphaericus, Sida crystallina* and *Scapholeberis mucronata* were grouped as "other Cladocera". *Leptodiaptomus ashlandi, Diacyclops bicuspidatus thomasi, Mesocyclops edax, Epischura nevadensis,* Harpacticoid sp. and juvenile copepods (Calanoid/Cyclopoid copepodids and nauplii) were grouped as "copepod sp." *Daphnia* sp. and other Cladocera were examined separately due to their differing importance in the diets of both kokanee salmon and rainbow trout (Underwood et al. 1996 and 1997; Griffith and Scholz 1991).

Significant size selective bias in rotifer data collection occurred during 1997 as evidenced by measured lengths up to ten times smaller than the mesh openings of sampling nets. Therefore, although observed rotifer species composition is presented in Table 3.7, rotifers have been removed from all data analysis. As is consistent with previous years, reference to total zooplankton will exclude rotifers and refer only to *Daphnia,* other Cladocera and copepod species.

3.4.2 Total Zooplankton Densities

In 1997, copepods were the most abundant taxon collected from Lake Roosevelt, comprising 80.0 % of total zooplankton enumerated at all stations. *Daphnia* sp. comprised 16.9 % of total zooplankton observed, while other Cladocera accounted for 3.2 %. Considerable variation in the timing, duration and magnitude of peak densities was noted for each of the three zooplankton groups. Other Cladocera densities peaked in

Table 3.7 Zooplankton taxa historically identified in Lake Roosevelt including those identified during the 1997 study period (*).

Phylum Anthropoid
Class Crustacea
Subclass Branchiopoda
Order Cladocera
Family Daphnidae
1. _Ceriodaphnia quadranqularis_
2. *_Ceriodaphnia reticulata_
3. *_Daphnia schødleri_
4. *_Daphnia pulex_
5. *_Daphnia retrocurva_
6. *_Daphnia galeata mendotae_
7. *_Daphnia thorata_
8. _Simocephalus serrulatus_
9. *_Scapholeberis mucronata_

Family Chydoridae
10. _Alona guttata_
11. *_Alona quadrangularis_
12. *_Chydorus sphaericus_
13. *_Leydigia leydigi_
14. *_Biaptura affinis_
15. *_Pleuroxus striatus_

Family Sididae
16. *_Diaphanosoma brachyurum_
17. _Diaphanosoma birgei_
18. *_Sida crystallina_

Family Bosminidae
19. *_Bosmina longirostris_
20. *_Bosmina coregoni_

Family Leptodoriidae
21. *_Leptodora kindtii_

Subclass Copepoda
Order Eucopepoda
Suborder Calanoida
Family Diaptomidae
22. *_Leptodiaptomus ashlandi_
23. _Skistodiaptomus oregonensis_

Family Temoridae
24. *_Epischura nevadensis_

Suborder Cyclopoida
Family Cyclopoidae
25. *_Diacyclops bicuspidatus thomasi_
26. *_Mesocyclops edax_

Suborder Harpacticoida
Family Harpacticoidae
27. *_Bryocamptus_ sp.

Phylum Rotifera
Class Monogononta
Order Flosculariacea
Family Conochilidae
28. *_Conochilus unicornis_
29. *_C. dossarius_

Family Testudinellidae
30. _Testudinella_ sp.
31. *_Pompholyx sulcata_

Family Filiniidae
32. _Filinia terminalis_
33. *_Filinia longiseta_

Order Plioma
Family Synchaetidae
34. _Polyarthra_ sp.
35. *_Synchaeta pectinata_
36. *_Polyarthra vulgaris_

Family Asplanchnidae
37. *_Asplanchna_ sp.
38. _Asplanchna herricki_
39. _Asplanchna priodonta_

Family Brachionidae
40. _B. quadridentata_
41. *_B. calyciflorus_
42. *_Brachionus patulus_
43. *_Brachionus ureolaris_
44. *_Kellicottia longispina_
45. _Keratella_ sp.
46. *_Keratella cochlearis_
47. *_Keratella quadrata_
48. *_Keratella serrulata_
49. *_Notholca_ sp.
50. *_Notholoca acuminata_
51. *_Platyas quadricornus_

Family Euchlanidae
52. _Euchlanis dilatata_
53. *_Euchlanis calpidia_

Family Trichotriidae
54. _Trichotria tetractis_
55. *_Trichotria pocillum_

Family Trichocercidae
56. *_Trichocerca_ sp.

Family Lecanidae
57. *_Lecane_ sp.

Family Gastropodidae
58. *_Gastropus stylifer_

Order Collothecacea
Family Collothecidae
59. *_Collotheca libera_

mid-July (454 organisms/m^3), while *Daphnia* sp. peaked in early September (1,742 organisms/m^3) and copepod sp. in early October (7,248 organisms/m^3; Table 3.8). Peak other Cladocera densities were 3 to 4 times less than peak *Daphnia* sp. densities and nearly 16 times less than peak copepod sp. densities. Reservoir average densities above 100 organisms/m^3 occurred from late-June through early-August for other Cladocera, from late-June through mid-October for *Daphnia* sp. and from mid-June through late December for copepod sp. (Table 3.8).

Reservoir average densities of total zooplankton remained low (< 275 organisms/m^3) from January through May except for a short bloom (primarily copepods) in mid-February (884 organisms/m^3). By early June, notable seasonal increases in density began for each major group, reaching reservoir maximum total zooplankton densities in early October (7,530 organisms/m^3). By late December, reservoir average total zooplankton densities returned to near annual lows (143 organisms/m^3; Table 3.8).

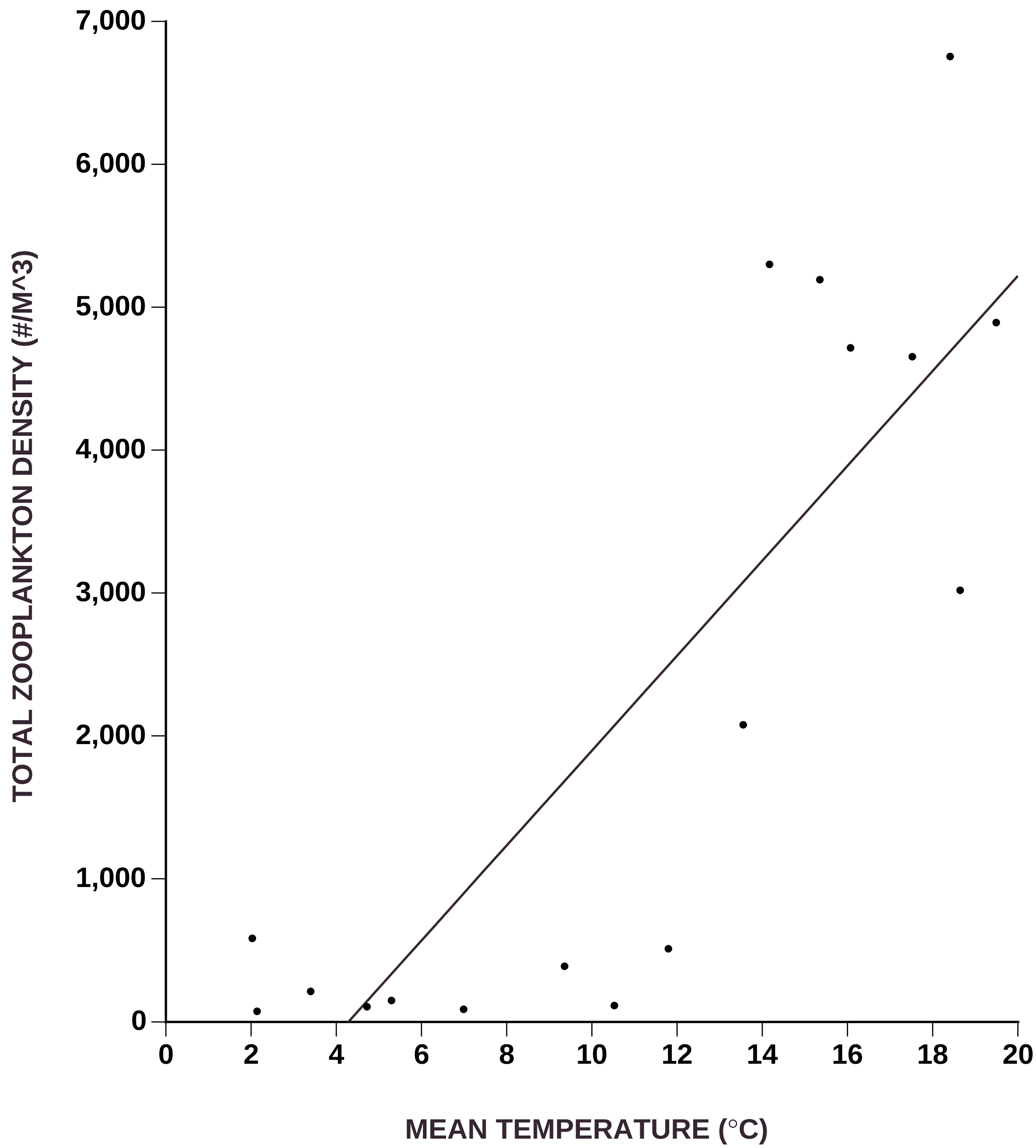
Attempts to model spatial variations in zooplankton densities using stepwise regression on localized environmental variables (chlorophyll *a*, secchi depth, daily WRT, daily temperature, and reservoir inflow, outflow and elevation) were largely unsuccessful (maximum $r^2 = 0.30$). However, temporal variations in total zooplankton densities in 1997 (across sample dates) were best described as a function of reservoir mean temperature across all sites ($r^2 = 0.70$; $p < 0.0001$; Figure 3.7). Few significant ($p < 0.05$) spatial and temporal differences were noted in total zooplankton densities during 1997. Total zooplankton densities at San Poil River and San Poil confluence sites were significantly higher ($p = 0.0001$) than upper-mainstem Columbia sites (Evan's Landing, Kettle Falls, Gifford and Hunters). Also, densities of total zooplankton collected on July 10th, July 23rd, August 5th and October 2nd were significantly higher ($p = 0.0001$) than values reported for all other sample dates.

3.4.3 Zooplankton lengths

In 1997, of the 18 adult non-rotifer zooplankton species collected from Lake Roosevelt, eight had annual mean lengths ≥ 1.0 mm (maximum: 1.7 mm); five had annual mean lengths ≥ 0.5 and < 1.0 mm and five had annual mean lengths < 0.5 mm (minimum: 0.2 mm). Accordingly, *Daphnia* had the highest mean length by taxonomic group (1.11 mm; range: 0.18 - 3.03 mm), followed by other Cladocera (0.72 mm; range: 0.19 - 3.33 mm), and copepods (0.65 mm; range: 0.25 - 2.56 mm; Table 3.9).

Table 3.8 Reservoir mean zooplankton density (#/m^3) by taxonomic group and sample date for 1997.

Approximate Sample Date	*Daphnia*	Other Cladocera	Copepoda	Total Zooplankton
Jan-15	23	2	43	67
Feb-11	3	11	257	271
Feb-19	36	12	837	884
Mar-13	2	2	203	207
Mar-28	4	2	94	100
Apr-17	6	5	71	81
Apr-28	--	--	--	--
May-14	85	9	289	383
May-28	2	7	99	108
Jun-12	20	19	466	505
Jun-25	102	273	1,697	2,072
Jul-10	589	454	4,143	5,186
Jul-23	459	281	3,969	4,709
Aug-5	602	104	6,041	6,748
Aug-18	1,653	19	3,215	4,886
Sep-3	1,072	37	1,905	3,013
Sep-17	1,742	35	2,871	4,648
Oct-2	265	17	7,248	7,530
Oct-13	800	140	2,117	3,057
Nov-18	--	--	--	--
Dec-22	37	1	105	143
Mean	**344**	**65**	**1,631**	**2,040**



$Y = -1{,}423.3 + 332.1 * X;\ r^2 = 0.70;\ P < 0.0001$

Figure 3.7 Regression plot of 1997 reservoir mean temperature (ºC) versus reservoir mean total zooplankton density (#/m^3).

Table 3.9 Annual mean zooplankton lengths (mm) by species for 1997 Lake Roosevelt samples.

Species	Mean Length	Standard Deviation	n	Observed Range
Daphnia				
Daphnia pulex	1.72	0.48	167	(0.67 - 3.03)
Daphnia retrocurva	1.21	0.43	261	(0.48 - 2.63)
Daphnia schødleri	0.88	0.26	268	(0.43 - 2.43)
Daphnia thorata	1.60	--	1	
Juvenile *Daphnia*	0.37	0.14	94	(0.18 - 0.77)
Other Cladocera				
Alona quadrangularis	0.40	0.08	6	(0.29 - 0.50)
Bosmina longirostris	0.34	0.07	325	(0.22 - 0.62)
Ceriodaphnia reticulata	0.63	0.12	2	(0.55 - 0.72)
Chydorus sphaericus	0.28	0.05	68	(0.19 - 0.41)
Diaphanosoma brachyurum	0.89	0.29	19	(0.50 - 1.69)
Leptodora kindtii	1.42	0.97	13	(0.50 - 3.33)
Scapholeberis mucronata	0.48	0.14	4	(0.32 - 0.62)
Sida crystallina	1.40	0.40	9	(0.59 - 1.90)
Pleuroxus striatus	0.37	0.07	6	(0.31 - 0.50)
Copepoda				
Diacyclops bicus. thomasi	0.92	0.17	1,023	(0.55 - 2.23)
Epischura nevadensis	1.70	0.53	28	(0.71 - 2.56)
Harpacticoid sp.	0.56	0.12	7	(0.42 - 0.73)
Leptodiaptomus ashlandi	1.02	0.21	652	(0.52 - 2.23)
Mesocyclops edax	1.23	--	1	
Calanoid copepodid	0.45	0.07	432	(0.25 - 0.72)
Cyclopoid copepodid	0.45	0.07	913	(0.25 - 0.52)
Nauplii	0.24	0.07	649	(0.09 - 0.52)

Of all zooplankton organisms measured in 1997 (n = 4,948), 77.5 % were less than 1.0 mm in length, 20.8 % were ≥ 1.0 and < 2.0 mm, and 1.7 % were ≥ 2.0 mm (Table 3.10). Fifty one percent of measured *Daphnia* sp. fell between 0.6 and 1.2 mm, 91.4 % of measured other Cladocera fell between 0.2 and 0.6 mm and 90.1 % of measured copepod sp. fell between 0.2 and 1.2 mm (Table 3.10).

Although total zooplankton lengths observed at mid-reservoir stations (Porcupine Bay, Confluence, Seven Bays and Keller Ferry) were apparently larger than other sites, these differences were not found to be significant ($p > 0.10$). However, zooplankton collected in August and December were significantly larger ($p = 0.0001$) than organisms collected at other times of the year, primarily due to increased relative abundance of *Daphnia pulex* and *Diacyclops thomasi* in August and *Diacyclops thomasi* in December (Table 3.8). Also, zooplankton collected in June were significantly smaller than those collected in other months ($p = 0.006$) corresponding with increased relative abundance of smaller (other) Cladocera (Table 3.8).

Of measured *Daphnia* sp., *Daphnia schødleri* were smallest, averaging 0.9 mm in length, *Daphnia pulex* were largest, averaging 1.7 mm in length and *Daphnia retrocurva* were medium sized, averaging 1.2 mm in length (Table 3.11). *Daphnia pulex* also had a wider distribution of larger sizes than either *D. schødleri* or *D. retrocurva* (Table 3.11) which has implications for fish food quality. As with total zooplankton, *Daphnia* collected in August or December were significantly larger than those collected during other times of the year ($p < 0.0001$). No significant differences in *Daphnia* lengths were observed between locations in 1997.

3.5 Zooplankton Biomass

3.5.1 Total Zooplankton Biomass

Highest annual mean total zooplankton biomass values by location were recorded at Porcupine Bay (28,864 $\mu g/m^3$) and San Poil River (25,253 $\mu g/m^3$) during 1997. Lowest annual mean total zooplankton biomass values were recorded at Evan's Landing (378 $\mu g/m^3$) and Kettle Falls (393 $\mu g/m^3$). Overall, annual mean total zooplankton biomass values were low (< 2,900 $\mu g/m^3$) from Hunters upstream (Gifford, Kettle Falls and Evan's Landing) and high (> 9,200 $\mu g/m^3$) at mid and lower reservoir sites (Porcupine Bay, Seven Bays, Keller Ferry, San Poil, San Poil confluence, and Spring Canyon; Table 3.12).

Table 3.10 Zooplankton relative abundance by size class and taxonomic group for 1997 Lake Roosevelt samples.

Size Class (mm)	*Daphnia* (n = 791)	Other Cladocera (n = 452)	Copepoda (n = 3,705)	Total Zooplankton (n = 4,948)
0.0 - 0.2	0.3	0.2	4.8	3.7
0.2 - 0.4	8.5	72.8	21.4	24.0
0.4 - 0.6	4.6	18.6	26.9	22.6
0.6 - 0.8	19.5	2.7	10.0	10.9
0.8 - 1.0	17.7	1.3	17.9	16.4
1.0 - 1.2	13.5	1.1	13.9	12.7
1.2 - 1.4	8.7	0.7	3.5	4.1
1.4 - 1.6	9.0	0.9	0.7	2.1
1.6 - 1.8	5.9	0.7	0.2	1.2
1.8 - 2.0	3.4	0.2	0.2	0.8
2.0 - 2.2	4.1	0.0	0.2	0.8
2.2 - 2.4	2.8	0.4	0.1	0.6
2.4 - 2.6	1.5	0.2	0.1	0.3
2.6 - 2.8	0.4			0.1
2.8 - 3.0	0.1			<0.1
3.0 - 3.2	0.1			<0.1
3.2 - 3.4		0.2		<0.1

Table 3.11 Relative abundance by size class for *Daphnia* sp. collected from Lake Roosevelt in 1997.

Size Class (mm)	*Daphnia pulex* (n = 167)	*Daphnia retrocurva* (n = 261)	*Daphnia schødleri* (n = 268)	*Daphnia thorata* (n = 1)	Juvenile *Daphnia* (n = 94)
0.0 - 0.2					2.1
0.2 - 0.4					71.3
0.4 - 0.6		2.3	4.5		19.1
0.6 - 0.8	1.2	16.9	37.7		7.4
0.8 - 1.0	3.6	16.5	34.0		
1.0 - 1.2	10.8	18.0	15.7		
1.2 - 1.4	13.8	14.2	3.4		
1.4 - 1.6	15.6	14.6	2.6		
1.6 - 1.8	14.4	7.7	0.7	100.0	
1.8 - 2.0	9.0	3.8	0.7		
2.0 - 2.2	12.0	3.8	0.4		
2.2 - 2.4	10.8	1.9	0.4		
2.4 - 2.6	6.6				
2.6 - 2.8	1.2	0.4			
2.8 - 3.0	0.6				
3.0 - 3.2	0.6				

Table 3.12 Monthly mean total zooplankton biomass values ($\mu g/m^3$) at each Index Station in 1997. No data was collected during November 1997.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Dec	Mean
Evan's Landing*	--	--	--	--	156	384	558	226	210	--	733	**378**
Kettle Falls	--	--	--	--	178	794	432	459	100	--	--	**393**
Gifford	--	90	141	426	87	602	773	858	731	--	27	**415**
Hunters	--	--	761	--	121	275	636	4,829	11,379	--	19	**2,820**
Porcupine Bay	63	--	130	--	945	2,259	14,054	181,772	33,847	19,945	--	**28,864**
Confluence	48	1,832	310	--	141	1,773	12,694	11,651	49,217	12,047	--	**9,243**
Seven Bays	315	255	185	373	212	780	14,674	22,781	42,781	9,775	--	**9,213**
Keller Ferry	205	175	411	--	504	430	12,391	27,009	33,488	5,145	140	**7,660**
San Poil Conf.*	--	--	--	--	763	409	12,254	36,013	56,139	10,805	432	**13,689**
San Poil River	--	--	--	--	25,302	3,451	42,098	87,385	12,872	5,450	216	**25,253**
Spring Canyon	4,279	159	405	405	606	898	20,976	93,218	56,603	29,150	8,160	**19,533**
Mean	**982**	**502**	**335**	**401**	**2,638**	**1,096**	**11,958**	**42,382**	**27,033**	**13,188**	**1,390**	**1,068**

***** Not included as a sampling location until May, 1997.

Total zooplankton biomass values were consistently low (generally < 1,000 μg/m^3) at all sites sampled from January through April. Increases in zooplankton biomass began during May and June resulting in the accumulation of a large standing crop from July through October at mid and lower reservoir sites (> 10,000 μg/m^3). By December, reservoir wide total zooplankton biomass values were reduced considerably (1,390 μg/m^3; Table 3.12).

During 1997, *Daphnia* accounted for 68.6 % of total zooplankton biomass observed in Lake Roosevelt followed by copepod sp. (30.6 %) and other Cladocera (0.8 %; Table 3.13). Ninety-five percent of reservoir wide zooplankton biomass in Lake Roosevelt was attributed to just six species; *Daphnia pulex*, (32.3 %); *D. schødleri*, (21.3 %); *D. retrocurva*, (12.9 %); *Diacyclops bicuspidatus thomasi*, (12.7 %); and *Leptodiaptomus ashlandi* , (12.7 %). All other zooplankton species each accounted for less than 5.0 % of total biomass observed in Lake Roosevelt during 1997 (Figure 3.8).

During the 1997 growing season, temporal variation in relative biomass by species was noted. From late June to early August , five species (*Diacyclops bicuspidatus thomasi*, *Daphnia pulex, D. schødleri*, *D. retrocurva*, and *Leptodiaptomus ashlandi*) contributed about equally toward total zooplankton biomass. From mid-August through early September, *Daphnia pulex* dominated total zooplankton biomass, while from early September through mid-October, three species (*Daphnia retrocurva*, *D. pulex*, and *Leptodiaptomus ashlandi*) contributed significantly toward total zooplankton biomass. (Figure 3.8).

Similar to zooplankton density, attempts to model spatial variations in zooplankton biomass based on localized environmental variables (chlorophyll *a*, secchi depth, daily WRT, daily temperature, and reservoir inflow, outflow and elevation) using stepwise regression were largely unsuccessful (maximum $r^2 = 0.21$). Temporal variations in total zooplankton biomass in 1997 (across sample dates) were best described as a function of reservoir mean temperature across all sites ($r^2 = 0.60$, $p = 0.0006$; Figure 3.9).

3.5.2 *Daphnia* Biomass

In 1997, highest annual mean total *Daphnia* biomass values were recorded at Porcupine Bay (24,499 μg/m^3) and San Poil River (15,418 μg/m^3). Lowest annual mean total *Daphnia* biomass values were recorded at Kettle Falls and Gifford (85 and 123 μg/m^3 respectively). Annual mean *Daphnia* sp. biomass values were relatively low at all upper

Table 3.13 Annual mean biomass values (µg/m^3) by location with relative abundance by taxonomic group (%) for 1997 Lake Roosevelt zooplankton samples.

Location	*Daphnia*	Other Cladocera	Copepoda	Total Zooplankton
Evan's Landing	142 (37.5)	13 (3.4)	224 (59.1)	**378**
Kettle Falls	85 (21.7)	28 (7.2)	279 (71.1)	**393**
Gifford	122 (29.3)	37 (8.9)	256 (61.8)	**415**
Hunters	1,096 (38.9)	99 (3.5)	1,502 (57.6)	**2,821**
Section 1 Mean	**361**	**44**	**596**	**1,002**
Porcupine Bay	25,498 (88.3)	92 (0.3)	3,274 (11.3)	**28,864**
Confluence	6,710 (72.6)	220 (2.2)	2,328 (25.2)	**9,243**
Seven Bays	5,671 (61.5)	190 (2.1)	3,352 (36.4)	**9,213**
Section 2 Mean	**12,627**	**162**	**2,985**	**15,773**
Keller Ferry	3,297 (43.0)	76 (1.0)	4,287 (56.0)	**7,660**
San Poil Confl.	7,859 (57.4)	129 (1.0)	5,701 (41.6)	**13,689**
San Poil River	15,497 (61.4)	92 (0.4)	9,664 (38.2)	**25,253**
Spring Canyon	14,511 (74.3)	26 (0.1)	4,996 (25.6)	**19,533**
Section 3 Mean	**10,291**	**81**	**6,162**	**16,534**
Reservoir Mean	**7,317 (68.6)**	**90 (0.8)**	**3,272 (30.6)**	**10,678 (100.0)**

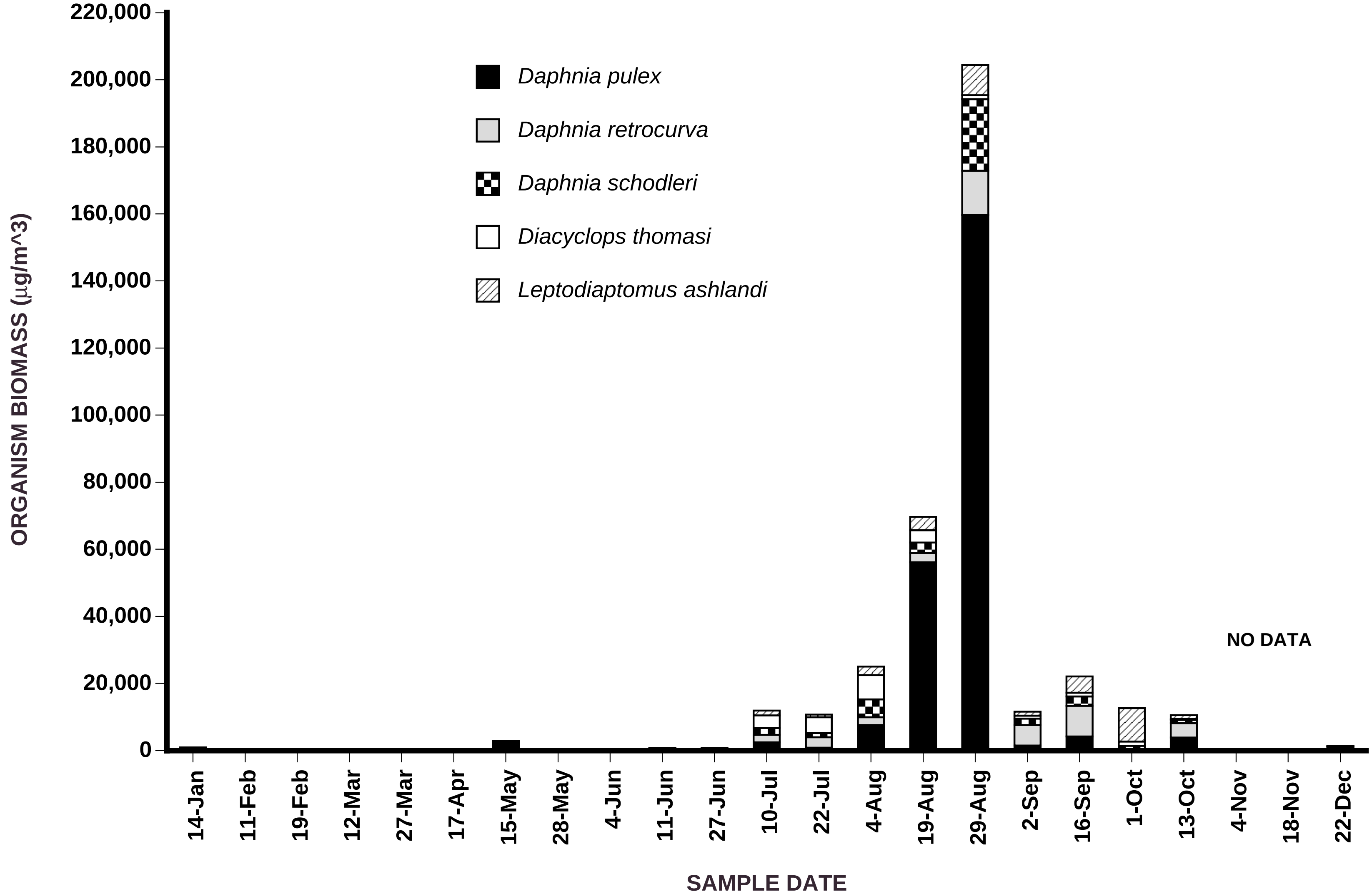
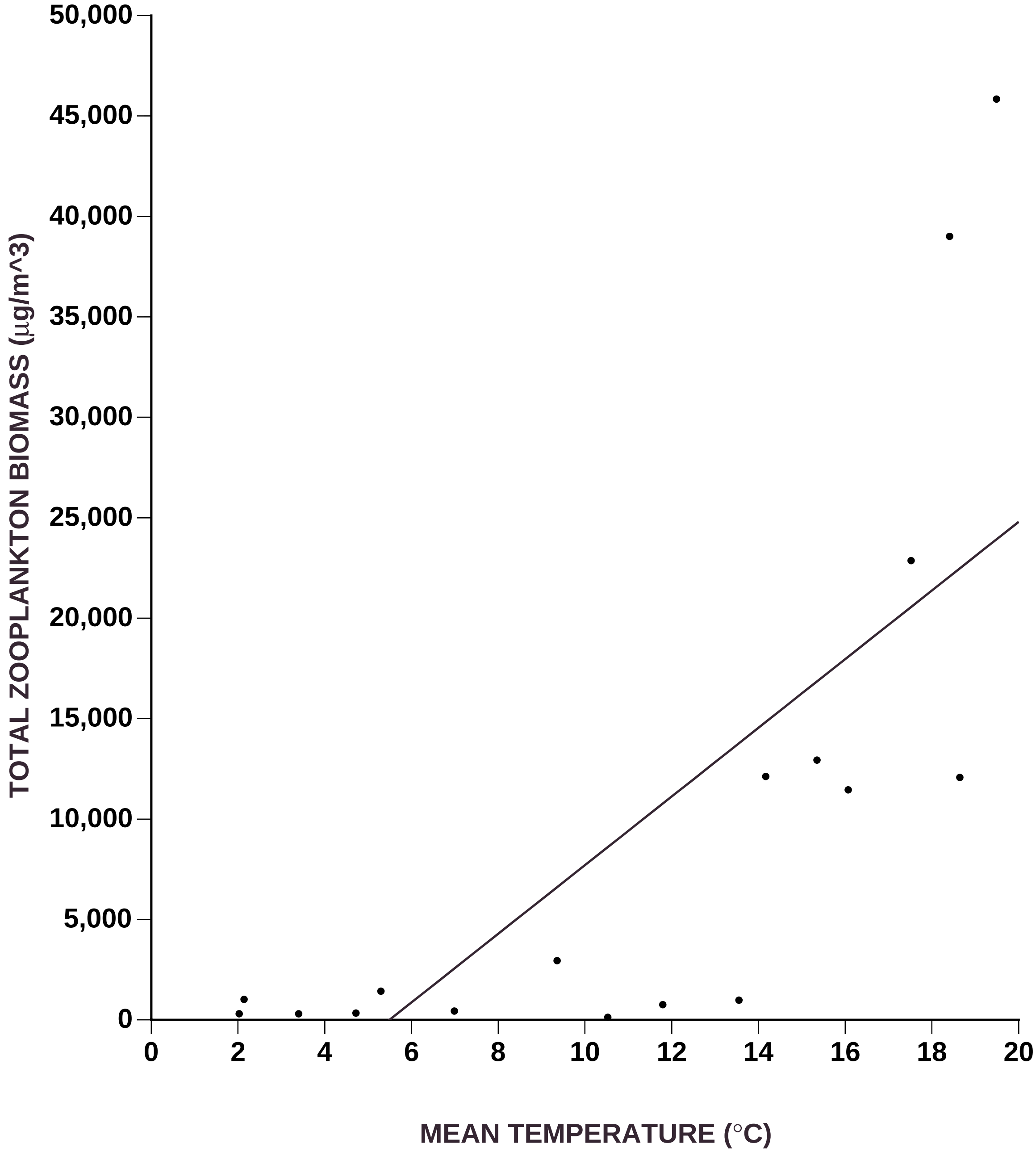


Figure 3.8 Reservoir mean total zooplankton species biomass (µg/m³) by sample date for Lake Roosevelt in 1997.



