Resident Fish Stock Status above Chief Joseph and Grand Coulee Dams

Annual Report
2000

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Resident Fish Stock Status above Chief Joseph and Grand Coulee Dams
Project # 199700400
2000 Annual Report

PREPARED BY:

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PREPARED FOR:

U.S. DEPARTMENT OF ENERGY
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PROJECT NUMBER 199700400
CONTRACT NUMBER 97-BI-35900

Executive Summary

The Resident Fish Stock Status above Chief Joseph and Grand Coulee Dams Project, commonly known as the Joint Stock Assessment Project (JSAP) is a management tool using ecosystem principles to manage artificial fish assemblages and native fish in altered environments existing in the Columbia River System above Chief Joseph and Grand Coulee Dams (blocked area). The three-phase approach of this project will enhance the fisheries resources of the blocked area by identifying data gaps, filling data gaps with research, and implementing management recommendations based on research results. The Blocked Area fisheries information housed in a central location will allow managers to view the entire system while making decisions, rather than basing management decisions on isolated portions of the system.

The JSAP (NWPPC program measure 10.8B.26) is designed and guided jointly by fisheries managers in the blocked area and the Columbia Basin blocked area management plan (1998). The initial year of the project (1997) identified the need for a central data storage and analysis facility, coordination with the StreamNet project, compilation of blocked area fisheries information, and a report on the ecological condition of the Spokane River System. These needs were addressed in 1998 by acquiring a central location with a data storage and analysis system, coordinating a pilot project with StreamNet, compiling fisheries distribution data throughout the blocked area, identifying data gaps based on compiled information, and researching the ecological condition of the Spokane River.

In order to ensure that any additional information collected throughout the life of this project will be easily stored and manipulated by the central storage facility, it was necessary to develop standardized methodologies between the JSAP fisheries managers. The use of common collection and analytical tools is essential to the process of streamlining joint management decisions. In 1999 and 2000 the project began to address some of the identified data gaps, throughout the blocked area, with a variety of newly developed sampling projects, as well as, continuing with ongoing data collection of established projects.

Introduction

The area currently known as the blocked area was a highly productive, stable ecosystem prior to hydroelectric development (Scholz et al. 1985). This area contained healthy, native, self-sustaining populations of resident fish, wildlife, and anadromous fish. The native fish assemblage consisted of resident salmonids (trout, whitefish, char), anadromous salmonids (salmon, steelhead), catostomids (suckers), and cyprinids (minnows) very well adapted to pristine riverine conditions.

The amount of the anadromous fish resources was enormous throughout pre-dam history (Scholz et al. 1985, Osterman 1995, and Hewes 1973). Scholz et al. (1985) conservatively estimated the total salmon and steelhead escapement above the current Grand Coulee Dam location was between 1.1 million and 1.9 million fish annually. This estimate was calculated after Upper Columbia stocks targeted by lower river fisheries had been harvested, thus the anadromous fish production in the Upper Columbia was far greater than estimated escapements. This abundant resource supported the Upper Columbia ecosystem by transporting nutrients back to the Upper Columbia. The large nutrient transport by anadromous fish to the Upper Columbia played a functional role in supporting resident fish, wildlife, riparian communities, and human populations, thus making anadromous fish the keystone component (Willson and Halupka 1995; Cederholm et al. 1989; Kline et al. 1989; and Mills et al. 1993) in the Upper Columbia System. Anadromous fish provided 18,000,000 pounds annually to an Indian population of 50,000 individuals (Scholz et al. 1985).

The resident fish population was also very abundant in the Upper Columbia area (Scholz et al. 1985, Osterman 1995, and Bonga 1978). For example, in a U.S. Fish Commission Survey, Bean (1894) and Gilbert and Evermann (1895) noted that cutthroat trout and mountain whitefish were abundant in the Spokane River System. Gilbert and Evermann (1895) also noted that bull trout were abundant in the Pend Oreille River in an 1894 survey of that stream. To provide an idea of the numbers of resident trout found in these systems Lt. Abercrombie (U.S. Army) reported that a party of three anglers caught about 450 cutthroat trout in one afternoon fishing on the Spokane River near the City of Spokane Falls in August, 1877 (Scholz et al. 1985). Indian people harvested an estimated 153,000 resident fish accounting for 360,000 pounds of resident fish annually (Scholz et al. 1985).

The construction of Grand Coulee Dam eliminated over 1,140 linear miles of anadromous fish spawning and rearing habitat in the Upper Columbia River System (Scholz et al. 1985). In addition to the blockage and loss of habitat, dams and impoundments have created vast changes in the environment. Free-flowing rivers with rapids and gravel bars for spawning and incubation have been replaced with a series of reservoirs and impoundments. These severe habitat alterations have created habitat conditions more suitable for non-native species than for native species. This condition has allowed non-native species to thrive, effectively displacing native species.

The fish assemblage existing today in the blocked area is drastically different than pre-dam development. Anadromous fish, the keystone component of the Upper Columbia, are extinct due to the construction of Grand Coulee Dam. Thirty-six (36) resident fish species are known to exist in the blocked area, the majority of which are not native. This largely non-native assemblage is, in part, the product of authorized and unauthorized introductions. Of the remaining native resident species bull trout (*Salvelinus confluentus*) are listed as threatened, westslope cutthroat trout (*Oncorhynchus clarki lewisi*) have been petitioned for listing, and redband rainbow (*O. mykiss*) are likely to be petitioned for listing under the Endangered Species Act (1973). Dynamics of the current system have been developing over the last five decades, and have not reached equilibrium. Managers today are unclear of simple ecological aspects of the system such as distribution and range of the 36 known species.

