B O N N E V I L L E   P O W E R   A D M I N I S T R A T I O N

# Lake Roosevelt Fisheries Evaluation Program, Part A

## Fisheries Creel Survey and Population Status Analysis

Annual Report 1998 | May 2002 | DOE/BP-32148-4

This Document should be cited as follows:

*Spotts, Jim, John Shields, Keith Underwood, Thomas Cichosz, "Lake Roosevelt Fisheries Evaluation Program, Part A; Fisheries Creel Survey and Population Status Analysis", 1998 Annual Report, Project No. 199404300, 96 electronic pages, (BPA Report DOE/BP-32148-4)*

Bonneville Power Administration
P.O. Box 3621
Portland, OR 97208

This report was funded by the Bonneville Power Administration (BPA), U.S. Department of Energy, as part of BPA's program to protect, mitigate, and enhance fish and wildlife affected by the development and operation of hydroelectric facilities on the Columbia River and its tributaries. The views in this report are the author's and do not necessarily represent the views of BPA.

# ANNUAL REPORT 1998, PART A. LAKE ROOSEVELT FISHERIES EVALUATION PROGRAM, FISHERIES CREEL SURVEY AND POPULATION STATUS ANALYSIS.

Spokane Tribe of Indians
Department of Natural Resources-Fisheries
Lake Roosevelt Fisheries Evaluation Program
P.O. Box 480
Wellpinit, WA 99040

by

Jim Spotts
John Shields
Keith Underwood
And
Tom Cichosz

for

Charlie Craig, Project Manager
U.S. Department of Energy
Bonneville Power Administration
Division of Fish and Wildlife
P.O. Box 3621
Portland, OR 97208-3621

Current Contract Number 00005756
Current Project Number 1994-043-00

Original 1998 Contract Number 94BI32148
Original 1998 Project Number 94-043

May 2002

## DISCLAIMER

The opinions, findings, conclusions or recommendations expressed in this report are those of the author(s), and do not necessarily reflect the views of the Bonneville Power Administration and the Northwest Power Planning Council, nor does the mention of trade names or commercial products constitute endorsement or recommendation for use by the Lake Roosevelt Fisheries Evaluation Program, and/or the Federal Government.

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.

**Suggested citation:**

Spotts, J.V., J.P. Shields, K.D. Underwood, and T.C. Cichosz. 2000. Annual Report 1998, Part A. Lake Roosevelt Fisheries Evaluation Program, Creel Survey and Population Status Analysis. Spokane Tribe of Indians. Department of Natural Resources. Prepared for the Bonneville Power Administration. Division of Fish and Wildlife. Portland, OR. Project Number 199404300.

# EXECUTIVE SUMMARY

The Lake Roosevelt Fisheries Evaluation 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, and is now referred to as the Lake Roosevelt Fisheries Evaluation Program.

Creel and angler surveys estimated that anglers made 196,775 trips to Lake Roosevelt during 1998, with an economic value of $8.0 million dollars, based on the Consumer Price Index (CPI). In 1998 it was estimated that 9,980 kokanee salmon, 226,809 rainbow trout, 119,346 walleye, and over 14,000 smallmouth bass and other species were harvested. Creel data indicates that hatchery reared rainbow trout contribute substantially to the Lake Roosevelt fishery. The contribution of kokanee salmon to the creel has not met the expectations of fishery managers to date, and is limited by entrainment from the reservoir, predation, and possible fish culture obstacles.

The 1998 Lake Roosevelt Fisheries Creel and Population Analysis Annual Report includes analyses of the relative abundance of fish species, and reservoir habitat relationships (1990-1998). Fisheries surveys (1990-1998) indicate that walleye and burbot populations appear to be increasing, while yellow perch, a preferred walleye prey species, and other prey species are decreasing in abundance. The long term decreasing abundance of yellow perch and other prey species are suspected to be the result of the lack of suitable multiple reservoir elevation spawning and rearing refugia for spring spawning reservoir prey species, resulting from seasonal spring-early summer reservoir elevation manipulations, and walleye predation.

Reservoir water management is both directly, and indirectly influencing the success of mitigation hatchery production of kokanee salmon and rainbow trout. Tag return data suggested excessive entrainment occurred in 1997, with 97 percent of tag recoveries from rainbow trout coming from below Grand Coulee Dam. High water years appear to have substantial entrainment impacts on salmonids. The 1998 salmonid harvest has improved from the previous two years, due to the relatively water friendly year of 1998, from the harvest observed in the 1996-1997 high water years, which were particularly detrimental to the reservoir salmonid fisheries. Impacts from those water years are still evident in the reservoir fish populations. Analysis of historical relative

species abundance, tagging data and hydroacoustical studies, indicate that hydro-operations have a substantial influence on the annual standing crop of reservoir salmonid populations due to entrainment losses, and limited prey species recruitment, due to reservoir elevation level fluctuation, and corresponding reproductive success.

# ACKNOWLEDGMENTS

We gratefully acknowledge Dr. Allan Scholz, and Dr. Ross Black (Eastern Washington University), and Casey Baldwin (WDFW) for advice and scientific input on this project. We thank William Matt Sr., Hank Etue, Randy Peone, Andy Moss, Joni Wynecoop, (Spokane Tribe of Indians), Jim Meskan (Washington Department of Fish and Wildlife), and Leroy Williams (Colville Confederated Tribes), for collection of creel and fisheries population data, and assistance with other fisheries management, and fish culture monitoring operations.

We also thank Rudy Peone, Tim Peone, and Mary Verner (Spokane Tribe of Indians), John Whalen, Casey Baldwin and Mitch Combs (WDFW), Jerry Marco, Kirk Truscott, Monty Miller, and Richard LeCaire (Colville Confederated Tribes), for counsel, advise and support in all areas. Special thanks goes to John Shields for his patience, support and contributions throughout the preparation of this document. We recognize the National Park Service (USDI), for graciously providing camping at no cost to the project. A thanks also goes to Charlie Craig (BPA, Division of Fish and Wildlife), who served as BPA project manager.

This project was supported by a contract from the U.S. Department of Energy, Bonneville Power Administration (BPA), *Contact No.94BI32148 and Project No. 94-043.* Additional financial support for this project was provided by a grant from the U.S. Department of Interior, Bureau of Indian Affairs to the Upper Columbia United Tribes (UCUT; *Grant No. P12614208001).*

# TABLE OF CONTENTS



## Table of Contents **Page**

# LIST OF TABLES

**Table** **Page**

<u>**Table**</u> <u>**Page**</u>

# Figures

**List of Figures** **Page**

# 1.0 Introduction

**1.1 Background:** Since the construction of Grand Coulee Dam in 1939, anadromous fish migrations were permanently blocked to waters in the United States and Canada historically utilized for reproduction and rearing. The dam, constructed without a fish ladder, prohibited steelhead trout, chinook, coho and sockeye salmon from exploiting approximately 1835 km (1,140 miles) of the upper Columbia River Drainage in the United Sates and Canada (Mullan 1985, 1987 and Mullan et al. 1993).

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

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

**1.2 Project History:** The Lake Roosevelt Monitoring Program began July 1988. The primary objectives were to determine and evaluate stocking strategies of hatchery origin kokanee salmon

(*Oncorhynchus nerka*) that maximized angler harvest and the return of kokanee salmon to egg collection facilities, and supplemental rainbow trout (*Oncorhynchus mykiss*) stocking to maximize angler harvest, and sport fishing opportunities. In addition, the project collected baseline data to evaluate effects of stocking kokanee salmon and rainbow trout upon the ecosystem, and assessed the effectiveness of kokanee salmon and rainbow trout mitigation stocking strategies.

Responsibilities of the Monitoring Program included, but were not limited to: conducting annual reservoir wide creel surveys; sampling fishery populations during spring; summer and fall via electrofishing and gillnet surveys; collection of information on diet and growth; annual evaluations of age/length/condition factors of target fish species; and the evaluation of predator/prey relationships in Lake Roosevelt. Supplemental data has also been collected and analyzed to determine food availability and utilization by different fish species, and angler use information (e.g. annual harvest success rates by angler and location).

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

The objective of the Data Collection Project is to develop a biological model for Lake Roosevelt that will predict in-reservoir biological responses to a range of water management operational scenarios, and to accordingly develop fisheries and reservoir management 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, hydropower generation, irrigation, and downstream resident and anadromous fisheries).

Major components of the Lake Roosevelt model will be: 1) Quantification of fish entrainment; 2) Impacts to phytoplankton, zooplankton and fish caused by reservoir draw downs; 3) Low water retention times, as related to reservoir hydropower and flood control operations; 4) Seasonal quantification, distribution, habitat use, and species specific prey item utilization; and 5) Evaluations of fish growth, and the relationships to reservoir operations, prey abundance, and predator/prey relationships.

The current Lake Roosevelt Fisheries Evaluation 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 Fisheries Evaluation Program continues work historically completed under the separate projects, and will develop a biological rule curve regarding water management, and hatchery supplementation strategies for Lake Roosevelt to maximize fisheries related mitigation, and habitat enhancement strategies in the area now impounded by Grand Coulee Dam (Lake Roosevelt).

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. (1999).

**1.3 Description of Study Area:** Lake Roosevelt is a 243-kilometer (151 miles) main stem Columbia River impoundment, including the San Poil and Spokane Arms, formed by the construction of Grand Coulee Dam in 1939 (Figure 1). Filled in 1941, the reservoir inundates 33,490 hectares (129 $miles^2$) at a full pool elevation of 393 m (1290 feet) above mean sea level. It has a maximum width of 3.4 km (2.1 miles) and a maximum depth of 122 m (400 feet). 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 (Stober et al. 1981).

**1.4 1998 Study Objectives:** Objectives of the Lake Roosevelt Fisheries Evaluation Program for 1998 were:

1) Through electrofishing, gill net sets, and beach seine sampling methodologies, estimate the relative abundance of fishes in Lake Roosevelt to evaluate species population trends.

2) Back calculate length at age of selected fish species collected from Lake Roosevelt to assess annual growth rates by year class.

3) Comparing and contrasting historical (1988-1997) fishery and reservoir data, to data collected during 1998 to evaluate the current status of fishery populations.

4) Through formal creel census protocol, contact anglers and conduct estimates of annual and historic (1990-1998) angler pressure and harvest, average size of fish harvested, and conduct comparative assessments of the economic value of the fishery.

5) Assess ecological impacts, relative importance of predator/prey relationships, and dietary overlap for the majority of fish species in Lake Roosevelt.

6) Evaluate the performance of hatchery stocks of kokanee salmon and rainbow trout as they contribute to the fishery, and return to egg collection facilities.

7) Address flood control, hydropower, and irrigation water uses as related to entrainment of fish, and reservoir ecosystem stability.

## 2.0 Creel Survey and Data Analysis Procedures

**2.1 Creel Survey Protocol**: 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 and 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, represented by the Spokane Tribe, Colville Confederated Tribes, and Washington Department of Fish and Wildlife, conducted angler interviews at access points along Lake Roosevelt. The lake was divided into three sections (1-upper, 2-middle and 3-lower), with one creel clerk permanently assigned to each section (Figure 1). 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 AM and PM time periods (08:00 to 16:30).

Schedules for roving instantaneous pressure counts are randomly selected on approximately eighteen weekdays and four weekend/holidays per month, with half of the surveys conducted during AM hours and the other half conducted during PM hours. The remaining AM or PM 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 are randomly assigned on a monthly basis 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 (effort), species targeted, catch data (length and species), number of fish kept or released, complete/incomplete trip, angler satisfaction, and zip code of angler origin.

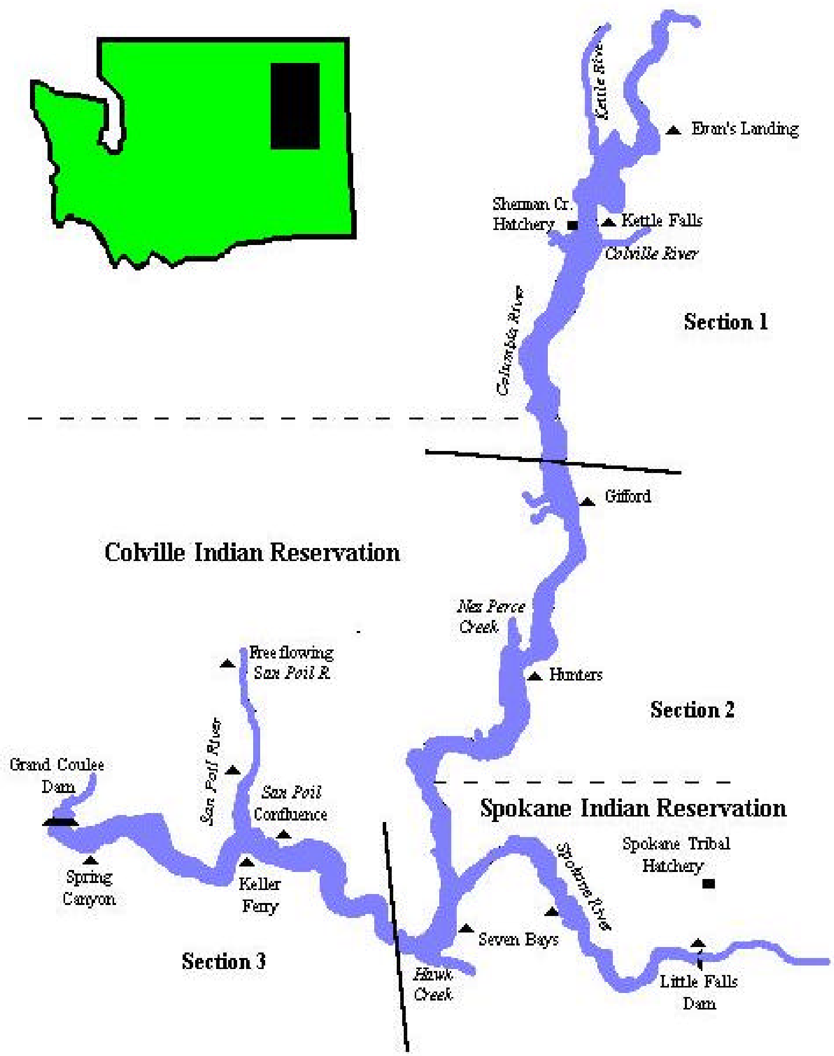


**Figure 1.** **Lake Roosevelt and creel sampling and data collection stations. Triangles represent water quality and fisheries data collection stations.**

Fish harvested were identified to species, measured (mm), weighed (g), and were examined for floy tags, fin clips, and eroded fins (used to differentiate wild/natural from hatchery origin salmonids). 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 collected from adipose clipped (hatchery origin) kokanee salmon for coded wire tag (CWT) analysis.

Incoming boaters (angler or non-angler) were surveyed to determine the number of boats angling, and the number of anglers per boat. For the duration of 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.

Historical fisheries data (1990-1997) was utilized in conjunction with information collected from December 1997 through November 1998 to conduct the analysis of the 1998 Lake Roosevelt Fisheries Evaluation Report. Quarters were established based on historic weather trends and angler use of the fishery as December (1997) through February (1998) winter, March through May (spring), June through August (summer), and September through November (fall). December 1997 was included in the 1998 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.

From 1990-1997, with exception of 1996, 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). Aerial counts were discontinued for the 1998 creel. Correction factors derived from the 1990-1997 aerial counts were utilized for the 1998 creel survey data analysis.

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 (CI) 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.

Complete and incomplete angler trips were used to compute catch per unit effort (CPUE), and harvest per unit effort (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 taxon 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.

Studies by Fletcher (1988) and Malvestuto et al. (1978) indicate that catch per unit of effort (CPUE) data calculated independently from complete, and incomplete trip data are not statistically different. Thus, we have historically assumed that the same would hold true in estimating harvest per unit of effort (HPUE).

**2.2 Economic Analysis**: 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):

$$D_{98} = \left( \frac{D_{85} x C_{98}}{C_{85}} \right)$$

Where: $D_{98}$ = dollar value per fishing trip for the Lake Roosevelt fishery in 1998 ($38.89);

$C_{85}$ = regional CPI for 1985 ($167.89);

$C_{98}$ = regional CPI for 1998 ($251.13); 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 1998 was estimated by dividing the calculated 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 1998-dollar value was multiplied by total number of angler trips in 1998 to provide an estimate of the economic value of the fishery.

**2.3 Fisheries Surveys:** Fish were collected from ten index stations in Lake Roosevelt during 1998 (Figure 1) to determine their relative abundance, growth rates, diet, origin, and condition factors. It is assumed that through seasonal and location sampling stratification that individual fish species are collected in approximately their relative proportion and abundance in the reservoir in any given year.

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. Approximately five, ten-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 1400 hrs) and pulled the next morning (approximately 1000 hrs).

All fish captured were identified to species according to *The Inland Fishes of Washington* (Wydoski and Whitney 1979), and each fish sampled was measured to the nearest millimeter (total length mm). New classifications and criteria were utilized when the Society of Herpetologists and Ichthyologists reclassified a particular genus and/or species. Scale samples were taken from a representative sample of each species collected to back calculate 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.

**2.4 Age, Back Calculations, and Condition Factor:** In the field, scales were collected 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 (Hile 1970; Carlander 1950 and 1981). Due to a small number of samples, fish length at scale formation was assumed 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 to be 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).

**2.5 Feeding Habit Evaluation Procedures:** Fish stomachs were collected from up to ten individuals of each fish species per index station and season. Additionally, creel clerks obtained a handful of kokanee salmon stomachs 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 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:

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

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-specific 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 zero (no overlap) to one (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 and Discussion

**3.1 Fisheries Sampling:** In 1998 we sampled a total of 41.5 hours by electrofishing and 2,624.4 hours by gillnetting, and captured twenty-two fish species representing eight families (Table 3.1). A total of 7,684 fish were collected by electrofishing (6,702) and gillnet (982) surveys yielding respective overall catch-per-unit-effort (CPUE) of 161.6, and 0.37 fish/hour (Table 3.2).

The most commonly collected fish species during 1998 electrofishing and gillnet surveys was the walleye which made up 32 percent of our total catch (Tables 3.2, 3.3 and 3.4). Walleye are a non-native species that were initially introduced as fry originating from Oneida Lake (New York State) by the U.S. Fish and Wildlife Service on several occasions during the early 1950's (Brown and Williams 1983). Walleye are now the dominant species in Lake Roosevelt (Tables 3.2, 3.3 and 3.4), and are the primary apex predator in the system (Beckman et al. 1985; Baldwin et al. 1999). Conversely, preferred forage species for walleye such as yellow perch (also non-native) have declined dramatically since the early 1980's, and there is no evidence of a surfeit of forage species to sustain larger densities of walleye (Beckman et al. 1985).

In the late 1980's and early 1990's yellow perch were the dominant taxon in electrofishing surveys. Prey species of fish based on relative abundance surveys appear to be decreasing, whereas walleye relative abundance has been increasing (Tables 3.2, 3.3 and 3.4).

The decline of yellow perch in Lake Roosevelt over the past two decades has been linked to water management changes associated with springtime reservoir elevation manipulations limiting yellow perch reproductive success, and a corresponding increase in predatory species (D. Fletcher personal communication; Noble 1979).