$Y = -9,382.2 + 1,708.9 * X$; $r^2 = 0.60$; $P = 0.0006$

Figure 3.9 Regression plot of 1997 reservoir mean temperature (°C) versus reservoir mean total zooplankton biomass (μg/m^3).

mainstem Columbia River sites (Hunters, Gifford, Kettle Falls and Evan's Landing) and high at mid and lower reservoir sites (Porcupine Bay, Seven Bays, Confluence, Keller Ferry, San Poil Confluence, San Poil River and Spring Canyon). In terms of total *Daphnia* biomass, Porcupine Bay was the most productive site on the reservoir (Table 3.14).

Monthly mean *Daphnia* sp. biomass values were consistently low (< 1,000 $\mu g/m^3$) at all upper mainstem Columbia River sites (Hunters, Gifford, Kettle Falls and Evan's Landing) with the exception of Hunters in September (6,385 $\mu g/m^3$). Monthly mean *Daphnia* sp. biomass values at mid and lower reservoir sites (Porcupine Bay, Confluence, Seven Bays, Keller Ferry, San Poil Confluence, San Poil River and Spring Canyon) were low (< 1,000 $\mu g/m^3$) from January through May except for Spring Canyon in January (4,018 $\mu g/m^3$) and San Poil River in May (22,710 $\mu g/m^3$). Beginning in May or June, *Daphnia* sp. biomass began to increase at most sites, reaching monthly maximum values in August or September at all sites except Evan's Landing (644 $\mu g/m^3$ in December). Total *Daphnia* biomass values were significantly ($p < 0.0001$) higher in August than other sample dates. During October and December, substantial reductions in *Daphnia* sp. biomass were noted at all sites except Evan's Landing (Table 3.14).

Daphnia pulex accounted for 46.2 % (3,884 $\mu g/m^3$) of reservoir wide total *Daphnia* biomass followed by *D. schødleri* at 30.5 % (2,559 $\mu g/m^3$), *D. retrocurva* at 18.9 % (1,586 $\mu g/m^3$), *D. thorata* at 4.1 % (348 $\mu g/m^3$) and juvenile *Daphnia* at 0.3 % (26 $\mu g/m^3$). As with total zooplankton biomass, temporal variations in contributions made by individual species toward total *Daphnia* biomass were noted in 1997. From late June through early August, *D. pulex*, *D. schødleri* and *D. retrocurva* contributed about equally toward total *Daphnia* biomass. From early August through early September, *D. pulex* dominated total *Daphnia* biomass, while from early September through mid-October, *D. schødleri* , *D. pulex* and *D. retrocurva* contributed to total *Daphnia* biomass (Figure 3.10).

Maximum monthly total *Daphnia* biomass values were recorded in August at Porcupine Bay (166,650 $\mu g/m^3$) and Spring Canyon (76,944 $\mu g/m^3$; Table 3.14). Attempts to model spatial variations in *Daphnia* sp. biomass using stepwise regression of localized environmental variables were again unsuccessful (maximum $r^2 = 0.11$). Temporal variations in *Daphnia* sp. biomass for 1997 were again best described as a function of reservoir mean temperature across all sites ($r^2 = 0.51$; $p = 0.0013$).

Table 3.14 **Monthly mean *Daphnia* sp. biomass values (µg/m^3) by Index Station in 1997. No data was collected in November.**

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Dec	Mean
Evan's Landing*	--	--	--	--	18	2	74	11	99	--	644	**142**
Kettle Falls	--	--	--	--	75	7	123	165	57	--	--	**85**
Gifford	--	25	9	258	28	31	288	0	460	--	9	**123**
Hunters	--	--	761	--	19	33	15	465	6,385	--	0	**1,097**
Porcupine Bay	16	26	59	--	133	1,598	9,132	166,650	31,934	19,945	--	**24,499**
Confluence	36	200	11	180	71	122	6,918	6,140	50,832	10,765	--	**7,528**
Seven Bays	272	125	44	190	26	91	8,168	6,457	33,782	7,568	--	**5,672**
Keller Ferry	174	43	254	--	51	22	3,834	12,201	19,431	210	45	**3,627**
San Poil Conf.*	--	--	--	--	494	616	3,630	16,212	56,139	10,805	314	**12,601**
San Poil River	--	--	--	--	22,710	2,434	20,580	58,380	3,644	77	103	**15,418**
Spring Canyon	4,018	54	162	153	45	583	13,064	76,944	53,100	3,960	7,519	**14,509**
Mean	**903**	**79**	**186**	**195**	**2,151**	**504**	**5,984**	**31,239**	**23,260**	**7,619**	**1,233**	**7,257**

"*" Not included as a sampling location until May, 1997.

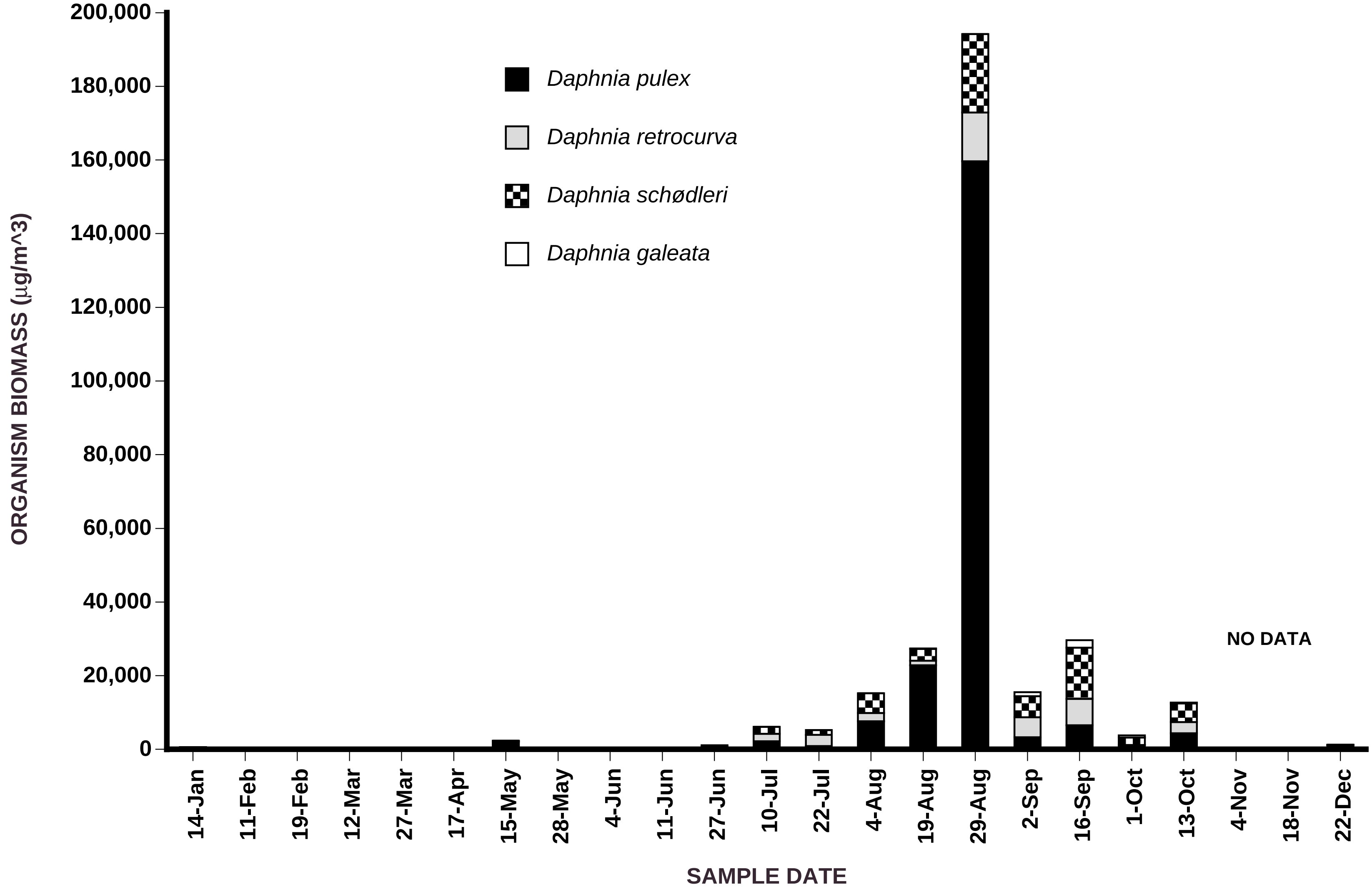


Figure 3.10 Reservoir mean *Daphnia* sp. biomass (µg/m^3) by sample date for Lake Roosevelt in 1997.

3.5.3 Other Cladocera Biomass

In general, contributions to total zooplankton biomass made by other Cladocera were insignificant (0.8 %) when compared with *Daphnia* and copepod taxa (Table 3.13). On an annual mean basis, other Cladocera biomass values were highest at the Confluence (204 $\mu g/m^3$) and Seven Bays (190 $\mu g/m^3$) and lowest at Evan's Landing (13 $\mu g/m^3$) and Spring Canyon (26 $\mu g/m^3$). Annual mean other Cladocera biomass values were lowest (< 50 $\mu g/m^3$) at upper and lower ends of Lake Roosevelt (Evan's Landing, Kettle Falls, Gifford and Spring Canyon) and highest (> 100 $\mu g/m^3$) at mid-reservoir sites (Porcupine Bay, Confluence, Seven Bays and San Poil Confluence). Highest annual other Cladocera productivity occurred at the Confluence in 1997 (Table 3.15) No significant differences in total other Cladocera biomass values were observed between locations in 1997.

Monthly mean other Cladocera biomass values were less than 50 $\mu g/m^3$ at all locations sampled during winter and spring months. In May, other Cladocera biomass began to increase at most sites, reaching monthly maximum values in July at all locations except Kettle Falls (51 $\mu g/m^3$ in August) and the Confluence (644 $\mu g/m^3$ in September). From July through October, total other Cladocera biomass values remained relatively high at most locations (Table 3.15). Total other Cladocera biomass values were significantly ($p < 0.0001$) higher on July 10th than on any other sample date.

Bosmina longirostris accounted for 65 % (45 $\mu g/m^3$) of mean reservoir wide other Cladocera biomass followed by *Sida crystallina* and *Scapholeberis mucronata* at 12.8 % (8.9 $\mu g/m^3$) and *Leptodora kindti* at 6 % (4 $\mu g/m^3$). Additional other Cladocera species accounted for less than 1 $\mu g/m^3$ (1.5 %) respectively on an annual basis (Figure 3.11). Monthly maximum *Bosmina longirostris* biomass values were recorded in July (312 $\mu g/m^3$) while *Sida crystallina* and *Leptodora kindti* peaked in September (102 and 62 $\mu g/m^3$ respectively).

Stepwise regression of localized environmental variables was unsuccessful at describing spatial variations in other Cladocera biomass (maximum $r^2 = 0.01$). Temporal variations in total other Cladocera biomass were again best described as a function of reservoir mean temperature across all sites. However, the relationship with temperature was the poorest of any zooplankton group studied in 1997 ($r^2 = 0.34$; $p = 0.0148$).

Table 3.15 Monthly mean Other Cladocera biomass values ($\mu g/m^3$) at each Index Station in 1997. No data was collected in November.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Dec	Mean
Evan's Landing*	--	--	--	--	5	25	28	13	3	--	2	**13**
Kettle Falls	--	--	--	--	7	33	41	51	9	--	--	**29**
Gifford	--	2	6	20	5	95	128	31	44	--	< 1	**37**
Hunters	--	--	--	--	8	19	208	185	176	--	< 1	**99**
Porcupine Bay	3	--	7	--	26	61	316	229	192	--	--	**119**
Confluence	< 1	47	4	--	6	140	455	403	644	142	--	**204**
Seven Bays	< 1	3	1	6	3	18	658	395	522	294	--	**190**
Keller Ferry	3	3	2	--	15	5	607	73	14	4	1	**73**
San Poil Conf.*	--	--	--	--	8	32	464	108	--	--	< 1	**122**
San Poil River	--	--	--	--	48	5	528	55	< 1	5	1	**92**
Spring Canyon	< 1	4	2	5	11	3	187	36	11	21	0	**26**
Mean	**2**	**15**	**3**	**7**	**10**	**28**	**337**	**105**	**178**	**77**	**< 1**	

"*" Not included as a sampling location until May, 1997.

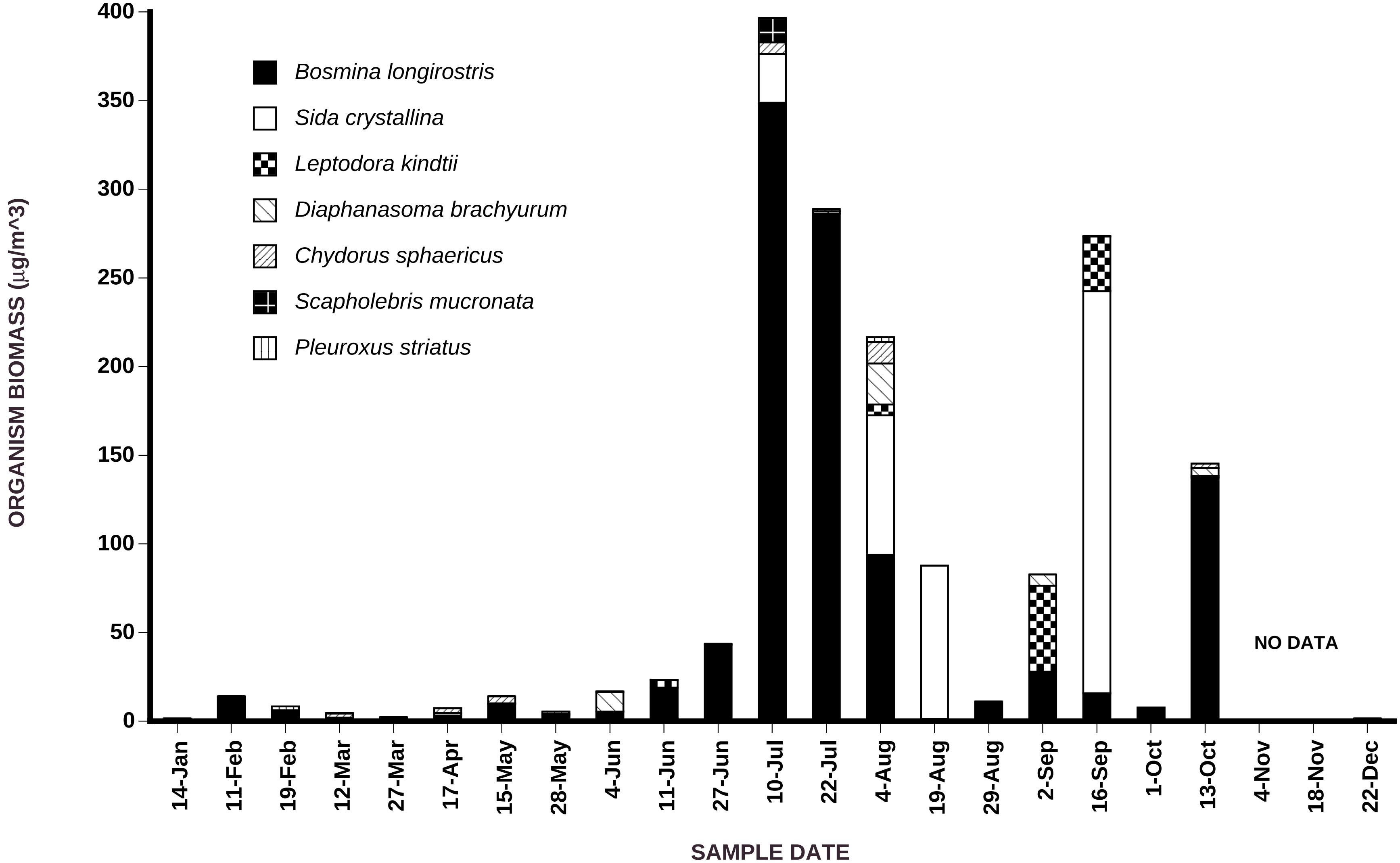


Figure 3.11 Reservoir mean Other Cladocera biomass (μg/m^3) by sample date for Lake Roosevelt in 1997.

3.5.4 Copepoda Biomass

Annual mean copepod biomass values were highest at San Poil River (9,643 $\mu g/m^3$) and San Poil confluence (5,701 $\mu g/m^3$) and lowest at Evan's Landing (224 $\mu g/m^3$) and Gifford (256 $\mu g/m^3$) in 1997. Reservoir mean total copepod biomass was significantly positively correlated with reservoir mean temperature ($r^2 = 0.56$; $p = 0.0049$). Consistently low biomass values (< 280 $\mu g/m^3$) were recorded at upper mainstem Columbia River sites (Evan's Landing, Kettle Falls and Gifford) while down-reservoir sites (Keller Ferry, San Poil confluence, San Poil River and Spring Canyon) recorded high annual mean biomass values (> 4,200 $\mu g/m^3$). Central reservoir sites (Porcupine Bay, Confluence, Seven Bays and Keller Ferry) had intermediate annual mean copepod biomass values (range 2,328 to 3,352 $\mu g/m^3$). Annual mean total copepod biomass values at San Poil River were significantly higher ($p < 0.006$) than all other sample sites except Keller Ferry and Spring Canyon.

Monthly mean copepod biomass values were less than 1,000 $\mu g/m^3$ from January through June and in December at all locations except for the San Poil River in May (2,544 $\mu g/m^3$) and the Confluence in February (1,664 $\mu g/m^3$) and June (1,450 $\mu g/m^3$). Seasonal increases in copepod biomass began in May or June, reaching monthly maximums in June at Kettle Falls, in July at Evan's Landing, in September at Hunters, in October at Spring Canyon and in August at all other sites (Gifford, Porcupine Bay, Confluence, Seven Bays, Keller Ferry, San Poil Confluence and San Poil River). Reservoir wide total copepod biomass was significantly higher ($p < 0.001$) in August than in other sample months. Maximum monthly copepod biomass values were observed in August at the San Poil River (28,950 $\mu g/m^3$) and at Spring Canyon in October (25,168 $\mu g/m^3$). Lowest monthly Copepoda biomass values were recorded in January at the Confluence (12 $\mu g/m^3$) and in December at Gifford (17 $\mu g/m^3$; Table 3.16).

Leptodiaptomus ashlandi accounted for 44 % (998 $\mu g/m^3$) of annual reservoir wide copepod biomass, followed by *Diacyclops bicuspidatus thomasi* at 43 % (978 $\mu g/m^3$), *Epischura nevadensis* at 7.3 % (167 $\mu g/m^3$), Cyclopoid copepodids at 3 % (73 $\mu g/m^3$) and Calanoid copepodids at 3 % (60 $\mu g/m^3$; Figure 3.12). Other individual copepod taxa (*Mesocyclops edax*, Harpacticoid sp. and Nauplii) accounted for less than 1 % of annual total copepod biomass. Maximum biomass values occurred in mid-July for Cyclopoid copepodids (473 $\mu g/m^3$), early-August for *Diacyclops bicuspidatus thomasi* (7,282 $\mu g/m^3$), mid-August for *Epischura nevadensis* (2,664 $\mu g/m^3$), late-August for Calanoid

Table 3.16 Monthly mean copepod sp. biomass values ($\mu g/m^3$) at each Index Station in 1997. No data was collected in November.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Dec	Mean
Evan's Landing*	--	--	--	--	133	357	455	202	108	--	87	**224**
Kettle Falls	--	--	--	--	96	754	269	243	33	--	--	**279**
Gifford	--	63	127	149	65	476	357	827	227	--	17	**256**
Hunters	--	--	--	--	96	223	414	4,180	4,818	--	18	**1,625**
Porcupine Bay	44	--	75	--	786	600	4,606	14,893	1,914	--	--	**3,274**
Confluence	12	1,664	296	--	64	1,450	5,320	5,827	5,177	1,140	--	**2,328**
Seven Bays	42	128	139	178	106	762	5,848	15,928	8,477	1,913	--	**3,352**
Keller Ferry	29	128	155	--	438	403	7,914	14,734	14,044	4,931	94	**4,287**
San Poil Conf.*	--	--	--	--	261	306	8,129	19,693	--	--	118	**5,701**
San Poil River	--	--	--	--	2,544	307	20,989	28,950	9,229	5,367	112	**9,643**
Spring Canyon	261	101	241	247	551	296	7,725	16,239	3,492	25,168	642	**4,996**
Mean	**78**	**625**	**180**	**191**	**293**	**483**	**5,783**	**11,467**	**4,393**	**6,674**	**155**	

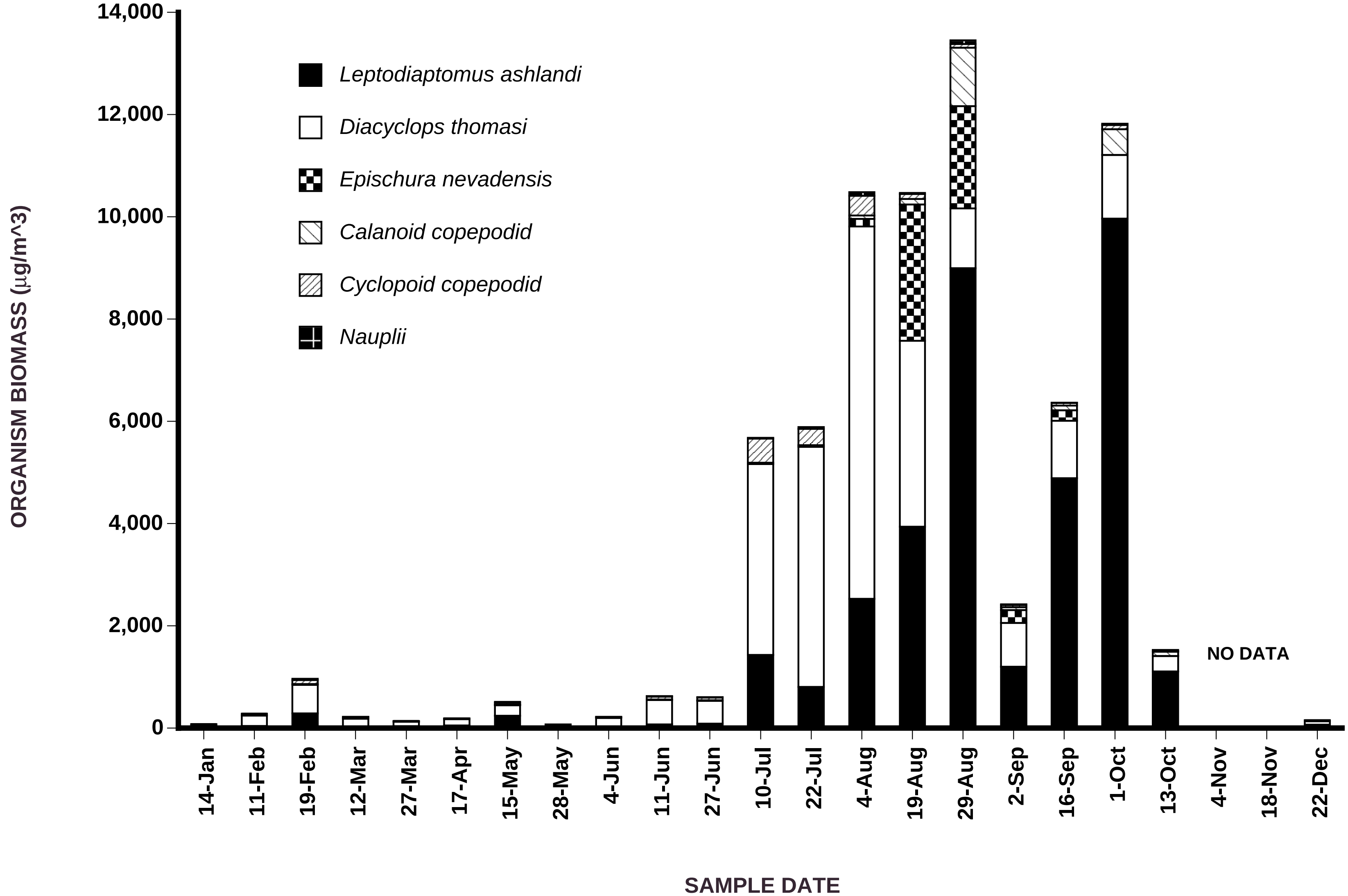


Figure 3.12 Reservoir mean copepod species biomass ($\mu g/m^3$) by sample date for Lake Roosevelt in 1997.

copepodids (1,148 $\mu g/m^3$) and Nauplii (67 $\mu g/m^3$) and in early-October for *Leptodiaptomus ashlandi* (9,963 $\mu g/m^3$; Figure 3.12).

3.6 Tagging Studies

In 1997, 10,000 rainbow trout were floy tagged at each of the Kettle Falls and Seven Bays net-pens sites during February. Handling/tagging mortality for rainbow trout was assumed to be less than 0.5% based on previous studies (Underwood and Shields 1995). In 1997, rainbow trout were released from Kettle Falls net-pens in mid-May and from Seven Bays net-pens in early June. A total of 151 tags were returned from these release groups (Table 3.17), yielding an overall recapture rate of 0.76% for rainbow trout tagged during 1997.

Tag returns from rainbow trout during 1997 were distributed evenly between those released at Kettle Falls (74) and Seven Bays (77). The majority of rainbow trout tag returns came from the Rock Island Dam Smolt Monitoring Station (monitoring period March 31 – August 31, 1997; 79%, n=120), a tern study conducted near Astoria, Oregon (10%, n=15) and the John Day Dam Fish Passage Center (5%, n=7; Table 3.18). Rainbow trout tag returns from Kettle Falls releases came from the Rock Island Dam Smolt Monitoring Station (81%, n=60), Astoria, Oregon (14%, n=10), the John Day Dam Fish Passage Center (3%, n=2), Wanapum Dam (1%, n=1) and Seven Bays (1%, n=1). Rainbow trout tag returns from the Seven Bays releases came from the Rock Island Dam Smolt Monitoring Station (78%, n=60), John Day Dam Fish Passage Center (6.5%, n=5), Astoria, Oregon (6.5%, n=5), Rufus Woods Reservoir (4%, n=3), near Keller Ferry (4%, n=3) and near Little Falls (1%, n=1; Table 3.19).

Entrainment indices for rainbow trout suggest that entrainment was high for both release groups during 1997 (Table 3.17). May releases from Kettle Falls resulted in 73 of 74 rainbow trout tag returns (99%) coming from areas below Grand Coulee Dam (Tables 3.17 and 3.18). June releases from Seven Bays resulted in 73 of 77 rainbow trout (95%) re-captured below Grand Coulee Dam (Table 3.17 and 3.19).

Kokanee salmon floy tagging was conducted as part of this program for the first time in 1997 with 10,000 kokanee salmon tagged at the Sherman Creek Hatchery. Combined handling mortality and tag loss for kokanee salmon was approximately 11% based on raceway observations following tagging. Floy tagged kokanee salmon (8,922) were released from the hatchery on June 30, 1997. A single kokanee salmon floy tag was

Table 3.17 Summary of rainbow trout release times, water retention time and subsequent recapture numbers and percentages within the year of release.