The Upper Columbia Blocked Area Management Plan (1998) states the overarching vision of the Blocked area fish managers is to achieve a healthy Columbia River ecosystem that supports viable and genetically diverse fish species that in turn provide direct benefits to society, including harvest. The Blocked Area fish managers have further defined two alternative visions for the currently Blocked Area:

(1) Development of a stable Upper Columbia River producing sustainable resident fish populations and harvest, equal to the level of historical (pre-dam) conditions, and/or
(2) Re-introduction of anadromous salmon and steelhead runs above Chief Joseph and Grand Coulee dams in areas where they historically occurred and to restore anadromous and resident fish abundance and harvest to historical levels.

The managers are charged with providing subsistence and recreational fisheries in the Blocked Area given historical expectations and current environmental conditions. This task is extremely unique in that nearly every variable throughout the system is artificial from the species assemblage, to the available habitats, to river level fluctuations. The JSAP has been designed to function as a tool for Blocked Area fish managers. This tool will focus on understanding the dynamics of fish and their habitats throughout the Blocked area and recommend management action based on the best available science and the condition of the entire Blocked Area ecosystem. The JSAP allows managers to view the Blocked Area as a system by compiling previously collected data, organizing available data, identifying areas needing data, performing necessary research, and recommending management actions.

In 1980, the United States Congress enacted the Northwest Power Planning and Conservation Act (PL 96-501, 1980), which established the Northwest Power Planning Council (NPPC). The NPPC was directed by Congress to develop a regional Power Plan and also the Columbia River Basin Fish and Wildlife Program (FWP) to restore or replace losses of fish caused by construction and operation of hydroelectric dams in the Columbia River Basin. In developing the FWP, Congress specifically directed NPPC to solicit recommendations for measures to be included in the Program from the region's fish and wildlife agencies and Indian tribes. All measures adopted by the Council were also required to be consistent with the management objectives of the agencies and tribes [Section 4.(h)(6)(A)], the legal rights of Indian tribes in the region [Section 4.(h)(6)(D)] and be based upon and supported by the best available scientific knowledge [Section 4.(h)(6)(B)]. The JSAP specifically addresses Council measure 10.8B.26.

Information gathered by other projects has been provided to the JSAP for synthesis. Synthesized information consists of habitat information, fish distribution information, stocking histories, and results of enhancement monitoring and evaluations. The JSAP project is successful when managers use synthesized information to successfully implement management recommendations and ultimately achieve stated goals and objectives in the Upper Columbia Blocked Area Management Plan and Subbasin Plans. Managers using synthesized information for recommendations depend on the JSAP to provide accurate and precise synthesis of available information. Likewise, the JSAP depends on quality data collection procedures used by individual projects. Thus, the symbiotic relationships between projects have positive synergistic effects on successful implementation of management actions in the blocked area by making the best available science available.

Acknowledgements

We would like to thank Glen Nenema (Chairman, Kalispel Tribal Council), the Kalispel Tribal Council, and members of the Tribe for providing support and the opportunity to implement this project. We would like to thank the participating project members and their respective staffs for their willingness to integrate ideologies and staff as a means of broader scoped fisheries management. We also greatly appreciate the interest, cooperation, participation and funding from non-project member sources: Seattle City Light, John Blum, Andrew Scott (Duke Engineering and Services), Tim Riley, Pend Oreille PUD and EPA. Special thanks to Deane Osterman (Director, KNRD) and Joe Maroney (Fisheries Program Manager, KNRD) for representing the project regionally.

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Kalispel Tribe of Indians
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Appendix 1. Zoological Investigation of Halfmoon and Yocum Lakes, Pend Oreille Co., Washington.

Introduction

Although many of the fish documented in the Kalispel Resident Fish Project (Project # 9500600) snorkel surveys were of a size class to suggest possible adfluvial populations, little was known about what species and which tributaries to the Box Canyon Reservoir might exhibit an adfluvial life history. In 2000 an adfluvial trapping program was completed to determine the species, locations, and potential triggering mechanisms for adfluvial migration within the reservoir and its tributaries. Analysis of the known information on these water bodies identified the lack of information critical to the management of Box Canyon Reservoir and its associated tributaries. Gathering this information was the basis for the Kalispel Tribe's 2000 scope of work and the substance of this report. The questions to be answered and data collected were as follows:

A) Adfluvial migration patterns of the Box Canyon tributary fish
   1. Species present
   2. Migration timing
   3. Upstream movements
   4. Downstream movements
B) Migration patterns of the Box Canyon Reservoir fish
   1. Radio telemetry study in the Box Canyon Reservoir
C) Ecological information on Yokum and Half Moon Lakes
   1. Eastern Washington University lake assessments (see Appendix)

Of the 11 tributaries with trap sites, 3 showed indications of adfluvial populations. Indian Creek, Skookum and the LeClerc Creek systems all displayed varying numbers of adfluvial brown trout (*Salmo truta*). The adult upstream migration appeared to begin in early October with an out migration throughout the month of November as water temperatures approached 6° C. Juvenile out migration appeared to be triggered both by spring flows and a water temperature of 8-9° C. Limited data on mountain whitefish (*Prosopium williamsoni*), westslope cutthroat trout (*Oncorhynchus clarki lewisi*) and bull tout (*Salvelinus confluentus*) did not provide enough of a basis to determine adfluvial populations, other than on a very small remnant scale.