**Table 3.1 Taxa list of fish species collected during electrofishing and gillnet surveys in Lake Roosevelt.**

| Family *Species* | Common Name |
|---|---|
| **Acipenseridae** | |
| *Acipenser transmontanus* | White Sturgeon |
| **Salmonidae** | |
| *Oncorhynchus 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 |
| **Cyprinidae** | |
| *Cyprinus carpio* | Carp |
| *Mylocheilus caurinus* | Peamouth |
| *Ptychocheilus oregonensis* | Northern pikeminnow |
| *Tinca tinca* | Tench |
| **Catostomidae** | |
| *Catostomus macrocheilus* | Largescale sucker |
| *Catostomus catostomus* | Longnose sucker |
| *Catostomus columbianus* | Bridgelip sucker |
| **Gadidae** | |
| *Lota lota* | Burbot |
| **Centrarchidae** | |
| *Micropterus dolomieui* | Smallmouth bass |
| *Micropterus salmoides* | Largemouth bass |
| *Pomoxis nigromaculatus* | Black crappie |
| **Percidae** | |
| *Stizostedion vitreum vitreum* | Walleye |
| *Perca flavescens* | Yellow perch |
| **Cottidae** | |
| *Cottus sp.* | Sculpin |

**Table 3.2 Catch per unit effort (fish/hr) and relative abundance of fish species captured by electrofishing and gillnet surveys in Lake Roosevelt during 1998.**

| | Electrofishing | | | Gillnetting | | | Total | |
|---|---|---|---|---|---|---|---|---|
| **Species** | **CPUE** | **No.** | **%** | **CPUE** | **No.** | **%** | **No.** | **%** |
| White sturgeon | 0.00 | 0 | 0 | <0.01 | 6 | <1 | **6** | **<1** |
| Brook trout | 1.37 | 57 | <1 | 0.00 | 0 | 0 | **57** | **<1** |
| Brown trout | 0.41 | 17 | <1 | 0.00 | 0 | 0 | **17** | **<1** |
| Chinook salmon | 0.07 | 3 | <1 | 0.00 | 0 | 0 | **3** | **<1** |
| Kokanee salmon | 12.54 | 520 | 8 | <0.01 | 12 | 1 | **532** | **7** |
| Lake whitefish | 0.68 | 28 | <1 | 0.15 | 394 | 40 | **422** | **5** |
| Mountain whitefish | 0.17 | 7 | <1 | 0.00 | 0 | 0 | **7** | **<1** |
| Rainbow trout | 19.85 | 823 | 12 | 0.02 | 60 | 6 | **883** | **11** |
| Carp | 2.00 | 83 | 1 | <0.01 | 3 | <1 | **86** | **1** |
| Northern pikeminnow | 1.37 | 57 | <1 | 0.01 | 17 | 2 | **74** | **<1** |
| Peamouth | 0.02 | 1 | <1 | 0.00 | 0 | 0 | **1** | **<1** |
| Tench | 0.12 | 5 | <1 | <0.01 | 1 | <1 | **6** | **<1** |
| Bridgelip sucker | 0.05 | 2 | <1 | 0.00 | 0 | 0 | **2** | **<1** |
| Largescale sucker | 44.59 | 1,849 | 28 | 0.01 | 27 | 3 | **1,876** | **24** |
| Longnose sucker | 0.82 | 34 | <1 | 0.02 | 51 | 5 | **85** | **1** |
| Burbot | 3.04 | 126 | 2 | 0.03 | 83 | 9 | **209** | **3** |
| Black crappie | 0.17 | 7 | <1 | 0.00 | 0 | 0 | **7** | **<1** |
| Largemouth bass | 0.05 | 2 | <1 | 0.00 | 0 | 0 | **2** | **<1** |
| Smallmouth bass | 9.04 | 375 | 6 | 0.04 | 115 | 12 | **490** | **6** |
| Walleye | 55.01 | 2,281 | 34 | 0.07 | 181 | 19 | **2,462** | **32** |
| Yellow perch | .17 | 7 | <1 | 0.01 | 21 | 2 | **28** | **<1** |
| *Cottus* spp. | 9.82 | 407 | 6 | 0.00 | 0 | 0 | **407** | **5** |
| **Totals** | **161.6** | **6,702** | | **0.37** | **982** | | **7,684** | |

The largescale sucker was the second most abundant fish collected, comprising 24 percent of our total catch. Kokanee salmon 7%, rainbow trout 12%, sculpins 5%, lake whitefish 5%, and smallmouth bass 2% were also important in our 1998 relative abundance surveys (Table 3.2).

Dominant species collected in electrofishing surveys were walleye 34% and largescale suckers 28%, whereas lake whitefish 40%, walleye 19%, smallmouth bass 12%, and burbot 9% were most abundant in gillnet surveys (Table 3.3).

Relative abundance of fish species sampled from Lake Roosevelt by electrofishing and gillnetting has for some species remained relatively consistent since 1989, however, some substantive species abundance changes have been observed (Tables3.2, 3.3 and 3.4).

Largescale suckers have historically been the most abundant species (12-52%) in our electrofishing catches since 1990, and accounted for 28 percent of the electrofishing catch in 1998 (Table 3.3). In 1998 walleye were the predominant taxon and comprised 32 percent of fish caught in 1998 surveys, replacing largescale suckers (28 percent in 1998) as the predominant species for the first time since 1991 (Table 3.2, 3.3, and 3.4). Yellow perch were the dominant taxon in electrofishing surveys in 1989 (44%) and 1990 (48%), but as previously discussed, declined dramatically (<2%) in relative abundance since 1990 (Tables 3.3 and 3.4).

Populations of northern pikeminnow, an apex predator, have decreased from approximately 5 percent to 1 percent in relative abundance surveys over the past decade (Tables 3.2, 3.3, and 3.4). The reason for this population decline is unknown, however, predation, and recent reservoir water management scenarios may be limiting production of this species.

**Table 3.3 Comparison of relative abundance (%) of fish collected during the 1989 through 1998 sampling periods via electro shocking.**

| **Year** | **1989** | **1990** | **1991** | **1992** | **1993** | **1994** | **1995** | **1996** | **1997** | **1998** |
|---|---|---|---|---|---|---|---|---|---|---|
| **Species** | | | | **Effort** | **(hrs)** | | | | | |
| White sturgeon | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Brook trout | <1 | <1 | <1 | 1 | <1 | <1 | <1 | 1 | <1 | <1 |
| Brown trout | <1 | <1 | <1 | <1 | 1 | <1 | <1 | 2 | <1 | <1 |
| Bull trout | <1 | <1 | 0 | 0 | 0 | <1 | <1 | 0 | 0 | 0 |
| Chinook salmon | <1 | <1 | <1 | <1 | <1 | <1 | <1 | 0 | <1 | <1 |
| Cutthroat trout | 0 | 0 | 0 | 0 | 0 | 0 | 0 | <1 | 0 | 0 |
| Kokanee salmon | 2 | <1 | <1 | 3 | 1 | 4 | 22 | 4 | 1 | 8 |
| Lake whitefish | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Mtn. whitefish | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Rainbow trout | 6 | 3 | 4 | 6 | 9 | 7 | 5 | 7 | 5 | 12 |
| Carp | 2 | 2 | <1 | 2 | 1 | 1 | 2 | 2 | 7 | 1 |
| Chiselmouth | 0 | <1 | 0 | <1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Peamouth | <1 | 0 | <1 | <1 | 0 | 0 | 0 | 0 | <1 | <1 |
| Redside shiner | 0 | <1 | 0 | <1 | 0 | <1 | <1 | 0 | <1 | 0 |
| N. pikeminnow | 4 | 6 | 3 | 2 | 8 | 4 | 2 | 2 | 2 | <1 |
| Tench | <1 | <1 | <1 | <1 | 0 | <1 | <1 | <1 | <1 | <1 |
| Bridgelip sucker | 1 | <1 | <1 | <1 | 0 | <1 | <1 | 2 | <1 | <1 |
| Largescale- | 12 | 19 | 35 | 46 | 46 | 36 | 30 | 44 | 52 | 28 |
| Longnose sucker | <1 | 2 | <1 | <1 | 0 | 2 | <1 | 1 | <1 | <1 |
| *Catostomus spp.* | 7 | 0 | 0 | 0 | 0 | 0 | <1 | 5 | 0 | 0 |
| Bullhead | <1 | <1 | <1 | 0 | <1 | <1 | <1 | 0 | 0 | 0 |
| Burbot | <1 | <1 | <1 | <1 | 0 | <1 | <1 | 3 | 4 | 2 |
| Crappie | <1 | <1 | <1 | 1 | 0 | <1 | <1 | 0 | 0 | <1 |
| Largemouth bass | <1 | <1 | <1 | <1 | 0 | 0 | 0 | 0 | <1 | <1 |
| Pumpkinseed | <1 | <1 | 0 | 0 | 0 | 2 | 0 | 0 | <1 | 0 |
| Smallmouth bass | 1 | 3 | 15 | 7 | 9 | 8 | 10 | 6 | 9 | 6 |
| Walleye | 16 | 13 | 11 | 8 | 11 | 7 | 11 | 19 | 12 | 34 |
| Yellow perch | 44 | 48 | 30 | 20 | 11 | 12 | 7 | 2 | 3 | <1 |
| *Cottus spp.* | 2 | 2 | <1 | 2 | 3 | 16 | 6 | 1 | 2 | 6 |

**Table 3.4 Comparison of relative abundance (%) of fish collected during the 1989 through 1998 sampling periods via gillnetting.**

| Year | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 |
|---|---|---|---|---|---|---|---|---|---|---|
| **Species** | | | | **Effort** | **(hrs)** | | | | | |
| White sturgeon | <1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | <1 |
| Brook trout | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Brown trout | 0 | 0 | 0 | 0 | 0 | 0 | <1 | 0 | <1 | 0 |
| Bull trout | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Chinook | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cutthroat trout | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Kokanee | <1 | 2 | <1 | < | 2 | 1 | 5 | 5 | <1 | 1 |
| Lake whitefish | 31 | 33 | 23 | 15 | 33 | 40 | 46 | 51 | 37 | 40 |
| Mtn. whitefish | <1 | 0 | 0 | 0 | 0 | 0 | <1 | 0 | 0 | 0 |
| Rainbow trout | 2 | 8 | 9 | 14 | 2 | 2 | 4 | 6 | <1 | 6 |
| Carp | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | <1 | <1 |
| Chiselmouth | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Peamouth | <1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | <1 | 0 |
| Redside shiner | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| N. pikeminnow | 5 | 4 | 5 | 3 | 0 | 2 | 2 | <1 | 2 | 2 |
| Tench | 0 | 0 | 0 | 0 | 0 | 0 | <1 | 0 | 0 | <1 |
| Bridgelip | 1 | 0 | <1 | 0 | 0 | 0 | 3 | <1 | <1 | 0 |
| Largescale | 15 | 20 | 11 | 6 | 16 | 15 | 4 | 6 | 9 | 3 |
| Longnose | 1 | 2 | <1 | 2 | 0 | 1 | 2 | 1 | 4 | 5 |
| *Catostomus* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bullhead | <1 | 0 | 0 | 0 | 0 | 0 | 0 | <1 | 0 | 0 |
| Burbot | <1 | <1 | 1 | 0 | 7 | 4 | 4 | 10 | 13 | 9 |
| Crappie | 0 | 0 | 0 | 0 | 0 | <1 | 0 | 0 | <1 | 0 |
| Largemouth | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pumpkinseed | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Smallmouth | 6 | 3 | 7 | 10 | 0 | 6 | 3 | 0 | 3 | 12 |
| Walleye | 32 | 21 | 39 | 48 | 35 | 19 | 18 | 15 | 27 | 19 |
| Yellow perch | 5 | 46 | 3 | 3 | 5 | 10 | 7 | 3 | 3 | 2 |
| *Cottus spp.* | 0 | <1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Relative abundance surveys imply that substantial annual harvest of rainbow trout may not be adversely impacting natural origin rainbow trout within Lake Roosevelt. Natural origin rainbow trout have accounted for approximately 50 percent of all rainbow trout observed in our relative abundance surveys since 1994. This is, however, not reflective of our creel survey data. Hatchery origin rainbow trout comprise greater than 90 percent of angler creeled fish. Fisheries surveys indicate that natural origin adfluvial rainbow trout are most commonly associated with inlet streams flowing into Lake Roosevelt, throughout shoreline and pelagic areas of the lake. This association is presumed to be associated with reproductive behavior, tributary macroinvertebrate drift, nutrient inputs, other food sources, and behavioral characteristics associated with more complex riverine/lacustrine interface habitats.

Kokanee salmon and rainbow trout, respectively accounted for 7 and 12 percent of the fish collected during 1998 electrofishing surveys, representing an increase in relative abundance of both species with respect to substantial reservoir elevations manipulations resulting from high flows and severe draw downs in the water years of 1996 and 1997 (Table 3.3).

Lake whitefish and walleye, accounted for 40 and 19 percent, respectively of gillnet catches in 1998. 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 sample catch since 1989 (Table 3.4). Since 1989, lake whitefish have accounted for 15 to 51 percent of our gillnet catch, whereas walleye have accounted for 15 to 48 percent of the annual sample catch during the same period (Table 3.4).

In 1998 surveys, burbot were less abundant than in 1996 and 1997, but more abundant than in all other years surveyed (Tables 3.3 and 3.4). Survey data indicates burbot have increased in relative abundance in both electrofishing and gillnet surveys, and were three to four times more abundant in 1996, 1997 and 1998 than in previous years (Tables 3.2, 3.3 and 3.4). Field observations and increased CPUE’s suggest that the increase in total abundance is a real phenomena, rather than a decrease in abundance of other species.

The biological and/or abiotic explanations regarding the sudden and apparent increase in burbot populations is not understood.

Beach seine surveys (Table 3.5) were conducted as part of this program for the second time in 1998 (first time in 1997). Beach seine 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. The YOY fish are very important in the diets of many piciverous fish species in Lake Roosevelt, including walleye, northern pikeminnow, burbot, smallmouth bass, yellow perch, and at times, rainbow trout (Wydoski and Whitney 1979; Cichosz et al. 1998).

Beach seine surveys conducted during 1998 yielded a total of 1,666 fish, with 1,557 collected during our July survey (Table 3.5). Walleye fry (643), sucker larvae/fry (531) and rainbow trout fry (426) dominated beachseine collections, accounting for over 95 percent of the fish collected (Table 3.5). Carp, sculpins, largescale sucker, and smallmouth bass were also collected by beachseine in 1998, but each of these species accounted for only a small fraction of the total catch (Table 3.5). The majority of the samples were collected from the Gifford and Hunters sample site areas (Figure 1).

In 1997 beach seine surveys collected 487 YOY yellow perch, however, beach seine surveys in 1998 did not capture any YOY yellow perch in Lake Roosevelt. The reason for the shoreline absence of YOY yellow perch in 1998 is unknown; however, it is suspected that the observed lack of yellow perch is to some degree the combination of the 1996-1997 high water years, and resultant reservoir management in the spring of 1996 and 1997. This is suspected to have led to reproductive failures (multiple year class failures) due to rapidly dropping reservoir levels during the late spring timing of yellow perch spawning. It should also be noted that that the yellow perch population has been declining for the past two decades, and suspected to be related to contemporary reservoir water management manipulations for, hydropower, flood control, irrigation, and downstream anadromous fish flow augmentations.

In addition to a lack of YOY yellow perch, YOY smallmouth bass were not observed in beach seines surveys in 1998. In 1997, 335 YOY smallmouth bass 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 (Figure 1).

**Table 3.5 Catch and relative abundance of fish species captured by beach seining surveys in Lake Roosevelt during 1998.**

| | May | | July | | Total | |
|---|---|---|---|---|---|---|
| **Species** | **No.** | **%** | **No.** | **%** | **No.** | **%** |
| Rainbow trout | 8 | 7 | 418 | 27 | **426** | **26** |
| Carp | 0 | 0 | 49 | 3 | **49** | **3** |
| Largescale sucker | 1 | <1 | 0 | 0 | **1** | **<1** |
| Sucker fry | 73 | 67 | 458 | 29 | **531** | **32** |
| Smallmouth bass | 0 | 0 | 3 | <1 | **3** | **<1** |
| Walleye | 15 | 14 | 628 | 40 | **643** | **39** |
| *Cottus* spp. | 12 | 11 | 1 | <1 | **13** | **<1** |
| **Totals** | **109** | | **1,557** | | **1,666** | |

Yellow perch are considered both a sport fish and an important forage species of walleye (Groen and Schroder 1978; Wydoski and Whitney 1979; Ney 1981, ). In 1997, yellow perch were collected from five standardized sampling locations including; Gifford, Hunters, Porcupine Bay, Seven Bays, and Keller Ferry (Figure 1), and represented 1 to 3 percent of the fishery populations documented in relative abundance surveys a decade ago. It has been hypothesized that the overall collapse (1980-1998) of the yellow perch population in Lake Roosevelt is related to historically evolving reservoir water management scenarios (specifically spring draw down scenarios), which has been linked to limiting the ability of the existing yellow perch population to successfully reproduce (D. Fletcher, personal communication). Severe spring reservoir elevation manipulations result in desertion of favorable nesting sites, disruption of spawning, dewatering of nesting areas, and direct egg mortality (Keith 1975; Groen and Schroder 1978; Ploskey 1981).

**3.2 Growth and condition of rainbow, kokanee and walleye:** Lengths, weights and condition factors were determined for 139 rainbow trout collected during gillnet and electrofishing surveys in 1998 (Table 3.6). Condition factors of rainbow trout, which have been observed on Lake Roosevelt, ranged from 1.32 (age 1), to 1.21 (age 4; Table 3.7). Annual growth increments taken from mean back calculated lengths at each age show a slight decline in growth with increased age, however, it should be noted that a trout with a condition factor of 1.00 is considered to be in good to condition. Estimated annual growth increments for rainbow trout ranged from 122 mm age 1 to 47 mm age 4 (Table 3.7).

Lengths, weights and condition factors were determined for 34 kokanee salmon collected during gillnet, electrofishing and test fishery surveys in 1998 (Table 3.8). Condition factors of kokanee salmon ranged from 0.80 (age 1) to 0.98 (age 3; Table 3.8). Condition factors were lowest for age one fish (0.80), highest at age two (1.08), with a slight decline at age three (0.98; Table 3.7). Annual growth increments for ages one through three, ranged from150 mm/yr to 110 mm/yr, exhibiting a slight decrease in annual growth with increasing age (Table 3.9).

We determined length; weight and condition factors for 301 walleye sampled by electrofishing and gillnet surveys in 1998 (Table 3.10). Walleye collected in 1998 ranged from age 1 to age 8, and the mean condition factor for walleye was variable with age, although gradually decreasing with age, ranging from 1.10 at age 1, to 0.93 at age 8 (Table 3.10). Back calculated length at age shows relatively rapid growth (129 mm/yr to 93 mm/yr) in younger walleye, at ages 1 to 2 (Table 3.11). Older age classes (ages 6 through 8) exhibited considerably slower growth rates of 69 mm/yr to 38 mm/yr, respectively (Table 3.11).