Release Date	Mean Monthly WRT	Tags Released	Tags Recovered	Percent Tags Recovered	Number Recovered In FDR	Percent Recovered In FDR	# Recovered Below Grand Coulee Dam	% Recovered Below Grand Coulee Dam
March 89	36	768	1	<1	1	100	0	0
March 90	32	1,441	5	<1	2	40	3	60
March 92	48	5,999	82	1	79	96	3	4
March 93	67	7,974	11	<1	10	91	1	9
March 94	55	9,994	73	<1	68	93	5	7
April 89	33	985	14	1	12	86	2	14
April 90	31	1,470	31	1	22	73	9	27
April 91	18	2,300	64	3	43	67	21	33
April 92	51	5,998	139	2	135	97	4	3
April 93	87	7,992	36	<1	20	56	16	44
April 94	55	7,998	107	1	107	100	0	0
April 96	19	4,998	25	<1	3	12	22	88
May 88	40	1,171	77	7	77	100	0	0
May 90	29	1,450	36	2	27	75	9	25
May 92	34	6,000	203	3	198	98	5	2
May 93	39	4,999	53	1	52	98	1	2
May 94	44	8,983	127	1	124	98	3	2
May 95	39	12,984	104	<1	103	99	1	1
May 97	11	10,000	74	<1	1	1	73	99
June 91	29	296	28	9	23	82	5	18
June 92	34	3,000	85	3	85	100	0	0
June 93	50	296	8	3	8	100	0	0
June 96	22	9,950	177	2	144	81	33	19
June 97	16	10,000	77	<1	4	5	73	95
July 91	36	1,749	113	7	107	95	6	5

Table 3.18 Number and percent of tagged rainbow trout captured at various locations from the Kettle Falls releases in 1997.

CAPTURE LOCATION	# CAPTURED	% CAPTURED
Seven Bays	1	1.4
Wanapum Dam	1	1.4
John Day Dam	2	2.7
Astoria, OR	10	13.5
Rock Island Dam	60	81.1
TOTAL	**74**	

Table 3.19 Number and percent of tagged rainbow trout captured at various locations from the Seven Bays releases in 1997.

CAPTURE LOCATION	# CAPTURED	% CAPTURED
Little Falls	1	1.3
Keller Ferry	3	3.9
Rufus Woods	3	3.9
John Day Dam	5	6.5
Astoria, OR	5	6.5
Rock Island Dam	60	77.9
TOTAL	**77**	

returned in 1997 by an angler who removed it from the stomach of a northern squawfish captured near Kettle Falls. Nine other floy tags were collected from two year old ‘jacks’ during fall spawning surveys in 1997, eight from the Kettle Falls area and one near Seven Bays.

3.7 Creel Surveys

We estimated that total annual fishing pressure exerted in Lake Roosevelt during 1997 was 756,186 angler hours (Table 3.20). Our estimates of annual fishing pressure were highest in Section 2 (473,298 hrs), moderate in Section 3 (219,874 hours), and lowest in Section 1 (63,014 hrs; Table 3.20). Monthly fishing pressure was greatest during June (299,953 hrs) and July (180,471 hrs), and lowest during March (6,205 hrs) and April (1,256 hrs; Table 3.20).

Our estimates (from mean trip lengths and pressure estimates) indicate that anglers made 146,264 fishing trips to Lake Roosevelt from December 1996 through November 1997 (Table 3.21). An estimated total of 11,877 angler trips were made in Section 1; 91,251 angler trips in Section 2 and 35,534 trips in Section 3 during 1997 (Table 3.21). Sectional trip estimates do not sum to the annual estimate due to differences in calculation; quarterly averages were used for mean trip length to estimate the number of angler trips in some sections / months, whereas annual estimates were based solely on existing trip length data.

On a reservoir wide basis, the greatest number of estimated trips were during June (53,055), July (32,160) and September (17,434; Table 3.21). In all other months we estimated less than 10,000 angler trips were made to Lake Roosevelt, with estimated numbers of angler trips being lowest in March (1,668 angler trips) and April (349 angler trips). Fishing pressure and number of trips followed similar trends between months and sections in 1997. In general, estimated angler pressure and trip numbers were highest during summer and fall (June – October), moderate during winter (December - February), and low during spring drawdown (March – April; Tables 3.20 and 3.21).

During 1997, the overall mean annual harvest rate (fish kept per angler hour) in Lake Roosevelt for all species combined was 0.190, equating to 5.3 angler hours exerted for each fish harvested (Table 3.22). The 1997 annual mean harvest rate was 0.012 (83.3 angler hrs/fish) for rainbow trout, 0.172 (5.8 angler hrs/fish) for walleye (*Stizostedion vitreum vitreum*), 0.001 (1,000 angler hrs/fish) for smallmouth bass (*Micropterus*

Table 3.20 Total monthly angler pressure estimates in hours (± 95% CI), by creel section on Lake Roosevelt from December 1996, through November, 1997.

	Section			
Month	**1**	**2**	**3**	**Total**
December	407 ± 82	16,747 ± 571	0 ± 0	**17,154 ± 653**
January	235 ± 112	12,949 ± 771	2,268 ± 144	**15,452 ± 1,027**
February	1,152 ± 95	17,562 ± 1,057	3,813 ± 127	**22,527 ± 1,279**
March	764 ± 123	2,036 ± 603	3,378 ± 592	**6,205 ± 1,318**
April	14 ± 39	192 ± 183	1,050 ± 116	**1,256 ± 338**
May	853 ± 32	2,115 ± 390	13,546 ± 167	**16,514 ± 589**
June	31,274 ± 1,382	227,354 ± 6,572	41,325 ± 542	**299,953 ± 8,496**
July	8,692 ± 548	124,802 ± 8,021	46,977 ± 1,166	**180,471 ± 9,735**
August	11,884 ± 1,135	9,455 ± 1,291	14,017 ± 473	**35,356 ± 2,899**
September	5,429 ± 213	24,570 ± 1,834	69,120 ± 783	**99,119 ± 2,830**
October	1,913 ± 83	22,735 ± 1,561	22,444 ± 295	**47,110 ± 1,939**
November	397 ± 16	12,766 ± 948	1,936 ± 0	**15,099 ± 964**
Total	63,014 ± 3,860	473,298 ± 23,802	219,874 ± 4,405	**756,186 ± 32,067**

Table 3.21 Angler trip estimates by section based on angler hours and average trip length for Lake Roosevelt from December, 1996 through November, 1997.

	Section	Mean Trip Length	No. Angler Hours	No. Angler Trips
December	**1**	2.7	407	151
	2	5.1	16,747	3,284
	3	2.2	0	0
January	**1**	2.0	235	118
	2	4.7	12,949	2,755
	3	2.2	2,268	1,031
February	**1**	2.8	1,152	411
	2	5.0	17,562	3,512
	3	2.2	3,813	1,733
March	**1**	1.7	764	449
	2	4.7	2,036	433
	3	4.3	3,378	786
April	**1**	3.7	14	4
	2	1.9	192	101
	3	4.3	1,050	244
May	**1**	5.7	853	150
	2	3.3	2,115	641
	3	4.3	13,546	3,150
June	**1**	5.8	31,274	5,392
	2	5.4	227,354	42,103
	3	7.5	41,325	5,510
July	**1**	6.1	8,692	1,425
	2	5.1	124,802	24,471
	3	7.5	46,977	6,264
August	**1**	5.2	11,884	2,285
	2	5.3	9,455	1,784
	3	7.5	14,017	1,869
September	**1**	5.9	5,429	920
	2	4.3	24,570	5,714
	3	6.4	69,120	10,800
October	**1**	3.9	1,913	491
	2	5.1	22,735	4,458
	3	5.8	22,444	3,870
November	**1**	4.9	397	81
	2	6.4	12,766	1,995
	3	7.0	1,936	277
Total		**5.17**	**756,186**	**146,264**

Table 3.22 Harvest per unit effort (HPUE) by species and section from December, 1996 through November, 1997 in Lake Roosevelt. HPUE equals the number of fish kept per angler hour.

	Section			
	1	**2**	**3**	**Annual**
Kokanee salmon	0.000	0.000	0.013	**0.001**
Rainbow trout	0.007	0.005	0.063	**0.012**
Walleye	0.320	0.105	0.004	**0.172**
Smallmouth bass	0.003	0.001	0.000	**0.001**
White sturgeon	0.000	0.000	0.000	**0.000**
Other species	0.008	0.000	0.000	**0.003**
Annual HPUE	**0.337**	**0.110**	**0.080**	**0.190**

dolomieui), and 0.001 (1,000 angler hrs/fish) for kokanee salmon (Table 3.22). The highest harvest rates by species were in Section 1 for walleye (0.320; 3.1 angler hrs/fish) and smallmouth bass (0.003; 333 angler hrs/fish), and in Section 3 for kokanee salmon (0.013; 77 angler hrs/fish) and rainbow trout (0.063; 16 angler hrs/fish; Table 3.22).

The overall mean annual catch rate (fish kept and released per angler hour) for all species combined in Lake Roosevelt during 1997 was 0.362, meaning that anglers exerted approximately 2.8 hours of effort for each fish caught (Table 3.23). Mean annual catch rates by species in 1997 were 0.012 (83 angler hrs/fish) for rainbow trout, 0.337 (3.0 angler hrs/fish) for walleye, 0.002 (500 angler hrs/fish) for smallmouth bass, and 0.001 (1,000 angler hrs/fish) for kokanee salmon (Table 3.23). Catch rates for individual species were highest in Section 1 for walleye (0.624; 1.6 angler hrs/fish) and smallmouth bass (0.003; 333 angler hrs/fish), and in Section 3 for kokanee salmon (0.013; 77 angler hrs/fish) and rainbow trout (0.063; 16 angler hrs/fish; Table 3.23).

Table 3.23 Catch per unit effort (CPUE) by species and section from December, 1996 through November, 1997 in Lake Roosevelt. CPUE equals the number of fish caught (kept or released) per angler hour.

	Section			
	1	**2**	**3**	**Annual**
Kokanee salmon	0.000	0.000	0.013	**0.001**
Rainbow trout	0.007	0.005	0.063	**0.012**
Walleye	0.624	0.209	0.004	**0.337**
Smallmouth bass	0.003	0.002	0.000	**0.002**
White sturgeon	0.000	0.000	0.000	**0.000**
Other species	0.016	0.007	0.000	**0.010**
Annual CPUE	**0.649**	**0.222**	**0.080**	**0.362**

Walleye were the largest contributors to harvest from Lake Roosevelt in 1997. Harvest of walleye was estimated at 87,515 fish, accounting for over 90 percent of the total harvest (Table 3.24). Walleye were primarily harvested from Sections 1 (19,009) and 2 (67,937; Table 3.24) during 1997. Approximately 7.8 percent of the walleye recorded in the creel during 1997 were within the illegal size restrictions (406 - 508 mm; 16 - 20 in.) established by WDFW. We estimated that 6,826 walleye were inadvertently harvested within the illegal size range during 1997.

Harvest of rainbow trout and smallmouth bass were estimated at 5,366 and 2,331 fish, respectively, accounting for approximately eight percent of the total harvest (Table 3.24). Rainbow trout were primarily harvested from Section 3 (4,327) whereas smallmouth bass were harvested primarily from Section 2 (2,134 fish; Table 3.24). Estimated harvest of, kokanee salmon (588), and other species (346) accounted for less than one percent of the total harvest in 1997 (Table 3.24). Estimated total catch (Table 3.25) and harvest (Table 3.24) of fish from Lake Roosevelt during 1997 were highest in Section 2 , and lowest in Section 3.

Table 3.24 Estimated number of fish harvested (kept), with ± 95% confidence intervals, for Lake Roosevelt from December, 1996 through November, 1997.

	Section			
	1	**2**	**3**	**Total**
Kokanee salmon	0	0	588 (±37)	**588 (±37)**
Rainbow trout	270 (±27)	759 (±64)	4,327 (±91)	**5,366 (±182)**
Walleye	19,009 (±932)	67,937 (±2,874)	569 (±14)	**87,515 (±3,820)**
Smallmouth bass	197 (±9)	2,134 (±62)	0	**2,331 (±71)**
White sturgeon *	0	0	0	**0**
Other species	346 (±15)	0	0	**346 (±15)**
Annual Harvest	**19,822 (±983)**	**70,830 (±3,000)**	**5,483 (±143)**	**96,135 (±4,126)**

* White sturgeon fishery was closed to harvest in 1997.

Table 3.25 Estimated number of fish caught (kept and released), with ± 95% confidence intervals, for Lake Roosevelt from December, 1996 through November, 1997.

	Section			
	1	**2**	**3**	**Total**
Kokanee salmon	0	0	588 (±37)	**588 (±37)**
Rainbow trout	270 (±27)	759 (±64)	4,327 (±91)	**5,366 (±182)**
Walleye	37,679 (±1,797)	109,068 (±5,065)	569 (±14)	**147,316 (±6,876)**
Smallmouth bass	197 (±9)	2,399 (±79)	0	**2,596 (±88)**
White sturgeon	0	0	0	**0**
Other species	802 (±46)	7,727 (±270)	0	**8,529 (±316)**
Annual Catch	**38,948 (±1,879)**	**119,953 (±5,478)**	**5,483 (±143)**	**164,395 (±7,499)**

Both catch rates and (estimated) numbers of fish caught from Lake Roosevelt during 1997 were similar to harvest rates / estimates for individual species with the exception of walleye and smallmouth bass (Tables 3.22 through 3.25). The mean annual catch rates for walleye (0.337) was approximately twice the mean annual harvest rate (0.172) during 1997 (Tables 3.22 and 3.23). Catch estimates for both walleye (147,316) and smallmouth bass (2,596) were also higher than harvest estimates for these species (87,515 and 2,331, respectively) in 1997 (Tables 3.24 and 3.25).

In 1997, rainbow trout harvested from Section 3 were apparently larger by both length and weight than those harvested in Sections 1 or 2, although our sample size in Sections 1 and 2 were low (Table 3.26). Mean length and weight of rainbow trout harvested from Sections 1 and 2 were similar in 1997 (Table 3.26). Rainbow trout harvested in Section 3 averaged 364 mm in length and 716 grams in weight (Table 3.26). In contrast, rainbow trout harvested from Sections 1 and 2 had respective mean lengths of 456 and 421 mm, and respective mean weights of 966 and 822 grams (Table 3.26).Walleye observed in the creel in Sections 1 and 2 during 1997 were smaller by length and weight than those observed in Section 3, however our sample size was low in Section 3 (Table 3.26). Walleye sampled in Sections 1 and 2 had respective mean lengths of 366 and 380 mm and mean weights of 385 and 508 grams. Walleye sampled from Section 3 had a mean length of 540 mm and mean weight of 1,124 grams (Table 3.26). Only 2 percent of walleye creeled in Section 1 during 1997 were within the upper legal size limit (> 20 in). In contrast, 13 and 50 percent of the walleye creeled in Sections 2 and 3, respectively, were in the upper legal size limit.

Relative abundance of fishes other than walleye in 1997 creel surveys was low and accounted for only 9.1 percent of the total number of fish observed (Table 3.26). Burbot (*Lota lota*), and yellow perch (*Perca flavescens*) were noted in the creel exclusively from Section 1 during 1997 (Table 3.26). In contrast, kokanee salmon were noted in the creel only in Section 3 (Table 3.26).

Based on 1997 creel surveys, 68 percent of walleye anglers were satisfied with the fishery in 1997 (Table 3.27). Satisfaction rates of anglers targeting rainbow trout (15%) or kokanee salmon (31%) were notably lower during the same period (Table 3.27). The highest seasonal satisfaction rates among kokanee salmon (60%) was noted during the winter (Table 3.27). Walleye anglers interviewed were most satisfied (82%) during the spring, whereas rainbow trout anglers reported highest satisfaction (24%) during the

Table 3.26 Annual numbers (n) and mean lengths (mm) and weights (g) for fish observed in the Lake Roosevelt creel from December, 1996 through November, 1997. Plus/minus values indicate standard deviations.

	Kokanee Salmon	Rainbow	Walleye	Small-mouth Bass	Burbot	Yellow Perch
Sec 1						
n	-	5	244	2	4	2
Ln	-	456±56	366±43	378±33	523±32	243±59
Wt	-	966±376	385±188	488±272	768±98	160±85
Sec 2						
n	-	5	114	1	-	-
Ln	-	421±88	380±76	305±0	-	-
Wt	-	822±227	508±352	226±0	-	-
Sec 3						
n	3	15	1	-	-	-
Ln	338±16	366±59	686±0	-	-	-
Wt	-	676±183	272±0	-	-	-
Total						
n	**3**	**25**	**359**	**3**	**4**	**2**
Ln	**338±42**	**395±73**	**372±58**	**354±48**	**523±32**	**243±59**
Wt	**---**	**768±262**	**422±254**	**400±245**	**768±98**	**160±85**

Table 3.27 Percent of anglers that were satisfied with the fishery by species, section and season from December, 1996 through November, 1997.

Quarter Section	Kokanee Salmon	Rainbow Trout	Walleye	White Sturgeon
Winter				
1	-	6%	-	-
2	-	0%	0%	-
3	60%	-	-	-
Spring				
1	-	0%	100%	-
2	-	17%	0%	-
3	-	0%	-	-
Summer				
1	-	29%	71%	-
2	-	50%	79%	-
3	0%	0%	-	-
Fall				
1	-	0%	0%	-
2	100%	28%	41%	-
3	0%	8%	-	-
Qrtly Totals				
Winter	**60%**	**3%**	**0%**	**-**
Spring	**-**	**7%**	**82%**	**-**
Summer	**0%**	**24%**	**75%**	**-**
Fall	**17%**	**22%**	**40%**	**-**
Annual Total	**31%**	**15%**	**68%**	**0%**

summer (Table 3.27). No white sturgeon anglers were encountered during 1997 creel surveys, so sturgeon angler satisfaction could not be assessed.

Of all anglers interviewed on Lake Roosevelt during 1997, 56% targeted walleye, 31% targeted rainbow trout, 3% targeted kokanee salmon and 10% targeted other species (Table 3.28). On a reservoir wide basis, walleye were the principal species targeted in the summer (63%) months, whereas rainbow trout were the principal target species during winter (77%), spring (65%), and fall (45%), respectively (Table 3.28). In Section 1, walleye were the most frequently targeted species during the spring (50%) and summer (94%), however rainbow trout were most frequently targeted in winter (100%) and fall (67%; Table 3.28). Section 2 was dominated by rainbow trout anglers during the winter (73%), spring (76%), and by walleye anglers during summer (82%) and fall (49%; Table 3.28). The fishery in Section 3 was dominated (62%) by kokanee salmon anglers during the winter months, and by rainbow trout anglers in all seasons during 1997 (67-83%; Table 3.28).

We estimated the economic value of the Lake Roosevelt fishery in 1997 to be $5,841,784 (Table 3.29). This estimate is based on an estimated 146,264 angler trips at an average cost of $39.94 per trip according to the regional consumer price index.

3.8 Fisheries Surveys and Relative Abundance

In 1997 we sampled a total of 34.3 hours by electrofishing and 1,869.2 hours by gillnetting in Lake Roosevelt. Twenty three fish species representing 7 families were collected in 1997 relative abundance surveys (Table 3.30). A total of 4,533 fish were collected by electrofishing (3,871) and gillnet (662) surveys yielding respective overall CPUE's of 113 and 0.35 fish/hour (Table 3.31). The most commonly collected fish species during 1997 electrofishing and gillnet surveys was the largescale sucker (*Catostomus macrocheilus*) which made up 46 percent of our total catch (Table 3.31). Walleye were the second most abundant fish collected, comprising 14 percent of our total catch. Smallmouth bass (8%), carp (*Cyprinus carpio*; 7%), lake whitefish (*Coregonus clupeaformis*; 6%), and burbot (5%) were also important in our 1997 relative abundance surveys (Table 3.31). Dominant species collected by electrofishing surveys were largescale suckers (52%) and walleyes (12%) whereas lake whitefish (37%), walleyes (27%) and burbot (13%) were most abundant in gillnet surveys (Table 3.31).

Table 3.28 Percent of anglers targeting various fish species by section and season on Lake Roosevelt from December, 1996 through November, 1997.

Quarter Section	Kokanee Salmon	Rainbow	Walleye	Other*
Winter				
1	0%	100%	0%	0%
2	0%	73%	3%	24%
3	62%	39%	0%	0%
Spring				
1	0%	44%	50%	6%
2	0%	76%	18%	6%
3	33%	67%	0%	0%
Summer				
1	0%	6%	94%	0%
2	0%	3%	82%	15%
3	17%	83%	0%	0%
Fall				
1	0%	67%	33%	0%
2	1%	41%	49%	9%
3	29%	71%	0%	0%
Qrtly Totals				
Winter	**7%**	**77%**	**2%**	**15%**
Spring	**4%**	**65%**	**26%**	**5%**
Summer	**1%**	**7%**	**83%**	**9%**
Fall	**4%**	**45%**	**42%**	**8%**
Annual Total	**3%**	**31%**	**56%**	**10%**

* Includes anglers targeting ‘any’ fish.

Table 3.29 Economic value of the sport fishery in Lake Roosevelt during December, 1996 through November, 1997.

	1985	1997
Consumer Price Index	$167.87	$257.87
Dollars Spent per Angler Trip	$26.00	$39.94
Number of Angler Trips		146,264
Economic Value of Fishery		**$5,841,784**

Beachseine surveys conducted during 1997 yielded a total of 6,199 fish, with 6,194 collected during our July / August survey (Table 3.32). Sucker larvae/fry were the most prevalent group collected, accounting for over 75 percent of the fish collected by beachseine (Table 3.32). Yellow perch, smallmouth bass, and walleye young of year were also commonly collected by beachseine and comprised 7.9, 5.4 and 2.3 percent of the total number of fish collected (Table 3.32).

3.9 Age, Back Calculations and Condition Factor

Length, weight and scales were taken from each of 18 kokanee salmon collected during electrofishing and gillnet surveys in 1997. The mean condition factors of age 1 and age 2 kokanee salmon were 0.91 and 1.16, respectively (Table 3.33). No kokanee salmon greater than age 2 were collected in our standardized fisheries surveys in 1997. Back calculated length at age of kokanee salmon indicated an average growth of 117 mm to age 1 and 125 mm from age 1 to age 2 (Table 3.34). These growth increments translate to mean total lengths of 117 mm at age 1 and 242 mm at age 2 for kokanee salmon (Table 3.34).

Table 3.30 Taxa list of fish species collected during 1997 electrofishing and gillnet surveys in Lake Roosevelt.

Family species	Common Name
Catostomidae	
Catostomus macrocheilus	Largescale sucker
Catostomus catostomus	Longnose sucker
Catostomus columbianus	Bridgelip sucker
Centrarchidae	
Lepomis gibbosus	Pumpkinseed
Micropterus dolomieui	Smallmouth bass
Micropterus salmoides	Largemouth bass
Pomoxis nigromaculatus	Black crappie
Cottidae	
Cottus beldingi	Piute sculpin
Cyprinidae	
Cyprinus carpio	Carp
Mylocheilus caurinus	Peamouth
Ptychocheilus oregonensis	Northern squawfish
Richardsonius balteatus	Redside shiner
Tinca tinca	Tench
Gadidae	
Lota lota	Burbot
Percidae	
Stizostedion vitreum vitreum	Walleye
Perca flavescens	Yellow perch
Salmonidae	
Salmo trutta	Brown trout
Salvelinus fontinalis	Brook trout
Oncorhynchus tshawytscha	Chinook salmon
Oncorhynchus nerka	Kokanee salmon
Coregonus clupeaformis	Lake whitefish
Prosopium williamsoni	Mountain whitefish
Oncorhynchus mykiss	Rainbow trout

Table 3.31 Catch per unit effort (fish/hr) and relative abundance of fish species captured by electrofishing and gillnet surveys in Lake Roosevelt during 1997.

	Electrofishing			Gillnetting			Total	
	CPUE	No.	%	CPUE	No.	%	No.	%
Black crappie	0.00	0	0	<0.01	1	<1	**1**	**<1**
Brook trout	0.23	8	<1	0.00	0	0	**8**	**<1**
Bridgelip sucker	0.32	11	<1	<0.01	4	<1	**15**	**<1**
Brown trout	0.47	16	<1	<0.01	1	<1	**17**	**<1**
Burbot	4.06	139	4	0.04	84	13	**223**	**5**
Carp	8.46	290	7	<0.01	5	<1	**295**	**7**
Chinook salmon	0.09	3	<1	0.00	0	0	**3**	**<1**
Cottus sp.	2.07	71	2	0.00	0	0	**71**	**2**
Kokanee salmon	1.66	57	1	<0.01	3	<1	**60**	**1**
Lake whitefish	0.93	32	<1	0.13	243	37	**275**	**6**
Largemouth bass	0.03	1	<1	0.00	0	0	**1**	**<1**
Largescale sucker	59.21	2,029	52	0.03	62	9	**2,091**	**46**
Longnose sucker	0.32	11	<1	0.01	25	4	**36**	**<1**
Mountain whitefish	0.12	4	<1	0.00	0	0	**4**	**<1**
Northern squawfish	2.42	83	2	0.01	12	2	**95**	**2**
Peamouth	0.03	1	<1	<0.01	1	<1	**2**	**<1**
Pumpkinseed	0.20	7	<1	0.00	0	0	**7**	**<1**
Rainbow trout	5.19	178	5	<0.01	6	<1	**184**	**4**
Redside shiner	0.35	12	<1	0.00	0	0	**12**	**<1**
Smallmouth bass	9.83	337	9	0.01	19	3	**356**	**8**
Tench	0.06	2	<1	0.00	0	0	**2**	**<1**
Walleye	13.31	456	12	0.10	178	27	**634**	**14**
Yellow perch	3.59	123	3	0.01	18	3	**141**	**3**
Totals	**113.0**	**3,871**		**0.35**	**662**		**4,533**	

Table 3.32 Catch and relative abundance of fish species captured by beachseining surveys in Lake Roosevelt during 1997.

	July / August		Sept. / Oct.		Total	
	No.	**%**	**No.**	**%**	**No.**	**%**
Bridgelip sucker	1	<1	0	0	**1**	**<1**
Carp	24	<1	1	20.0	**25**	**<1**
Cottus sp.	71	1.1	1	20.0	**72**	**1.2**
Kokanee salmon	1	<1	0	0	**1**	**<1**
Lake whitefish	1	<1	0	0	**1**	**<1**
Largescale sucker	2	<1	0	0	**2**	**<1**
Longnose sucker	3	<1	0	0	**3**	**<1**
Northern squawfish	3	<1	0	0	**3**	**<1**
Pumpkinseed	2	<1	0	0	**2**	**<1**
Rainbow trout	4	<1	3	60.0	**7**	**<1**
Redside shiner	2	<1	0	0	**2**	**<1**
Smallmouth bass	335	5.4	0	0	**335**	**5.4**
Sucker larvae / fry	4,642	74.9	0	0	**4,642**	**74.9**
Sucker / Cyprinid larvae / fry*	475	7.7	0	0	**475**	**7.7**
Walleye	141	2.3	0	0	**141**	**2.3**
Yellow perch	487	7.9	0	0	**487**	**7.9**
Totals	**6,194**		**5**		**6,199**	

* Large numbers of mixed sucker and cyprinid larvae /fry ranging from 20 to 40 mm in length made accurate field identification impractical. Composition was approximately 80% suckers, 20% unidentified cyprinids.

Table 3.33 Lengths, weights, and condition factors (mean ± standard deviation) of kokanee salmon collected during 1997.

Age	n	Length (mm)	Weight (g)	Condition Factor
0+	0	- ± -	- ± -	- ± -
1+	12	202 ± 26	83 ± 55	0.91 ± 0.21
2+	6	341 ± 60	506 ± 260	1.16 ± 0.16

Table 3.34 Back calculated total length (mean ± standard deviation) of kokanee salmon sampled during 1997.

		Back Calculated Total Length (mm) at Annulus	
Cohort	**n**	**1**	**2**
1996	12	114 ± 20	
1995	6	124 ± 60	242 ± 107
Total:	**18**		
Mean:		**117 ± 37**	**242 ± 107**
Annual Growth		**117**	**125**

Lengths, weights and condition factors were determined for 35 rainbow trout collected during gillnet and electrofishing surveys in 1997 (Table 3.35). Condition factors of rainbow trout ranged from 1.00 (age 4) to 1.37 (age 3; Table 3.35). Condition factors for ages 2 (1.32) and 3 were similar and relatively high (> 1.30) whereas those for age 1 (1.03) and age 4 rainbow trout were lower (Table 3.35). Annual growth increments taken from mean back calculated lengths at each age show a decline in growth with increased age. Estimated growth increments for rainbow trout ranged from 136 mm (to age 1), to 35 mm (age 4; Table 3.36).

We determined length, weight and condition factor of 317 walleye sampled by electrofishing and gillnet surveys in 1997 (Table 3.37). Walleye collected in 1997 ranged from age 0 to age 10, and the mean condition factor for walleyes generally increased with age, ranging from 0.75 at age 1 to 1.17 at age 10 (Table 3.37). Back calculated length at age shows relatively rapid growth (105 - 109 mm/yr.) in younger walleye (age 1 and 2), and a generally declining growth rate thereafter (Table 3.38).

3.10 Feeding Habits

Stomachs contents were examined from 16 fish species representing 6 families (Salmonidae, Catostomidae, Centrarchidae, Cyprinidae, Percidae, and Gadidae) collected from Lake Roosevelt during 1997. A total of 333 individual stomachs were examined, of which 56 were empty upon laboratory examination. Full stomachs were examined from kokanee salmon (n=18), rainbow trout (n=27), lake whitefish (n=6) mountain whitefish (n=6), bridgelip sucker (n=4), longnose sucker (n=3), largescale sucker (n=61), largemouth bass (n=1), smallmouth bass (n=12), pumpkinseed (n=5), northern squawfish (n=19), redside shiner (n=3), peamouth (n=2), walleye (n=72), yellow perch (n=9), and burbot (n=29).