To further our understanding of migrational habits from and within the reservoir, a radio telemetry tracking study was conducted in the reservoir beginning in December of 1998. A total of 61 fish were implanted with transmitters from 6 different species of fish: brown tout, westslope cutthroat tout, mountain whitefish, lake whitefish (*Coregonus clupeaformis*), rainbow trout (*Oncorhynchus mykiss*) and largemouth bass (*Micropterus salmoides*). Initial plans called for up to 25-30 fish of each species to be implanted; however, after six months of intense field efforts only brown trout and largemouth bass populations yielded enough fish over the size limitation (≥1lb.) to approximate the desired number of tagged fish. Brown trout moved actively throughout the reservoir and seemed to be found in or around the cooler tributaries as reservoir temperatures approached 18° C in late summer. Bass movement was also fairly active and seemed to transition from shallow vegetated areas for spawning to deep dense submerged aquatic macrophyte beds within the main body of the reservoir.

The limited numbers of large adult salmonids (other than brown trout) collected in either the adfluvial traps or the tracking study suggests that brown trout may be the only adfluvial salmonid population of any significant size.

Methodology

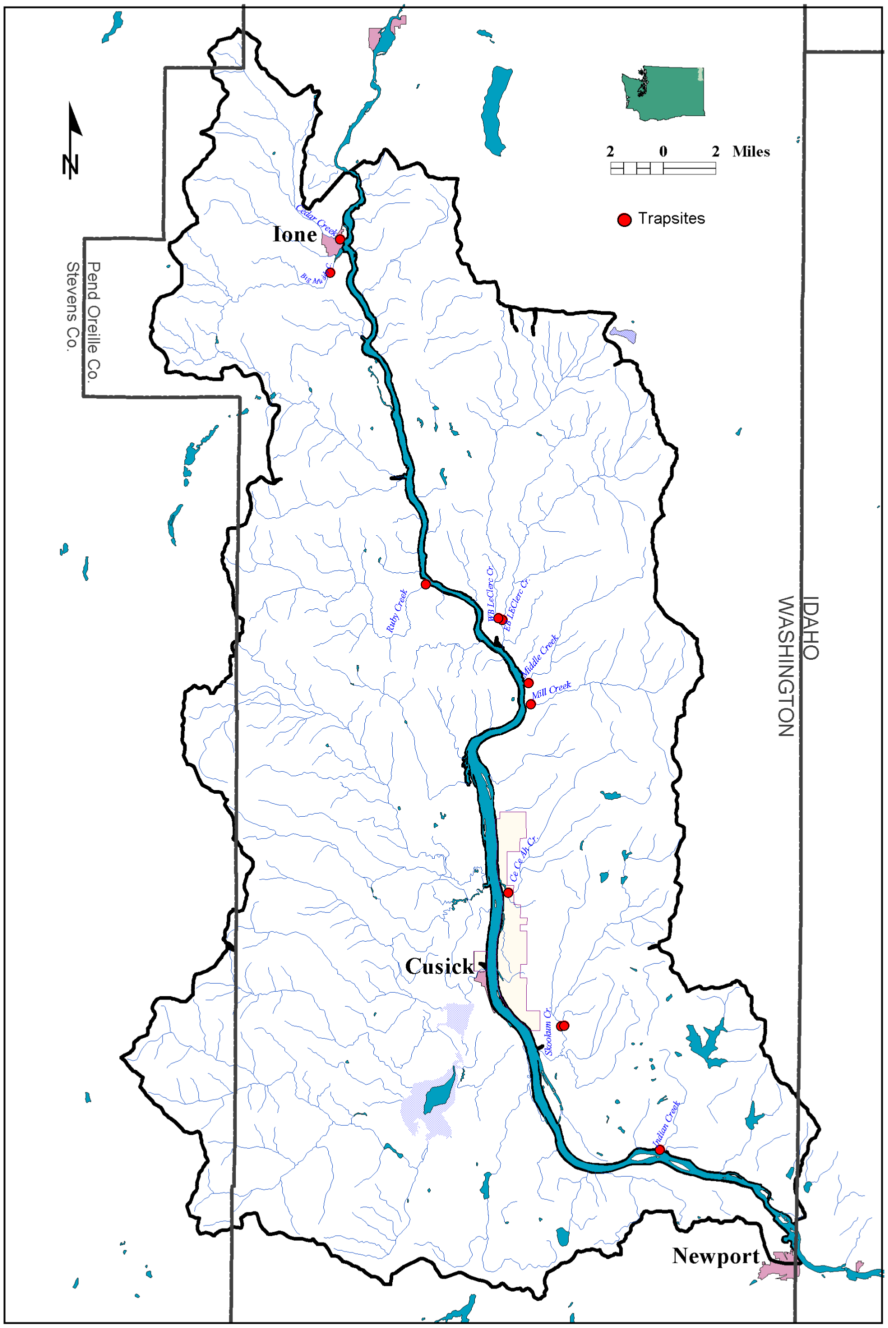
Adfluvial migration patterns of Box Canyon tributary fish