**Table 3.6 Lengths, weights, and condition factors (mean ± standard deviation) of rainbow trout collected during 1998.**

| Age | n | Length (mm) | | | Weight (g) | | | Condition Factors | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 0+ | 0 | - | ± | - | - | ± | - | - | ± | - |
| 1+ | 139 | 122 | ± | 35 | 144 | ± | 114 | 1.32 | ± | 0.38 |
| 2+ | 95 | 222 | ± | 56 | 327 | ± | 147 | 1.29 | ± | 0.28 |
| 3+ | 297 | 370 | ± | 73 | 669 | ± | 734 | 1.25 | ± | 0.26 |
| 4+ | 4 | 344 | ± | 28 | 750 | ± | 204 | 1.21 | ± | 0.19 |

**Table 3.7 Back calculated total length (mean ± standard deviation) of rainbow trout sampled during 1998.**

| | | Back calculated total length (mm) at annulus | | | |
|---|---|---|---|---|---|
| **Cohort** | **n** | **1** | **2** | **3** | **4** |
| 1997 | 44 | 127 ± 43 | | | |
| 1996 | 70 | 125 ± 28 | 234 ± 49 | | |
| 1995 | 21 | 104 ± 38 | 194 ± 67 | 303 ± 78 | |
| 1994 | 4 | 104 ± 27 | 170 ± 24 | 265 ± 32 | 344 ± 28 |
| **Total n:** | **139** | | | | |
| **Mean:** | | **122 ± 35** | **222 ± 56** | **279 ± 73** | **344 ± 28** |
| **Annual Growth:** | | **122** | **100** | **75** | **47** |

**Table 3.8 Lengths, weights, and condition factors (mean ± standard deviation) of kokanee salmon collected during 1998.**

| Age | n | Length (mm) | | | Weight (g) | | | Condition Factors | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1+ | 10 | 150 | ± | 30 | 216 | ± | 135 | 0.80 | ± | 0.33 |
| 2+ | 23 | 294 | ± | 47 | 500 | ± | 157 | 1.08 | ± | 0.29 |
| 3+ | 1 | 404 | ± | 0 | 750 | ± | 0 | 0.98 | ± | 0 |

**Table 3.9 Back calculated total length (mean ± standard deviation) of kokanee salmon sampled in 1998.**

| Back calculated total Length (mm) at Annulus | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Cohort** | **n** | **1** | | **2** | | **3** | |
| 1997 | 10 | 154 | ± 38 | | | | |
| 1996 | 23 | 150 | ± 27 | 299 | ± 47 | | |
| 1995 | 1 | 103 | ± 0 | 186 | ± 0 | 404 | ± 0 |
| **Total:** | **34** | | | | | | |
| **Mean:** | | **150** | **± 30** | **294** | **± 47** | **404** | **± 0** |
| **Annual Growth:** | | **150** | | **144** | | **110** | |

**Table 3.10 Lengths, weights, and condition factors (mean ± standard deviation) of walleye collected during 1998.**

| Age | n | Length (mm) | | | Weight (g) | | | Condition Factors | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 0+ | 0 | - | ± | - | - | ± | - | - | ± | - |
| 1+ | 82 | 142 | ± | 40 | 95 | ± | 61 | 1.10 | ± | 0.34 |
| 2+ | 93 | 229 | ± | 48 | 223 | ± | 102 | 1.03 | ± | 0.24 |
| 3+ | 85 | 295 | ± | 42 | 366 | ± | 153 | 0.93 | ± | 0.17 |
| 4+ | 27 | 381 | ± | 39 | 778 | ± | 251 | 1.03 | ± | 0.15 |
| 5+ | 11 | 464 | ± | 82 | 1293 | ± | 485 | 1.01 | ± | 0.15 |
| 6+ | 4 | 527 | ± | 134 | 1613 | ± | 1025 | 0.80 | ± | 0.09 |
| 7+ | 1 | 614 | ± | 0 | 3000 | ± | 0 | 1.00 | ± | 0 |
| 8+ | 2 | 648 | ± | 22 | 2875 | ± | 177 | 0.93 | ± | 0.05 |

**Table 3.11 Back calculated total length (mean ± standard deviation) of walleye sampled during 1998.**

| Cohort | n | 1 | | | 2 | | | 3 | | | 4 | | | 5 | | | 6 | | | 7 | | | 8 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1997 | 82 | 142 | ± | 48 | | | | | | | | | | | | | | | | | | | | | |
| 1996 | 93 | 127 | ± | 32 | 229 | ± | 48 | | | | | | | | | | | | | | | | | | |
| 1995 | 85 | 117 | ± | 32 | 210 | ± | 42 | 295 | ± | 42 | | | | | | | | | | | | | | | |
| 1994 | 27 | 130 | ± | 36 | 226 | ± | 30 | 307 | ± | 37 | 381 | ± | 39 | | | | | | | | | | | | |
| 1993 | 11 | 131 | ± | 32 | 252 | ± | 59 | 333 | ± | 74 | 402 | ± | 75 | 464 | ± | 82 | | | | | | | | | |
| 1992 | 4 | 116 | ± | 21 | 202 | ± | 27 | 307 | ± | 54 | 392 | ± | 86 | 463 | ± | 125 | 527 | ± | 134 | | | | | | |
| 1991 | 1 | 191 | ± | 0 | 297 | ± | 0 | 407 | ± | 0 | 453 | ± | 0 | 518 | ± | 0 | 563 | ± | 0 | 614 | ± | 0 | | | |
| 1990 | 2 | 149 | ± | 2 | 227 | ± | 16 | 345 | ± | 19 | 449 | ± | 49 | 510 | ± | 54 | 557 | ± | 47 | 609 | ± | 33 | 648 | ± | 22 |
| **Total n:** | **301** | | | | | | | | | | | | | | | | | | | | | | | | |
| **Means Std. Dev:** | | **129** | **±** | **36** | **222** | **±** | **45** | **303** | **±** | **47** | **392** | **±** | **55** | **472** | **±** | **85** | **541** | **±** | **96** | **609** | **±** | **33** | **648** | **±** | **22** |
| **Annual Growth:** | | **129** | | | **93** | | | **81** | | | **89** | | | **80** | | | **69** | | | **69** | | | **38** | | |

**3.3 Reservoir Ecology, Species Utilization, and Fish Diet:** Reservoir biotic communities are young, very dynamic, and the relationships are not as highly evolved or stable as in lake systems (Baxter 1977). Diversity and complexity, in the case of reservoirs, do not necessarily imply stability, because of too little time for development of long-term homeostasis, and extensive annual and seasonal abiotic environmental changes. Nevertheless, basic relationships between primary producers, primary consumers, and secondary consumers will hold, although annually modified by abiotic factors (Bayly and Williams 1973; Baxter 1977; Magnuson 1991; Kerfoot 1995). Life history characteristics are reasonably well known for the most common Lake Roosevelt fish and planktonic species, as is the general nature of impacts of major abiotic reservoir environmental variables on those life history characteristics.

The structure of a system of populations can be defined to include not only the species populations present in the system, but also their abundance and distribution. We take the organization of the system of populations to be the inferred interrelations among the populations. The organization of a system of populations underlies and determines its structure. Interrelationships between species populations such as the processes of predation, competition, commensalisms, and mutualism are important parts of the system organization, and can be used to account for, or explain the structure of ecosystems and populations (Horn 1966; Mac Arthur 1968; Kerfoot 1995). It should be noted that young of virtually all fish in Lake Roosevelt are at some life stage predators on planktonic organisms. Major differences in the abundance, and decline of certain fish species in Lake Roosevelt is dependent on geographical variation in timing of plankton blooms, successful spawning of reservoir fishes, entrainment, and predator/prey relationships.

A diverse multifunctional fish population in a steady state is implicitly structured to allow competitive and predative processes to occur simultaneously. Changing the balance between different trophic components can alter these processes. Predation, as indicated for apex predators such as walleye, northern pikeminnow, and burbot, may focus on specific species or age classes at specific times, and thereby may improve, or dramatically alter production at all levels in the food web (i.e., phytoplankton, zooplankton, benthos, fish). Such systems are “predation dominant”. Systems lacking apex predators are “competition dominant”. In “competition dominant systems” growth and production are stifled due to lack of resources, with a large component of the system energy intake going into maintenance rather than production activities (Regier et al. 1979). Lake Roosevelt is a predator dominated system, and is suspected to be so to a degree that may necessitate management of predator species populations, specifically to attempt to achieve fisheries population stability by preventing over exploitation of prey species (Figure 2).

Stated simply, predation is the process of consumption of individuals (or parts/age classes of individuals) of another population when abundant, or members of the same population (the predator) when alternative prey species are scarce.

Of all predators that are present in Lake Roosevelt, only walleye have the potential for significantly affecting the abundance of reservoir prey species, both resident and hatchery origin. Walleye are large, the most abundant predator species in the reservoir (Figure 2), and opportunistic predators that feed on a variety of prey items, and switch their feeding habits when spatially, or temporally segregated from a commonly consumed prey (Fourney 1974; Nelson and Walburg 1974; Zart 1980). Walleye exploitation of fish prey items in 1998 included the following fish families by dry weight percentage; Cottidae 13.47%, unidentifiable Osteichtyes 12.92%, Salmonidae 9.85%, Percidae 8.59%, Catostomidae 3.33%, Cyprinidae 3.04%, Centrarchidae 0.39%, which represents approximately 52 percent of the Lake Roosevelt Walleye diet (Table 3.13). The remaining 48 percent of the diet (juvenile and adult) was comprised of wide variety of prey items, including macroinvertebrate, terrestrial, planktonic and other unidentifiable organisms (Table 3.13).

It has been hypothesized that the walleye family (Percidae) may be cannibalizing itself to a substantial degree. This hypothesis is based on the fact that walleye are members of the Percidae family, which currently comprises 8.59 percent of the walleye diet in population samples. This in itself would not be surprising if yellow perch populations were present in significant numbers. However, multiple sampling techniques have documented few remnants of yellow perch populations (family Percidae) in Lake Roosevelt in recent years, and walleye are the only other known member of the Percidae family in the reservoir.

Stomach and diet analyses conducted from 1989 to 1998 in Lake Roosevelt indicate juvenile walleye diets are dominated by members of the families Cladocera and Dipteria (Table 3.13). Fingerlings first feed on planktonic organisms, then as they grow their diet includes insect larvae, and when about three to four inches, includes fish. By the time walleye reach six inches or greater their diet is dominated by fishes. The “adult” walleye is primarily carnivorous, and its diet consists of mostly fishes, although other food items are exploited when available. Forbes and Richardson 1920, in *The Fishes of Illinois* made the following extrapolations of piciverous walleye predatory capability based on one specimen**:**

> *From a single wall-eyed pike caught in Peoria Lake, ten specimens of gizzard shad were taken, each from three to four inches long……. Reckoning the average life span of a pike at three years, the smallest reasonable estimate of food for each pike would fall somewhere between eighteen hundred and three thousand fishes, and a hundred pike-perch such as should be taken along a few miles of river like the Illinois would require180,000 to 300,000 fishes for their food.*

Although, the above reference does indeed have its limitations regarding scientific applicability, it does illustrate a perhaps exaggerated illustration of the predaceous potential and nature of the most abundant fish species in Lake Roosevelt, the walleye.

Walleye are an esteemed sport fish in Lake Roosevelt; however, their piciverous nature is often viewed as a suspected, however, an as yet inadequately documented threat to the mitigation salmonid hatchery production programs on Lake Roosevelt. Based on the stomach analysis of 181 walleye, predation of the members of the Salmonidae family (all species) comprised approximately ten percent (by dry weight) of the walleye diet in 1998 (Table 3.13). Predation in 1989 of members of the Salmonidae family was 4.9 percent (Peone et al. 1989). It should be noted that identification of salmonid species in 1989 was based on whole fish. Currently, digested fish are identified by anatomical characteristics, if undigested specimens are unavailable. Based on diet analysis criteria, it is unknown what percentage of the digested salmonids sampled were kokanee salmon, rainbow trout, or whitefish. Relative abundance surveys conducted in 1998 indicate that kokanee salmon, rainbow trout, and whitefish represented 27, 49 and 22 percent, respectively, of the Salmonidae family. It is suspected that walleye predation of salmonids in Lake Roosevelt is related to seasonal relative abundance (releases from hatchery facilities or net pen facilities). Walleye predation in other Columbia River reservoirs appears to be most intense on sub-yearling and yearling salmonids (salmon and summer steelhead), during salmonid smolt migrations when fish densities are highest (Ricker 1941; Ricker 1952; Gray et al. 1984).

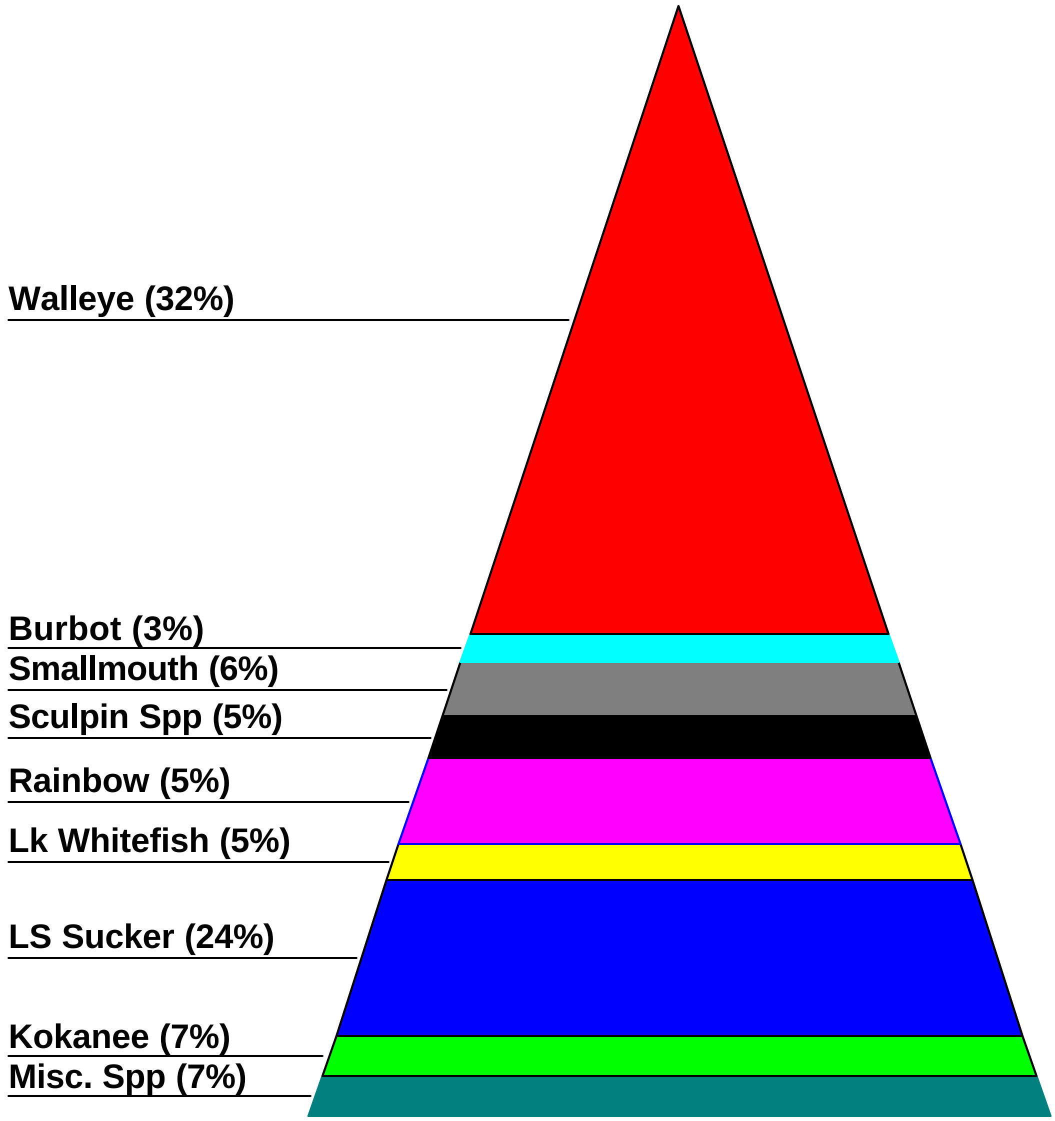


**Figure 2. Relative abundance trophic pyramid of fish species based on relative abundance surveys in Lake Roosevelt, 1998. Top of figure represents apex predators, bottom lower planktivores.**

Miscellaneous species each represented less than, or equal to 1% of total catch, and include; brown and brook trout, Mt. whitefish, yellow perch, large and smallmouth bass, peamouth, N. pikeminnow, crappie, longnose sucker, tench, and carp.

Based on bioenergetics modeling conducted by the Washington Department of Fish and Wildlife, it was estimated that piscivory of kokanee salmon and rainbow trout could account for substantial mortalities of Lake Roosevelt salmonid hatchery releases (Baldwin et al. 1999). It has been identified by the Lake Roosevelt fishery managers that instantaneous walleye predation takes place shortly after releases of hatchery origin kokanee salmon (C. Baldwin, personal communication). Estimates, based on stomach analysis at the Sherman Creek State Fish Hatchery, indicate that instantaneous post-release of salmonids by walleye predation is occurring to an as yet not adequately documented degree. However, preliminary estimates indicate that instantaneous post release predation may be as high as 20 plus percent (C. Baldwin, personal communication). Quantitative analysis of post release net pen kokanee salmon, and rainbow trout predation related mortalities from walleye have only been conducted seasonally. A more in-depth investigation into the predation of hatchery origin salmonids by walleye needs to be conducted to further evaluate the amount of predation occurring.

Data collection efforts imply that the majority of known walleye predation of kokanee salmon and rainbow trout begins immediately upon salmonid releases from hatchery and rearing facilities, and during staging of salmonids for spawning activities at hatcheries and spawning tributaries. Stomach content data analysis indicates that piscivory on kokanee salmon and other salmonids also occurs throughout the year (A. Scholz, personal communication).

In Lake Roosevelt large piscivores (walleye) are dominant in both numbers and trophic status. The size, high fecundity and piciverous capabilities of the walleye population may be close to exceeding its carrying capacity, as evidenced by the apparent collapse of the yellow perch population, decline in abundance of another apex predator, the northern pikeminnow, reductions of largescale sucker populations, increases in predation of members of the family Salmonidae, and increasing overall relative abundance of walleye in recent years as compared to other reservoir species (Figure 2).

Walleye contribute substantially to the creel in Lake Roosevelt, and increasing our understanding of the predator/prey aspect of the walleye life cycle as it relates to the overall reservoir ecology will improve future fisheries management.

In 1997 Lake Roosevelt walleye and burbot diets substantially overlapped 0.85, based on Index of Relative Importance (IRI) calculations (Cichosz et al. 1999). However, in 1998 the IRI dietary overlap was only 0.34 (Table 3.12). Both species are piciverous, and the resulting dietary and ecological shift is not understood. This reduction in diet overlap from 1997 to 1998 of these two piciverous species may possibly be the result of back-to back-years of poor reservoir conditions in 1996 and 1997 (high water years resulting in substantial entrainment losses and reproductive failures of preferred prey species), and resulting deficit of juvenile fish species availability, and/or sizes exploitable by burbot.

The feeding habits and growth rates of kokanee salmon and rainbow trout in Lake Roosevelt has not changed appreciably since 1989, and these two species have exhibited a consistently high dietary overlap throughout this study (0.65-0.91). The dietary overlap in 1998 was 0.71 (Table 3.12). In addition, diets of both kokanee salmon and rainbow trout show significant overlap with lake whitefish during 1998 (0.67 and 0.75, respectively). The diet overlap is, however, less than that observed during the 1997 water year, and is suspected to be the result of different flood control, and hydropower water management scenarios between 1996-1997, and 1998, and corresponding ecosystem responses simplifying the food web.

Calculated Index of Relative Importance (IRI) values in 1998 indicate that for kokanee salmon, rainbow trout and lake whitefish, cladocerans and chironomids are the most important foods in the diet of each of these species in Lake Roosevelt (Table 3.12), which is consistent with other findings (Wydoski and Whitney 1979). The rainbow trout is more of a generalist in feeding behavior than the kokanee salmon, and utilizes a wider variety of aquatic organisms, and will exploit terrestrial organisms and small fish when available. 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). It is also apparent that planktonic food supplies, based on their observed excellent growth rates is not a limiting factor of these species, at least not at existing population levels. Thus, it is logical to assume that food supply does not limit the growth of juvenile, or adult planktivores in Lake Roosevelt since limited supplies of a common resource would be noticeable by all species utilizing that resource.

With change in reservoir conditions, angler exploitation, and exotic species introductions, reservoir ecosystems inevitably change, and become based on a whole new set of biological and abiotic factors often result in substantial ecological fluctuations. Often such stresses on the ecosystem tend to deform a community toward large piscivores, and away from specialist planktivores and benthivores (May 1974).