Of the 16 species examined from Lake Roosevelt during 1997, seven exhibited substantial diet overlap (≥ 0.70) with at least one other species. Rainbow trout exhibited substantial dietary overlap with both kokanee salmon (0.91) and lake whitefish (0.86; Table 3.39). Substantial dietary overlap was also noted between kokanee salmon and lake whitefish (0.93), walleye and burbot (0.85), and peamouth and pumpkinseed (0.71) during 1997 (Table 3.39). Relatively high (≥ 0.60) dietary overlap involved additional species, showing diet overlap of longnose suckers with both largescale suckers (0.60) and mountain whitefish (0.64), as well as between rainbow trout and largescale suckers (0.68) and smallmouth bass and burbot (0.61; Table 3.39).

Table 3.35 Lengths, weights, and condition factors (mean ± standard deviation) of rainbow trout collected during 1997.

Age	n	Length (mm)	Weight (g)	Condition Factor
0+	0	- ± -	- ± -	- ± -
1+	5	212 ± 23	101 ± 35	1.03 ± 0.05
2+	11	320 ± 39	455 ± 132	1.32 ± 0.17
3+	11	370 ± 39	691 ± 153	1.37 ± 0.17
4+	8	429 ± 58	989 ± 261	1.00 ± 0.42

Table 3.36 Back calculated total length (mean ± standard deviation) of rainbow trout sampled during 1997.

		Back Calculated Total Length (mm) at Annulus			
Cohort	**n**	**1**	**2**	**3**	**4**
1996	5	120 ± 12			
1995	11	113 ± 28	243 ± 35		
1994	11	143 ± 82	251 ± 70	318 ± 39	
1993	8	166 ± 84	255 ± 85	348 ± 82	367 ± 107
Total:	**81**				
Mean:		**136 ± 64**	**248 ± 62**	**332 ± 63**	**367 ± 107**
Annual Growth		**136**	**112**	**84**	**35**

Table 3.37 Lengths, weights, and condition factors (mean ± standard deviation) of walleye collected during 1997.

Age	n	Length (mm)			Weight (g)			Condition Factor		
0+	3	141	±	23	19	±	3	0.75	±	0.28
1+	22	195	±	39	69	±	44	0.84	±	0.33
2+	124	259	±	35	155	±	70	0.84	±	0.26
3+	93	346	±	39	387	±	150	0.93	±	0.51
4+	46	410	±	49	634	±	299	0.86	±	0.17
5+	16	480	±	78	1,172	±	619	0.97	±	0.25
6+	9	572	±	75	1,846	±	831	0.94	±	0.10
7+	1	460	±	0	820	±	0	0.84	±	0
8+	2	650	±	141	3,554	±	3,314	1.06	±	0.47
9+	0	-	±	-	-	±	-	-	±	-
10+	1	730	±	0	4,536	±	0	1.17	±	0

Cladocerans were the most important food item consumed by kokanee salmon (IRI=73.75), rainbow trout (IRI= 51.36) and lake whitefish (IRI=63.44; Table 3.40) from which stomachs were examined in 1997. Walleye and burbot fed primarily on fish (IRI=66.86 and 55.51, respectively), however cladocerans were also important in the diets of both species (IRI=18.82 and 17.27, respectively; Table 3.40). Two food items were found in stomachs examined from peamouth during 1997; Corixidae (IRI=45.28) and Hydracarina (IRI=54.72; Table 3.40). Corixidae were also important in the diet of pumpkinseed sampled during 1997 (IRI=43.28), as were Hydracarina (IRI=14.33) and Oligochaeta (IRI=17.97; Table 3.40).

Table 3.38 Back calculated total length (mean ± standard deviation) of walleye sampled during 1997.

Cohort	n	1	2	3	4	5	6	7	8	9	10
1996	22	121 ± 29									
1995	123	106 ± 32	209 ± 49								
1994	94	107 ± 25	216 ± 44	308 ± 45							
1993	46	110 ± 26	216 ± 46	296 ± 48	373 ± 52						
1992	16	119 ± 22	214 ± 54	302 ± 63	378 ± 82	443 ± 91					
1991	9	125 ± 35	236 ± 66	349 ± 74	430 ± 79	496 ± 80	548 ± 82				
1990	1	79 ± 0	132 ± 0	256 ± 0	287 ± 0	340 ± 0	370 ± 0	422 ± 0			
1989	2	152 ± 30	309 ± 56	404 ± 73	456 ± 94	501 ± 111	541 ± 120	579 ± 126	640 ± 139		
1988	0	--- ± --	--- ± --	--- ± --	--- ± --	--- ± --	--- ± --	--- ± --	--- ± --	--- ± --	
1987	1	136 ± 0	201 ± 0	329 ± 0	425 ± 0	485 ± 0	517 ± 0	574 ± 0	626 ± 0	674 ± 0	710 ± 0
Total:	**314**										
Means:		**109 ± 29**	**214 ± 49**	**307 ± 52**	**382 ± 66**	**461 ± 89**	**531 ± 90**	**539 ± 107**	**636 ± 98**	**674 ± 0**	**710 ± 0**
Annual Growth		**109**	**105**	**93**	**75**	**79**	**70**	**8**	**97**	**38**	**36**

Table 3.39 Diet overlap of various fish species sampled from Lake Roosevelt during 1997. Overlap values are based on IRI calculations.

Species	n	Diet Overlap															
		Bridgelip sucker	Burbot	Kokanee salmon	Lake whitefish	Largemouth bass	Largescale sucker	Longnose sucker	Mtn whitefish	N squawfish	Pumpkinseed	Peamouth	Rainbow trout	Redside shiner	Smallmouth bass	Walleye	Yellow perch
Bridgelip sucker	4	1.00															
Burbot	29	0.11	1.00														
Kokanee salmon	18	0.40	0.19	1.00													
Lake whitefish	6	0.39	0.14	0.93	1.00												
Largemouth bass	1	0.00	0.26	0.00	0.00	1.00											
Largescale sucker	61	0.58	0.19	0.56	0.52	0.01	1.00										
Longnose sucker	3	0.33	0.09	0.15	0.16	0.00	0.60	1.00									
Mtn. whitefish	6	0.13	0.21	0.14	0.10	0.00	0.44	0.64	1.00								
N. squawfish	19	0.41	0.10	0.01	0.00	0.00	0.16	0.07	0.03	1.00							
Pumpkinseed	5	0.35	0.07	0.01	0.02	0.06	0.22	0.25	0.00	0.16	1.00						
Peamouth	2	0.05	0.03	0.00	0.07	0.00	0.05	0.14	0.00	0.00	0.71	1.00					
Rainbow trout	27	0.46	0.27	0.91	0.86	0.02	0.68	0.17	0.19	0.06	0.10	0.03	1.00				
Redside shiner	3	0.08	0.02	0.01	0.03	0.00	0.13	0.04	0.02	0.00	0.26	0.00	0.10	1.00			
Smallmouth bass	12	0.05	0.61	0.00	0.00	0.00	0.10	0.00	0.03	0.10	0.19	0.00	0.09	0.52	1.00		
Walleye	72	0.19	0.85	0.36	0.33	0.27	0.32	0.10	0.25	0.12	0.03	0.00	0.44	0.03	0.58	1.00	
Yellow perch	9	0.24	0.48	0.11	0.13	0.00	0.45	0.28	0.39	0.25	0.40	0.14	0.21	0.10	0.41	0.50	1.00

Table 3.40 Index of relative importance (IRI) for prey items identified in stomachs of fish species collected from Lake Roosevelt which exhibited substantial (≥ 0.70) dietary overlap with at least one other species during 1997.

PREY ITEM	Kokanee Salmon	Rainbow Trout	Lake Whitefish	Peamouth	Pumpkin-seed	Walleye	Burbot
(n)	18	27	6	2	5	72	29
Osteichthyes							
Catostomidae	--	--	--	--	--	11.49	--
Centrarchidae	--	--	--	--	--	2.34	--
Cottidae	--	0.93	--	--	--	11.84	19.78
Cyprinidae	--	0.90	--	--	--	13.48	12.66
Percidae	--	--	--	--	--	3.07	--
Salmonidae	--	1.18	--	--	--	--	--
Unidentified fish	--	0.81	--	--	--	24.64	23.07
Fish eggs	--	--	--	--	--	--	--
Coleoptera							
Coleoptera sp.	--	4.54	--	--	--	--	--
Dytiscidae	--	--	--	--	--	--	--
Elmidae	--	1.54	--	--	--	--	--
Gyrinidae adult	--	--	--	--	--	--	--
Gyrinidae larvae	--	--	--	--	--	0.42	--
Diptera							
Diptera sp.	--	0.73	--	--	--	0.72	--
Chironomidae pupa	8.21	9.35	18.40	--	--	5.40	--
Chironomidae larvae	6.20	3.50	4.47	--	--	1.47	3.66
Chironomidae Adult	--	--	--	--	--	--	--
Simuliidae larvae	--	1.41	--	--	--	--	--
Tipulidae pupa	--	1.42	--	--	--	--	--
Ephemeroptera							
Ephemeroptera sp.	--	--	--	--	--	0.46	--
Baetidae	--	0.70	4.54	--	--	1.27	2.98
Heptageniidae	--	--	--	--	--	--	2.69

Table 3.40 Continued

PREY ITEM	Kokanee Salmon	Rainbow Trout	Lake Whitefish	Peamouth	Pumpkin-seed	Walleye	Burbot
Hemiptera sp.	--	1.15	--	--	--	--	--
Corixidae	--	1.52	--	45.28	43.28	--	1.98
Saldidae	--	1.40	--	--	--	--	--
Hymenoptera							
Hymenoptera sp.	--	1.51	--	--	--	--	--
Formicidae	--	0.72	--	--	--	--	--
Odonata							
Anisoptera	--	--	--	--		--	1.00
Zygoptera	--	0.72	--	--	8.92	0.42	1.01
Orthoptera							
Crytacanthacridinae	--	1.29	--	--	--	--	--
Plecoptera							
Plecoptera sp.	--	0.75	--	--	--	0.42	1.05
Perlodidae	--	--	--	--	--	--	1.26
Trichoptera							
Trichoptera sp.	--	--	--	--	--	0.56	--
Limnephilidae	--	--	--	--	--	--	1.03
Glossosomatidae	--	--	--	--	--	--	--
Arachnoidea							
Hydracarina sp.	--	0.71	9.15	54.72	14.33	--	--
Oligochaeta							
Lumbriculidae	1.54	3.75	--	--	17.97	1.89	1.45
Turbellaria							
Turbellaria sp.	--	0.70	--	--	--	--	--

Table 3.40 Continued.

PREY ITEM	Kokanee Salmon	Rainbow Trout	Lake Whitefish	Peamouth	Pumpkin-seed	Walleye	Burbot
Cladocera							
Cladocera sp.	--	--	--	--	--	--	--
Leptodora. kindti	6.94	9.92	--	--	--	5.02	10.96
Daphnia sp.	55.80	40.70	63.44	--	--	13.80	6.31
Bosmina longirostris	11.01	0.74	--	--	--	--	--
Copepoda							
Copepoda sp.	10.30	1.23	--	--	--	--	--
Decapoda							
Astacidae	--	--	--	--	--	--	7.24
Gastropoda							
Gastropoda sp.	--	--	--	--	--	--	1.03
Lymnaeidae	--	--	--	--	--	--	--
Planorbidae	--	0.71	--	--	--	--	--
Physidae	--	--	--	--	--	--	--
Ostracoda							
Cypridae	--	--	--	--	--	--	--
	--	4.77	--	--	--	0.85	1.02
Vegetation	--	0.70	--	--	--	0.43	--

4.0 DISCUSSION

4.1 Reservoir Operations and Hydrology

Reservoir operations have a pronounced influence on Lake Roosevelt biota, primarily through reductions in suitable habitat, and entrainment of fish, zooplankton, and nutrients from Lake Roosevelt. Entrainment of fishes from Lake Roosevelt has previously been linked to water retention times within the system (Griffith et al. 1995; Scholz 1991). We used historical data (Jan. 1, 1990 through Oct. 1,1995) in a stepwise regression analysis to examine the relative influence of various parameters on estimated water retention times in Lake Roosevelt. Reservoir operations (outflow from Grand Coulee Dam) accounted for approximately 80 percent of the variance in estimated water retention time(s) in Lake Roosevelt (r^2=0.797; $p<0.0001$). In contrast, factors not resulting from reservoir operations (Lake Roosevelt inflow, elevation, storage, and spill; discharge of the Spokane, Kettle, and Colville rivers, and the Columbia River near the international border) individually accounted for less than 2.5 percent of the variance in water retention times.

Grand Coulee Dam was commissioned by congress to operate for power, flood control, irrigation, with secondary considerations for recreation, fisheries and navigation. Reservoir operations therefore depend on many factors and differ by season and year. Reservoir operations in January and February, 1997 were predominantly controlled by power production, resulting in fairly stable lake elevations from January 1 through February 15 (Figure 3.1). Reservoir operations from mid-February through May, 1997 were determined primarily by flood control needs, and high spring runoff (137 % of normal; January through July) resulted in Lake Roosevelt being drawn down to its lowest level since this study began in 1988 (1,209 ft.; Figure 3.1). Reservoir operations during late May and June, 1997 were directed at meeting refill objectives (85% probability of refill by July 1) as well as Priest Rapids and McNary Dam flow targets defined by the National Marine Fisheries Service's Biological Opinion. In 1997, Lake Roosevelt also released water to meet anadromous fish needs in accordance with the Endangered Species Act (ESA) and NMFS Biological Opinion resulting in a ten foot drawdown during August (Figure 3.1). From September through December, 1997, Lake Roosevelt was operated primarily for power production.

The annual hydrograph for Lake Roosevelt during 1997 was most similar to that observed in 1989 when water levels in Lake Roosevelt reached a minimum of 1,221 ft. (Peone et al.

1990). Monthly mean reservoir elevations in Lake Roosevelt from January through May, 1997 were lower than in previous years, reflecting the pronounced influence of flood control strategies in determining reservoir operations. Monthly mean reservoir elevations from June through December, 1997 were comparable to those in previous years (Table 4.1).

Mean monthly outflows from Lake Roosevelt during 1997 were higher than any year since 1991 from May through December (Table 4.1). Mean monthly outflows during all other months in 1997 were higher than all years except 1991 and / or 1996 (Table 4.1). In contrast, monthly mean water retention times from February through November, 1997 were lower than all years since 1991 (Table 4.1). High outflows corresponding with low water retention times in Lake Roosevelt supports our finding that outflow is more important than other factors (inflows, elevation, storage volume) in determining water retention time within Lake Roosevelt.

4.2 Water Quality

4.2.1 Total Dissolved Gas

The U.S Environmental Protection Agency (EPA) has set a surface water standard stating that TDG levels should not exceed 110% saturation. All recorded TDG levels in Lake Roosevelt during our 1997 monitoring exceeded 100% saturation, and maximum observed levels were as high as 139% saturation (Table 3.2). Surface saturation of TDG was as high as 121% in Lake Roosevelt during 1997 (Figure 3.2). Approximately 50% of all observations, and 30% of surface observations exceeded the EPA surface water quality criteria during 1997.

To assess the potential impact of high TDG on Lake Roosevelt fishes, compensation depths were calculated (Colt 1984) for all recorded TDG levels recorded during 1997. Our data indicate that no potential existed for the development of gas bubble disease in Lake Roosevelt fishes at depths of 3 m or greater. Compensation depth is the depth where, given a particular level of TDG supersaturation, gas bubbles can no longer form in the tissues or bloodstream of fishes due to the compensating effect of hydrostatic pressure. Therefore, no potential for the development of gas bubble disease exists at or below the compensation depth. Our data indicate that there was potential for development of gas bubble disease in the surface waters of Lake Roosevelt in all months during 1997. However, calculated compensation depths did not exceed 2.5m during 1997.

Table 4.1 Comparison of monthly mean outflow, water retention times (WRT), and elevations in Lake Roosevelt since 1991.

	1991	1992	1993	1994	1995	1996	1997
Mean Outflow (kcfs)							
January	142.0	101.5	100.5	77.2	88.3	154.9	141.6
February	131.3	77.7	85.9	103.6	94.0	154.9	142.4
March	151.0	92.6	53.9	77.7	90.1	144.4	129.2
April	153.4	79.3	48.4	73.0	84.5	147.7	152.7
May	146.4	112.1	119.0	99.6	93.5	167.8	218.4
June	145.7	131.7	95.7	135.9	117.8	173.1	258.1
July	129.6	80.6	97.2	95.8	110.5	157.9	169.2
August	125.7	81.7	81.7	73.3	91.9	131.2	135.3
September	78.0	73.0	73.0	55.9	65.9	90.8	97.5
October	84.7	65.9	62.5	64.0	80.6	90.7	106.6
November	87.9	81.9	84.2	75.7	91.9	93.9	95.1
December	87.9	109.9	109.9	83.5	141.6	110.7	127.8
Mean WRT (Days)							
January	32.2	45.1	40.2	61.8	49.3	28.4	30.3
February	34.1	59.0	44.0	42.5	42.6	31.7	23.3
March	25.0	48.4	67.1	54.9	42.4	23.9	23.4
April	17.7	51.2	87.1	55.0	47.5	18.6	15.9
May	18.5	34.4	39.4	44.0	39.4	15.7	10.8
June	29.2	33.7	49.6	30.1	40.1	21.8	16.1
July	35.8	62.1	46.9	43.5	41.4	29.4	27.1
August	37.0	56.8	56.8	58.7	47.2	34.3	33.2
September	59.1	61.0	61.0	78.4	69.0	47.9	46.5
October	55.8	69.0	73.5	72.6	56.7	49.2	42.8
November	53.2	56.3	51.4	60.1	50.4	48.3	47.7
December	53.2	37.5	37.5	56.3	32.4	38.9	33.5
Mean elevation (add 1,200 = ft. MSL)							
January	83.9	87.1	67.5	85.4	78.3	81.6	73.0
February	85.1	87.8	63.5	81.8	66.3	80.7	53.7
March	67.5	81.4	56.0	76.5	59.0	58.5	39.4
April	35.4	67.9	71.8	68.1	65.8	35.1	20.8
May	34.9	66.4	84.7	80.5	59.8	32.3	23.4
June	75.2	81.1	87.5	76.0	83.6	67.8	75.3
July	88.3	86.6	86.4	74.9	86.9	87.9	87.7
August	88.5	85.9	85.9	77.1	80.9	84.9	85.8
September	87.0	81.3	81.3	81.3	85.1	80.7	84.4
October	87.0	84.1	81.9	87.2	85.8	84.1	83.9
November	86.7	84.2	78.8	84.7	86.5	84.2	86.5
December	86.0	73.0	79.0	84.2	87.0	78.5	80.3

4.2.1.1 Spatial Trends

In our spatial comparisons, little difference was noted between reaches at or near the reservoir surface, but gas saturation levels between reaches became increasingly divergent with depth (Figure 3.3). It appears that, as dissolved gasses dissipate from the lake surface to the atmosphere, the surface waters are re-supplied with gas from underlying waters. Although physically lost from the lake surface, dissolved gasses appear to be functionally lost from depth progressing downstream through Lake Roosevelt, and resulting in vertical as well as horizontal TDG gradients throughout the reservoir.

Total dissolved gas concentrations within the Spokane River arm of Lake Roosevelt were significantly less than in the mainstem Columbia River, with at least two possible explanations. One potential explanation is that dissolved gas production (and / or retention) in the Spokane River may be less than that in the Columbia River leading to lower observed TDG saturation levels in the Spokane River arm of Lake Roosevelt. Production of supersaturated TDG conditions in the Columbia River basin primarily results from water being spilled over dams during high flow events. The degree to which waters become supersaturated during spill is dependent upon various factors including the physical characteristics of the water (i.e. temperature), the structure of the dam and associated spillway(s), the proportion of water discharged as spill, and tailrace morphology. Numerous factors also affect the rates at which excess dissolved gasses are released from a river or reservoir, including reservoir morphology and limnology. Production of excess TDG may therefore differ widely between river systems, and may be lower in the Spokane River relative to the Columbia River.

Another potential explanation for reduced TDG saturation levels in the Spokane River arm of Lake Roosevelt may be related to de-gassing of waters spilled over Little Falls Dam. Waters spilled over Little Falls Dam do not have an opportunity to plunge to substantial depth(s), and therefore probably do not increase in TDG levels coming across the dam. In addition, the tailrace of Little Falls Dam consists of a shallow, narrow reach consisting primarily of jagged bedrock substrate. High turbulence caused by the tailrace morphology may actually lead to de-gassing of waters by increasing the relative air / water interface and subsequent ability for gas transfer.

4.2.1.2 Temporal Trends

Total dissolved gas saturation levels are closely tied to spill levels within the Upper Columbia River Basin, and are therefore generally highest during spring flow events. We began monitoring of TDG saturation levels in Lake Roosevelt during late spring (May, 1997) and continued through years end. Mean TDG saturation levels generally declined monthly from May through December in Lake Roosevelt during 1997 however TDG concentrations remained supersaturated throughout our monitoring period (Table 3.3). The 1997 water year produced above average flows and resulted in water retention times in Lake Roosevelt being well below ‘normal’ in most months. This reduction in WRT probably contributed to the maintenance of relatively high TDG content in Lake Roosevelt by reducing the time available for excess gasses to bleed off from Lake Roosevelt to the atmosphere. The drawdown of Lake Roosevelt during spring and summer decrease the reservoir surface area, further reducing the potential for excess dissolved gasses to be lost from Lake Roosevelt to the atmosphere.

4.3 Primary Production

4.3.1 Chlorophyll *a*

Although differences in chlorophyll *a* levels were not significant between depths within the euphotic zone, observed concentrations were generally lower near the surface. Photosynthesis is commonly inhibited in surface waters due to prohibitive light intensity (Goldman and Horne 1983; Wetzel 1983) during some seasons, or under low turbidity conditions. Lake Roosevelt does not generally exhibit highly turbid conditions in the pelagic zone except during periods of high runoff. Reduced correlation of ambient light levels with chlorophyll *a* concentrations in the upper ($r = 0.252$; $p = 0.0015$), relative to the middle ($r = 0.369$; $p < 0.0001$), and lower ($r = 0.395$; $p < 0.0001$) portions of the euphotic zone suggests that primary production was potentially photoinhibited in surface waters under some conditions in Lake Roosevelt during 1997.

Mean monthly concentrations of chlorophyll *a* were highest in June (Table 3.4) when they were strongly influenced by high (10-17 mg/m^3) concentrations at Porcupine Bay. Chlorophyll a levels during May and July were also high relative to other months (Table 3.4), but were less influenced by conditions at any single site and represented increased productivity at areas throughout Lake Roosevelt.

Monthly mean chlorophyll a concentrations and total phytoplankton densities in Lake Roosevelt were highly correlated during 1997 ($r=0.990$; $p<0.0001$). This correlation suggests that measurement of chlorophyll a concentrations can be used as a time and cost efficient method to assess primary production in Lake Roosevelt. However, speciation of phytoplankton samples should continue for at least one more full year to better assess annual variation in species composition, densities, and relative volumes available to secondary consumers in Lake Roosevelt.

4.3.2 Periphyton and Phytoplankton

Primary producers form the basis of aquatic food webs, and therefore have an important influence on standing crops of higher trophic levels within a given lake or reservoir system. Zooplankton are selective feeders, feeding primarily on diatoms (Bacillariophyceae), and small green algae (Chlorophyceae; Goldman and Horne 1983). Unicellular flagellates (Cryptophyceae) are also important in the diet of many zooplankton (Thorp and Covich 1991; Pennak 1989). The importance of these groups in both periphyton and phytoplankton collections suggest that lake operations (or other factors) that influence primary production in Lake Roosevelt have the potential to impact higher trophic levels as well, either directly or indirectly.

Phytoplankton are important primary producers in aquatic systems (Goldman and Horne 1983), with periphyton being the dominant group of producers in many lake systems (Wetzel 1983). Since periphyton production occurs only in relatively shallow littoral areas, drawdowns that reduce the availability of these areas within Lake Roosevelt may adversely impact annual production of all trophic levels. Completion of a detailed bathymetric map of Lake Roosevelt will help to better define changes in available littoral habitat relative to water levels within the lake.

Water level fluctuations have the potential to adversely or beneficially influence primary production in Lake Roosevelt, dependent on timing and direction of fluctuations. Colonization rates of periphyton were not additive across colonization periods during 1997 suggesting that two week colonization periods are insufficient to reach a ‘steady state’ population in Lake Roosevelt. Most populations, when colonizing newly created habitat, will experience a rapid increase in density to a point beyond equilibrium with environmental conditions, followed by a decline in population as the carrying capacity of the environment is realized. In this manner, water level increases which expose additional habitat to colonization may enhance short term productivity due to a resultant ‘boom’ in periphyton production. In contrast, water level declines may decrease overall production by exposing additional habitat where production levels are lowest (bottom of the euphotic zone) while eliminating areas of high productivity (surface waters). No substantial population ‘boom’ would be expected during a drawdown scenario because newly exposed habitats near the bottom of the euphotic zone are far less productive than near surface waters (See Section 3.3.2).

4.4 Zooplankton

4.4.1 Species Identified

The zooplankton species composition of Lake Roosevelt is diverse and provides a high density of food items during the growing season (May – October) when compared with other regionally productive kokanee lakes (Rieman and Bowler 1980; Stober et al. 1980; Thompson, University of British Columbia, Personal Communication). Brooks and Dodson (1965) showed that when zooplankton predation is of low intensity or absent, small zooplankton herbivores will be out-competed and eliminated by more efficient large forms (calanoid copepods and large Cladocera). When predation is of high intensity, predators will eliminate the large forms thereby allowing smaller zooplankton (rotifers, small Cladocera and small copepods) to become dominant. When predation is of moderate intensity, predators will reduce the abundance of large zooplankton so that small zooplankton species are not eliminated by competition. Thus, competition forces zooplankton communities toward larger-bodied organisms, while fish predation forces them toward smaller-bodied species.

Analysis of zooplankton size distributions for Lake Roosevelt indicate an abundant population of small (0.2 - 0.5 mm), medium (0.5 - 1.0 mm) and large (< 1.0 mm) organisms (Table 3.9), coupled with a highly diverse *Daphnia* population and the presence of a large invertebrate predator (*Leptodora kindtii*). This community structure suggests that planktivorous fish (kokanee salmon, rainbow trout, etc.) do not have a substantial predatory influence on the zooplankton community within Lake Roosevelt.

4.4.2 Zooplankton Densities

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

In most years in Lake Roosevelt, total zooplankton abundance is low from January through April, but it begins to increase by May or June coinciding with abundant algal food (primarily Bacillariophyceae; See section 3.3.3) and warming water temperatures. Typical of many large reservoirs (Pennak, 1989), total zooplankton densities in Lake Roosevelt are consistently high from June through October, providing a large food base for planktivorous fish. By November, total zooplankton densities decrease, reaching near minimum densities by December (Figure 4.1). In most years since 1991, total zooplankton abundance in Lake Roosevelt has been driven by copepod densities. Copepods are generally more successful than Cladocera in oligotrophic lakes due to selective feeding abilities and obligate sexuality (McNaught 1975 and Allan 1976).

From 1991 through 1997, reservoir mean total zooplankton densities ranged from 1,313 organisms/m^3 in 1993 to 9,151 organisms/m^3 in 1991. Reservoir mean total zooplankton densities in 1997 (2,297 organisms/m^3) were lower than any year except 1993 and 1994 and 62 % of the 1991 - 1997 average (Table 4.2). Reservoir mean total zooplankton densities in 1991 and 1992 were significantly higher ($p < 0.05$) than in any subsequent year of this study. From 1991 though 1996, total zooplankton density curves were monocyclic, however densities in 1997 exhibited dicyclic peaks in August and October. Reasons for the shift to dicyclic population densities in 1997 are unclear, but it is not uncommon for zooplankton densities to vary considerably within even a single species in the same lake from one year to the next (Pennak, 1989).

Total *Daphnia* densities were lower in 1997 (405 organisms/m^3) than all previous years monitored and only 44 % of the 1991 - 1997 average. Densities of total Copepoda in 1997 (1,828 organisms/m^3) were lower than any year except 1993 (489 organisms/m^3) and 1994 (575 organisms/m^3) and 60 % of the 1991 - 1997 average. Reservoir mean other Cladocera densities in 1997 (64 organisms/ m^3) were 80 % of 1991 - 1997 average (Table 4.2). Timing and magnitude of minimum and maximum total zooplankton densities varied between years in Lake Roosevelt, with maximum annual densities occurring from June through October dependent upon the year (Figure 4.1).

No notable differences in total zooplankton density trends were evident between high (1991, 1996 and 1997) and low water years (1992,1993, 1994 and 1995) but trends were evident between cool and warm water temperature years. In general, the coolest water temperature years (1993, 1994 and 1997) had the lowest reservoir mean total zooplankton biomass, while the warmest years (1991, 1992, 1995 and 1996) recorded the highest total zooplankton biomass (Table 4.2)

For Lake Roosevelt in 1997, temporal changes in mean temperature was the best predictor ($r^2 = 0.60$) of total zooplankton density (Figure 3.9). Water temperature is a major regulating factor in aquatic ecosystems affecting growth, development, reproduction, respiration and birth rate (Goss and Bunting 1983). Overall, cooler temperatures retard growth and reproduction of zooplankton while warmer temperatures within physiological tolerance limits accelerate growth (Lei and Armitage 1980). Temperature tolerances vary between zooplankton species and annual temperature variations have been shown to impact zooplankton species composition in other systems (Goss and Bunting 1983).

Table 4.2 Mean zooplankton density (#/m^3) by taxonomic group for 1991 through 1997 Lake Roosevelt zooplankton samples.