The number of tributaries selected for trapping varied during 1998 through 2000. All tributaries were located along the 57 mile long Box Canyon Reservoir. The trap locations were on both sides of the Reservoir and ranged from Indian Creek (River Mile 81) located at the southern end to Cedar Creek (River Mile 38) located downstream at the northern end three miles from the dam (see Figure 1). In 1998, eleven tributaries were cooperatively selected by biologists from Duke Engineering and Services (DE&S) and the Kalispel Tribe. That number was reduced to eight in 1999 and 2000 because of very low capture numbers in three of the tributaries (Mill, Middle and Big Muddy Creek). The criteria for stream selection included specific characteristics including the ability to support salmonid species, existing physical habitat, seasonal flows, and seasonal water temperatures. Once the tributaries were identified, a trapping site was selected in close proximity to the tributary's confluence with the Pend Oreille River, but still remaining upstream of any sloughs. The placement of the traps within the stream was critical to accomplish the primary goal of capturing upstream and downstream migrating fish.

The traps were installed in several stages. The first stage involved anchoring a heavy plastic liner onto the stream bottom to minimize undercutting of the traps and panels. Next, custom fabricated steel flip panels were installed in five foot sections and held in place with steel fence posts, re-bar and heavy duty plastic cable ties. These flip panels were designed to minimize the cleaning time and allow one person to clean the traps if necessary. The flip panels also allowed the trap to remain in place during some high flows thus reducing maintenance time. Sand bags were used to direct stream flows as needed. The panels were generally placed in a "W" shape in order to accommodate both the upstream and downstream catch boxes. The configuration of the panels directed migrating fish either through a tube to the downstream box or through a one way gate into the upstream box. Each trap site was snorkeled at least once every six weeks to check for needed underwater repairs and maintenance. Above water maintenance was done daily as needed.

The majority of traps were installed in the spring and removed in early winter. The traps were checked every day during their operation. The panels were cleaned a minimum of once a day. When a fish was caught, it was identified and recorded along with the date and trap location. If the fish species was a salmonid (trout or whitefish, excluding kokanee (*Oncorhynchus nerka*)), it was measured and weighed, and if greater than 100 mm, a numbered color coded tag was attached. Recaptures were also noted. In addition to the daily fish data, air and water temperatures were recorded along with a staff gauge reading. Stream flows were measured when significant changes occurred and the results used to develop a stage/discharge relationship from the staff gauge readings to determine the daily tributary flow. Thermographs were placed in the tributary adjacent to each trapping location and multiple daily recordings were taken during the entire trapping season.

Figure 1 Box Canyon Reservoir Trap Sites



Migration patterns of Box Canyon Reservoir fish

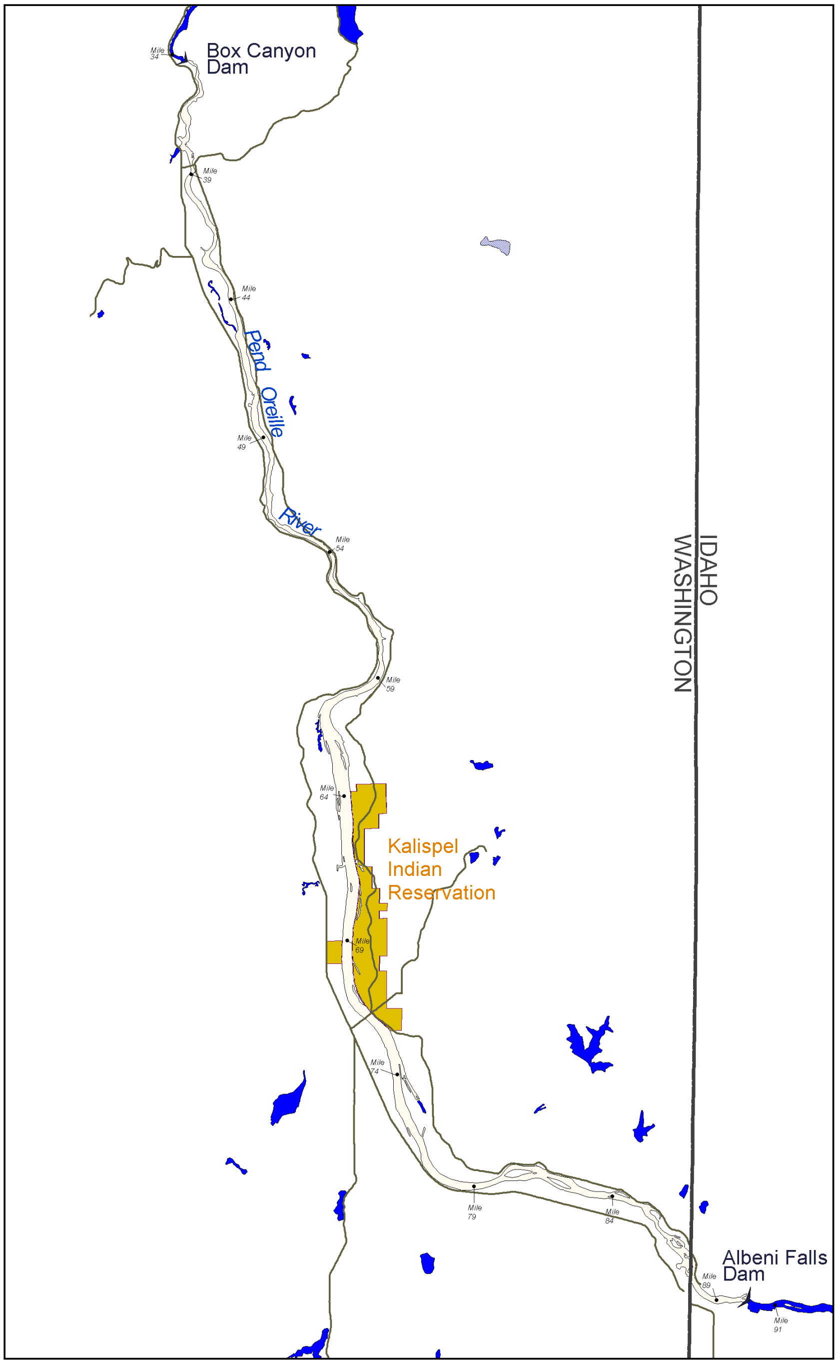
Five salmonid species including brown trout (*Salmo trutta*), rainbow trout (*Oncorhynchus mykiss*), westslope cutthroat trout (*O. clarki lewisi*), mountain whitefish (*Prosopium williamsoni*) and lake whitefish (*Coregonus clupeaformis*) were chosen to be monitored. In addition, largemouth bass (*Micropterus salmoides*) were also monitored. Beginning in October 1998 and ending in June 1999, repeated electrofishing efforts were conducted throughout the entire length of the Box Canyon Reservoir (BCR) to collect individuals of each species. Initial plans called for up to 25-30 fish of each species to be implanted with radio tags. However after six months of intense field efforts, 61 fish were implanted with transmitters out of an anticipated 140 fish. Capture was suspended when water temperatures in the reservoir exceeded 60° F due to potential infection from surgical procedures or during spawning periods of the target species.