**Table 3.12 Diet overlap of various fish species sampled from Lake Roosevelt during 1998. Overlap values are based on IRI calculations.**

| Species | n | Black crappie | Bridgelip sucker | Burbot | Kokanee salmon | Lake whitefish | Largemouth bass | Largescale sucker | Longnose sucker | Mountain whitefish | Northern pikeminnow | Peamouth chub | Rainbow trout | Tench | Smallmouth bass | Walleye | Yellow Perch |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Black crappie | 2 | 1.00 | | | | | | | | | | | | | | | |
| Bridgelip sucker | 1 | 0.01 | 1.00 | | | | | | | | | | | | | | |
| Burbot | 29 | 0.06 | 0.10 | 1.00 | | | | | | | | | | | | | |
| Kokanee salmon | 70 | 0.00 | 0.00 | 0.00 | 1.00 | | | | | | | | | | | | |
| Lake whitefish | 19 | 0.13 | 0.31 | 0.10 | 0.67 | 1.00 | | | | | | | | | | | |
| Largemouth bass | 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 1.00 | | | | | | | | | | |
| Largescale sucker | 97 | 0.05 | 0.62 | 0.15 | 0.47 | 0.76 | 0.02 | 1.00 | | | | | | | | | |
| Longnose sucker | 15 | 0.33 | 0.64 | 0.13 | 0.00 | 0.44 | 0.00 | 0.72 | 1.00 | | | | | | | | |
| Mtn. whitefish | 6 | 0.00 | 0.10 | 0.04 | 0.80 | 0.70 | 0.00 | 0.52 | 0.14 | 1.00 | | | | | | | |
| N. pikeminnow | 19 | 0.01 | 0.15 | 0.32 | 0.00 | 0.08 | 0.05 | 0.17 | 0.18 | 0.02 | 1.00 | | | | | | |
| Peamouth | 1 | 0.04 | 0.21 | 0.04 | 0.01 | 0.07 | 0.00 | 0.07 | 0.05 | 0.00 | 0.10 | 1.00 | | | | | |
| Rainbow trout | 111 | 0.06 | 0.09 | 0.10 | 0.71 | 0.75 | 0.09 | 0.57 | 0.16 | 0.69 | 0.05 | 0.04 | 1.00 | | | | |
| Tench | 2 | 0.18 | 0.63 | 0.12 | 0.00 | 0.35 | 0.00 | 0.67 | 0.72 | 0.17 | 0.14 | 0.00 | 0.10 | 1.00 | | | |
| Smallmouth bass | 54 | 0.01 | 0.07 | 0.10 | 0.57 | 0.55 | 0.08 | 0.41 | 0.07 | 0.55 | 0.10 | 0.15 | 0.73 | 0.04 | 1.00 | | |
| Walleye | 181 | 0.15 | 0.03 | 0.34 | 0.43 | 0.51 | 0.01 | 0.31 | 0.10 | 0.46 | 0.03 | 0.01 | 0.62 | 0.05 | 0.78 | 1.00 | |
| Yellow perch | 5 | 0.14 | 0.14 | 0.28 | 0.00 | 0.15 | 0.28 | 0.16 | 0.16 | 0.12 | 0.07 | 0.09 | 0.27 | 0.15 | 0.51 | 0.50 | 1.00 |

(Column group heading: Diet Overlap)

**Table 3.13 Index of relative importance (IRI) for prey items identified in stomachs of fish species collected from Lake Roosevelt exhibiting substantial (³ 0.60) dietary overlap with at least one other species during 1998.**

| PREY ITEM | Bridgelip Sucker | Kokanee Salmon | Lake Whitefish | Largescale Sucker | Longnose Sucker | Mtn. Whitefish | Rainbow Trout | Smallmouth Bass | Walleye |
|---|---|---|---|---|---|---|---|---|---|
| **(n)** | **(1)** | **(70)** | **(19)** | **(97)** | **(15)** | **(6)** | **(111)** | **(54)** | **(181)** |
| **Amphipoda** | | | | | | | | | |
| Amphipod spp. | -- | -- | -- | 0.22 | -- | -- | 0.17 | -- | -- |
| Decapoda | -- | -- | -- | -- | -- | -- | 0.4 | 2.32 | 0.29 |
| **Annelida** | | | | | | | | | |
| Hirudinea spp. | -- | -- | -- | -- | -- | -- | 0.18 | -- | 0.16 |
| Oligochaeta spp. | -- | -- | -- | 1.57 | -- | -- | 0.67 | 1.14 | 0.33 |
| **Anura** | | | | | | | | | |
| Bufonidae | -- | -- | -- | -- | -- | -- | 0.41 | -- | -- |
| **Arthropoda** | | | | | | | | | |
| Arachnida | -- | -- | -- | -- | -- | -- | 0.53 | -- | -- |
| **Cladocera** | | | | | | | | | |
| A. quadrangularis | -- | -- | -- | 0.58 | 15.16 | -- | 0.19 | -- | -- |
| B. longirostris | -- | -- | 3.06 | 0.37 | -- | -- | 0.18 | -- | -- |
| C. quadrangulata | -- | -- | -- | 0.26 | -- | -- | -- | -- | -- |
| D. galeata | -- | 8.76 | 10.87 | 2.51 | -- | 4.42 | 3.62 | -- | 0.16 |
| D. pulex | -- | 48.88 | 24.99 | 16.99 | -- | 40.12 | 23.59 | 20.79 | 15.91 |
| D. retrocurva | -- | 0.53 | 3.33 | 0.76 | -- | -- | 0.35 | -- | -- |
| D. schodleri | -- | 12.78 | -- | 4.92 | -- | -- | 9.43 | 5.25 | 0.34 |
| D. thorata | -- | 0.98 | -- | 0.86 | -- | -- | 0.53 | -- | -- |

**Table 3.13 Continued**

| | PREY ITEM | Bridgelip Sucker | Kokanee Salmon | Lake Whitefish | Largescale Sucker | Longnose Sucker | Mtn. Whitefish | Rainbow Trout | Smallmouth Bass | Walleye |
|---|---|---|---|---|---|---|---|---|---|---|
| | **(n)** | **(1)** | **(70)** | **(19)** | **(97)** | **(15)** | **(6)** | **(111)** | **(54)** | **(181)** |
| | Daphnia spp. | -- | 15.7 | 2.83 | 3.84 | -- | -- | 0.83 | 0.63 | |
| | Eppipial eggs | -- | 0.79 | -- | 0.8 | -- | -- | -- | -- | |
| | L. kindtii | -- | -- | -- | -- | -- | 3.88 | 5.31 | 0.63 | |
| | S. crystallina | -- | -- | -- | -- | -- | -- | 0.2 | -- | |
| **Coleoptera** | | | | | | | | | | |
| | Coleoptera spp. | -- | 0.36 | -- | -- | 1.75 | -- | 0.72 | -- | 0.31 |
| | Dryopidae | -- | -- | -- | 0.22 | -- | -- | -- | -- | -- |
| | Dytiscidae | -- | -- | -- | -- | -- | -- | -- | 1.73 | -- |
| | Elmidae | -- | -- | 1.17 | 0.9 | -- | -- | 0.35 | -- | 0.16 |
| | Hydrophilidae | -- | -- | -- | -- | -- | -- | -- | -- | 0.19 |
| **Crustacea** | | | | | | | | | | |
| | Chilopoda | -- | 0.38 | -- | -- | -- | -- | -- | -- | -- |
| **Decapoda** | | | | | | | | | | |
| | Astacidae | -- | -- | -- | -- | -- | -- | -- | -- | 0.32 |
| **Diptera** | | | | | | | | | | |
| | Chironomidae adult | -- | -- | -- | -- | -- | -- | 0.36 | -- | 0.51 |
| | Chironomidae larvae | -- | -- | 6.07 | 2.3 | 17.26 | -- | 1.79 | -- | 3.54 |
| | Chironomidae pupa | -- | 1.18 | 13.33 | 1.55 | 3.23 | -- | 5.54 | 2.71 | 6.09 |
| | Simulidae spp. | -- | -- | -- | -- | -- | -- | 0.35 | -- | -- |
| | Tipulidae spp. | -- | -- | -- | -- | -- | -- | 0.35 | -- | -- |
| **Ephemeroptera** | | | | | | | | | | |
| | Batidae spp. | -- | -- | 1.23 | 0.22 | -- | -- | 1.96 | 1.1 | 0.95 |
| | Ephemeroptera spp. | -- | -- | -- | 0.44 | 1.51 | -- | 0.52 | -- | 0.32 |
| | Heptageniidae | -- | -- | -- | 0.22 | -- | -- | 0.52 | 0.66 | -- |

**Table 3.13 Continued**

| PREY ITEM | Bridgelip Sucker | Kokanee Salmon | Lake Whitefish | Largescale Sucker | Longnose Sucker | Mtn. Whitefish | Rainbow Trout | Smallmouth Bass | Walleye |
|---|---|---|---|---|---|---|---|---|---|
| (n) | (1) | (70) | (19) | (97) | (15) | (6) | (111) | (54) | (181) |
| **Eucopoda** | | | | | | | | | |
| D. b. thomasi | -- | 0.37 | 1.28 | 1.31 | -- | -- | -- | -- | -- |
| E. nevadensis | -- | 7.82 | 4.28 | 3.85 | -- | 7.99 | 4.52 | 3.83 | 1.33 |
| L. ashlandi | -- | 0.38 | -- | -- | -- | -- | -- | -- | 0.4 |
| M. edax | -- | -- | -- | -- | 1.52 | -- | 0.18 | -- | -- |
| **Gastropoda** | | | | | | | | | |
| Gastropoda spp. | -- | -- | -- | 0.44 | -- | -- | -- | -- | -- |
| Lymnaeidae spp. | -- | -- | -- | 0.47 | -- | -- | 1.04 | -- | -- |
| Physidae spp. | -- | -- | -- | 1.41 | 3.67 | -- | 7.82 | -- | -- |
| Planorbidae spp. | -- | -- | -- | 3.18 | 1.47 | -- | 0.18 | -- | -- |
| **Hemiptera** | | | | | | | | | |
| Belostomatid | -- | -- | -- | -- | -- | -- | 0.18 | -- | -- |
| Corixidae spp. | -- | -- | 1.18 | 1.12 | -- | -- | 5.17 | 4.52 | 0.34 |
| Hemiptera spp. | -- | -- | -- | -- | 1.46 | -- | 0.73 | -- | -- |
| Homoptera | -- | -- | -- | -- | -- | -- | 0.2 | -- | -- |
| **Hydrachnellae** | | | | | | | | | |
| Hydracharina | -- | -- | 1.34 | 0.22 | 1.48 | -- | 0.71 | -- | -- |
| **Nematoda** | | | | | | | | | |
| Nematoda spp. | -- | 0.36 | -- | 2.03 | 6.59 | -- | -- | -- | 0.33 |
| **Odonata** | | | | | | | | | |
| Anisoptera | -- | -- | -- | -- | -- | -- | 0.28 | 0.59 | -- |
| Zygoptera | -- | -- | -- | -- | -- | -- | 0.17 | -- | 0.16 |
| **Organic Matter** | | | | | | | | | |
| Seeds | -- | 0.37 | -- | 1.54 | -- | -- | 0.17 | -- | 0.2 |
| Unid. Org. Matter | 82 | -- | 14.74 | 31.04 | 33.71 | 5.76 | 3.74 | 1.72 | 1.29 |

**Table 3.13 Continued**

| | PREY ITEM | Bridgelip Sucker | Kokanee Salmon | Lake Whitefish | Largescale Sucker | Longnose Sucker | Mtn. Whitefish | Rainbow Trout | Smallmouth Bass | Walleye |
|---|---|---|---|---|---|---|---|---|---|---|
| | (n) | (1) | (70) | (19) | (97) | (15) | (6) | (111) | (54) | (181) |
| **Osteichtyes** | | | | | | | | | | |
| | Catostomidae | -- | -- | -- | -- | -- | -- | 1.07 | 3.48 | 3.33 |
| | Centrarchidae | -- | -- | -- | -- | -- | -- | 0.61 | 4.05 | 0.39 |
| | Cottidae | -- | -- | -- | -- | -- | -- | 3.15 | 19.51 | 13.47 |
| | Cyprinidae | -- | -- | -- | -- | -- | -- | 1.16 | 2.45 | 3.04 |
| | Fish scales | -- | -- | -- | -- | -- | 4.3 | -- | -- | 0.31 |
| | Osteichthyes spp. | -- | -- | -- | -- | -- | -- | 0.24 | 5.99 | 12.92 |
| | Percidae | -- | -- | -- | -- | -- | -- | 0.97 | 1.98 | 8.59 |
| | Salmonidae | -- | -- | -- | -- | -- | -- | -- | 0.88 | 9.85 |
| **Pelecypoda** | | | | | | | | | | |
| | Sphaeridae | -- | -- | 1.31 | -- | -- | -- | -- | -- | -- |
| **Plecoptera** | | | | | | | | | | |
| | Perlodidae spp. | -- | -- | -- | -- | -- | -- | -- | -- | 0.32 |
| | Plecoptera spp. | -- | -- | -- | 1.32 | 1.46 | -- | 0.17 | -- | 0.52 |
| | Pteronarcys spp. | -- | -- | -- | 0.23 | -- | -- | -- | -- | -- |
| **Terrestrial Insects** | | | | | | | | | | |
| | Acrididae | -- | -- | -- | -- | -- | -- | 0.17 | -- | -- |
| | Formicidae | -- | -- | -- | 1.09 | -- | -- | 0.17 | 0.53 | -- |
| | Insect Parts | 17.79 | 0.36 | 3.85 | 3.98 | 3.18 | -- | 2.23 | 8.19 | 1.14 |
| | Terrestrial spp. | -- | -- | -- | 1 | -- | 5.05 | 4.32 | 1.8 | -- |
| **Trichoptera** | | | | | | | | | | |
| | Brachycentridae | -- | -- | -- | 0.68 | -- | 12.56 | -- | -- | -- |
| | Glossostomatidae | -- | -- | -- | 0.46 | -- | -- | -- | -- | -- |
| | Helicopsychidae | -- | -- | -- | 0.47 | -- | -- | -- | -- | -- |
| | Hydropsychidae | -- | -- | 2.72 | -- | 1.59 | -- | -- | -- | 0.47 |

## Table 3.13 Continued

| PREY ITEM | Bridgelip Sucker | Kokanee Salmon | Lake Whitefish | Largescale Sucker | Longnose Sucker | Mtn. Whitefish | Rainbow Trout | Smallmouth Bass | Walleye |
|---|---|---|---|---|---|---|---|---|---|
| **(n)** | **(1)** | **(70)** | **(19)** | **(97)** | **(15)** | **(6)** | **(111)** | **(54)** | **(181)** |
| Hydroptilidae | -- | -- | -- | 0.45 | -- | -- | 0.17 | -- | -- |
| Lepidostomatidae | -- | -- | -- | 0.22 | -- | -- | -- | -- | -- |
| Limnephilidae | -- | -- | 2.42 | 1.11 | 4.96 | 15.93 | -- | 1.82 | -- |
| Trichoptera pupa | -- | -- | -- | -- | -- | -- | 0.87 | -- | 0.52 |
| Trichoptera spp. | -- | -- | 2.88 | -- | -- | 0.52 | 1.71 | | 0.63 |

**3.4 Angler Creel Surveys, and Economic Analysis:** We estimated that total annual fishing pressure exerted in Lake Roosevelt during 1998 was 1,003,551 angler hours (Table 3.14). Our estimates of annual fishing pressure were highest in Section 2 (505,787 hrs), moderate in Section 3 (355,946 hours), and lowest in Section 1 (141,818 hrs; Table 3.14). Monthly fishing pressure was greatest during June (198,515 hrs), and lowest during April (28,543 hrs; Table 3.14).

Anglers made an estimated 196,775 fishing trips to Lake Roosevelt from December 1997 through November 1998 (Table 3.15). An estimated total of 23,692 angler trips were made in Section 1, 108,421 angler trips in Section 2, and 64,921 trips in Section 3 (Table 3.15). Sectional trip estimates do not sum to the annual estimate due to differences in calculation protocols. 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.

In general, estimated angler pressure and trip numbers were highest during summer and fall (June–October), and lowest during winter and spring (December-May; Tables 3.14 and 3.15). On a reservoir wide basis, the highest number of monthly angling trips was made during the June through September period, ranging from 24,565 (July) to 36,732 (September; Table 3.15). The winter quarter (December through February) and the spring draw down periods (April and May) had the fewest angler trips when less than 7,000 angler trips were made per month (Table 3.15)

During 1998, the overall mean annual harvest rate (fish kept per angler hour) in Lake Roosevelt for all species combined was 0.289, equating to 3.5 angler hours exerted for each fish harvested (Table 3.16). The 1998 annual mean harvest rate was 0.178 (5.6 CPUE angler hrs/fish) for rainbow trout, 0.086 (11.6 CPUE angler hrs/fish) for walleye, 0.009 (111.1 CPUE angler hrs/fish) for smallmouth bass, and 0.015 (66.7 CPUE angler hrs/fish) for kokanee salmon (Table 3.16).

**Table 3.14 Total monthly angler pressure estimates in hours (± 95% CI), by creel section on Lake Roosevelt from December 1997, through November 1998.**

| | Reservoir Survey Sections | | | |
|---|---|---|---|---|
| **Month** | **1** | **2** | **3** | **Total** |
| **December** | 411 ± 151 | 26,851 ± 1,927 | 3,992 ± 237 | **31,254 ± 2,315** |
| **January** | 92 ± 53 | 4,975 ± 514 | 29,314 ± 168 | **34,381 ± 735** |
| **February** | 652 ± 129 | 13,956 ± 483 | 26,533 ± 1,406 | **41,141 ± 2,018** |
| **March** | 1,310 ± 67 | 37,135 ± 2,487 | 31,582 ± 1,434 | **70,027 ± 3,988** |
| **April** | 2,635 ± 200 | 13,008 ± 1,172 | 12,900 ± 498 | **28,543 ± 1,870** |
| **May** | 11,653 ± 324 | 17,481 ± 1,048 | 2,466 ± 182 | **31,600 ± 1,554** |
| **June** | 34,401 ± 1,266 | 88,378 ± 4,541 | 75,736 ± 67 | **198,515 ± 5,874** |
| **July** | 37,382 ± 2,751 | 70,795 ± 3,969 | 17,538 ± 507 | **125,715 ± 7,227** |
| **August** | 27,379 ± 1,807 | 44,792 ± 2,210 | 58,957 ± 3,553 | **131,128 ± 7,570** |
| **September** | 19,466 ± 879 | 62,733 ± 2,404 | 84,542 ± 4,536 | **166,741 ± 7,819** |
| **October** | 5,464 ± 508 | 66,592 ± 4,700 | 11,559 ± 208 | **83,615 ± 5,416** |
| **November** | 973 ± 109 | 59,091 ± 1,393 | 827 ± 159 | **60,891 ± 1,661** |
| **Total** | 141,818 ± 8,244 | 505,787 ± 26,848 | 355,946 ± 12,955 | **1,003,551 ± 48,047** |

**Table 3.15 Angler trip estimates by section based on angler hours and average trip length for Lake Roosevelt from December 1997 through November 1998.**

| | Section | Mean Trip Length | No. Angler Hours | No. Angler Trips |
|---|---|---|---|---|
| **December** | **1** | 4.4 | 411 | 93 |
| | **2** | 5.5 | 26,851 | 4,882 |
| | **3** | 6.2 | 3,992 | 644 |
| **January** | **1** | 4.9 | 92 | 19 |
| | **2** | 3.8 | 4,975 | 1,309 |
| | **3** | 8.0 | 29,314 | 3,664 |
| **February** | **1** | 4.7 | 652 | 139 |
| | **2** | 4.9 | 13,956 | 2,848 |
| | **3** | 6.7 | 26,533 | 3,960 |
| **March** | **1** | 4.3 | 1,310 | 305 |
| | **2** | 4.0 | 37,135 | 9,284 |
| | **3** | 5.9 | 31,582 | 5,353 |
| **April** | **1** | 6.4 | 2,635 | 412 |
| | **2** | 3.7 | 13,008 | 3,516 |
| | **3** | 5.7 | 12,900 | 2,263 |
| **May** | **1** | 6.2 | 11,653 | 1,880 |
| | **2** | 4.4 | 17,481 | 3,973 |
| | **3** | 5.2 | 2,466 | 474 |
| **June** | **1** | 6.1 | 34,401 | 5,640 |
| | **2** | 4.9 | 88,378 | 18,036 |
| | **3** | 6.1 | 75,736 | 12,416 |
| **July** | **1** | 5.9 | 37,382 | 6,336 |
| | **2** | 4.4 | 70,795 | 16,090 |
| | **3** | 8.2 | 17,538 | 2,139 |
| **August** | **1** | 6.6 | 27,379 | 4,148 |
| | **2** | 5.1 | 44,792 | 8,783 |
| | **3** | 4.7 | 58,957 | 12,544 |
| **September** | **1** | 5.8 | 19,466 | 3,356 |
| | **2** | 4.3 | 62,733 | 14,589 |
| | **3** | 4.5 | 84,542 | 18,787 |
| **October** | **1** | 4.9 | 5,464 | 1,115 |
| | **2** | 4.7 | 66,592 | 14,169 |
| | **3** | 4.7 | 11,559 | 2,459 |
| **November** | **1** | 3.9 | 973 | 249 |
| | **2** | 5.4 | 59,091 | 10,942 |
| | **3** | 3.8 | 827 | 218 |
| **Total** | | **5.1** | **1,003,551** | **196,775** |

**Table 3.16 Harvest per unit effort (HPUE) by species and section from December 1997 through November 1998 in Lake Roosevelt. HPUE equals the number of fish kept per angler hour.**

| | Section | | | |
|---|---|---|---|---|
| | **1** | **2** | **3** | **Annual** |
| Kokanee salmon | 0.000 | 0.020 | 0.019 | **0.015** |
| Rainbow trout | 0.059 | 0.139 | 0.264 | **0.178** |
| Walleye | 0.191 | 0.133 | 0.000 | **0.086** |
| Smallmouth bass | 0.000 | 0.000 | 0.021 | **0.009** |
| White sturgeon | 0.000 | 0.000 | 0.000 | **0.000** |
| Other species | 0.000 | 0.000 | 0.000 | **0.000** |
| **Annual HPUE** | **0.250** | **0.292** | **0.304** | **0.289** |

**Table 3.17 Catch per unit effort (CPUE) by species and section from December 1997 through November 1998 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 | 0.020 | 0.021 | **0.016** |
| Rainbow trout | 0.059 | 0.144 | 0.270 | **0.183** |
| Walleye | 0.219 | 0.149 | 0.001 | **0.098** |
| Smallmouth bass | 0.000 | 0.006 | 0.250 | **0.113** |
| White sturgeon | 0.000 | 0.000 | 0.000 | **0.000** |
| Other species | 0.003 | 0.000 | 0.000 | **0.001** |
| **Annual CPUE** | **0.281** | **0.319** | **0.542** | **0.410** |

The highest harvest rates by species (Table 3.16) were in Section 1 for walleye 0.191 (CPUE 6.3 angler hrs/fish), in Section 2 for kokanee salmon 0.020; (CPUE 50.0 angler hrs/fish), and in Section 3 for rainbow trout 0.264 (CPUE 3.8 angler hrs/fish).