	Daphnia	Other Cladocera	Copepoda	Total Zooplankton
1991	1,361	260	7,531	9,151
1992	1,020	76	6,957	8,054
1993	807	17	489	1,313
1994	891	13	575	1,478
1995	918	111	2,095	3,141
1996	995	43	1,885	2,933
1997	405	64	1,828	2,297

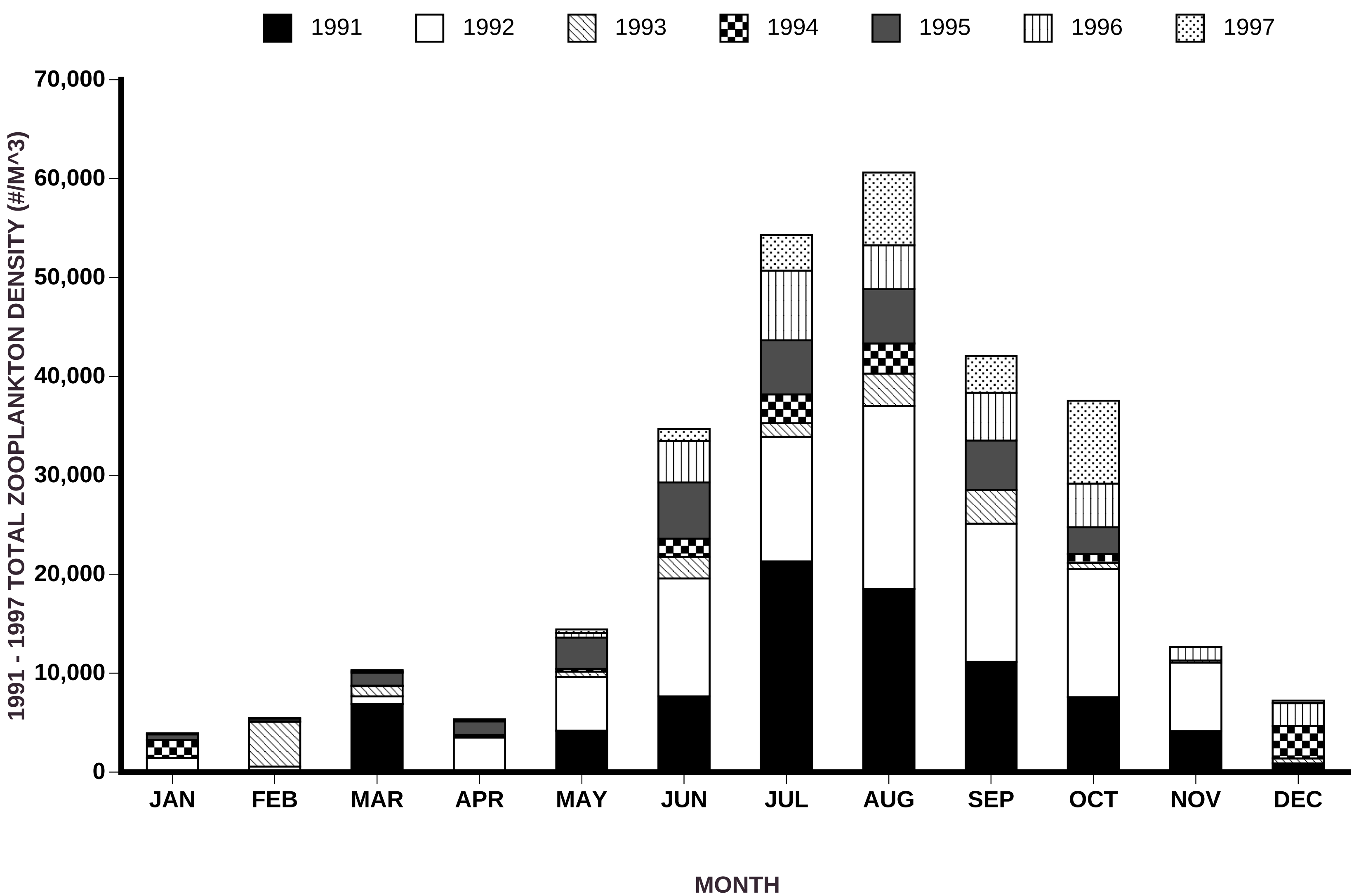


Figure 4.1 **Comparison of annual trends in monthly total zooplankton densities (#/m^3) for 1991 through 1997 Lake Roosevelt samples.**

Unsuccessful attempts to model zooplankton densities based on environmental variables other than temperature illustrates the complexity of interactions between zooplankton and their environment. In our attempts to model spatial variation in zooplankton densities based on environmental variables (chlorophyll a, secchi depth, WRT, reservoir inflow, outflow and elevation), no individual variable explained more than 6 % of the variance in zooplankton densities. However, our findings are comparable to other zooplankton modeling attempts on temperate rivers (Basu and Pick 1996) and in reservoirs (Dirnberger and Threlkeld 1986).

4.4.3 Zooplankton Lengths

Of the individual zooplankton measured in 1997 (n = 4,948), 77.5 % were less than 1.0 mm in length, 20.8 % were between 1.0 and 2.0 mm, and 1.7 % were greater than or equal to 2.0 mm (Table 3.10). *Daphnia* had the highest mean length by taxonomic group (1.11 mm; range: 0.20 - 3.0 mm), followed by other Cladocera (0.72 mm; range: 0.19 - 3.33 mm), and copepods (0.65 mm; range: 0.25 - 2.56 mm; Table 3.9).

The role of body size in planktonic herbivores has been a main focus of plankton ecology since competitive superiority of large-bodied species was suggested by Hrbacek (1962) and Brooks and Dodson (1965). In general, it was hypothesized that small-bodied zooplankton are more abundant in the presence of planktivorous fish because they are less vulnerable to predation by visual orienting planktivores (Zaret 1980; Kerfoot and Sih 1987; Gliwicz and Pijanowska 1989). In the absence of fish, large-bodied species dominate by monopolizing resources due to more efficient feeding abilities (Hall et al. 1976). Continued presence of large (> 2.0 mm), medium (1.0 - 2.0 mm) and small (< 1.0 mm) zooplankton in Lake Roosevelt (Table 3.9) suggests that the influence of fish predation on zooplankton in the system is low (Brooks and Dodson, 1965).

No significant ($p < 0.05$) differences in zooplankton sizes were observed between locations on an annual basis. However, zooplankton sizes were significantly larger ($p < 0.0001$) at Porcupine Bay and San Poil River during the summer growing season (May - October). Reasons for larger zooplankton sizes at these locations are unclear but length differences were driven primarily by increased representation of larger *Daphnia* . These findings suggest that conditions in tributary habitats favor *Daphnia* growth, most likely due to warmer water temperatures and / or higher densities of preferred phytoplankton species.

Zooplankton collected in August and December were significantly larger ($p = 0.0001$) than organisms collected at other times of the year. Also, zooplankton collected in June were significantly smaller than those collected in other months ($p = 0.006$). Reasons for these size differences appear to result from timing of reproductive events and seasonal changes in growth rates. In June, warm water temperatures and abundant food resources led to increased zooplankton reproduction and a higher proportion of juveniles in the population. Higher numbers of juveniles translate into smaller average sizes for individual species. In August, the zooplankton population was comprised primarily of older adult organisms which had matured over a period of abundant algal food resources (May - August; Figures 3.4 and 3.5) and warm water temperatures. Surprisingly, despite large size, most species exhibited low reproductive rates in August evidenced by low fecundity (R. Black, Eastern Washington University, Personal Communication). Low fecundity is linked to food limitation among zooplankton (Pennak, 1989) and suggests that overgrazing of algal resources by copepods and Cladocera likely occurred in August. Large average sizes in December were likely due to a predominance of large over-wintering adults.

4.5 Zooplankton Biomass

4.5.1 Total Zooplankton Biomass

Beginning in 1991, reservoir mean zooplankton biomass was computed as an average of biomass values observed at five index stations (Gifford, Porcupine Bay, Seven Bays, Keller Ferry and Spring Canyon). As previously discussed in section 4.3.2, between year comparisons of zooplankton biomass use the five site average in order to preserve comparability across years. Biomass estimates were only computed for *Daphnia* sp. prior to 1997, therefore between year comparisons of zooplankton biomass can only be made for this group.

Annual mean total zooplankton biomass values for Lake Roosevelt in 1997 was low (< 1,700 $\mu g/m^3$) from Hunters upstream (Gifford, Kettle Falls and Evan's Landing), high (7,660 - 19,533 $\mu g/m^3$) at mid and lower reservoir sites (Confluence, Seven Bays, Keller Ferry, San Poil Confluence and Spring Canyon). Highest annual mean biomass in 1997 (> 25,000 $\mu g/m^3$) was observed in tributary sites (Porcupine Bay and San Poil River; Table 3.12). Trends in total zooplankton biomass were driven primarily by changes in density except at Porcupine Bay where significantly larger zooplankton (predominantly *Daphnia* sp.) translated into the highest recorded biomass values at any location.

Temporal changes in reservoir mean temperature was significantly positively correlated with total zooplankton biomass for 1997 ($r^2 = 0.61$; $p = 0.0002$; Figure 3.9). None of the individual variables modeled for spatial effects on zooplankton biomass accounted for more than 7 % of the variance in zooplankton biomass. Variables included in our spatial modeling efforts were chlorophyll a, secchi depth, temperature, daily WRT, reservoir inflow, outflow and elevation.

Reservoir mean temperature by sample date was again the best predictor of total zooplankton biomass across all years from 1991 through 1997 ($r^2 = 0.41$; $p = 0.043$) although less so than for 1997 ($r^2 = 055$; $p = 0.0006$). Reasons for lowered r^2 values for the 1991 - 1997 period most likely result from annual variations in the Lake Roosevelt zooplankton population, again underlining the dynamic nature of reservoir zooplankton populations (Pennak, 1989).

In Lake Roosevelt, *Daphnia* sp. exhibit low annual abundance but are relatively large in size, copepod sp. were highly abundant but very small and other Cladocera were both low in abundance and relatively small (Tables 3.8 and 3.9). In 1997, *Daphnia* sp. made up 68.6% of the total annual zooplankton biomass despite accounting for only 16.9% of total zooplankton density. Copepod sp. accounted for 80.0% of total zooplankton density but only 30.6% of total zooplankton biomass while other Cladocera accounted for 3.2% of total zooplankton density and 0.8% of total zooplankton biomass (Tables 3.8 and 3.13 and Figure 3.8).

Carpenter and Kitchell (1988) have shown that planktivorous fishes (kokanee salmon, rainbow trout, lake whitefish, etc.) are selectively predaceous on zooplankton populations in that they tend to ingest larger, visually obvious individuals in preference to smaller individuals. A complex combination of size, escape ability and overall visibility make cladocerans generally more susceptible to predation than copepods (Kerfoot, 1975; O'Brian and Schmidt, 1979; Lewis 1979; Neill, 1981). In Lake Roosevelt, the largest zooplankton species are primarily *Daphnia* (*D. pulex, D. schødleri*, and *D. retrocurva*) but also include: *Leptodora kindtii*, *Sida crystallina*, and adult instars of *Diacyclops bicuspidatus thomasi*, *Leptodiaptomus ashlandi*, *Epischura nevadensis*, and *Mesocyclops edax*. Of these species, six *(D. pulex*, *D. schødleri*, *D. retrocurva*, *D. b. thomasi*, and *L. ashlandi*) accounted for 95% of the reservoir wide annual zooplankton biomass. The remaining species occurred at very low densities which translated into low annual mean biomass estimates (Figure 3.8). Calculated Index of Relative Importance (IRI) values show that Cladocera account for 74% of the diet of kokanee salmon, 51 % of the diet of rainbow trout and 63 % of the diet of lake whitefish emphasizing the importance of Cladocera in the food web of Lake Roosevelt (Table 3.40).

4.5.2 *Daphnia* Biomass

From 1991 through 1997, reservoir mean *Daphnia* sp. biomass values ranged from 1,681 $\mu g/m^3$ in 1992 to 27,803 $\mu g/m^3$ in 1994. *Daphnia* sp. biomass was lower in 1997 than in any year since 1991 and 1992 and was 65.6% of the 1991 - 1997 average. Timing and magnitude of minimum and maximum *Daphnia* sp. biomass values varied between years with maximum biomass occurring between June and October and following trends in *Daphnia* sp. density.

Numerous studies of limnetic zooplankton communities have identified temperature, predation, food availability and advection as major factors in regulating *Daphnia* biomass and densities in reservoirs (Goldman and Horne 1983; Brooks and Dodson, 1965; Dirnberger and Threlkeld 1986). Our data for 1997 found a strong correlation between temporal changes in reservoir mean temperature and total *Daphnia* biomass (r^2 = 0.57; p = 0.0071). Spatial modeling of localized environmental variables using stepwise regression was unsuccessful (maximum r^2 = 0.11).

Lowest annual mean *Daphnia* sp. biomass values (<1,100 $\mu g/m^3$) occurred at cooler upper mainstem Columbia River sites (Hunters, Gifford, Kettle Falls and Evan’s Landing; Table 3.14). High annual mean *Daphnia* sp. biomass values (3,600 - 14,500 $\mu g/m^3$) occurred at warmer mid and lower reservoir sites (Seven Bays, Keller Ferry, San Poil confluence, and Spring Canyon) while highest recorded biomass values (> 15,000 $\mu g/m^3$) occurred in tributary habitats corresponding with highest mean temperatures (Porcupine Bay and San Poil River).

Relatively little work has been done to define temperature effects on *Daphnia* over the wide variation of regimes which can be experienced in natural environments. However, several studies (Robertson, 1971; Lei and Clifford, 1974; Lei and Armitage, 1980; Goss and Bunting, 1983) have identified differential temperature tolerance among *Daphnia* sp. in the laboratory. In general, of the *Daphnia* sp. occurring in Lake Roosevelt, *D. pulex* appear to be the most warm water tolerant while *D. schødleri* and *D. retrocurva* are more warm water intolerant. These observations may explain the predominance of *D. pulex* in Lake Roosevelt during periods of highest water temperature (late August) as well as dominance of *D. retrocurva* and *D. schødleri* during cooler water periods (Figure 3.10).

4.5.3 Other Cladocera Biomass

Contributions to total zooplankton biomass made by other Cladocera were insignificant (0.8%) due to low relative abundance and predominantly small size. *Bosmina longirostris* accounted for the majority (65%) of annual mean other Cladocera biomass but was not identified as a major food item for planktivorous fishes (Table 3.40).

Other Cladocera densities peaked earlier (July 10th) than other taxonomic groups primarily due to increased cold tolerance among many of these species. Allan (1977) demonstrated successful reproduction at temperatures as low as 0 ^{o}C for *Bosmina longirostris* and at 4 ^{o}C *Ceriodaphnia reticulata.* In contrast, Goss and Bunting (1983) observed maximum egg production rates for *Daphnia pulex* and *D. magna* at temperatures between 15 and 20 ^{o}C with significant decreases occurring at temperatures above and below this range. It appears that cold temperature tolerance among other Cladocera species gains them a competitive advantage during early spring, but that they are out competed beginning in early summer by more efficient algal filtering *Daphnia* .

Regression analysis showed no significant relationship between reservoir mean temperature by sample date and total other Cladocera biomass and also yielded the lowest correlation coefficient ($r^2 = 0.28$) of any zooplankton group studied. Cold water tolerance coupled with the potential for competitive exclusion by *Daphnia* during warmer periods may explain this poor relationship. Maximum other Cladocera biomass values occurred at 13 ^{o}C temperatures while maximum *Daphnia* and copepod biomass values corresponded with temperatures of 15 and 14 ^{o}C respectively. It is possible that cold water tolerance among other Cladocera benefits planktivorous fishes by providing food resources during periods of poor *Daphnia* and copepod production.

4.5.4 Copepod Biomass

Annual mean Copepoda biomass values for Lake Roosevelt in 1997 were low (< 1,700 $\mu g/m^3$) from Hunters upstream (Gifford, Kettle Falls and Evan's Landing), high (7,660 - 19,533 $\mu g/m^3$) at mid and lower reservoir sites (Porcupine Bay, Confluence, Seven Bays, Keller Ferry, San Poil Confluence and Spring Canyon) and highest (> 9,600 $\mu g/m^3$) at San Poil River (Table 3.16). Total copepod biomass was consistently low (< 300 $\mu g/m^3$), from January through April except for a short peak at the Confluence in February (1,664 $\mu g/m^3$). By May or June, total copepod biomass began to increase leading to a substantial build-up of standing crop from July through October. By December, reservoir wide total zooplankton biomass values returned to near minimum values (Table 3.16). Again, trends in total copepod biomass were driven primarily by changes in density and showed significant correlation with temporal changes in reservoir mean water temperature (r^2 = 0.56; p = 0.0013).

Overall, copepod species provide a limited food base for large planktivorous fishes in Lake Roosevelt due to generally small size and low organism visibility. However, copepods may be critical for larval and juvenile fish growth as they are small enough be fed upon by gape limited fishes.

It is interesting to note that despite warm water temperatures and abundant algal reserves (based on chlorophyll a concentrations), copepod biomass was not highest at Porcupine Bay as occurred for *Daphnia*. Studies by Kerfoot (1977) and McNaught and Lane (1970) have provided a possible explanation for this phenomenon by identifying inverse relationships between copepod and cladoceran densities both in Lake Washington and the Great Lakes. These researchers concluded that high Cladocera abundance’s can reduce overall copepod abundance and biomass through the process of competitive exclusion. It appears that this may be the case for Porcupine bay where high numbers of *Daphnia* compete directly with copepods for food resources.

4.6 Tagging Studies / Entrainment

Since 1988, approximately 128,795 net-pen reared rainbow trout have been tagged and released into Lake Roosevelt. Approximately 1.6 percent of these tags (2,044) have been returned by various sources (Table 4.3). Tags from rainbow trout released into Lake Roosevelt have been returned up to five years after release, however the majority of tags returned (1,750; 85%) have been recovered in the same year that the fish are released (Table 4.3). Tag return rates for individual cohorts have ranged from less than one percent for fish released in 1993 and 1997 to eight percent for fish released in 1988 (Table 4.3). Our data indicates that entrainment during the first year following release is an accurate indicator of the total entrainment that will be realized by a particular cohort (Table 4.3) and suggests that the majority of entrainment occurs within the first year.

Water retention times (WRT) are closely related to flow conditions, and WRT’s below thirty days have previously been linked to increased entrainment rates of rainbow trout from Lake Roosevelt (Griffith et al. 1995; Scholz 1991). Our indices indicated that estimated entrainment of rainbow trout tagged at both Kettle Falls (99%) and Seven Bays (95%) during 1997 was the highest ever recorded by the Monitoring Program (Table 3.17). During ‘normal’ water years (1988, 1990 and 1992-95) our entrainment indices have

Table 4.3 Summary of all floy tags returned from rainbow trout released into Lake Roosevelt since 1988. Values in parenthesis indicate number of tags recovered from areas below Grand Coulee Dam.

Release Year	Tags Released	Number of Tags Returned: Release Year	+1 Year	+2 Year	+3 Year	+4 Year	+5 Year	Total Tags Returned	Tag Return Rate	Entrainment Index (Year of Release)	Entrainment Index (all years)
1988	**1,171**	77 (0)	16 (0)	1 (0)				**94 (0)**	**8%**	**0%**	**0%**
1989	**1,753**	15 (2)	28 (2)	1 (0)	3 (0)		2 (1)	**49 (5)**	**4%**	**13%**	**10%**
1990	**4,361**	72 (21)	19 (8)	3 (0)	1 (1)	1 (1)		**96 (31)**	**3%**	**29%**	**32%**
1991	**4,345**	205 (32)	45 (4)	2 (1)	1 (1)			**253 (38)**	**7%**	**16%**	**15%**
1992	**20,997**	509 (12)	10 (0)					**519 (12)**	**3%**	**2%**	**2%**
1993	**21,261**	108 (2)	34 (2)	3 (0)				**145 (4)**	**<1%**	**2%**	**3%**
1994	**26,975**	307 (8)	64 (3)	3 (0)	1 (0)			**375 (11)**	**1%**	**3%**	**3%**
1995	**12,984**	104 (1)	12 (1)	4 (0)				**120 (2)**	**1%**	**1%**	**2%**
1996	**14,948**	202 (55)	40 (7)					**242 (62)**	**2%**	**27%**	**26%**
1997	**20,000**	151 (146)						**151 (146)**	**<1%**	**97%**	**97%**
Total	**128,795**	**1,750 (279)**	**268 (27)**	**17 (1)**	**6 (2)**	**1 (1)**	**2 (1)**	**2,044 (311)**	**2%**	**16%**	**15%**

generally been low for rainbow trout (0-3%) with the exception of the1990 release group (32%; Table 4.3). In contrast, during high water years (1989, 1991, 1996 and 1997) our entrainment indices were considerably higher (15-97%; Table 4.3) for rainbow trout released into Lake Roosevelt.

Historically, net-pen reared rainbow trout have been released into Lake Roosevelt in spring or early summer (March-June). Cichosz et al. (1998) suggested that entrainment rates are a function not only of WRT, but also drawdown/refill scenarios at the time when fish are released into Lake Roosevelt. To further examine this hypothesis, we plotted the relationship between entrainment and WRT for rainbow trout released during drawdown (March-April) and refill (May-June) conditions in Lake Roosevelt (Figure 4.2). If monthly mean WRT are less than 20 day when rainbow trout are released from net-pens, high entrainment rates can be expected regardless of the timing of release (Figure 4.2). However, when monthly mean WRT's exceed 20 days in the month of release, there appears to be a distinct advantage to holding fish until May or June (following peak drawdown) to minimize entrainment (Figure 4.2). Our data indicates that entrainment may be reduced by approximately 12 percent at a WRT of 30 days and approximately 20 percent at a WRT of 40 days by holding rainbow trout for later releases in May or June. Based on both the available data and recent improvements to the net pens, we strongly recommend that any fish raised in net-pens in Lake Roosevelt be held until at least mid-May before release. Water depth and other environmental factors (water temperature) have historically played an important role in determining when fish were released from net-pens. However, modifications during 1996 and 1997 allow movement of net-pens to better accommodate changing water levels during spring drawdowns and will allow operators to hold fish longer in most years. Net-pen reared rainbow trout contribute extensively to the Lake Roosevelt fishery, and any reduction in entrainment rates which can be achieved should directly benefit both sport and tribal fisheries in Lake Roosevelt.

4.7 Historical Stocking and Lake Operations

Historically, stocking strategies and lake operations have been the two major factors effecting recruitment of hatchery origin rainbow trout and kokanee salmon into the Lake Roosevelt fishery. The Hatchery Coordination Team (Team) controls stocking strategies, whereas natural, political, and economic forces (anadromous fish flows, flood control, power production, irrigation) control lake operations. Members from the Washington

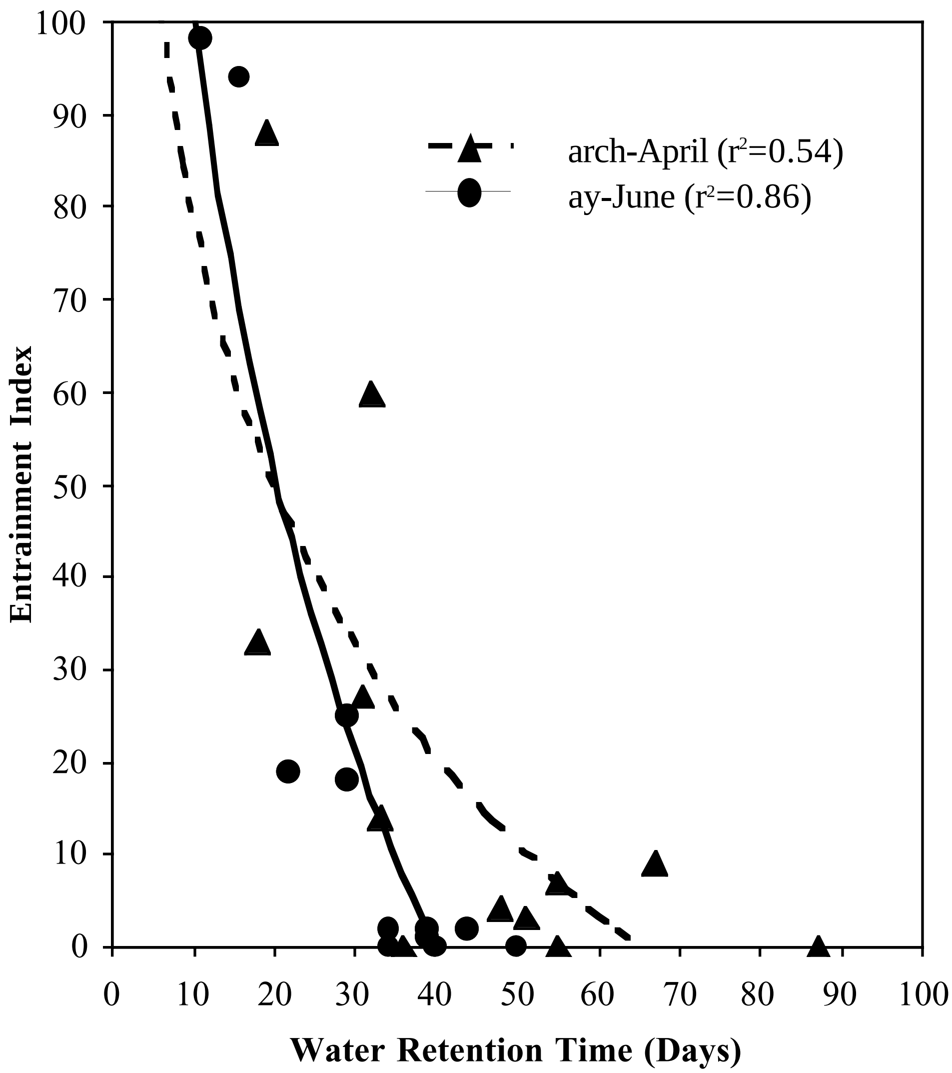


Figure 4.2 Relationship between entrainment and water retention time from 1988 to 1997. Data includes angler tag returns (above and below Grand Coulee Dam) and Fish Passage Center tag reports (below Grand Coulee Dam).

Department of Fish and Wildlife, the Colville Confederated Tribes, and the Spokane Tribe of Indians make up the Team and are charged with determining age and numbers of fish to be stocked and the most appropriate times and locations to stock fish.

Historical stocking strategies are discussed in Section 1.2, and summarized here for rainbow trout (Table 4.4) and kokanee salmon (Table 4.5). In 1994 Tilson et al. (1995) recommended that fry releases for kokanee salmon be discontinued, and that kokanee salmon be released as yearlings. The recommendation was made based on tag return data showing increased survival of kokanee salmon released as yearlings relative to those released as fry. Hatcheries have therefore outplanted higher percentages of kokanee salmon as yearlings since 1995. The shift has reduced the total number of kokanee salmon being stocked into Lake Roosevelt because yearlings require more space for hatchery rearing (Table 4.5). Stocking strategies for rainbow trout have historically involved net pen rearing to a yearling stage, and have therefore been unaffected by the recommendations of Tilson et al. (1995; Table 4.4).

Table 4.4 Summary of hatchery origin rainbow trout released into Lake Roosevelt from 1986 though 1997.

Year	Hatchery	Number
1986	Spokane (WDFW)	50,000
1987	Spokane (WDFW)	80,000
1988	Spokane (WDFW)	150,000
1989	Spokane (WDFW)	175,000
1990	Spokane (WDFW)	276,500
1991	Spokane Tribal	326,461
1992	Spokane Tribal	424,395
1993	Spokane Tribal	446,798
1994	Spokane Tribal	449,183
1995	Spokane Tribal	415,844
1996	Spokane Tribal	576,853
1997	Spokane Tribal	565,172

Table 4.5 Summary of hatchery origin kokanee salmon released into Lake Roosevelt from 1988 though 1996.

Year	Hatchery	Number	Life Stage	Size (#/lb)
1988	Ford	872,150	fry	500
1989	Ford	861,442	fry	280
1990	Ford	1,025,400	fry	247
1991	Spokane Tribal	1,674,577	fry	119
1992	Spokane Tribal	71,256	yearling	9
1992	Spokane Tribal	819,220	fry	158
1992	Sherman Creek	68,552	yearling	22
1992	Sherman Creek	1,099,000	fry	616[a]
1993	Spokane Tribal	21,190	yearling	7
1993	Spokane Tribal	1,024,293	fry	225
1993	Sherman Creek	72,508	yearling	15
1993	Sherman Creek	675,572	fry	228
1994	Spokane Tribal	123,254	yearling	10
1994	Spokane Tribal	1,910,255	fry	125
1994	Sherman Creek	90,881	yearling	11[a]
1994	Sherman Creek	1,087,161	fry	372[a]
1995	Spokane Tribal	1,401	brood	1
1995	Spokane Tribal	59,825	yearling	10
1995	Spokane Tribal	515,425	fry	202
1995	Sherman Creek	210,643	yearling	15[a]
1995	Sherman Creek	164,328	yearling	28[a]
1996	Spokane Tribal	54,194	yearling	9
1996	Sherman Creek	224,562	yearling	14[a]
1996	Sherman Creek	50,899	fry	52[a]
1997	Spokane Tribal	40,808	yearling	7
1997	Spokane Tribal	54,103	fry	117
1997	Sherman Creek	220,191	yearling	15[a]
1997	Sherman Creek	261,092	fry	41[a]

a size transferred from Spokane Tribal Hatchery not at release.

With the exception of January and December, respective mean monthly water retention times during 1997 were the lowest observed since 1991, remaining below 30 days from February through July (Table 4.1). Water retention times below 30 days apparently reduce zooplankton and fish densities in Lake Roosevelt through entrainment, thereby negatively impacting the fishery (Voeller 1996; Griffith et al. 1995; Griffith and Scholz 1991; Peone et al. 1990).