Two types of Lotek radio tags were used, which were expected to provide up to 14 months of radio signals based on battery life. One type of tag gave location information of an individual fish while the other type gave water temperature in addition to fish location information. Tags were surgically implanted into the gut cavity of selected fish over one pound in weight. In addition, small colored and numbered plastic tags were attached to the dorsal fins to identify the fish. Fish were then revived and released at the approximate point of capture.

Mobile tracking of the tagged fish was conducted on a biweekly schedule starting in late October 1998. The tracking occurred for approximately 23 months using a portable Lotek SRX 400 unit and was conducted either via boat or vehicle over the entire length of the reservoir. Tracking was conducted on the boat traveling up and down the entire length of the reservoir. A complete sweep of the reservoir from end to end normally took 3 to 4 days to complete. Several times during the 23 months of tracking, underwater surveillance was conducted to attempt to identify the substrates in the general location of the tagged fish. Snorkeling, diving, and use of an underwater video camera were the methods employed to record substrate data. Once fish were located, a water temperature and depth to substrate were noted and a GPS reading was taken at the fish's approximate location. Locating fish was difficult at times because water depth and antenna alignment would greatly influence the tag signal strength. Fish in water greater than 6 meters were difficult to detect.

Stationary tracking was done using an additional Lotek SRX 400 unit set up at the Box Canyon Dam (see Figure 2.). This unit took continuous readings below the dam in the tailrace and spillway. This unit employed seven stationary antennas. Three antennae were located above the water and canvassed the spillway, turbines and slightly downstream. In addition, four underwater antennae were also used: one below the turbines; two below the spillway; and one below the Visitors Center. Data were downloaded approximately every four weeks.

Figure 2 Box Canyon Reservoir



Results

Adfluvial migration patterns of Box Canyon tributary

From 1998 through 2000 a total of 1,676 fish were captured in 11 tributaries to the Box Canyon Reservoir. Of that total, 1,475 were one of the seven salmonid species collected. Table 1 is a listing of those species and their numbers collected by years. In 1998, 11 upstream and downstream traps were functioning for a total of 1,942 trap days. In 1999 and 2000, 8 traps were operated for a total of 1,726 and 1,689 trap days respectively.

Table1. Number of salmonids caught in traps by year.

	1998	1999	2000	Totals
Brown Trout	306	257	129	692
Brook Trout	297	184	91	572
Rainbow Trout	35	12	17	64
Mountain Whitefish	48	3	22	73
Westslope Cutthroat	30	9	3	42
Kokanee	22	7	2	31
Bull Trout	0	1	0	1
Totals	**738**	**473**	**264**	**1475**

Non-native brown trout and brook trout accounted for 86% of the total salmonids captured during the three-year period. Brown trout were the most common fish captured overall and on an annual basis particularly in Indian, CCA, East Branch LeClerc, North and Main Branches of Skookum Creeks. More than 90% of all the brown trout captured came from these five streams. Attachment 1 shows the numbers of salmonids caught each year by tributaries in which they were captured. It also shows the numbers with respect to upstream or downstream movement. Approximately 70% of the fish captured were in the downstream traps (1,098 fish). Only one bull trout was captured during the trapping sessions. A large (610mm) gravid female was caught in Indian Creek in September of 1999 in the upstream trap.