The overall mean annual catch rate (fish kept and released per angler hour) for all species combined in Lake Roosevelt during 1998 was 0.410, or approximately 2.4 hours of effort exerted for each fish caught (Table 3.17). Mean annual catch rates by species in 1998 were 0.183 (5.5 CPUE angler hrs/fish) for rainbow trout, 0.098 (10.2 CPUE angler hrs/fish) for walleye, 0.016 (62.5 CPUE angler hrs/fish) for kokanee salmon, and 0.113 (8.8 CPUE angler hrs/fish) for smallmouth bass (Table 3.17). Catch rates for individual species were highest in Section 1 (upper) for walleye 0.219 (4.6 CPUE angler hrs/fish) and in Section 3 (lower) for kokanee salmon 0.021 (47.6 CPUE angler hrs/fish), rainbow trout 0.270 (3.7 CPUE angler hrs/fish) and smallmouth bass 0.250 (4.0 CPUE angler hrs/fish; Table 3.17). Rainbow trout were the largest contributors to harvest from Lake Roosevelt in 1998. Rainbow trout harvest was estimated at 226,809 fish, accounting for over 60 percent of the total harvest (Table 3.18). Rainbow trout were primarily harvested from Sections 2 (94,269), and 3 (128,424), during 1998 (Table 3.18).

The creel data also suggests that no kokanee were harvested in Section 1, and no walleye were harvested in Section 3 (Table 3.18). This apparent segregation of the two species in creel surveys has for the most part been consistent since the Lake Roosevelt Project began. The presence/absence of these species in these two areas is not understood, but is thought to be related to forage and habitat factors. Although creel surveys are not identifying walleye in the Section 3 catch, it is known that walleye are entrained through Grand Coulee Dam, and have seeded the mid and lower Columbia River (Zook 1983; and Mullan et al. 1986), have been documented by the Washington Department of Fish and Wildlife through offshore net sets, and Eastern Washington University researchers have captured them in the San Poil River. Therefore, walleye are present, at least seasonally in the lower reaches of the reservoir; however, they are for unknown reasons not reflected in the creel survey data.

We estimated that 119,346 walleye were harvested from Lake Roosevelt during 1998, comprising 32 percent of the total harvest (Table 3.18). Harvested walleye were noted in the creel only in Sections 1 and 2 where harvest estimates were 34,943 and 84,403, respectively (Table 3.18). Approximately 3.5 percent of the walleye recorded in the creel during 1998 were within the illegal size restrictions (406-508 mm; 16-20 in.) established by WDFW. We estimate that approximately 4,200 walleye were harvested within the illegal size range during 1998.

Harvest of kokanee salmon and smallmouth bass were estimated at 9,980 and 14,062 fish, respectively, accounting for approximately seven percent of the total harvest (Table 3.18). Kokanee salmon were harvested from Sections 2 (4,701) and 3 (5,279), whereas smallmouth bass were harvested exclusively from Section 3 (Table 3.18). Both catch rates and estimated numbers of fish caught from Lake Roosevelt during 1998 were higher than harvest rates/estimates for individual species, with the most pronounced differences in smallmouth bass and walleye (Tables 3.16 through 3.18). The mean annual catch rates for smallmouth bass (0.113) was approximately twelve times the mean annual harvest rate (0.09) during 1998 (Table 3.16).

**Table 3.18 Estimated number of fish harvested (kept), with ± 95% confidence intervals for Lake Roosevelt from December 1997 through November 1998.**

| | Section | | | |
|---|---|---|---|---|
| | **1** | **2** | **3** | **Total** |
| Kokanee salmon | 0 | 4,701<br>(±321) | 5,279<br>(±218) | **9,980<br>(±539)** |
| Rainbow trout | 4,116<br>(±316) | 94,269<br>(±5,366) | 128,424<br>(±4,673) | **226,809<br>(±10,355)** |
| Walleye | 34,943<br>(±1,939) | 84,403<br>(±4,359) | 0 | **119,346<br>(±6,298)** |
| Smallmouth bass | 0 | 0 | 14,062<br>(±847) | **14,062<br>(±847)** |
| White sturgeon * | 0 | 0 | 0 | **0** |
| Other species | 0 | 0 | 0 | **0** |
| **Annual Harvest** | **39,059<br>(±2,255)** | **183,373<br>(±10,045)** | **147,765<br>(±5,739)** | **370,197<br>(±18,039)** |

**Table 3.19 Estimated numbers of fish caught (kept and released), with ± 95% confidence intervals, for Lake Roosevelt from December 1997 through November 1998.**

| | Section | | | |
|---|---|---|---|---|
| | **1** | **2** | **3** | **Total** |
| **Kokanee salmon** | 0 | 4,701<br>(±321) | 5,487<br>(±222) | **10,188**<br>**(±543)** |
| **Rainbow trout** | 4,116<br>(±316) | 97,831<br>(±5,549) | 131,089<br>(±4,776) | **233,036**<br>**(±10,641)** |
| **Walleye** | 38,635<br>(±2,138) | 94,526<br>(±4,904) | 80<br>(±6) | **133,241**<br>**(±7,048)** |
| **Smallmouth bass** | 0 | 3,314<br>(±164) | 213,864<br>(±5,490) | **217,178**<br>**(±5,654)** |
| **White sturgeon** | 0 | 0 | 0 | **0** |
| **Other species** | 65<br>(±7) | 0 | 0 | **0** |
| **Annual Catch** | **42,816**<br>**(±2,461)** | **200,372**<br>**(±10,936)** | **350,520**<br>**(±10,494)** | **593,708**<br>**(±23,891)** |

In 1998, rainbow trout harvested from Section 3 were apparently larger by both length and weight than those harvested in Sections 1 or 2 (Table 3.20). Mean length of rainbow trout harvested from Sections 1 and 2 were similar in 1998; however, mean weight of rainbow trout harvested was greater in Section 2 (Table 3.20). Rainbow trout harvested in Section 3 averaged 376 mm in length and 777 grams in weight (Table 3.20). In contrast, rainbow trout harvested from Sections 1 and 2 had respective mean lengths of 333 and 339 mm, and respective mean weights of 403 and 504 grams (Table 3.20). The larger rainbow trout observed in the lower reaches of the reservoir corresponds with substantially higher densities of prey items (e.g. Cladocerans and Dipterans), which both kokanee salmon and rainbow intensely exploit (Shields et al. 1997; Cichosz et al. 1999).

**Table 3.20 Annual numbers (n) and mean lengths (mm) and weights (g) for fish observed in the Lake Roosevelt creel from December 1997 through November 1998. Plus/minus values indicate standard deviations.**

| | | Kokanee | Rainbow | Walleye | Smallmouth Bass |
|---|---|---|---|---|---|
| **Sec 1** | | | | | |
| | **N** | - | 53 | 217 | - |
| | **Ln** | - | 333±47 | 353±36 | - |
| | **Wt** | - | 403±160 | 345±86 | - |
| **Sec 2** | | | | | |
| | **n** | 24 | 134 | 152 | - |
| | **Ln** | 364±36 | 339±56 | 351±75 | - |
| | **Wt** | 472±124 | 504±172 | 458±360 | - |
| **Sec 3** | | | | | |
| | **n** | 29 | 399 | - | 30 |
| | **Ln** | 350±33 | 376±64 | - | 229±0 |
| | **Wt** | 717±165 | 777±258 | - | - |
| **Total** | | | | | |
| | **n** | **53** | **586** | **369** | **30** |
| | **Ln** | **356±35** | **364±64** | **352±55** | **229±0** |
| | **Wt** | **606±191** | **680±273** | **392±246** | **---** |

Walleye were observed in the creel only in Sections 1 and 2 during 1998. Walleye were similar in length from both sections (353 and 351 mm, respectively); however, mean weight of walleyes harvested was greater in Section 2, 458 g. versus 345 g., (Table 3.20). Only 1 percent of walleye creeled in Section 1 during 1998 were within the upper legal size limit (> 20 in). In contrast, 7 percent of the walleye creeled in Section 2 were in the upper legal size limit.

Based on creel surveys, 59 percent of walleye anglers were satisfied with the fishery in 1998 (Table 3.21). Satisfaction rates of anglers targeting rainbow trout (35%), or kokanee salmon (24%) were notably lower during the same period (Table 3.21). The highest seasonal satisfaction rates among kokanee salmon anglers (56%) were noted during the fall (Table 3.21). Walleye and rainbow trout anglers interviewed were most satisfied (72% and 48%, respectively) during the summer (Table 3.21). Of all anglers interviewed on Lake Roosevelt during 1998, (48%) targeted rainbow trout, (27%) targeted walleye, (18%) targeted kokanee salmon and (8%) targeted other species such as burbot and smallmouth bass (Table 3.22). On a reservoir wide-basis, walleye were the principal species targeted in the summer months (57%), whereas rainbow trout were the principal target species during winter months (55%), and fall months (79%; Table 3.22). Walleye and rainbow trout received nearly equally proportions of angler pressure during the spring of 1998 (34 and 33 percent, respectively).

**Table 3.21 Percent of anglers that were satisfied with the fishery by species, section and season from December 1997 through November 1998.**

| Quarter Section | Kokanee Salmon | Rainbow Trout | Walleye | White Sturgeon |
|---|---|---|---|---|
| **Winter** | | | | |
| **1** | - | 0% | - | - |
| **2** | 44% | 18% | 36% | - |
| **3** | 4% | 17% | - | - |
| **Spring** | | | | |
| **1** | - | 0% | 46% | - |
| **2** | 40% | 30% | 39% | - |
| **3** | 19% | 0% | - | - |
| **Summer** | | | | |
| **1** | - | 50% | 67% | - |
| **2** | - | 33% | 82% | - |
| **3** | 36% | 60% | - | - |
| **Fall** | | | | |
| **1** | - | 59% | 88% | - |
| **2** | 100% | 63% | 18% | - |
| **3** | 54% | 34% | - | - |
| **Qrtly Totals** | | | | |
| **Winter** | **9%** | **13%** | **36%** | **-** |
| **Spring** | **23%** | **16%** | **43%** | **-** |
| **Summer** | **36%** | **48%** | **72%** | **-** |
| **Fall** | **56%** | **47%** | **47%** | **-** |
| **Annual Total** | **24%** | **35%** | **59%** | **0%** |

**Table 3.22 Percent of anglers targeting various fish species by section and season on Lake Roosevelt from December 1997 through November 1998.**

| Quarter Section | Kokanee Salmon | Rainbow | Walleye | Other |
|---|---|---|---|---|
| **Winter** | | | | |
| **1** | - | 84% | - | 16% |
| **2** | 6% | 66% | 16% | 12% |
| **3** | 71% | 29% | - | - |
| **Spring** | | | | |
| **1** | - | 21% | 76% | 3% |
| **2** | 10% | 42% | 37% | 11% |
| **3** | 81% | 17% | - | 2% |
| **Summer** | | | | |
| **1** | - | 21% | 79% | - |
| **2** | - | 13% | 62% | 25% |
| **3** | 85% | 9% | - | 6% |
| **Fall** | | | | |
| **1** | - | 80% | - | 20% |
| **2** | 2% | 75% | 15% | 8% |
| **3** | 17% | 83% | - | - |
| **Qrtly Totals** | | | | |
| **Winter** | 27% | 55% | 10% | 8% |
| **Spring** | 25% | 33% | 34% | 8% |
| **Summer** | 15% | 15% | 57% | 13% |
| **Fall** | 8% | 79% | 10% | 4% |
| **Annual Total** | **18%** | **48%** | **27%** | **8%** |

We estimated the economic value of the Lake Roosevelt fishery in 1998 to be $8,004,807 (Table 3.23). This estimate is based on an estimated 196,755 angler trips at an average cost of $40.68 per trip as adjusted to the current to the regional consumer price index.

•

**Table 3.23 Economic value of the sport fishery in Lake Roosevelt during December 1997 through November 1998.**

| | 1985 | 1998 |
|---|---|---|
| Consumer Price Index | $167.87 | $262.66 |
| Dollars Spent per Angler Trip | $26.00 | $40.68 |
| Number of Angler Trips | | 196,775.00 |
| **Economic Value of Fishery** | | **$8,004,807.00** |

In 1998, the estimated number of angler trips to Lake Roosevelt and the economic value of the fishery increased relative to 1996 and 1997, but were lower than in all other years since 1991 (Table 4.1). The economic value of the Lake Roosevelt fishery in 1998 was approximately $2.2 million greater than in 1997, but less than half of the estimated value of the 1993 and 1994 fisheries (Table 4.1). The estimated annual number of angler trips to Lake Roosevelt peaked in 1993, declined through 1997, increasing again in 1998 (Table 4.1). The estimated number of angler trips made in 1998 increased nearly 35 percent over the 1997 estimate (Table 4.1). It is suspected that the dramatic decline in the value of the fishery during 1996 to1998, from previous years, is attributable to the culmination of poor angler success rates, and limited boat access resulting from the low early spring water years of 1996 and 1997. The reservoir elevation was lowered during these years below normal, due to heavy runoff predictions.

It should be noted that there are numerous methodologies developed for conducting an economic analysis of the value of a fishery (i.e., economic impact surveys such as expenditure, or net value assessments, contingent value analyses, intangible benefit models, etc.). We realize that based on expenditure, or net value assessment models commonly used in assessing the value of a fishery (i.e., boats, motors, fuel, travel, tackle, food, lodging, etc.), the value of the fishery on a daily/annual basis would greatly exceed the Consumer Price Index (CPI) values, as adjusted (USFWS 1989), associated with the economic values associated with an angler trip (Fisher and Grambsch 1991). We have elected to use these as adjusted CPI economic values (U.S. Fish and Wildlife Service 1985) to provide consistent estimates for trend comparisons, however, they likely represent an underestimate of the true economic value of the fishery.

## 3.5 Lake Roosevelt kokanee salmon and rainbow trout hatchery production program (1986-1998):

The Lake Roosevelt Hatchery Coordination Team determines and evaluates kokanee salmon and rainbow trout stocking strategies, including age, size number, timing, stocks and locations. The Hatchery Coordination Team is comprised of hatchery managers and fishery managers from the Spokane Tribe of Indians (STOI), Colville Confederated Tribes (CCT), and Washington Department of Fish and Wildlife (WDFW), who coordinate and establish production goals and release strategies annually. These strategies are based on ongoing scientific research activities on Lake Roosevelt.

Abiotic, climatic, political, institutional, legal and economic realities (anadromous fish flows, flood control, power production, irrigation, ESA, etc.) dictate daily, seasonal and annual reservoir operations, which have a direct influence on the success of hatchery production programs.

From 1988 to 1990, kokanee salmon reared at the Ford Hatchery by the (WDFW) were stocked into Lake Roosevelt. Approximately 850,000 plus kokanee salmon fry were stocked into Sherman Creek and the Spokane River at Little Falls Dam, respectively, each year between May and July. The Spokane State Fish Hatchery (SFH) provided rainbow trout fry to the Lake Roosevelt Net Pen Program from 1986 to 1990. The number of rainbow trout provided by the Spokane (SFH) began at 50,000, and increased to 276,500 by 1990 (Table 3.25). Historical hatchery production, and origin from 1986 to 1998 are summarized for kokanee salmon (Table 3.24), and rainbow trout (Table 3.25).

The Spokane Tribal Hatchery began operation in 1990 as a full production facility, and began stocking kokanee salmon and rainbow trout into Lake Roosevelt in 1991. The Spokane Tribal Hatchery is a modern support and production facility, and operationally cultures and rears the kokanee salmon and rainbow trout for release as fingerlings and catchables, and also operates as a transfer facility to the WDFW Sherman Creek Hatchery, and Lake Roosevelt kokanee salmon and rainbow trout net pen rearing projects.

In 1998, approximately 501,206 kokanee yearlings and 87,421 fry were released from the Sherman Creek SFH, and 541,447 catchable rainbow trout were released from the net pen operation, and 125, 674 fry were released directly from the Spokane Tribal Hatchery. Approximately 10,000 (8,922 survived) kokanee salmon were floy (anchor) tagged for the first time in 1997 at the Sherman Creek Hatchery. In 1998, approximately 7,700 kokanee salmon were floy (anchor) tagged at the Sherman Creek facility.

Current production goals will attempt to produce 1 million kokanee yearlings (with anticipated new net pen facilities at Sherman Creek) to help reduce the instantaneous post release predation associated with fingerling plants (Tilson et al. 1994), and 500,000 plus rainbow trout reared in the net pen program to catchable size. The increased production of kokanee salmon yearlings is currently under review as to what stocks are most suitable for existing hatchery facilities, and other ecological considerations.

**Kokanee salmon:** The Sherman Creek Hatchery is a contemporary production facility operated by the WDFW near Kettle Falls, Washington that began rearing and releasing kokanee salmon in 1992. 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 as a result of limited adult returns, kokanee salmon eggs continue to be supplemented on an annual basis by the Lake Whatcom Hatchery, and more recently

Meadow Creek Hatchery in British Columbia. A portion of the kokanee salmon reared in the Spokane Tribal Hatchery are transferred to the Sherman Creek Hatchery in early spring for rearing in raceways and net-pens, prior to release as yearlings (Table 3.24).

**Table 3.24 Summary of hatchery origin kokanee salmon released** into Lake Roosevelt from 1988 though 1998.

| 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 |
| 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 |
| 1994 | Sherman Creek | 1,087,161 | fry | 372 |
| 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 |
| 1995 | Sherman Creek | 164,328 | yearling | 28 |
| 1996 | Spokane Tribal | 54,194 | yearling | 9 |
| 1996 | Sherman Creek | 224,562 | yearling | 14 |
| 1996 | Sherman Creek | 50,899 | fry | 52 |
| 1997 | Spokane Tribal | 40,808 | yearling | 7 |
| 1997 | Spokane Tribal | 54,103 | fry | 117 |
| 1997 | Sherman Creek | 220,191 | yearling | 15 |
| 1997 | Sherman Creek | 261,092 | fry | 41 |
| 1998 | Spokane Tribal | 49,750 | yearling | 11 |
| 1998 | Spokane Tribal | 365,542 | fry | 120 |
| 1998 | Sherman Creek | 501,206 | yearling | 12 |
| 1998 | Sherman Creek | 87,421 | fry | 82 |

The combined Sherman Creek State Fish Hatchery and Spokane Tribal Hatchery original production goals were initially 8 million kokanee salmon fry for release into Lake Roosevelt and 500,000 rainbow trout fry for the Lake Roosevelt Net Pen Program. 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, until production of kokanee started to shift to yearlings.

In 1994 Tilson et al. (1994) recommended that fry releases for kokanee salmon be discontinued, and that kokanee salmon be released as yearlings. The recommendation was made based on CWT tag return data indicating increased survival of kokanee salmon released as yearlings relative to those released as fry. Therefore, beginning in 1995, a shift towards yearling production of kokanee salmon was undertaken at both Sherman Creek Hatchery and the Spokane Tribal Hatchery in hopes of increasing angler harvest, and adult returns to egg collection facilities. This stocking strategy has not increased angler harvest, hatchery returns, and has reduced the number of kokanee salmon being stocked into Lake Roosevelt.

Stocking strategies, lake operations and predation have previously been identified as major factors effecting recruitment of hatchery origin kokanee salmon into the Lake Roosevelt fishery (Tilson et al. 1995; Chicosz et al. 1999; and Baldwin et al. 1999). However, recent emphasis on planting large numbers of yearling kokanee, may have created a new limiting factor. Since 1995 with the implementation of yearling kokanee salmon stocking, the relative proportions of precocious (sexually mature) hatchery origin kokanee salmon in the population have apparently increased (T. Peone, personal communication). These precocious individuals were first identified in the kokanee culture program in 1997 (T. Peone, personal communication).

Fish culture induced precocity is associated with near optimal growth conditions in a fish culture environment, and can be stock dependent. Contemporary fish culture practices promote good fish health, maintenance of suitable water temperatures resulting in improved food conversion rates and high growth rates, all of which likely contribute to the increased precocity rates observed.