In Lake Roosevelt, with water retention times below 30 days generally coincide with lake elevations below 1,240 feet MSL (Griffith and Scholz 1991; Griffith et al. 1995), however this is dependent on flows and dam operations. Spring drawdowns in 1989, 1991 and 1996 resulted in water levels below 1,240 MSL and water retention times less than 30 days (Table 4.1), and were considered particularly detrimental to the fishery (Peone et al. 1990; Griffith and Scholz 1991; Thatcher et al. 1993 and 1994; Griffith et al. 1995). In contrast 1992 through 1995 had higher mean water levels and water retention times, and were less detrimental to the fishery based on both tag returns and creel results (Underwood et al. 1997). Extensive drawdowns in 1997 resulted in conditions more severe than those in 1991 with regard to lake elevations and water retention times in Lake Roosevelt (Table 4.1).

4.8 Creel Survey Trends

In 1997, the estimated number of angler trips to Lake Roosevelt and the economic value of the fishery were lower than any year since 1990 and 1991, respectively (Table 4.6). The economic value of the Lake Roosevelt fishery in 1997 was approximately $1.1 million less than in 1996, and less than one third of the estimated value of the fishery in 1993 and 1994 (Table 4.6). The estimated annual number of angler trips to Lake Roosevelt peaked in 1993 and has been declining since (Table 4.6). The estimated number of angler trips made in 1997 was approximately one fourth of the 1993 estimate, and was reduced approximately 15% from 1996 (Table 4.6). Continued reduction in the number of angler trips (and the resultant reduction in estimated economic value of the fishery) during 1997 was potentially a result of de-watering of boat ramps during the spring drawdown which prohibited anglers from accessing much of Lake Roosevelt during the spring (Tables 3.20 and 3.21). Angler comments during 1997 creel surveys also implied that angler pressure

Table 4.6 **Summary of angler trips, number of fish caught and harvested, catch and harvest per unit of effort and mean lengths of kokanee salmon, rainbow trout and walleye observed during creel surveys from 1990 through 1997.**

	1990	1991	1992	1993	1994	1995	1996	1997
Economic Value (millions of dollars)	5.3	12.8	9.7	20.7	19.1	8.7	6.9	5.8
Angler Trips	171,725	398,408	291,380	594,508	469,998	232,202	176,769	146,264
No. Caught								
Kokanee salmon	17,756	31,651	8,146	13,986	16,567	32,353	1,265	588
Rainbow trout	81,560	81,529	167,156	402,277	499,460	125,958	76,915	5,356
Walleye	116,473	231,813	163,995	337,413	123,612	73,667	142,873	147,316
No. Harvested								
Kokanee salmon	17,515	31,651	8,021	13,960	16,567	32,353	1,265	588
Rainbow trout	79,683	73,777	140,609	398,943	499,293	122,939	76,782	5,356
Walleye	82,284	168,736	118,863	307,663	53,589	40,185	104,055	87,515
CPUE (per hr)								
Kokanee salmon	0.03	0.06	0.03	0.01	<0.01	0.02	<0.01	<0.01
Rainbow trout	0.13	0.20	0.22	0.17	0.21	0.08	0.10	0.01
Walleye	0.11	0.11	0.15	0.12	0.08	0.13	0.30	0.34
HPUE (per hr)								
Kokanee salmon	0.02	0.06	0.03	0.01	<0.01	0.02	<0.01	<0.01
Rainbow trout	0.12	0.20	0.18	0.16	0.21	0.08	0.10	0.01
Walleye	0.08	0.08	0.11	0.08	0.05	0.06	0.16	0.17
Mean Length (mm)								
Kokanee salmon	391	361	436	486	481	467	438	338
Rainbow trout	346	348	422	471	473	410	363	395
Walleye	376	397	361	382	385	370	372	372

was reduced due to a lower expectation of quality fishing in Lake Roosevelt following the dramatic spring drawdown. Angler interviews conducted during other activities (i.e. sportsman shows) during 1997 also illustrated a general angler belief that the substantial drawdown of Lake Roosevelt would have a severe negative impact on the fishery.

4.8.1 Rainbow trout

Rainbow trout stocked into Lake Roosevelt from net pens contribute substantially to the fishery. Since 1994, rainbow trout have accounted for approximately 63% (range 5-82%) of the estimated total harvest from Lake Roosevelt. The annual percentage of rainbow trout creeled that were determined to be of net pen origin (See Section 2.5) has ranged from 91.5% (1995) to 100% (1997). The rainbow trout stocked from net pens recruit into the fishery in the same year as being stocked, and the majority of rainbow trout are harvested that same year (Peone et al. 1990, Griffith and Scholz 1991, Griffith et al. 1995, Griffith and McDowel 1996, Voeller 1996).

Estimates of rainbow trout catch and harvest showed an increasing trend from 1990 through 1994, followed by a notable decline through 1997. Based on our creel data, estimated catch and harvest of rainbow trout in 1997 was the lowest since 1990 (Table 4.6).

Rainbow trout catch and harvest rates (CPUE and HPUE) in 1997 were lower than in previous years (Table 4.6), probably as a result of reservoir operations. Decreased water retention time (a result of drawdown) have been related to entrainment of rainbow trout through Grand Coulee Dam (Griffith and McDowel 1996). Our tag return data suggests that entrainment rates were high in 1997, with over ninety percent of tags recovered from 1997 releases coming from below Grand Coulee Dam. This includes 99 percent of those from May releases (from Kettle Falls; Table 3.17) when Lake Roosevelt was still drawn down considerably (Table 3.1). Estimates of entrainment were also high (up to 89%) for fish released from 1989 through 1991, and in April of 1996 (Table 3.17). In contrast, entrainment rates from 1992 through 1995 were relatively low, ranging from 0-3 percent (Table 3.17). Minimum reservoir elevations in 1989, 1991, 1996 and 1997 were below 1,230’ MSL whereas from 1992 through 1995 drawdowns were less severe and resulted in minimum water levels above 1250’ MSL. Reservoir operations during 1997 were similar to those in 1989, 1991 and 1996, and increased entrainment of rainbow trout in these years is probably due to increased severity of spring drawdowns in Lake Roosevelt.

4.8.2 Kokanee Salmon

Creel data indicates a dramatic reduction in abundance of kokanee salmon since 1995 in terms of numbers caught or harvested (Table 4.6). Our estimate of kokanee salmon harvest from Lake Roosevelt in 1997 represents roughly 50 percent of the 1996 harvest, and only 1.7 percent of the estimated 1995 harvest. Three primary factors probably contribute to the dramatic decline in estimated kokanee salmon harvest observed in recent years.

One factor probably contributing to our low estimates of kokanee salmon harvest is high entrainment through Grand Coulee Dam in 1996 and 1997 resulting from prohibitive lake operations. Kokanee salmon abundance in Lake Roosevelt has previously been related to entrainment rates and water retention times (Underwood et al. 1997; Underwood et al. 1996), and Cichosz et al (1998) suggested that the 1996 drawdown of Lake Roosevelt significantly impacted the kokanee salmon fishery due to resultant high entrainment. Estimated entrainment of rainbow trout from Lake Roosevelt was high in 1996 and 1997 (Table 3.17), and Underwood et al. (1996 and 1997) suggested that entrainment of kokanee salmon from Lake Roosevelt may exceed that of rainbow trout, especially in years of substantial drawdown. Tilson et al. (1994) and Scholz et al. (1992 and 1993) found that yearling kokanee salmon go through a partial smoltification phase during April that results in an increased tendency to migrate downstream. The increased migration tendency coincides with the peak of annual spring drawdown in most years and may result in increased entrainment rates relative to other fishes.

Kokanee salmon do not enter the creel until they are approximately 300 mm in length and two years of age (Underwood et al. 1997), suggesting that major entrainment events of yearlings should be recognized in the following year whereas those involving mixed age classes may have a more immediate impact on the fishery. A major decline in kokanee salmon harvest in 1996 suggested that kokanee salmon of all ages were potentially entrained in high numbers during the spring drawdown (Cichosz et al 1998). This idea was further substantiated by low harvest rates in 1997, suggesting high entrainment rates of yearling kokanee salmon during the 1996 drawdown. Hydroacoustic surveys conducted by the Colville Tribe will provide information on 1997 entrainment of kokanee salmon and other fishes from Lake Roosevelt and help to further define the relationship between entrainment rates and reservoir operations.

A second factor that probably influences harvest estimates of kokanee salmon from Lake Roosevelt is the amount of fishing pressure exerted. Many of the boat ramps on Lake

Roosevelt are de-watered during spring drawdowns, and in years of more substantial drawdowns (i.e. 1996 and 1997), the duration of limited boat access to the lake is increased. All Park Service boat ramps on Lake Roosevelt are de-watered at lake elevations below 1,229’, and below a lake elevation of 1,240’ only five boat ramps are functional. Kokanee salmon are generally harvested from the lower reaches of Lake Roosevelt during the winter and spring, and in years of increased drawdown, access to this fishery may be severely limited by water levels in Lake Roosevelt. Limited access to the kokanee salmon fishery will result in less angler hours exerted and decreased harvest estimates during some years.

The third factor that has probably contributed to the dramatic reduction in our harvest estimates since 1995 is the sensitivity of our creel analysis. In years of decreased angling pressure and / or decreased angler success, the probability of our creel clerks encountering a successful kokanee salmon angler decreases. In contrast, during years of high angler pressure / success, creel clerks would be expected to interview more anglers harvesting fish regardless of the location or time of day at which interviews are conducted. The probable decrease in the creel sensitivity during low pressure or low harvest years would imply that we underestimated harvest of kokanee salmon in 1996 and 1997. We do believe however that creel analysis is an accurate method to represent long term trends in harvest, and that the dramatic decline in estimated kokanee harvest is real although the estimated harvest numbers may be inaccurate.

4.8.3 Walleye

Estimated catch and harvest rates for walleye in Lake Roosevelt have increased markedly in 1996 and 1997 relative to previous years (Table 4.6). The percentage of anglers targeting walleye in Lake Roosevelt was also higher in 1996 (44%) and 1997 (56%; Table 3.28) than in previous years (18-29%). Observed increases in catch and harvest rates of walleye during 1996 and 1997 are due, in part, to the methods employed to estimate them. In calculating catch and harvest rates we utilize total (not species specific) angler pressure to avoid problems associated with anglers who catch species other than their target species. Therefore, an increase in the percentage of anglers targeting a given species typically results in a coincidental increase in the estimated catch / harvest rate simply because a higher proportion of the total effort is expended specifically targeting that species. We do believe that the noted increase in catch and harvest rates during 1996 and 1997 are real, however the coincidental shift in angler pressure makes it difficult to interpret the actual amount of this increase.

Walleye CPUE and HPUE increased from 1990 through 1992, then declined until 1994, and generally increased again through 1997 (Table 4.6). Mean length of walleye harvested has generally followed an inverse trend, suggesting that in years of increased walleye harvest, smaller fish comprise a higher percentage of the creel. This suggests that recruitment of relatively strong year classes can have a notable impact on the fishery. Walleye recruit to the fishery between 350 and 400 mm total length, corresponding to walleye 3 to 4 years of age (Cichosz et al 1998). Our creel data suggests a particularly strong year class from 1989 or 1990 (1993 harvest), a relatively weak year class in 1991 or 1992 (1995 harvest), and strong year class(es) again in 1993 and/or 1994 (1996 and 1997 harvest).

Similarly to previous years, catch estimates and rates for walleye exceeded our estimates of annual harvest and harvest rates. A slot limit exists for walleye in Lake Roosevelt, allowing harvest of walleye under 406 mm (16 inches) or over 508 mm (20 inches) in length. The slot limit results in anglers releasing intermediate sized walleye, and leads to catch rates exceeding harvest rates in all years. Creel results indicate that during 1997, approximately 40 percent of walleye caught by anglers in Lake Roosevelt were released (estimated catch - estimated harvest / estimated catch; Table 4.6). Past creel results show that the proportion of walleye released by Lake Roosevelt anglers has been variable since 1990, ranging from nine (1993) to 57 percent (1994; Table 4.6) annually.

The Lake Roosevelt fishery is consumptive in nature, so we assume that the vast majority of walleyes released by anglers are either relatively small fish (< 350 mm) or fall within the protective slot limit established by the WDFW. Therefore, variability in year class strength will have a pronounced impact on the proportion of the walleye population available for harvest. Strong year classes reduce the harvestable proportion of the population both prior to their recruitment to harvestable size, and for approximately two years when they are within the slot limit. In contrast, strong year classes enhance the harvestable proportion of the population during years when they are available for harvest. The actual effect of year class strength on the harvestable proportion of walleye is difficult to define due to variable growth across years (Table 3.38) and the fact that multiple year classes are available to the fishery in any year. Irregular growth of walleye from year to year (Table 3.38) has also complicated our efforts to use length frequency analysis to track survival of individual year classes of walleye through time in Lake Roosevelt.

It has been suggested that harvest rates may be negatively impacting the survival and spawning success of walleye in Lake Roosevelt (Dr. Allan Scholz, Eastern Washington

University, Personal Communication). Creel data indicates that walleye harvest has been variable since 1990, ranging from approximately 40,000 (1995) to 300,000 (1993) walleye per year (Table 4.6). Current harvest regulations for Lake Roosevelt walleye have been in place since 1985, and were implemented to reduce concerns of overharvest and insufficient spawner recruitment. Studies underway to define the current status of the walleye population in Lake Roosevelt should be completed by early 1999. We strongly recommend that the co-managers of the Lake Roosevelt fishery (STOI, CCT, WDFW) utilize results of current studies in conjunction with past data to assess the success of current regulations during 1999, and to define any changes necessary to maintain a successful fishery.

4.8.4 Smallmouth Bass

We estimated that approximately 93 percent of smallmouth bass caught by anglers in Lake Roosevelt during 1997 were harvested (Tables 3.24 and 3.25). This represents a significant change from previous years in which only about 3 percent of smallmouth bass caught were presumed to be harvested (Cichosz et al 1998). Cichosz et al (1998) suggested that smallmouth bass were probably considered as incidental catch by anglers in Lake Roosevelt based on the large disparity between catch and harvest rates. The percentage of anglers targeting ‘other species’ (including smallmouth bass) in 1997 was similar (10%; Table 3.28) to previous years (Cichosz et al 1998). However, the increase in relative harvest rates implies that more Lake Roosevelt anglers may have specifically targeted smallmouth bass in 1997 relative to previous years.

4.9 Relative Abundance

Relative abundance of fish species sampled from Lake Roosevelt by electrofishing and gillnetting has remained relatively consistent since 1989 with only a few substantive changes (Tables 4.7 and 4.8). Largescale suckers have been abundant (12-52%) in our electrofishing catches since 1989, and have been the dominant taxon since 1991 (Table 4.7). Yellow perch were the dominant taxon in electrofishing surveys in 1989 (44%) and 1990 (48%), but have declined dramatically in relative abundance since 1990 (Table 4.7). Kokanee salmon and rainbow trout respectively, accounted for one and five percent of the fish collected during 1997 electrofishing surveys, which was similar to most previous years for both species (Table 4.7).

Relative abundance surveys suggest that substantial annual harvest of rainbow trout (See Section 4.8.1) does not appear to be negatively impacting wild stocks of rainbow trout within Lake Roosevelt. Wild rainbow trout have accounted for 48 percent of all rainbow trout observed in our relative abundance surveys since 1994, ranging annually from 36 (1996) to 61 percent (1997). Our relative abundance surveys indicate that wild rainbow trout are most commonly associated with inlet streams flowing into Lake Roosevelt, whereas net pen reared rainbow trout are most common throughout shoreline and pelagic areas of the lake.

Relative abundance of fishes in gillnet surveys has been dominated by lake whitefish and walleye. Relative abundance of these two taxa in gillnet surveys has been somewhat variable however these taxa combined have accounted for approximately 60 percent of the annual catch since 1989 (Table 4.8). Lake whitefish accounted for 37 percent of our gillnet catch in 1997, and between 15 and 51 percent of our gillnet catch since 1989 (Table 4.8). Walleye accounted for 27 percent of our gillnet catch in 1997, and between 15 and 48 percent of the annual catch since 1989 (Table 4.8). Rainbow trout and kokanee salmon each made up less than one percent of our total gillnet catch during 1997 (Table 4.8). For both species this represents a relative decline in abundance when compared to 1995 and 1996, and for rainbow trout 1997 relative abundance was the lowest since 1989 (Table 4.8).

Burbot have recently increased in relative abundance in both electrofishing and gillnet surveys, and were three to four times more abundant in 1996 and 1997 than in previous years (Tables 4.7 and 4.8). Field observations and increased CPUE's suggest that the increase in relative abundance of burbot represents an actual increase in recent years (rather than a coincidental decrease in the abundance of other species). Largescale suckers are prevalent in both gillnet and electrofishing surveys but generally account for a higher percentage of total catch in electrofishing surveys (Tables 4.7 and 4.8). Largescale suckers have accounted for over 30 percent of electrofishing catch since 1991 (Table 4.7), and between 4 and 11 percent of gillnet catch during the same period (Table 4.8), with no notable trend in their abundance.

Beachseine surveys were conducted in Lake Roosevelt as part of this program for the first time in 1997. Beachseine surveys collected primarily young of year (YOY) and age 1 fish, with less than one percent of the fish collected exceeding 150 mm in total length. Presence of YOY fishes is an indicator of spawning activity (generally upstream of the rearing area), however downstream displacement of larvae is a function of flow and water velocity

Table 4.7 Comparison of relative abundance (%) of fish collected during the 1989 through 1997 sampling periods via electroshocking.

	1989	1990	1991	1992	1993	1994	1995	1996	1997
Effort (hrs)									
Bridgelip sucker	1	<1	<1	<1	0	<1	<1	2	<1
Brook trout	<1	<1	<1	1	<1	<1	<1	1	<1
Bullhead	<1	<1	<1	0	<1	<1	<1	0	0
Brown trout	<1	<1	<1	<1	1	<1	<1	2	<1
Bull trout	<1	<1	0	0	0	<1	<1	0	0
Burbot	<1	<1	<1	<1	0	<1	<1	3	4
Carp	2	2	<1	2	1	1	2	2	7
Chinook salmon	<1	<1	<1	<1	<1	<1	<1	0	<1
Chiselmouth	0	<1	0	<1	0	0	0	0	0
Cottus sp.	2	2	<1	2	3	16	6	1	2
Crappie	<1	<1	<1	1	0	<1	<1	0	0
Cutthroat trout	0	0	0	0	0	0	0	<1	0
Kokanee salmon	2	<1	<1	3	1	4	22	4	1
Lake whitefish	<1	<1	<1	<1	<1	<1	<1	<1	<1
Largemouth bass	<1	<1	<1	<1	0	0	0	0	<1
Largescale sucker	12	19	35	46	46	36	30	44	52
Longnose sucker	<1	2	<1	<1	0	2	<1	1	<1
Mtn. whitefish	<1	<1	<1	<1	<1	<1	<1	<1	<1
Peamouth	<1	0	<1	<1	0	0	0	0	<1
Pumpkinseed	<1	<1	0	0	0	2	0	0	<1
Rainbow trout	6	3	4	6	9	7	5	7	5
Redside shiner	0	<1	0	<1	0	<1	<1	0	<1
Smallmouth bass	1	3	15	7	9	8	10	6	9
N. squawfish	4	6	3	2	8	4	2	2	2
White sturgeon	0	0	0	0	0	0	0	0	0
Catostomus sp.	7	0	0	0	0	0	<1	5	0
Tench	<1	<1	<1	<1	0	<1	<1	<1	<1
Walleye	16	13	11	8	11	7	11	19	12
Yellow perch	44	48	30	20	11	12	7	2	3

Table 4.8 Comparison of relative abundance (%) of fish collected during the 1989 through 1997 sampling periods via gillnetting.

Effort (hrs)	1989	1990	1991	1992	1993	1994	1995	1996	1997
Bridgelip sucker	1	0	<1	0	0	0	3	<1	<1
Brook trout	0	0	0	0	0	0	0	0	0
Bullhead	<1	0	0	0	0	0	0	<1	0
Brown trout	0	0	0	0	0	0	<1	0	<1
Bull trout	0	0	0	0	0	0	0	0	0
Burbot	<1	<1	1	0	7	4	4	10	13
Carp	0	1	0	0	0	1	0	1	<1
Chinook salmon	0	0	0	0	0	0	0	0	0
Chiselmouth	0	0	0	0	0	0	0	0	0
Cottus sp.	0	<1	0	0	0	0	0	0	0
Crappie	0	0	0	0	0	<1	0	0	<1
Cutthroat trout	0	0	0	0	0	0	0	0	0
Kokanee salmon	<1	2	<1	<1	2	1	5	5	<1
Lake whitefish	31	33	23	15	33	40	46	51	37
Largemouth bass	0	0	0	0	0	0	0	0	0
Largescale sucker	15	20	11	6	16	15	4	6	9
Longnose sucker	1	2	<1	2	0	1	2	1	4
Mtn. whitefish	<1	0	0	0	0	0	<1	0	0
Peamouth	<1	0	0	0	0	0	0	0	<1
Pumpkinseed	0	0	0	0	0	0	0	0	0
Rainbow trout	2	8	9	14	2	2	4	6	<1
Redside shiner	0	0	0	0	0	0	0	0	0
Smallmouth bass	6	3	7	10	0	6	3	0	3
N. squawfish	5	4	5	3	0	2	2	<1	2
White sturgeon	<1	0	0	0	0	0	0	0	0
Catostomus sp.	0	0	0	0	0	0	0	0	0
Tench	0	0	0	0	0	0	<1	0	0
Walleye	32	21	39	48	35	19	18	15	27
Yellow perch	5	46	3	3	5	10	7	3	3

making it difficult to determine where actual spawning has occurred. In addition, YOY fish are important in the diets of many fishes in Lake Roosevelt, including walleye, smallmouth bass and, at times, rainbow trout (Wydoski and Whitney 1979).

Sucker larvae/fry were the most commonly collected taxa in 1997 beachseine surveys, and were collected primarily from Gifford (>1,300 collected) and Hunters (> 3,100 collected). Game species important in beachseine surveys included yellow perch (487), smallmouth bass (335), and walleye (141). Yellow perch are considered both a sport fish and an important forage species of walleye (Wydoski and Whitney 1979), and were collected from five standardized sampling locations in 1997; Gifford, Hunters, Porcupine Bay, Seven Bays, and Keller Ferry. Smallmouth bass YOY were collected throughout the central and lower portions of Lake Roosevelt including the Spokane River arm (Porcupine Bay), and all locations from Seven Bays downstream to Spring Canyon. Smallmouth bass prefer relatively warm waters (> 60^0F; Wydoski and Whitney 1979) for both spawning and non-spawning activity, which probably explains their apparent absence in the upper reaches of Lake Roosevelt where cooler temperatures prevail. Walleye YOY were collected by beachseine at Gifford, Porcupine Bay, and Seven Bays during 1997, suggesting spawning activity in the upper reaches of Lake Roosevelt as well as in the Spokane River arm. Walleye contribute substantially to the creel in Lake Roosevelt, and increasing our understanding of the walleye life cycle (including spawning/rearing habits) will potentially benefit future fisheries management.

4.10 Growth and Feeding

Growth rates of kokanee salmon and rainbow trout in Lake Roosevelt have not changed appreciably since 1989. In contrast, Cichosz et al. (1998) reported that the growth rate of walleye in Lake Roosevelt appeared to have declined following the 1991 growing season. However, 1997 data shows variable walleye growth across years with no apparent pattern or trend (Table 3.38), suggesting that the trend in walleye growth noted by Cichosz et al. (1998) may have been an artifact of the data set.

The feeding habits of kokanee salmon and rainbow trout in Lake Roosevelt have not changed appreciably since 1989 and these two species have exhibited a consistently high dietary overlap throughout this study (0.65-0.91). In addition, diets of both kokanee salmon and rainbow trout show substantial overlap with lake whitefish during 1997 (0.93 and 0.86, respectively). Calculated IRI values indicate that cladocerans and chironomids are the most important foods in the diet of each of these three species in Lake Roosevelt (Table 3.40), which is consistent with other findings (Simpson and Wallace 1982; Wydoski and Whitney 1979). Kokanee salmon and rainbow trout sampled from Lake Roosevelt have historically had higher growth rates than those reported from other northern lakes (Peone et al. 1990), and the same was true in 1997 suggesting that food supply is not limiting growth of these species. Similarly then, it is reasonable to assume that food supply does not limit the growth of other planktivores in Lake Roosevelt (i.e. lake whitefish), since a limited supply of a common resource would most likely be recognized by all species utilizing that resource.

Walleye and burbot in Lake Roosevelt overlapped substantially in their diets during 1997 (0.85), with both species relying heavily on fish as a primary food source (IRI=66.86 and 55.01, respectively). The shift in walleye diet from yellow perch to other fish species in recent years (Cichosz 1998) may increase the potential for competition between burbot and walleye in Lake Roosevelt since both feed primarily on fishes (Simpson and Wallace 1982; Wydoski and Whitney 1979). Index of relative importance values indicated that similar prey fishes (particularly cottids and cyprinids) were important food sources for both walleye and burbot in Lake Roosevelt during 1997 (Table 3.40) and suggest that the potential for interspecific competition exists. However, growth of Lake Roosevelt walleye has not declined through time (Figure 4.3), suggesting that current forage fish densities are sufficient to maintain the existing populations of piscivores in Lake Roosevelt.

Pumpkinseed and peamouth collected from Lake Roosevelt during 1997 exhibited substantial diet overlap (0.71), with Corixidae and Hydracarina dominating the diets of both species (Table 3.40). Diet similarities of pumpkinseed and peamouth probably arise from similar habitat use, as both species generally inhabit littoral areas and are commonly associated with vegetative cover (Simpson and Wallace 1982; Wydoski and Whitney 1979). Similarly, Corixidae and Hydracarina are generally abundant in areas with aquatic vegetation (Borror et al. 1989; Pennak 1989), making them a potentially important food source for both pumpkinseed and peamouth in areas where they coexist. However, due to low relative abundance of pumpkinseed and peamouth (Table 3.31) there is probably little inter or intra-specific competition involving these two species in Lake Roosevelt.

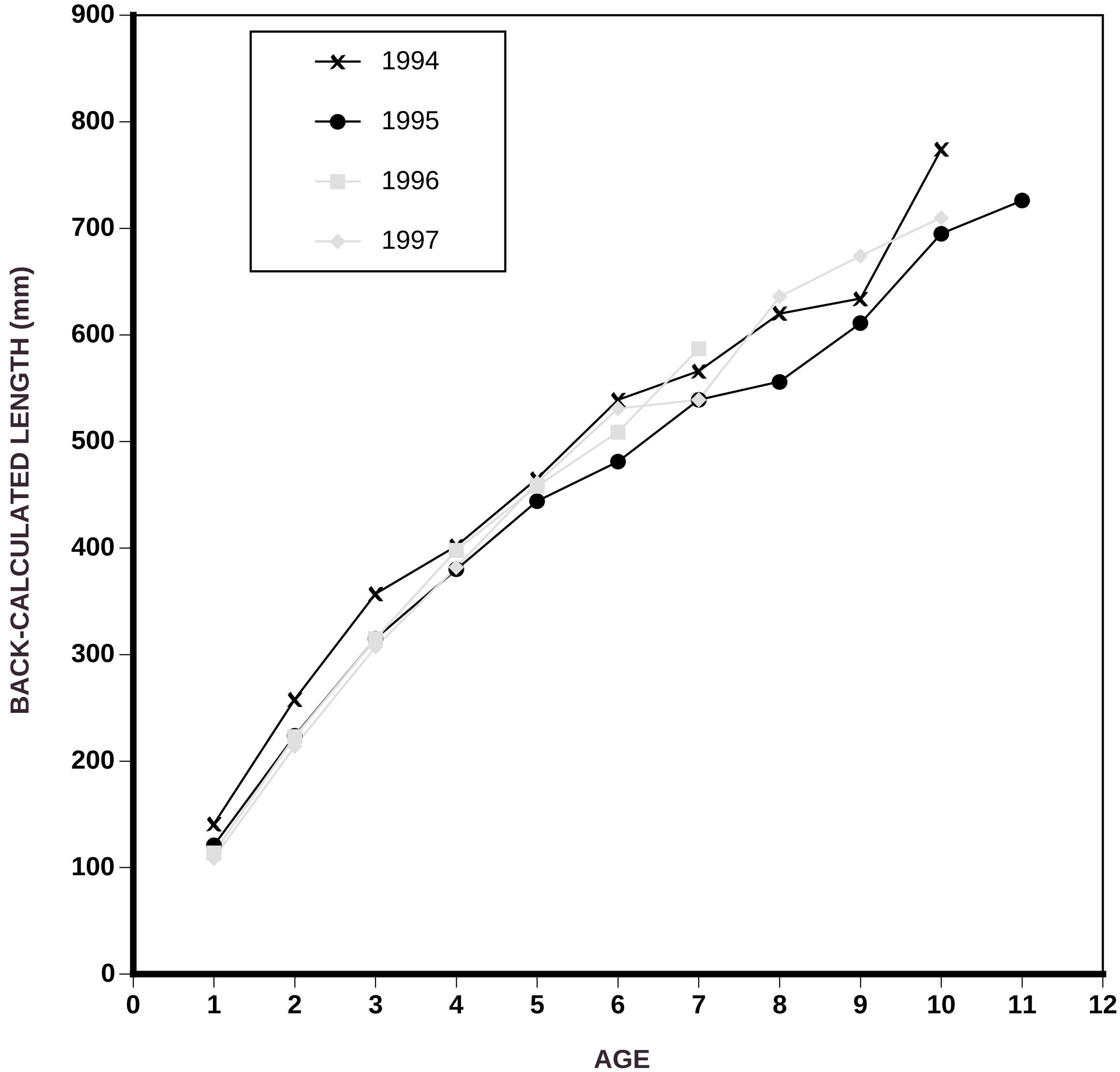


Figure 4.3 Comparison of back calculated length at age for walleye sampled from Lake Roosevelt between 1994 and 1997.