Of the five non-salmonid species of fish captured, sculpin were the most common species (Table 2). Sculpin accounted for 86% of the non-salmonid take. Seventy-six percent of non-salmonids were captured in downstream traps. Attachment 2 shows the total non-salmonid catch by year and tributary. No non-salmonids tagged in tributaries to Box Canyon Reservoir.

Table 2. Number of non-salmonids caught in traps by year.

	1998	1999	2000	Totals
Sculpin	101	29	33	163
N. Pikeminnow	6	5	2	13
Bridgelip Sucker	2	2	2	6
Largescale Sucke	1	0	5	6
Yellow Perch	0	2	0	2
Totals	**110**	**38**	**42**	**190**

Water temperature appeared to be one of the triggering mechanisms for large scale fish movement annually. Each year saw elevated fish captures when water temperatures in the tributaries ranged from 6-9º C and again at temperatures ranging from13-16º C (Figure 3). The number of fish captured daily approached zero when temperatures in the tributaries fell below 3º C or climbed above 18º C. Photoperiod, which at least partially controls water temperatures, also showed two sets of peaks annually. Peak capture dates occurred between the middle of July through the middle of August and again from the beginning of October through the end of November (Figure 4).

Figure 3: All Box Canyon Tributaries: Temperature vs. Captures

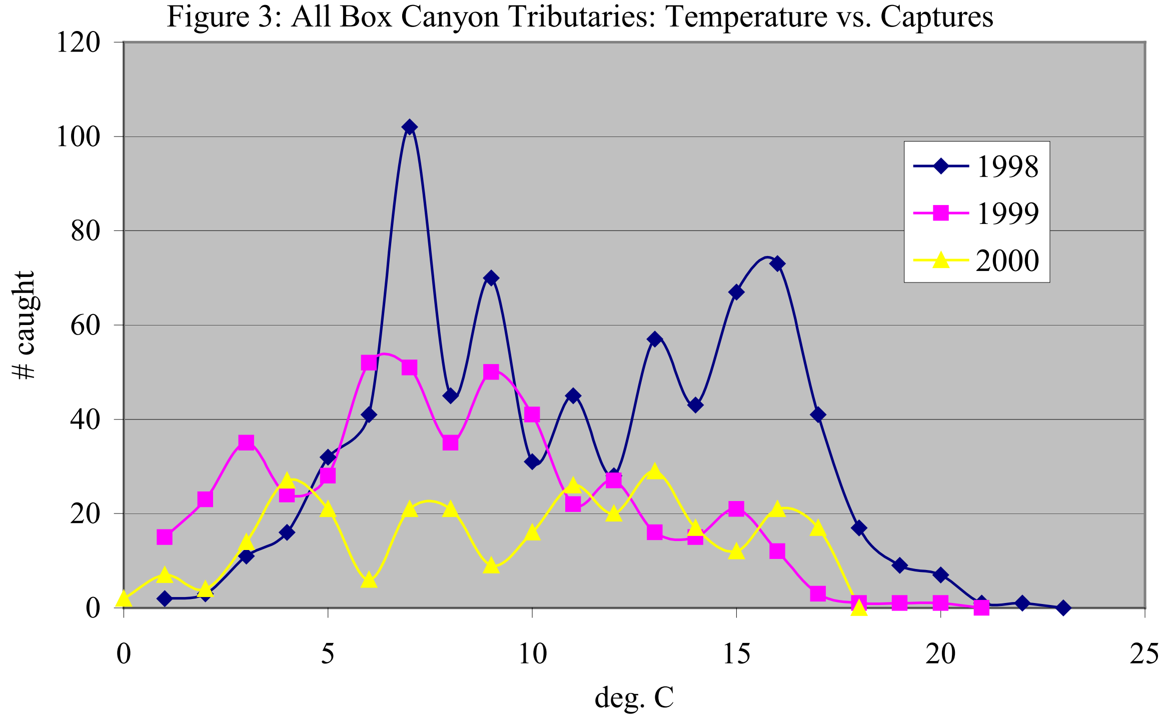
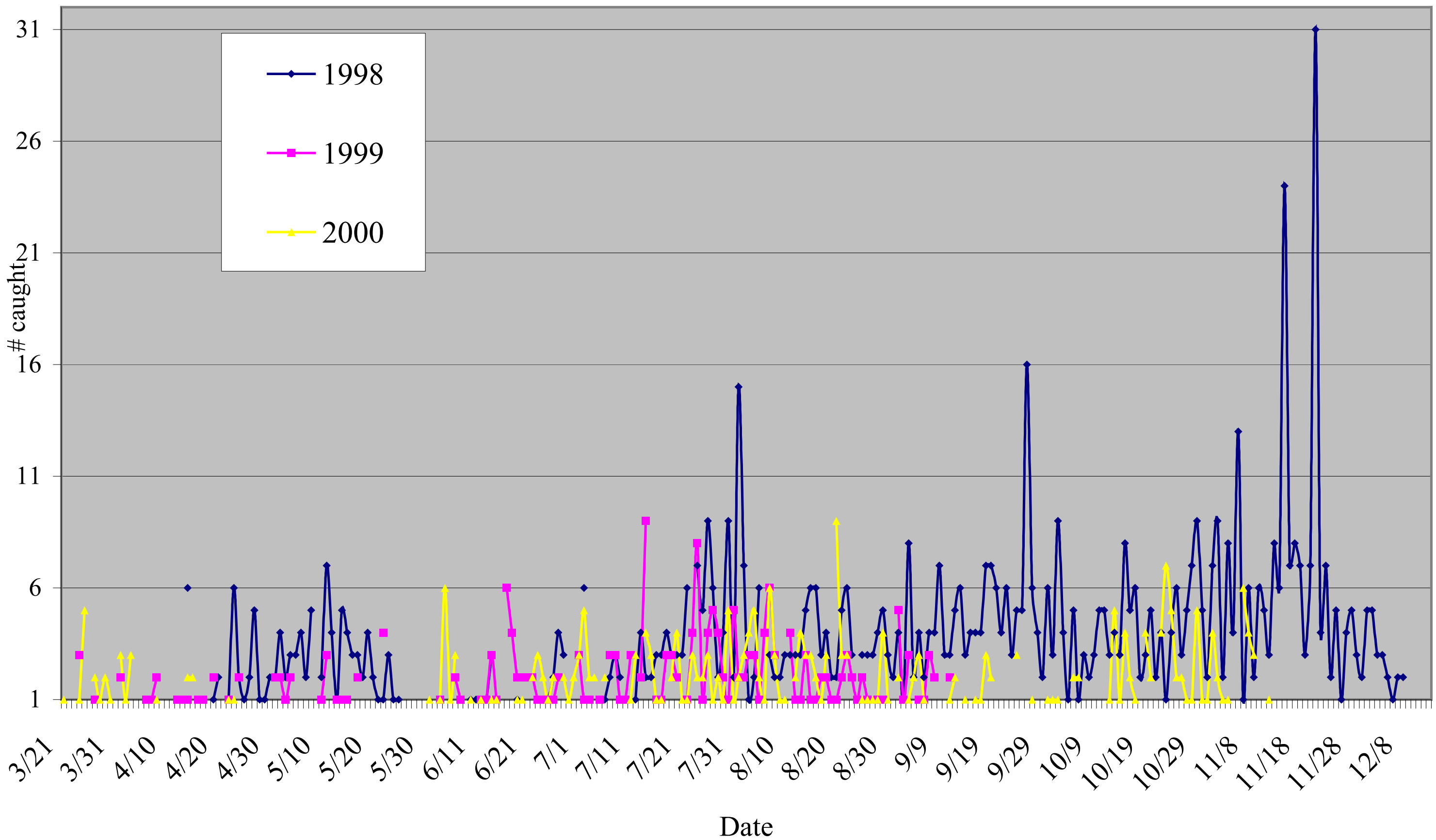