Hatchery origin (Spokane and Sherman Creek Hatcheries) kokanee salmon have represented a small component (2 to 10 percent) of the annual kokanee catch by both anglers and fisheries agencies evaluating the Lake Roosevelt fishery. The reason for the small contribution of the hatchery kokanee is not fully understood, however it is suspected that precocity, predation, and entrainment losses combined are all contributory factors. The bulk of the kokanee salmon observed in the creel and annual test fisheries are suspected to be either originating from upstream reservoirs, or from an as yet to be identified in-reservoir, or tributary(s) natural production sites.

The consensus of the Lake Roosevelt fishery managers is that the kokanee hatchery program will not live up to full expectations until fish entrainment problems are minimized, suitable kokanee stocks are identified, fish culture practices are modified to reduce the frequency of precocious individuals in the kokanee salmon culture program, and predation problems are fully addressed.

**Rainbow Trout:** The Lake Roosevelt Development Association (LRDA) a nonprofit group operates the Net Pen Program for rainbow trout. The LRDA operates approximately 30 net pens at Hunters, Seven Bays, Two Rivers, Keller Ferry, Lincoln, Hall Creek and Kettle Falls, largely through volunteer efforts. Stocking strategies for rainbow trout have historically involved hatchery incubation to juvenile size, and then net pen rearing to a yearling stage, and have to date been the most successful of the hatchery production programs (Table 3.25).

Rainbow trout are stocked in net pens during October and held until May or June when they are released as yearlings. Prior to release, approximately 20,000 plus rainbow trout test groups are selected from the net pen operations, or raceways. All fish are measured to the nearest millimeter, and tagged with individually numbered floy (anchor) tags into the posterior base of the dorsal fin. Once measured and tagged, rainbow trout are returned to the net pens until release.

**Table 3.25 Summary of hatchery origin rainbow trout (catchables) released into Lake Roosevelt from 1986 though 1998.**

| 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 | 565,172 |
| 1997 | Spokane Tribal | 565,172 |
| 1998 a/ | Spokane Tribal | 541,447 |

a/ In 1998 an additional 125,674 fry were stocked at different locations in Lake Roosevelt.

To maximize angler tag returns for adipose clipped, floy or CWT tagged kokanee salmon and rainbow trout, informational posters describing the Lake Roosevelt Fisheries Evaluation 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 identifying marks and tags and requested that anglers return fish capture data with the following recapture information; 1) recapture date, 2) location, 3) fish length, and 4) fish weight. Anglers returning tag information are sent a letter informing them of the fish release date, location, and length at release. Anglers are also provided with a brief summary of the tagging program. Tag return data has been used to estimate growth rates of rainbow trout within Lake Roosevelt, and entrainment rates of these species from Lake Roosevelt.

**3.6 Reservoir Operations and Entrainment:** 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, and have a pronounced influence on the aquatic biota of Lake Roosevelt.

**Reservoir Operations**: Reservoir operations from late fall to late winter are determined by hydropower production, resulting in lower, but relatively stable reservoir levels (Table 3.26). Reservoir operations from late winter to late spring are determined by spring runoff, and resultant flood control requirements, and are characterized by substantial reductions in reservoir elevations and reduced water residence times (WRT's). Reservoir operations from early summer through early fall are generally directed at refill, and maintenance of stable summer/early fall water recreation levels (Table 3.26).

WRT's are closely related to reservoir flow conditions (inflow/outflow), and spring time WRT's below thirty days (reservoir discharge greater than 100,000 cfs; (Table 3.26 and Figure 4) have been linked to increased entrainment rates of kokanee salmon and rainbow trout from Lake Roosevelt (Griffith et al. 1995; Scholz 1991; Chichoz 1999).

Operations of hydroelectric and flood control facilities affects the physiochemical properties of impounded water and associated biological communities (Cole and Deitner 1991). The impacts are related to water levels changes, the location and operation of the withdrawal facilities (penstocks), and the shape of the reservoir basin. Run of river projects with minimal storage have less impact on the stream's biological community natural fluctuations (Loar and Hildebrand 1981; Stober 1983). Use of impounded water to generate electricity, or flood control adversely affects reproduction of fish and benthos, energy transfer, and recruitment and entrainment of nutrients, fish, and other biota through the dam penstocks, or spillways during periods of high reservoir discharges and reservoir elevation manipulations (Table 3.26 and Figure 3).

Reservoir operations and annually variable water level manipulations have virtually eliminated littoral zone habitats, and associated littoral zone productivity (e.g. macroinvertebrate production, aquatic macrophytes, shoreline vegetation, etc.). Consequently, many fish populations in the reservoir are dependent on annually variable in-reservoir periphyton, phytoplankton, and zooplankton production. Observed growth rates and condition factors of salmonid populations in the reservoir (kokanee and

**Table 3.26 Comparison of monthly mean outflow, water retention times (WRT), and elevations in Lake Roosevelt for years of record 1991 to 1998.**

| Year of Record | 1991 a/ | 1992 | 1993 | 1994 | 1995 | 1996 a/ | 1997 a/ | 1998 |
|---|---|---|---|---|---|---|---|---|
| **Mean Outflow (kcfs)** | | | | | | | | |
| January | 142.0 | 101.5 | 100.5 | 77.2 | 88.3 | 154.9 | 141.6 | 107.2 |
| February | 131.3 | 77.7 | 85.9 | 103.6 | 94.0 | 154.9 | 142.4 | 129.6 |
| March | 151.0 | 92.6 | 53.9 | 77.7 | 90.1 | 144.4 | 129.2 | 107.4 |
| April | 153.4 | 79.3 | 48.4 | 73.0 | 84.5 | 147.7 | 152.7 | 67.8 |
| May | 146.4 | 112.1 | 119.0 | 99.6 | 93.5 | 167.8 | 218.4 | 132.9 |
| June | 145.7 | 131.7 | 95.7 | 135.9 | 117.8 | 173.1 | 258.1 | 142.6 |
| July | 129.6 | 80.6 | 97.2 | 95.8 | 110.5 | 157.9 | 169.2 | 116.3 |
| August | 125.7 | 81.7 | 81.7 | 73.3 | 91.9 | 131.2 | 135.3 | 105.3 |
| September | 78.0 | 73.0 | 73.0 | 55.9 | 65.9 | 90.8 | 97.5 | 76.2 |
| October | 84.7 | 65.9 | 62.5 | 64.0 | 80.6 | 90.7 | 106.6 | 65.6 |
| November | 87.9 | 81.9 | 84.2 | 75.7 | 91.9 | 93.9 | 95.1 | 76.0 |
| December | 87.9 | 109.9 | 109.9 | 83.5 | 141.6 | 110.7 | 127.8 | 95.7 |
| **Mean WRT (Days)** | | | | | | | | |
| January | 32.2 | 45.1 | 40.2 | 61.8 | 49.3 | 28.4 | 30.3 | 37.3 |
| February | 34.1 | 59.0 | 44.0 | 42.5 | 42.6 | 31.7 | 23.3 | 26.7 |
| March | 25.0 | 48.4 | 67.1 | 54.9 | 42.4 | 23.9 | 23.4 | 32.9 |
| April | 17.7 | 51.2 | 87.1 | 55.0 | 47.5 | 18.6 | 15.9 | 61.6 |
| May | 18.5 | 34.4 | 39.4 | 44.0 | 39.4 | 15.7 | 10.8 | 33.8 |
| June | 29.2 | 33.7 | 49.6 | 30.1 | 40.1 | 21.8 | 16.1 | 33.3 |
| July | 35.8 | 62.1 | 46.9 | 43.5 | 41.4 | 29.4 | 27.1 | 39.0 |
| August | 37.0 | 56.8 | 56.8 | 58.7 | 47.2 | 34.3 | 33.2 | 42.6 |
| September | 59.1 | 61.0 | 61.0 | 78.4 | 69.0 | 47.9 | 46.5 | 57.2 |
| October | 55.8 | 69.0 | 73.5 | 72.6 | 56.7 | 49.2 | 42.8 | 68.3 |
| November | 53.2 | 56.3 | 51.4 | 60.1 | 50.4 | 48.3 | 47.7 | 61.1 |
| December | 53.2 | 37.5 | 37.5 | | | | 33.5 | 47.0 |
| **Mean elevation (add 1,200 = ft. MSL)** | | | | | | | | |
| January | 83.9 | 87.1 | 67.5 | 85.4 | 78.3 | 81.6 | 73.0 | 68.8 |
| February | 85.1 | 87.8 | 63.5 | 81.8 | 66.3 | 80.7 | 53.7 | 58.2 |
| March | 67.5 | 81.4 | 56.0 | 76.5 | 59.0 | 58.5 | 39.4 | 55.0 |
| April | 35.4 | 67.9 | 71.8 | 68.1 | 65.8 | 35.1 | 20.8 | 69.5 |
| May | 34.9 | 66.4 | 84.7 | 80.5 | 59.8 | 32.3 | 23.4 | 81.6 |
| June | 75.2 | 81.1 | 87.5 | 76.0 | 83.6 | 67.8 | 75.3 | 87.6 |
| July | 88.3 | 86.6 | 86.4 | 74.9 | 86.9 | 87.9 | 87.7 | 86.6 |
| August | 88.5 | 85.9 | 85.9 | 77.1 | 80.9 | 84.9 | 85.8 | 82.4 |
| September | 87.0 | 81.3 | 81.3 | 81.3 | 85.1 | 80.7 | 84.4 | 81.0 |
| October | 87.0 | 84.1 | 81.9 | 87.2 | 85.8 | 84.1 | 83.9 | 83.1 |
| November | 86.7 | 84.2 | 78.8 | 84.7 | 86.5 | 84.2 | 86.5 | 81.3 |
| December | 86.0 | 73.0 | 79.0 | 84.2 | 87.0 | 78.5 | 80.3 | 79.2 |

a/ Years with low average monthly spring WRT's/low reservoir elevations, and high entrainment rates.

rainbow) indicate that at current population levels, planktonic forage productivity and availability (zooplankton) appear to be ample. Reservoir productivity is, however, annually quite variable (Shields and Underwood 1997). Lake Roosevelt productivity is in a downward trend due to reservoir aging, absence of returning salmon and associated carcass nutrients, and reductions in waste effluent from commercial and municipal facilities.

Based on relative abundance surveys, many spring spawning prey fish species that attempt reproduction prior to, or during spring lake elevation draw downs appear to experience frequent year class failures, and are not successfully recruiting individuals into the Lake Roosevelt food web.

Walleye are primarily spawning in the headwaters of main tributaries (San Poil and Spokane arms) in the spring during reservoir draw downs, and based on relative population size appear to be less vulnerable to the effects of main-stem reservoir elevation manipulations, than other mainstem spring spawning species. This hypothesis is supported by the increasing relative abundance of walleye and the decreasing abundance of main stem spring spawning prey species.

In August 1994, Lake Roosevelt began releasing water to meet anadromous fish needs to satisfy downstream flow targets for endangered species identified in the National Marine Fisheries Service's (NMFS) Biological Opinion (BO). From 1995 to 1998 Lake Roosevelt late flow augmentation releases have varied depending on other Columbia River basin stream flow needs. At present, negotiations are being conducted under the auspices of the ESA, which will require more reservoir release and storage manipulations to augment downstream anadromous fish smolt escapement, and adult spawning and migration flows. The in-reservoir environmental impacts of additional reservoir elevation manipulations are not known. It is believed, based on reservoir ecological and fisheries biological data collected by the Lake Roosevelt Fisheries Evaluation Program concerning seasonal reservoir elevation manipulations (e g. flood control, hydropower, and downstream fisheries flow augmentations), that any additional abiotic seasonal and annual reservoir elevation manipulations will be particularly detrimental to the tenuous ecological reservoir stability, and aquatic biota of Lake Roosevelt.

Flood control and hydropower management water level manipulation of Lake Roosevelt substantially limits the rainbow trout and kokanee salmon fisheries through annual entrainment losses, and substantially reduces the successful reproductive activities of spring spawning prey species utilized by walleye. These losses are especially acute during high water years (outflows greater than 110-120 KCFS), with associated shortened spring WRT's, and reduced lake elevations, such as 1990-1991, 1996-1997 (Tables 3.27, 3.28; and Figures 3 and 4). Also, deeper drafts of the reservoir cause slower refills, which delays spring water temperature warming, associated plankton blooms, and subsequent reduced juvenile fish survival.

It should be noted that entrainment investigations with the longest database, have utilized tagged rainbow trout as a surrogate for hatchery salmonid species entrainment (Table 3.28). Based on all historical stocking data, harvest data, age class structure, species-specific migratory behavior, and the tendency of kokanee salmon to concentrate in the most productive areas of Lake Roosevelt near Grand Coulee Dam, it is likely that entrainment rates for kokanee salmon substantially exceed that of rainbow trout (Figure 4.1). The numbers and ages of kokanee and rainbow stocked is approximately the same, however, the inconsistencies of kokanee salmon in the creel, indicate that the number of rainbow trout annually recruited to the creel is approximately 7 to 8 times the number of kokanee observed for the years of record 1990 to 1998 (Figure 4.1).

Our entrainment indices for rainbow trout tagged at both Kettle Falls 99% and Seven Bays 95% during 1997 was the highest ever recorded by the Lake Roosevelt Fisheries Evaluation Program (Table 3.28). During 'normal' water years (1988, 1990, 1992-95 and 1998) our entrainment indices have generally been low for rainbow trout (0-3%) with the exception of the1990 release group (32%; Table 3.28). In contrast, during high water years (1989, 1991, 1996 and 1997) our entrainment indices were considerably higher (15-97%; Table 3.28) for rainbow trout released into Lake Roosevelt, resulting in poor fishing opportunities.

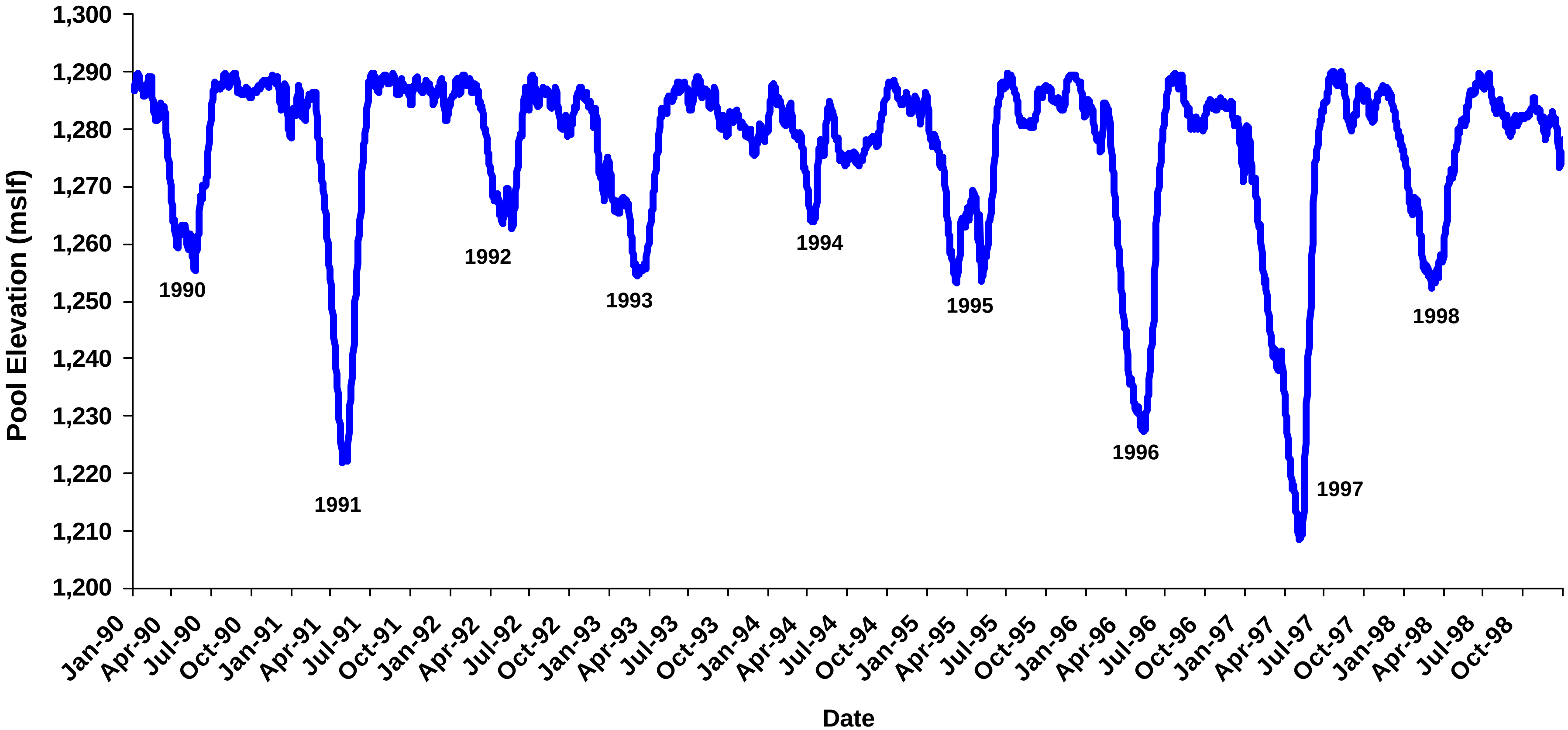


**Figure 3.** Lake Roosevelt hydrograph 1990-1998 illustrating the magnitude of spring flood control and hydropower releases on reservoir elevations (MSL). The reservoir draw down years of record 1991, 1996 and 1997 resulted in marginal angling success rates.

In Lake Roosevelt, it is apparent that the entrainment of fish occurs from a significant to catastrophic degree, depending on species and water year.

Due to sampling difficulties, the magnitude of the impact of entrainment on the fishery has not been precisely quantified regarding species and total numbers entrained.

It is known, extensive back-to-back reservoir draw owns during 1996 and 1997 resulted in detrimental fishery entrainment conditions more acute than those historically observed regarding lake elevations manipulations and water retention times in Lake Roosevelt (Figure 4). Entrainment of fish from the reservoir has been identified as one of the more significant problems limiting the Lake Roosevelt fishery that needs to be curtailed, to began to realize the potential of the hatchery production programs necessary to provide a fishery for Lake Roosevelt. Entrainment loss estimates of rainbow trout conducted by the Spokane Tribal Fisheries (STI-tag return data) estimate that entrainment may conservatively vary from 0 to 97 percent (Cichosz et al. 1999). Concurrently, pelagic entrainment loss estimates calculated by the Washington Department of Fish and Wildlife and Colville Confederated Tribes, utilizing hydroacoustic penstock intake sampling, and pelagic monitoring and sampling estimated annual entrainment losses of pelagic fish species at 22 to 99 percent (Baldwin et al. 1999; LeCaire 1999).

In 1998, kokanee salmon and rainbow trout were released into Lake Roosevelt following the draw down period, and the success of those releases, and overall water reservoir water management probably contributed to the improved 1998 harvest.

Historically, net-pen rainbow have been released into Lake Roosevelt in spring or early summer (March-June). Cichosz et al. (1998) suggested that entrainment rates are not only a function of WRT, but also draw down/refill scenarios at the time when fish are released into Lake Roosevelt. To evaluate this hypothesis, the relationship between entrainment and WRT for rainbow trout released during draw down was evaluated (March-April) and refill (May-June) in Lake Roosevelt for the years of record 1988 to 1998 (Figure 5).