5.0 RECOMMENDATIONS AND RESEARCH NEEDS

- Continue to tag 10,000 rainbow trout at Kettle Falls and Seven Bays to maintain adequate numbers of tag returns.

- Continue to floy tag 10,000 kokanee salmon smolts for release from Sherman Creek Hatchery in an attempt to increase the number of coded wire tag returns sent in by anglers.

- Continue to hold net pen rainbow trout until at least May 1 (later if possible) before release, to help reduce entrainment losses.

- Maintain the current intensity of zooplankton and water quality sampling to better relate the effects of reservoir operations to zooplankton production.

- Continue to collect zooplankton and water quality data at current sites.

- Collect nutrient and zooplankton production rate data for model development.

- Continue standardized fishery surveys, including beachseining, to assess long term changes in the Lake Roosevelt fishery.

- Establish strength of past walleye cohorts through length frequency analysis to determine if variations in mean length are related to cohort strength or other factors.

- Assess impacts of reduced water retention time on zooplankton production and relate to variations in kokanee salmon growth.

- In conjunction with other fishery co-managers, address the intent and success of current harvest regulations for walleye in Lake Roosevelt.

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APPENDIX A

Creel Data and Calculations

Table A.1 Correction Factor for boat trailers counted by creel to boats counted by air in 1992, 1993 and 1997. Split by weekday (WD) and weekend (WE) strata.

STRATA		YEAR 1992	1993	1997	1992-1997 MEAN	±	STDEV
WINTER	WD	1.07	1.07	1.54	1.53	±	0.67
	WKND	2.49	2.49	2.28	2.28	±	1.40
SPRING	WD	1.50	1.50	1.39	1.39	±	1.00
	WKND	0.77	0.77	0.97	0.97	±	0.50
SUMMER	WD	1.13	1.13	0.89	0.89	±	0.62
	WKND	1.05	1.05	1.26	1.26	±	0.52
FALL	WD	1.27	0.87	1.14	1.14	±	0.44
	WKND	1.10	1.33	1.38	1.38	±	0.75

Table A.2 Section 1 pressure estimates in hours for boat anglers in 1997 with intermediate calculations.

STRATA		Correct. factor	Boat trailers per day	% of boats fishing	Anglers per boat	Anglers per boat S.D.	Corrected mean angler	Corrected Mean angler S.D.
December	WD	1.54	0.00	---	---	---	0.0	0.0
	WE	2.28	0.67	100.00	2.00	0.00	3.0	0.0
January	WD	1.54	0.05	100.00	2.00	0.00	0.1	0.0
	WE	2.28	0.00	---	---	---	0.0	0.0
February	WD	1.54	0.14	100.00	2.00	0.00	0.4	0.0
	WE	2.28	2.00	100.00	2.00	0.00	9.1	0.0
March	WD	1.39	0.04	100.00	2.00	0.00	0.1	0.0
	WE	0.97	1.71	100.00	2.00	0.00	3.3	0.0
April	WD	1.39	0.00	---	---	---	0.0	0.0
	WE	0.97	0.00	---	---	---	0.0	0.0
May	WD	1.39	0.13	100.00	3.00	0.00	0.6	0.0
	WE	0.97	1.00	100.00	1.50	0.71	1.5	0.7
June	WD	0.89	6.18	75.56	2.04	0.83	8.5	3.4
	WE	1.26	38.20	76.19	3.00	0.78	110.1	28.8
July	WD	0.89	13.88	29.47	2.61	0.99	9.5	3.6
	WE	1.26	51.63	8.24	2.78	1.28	14.9	6.9
August	WD	0.89	16.37	30.44	2.30	1.34	10.2	6.0
	WE	1.26	55.83	18.18	2.20	1.27	28.2	16.2
September	WD	1.14	2.13	12.50	2.00	1.16	0.6	0.4
	WE	1.38	9.83	100.00	2.75	0.50	37.4	6.8
October	WD	1.14	0.69	50.00	1.25	0.50	0.5	0.2
	WE	1.38	3.86	100.00	2.75	0.50	14.7	2.7
November	WD	1.14	0.00	---	---	---	0.0	0.0
	WE	1.38	0.67	100.00	2.75	0.50	2.5	0.5
Annual	**WD**	**1.24**	**3.30**	**66.44**	**2.13**	**0.54**	**2.6**	**1.1**
	WE	**1.47**	**13.78**	**73.21**	**2.39**	**0.55**	**18.7**	**5.2**

Table A.3 **Section 2 pressure estimates in hours for boat anglers in 1997 with intermediate calculations.**

STRATA		Correct. factor	Boat trailers per day	% of boats fishing	Anglers per boat	Anglers per boat S.D.	Corrected mean angler	Corrected Mean angler S.D.
December	WD	1.54	1.67	100.00	3.00	0.00	7.7	0.0
	WE	2.28	2.75	100.00	1.50	0.71	9.4	4.4
January	WD	1.54	1.30	100.00	2.00	0.00	4.0	0.0
	WE	2.28	5.33	100.00	1.75	0.36	21.2	4.4
February	WD	1.54	2.00	100.00	2.50	1.29	7.7	4.0
	WE	2.28	2.50	100.00	2.00	0.00	11.4	0.0
March	WD	1.39	0.23	100.00	2.83	1.00	0.9	0.3
	WE	0.97	2.14	100.00	3.00	1.41	6.3	2.9
April	WD	1.39	0.00	---	---	---	0.0	0.0
	WE	0.97	0.00	---	---	---	0.0	0.0
May	WD	1.39	0.00	---	---	---	0.0	0.0
	WE	0.97	0.71	100.00	2.67	0.58	1.9	0.4
June	WD	0.89	18.09	94.74	2.00	0.67	30.6	10.2
	WE	1.26	57.50	75.00	3.00	0.93	163.1	50.4
July	WD	0.89	45.50	25.10	3.77	1.64	38.4	16.7
	WE	1.26	218.60	31.18	3.38	1.46	290.1	125.7
August	WD	0.89	70.57	5.79	3.53	1.76	12.9	6.4
	WE	1.26	106.80	2.60	3.08	1.29	10.8	4.5
September	WD	1.14	13.17	79.17	2.29	0.85	27.3	10.1
	WE	1.38	21.83	35.48	2.58	1.00	27.7	10.7
October	WD	1.14	5.86	93.75	1.88	0.70	11.8	4.4
	WE	1.38	20.67	72.73	2.36	0.93	49.0	19.3
November	WD	1.14	4.78	33.33	1.50	0.71	2.7	1.3
	WE	1.38	10.20	100.00	2.14	0.38	30.2	5.3
Annual	**WD**	**1.24**	**13.60**	**73.19**	**2.53**	**0.86**	**12.0**	**4.4**
	WE	**1.47**	**37.42**	**67.46**	**2.44**	**0.82**	**51.7**	**19.0**

Table A.4 **Section 3 pressure estimates in hours for boat anglers in 1997 with intermediate calculations.**

STRATA		Correct. factor	Boat trailers per day	% of boats fishing	Anglers per boat	Anglers per boat S.D.	Corrected mean angler	Corrected Mean angler S.D.
December	WD	1.54	0.00	---	---	---	0.0	0.0
	WE	2.28	0.00	---	---	---	0.0	0.0
January	WD	1.54	5.23	100.00	1.00	0.00	8.0	0.0
	WE	2.28	1.75	100.00	1.00	0.00	4.0	0.0
February	WD	1.54	2.75	100.00	1.00	0.00	4.2	0.0
	WE	2.28	6.25	100.00	1.00	0.00	14.2	0.0
March	WD	1.39	2.00	100.00	2.00	0.00	5.6	0.0
	WE	0.97	2.00	100.00	2.00	0.00	3.9	0.0
April	WD	1.39	0.53	100.00	2.00	0.00	1.5	0.0
	WE	0.97	0.25	100.00	2.00	0.00	0.5	0.0
May	WD	1.39	0.79	100.00	2.00	0.00	2.2	0.0
	WE	0.97	17.17	100.00	2.00	0.00	33.4	0.0
June	WD	0.89	6.63	94.74	1.71	0.76	9.6	4.2
	WE	1.26	22.33	75.00	1.75	0.00	37.0	0.0
July	WD	0.89	52.83	25.10	1.71	0.76	20.3	9.0
	WE	1.26	80.14	31.18	1.75	0.00	55.1	0.0
August	WD	0.89	107.27	5.79	1.71	0.76	9.5	4.2
	WE	1.26	87.29	2.60	1.75	0.00	5.0	0.0
September	WD	1.14	22.17	79.17	1.90	0.23	38.1	4.6
	WE	1.38	29.50	35.48	2.00	0.00	28.9	0.0
October	WD	1.14	6.65	93.75	1.80	0.45	12.8	3.2
	WE	1.38	22.25	72.73	2.00	0.00	44.7	0.0
November	WD	1.14	1.18	33.33	2.00	0.00	0.9	0.0
	WE	1.38	2.44	100.00	2.00	0.00	6.7	0.0
Annual	**WD**	**1.24**	**18.70**	**75.62**	**1.71**	**0.27**	**9.4**	**2.1**
	WE	**1.47**	**22.61**	**67.46**	**1.75**	**0.00**	**19.5**	**0.0**

Table A.5 Section 1 angling pressure estimates (hrs) from December 1996 to November 1997 with intermediate calculations.

STRATA	Hours per day Hd	Days per month Ds	Hours per Ns	Hours creeled per n	Time correction Ns/n	Angler hours per Ha	Mean anglers Xd	Mean anglers ± per Xs	anglers ± per Sd	anglers per Ss	Pressure estimate per PE	95% C.I. per CI
DECEMBER												
WEEKDAY												
SHORE	8.40	22	184.80	55.00	3.36	1.75	0.5	10.0	0.8	18.0	**59**	**65**
BOAT	8.40	22	184.80	55.00	3.36	---	0.0	0.0	0.0	0.0	**0**	**0**
WEEKEND												
SHORE	8.40	9	75.60	20.00	3.78	3.17	0.3	2.3	0.5	4.5	**27**	**17**
BOAT	8.40	9	75.60	20.00	3.78	3.15	3.0	27.0	0.0	0.0	**321**	**0**
TOTAL	**8.40**	**31**	**260.40**	**75.00**			**3.7**	**39.3**	**1.3**	**22.5**	**407**	**82**
JANUARY												
WEEKDAY												
SHORE	8.83	23	203.09	63.00	3.22	3.11	0.5	10.6	0.7	15.2	**107**	**53**
BOAT	8.83	23	203.09	63.00	3.22	2.67	0.1	2.3	0.0	0.0	**20**	**0**
WEEKEND												
SHORE	8.83	8	70.64	10.25	6.89	1.97	1.0	8.0	1.4	11.3	**108**	**58**
BOAT	8.83	8	70.64	10.25	6.89	---	0.0	0.0	0.0	0.0	**0**	**0**
TOTAL	**8.83**	**31**	**273.73**	**73.25**			**1.6**	**20.9**	**2.1**	**26.5**	**235**	**112**
FEBRUARY												
WEEKDAY												
SHORE	10.25	20	205.00	65.00	3.15	3.12	0.4	8.6	0.8	15.1	**84**	**53**
BOAT	10.25	20	205.00	65.00	3.15	2.67	0.4	8.0	0.0	0.0	**67**	**0**
WEEKEND												
SHORE	10.25	8	82.00	30.00	2.73	2.83	2.5	20.0	1.6	13.1	**155**	**43**
BOAT	10.25	8	82.00	30.00	2.73	4.25	9.1	72.8	0.0	0.0	**846**	**0**
TOTAL	**10.25**	**28**	**287.00**	**95.00**			**12.4**	**109.4**	**2.4**	**28.3**	**1,152**	**95**

Table A.5 Continued.

STRATA	Hours per day Hd	Days per month Ds	Hours per Ns	Hours creeled per n	Time correction Ns/n	Angler hours per Ha	Mean anglers Xd	Mean anglers ± per Xs	anglers ± per Sd	anglers per Ss	Pressure estimate per PE	95% C.I. per CI
MARCH												
WEEKDAY												
SHORE	11.97	21	251.37	76.50	3.29	1.50	0.6	13.1	1.1	22.8	**65**	**81**
BOAT	11.97	21	251.37	76.50	3.29	2.53	0.1	2.1	0.0	0.0	**17**	**0**
WEEKEND												
SHORE	11.97	10	119.70	35.00	3.42	3.00	1.0	0.0	1.2	11.6	**0**	**42**
BOAT	11.97	10	119.70	35.00	3.42	6.04	3.3	33.0	0.0	0.0	**682**	**0**
TOTAL	**11.97**	**31**	**371.07**	**111.50**			**5.0**	**48.2**	**2.2**	**34.4**	**764**	**123**
APRIL												
WEEKDAY												
SHORE	13.68	22	300.96	85.00	3.54	1.50	0.1	2.6	0.5	10.7	**14**	**39**
BOAT	13.68	22	300.96	85.00	3.54	---	0.0	0.0	0.0	0.0	**0**	**0**
WEEKEND												
SHORE	13.68	8	109.44	20.00	5.47	---	0.0	0.0	0.0	0.0	**0**	**0**
BOAT	13.68	8	109.44	20.00	5.47	---	0.0	0.0	0.0	0.0	**0**	**0**
TOTAL	**13.68**	**30**	**410.40**	**105.00**			**0.1**	**2.6**	**0.5**	**10.7**	**14**	**39**
MAY												
WEEKDAY												
SHORE	15.20	22	334.40	82.50	4.05	---	0.0	0.0	0.0	0.0	**0**	**0**
BOAT	15.20	22	334.40	82.50	4.05	5.5	0.6	13.2	0.0	0.0	**295**	**0**
WEEKEND												
SHORE	15.20	9	136.80	20.00	6.84	---	0.0	0.0	0.0	0.0	**0**	**0**
BOAT	15.20	9	136.80	20.00	6.84	6.04	1.5	13.5	0.7	6.3	**558**	**32**
TOTAL	**15.20**	**31**	**471.20**	**102.50**			**2.1**	**26.7**	**0.7**	**6.3**	**853**	**32**

Table A.5 Continued.

STRATA	Hours per day Hd	Days per month Ds	Hours per Ns	Hours creeled per n	Time correction Ns/n	Angler hours per Ha	Mean anglers Xd	Mean anglers per Xs	± anglers per Sd	± anglers per Ss	Pressure estimate per PE	95% C.I. per CI
JUNE												
WEEKDAY												
SHORE	16.02	21	336.42	85.00	3.96	7.62	0.4	7.4	0.8	16.8	**222**	**66**
BOAT	16.02	21	336.42	85.00	3.96	5.44	8.5	178.5	3.4	71.4	**3,845**	**278**
WEEKEND												
SHORE	16.02	9	144.18	34.50	4.18	---	0.0	0.0	0.0	0.0	**0**	**0**
BOAT	16.02	9	144.18	34.50	4.18	6.57	110.1	990.9	28.8	259.2	**27,207**	**1,039**
TOTAL	**16.02**	**30**	**480.60**	**119.50**			**119.0**	**1176.8**	**33.0**	**347.4**	**31,274**	**1,382**
JULY												
WEEKDAY												
SHORE	15.67	23	360.41	89.00	4.05	---	0.0	0.0	0.0	0.0	**0**	**0**
BOAT	15.67	23	360.41	89.00	4.05	6.23	9.5	218.5	3.6	82.8	**5,514**	**327**
WEEKEND												
SHORE	15.67	8	125.36	30.00	4.18	---	0.0	0.0	0.0	0.0	**0**	**0**
BOAT	15.67	8	125.36	30.00	4.18	6.38	14.9	119.2	6.9	55.2	**3,177**	**221**
TOTAL	**15.67**	**31**	**485.77**	**119.00**			**24.4**	**337.7**	**10.5**	**138.0**	**8,692**	**548**
AUGUST												
WEEKDAY												
SHORE	14.38	21	301.98	95.00	3.18	---	0.0	0.0	0.0	0.0	**0**	**0**
BOAT	14.38	21	301.98	95.00	3.18	4.7	10.2	214.2	6.0	126.0	**3,216**	**440**
WEEKEND												
SHORE	14.38	10	143.80	30.00	4.79	---	0.0	0.0	0.0	0.0	**0**	**0**
BOAT	14.38	10	143.80	30.00	4.79	6.41	28.2	282.0	16.2	162.0	**8,669**	**695**
TOTAL	**14.38**	**31**	**445.78**	**125.00**			**38.4**	**496.2**	**22.2**	**288.0**	**11,884**	**1,135**

Table A.5 Continued.

STRATA	Hours per day Hd	Days per month Ds	Hours per Ns	Hours creeled per n	Time correction Ns/n	Angler hours per Ha	Mean anglers Xd	Mean anglers per Xs	± anglers per Sd	± anglers per Ss	Pressure estimate per PE	95% C.I. per CI
SEPTEMBER												
WEEKDAY												
SHORE	12.45	22	273.90	74.00	3.70	---	0.0	0.0	0.0	0.0	**0**	**0**
BOAT	12.45	22	273.90	74.00	3.70	5.85	0.6	13.2	0.4	8.8	**286**	**33**
WEEKEND												
SHORE	12.45	8	99.60	35.00	2.85	---	0.0	0.0	0.0	0.0	**0**	**0**
BOAT	12.45	8	99.60	35.00	2.85	6.04	37.4	299.2	6.8	54.4	**5,143**	**180**
TOTAL	**12.45**	**30**	**373.50**	**109.00**			**38.0**	**312.4**	**7.2**	**63.2**	**5,429**	**213**
OCTOBER												
WEEKDAY												
SHORE	10.73	23	246.79	70.00	3.53	1.50	0.0	0.0	0.0	0.0	**0**	**0**
BOAT	10.73	23	246.79	70.00	3.53	4.21	0.5	11.5	0.2	4.6	**171**	**17**
WEEKEND												
SHORE	10.73	8	85.84	35.00	2.45	3.00	0.0	0.0	0.0	0.0	**0**	**0**
BOAT	10.73	8	85.84	35.00	2.45	6.04	14.7	117.6	2.7	21.6	**1,742**	**66**
TOTAL	**10.73**	**31**	**332.63**	**105.00**			**15.2**	**129.1**	**2.9**	**26.2**	**1,913**	**83**
NOVEMBER												
WEEKDAY												
SHORE	9.20	20	184.00	45.00	4.09	---	0.0	0.0	0.0	0.0	**0**	**0**
BOAT	9.20	20	184.00	45.00	4.09	---	0.0	0.0	0.0	0.0	**0**	**0**
WEEKEND												
SHORE	9.20	10	92.00	35.00	2.63	---	0.0	0.0	0.0	0.0	**0**	**0**
BOAT	9.20	10	92.00	35.00	2.63	6.04	2.5	25.0	0.5	5.0	**397**	**16**
TOTAL	**9.20**	**30**	**276.00**	**80.00**			**2.5**	**25.0**	**0.5**	**5.0**	**397**	**16**
ANNUAL TOTAL	**146.8**	**366**	**4468.1**	**1219.8**			**262.4**	**2724.2**	**85.5**	**996.4**	**63,013**	**3,861**

Table A.6 Section 2 angling pressure estimates (hrs) from December 1996 to November 1997 with intermediate calculations.

STRATA	Hours per day Hd	Days per month Ds	Hours per Ns	Hours creeled per n	Time correction Ns/n	Angler hours per Ha	Mean anglers Xd	Mean anglers ± per Xs	anglers ± per Sd	anglers per Ss	Pressure estimate per PE	95% C.I. per CI
DECEMBER												
WEEKDAY												
SHORE	8.40	22	184.80	17.03	10.85	5.29	0.8	18.3	1.2	25.7	**1,051**	**166**
BOAT	8.40	22	184.80	17.03	10.85	6.58	7.7	169.4	0.0	0.0	**12,093**	**0**
WEEKEND												
SHORE	8.40	9	75.60	13.98	5.41	5.19	4.0	36.0	5.5	49.3	**1,011**	**225**
BOAT	8.40	9	75.60	13.98	5.41	5.67	9.4	84.6	4.4	39.6	**2,592**	**180**
TOTAL	**8.40**	**31**	**260.40**	**31.02**			**21.9**	**308.3**	**11.0**	**114.6**	**16,747**	**571**
JANUARY												
WEEKDAY												
SHORE	8.83	23	203.09	40.07	5.07	3.97	2.4	55.2	2.9	67.0	**1,112**	**296**
BOAT	8.83	23	203.09	40.07	5.07	6.05	4.0	92.0	0.0	0.0	**2,821**	**0**
WEEKEND												
SHORE	8.83	8	70.64	10.67	6.62	5.40	5.7	45.3	7.4	59.0	**1,619**	**297**
BOAT	8.83	8	70.64	10.67	6.62	6.59	21.2	169.6	4.4	35.2	**7,396**	**178**
TOTAL	**8.83**	**31**	**273.73**	**50.73**			**33.3**	**362.1**	**14.7**	**161.2**	**12,949**	**771**
FEBRUARY												
WEEKDAY												
SHORE	10.25	20	205.00	32.60	6.29	3.90	5.5	110.0	4.5	90.4	**2,696**	**444**
BOAT	10.25	20	205.00	32.60	6.29	5.10	7.7	154.0	4.0	80.0	**4,935**	**393**
WEEKEND												
SHORE	10.25	8	82.00	13.42	6.11	5.60	21.0	168.0	5.7	45.2	**5,750**	**219**
BOAT	10.25	8	82.00	13.42	6.11	7.50	11.4	91.2	0.0	0.0	**4,180**	**0**
TOTAL	**10.25**	**28**	**287.00**	**46.02**			**45.6**	**523.2**	**14.2**	**215.6**	**17,562**	**1,057**

Table A.6 Continued.

STRATA	Hours per day Hd	Days per month Ds	Hours per Ns	Hours creeled per n	Time correction Ns/n	Angler hours per Ha	Mean anglers Xd	Mean anglers per Xs	± anglers per Sd	± anglers per Ss	Pressure estimate per PE	95% C.I. per CI
MARCH												
WEEKDAY												
SHORE	11.97	21	251.37	36.85	6.82	2.90	0.2	4.9	0.8	17.5	**96**	**89**
BOAT	11.97	21	251.37	36.85	6.82	5.40	0.8	16.8	0.3	6.3	**619**	**32**
WEEKEND												
SHORE	11.97	10	119.70	26.15	4.58	3.94	8.7	0.0	8.6	85.8	**0**	**360**
BOAT	11.97	10	119.70	26.15	4.58	4.58	6.3	63.0	2.9	29.0	**1,322**	**122**
TOTAL	11.97	31	371.07	63.00			**16.0**	**84.7**	**12.6**	**138.5**	**2,036**	**603**
APRIL												
WEEKDAY												
SHORE	13.68	22	300.96	42.95	7.01	2.90	0.4	9.5	1.6	35.3	**192**	**183**
BOAT	13.68	22	300.96	42.95	7.01	---	0.0	0.0	0.0	0.0	**0**	**0**
WEEKEND												
SHORE	13.68	8	109.44	10.74	10.19	3.94		0.0	0.0	0.0	**0**	**0**
BOAT	13.68	8	109.44	10.74	10.19	4.89	0.0	0.0	0.0	0.0	**0**	**0**
TOTAL	13.68	30	410.40	53.69			**0.4**	**9.5**	**1.6**	**35.3**	**192**	**183**
MAY												
WEEKDAY												
SHORE	15.20	22	334.40	37.55	8.91	2.90	1.2	25.4	2.0	43.9	**656**	**257**
BOAT	15.20	22	334.40	37.55	8.91	---	0.0	0.0	0.0	0.0	**0**	**0**
WEEKEND												
SHORE	15.20	9	136.80	14.32	9.56	3.94	1.8	16.2	2.0	18.4	**610**	**112**
BOAT	15.20	9	136.80	14.32	9.56	5.20	1.9	17.1	0.4	3.6	**849**	**22**
TOTAL	**15.20**	**31**	**471.20**	**51.87**			**4.9**	**58.7**	**4.4**	**65.9**	**2,115**	**390**

Table A.6 Continued.

STRATA	Hours per day Hd	Days per month Ds	Hours per Ns	Hours creeled per n	Time correction Ns/n	Angler hours per Ha	Mean anglers Xd	Mean anglers per Xs	± anglers per Sd	± anglers per Ss	Pressure estimate per PE	95% C.I. per CI
JUNE												
WEEKDAY												
SHORE	16.02	21	336.42	40.75	8.26	3.03	2.5	52.5	2.8	58.8	**1,311**	**331**
BOAT	16.02	21	336.42	40.75	8.26	4.58	30.6	642.6	10.2	214.2	**24,297**	**1,206**
WEEKEND												
SHORE	16.02	9	144.18	4.88	29.53	4.85	4.5	40.5	2.1	19.1	**5,794**	**203**
BOAT	16.02	9	144.18	4.88	29.53	4.52	163.1	1467.9	50.4	453.6	**195,952**	**4,831**
TOTAL	16.02	30	480.60	45.63			**200.7**	**2203.5**	**65.5**	**745.7**	**227,354**	**6,572**
JULY												
WEEKDAY												
SHORE	15.67	23	360.41	27.03	13.33	4.84	0.5	11.5	1.1	24.8	**743**	**178**
BOAT	15.67	23	360.41	27.03	13.33	3.00	38.4	883.2	16.7	384.1	**35,325**	**2,749**
WEEKEND												
SHORE	15.67	8	125.36	19.73	6.35	4.85	5.6	44.8	3.2	25.7	**1,379**	**127**
BOAT	15.67	8	125.36	19.73	6.35	5.93	290.1	2320.8	125.7	1005.6	**87,356**	**4,968**
TOTAL	**15.67**	**31**	**485.77**	**46.77**			**334.6**	**3260.3**	**146.7**	**1440.2**	**124,802**	**8,021**
AUGUST												
WEEKDAY												
SHORE	14.38	21	301.98	42.83	7.05	6.50	0.9	18.0	1.9	40.2	**825**	**209**
BOAT	14.38	21	301.98	42.83	7.05	1.50	12.9	270.9	6.4	134.4	**2,865**	**699**
WEEKEND												
SHORE	14.38	10	143.80	15.77	9.12	4.85	1.4	14.0	1.9	19.5	**619**	**115**
BOAT	14.38	10	143.80	15.77	9.12	5.23	10.8	108.0	4.5	45.0	**5,147**	**266**
TOTAL	**14.38**	**31**	**445.78**	**58.60**			**26.0**	**410.9**	**14.8**	**239.1**	**9,455**	**1,291**

Table A.6 Continued

STRATA	Hours per day Hd	Days per month Ds	Hours per Ns	Hours creeled per n	Time correction Ns/n	Angler hours per Ha	Mean anglers Xd	Mean anglers per Xs	± anglers per Sd	± anglers per Ss	Pressure estimate per PE	95% C.I. per CI
SEPTEMBER												
WEEKDAY												
SHORE	12.45	22	273.90	34.90	7.85	2.39	0.8	16.5	1.5	34.0	**309**	**187**
BOAT	12.45	22	273.90	34.90	7.85	4.18	27.3	600.6	10.1	222.2	**19,722**	**1,220**
WEEKEND												
SHORE	12.45	8	99.60	18.30	5.44	5.75	0.8	6.7	1.0	7.9	**209**	**36**
BOAT	12.45	8	99.60	18.30	5.44	3.59	27.7	221.6	10.7	85.6	**4,330**	**391**
TOTAL	**12.45**	**30**	**373.50**	**53.20**			**56.6**	**845.4**	**23.3**	**349.7**	**24,570**	**1,834**
OCTOBER												
WEEKDAY												
SHORE	10.73	23	246.79	52.10	4.74	2.39	0.2	4.9	0.6	13.3	**56**	**57**
BOAT	10.73	23	246.79	52.10	4.74	5.05	11.8	271.4	4.4	101.2	**6,495**	**432**
WEEKEND												
SHORE	10.73	8	85.84	11.62	7.39	5.75	5.8	46.7	5.9	46.8	**1,983**	**250**
BOAT	10.73	8	85.84	11.62	7.39	4.90	49.0	392.0	19.3	154.4	**14,202**	**823**
TOTAL	**10.73**	**31**	**332.63**	**63.72**			**66.8**	**715.0**	**30.1**	**315.7**	**22,735**	**1,561**
NOVEMBER												
WEEKDAY												
SHORE	9.20	20	184.00	20.13	9.14	2.39	0.8	15.5	2.0	39.7	**339**	**235**
BOAT	9.20	20	184.00	20.13	9.14	5.00	2.7	54.0	1.3	26.0	**2,468**	**154**
WEEKEND												
SHORE	9.20	10	92.00	17.17	5.36	5.75	8.2	82.0	7.0	70.1	**2,527**	**318**
BOAT	9.20	10	92.00	17.17	5.36	4.59	30.2	302.0	5.3	53.0	**7,432**	**240**
TOTAL	**9.20**	**30**	**276.00**	**37.30**			**41.9**	**453.5**	**15.6**	**188.9**	**12,766**	**948**
ANNUAL TOTAL	**146.8**	**366**	**4468.1**	**601.5**			**848.7**	**9235.0**	**354.6**	**4010.5**	**473,283**	**23,801**

Table A.7 Section 3 angling pressure estimates (hrs) from December 1996 to November 1997 with intermediate calculations.