Figure 4: All Box Canyon Reservoir Tributaries: 1998 - 2000 Date vs. Captures



It should be noted that when comparing overall tributary trapping results between the 1998, 1999 and 2000 years, the 1999 and 2000 data is based on the results of operating 8 traps while the 1998 data is based on 11 operating traps. The length of time each trap fished throughout the year varied due to factors such as weather, flows (both in the tributary and in the Pend Oreille River), trap durability and access.

Combining the three years of capture data (1998 through 2000) indicated the main branch of Skookum Creek was the most active trapping location for salmonid species with a total of 298 recorded fish captures. Indian Creek and the north fork of Skookum Creek had the next two highest captures numbers for the three years with 220 and 208 salmonids, respectively. The least active trapping site fished during the three seasons was the West Branch LeClerc Creek with a total of 94 salmonids caught. This number was likely reduced do to shortened trapping seasons experienced by difficulties maintaining the trap operation during fluctuating high flows of spring runoff. Mill Creek, Middle Creek and Big Muddy Creek were all abandoned as trapping sites in 1999 after very low catch numbers were recorded in 1998.

Migration patterns of Box Canyon Reservoir fish

The individual tagged fish information is given in Table 3, including the species of fish tagged, the type of tag, location of release and general fish characteristics. In order to monitor for one year, nine gram transmitters with appropriately sized batteries were required. This requirement dictated the use of only fish at least one pound in weight, since tags cannot constitute more than 2% of body weight. Trout constitute <1% of the fish in the reservoir and finding fish ≥1 pound was difficult. A total of 61 tags were implanted in six different species over a 9-month period. Nine temperature tags were implanted in brown trout and largemouth bass. The remaining 52 tags were implanted in all six species of fish. During the study, five confirmed mortalities of tagged fish were recorded. Three fish (one brown trout and two largemouth bass) were taken by anglers; one largemouth bass became trapped in a desiccated slough and one brown trout was captured by a bald eagle (tag located below the nest). Although all fish were not located every time a search was conducted, only three fish, a largemouth bass, a brown trout and a mountain whitefish, have never been accounted for after they were initially tagged. It is not known whether these fish were removed from the system, are in areas that prevent access, or had faulty transmitters.

Table 3. Fish tagged in Box Canyon Reservoir 1998-1999.