**Table 3.27 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: ReleaseYear Returns | +1 | +2 | +3 | +4 | +5 | Tags Returned | Tag Return Rate | Entrainment Index–All Years of Record |
|---|---|---|---|---|---|---|---|---|---|---|
| **1988** | **1,171** | 77 (0) | 16 (0) | 1 (0) | | | | **94 (0)** | **8%** | **0%** |
| **1989** | **1,753** | 15 (2) | 28 (2) | 1 (0) | 3 (0) | | 2 (1) | **49 (5)** | **4%** | **10%** |
| **1990** | **4,361** | 72 (21) | 19 (8) | 3 (0) | 1 (1) | 1 (1) | | **96 (31)** | **3%** | **32%** |
| **1991** | **4,345** | 205 (32) | 45 (4) | 2 (1) | 1 (1) | | | **253 (38)** | **7%** | **15%** |
| **1992** | **20,997** | 509 (12) | 10 (0) | | | | | **519 (12)** | **3%** | **2%** |
| **1993** | **21,261** | 108 (2) | 34 (2) | 3 (0) | | | | **145 (4)** | **<1%** | **3%** |
| **1994** | **26,975** | 307 (8) | 64 (3) | 3 (0) | 1 (0) | | | **375 (11)** | **1%** | **3%** |
| **1995** | **12,984** | 104 (1) | 12 (1) | 4 (0) | | | | **120 (2)** | **1%** | **2%** |
| **1996** | **14,948** | 202 (55) | 40 (7) | | | | | **242 (62)** | **2%** | **26%** |
| **1997** | **20,000** | 151 (146) | 0 (0) | | | | | **151 (146)** | **<1%** | **97%** |
| **1998** | **19,981** | 601 (19) | 0 (0) | | | | 7 (2) | **629 (21)** | **3%** | **3%** |
| **Total** | **148,776** | **2351 (319)** | **258 (27)** | **17 (1)** | **6 (2)** | **1 (1)** | **9 (3)** | **2673 (332)** | **Avg 3%** | **Avg 18%** |

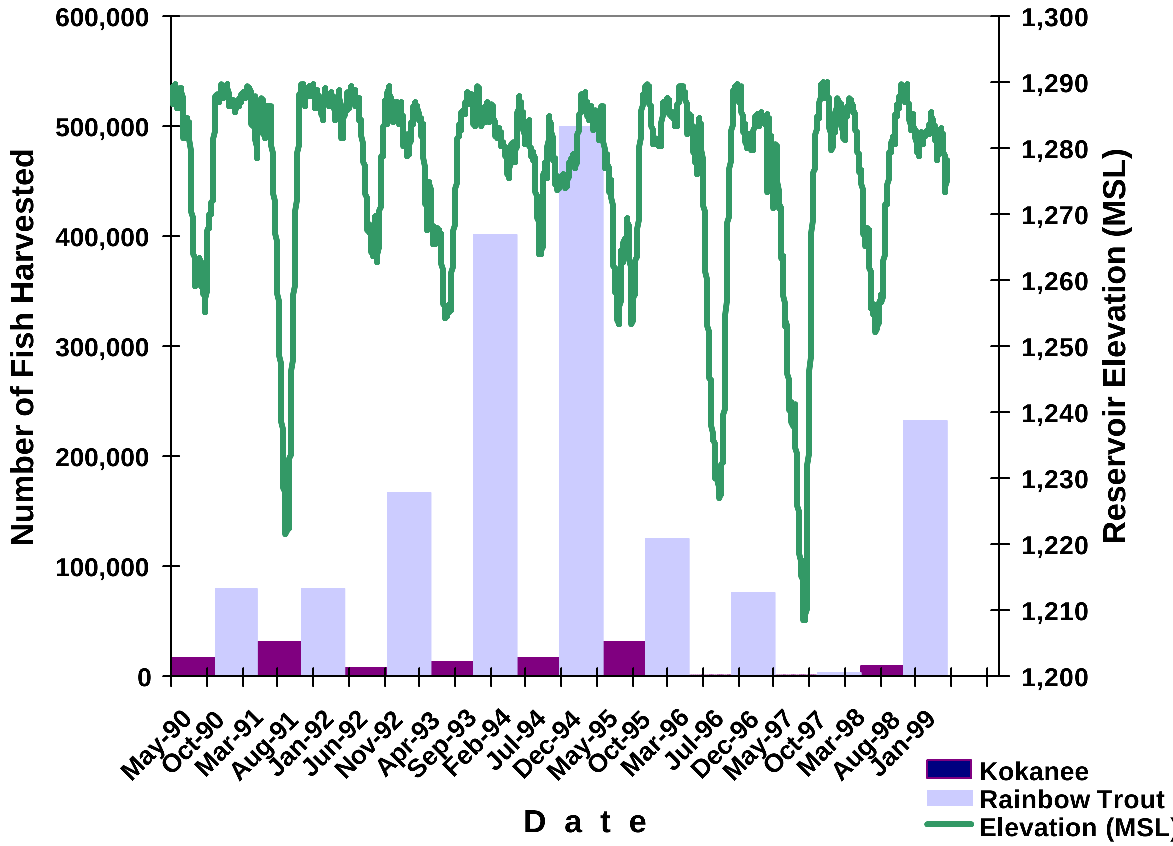


**Figure 4.** **Reservoir discharge for years of record 1991-1998 (avg daily cfs) during peak spring runoff (April-June), as related to annual standing crop of catchable sport fish species.**

*Note: Charted catch data assumes that the catchable population of target fish species is related to the standing crop of fish in the reservoir. Chart also assumes that reservoir outflow and corresponding low WRT's from April-June are responsible for majority of springtime instantaneous fish entrainment from reservoir. High water years (high reservoir outflow/low WRT's) result in poor angling success.

Based on this analysis, if monthly WRT's are less than 20 days when rainbow trout are released from net-pens, high entrainment rates can be expected, regardless of the timing of release (Figure 5).

However, when monthly WRT's and corresponding high reservoir discharges exceed 20 days in the month of release, there appears to be a distinct advantage to holding fish until June, or later depending on the level of reservoir refill and corresponding WRT's to minimize entrainment. The 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 even later release in June or early July (Cichosz et al. 1998). 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 (Table 3.27 and Figure 3).

Spring draw downs in 1989, 1991, 1996 and 1997 resulted in water levels well below 1,240 MSL and water retention times less than 30 days (Figure 3 and Table 3.26), 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; and Cichosz et al. 1997).

In 1998, kokanee salmon and rainbow trout were released into Lake Roosevelt following the draw down period, and the success of those releases and overall reservoir water management probably contributed to the 1998 harvest. The draw down of Lake Roosevelt during 1998 was relatively 'fish friendly' resulting in monthly mean minimum water levels of 1,255' MSL (Table 3.28), and did not entrain fish in numbers similar to the previous two years (1996 and 1997). These two factors in all likelihood contributed in larger numbers of hatchery fish recruited into the Lake Roosevelt fishery during 1998.

While entrainment losses in 1998 were not as severe as the previous two years, the fishery, and reservoir ecosystems are still recovering from the extreme reservoir manipulations experienced the previous two years.

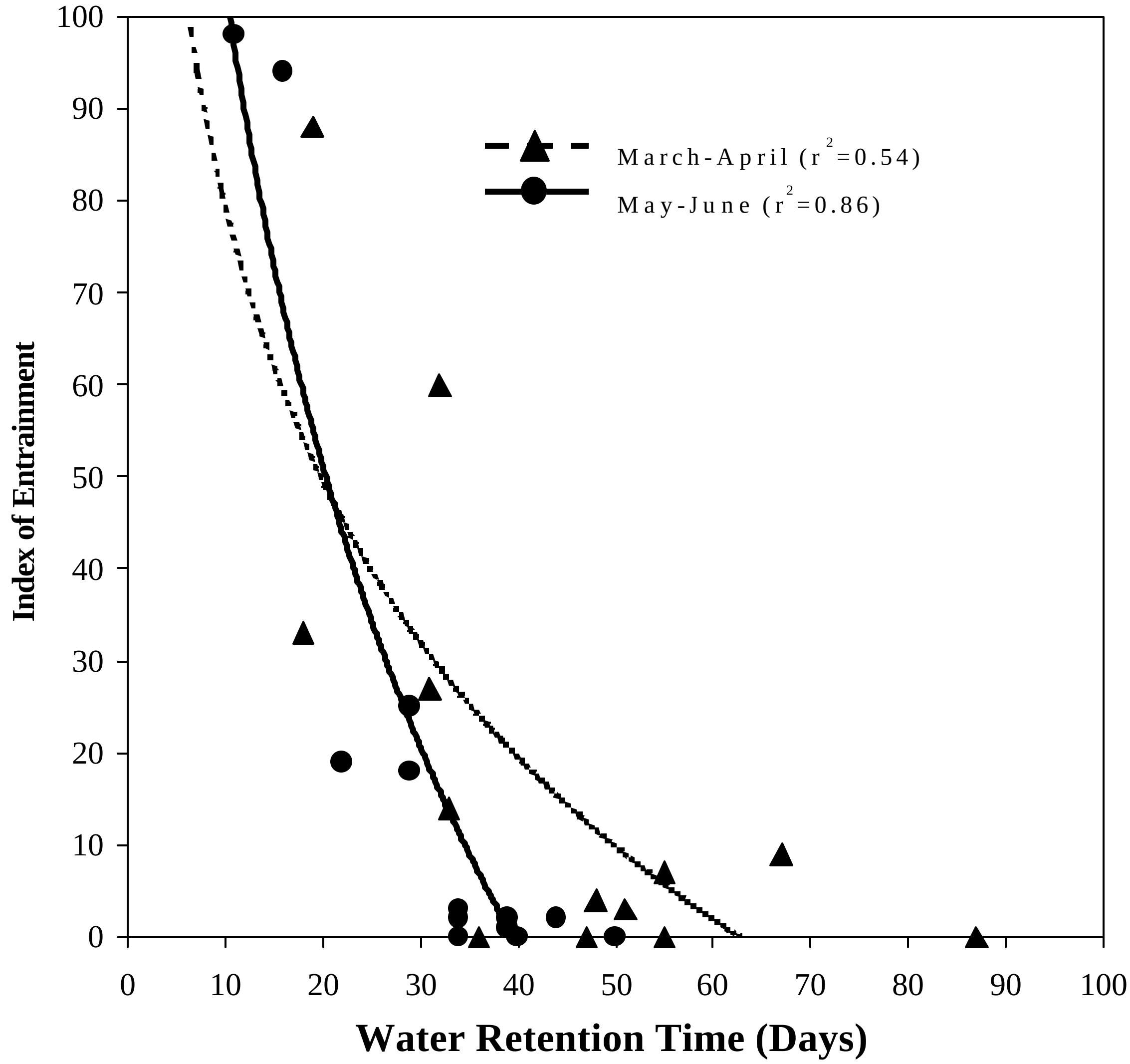


**Figure 5.** **Relationship between entrainment of rainbow trout (Tag Return Index) and water retention time (WRT) from 1988 to 1998. Data includes angler tag returns (above and below Grand Coulee Dam), and Fish Passage Center tag reports (below Grand Coulee Dam).**

**Table 3.28 Monthly and annual means for reservoir inflow, outflow, spill, reservoir elevation, storage capacity, and water retention time for Lake Roosevelt in 1998.**

| Month | Inflow (kcfs) | Outflow (kcfs) | Spill (kcfsd) | Reservoir Elevation (ft) | Storage Capacity (kcfsd) | Water Retention Time (Days) |
|---|---|---|---|---|---|---|
| January | 99.1 | 107.2 | 0.02 | 1268.8 | 3777.0 | 37.3 |
| February | 112.9 | 129.6 | 0.00 | 1258.2 | 3404.9 | 26.7 |
| March | 112.2 | 107.4 | 0.51 | 1255.0 | 3297.3 | 32.9 |
| April | 93.6 | 67.8 | 0.00 | 1269.5 | 3804.3 | 61.6 |
| May | 148.3 | 132.9 | 1.39 | 1281.6 | 4254.8 | 33.8 |
| June | 149.0 | 142.6 | 2.53 | 1287.6 | 4492.0 | 33.3 |
| July | 118.0 | 116.3 | 0.10 | 1286.6 | 4454.2 | 39.0 |
| August | 107.6 | 105.3 | 0.10 | 1282.4 | 4285.0 | 42.6 |
| September | 85.6 | 76.2 | 0.10 | 1281.0 | 4231.8 | 57.2 |
| October | 69.8 | 65.6 | 0.00 | 1283.1 | 4312.8 | 68.3 |
| November | 74.9 | 76.0 | 0.00 | 1281.3 | 4242.8 | 61.1 |
| December | 91.8 | 95.7 | 0.00 | 1279.2 | 4161.2 | 47.0 |
| **Mean 1998** | **105.3** | **101.8** | **0.40** | **1276.3** | **4161.2** | **45.0** |

Studies are currently being implemented by the Colville Confederated Tribes, Bonneville Power Administration, and the U.S. Bureau of Reclamation to assess and develop mitigative measures for fisheries entrainment losses. The first segment of the initial four-year study utilized hydroacoustics to evaluate pelagic fish losses (Baldwin et al. 1999; LeCaire 1999). Hydroacoustic testing will be conducted with strobe lights, to evaluate fish avoidance response to the lights, in an attempt to keep fish away from the third powerhouse cul-de-sac, where 80-90 percent of the entrainment losses occurred between 1996 and 1999 (R. LeCaire, personnal communication).

# 4.0 Summary and Recommendations

**Fisheries:** The following summarizes principle sport fisheries species (rainbow trout, kokanee salmon, and walleye) statistics for the years 1990 through 1998. These statistics include; economics, annual angler trips, number of selected species caught and harvested, annual catch per unit effort (CPUE), annual harvest per unit effort (HPUE), length data, and hydrologic data as it relates to the 1990 through 1998 fishery (Table 4.1).

**Rainbow trout:** Rainbow trout stocked into Lake Roosevelt from net pens contribute substantially to the fishery. The majority of rainbow trout stocked from net pens recruit into the fishery in the same year as being stocked (Peone et al. 1990; Griffith and Scholz 1991; Griffith et al. 1995; Griffith and McDowel 1996; Voeller 1996). Since 1994, rainbow trout averaged approximately 63% (range 5-82%) of the estimated total harvest from Lake Roosevelt. The percentage of rainbow trout harvested that were determined to be of net pen origin has ranged from 91.5% (1995) to 100% (1997). During 1998, rainbow trout accounted for 64 % of the estimated harvest of "all" species from Lake Roosevelt, and over 98 percent of those harvested were of net pen origin.

Estimates of rainbow trout catch and harvest showed an increasing trend from 1991 through 1994, declined steadily through 1997, and rebounded during 1998. Based on creel data, estimated catch of rainbow trout in 1998 was the third highest since 1990, being surpassed only in 1993 and 1994 (Table 4.1). In 1998, approximately 500,000 rainbow trout were stocked into Lake Roosevelt, and the resulting harvestable return to anglers was approximately 233,036 respectively (Tables 3.24, 3.25 and 4.1). In 1998, this represents an approximate hatchery to angler harvest return rate of 47 percent (Table 4.1).

**Table 4.1 Summary of economics, angler trips, number of fish caught and harvested, catch and harvest per unit of effort and mean lengths of kokanee, rainbow trout, and walleye; annual mean WRT days, annual mean reservoir elevations, and annual reservoir discharges (KCFS), for the years of record 1990-1998.**

| Year of Record | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 |
|---|---|---|---|---|---|---|---|---|---|
| **Economic Value Million/Dollars** | $5.30 | $12.80 | $9.70 | $20.70 | $19.20 | $8.70 | $6.90 | $5.80 | $8.00 |
| **Angler Trips** | 171,725 | 398,408 | 291,380 | 594,508 | 469,998 | 232,202 | 176,769 | 146,264 | 196,775 |
| **No. Fish Caught** | | | | | | | | | |
| Kokanee salmon | 17,756 | 31,651 | 8,146 | 13,986 | 16,567 | 32,353 | 1,265 | 588 | 10,188 |
| Rainbow trout | 81,560 | 81,529 | 167,156 | 402,277 | 499,460 | 125,958 | 76,915 | 5,356 | 233,036 |
| Walleye | 116,473 | 231,813 | 163,995 | 337,413 | 123,612 | 73,667 | 142,873 | 147,316 | 133,241 |
| **No. Fish Harvested** | | | | | | | | | |
| Kokanee salmon | 17,515 | 31,651 | 8,021 | 13,960 | 16,567 | 32,353 | 1,265 | 588 | 9,980 |
| Rainbow trout | 79,683 | 73,777 | 140,609 | 398,943 | 499,293 | 122,939 | 76,782 | 5,356 | 226,809 |
| Walleye | 82,284 | 168,736 | 118,863 | 307,663 | 53,589 | 40,185 | 104,055 | 87,515 | 119,346 |
| **CPUE (per hr)** | | | | | | | | | |
| Kokanee salmon | 0.03 | 0.06 | 0.03 | 0.01 | <0.01 | 0.02 | <0.01 | <0.01 | 0.02 |
| Rainbow trout | 0.13 | 0.2 | 0.22 | 0.17 | 0.21 | 0.08 | 0.1 | 0.01 | 0.18 |
| Walleye | 0.11 | 0.11 | 0.15 | 0.12 | 0.08 | 0.13 | 0.3 | 0.34 | 0.1 |
| **HPUE (per hr)** | | | | | | | | | |
| Kokanee salmon | 0.02 | 0.06 | 0.03 | 0.01 | <0.01 | 0.02 | <0.01 | <0.01 | 0.02 |
| Rainbow trout | 0.12 | 0.2 | 0.18 | 0.16 | 0.21 | 0.08 | 0.1 | 0.01 | 0.18 |
| Walleye | 0.08 | 0.08 | 0.11 | 0.08 | 0.05 | 0.06 | 0.16 | 0.17 | 0.09 |
| **Mean Length (mm)** | | | | | | | | | |
| Kokanee salmon | 391 | 361 | 436 | 486 | 481 | 467 | 438 | 338 | 356 |
| Rainbow trout | 346 | 348 | 422 | 471 | 473 | 410 | 363 | 395 | 364 |
| Walleye | 376 | 397 | 361 | 382 | 385 | 370 | 372 | 372 | 352 |
| **Mean WRT (Days)** | N/A | 36.1 | 52.5 | 56.5 | 54.7 | 47.8 | 31.7 | 29.2 | 45.1 |
| Std. Dev. | N/A | ± 14.3 | ± 11.3 | ± 14.9 | ± 14.1 | ± 8.7 | ± 12.1 | ± 12.1 | ± 13.7 |
| **Mean Lake Elevation** | | | | | | | | | |
| Add 1,200 ft=ft (MSL) | N/A | 75.4 | 80.6 | 77.1 | 54.7 | 54.7 | 71.4 | 66.2 | 76.2 |
| Std. Dev. | N/A | ± 19.8 | ± 7.4 | ± 10.1 | ± 17.8 | ± 11.2 | ± 19.4 | ± 27.4 | ± 21.7 |
| **Mean Reservoir** | | | | | | | | | |
| **Outflow (KCFS)** | N/A | 121.9 | 90.7 | 82.1 | 84.6 | 95.9 | 134.8 | 147.9 | 101.9 |
| Std. Dev. | N/A | ± 28.9 | ± 19.3 | ± 20.3 | ± 21.4 | ± 19.5 | ± 30.6 | ± 48.2 | ± 26.1 |

**Kokanee salmon:** Increased numbers of kokanee salmon were caught and/or harvested during 1998 relative to 1996 and 1997. The 1998 harvest was approximately 17 times that of 1997, and 8 times that of 1996, however, the increased percentage of fish in the creel represent a small proportion of the number of fish stocked into the reservoir. . Improved 1998 reservoir water elevation management may partially explain the observed increase in kokanee salmon harvest during 1998.

The 1998 kokanee salmon fishery in Lake Roosevelt may also have benefited from1997 recruitment of kokanee salmon to Lake Roosevelt through entrainment from upstream reservoirs (Underwood et al. 1996). Currently, the Colville Confederated Tribes are conducting a microsatelite DNA analysis study to determine the origin of the unmarked kokanee observed in the Lake Roosevelt fishery.

In summary, it is believed that reservoir entrainment, fish culture induced precocity, and predation are major contributory factors preventing kokanee salmon from recruiting into the fishery.

**Walleye:** A slot limit exists for walleye in Lake Roosevelt, requiring the release of walleye between 406 mm and 508 mm (16-20 inches) in length, resulting in catch rates that exceed harvest rates in all years. Estimated catch (HPUE) and harvest rates for walleye in Lake Roosevelt during 1998 were similar to those noted in previous years, with the exception of 1996 and 1997 (Table 4.1). During 1998, the percentage of anglers targeting walleye (27%) was reduced relative to 1996 and 1997 (44% and 56%, respectively), and comparable to that observed between 1990 and 1995 (18-29%). Creel results indicate that during 1998, approximately 10 percent of walleye caught by anglers in Lake Roosevelt were released (Table 4.1).

The Lake Roosevelt fishery is consumptive in nature, so we assume that the vast majority of walleye released by anglers are either relatively small fish (< 350 mm), or fall within the protective slot limit established by the WDFW. Therefore, year class strength probably has a notable impact on the walleye fishery and particularly on the percentage of fish released during any year (Table 4.1).

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 in the future, and to assist in defining any changes necessary to maintain a successful "multispecies fishery." At this time we feel that given the low abundance of reservoir prey fish, existing regulations may be contributing to a top-heavy predator based system (J. Spotts, personal observation).

Typically, for reservoirs, fisheries managers have assumed the existence of relatively simple predator-prey relationships as in lacustrine systems. Managers often use manipulation of apex predators to manage surplus prey species and set their management goals accordingly.