STRATA	Hours per day Hd	Days per month Ds	Hours per Ns	Hours creeled per n	Time correction Ns/n	Angler hours per Ha	Mean anglers Xd	Mean anglers per Xs	± anglers per Sd	± anglers per Ss	Pressure estimate per PE	95% C.I. per CI
DECEMBER												
WEEKDAY												
SHORE	8.40	22	184.80	51.75	3.57	---	0.0	0.0	0.0	0.0	**0**	**0**
BOAT	8.40	22	184.80	51.75	3.57	---	0.0	0.0	0.0	0.0	**0**	**0**
WEEKEND												
SHORE	8.40	9	75.60	5.50	13.75	---	0.0	0.0	0.0	0.0	**0**	**0**
BOAT	8.40	9	75.60	5.50	13.75	---	0.0	0.0	0.0	0.0	**0**	**0**
TOTAL	**8.40**	**31**	**260.40**	**57.25**			**0.0**	**0.0**	**0.0**	**0.0**	**0**	**0**
JANUARY												
WEEKDAY												
SHORE	8.83	23	203.09	48.25	4.21	2.44	0.8	19.5	1.3	30.9	**200**	**124**
BOAT	8.83	23	203.09	48.25	4.21	1.72	8.0	184.0	0.0	0.0	**1,332**	**0**
WEEKEND												
SHORE	8.83	8	70.64	15.50	4.56	3.75	0.5	4.0	0.6	4.6	**68**	**19**
BOAT	8.83	8	70.64	15.50	4.56	4.58	4.0	32.0	0.0	0.0	**668**	**0**
TOTAL	**8.83**	**31**	**273.73**	**63.75**			**13.3**	**239.5**	**1.9**	**35.6**	**2,268**	**144**
FEBRUARY												
WEEKDAY												
SHORE	10.25	20	205.00	38.00	5.39	0.75	0.9	18.3	1.2	23.3	**74**	**106**
BOAT	10.25	20	205.00	38.00	5.39	1.72	4.2	84.0	0.0	0.0	**779**	**0**
WEEKEND												
SHORE	10.25	8	82.00	14.83	5.53	3.75	0.5	4.0	0.6	4.6	**83**	**21**
BOAT	10.25	8	82.00	14.83	5.53	4.58	14.2	113.6	0.0	0.0	**2,876**	**0**
TOTAL	**10.25**	**28**	**287.00**	**52.83**			**19.8**	**219.9**	**1.7**	**27.9**	**3,813**	**127**

Table A.7 Continued.

STRATA	Hours per day Hd	Days per month Ds	Hours per Ns	Hours creeled per n	Time correction Ns/n	Angler hours per Ha	Mean anglers Xd	Mean anglers per Xs	± anglers per Sd	± anglers per Ss	Pressure estimate per PE	95% C.I. per CI
MARCH												
WEEKDAY												
SHORE	11.97	21	251.37	50.67	4.96	1.60	2.6	54.6	5.9	124.9	**0**	**545**
BOAT	11.97	21	251.37	50.67	4.96	2.58	5.6	117.6	0.0	0.0	**1,505**	**0**
WEEKEND												
SHORE	11.97	10	119.70	27.42	4.37	3.75	1.4	0.0	1.1	11.3	**0**	**46**
BOAT	11.97	10	119.70	27.42	4.37	11.00	3.9	39.0	0.0	0.0	**1,873**	**0**
TOTAL	**11.97**	**31**	**371.07**	**78.08**			**13.5**	**211.2**	**7.1**	**136.3**	**3,378**	**592**
APRIL												
WEEKDAY												
SHORE	13.68	22	300.96	46.25	6.51	1.60	0.8	17.6	0.9	19.0	**183**	**95**
BOAT	13.68	22	300.96	46.25	6.51	2.58	1.5	33.0	0.0	0.0	**554**	**0**
WEEKEND												
SHORE	13.68	8	109.44	14.50	7.55	3.75	0.3	2.0	0.5	4.0	**57**	**22**
BOAT	13.68	8	109.44	14.50	7.55	8.50	0.5	4.0	0.0	0.0	**257**	**0**
TOTAL	**13.68**	**30**	**410.40**	**60.75**			**3.1**	**56.6**	**1.4**	**23.0**	**1,050**	**116**
MAY												
WEEKDAY												
SHORE	15.20	22	334.40	43.17	7.75	1.60	1.2	25.7	1.2	26.2	**318**	**143**
BOAT	15.20	22	334.40	43.17	7.75	2.58	2.2	48.4	0.0	0.0	**967**	**0**
WEEKEND												
SHORE	15.20	9	136.80	20.25	6.76	3.75	0.3	3.0	0.5	4.6	**76**	**24**
BOAT	15.20	9	136.80	20.25	6.76	6.00	33.4	300.6	0.0	0.0	**12,184**	**0**
TOTAL	**15.20**	**31**	**471.20**	**63.42**			**37.1**	**377.7**	**1.7**	**30.9**	**13,546**	**167**

Table A.7 Continued.

STRATA	Hours per day Hd	Days per month Ds	Hours per Ns	Hours creeled per n	Time correction Ns/n	Angler hours per Ha	Mean anglers Xd	Mean anglers per Xs	± anglers per Sd	± anglers per Ss	Pressure estimate per PE	95% C.I. per CI
JUNE												
WEEKDAY												
SHORE	16.02	21	336.42	57.83	5.82	1.60	0.4	9.2	1.3	26.5	**85**	**125**
BOAT	16.02	21	336.42	57.83	5.82	7.51	9.6	201.6	4.2	88.2	**8,807**	**417**
WEEKEND												
SHORE	16.02	9	144.18	12.58	11.46	---	0.0	0.0	0.0	0.0	**0**	**0**
BOAT	16.02	9	144.18	12.58	11.46	8.50	37.0	333.0	0.0	0.0	**32,433**	**0**
TOTAL	**16.02**	**30**	**480.60**	**70.42**			**47.0**	**543.8**	**5.5**	**114.7**	**41,325**	**542**
JULY												
WEEKDAY												
SHORE	15.67	23	360.41	44.67	8.07	---	0.0	0.0	0.0	0.0	**0**	**0**
BOAT	15.67	23	360.41	44.67	8.07	7.51	20.3	466.9	9.0	207.0	**28,293**	**1,152**
WEEKEND												
SHORE	15.67	8	125.36	25.17	4.98	3.75	0.1	1.1	0.4	3.0	**21**	**13**
BOAT	15.67	8	125.36	25.17	4.98	8.50	55.1	440.8	0.0	0.0	**18,663**	**0**
TOTAL	**15.67**	**31**	**485.77**	**69.83**			**75.5**	**908.8**	**9.4**	**210.0**	**46,977**	**1,166**
AUGUST												
WEEKDAY												
SHORE	14.38	21	301.98	46.25	6.53	1.60	0.1	1.9	0.3	6.3	**20**	**32**
BOAT	14.38	21	301.98	46.25	6.53	7.51	9.5	199.5	4.2	88.2	**9,782**	**442**
WEEKEND												
SHORE	14.38	10	143.80	14.50	9.92	---	0.0	0.0	0.0	0.0	**0**	**0**
BOAT	14.38	10	143.80	14.50	9.92	8.50	5.0	50.0	0.0	0.0	**4,215**	**0**
TOTAL	**14.38**	**31**	**445.78**	**60.75**			**14.6**	**251.4**	**4.5**	**94.5**	**14,017**	**473**

Table A.7 Continued

STRATA	Hours per day Hd	Days per month Ds	Hours per Ns	Hours creeled per n	Time correction Ns/n	Angler hours per Ha	Mean anglers Xd	Mean anglers per Xs	± anglers per Sd	± anglers per Ss	Pressure estimate per PE	95% C.I. per CI
SEPTEMBER												
WEEKDAY												
SHORE	12.45	22	273.90	17.58	15.58	---	0.0	0.0	0.0	0.0	**0**	**0**
BOAT	12.45	22	273.90	17.58	15.58	6.19	38.1	635.8	4.6	101.2	**61,307**	**783**
WEEKEND												
SHORE	12.45	8	99.60	21.75	4.58	---	0.0	0.0	0.0	0.0	**0**	**0**
BOAT	12.45	8	99.60	21.75	4.58	7.38	28.9	231.2	0.0	0.0	**7,813**	**0**
TOTAL	**12.45**	**30**	**373.50**	**39.33**			**67.0**	**867.0**	**4.6**	**101.2**	**69,120**	**783**
OCTOBER												
WEEKDAY												
SHORE	10.73	23	246.79	59.08	4.18	---	0.0	0.0	0.0	0.0	**0**	**0**
BOAT	10.73	23	246.79	59.08	4.18	5.83	12.8	294.4	3.2	73.6	**7,172**	**295**
WEEKEND												
SHORE	10.73	8	85.84	14.83	5.79	---	0.0	0.0	0.0	0.0	**0**	**0**
BOAT	10.73	8	85.84	14.83	5.79	7.38	44.7	357.6	0.0	0.0	**15,273**	**0**
TOTAL	**10.73**	**31**	**332.63**	**73.92**			**57.5**	**652.0**	**3.2**	**73.6**	**22,444**	**295**
NOVEMBER												
WEEKDAY												
SHORE	9.20	20	184.00	40.83	4.51	---	0.0	0.0	0.0	0.0	**0**	**0**
BOAT	9.20	20	184.00	40.83	4.51	6.54	0.9	18.0	0.0	0.0	**530**	**0**
WEEKEND												
SHORE	9.20	10	92.00	32.33	2.85	---	0.0	0.0	0.0	0.0	**0**	**0**
BOAT	9.20	10	92.00	32.33	2.85	7.38	6.7	67.0	0.0	0.0	**1,406**	**0**
TOTAL	**9.20**	**30**	**276.00**	**73.17**			**7.6**	**85.0**	**0.0**	**0.0**	**1,936**	**0**
ANNUAL TOTAL	**146.8**	**366.0**	**4468.1**	**763.5**			**356.1**	**4412.9**	**41.0**	**847.7**	**219,877**	**4,405**

Table A.8 Section 1 harvest per unit effort (fish/kept/hour) in Lake Roosevelt from December 1996 through November 1997.

Species	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	Annual Mean
Kokanee	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
Rainbow	0.000	0.095	0.000	0.066	0.000	0.000	0.006	0.000	0.000	0.000	0.000	0.000	**0.007**
Walleye	0.000	0.000	0.000	0.000	0.000	0.507	0.486	0.278	0.081	0.000	0.000	0.000	**0.320**
Smallmouth	0.000	0.000	0.000	0.000	0.000	0.000	0.006	0.000	0.000	0.000	0.000	0.000	**0.003**
Sturgeon	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
Other sp.	0.000	0.000	0.000	0.000	0.000	0.059	0.009	0.000	0.000	0.000	0.000	0.000	**0.008**
Monthly HPUE	**0.000**	**0.095**	**0.000**	**0.066**	**0.000**	**0.566**	**0.508**	**0.278**	**0.081**	**0.000**	**0.000**	**0.000**	
												Annual HPUE	**0.337**

Table A.9 Section 2 harvest per unit effort (fish/kept/hour) in Lake Roosevelt from December 1996 through November 1997.

Species	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	Annual Mean
Kokanee	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
Rainbow	0.000	0.000	0.018	0.000	0.086	0.000	0.000	0.000	0.000	0.000	0.019	0.000	**0.005**
Walleye	0.000	0.000	0.000	0.000	0.000	0.000	0.188	0.189	0.000	0.069	0.000	0.000	**0.105**
Smallmouth	0.000	0.000	0.000	0.000	0.000	0.000	0.009	0.000	0.000	0.000	0.000	0.000	**0.001**
Sturgeon	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
Other sp.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
Monthly HPUE	**0.000**	**0.000**	**0.018**	**0.000**	**0.086**	**0.000**	**0.197**	**0.189**	**0.000**	**0.069**	**0.019**	**0.000**	

Annual HPUE 0.110

Table A.10 Section 3 harvest per unit effort (fish/kept/hour) in Lake Roosevelt from December 1996 through November 1997.

Species	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	Annual Mean
Kokanee	0.000	0.259	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.013**
Rainbow	0.000	0.259	0.000	0.000	0.000	0.000	0.000	0.012	0.000	0.000	0.135	0.072	**0.063**
Walleye	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.012	0.000	0.000	0.000	0.000	**0.004**
Smallmouth	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
Sturgeon	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
Other sp.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
Monthly HPUE	**0.000**	**0.518**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.024**	**0.000**	**0.000**	**0.135**	**0.072**	

Annual HPUE 0.080

Table A.11 Section 1 catch per unit effort (fish/hour – kept and released) in Lake Roosevelt from December 1996 through November 1997.

Species	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	Annual Mean
Kokanee	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
Rainbow	0.000	0.095	0.000	0.066	0.000	0.000	0.006	0.000	0.000	0.000	0.000	0.000	**0.007**
Walleye	0.000	0.000	0.000	0.000	0.000	1.327	1.019	0.357	0.132	0.000	0.000	0.000	**0.624**
Smallmouth	0.000	0.000	0.000	0.000	0.000	0.000	0.006	0.000	0.000	0.000	0.000	0.000	**0.003**
Sturgeon	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
Other sp.	0.000	0.047	0.000	0.066	0.000	0.059	0.022	0.000	0.000	0.000	0.000	0.000	**0.016**
Monthly HPUE	**0.000**	**0.142**	**0.000**	**0.131**	**0.000**	**1.386**	**1.054**	**0.357**	**0.132**	**0.000**	**0.000**	**0.000**	

Annual CPUE 0.649

Table A.12 Section 2 catch per unit effort (fish/hour – kept and released) in Lake Roosevelt from December 1996 through November 1997.

Species	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	Annual Mean
Kokanee	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
Rainbow	0.000	0.000	0.018	0.000	0.086	0.000	0.000	0.000	0.000	0.000	0.019	0.000	**0.005**
Walleye	0.000	0.000	0.000	0.000	0.000	0.000	0.244	0.416	0.000	0.069	0.000	0.000	**0.209**
Smallmouth	0.000	0.000	0.000	0.000	0.000	0.000	0.009	0.002	0.000	0.000	0.000	0.000	**0.002**
Sturgeon	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
Other sp.	0.000	0.000	0.000	0.000	0.000	0.000	0.028	0.011	0.000	0.000	0.000	0.000	**0.007**
Monthly HPUE	**0.000**	**0.000**	**0.018**	**0.000**	**0.086**	**0.000**	**0.282**	**0.428**	**0.000**	**0.069**	**0.019**	**0.000**	

Annual CPUE 0.222

Table A.13 Section 3 catch per unit effort (fish/hour – kept and released) in Lake Roosevelt from December 1996 through November 1997.

Species	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	Annual Mean
Kokanee	0.000	0.259	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.013**
Rainbow	0.000	0.259	0.000	0.000	0.000	0.000	0.000	0.012	0.000	0.000	0.135	0.072	**0.063**
Walleye	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.012	0.000	0.000	0.000	0.000	**0.004**
Smallmouth	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
Sturgeon	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
Other sp.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
Monthly HPUE	**0.000**	**0.518**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.024**	**0.000**	**0.000**	**0.135**	**0.072**	

Annual CPUE 0.080

Table A.14 Total monthly and annual harvest estimates with ± 95% confidence intervals from fish harvested by anglers on all sections of Lake Roosevelt from December 1996 through November 1997.

SPECIES	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	TOTAL
Kokanee salmon	0 ±0	588 ±37	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	**588** **±37**
Rainbow trout	0 ±0	610 ±48	311 ±19	50 ±8	17 ±16	0 ±0	197 ±9	569 ±14	0 ±0	0 ±0	3,462 ±70	139 ±0	**5,355** **±184**
Walleye	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	433 ±16	57,884 ±1,906	26,541 ±1,680	968 ±92	1,689 ±126	0 ±0	0 ±0	**87,515** **±3,820**
Smallmouth bass	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	2,331 ±71	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	**2,331** **±71**
Sturgeon	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	**0** **±0**
Other species	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	50 ±2	296 ±13	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	**346** **±15**
Monthly Total	**0** **±0**	**1,198** **±85**	**311** **±19**	**50** **±8**	**17** **±16**	**483** **±18**	**60,708** **±1,999**	**27,110** **±1,694**	**968** **±92**	**1,689** **±126**	**3,462** **±70**	**139** **±0**	**96,135** **±4,127**

Table A.15 Monthly and annual harvest estimates ± 95% confidence intervals for all fish species surveyed in Section 1 of Lake Roosevelt from December 1996 through November 1997.

SPECIES	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	TOTAL
Kokanee salmon	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	**0 ±0**
Rainbow trout	0 ±0	22 ±11	0 ±0	50 ±8	0 ±0	0 ±0	197 ±9	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	**270 ±27**
Walleye	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	433 ±16	15,196 ±672	2,412 ±152	968 ±92	0 ±0	0 ±0	0 ±0	**19,009 ±932**
Smallmouth bass	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	197 ±9	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	**197 ±9**
Sturgeon	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	**0 ±0**
Other species	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	50 ±2	296 ±13	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	**346 ±15**
Monthly Total	**0 ±0**	**22 ±11**	**0 ±0**	**50 ±8**	**0 ±0**	**483 ±18**	**15,887 ±702**	**2,412 ±152**	**968 ±92**	**0 ±0**	**0 ±0**	**0 ±0**	**19,822 ±983**

Table A.16 Monthly and annual harvest estimates ± 95% confidence intervals for all fish species surveyed in Section 2 of Lake Roosevelt from December 1996 through November 1997.

SPECIES	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	TOTAL
Kokanee salmon	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	**0 ±0**
Rainbow trout	0 ±0	0 ±0	311 ±19	0 ±0	17 ±16	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	431 ±30	0 ±0	**759 ±64**
Walleye	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	42,688 ±1,234	23,560 ±1,514	0 ±0	1,689 ±126	0 ±0	0 ±0	**67,937 ±2,874**
Smallmouth bass	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	2,134 ±62	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	**2,134 ±62**
Sturgeon	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	**0 ±0**
Other species	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	**0 ±0**
Monthly Total	**0 ±0**	**0 ±0**	**311 ±19**	**0 ±0**	**17 ±16**	**0 ±0**	**44,822 ±1,296**	**23,560 ±1,514**	**0 ±0**	**1,689 ±126**	**431 ±30**	**0 ±0**	**70,830 ±3,000**

Table A.17 **Monthly and annual harvest estimates ± 95% confidence intervals for all fish species surveyed in Section 3 of Lake Roosevelt from December 1996 through November 1997.**

SPECIES	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	TOTAL
Kokanee salmon	0 ±0	588 ±37	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	**588 ±37**
Rainbow trout	0 ±0	588 ±37	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	569 ±14	0 ±0	0 ±0	3,031 ±40	139 ±0	**4,327 ±91**
Walleye	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	569 ±14	0 ±0	0 ±0	0 ±0	0 ±0	**569 ±14**
Smallmouth bass	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	**0 ±0**
Sturgeon	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	**0 ±0**
Other species	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	**0 ±0**
Monthly Total	**0 ±0**	**1,175 ±75**	**0 ±0**	**0 ±0**	**0 ±0**	**0 ±0**	**0 ±0**	**1,138 ±28**	**0 ±0**	**0 ±0**	**3,031 ±40**	**139 ±0**	**5,483 ±143**

Table A.18 Total monthly and annual catch estimates ± 95% confidence intervals from all fish observed by creel clerks on all sections of Lake Roosevelt from December 1996 through November 1997.

SPECIES	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	TOTAL
Kokanee salmon	0 ±0	588 ±37	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	**588 ±37**
Rainbow trout	0 ±0	610 ±48	311 ±19	50 ±8	17 ±16	0 ±0	197 ±9	569 ±14	0 ±0	0 ±0	3,462 ±70	139 ±0	**5,355 ±184**
Walleye	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	1,132 ±42	87,367 ±3,012	55,555 ±3,545	1,573 ±150	1,689 ±126	0 ±0	0 ±0	**147,316 ±6,876**
Smallmouth bass	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	2,331 ±71	265 ±17	0 ±0	0 ±0	0 ±0	0 ±0	**2,596 ±88**
Sturgeon	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	**0 ±0**
Other species	0 ±0	11 ±5	0 ±0	50 ±8	0 ±0	50 ±2	7,094 ±216	1,324 ±85	0 ±0	0 ±0	0 ±0	0 ±0	**8,529 ±316**
Monthly Total	**0 ±0**	**1,208 ±91**	**311 ±19**	**100 ±16**	**17 ±16**	**1,182 ±44**	**96,989 ±3,308**	**57,712 ±3,661**	**1,573 ±150**	**1,689 ±126**	**3,462 ±70**	**139 ±0**	**164,385 ±7,500**

Table A.19 Monthly and annual catch estimates ± 95% confidence intervals for all fish species surveyed in Section 1 of Lake Roosevelt from December 1996 through November 1997.

SPECIES	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	TOTAL
Kokanee salmon	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	**0** **±0**
Rainbow trout	0 ±0	22 ±11	0 ±0	50 ±8	0 ±0	0 ±0	197 ±9	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	**270** **±27**
Walleye	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	1,132 ±42	31,873 ±1,408	3,101 ±196	1,573 ±150	0 ±0	0 ±0	0 ±0	**37,679** **±1,797**
Smallmouth bass	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	197 ±9	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	**197** **±9**
Sturgeon	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	**0** **±0**
Other species	0 ±0	11 ±5	0 ±0	50 ±8	0 ±0	50 ±2	691 ±31	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	**802** **±46**
Monthly Total	**0** **±0**	**33** **±16**	**0** **±0**	**100** **±16**	**0** **±0**	**1,182** **±44**	**32,958** **±1,457**	**3,101** **±196**	**1,573** **±150**	**0** **±0**	**0** **±0**	**0** **±0**	**38,948** **±1,879**

Table A.20 Monthly and annual catch estimates ± 95% confidence intervals for all fish species surveyed in Section 2 of Lake Roosevelt from December 1996 through November 1997.

SPECIES	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	TOTAL
Kokanee salmon	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	**0** **±0**
Rainbow trout	0 ±0	0 ±0	311 ±19	0 ±0	17 ±16	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	431 ±30	0 ±0	**759** **±64**
Walleye	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	55,494 ±1,604	51,885 ±3,335	0 ±0	1,689 ±126	0 ±0	0 ±0	**109,068** **±5,065**
Smallmouth bass	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	2,134 ±62	265 ±17	0 ±0	0 ±0	0 ±0	0 ±0	**2,399** **±79**
Sturgeon	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	**0** **±0**
Other species	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	6,403 ±185	1,324 ±85	0 ±0	0 ±0	0 ±0	0 ±0	**7,727** **±270**
Monthly Total	**0** **±0**	**0** **±0**	**311** **±19**	**0** **±0**	**17** **±16**	**0** **±0**	**64,031** **±1,851**	**53,473** **±3,437**	**0** **±0**	**1,689** **±126**	**431** **±30**	**0** **±0**	**119,953** **±5,478**

Table A.21 Monthly and annual catch estimates ± 95% confidence intervals for all fish species surveyed in Section 3 of Lake Roosevelt from December 1996 through November 1997.

SPECIES	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	TOTAL
Kokanee salmon	0 ±0	588 ±37	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	**588 ±37**
Rainbow trout	0 ±0	588 ±37	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	569 ±14	0 ±0	0 ±0	3,031 ±40	139 ±0	**4,327 ±91**
Walleye	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	569 ±14	0 ±0	0 ±0	0 ±0	0 ±0	**569 ±14**
Smallmouth bass	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	**0 ±0**
Sturgeon	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	**0 ±0**
Other species	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	0 ±0	**0 ±0**
Monthly Total	**0 ±0**	**1,175 ±75**	**0 ±0**	**0 ±0**	**0 ±0**	**0 ±0**	**0 ±0**	**1,138 ±28**	**0 ±0**	**0 ±0**	**3,031 ±40**	**139 ±0**	**5,483 ±143**

APPENDIX B

Summary of Work Completed by Subcontractors During 1997

KOKANEE SALMON (*Oncorhynchus nerka*) CODED WIRE TAGGING INVESTIGATIONS in LAKE ROOSEVELT, WA

ANNUAL REPORT 1997

Prepared by:

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ABSTRACT

The goal of the kokanee salmon coded wire tagging program in 1997 was to develop strategies that would promote a self-sustaining kokanee population in Lake Roosevelt. The main objective of this program was to assess factors which would improve adult returns to egg collection sites. This included: 1) assessing homing and adult return; and 2) assessing tagged fish recaptured below Grand Coulee Dam which would provide data on entrainment. Collection of sexually mature adult fish during the fall spawning season provided data on adult return rates and homing. Tagged kokanee monitored at Rock Island and Rocky Reach Dams provided data on entrainment. Coded wire tag returns from anglers would provided data for the Lake Roosevelt Monitoring Program on the harvest of hatchery fish. Also, data on dispersal of kokanee salmon after release in the summer may provide the Lake Roosevelt Monitoring Program with information regarding predation. Results indicated that the total recovery rate for coded wire tagged kokanee spawners in 1997 was 0.05%. For fish released at Sherman Creek, the recovery rate was higher, at 0.1%. Homing results indicated out of the fish released from Sherman Creek Hatchery and exposed to morpholine, 73% of the fish recovered were captured at Sherman Creek. This compared to 14% homing to the Spokane River for exposed fish and 50% homing for unexposed fish. There were no tagged kokanee seen in the creel, (only three kokanee salmon were observed by creel clerks in 1997) so harvest estimates of hatchery kokanee could not be determined. Results of preliminary investigations on dispersal of fish from Sherman Creek showed that two weeks after release, 36% (8 out of 22) of the total fish collected were captured at Sherman Creek. Also, 47% (10 of 22 fish) of the fish collected traveled to Little Falls Dam suggesting many of the fish did disperse. Tagged kokanee salmon collected below Grand Coulee Dam included six age 1 and two age 2 fish at the dams and three age 3 fish recovered from anglers below Grand Coulee Dam. Based on these results, it appeared that kokanee salmon released from Sherman Creek Hatchery provided the most returns and showed the best percent homing. It appeared that many of the fish dispersed from Sherman Creek cove suggesting that predation was not a problem after release. Entrainment estimates were difficult to assess. Although we have evidence of entrainment of kokanee, the magnitude of entrainment is unknown at this time because of problems with data collection in past years. Sampling at the dams did not begin early enough to look at entrainment during winter months and adipose clipped salmon smolts which were identified as hatchery sockeye could have been hatchery kokanee. These fish were not checked with a coded wire tag detector.

Based on our research, we recommend the following measures be implemented for research on kokanee salmon in Lake Roosevelt:

1) Determine if chemical imprinting is necessary.
2) Determine if fish reared and released from early run Lake Whatcom spawners return at higher rates than fish reared and released from middle run spawners.
3) Discontinue morpholine exposure for Spokane River releases.

We also recommend the following measures be implemented for management of kokanee salmon in Lake Roosevelt:

1) Locate alternative stocks of kokanee salmon.
2) Increase number of kokanee released into reservoir.
3) Continue to monitor entrainment. Start monitoring in December. Improve coordination with collection agencies at dams.
4) Look for alternatives to coded wire tagging.
5) Augment creel survey to collect more coded wire tagged kokanee.
6) Move Kettle Falls net pens to Sherman Creek.

Walleye (*Stizostedion vitreum vitreum*) Population Dynamics in Lake Roosevelt, Washington, 1997.

Annual Report 1997

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ABSTRACT

The purpose of this project was to determine the status of the walleye population in Lake Roosevelt, Washington. The objectives were to: 1) estimate the size of the walleye population via a mark-recapture study, 2) determine movements and growth of walleye in Lake Roosevelt, marked with floy tags, via angler returns and biologist recaptures, 3) Calculate age, growth, condition, and mortality of the walleye from scale samples and catch data, and 4) estimate young-of-the-year (YOY) walleye abundance in the Spokane River Arm of Lake Roosevelt. All walleye ≥ 150 mm total length (TL) were tagged with individually numbered floy tags, during five passes through the reservoir. The passes occurred between April 17 and December 17, 1997. Scale samples were taken from all size classes of walleye. Four estimates of walleye abundance were calculated. The Schnabel model (± 95% confidence interval), CAPTURE model (± 95% confidence interval), and Jolly-Seber model (± 95% confidence interval), estimates were 64,641 (50,116 ≤ N ≤ 83,380), 60,369 (9,780 ≤ N ≤ 497,180), 51,489 (3,145 ≤ N ≤ 163, 109), and, respectively. Walleye abundance in the range of 51,489 to 64,641 fish most likely underestimated the walleye population by a wide margin because creel data indicated that approximately 115,000 walleye were harvested in 1997. Underestimation of walleye abundance may have been the result of unequal capture probabilities of all the fish in the reservoir, likely due to a non-random sampling regime and failure of the walleye to move randomly in the reservoir. Walleye moved very little during the study period. Estimates of abundance were most likely estimates for the individual sampling locations, rather than for the entire reservoir, because the sum of the abundance estimates for the areas with recaptures (45,149) was similar to the estimates for the entire reservoir (51,489 to 64,641). A walleye abundance estimate for the entire reservoir (± 95% confidence interval), based on the total percent surface area of the sampling locations, was calculated as 237,742 (136,00 ≤ N ≤ 474,353). Relatively similar estimates provided by open and closed population models indicated both may be used to estimate the size of the Lake Roosevelt walleye population.

There were relatively few old walleye (> age 4) in Lake Roosevelt, compared to U.S. Fish and Wildlife Service (USFWS) data from 1980-1983 (Beckman et al. 1985). Walleye growth rates were average, compared to 16 walleye producing waters in the U.S. and Canada, but declined since 1990. Mean annual mortality rate of the walleye was average, relative to other walleye producing waters in the U.S. and Canada. Annual mortality rates increased from 0.35 to 0.54 after age 3 (363 mm TL), when the walleye were most likely recruiting to the angler harvest. Annual mortality decreased from 0.54 to 0.47 between the ages of 4 and 5, when the fish were most likely in the “slot.” After age 5, when walleye grew out of the “slot,” the mortality rate increased from 0.47 to 0.66.

Weaknesses of the study indicate a better estimate is needed. A better estimate would include a random sampling strategy.