Operations of hydroelectric and flood control projects affect reservoir fish species production, biological communities, and physiochemical properties of impounded water (Table 4.1). The impacts are both indirectly and directly related to drastic spring-early summer elevation manipulations, which have major adverse impacts to reservoir prey species reproductive efforts. Substantially receding water levels during spawning activities, depending on the magnitude of reservoir elevation manipulations, result in desertion of nests, disruption of spawning, and direct egg mortality (Groen and Schroeder 1978). Species differ with regard to the frequency and magnitude of water level fluctuation that can be tolerated before production and recruitment of young is affected (Baxter 1977; Noble 1981). These differences depend upon the life cycles of individual species, including such factors as spawning depth, length of spawning season, number of spawning attempts per season, duration of incubation, and available littoral zone refugia for juvenile fish to utilize.

Declining water levels and natural reproduction are incompatible for littoral spawning species with long incubation and emergence times, depending on the rate that water elevations deteriorate (Keith 1975; Groen and Schroder 1978). Littoral spawning species that are susceptible to rapidly declining water levels include; lake white fish, and burbot (Stober 1983). Declining water levels may also hinder spawning success of for many important prey species found in Lake Roosevelt.

Development of water resources for hydropower generation has beneficial and damaging aspects with regard to fisheries resources. Artificial impoundments, including those constructed for purposes of flood control and hydropower generation, have contributed to the United State's recreational fishing resource base. However, hydropower generation and flood control entails competing uses of water. To minimize such conflicts, reservoir fisheries managers, the angling public, and hydropower generation, irrigation and flood control proponents must adopt a willingness to provide the greatest realistic flexibility in project operations. Only then will we be able to place priorities on operational management objectives that result in predictable fisheries mitigation and compensation.

The Pacific Northwest Power Planning and Conservation Act (P.L. 96-501), which was passed in December 1980, represented a significant step forward in hydropower-fisheries interactions. The Act requires the conservation and restoration of the Columbia Basin's fish and wildlife resources that have been adversely affected by hydroelectric development and operations.

We may have an incomplete understanding of the control mechanisms and annual ecological adjustments of Lake Roosevelt fish populations and food web.
Due to the current influences of water management operations, the complexity of trophic level interactions in Lake Roosevelt may only be understood at a superficial level during periods of relative reservoir stability. Unfortunately, high water years are episodic and competition for upper Columbia River water continues to intensify.

Lake Roosevelt is the major hydropower and flood control point in the Columbia River system, and lake elevation management in the reservoir is the result of multiple upstream reservoirs, and their corresponding management responsibilities in Washington, Idaho, Montana, and Canada.

**4.1 Overview and Recommendations:** Reservoir biological communities, and fish populations are dynamic, and exist in an environment that is highly variable and largely uncontrollable. These abiotic and biotic fluctuations must be accounted for in management decisions, and in interpreting the results from reservoir monitoring and evaluation programs. Responses to management actions may occur over a long time frame, and will require long-term data sets to evaluate biotic responses to management actions, including both fisheries and water management activities. The principle data bases utilized to prepare these recommendations have been analyzed, prepared and compiled, with consistent, and complete data sets of nine plus years.

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

- Continue to work together with stakeholders to maximize benefits of hydro-operations while minimizing detrimental effects to the Lake Roosevelt ecosystem.

- Monitor and evaluate the artificial production program with respect to entrainment, fish culture, stocking strategies, and stock utilization.

- Continue standardized fishery surveys, (1999) last year done to assess long-term changes in the Lake Roosevelt fishery.

- Floy tag 30,000 rainbow trout and 10,000 kokanee salmon to unsure adequate number of tag returns.

- Assess predation as a limiting factor to the artificial production program.

# Section 5.0 Literature Citations

APHA, 1976. Standard methods for the examination of water and wastewater, 14th Edition. American Public Health Association. Washington, D.C.

Bayly, I.A.E., and W.D. Williams. 1973. Inland waters and their ecology. Longman Australia Publishing Company. Victoria, Australia.

Baldwin, C., M. Pollack, and S. Bonar. 1999. Washington Department of Fish and Wildlife Lake Roosevelt pelagic fish study, 1998. Prepared for Bonneville Power Administration. Portland, OR. Washington Department of Wildlife. Olympia, WA. 67 p.

Baxter, R.M. 1977. Environmental effects of dams and impoundments. Pages 255-283 *in* R.F. Johnson, P.W. Frank, and C.D. Michener, editors. Annual review of ecology and systematics. Annual Review Inc. Palo Alto, California.

Beckman, L.G., J.F. Novotny, W.R. Persond, and T.T. Terrel. 1985. Assessment of the fisheries and limnology in Lake Franklin Delano Roosevelt, 1980-83. Final report prepared for the U.S. Bureau of Reclamation. U.S. Fish and Wildlife Service. Willard, WA.

Bowen, S.H. 1983. Quantitative description of the diet. Pages 325-336 in L.A. Nielsen and D.L. Johnson, editors. Fisheries techniques. American Fisheries Society, Bethesda, Maryland.

Brown, L., and K.Williams, 1982. Mid-Columbia walleye fisheries-life history-management, 1979-1982. Washington Department of Game. Olympia, WA. Rep 85-20. 39 p.

Carlander, K.D. 1981. Caution on the use of the regression method of back-calculating, lengths from scale measurements. Fisheries 6:2-4.

Carlander, K.D. 1950. Some considerations in the use of the fish growth data based upon scale studies. Transactions of the American Fisheries Society 79:187-194.

Cichosz, T.C., J.P. Shields, and K.D. Underwood. 1998. Lake Roosevelt monitoring/data collection program, 1996 Annual Report *in* T.A. Cichosz, J.P. Shields, K.D. Underwood, and M. B. Tilson. Lake Roosevelt Fisheries and Limnological Research, 1996 Annual Report. Prepared for Bonneville Power Administration. Portland, OR. Project No. 94-043.

Cole, R.A., and R.A. Deitner. 1991. Sensitivity analysis for fishery management of a fluctuating reservoir simulated by the planning model RIOFISH. *In* Warm water Fisheries Symposium I. Pages 133-144. U.S. forest Service. Rocky Mountain Forest and Range Experiment Station. Ft. Collins, CO. General Technical Report RM-207.

Dumont, H.J., V.V. Isabella and S. Dumont. 1975. The dry weight estimate of biomass in a selection of Cladocera, Copepoda and Rotifera from the plankton, periphyton and benthos of continental water. Oecologia. 19:75-97.

Edmondson, W.T. (ed). 1959. Fresh-water biology. 2nd. ed. John Wiley and Sons. New York.

Edmondson, W.T. and G.G. Winberg. 1971. A manual for the assessment of secondary productivity in fresh waters. IBP Handbook No. 17.

Everhart, W.H. and W.D. Youngs. 1981. Principles of Fishery Science, 2nd Ed. Cornell University Press. Ithaca, New York.

Fisher, W.L., and A.E. Grambsch. 1991. Measuring recreational fisheries values. *In* Warmwater Fisheries Symposium I. Pages 343-349. United States Forest Service. Rocky Mountain Forest and Range Experiment Station. Ft. Collins, CO. General Technical Report RM-207.

Fletcher, D.H. 1988. Phase management research, first year's work at Kitsap Lake, Kitsap County, Washington. Washington Department of Wildlife, Fisheries Management Division, Olympia, Washington. Report No. 88-6:80.

Forbes, S.A., and R.E. Richardson. 1920. The Fishes of Illinois. 2$^{nd}$ Edition. State of. Illinois, Natural History Survey Division. 357 p.

Forney, J.L. 1974. Interactions between yellow perch abundance, walleye predation, and survival of alternate prey in Oneida Lake, New York. Transactions of the American Fisheries Society 103:15-24.

George, E.L. and W.F. Hadley. 1979. Food habitat partitioning between rock bass (*Ambloptites rupestris*) and smallmouth bass (*Micropterus dolomiceu*) young-of-the-year. Transactions of the American Fisheries Society 108:253-261.

Gilwicz, Z.M. and J. Pizanowska. 1989. The role of predation in zooplankton succession. In: Sommer, V. (ed.) Plankton ecology: Succession in planktonic communities. Springer, Berlin. p. 253-296.

Goldman, C.R. and A. J. Horne. 1983. Limnology. McGraw-Hill, New York.

Gray, G.A., G.M. Sonnevil, H.C. Hansel, C.W. Huntington, and D.E. Palmer. 1984. Feeding activity, rate of consumption, daily ration, and prey selection of major predators in John Day Reservoir. Prepared for the Bonneville Power Administration. U.S. Fish and Wildlife Service, National Fishery Research Center. Cook, WA.

Griffith, J.R. and A.C. McDowel. 1996. Measurement of Lake Roosevelt biota in relations to reservoir operations, Annual Report 1992. Bonneville Power Administration. Portland, OR. Project No. 88-63.

Griffith, J.R., A.C. McDowel and A.T. Scholz. 1995. Measurement of Lake Roosevelt biota in relation to reservoir operations. Annual Report 1991. Bonneville Power Administration. Portland, OR. Project No. 88-63.

Griffith, J.R. and A.T. Scholz. 1991. Lake Roosevelt Fisheries Monitoring Program, Annual Report 1990. Bonneville Power Administration. Portland, OR. Project No. 88-63.

Groen, C.L. and T.A. Schroeder. 1978. Effects of water level management on walleye and other cool water fish in Kansas Reservoirs. Pages 278-273 *in* R.L. Kendall, editor. Selected cool water fishes of North America. Special Publication 11, American Fisheries Society. Bethesda, Maryland.

Hall, D.J., C.W. Burns, and P.H. Crowly. 1976. The size-efficiency hypothesis and the size structure of zooplankton communities. Annul. Rev. Ecol. Syst. 7:177-208.

Hile, R. 1970. Body-scale relation and calculation of growth in fishes. Transactions of the American Fisheries Society. 99:468-474.
Horn, H.S. 1966. Measurement of "overlap" in comparative ecological studies. American Naturalist 100:419-429.

Hubert, W.A. 1983. Passive capture techniques. Pages 95-122 *in* L.A. Nielsen and D.L. Johnson, editors. Fisheries techniques. American Fisheries Society, Bethesda, Maryland.
.
Jearld, A. 1983. Age determination. Pages 301-324 *in* L.A. Nielsen and D.L. Johnson, editors. Fisheries techniques. American Fisheries Society, Bethesda, Maryland.

Keith, W.E. 1975. Management by water level manipulations. Pages 489-497. *in* R.H. Stroudand and H. Clepper, editors. Black bass biology and management. Sport Fishing Institute, Washington, D.C.

Kerfoot, W.C. and A. Sih, editors. 1987. Predation: direct and indirect impacts on aquatic communities. University Press of New England. Hanover, New Hampshire.

Kerfoot, W.C. 1995. The divergence of adjacent populations. Ecology 56:1298-1313.

LeCaire, R. 1999. Chief Joseph kokanee enhancement program. Colville Confederated Tribes. Project No. 9501100. Prepared for Bonneville Power Administration. Portland, OR. 69 p.

Lambou, V.W. 1961. Determination of fishing pressure from fishermen of party counts with a discussion of sampling problems. Proceedings of the Southeastern Association of Game and Fish Commissioners: 1961:380-401.

Lambou, V.W., 1966. Recommended method of reporting creel survey data for reservoirs. Oklahoma Fishery Research Laboratory. University of Oklahoma, Norman, OK. Bulletin No. 4.

Lei, C.H. and K.B. Armitage, 1980. Growth, development and body size of field and laboratory populations of *Daphnia ambigua*. Oikos 35:31-48.

Loar, J.M., and S.G. Hildebrand. 1983. A comparison of environmental issues related to development of small hydropower resources at new versus existing sites. Pages 279-297 *in* T.M. Veziro, editor, Alternative Energy Sources III, Volume 9, Policy/Environment. Hemisphere Publishing Corporation. Washington, D.C.

MacArthur, R.H. 1968. The theory of the niche, *in*: Lewontin, R.C. (ed.). Population Biology and Evolution. Syracuse University Press, Syracuse, New York.

Magnuson, J.J. 1991. Fish and fisheries ecology. Ecological Applications. 1:13-26.

Malvestuto, S.P. 1983. Sampling the recreational fishery. Pages 397-420 *in* L.A. Nielsen and D.L. Johnson, editors. Fisheries techniques. American Fisheries Society, Bethesda, Maryland.

Malvestuto, S.P., W.D. Davies, and W.C. Shelton. 1978. An evaluation of the roving creel survey with non-uniform probability sampling. Transactions of the American Fisheries Society. 107:255-262.

May, R.M., 1974. Stability and complexity in model ecosystems. Princeton University Press. Princeton, New Jersey.

Merritt, R.W., and K.W. Cummins. 1984. An introduction to the aquatic insects of North America. Kendell-Hunt. Dubuque, Iowa.

Morista, M. 1959. Measuring of interspecific association and similarity between communities. Member Faculty Science. Kyushu Univ. Sev. E. Biol. 3:65-3:80.

Mullan, J.W., M. Dell, S. Hays, and J. McGee.1986. Some factors affecting fish production in the Mid-Columbia River, 1934-1983. U.S. Fish and Wildlife Service Report No. FRI/FAO-85-15. 68 p.

Mullan, J.W., 1987. Overview of artificial and natural propagation of coho salmon (*Onchorynchus kisutch*) 1983. U.S. Fish and Wildlife Service. Rep. FRI/FAO-84-4. 37 p.

Mullan, J.W., 1987. Status and propagation of chinook salmon in the mid-Columbia River through 1985. U.S. Fish and Wildlife Service. Biol. Rep. 87(3) 111 p.

Nelson, W.R., and C.H. Walburg. 1977. Population dynamics of yellow perch (*Perca flavescens*), sauger (*Stizostedion canadense*), and walleye (*Stizostedion vitreum vitreum*) in four mainstem Missouri River reservoirs. Journal of the Fisheries Research Board of Canada. 34:1748-1763.

Ney, J.J. 1981. Forage-fish management in the United States. Transactions of the American Fisheries Society 110:725-781. Bethesda, Maryland

Noble, R.L. 1978. Growth of young yellow perch (*Perca flavescens*) in relation to zooplankton populations. Transactions of the American Fisheries Society. 104:731-728.

Noble, R.L. 1981. Management of forage fishes in impoundments of the southern United States. Transactions of the American Fisheries Society. 110:738-750.
NWPPC. 1987. Columbia River Basin Fish and Wildlife Program. Northwest Power Planning Council. Portland, OR. 246 p.

Novotany, D.W. and G.R. Prigel. 1974. Electrofishing boats: Improved designs and operation guidelines to increase the effectiveness of boom shockers. Wisconsin Department Natural Resources Technical Bulletin No. 73.

O'Brien, W.J. and Schmidt, A.J. 1979. The predator-prey interaction of planktivorous fish and zooplankton. Am. Sci. 67:572-581.

Pennak, R.W. 1989. Freshwater invertebrates of the United States, 3rd edition. Wiley and Sons, New York.

Peone, T., A.T. Scholz, J.R. Griffith, S. Graves, and M.G. Thatcher. 1990. Lake Roosevelt Fisheries Monitoring Program. Annual Report, 1988-89. Bonneville Power Administration. Portland, OR.

Peterson, R.H. and D.J. Martin-Robichaud. 1982. Food habits of fishes in ten New Brunswick Lakes. Can. Tech. Rep. Fish. Aquat. Sci. 1094:43.

Regier, H.A., J.E. Paloheimo, and V.F. Gallucci. 1979. Factors that influence the abundance of large piciverous fish. Pages 333-334. *In* H.Clepper, editor. Predator-prey systems in fisheries management, Sport Fishing Institute, Washington D.C., USA.

Reynolds, J.B. 1983. Electrofishing. Pages 147-164 *in* L.A. Nielsen and D.L. Johnson, editors. Fisheries techniques. American Fisheries Society, Bethesda, Maryland.

Ricker, W.E. 1941. The consumption of young sockeye salmon by predacious fish. Journal of the Fisheries Research Board of Canada 5:293-313.

Ricker, W.E. 1952. Numerical relations between abundance of predators and survival of prey. The Fish Culturist 13.

Scholz, A.T., K. O'Laughlin, D.R. Geist, D. Peone, J.K. Uehara, L. Fields, T. Kleist, I. Zozaya, T. Peone, and K. Teesatuskie. 1985. Compilation of information on salmon and steelhead total run size, catch and hydropower related losses in the Upper Columbia River Basin, above Grand Coulee Dam. Upper Columbia United Tribes Fisheries Center. Technical Report No. 2:165.

Shields, J.P. and K.D. Underwood. 1997. Measurement of Lake Roosevelt biota in relation to reservoir operations, 1996 Annual Report *in* K.D. Underwood and J.P. Shields. Lake Roosevelt Fisheries and Limnological Research, 1996 Annual Report. Bonneville Power Administration. Portland, OR. Project No. 88-63.

Shields, J.P. and K.D. Underwood. 1996. Measurement of Lake Roosevelt biota in relation to reservoir operations, 1995 Annual Report *in* K.D. Underwood and J.P. Shields. Lake Roosevelt Fisheries and Limnological Research, 1995 Annual Report. Bonneville Power Administration. Portland, Oregon. Project No. 88-63.

Stober, Q.J., M.E. Kopache and T.H. Jagielo. 1981. The limnology of Lake Roosevelt. Final Report Contract No. 14-16-0009-80-0004, to the U.S. Fish and Wildlife Service. National Fisheries Research Center, Seattle, WA. Fisheries Research Institute, University of Washington, Seattle, Washington. FRI-VW-8106.

Stober, Q.J. 1983. Overview of fisheries management in fluctuating reservoirs in the northwestern United States. Pages 26-27 *in* H.H. Allen and L.R. Aggus, editors. Effects of fluctuating reservoir water levels on fisheries, wildlife, and vegetation. Miscellaneous paper E-83-2, U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, Mississippi.

Thorpe, J.H. and A.P. Covich. 1991. Ecology and classification of North American freshwater invertebrates. Academic Press, Inc., New York.

Underwood, K.D. and J.P. Shields. 1996. Lake Roosevelt Fisheries Monitoring Program, Annual Report 1993. Bonneville Power Administration. Portland, Oregon. Project No. 88-63.

Underwood, K.D., J.P. Shields and M.B. Tilson. 1997. Lake Roosevelt Fisheries Monitoring Program, 1995 Annual Report *in* K.D. Underwood and J.P. Shields. Lake Roosevelt Fisheries and Limnological Research, 1995 Annual Report. Bonneville Power Administration. Portland, Oregon. Project No. 88-63.

Underwood, A.T. Scholz, and M.B. Tilson. 1996 Lake Roosevelt Fisheries and Limnological Research, 1996 Annual Report. Bonneville Power Administration. Portland, OR. Project No.94-043.

Underwood, K.D., J.P. Shields and M.B. Tilson. 1996. Lake Roosevelt Fisheries Monitoring Program, 1994 Annual Report *in* K.D. Underwood and J.P. Shields. Lake Roosevelt Fisheries and Limnological Research, 1994 Annual Report. Bonneville Power Administration. Portland, Oregon. Project No. 88-63.

U.S. Army Corps of Engineers. 1981-98. Reservoir storage tables for Grand Coulee Reservoir. Prepared from tables by U.S. Bureau of Reclamation and U.S. Geological Survey.

U.S. Fish and Wildlife Service. 1989. 1985 National survey of fishing and hunting, and wildlife associated recreation. U.S. Department of Interior. Fish and Wildlife Service. March 1989.

Voeller, A. C. 1996. Measurements of Lake Roosevelt biota in relations to reservoir operations. Annual Report 1993. Bonneville Power Administration. Portland, Oregon. Project No. 94-43.

Walburg, C.H., J.F. Novotny, K.E. Jacobs, W.D. Swink, T.M. Campbell, J. Nestler, and G.E. Saul. 1981. Effects of reservoir releases on tailwater ecology: A literature review. Technical Report E-81-12, U.S. Fish and Wildlife Service, Bowling Green, Kentucky, and U.S. Army Corps of Engineers, Vicksburg, Mississippi.

Ward, H.B. and G.C. Whipple. 1966. Freshwater Biology, 2nd Ed. John Wiley and Sons, New York.

Wetzel, R.G. 1983. Limnology. Saunders College Publishing. New York.

Wiggins, G.B. 1977. Larvae of the North American caddisfly genera (Trichoptera). University of Toronto. Toronto, Ontario, Canada.

Wydoski, R.S. and R.R. Whitney. 1979. Inland fishes of Washington. University of Washington Press. Seattle, Washington.

Zaret, T.G. 1980. Predation and freshwater communities. Yale University Press. New Haven, Connecticut.

Zook, W.J., 1983. Resident fisheries of Wells Pool. A draft review prepared for Public Utility District No. 1 of Douglas County, East Wenatchee, WA.