FISH TAG#	UTM LOCATION	DESCRIPTION	SPECIES	LENGTH (mm)	WEIGHT (Grams)	DATE TAGGED	Comments
149.069 (232 lite blue)		Mouth of Skookum	BRN	570	2600	10/27/98	
540.08		Mouth of Indian	BRN	534	1550	10/27/98	
540.30 (205 cerise/red)		Mouth of Indian	BRN	514	1450	10/27/98	
580.33 (208 cerise/red)		Released below Indian trap	BRN	470	810	11/18/98	
580.23	4829544 11715865	Mouth of Mill	BRN	362	499	10/28/98	
580.27	474567 5381322	5-10 mile S. of Ione bridge boat ramp by lighthouse	BRN	428	925	12/15/98	
580.30	0478289 5374278	W. Bank across from mouth of LeClerc Cr. and ds 200 m	BRN	420	850	12/10/99	
580.29	0477352 5376994	2 miles down st. of Outpost-Sierra Club house	BRN	450	700	12/10/99	
520.31		Above Newport bridge-East side by mill	BRN	426	600	2/3/99	
560.27	497151 5330227	on East side of second island downstream of Newport Bridge	BRN	455	850	3/3/99	

Table 3. Cont.

FISH TAG#	UTM LOCATION	DESCRIPTION	SPECIES	LENGTH (mm)	WEIGHT (Grams)	DATE TAGGED	Comments
540.23 (115 flo green)	0477776 5368635	Riverbend at Bible Camp	BRN	435	860	4/21/99	
520.29 (119 flo green)	0477776 5368635	Riverbend at Bible Camp	BRN	465	650	4/21/99	Harvested 5/25/99
580.24 (169 flo green)	0480458 5370813	Mouth of Mill Creek	BRN	405	625	4/21/99	
149.010 (125 flo green)	0497119 5338004	North end of Newport Island	BRN	530	1500	4/27/99	
520.27 (113 flo green)	0495709 5339377	West bank across from pioneer park	BRN	490	1000	4/27/99	
560.30 (122 flo green)	0477548 5396453	West bank across and u/s 100 yds from Sierra club house	BRN	375	475	4/28/99	
540.29 (108 flo green)	0477343 5376969	Rock pile at Sierra Club house	BRN	450	800	4/28/99	
540.21 (199 flo green)	0488779 5343369	Mouth of Indian	BRN	450		5/4/99	
560.31 (126 flo green)	0499152 5327624	South of Newport Bridge	BRN	585	1700	5/5/99	
149.039 (198 flo green)	0480563 5349859	West bank across from Skookum Creek	BRN	485	1400	5/12/99	
520.30 (165 flo green)		Newport boat launch	BRN	345	495	6/23/99	
149.119 (162 flo green)	0481553 5349407	Mouth of Skookum	BRN	585	2000	6/30/99	
580.25 (163 flo green)		Newport boat launch	LKW	380	500	6/23/99	
560.33 (160 flo green)		Newport boat launch	LKW	370	550	6/23/99	
149.059 (116 flo green)	0476864 5367111	Fountain Slough	LMB	405	1010	3/31/99	
580.26 (112 flo green)	0476864 5367111	Fountain Slough	LMB	380	790	3/31/99	
540.06 (111 flo green)		600 yds up into Red Norris Slough	LMB	42	1050	4/7/99	
149.049 (121 flo green)		600 yds up into Red Norris Slough	LMB	46	1700	4/7/99	
149.089 (117 flo green)	0471819 5389400	Tiger Slough	LMB	470	2000	4/8/99	
520.32 (flo green 114)	0496591 5337918	Ashenfelder Bay	LMB	440	1650	4/13/99	
560.18 (flo green 118)	0478470 5366082	Campbell Slough	LMB	405	1125	4/15/99	

Table 3. Cont.

FISH TAG#	UTM LOCATION	DESCRIPTION	SPECIES	LENGTH (mm)	WEIGHT (Grams)	DATE TAGGED	Comments
540.19 (195 flo green)	0478784 5354701	2000 ft. below Pow Wow	LMB	301	1000	4/27/99	
580.08 (196 flo green)	0496555 5337865	Ashenfelder Bay	LMB	345		5/12/99	
560.07 (355 flo green)		Usk Bridge slough	LMB	510	3100	5/26/99	
520.15 (123 flo green)		Usk Bridge slough	LMB	450	2400	5/26/99	
540.20 (124 flo green)	0469516 5398570	Ione boat launch	LMB	420	900	5/26/99	
580.14 (194 flo green)	0469516 5398570	Ione boat launch	LMB	390	850	5/26/99	
540.24 (197 flo green)	48'16'871 117'14'885	Red Norris Slough	LMB	405	800	6/2/99	
149.019 (107 maroon)	48'18'071 117'15'857	Davis Slough	LMB	505	1400	6/2/99	caught by angler
520.01 (351 flo green)	0494983 5341040	N. end of isl immediately d/s of USGS gage station	LMB	350	550	6/3/99	
560.32 (155 flo green)	0490663 5342747	u/s of Indian Cr. 1 mile by Sandy Shores, east bank	LMB	400	800	6/3/99	Harvested
540.01 (150 flo green)	0490663 5342747	u/s of Indian Cr. 1 mile by Sandy Shores, east bank	LMB	390	900	6/3/99	
580.09 (151 flo green)	0494310 5341196	Across from Exposure Peak at new A frame log cabin	LMB	430	875	6/3/99	Land locked died
149.109 (153 flo green)	0496265 5339701	Pioneer Park Slough	LMB	495	1600	6/3/99	
520.02 (353 flo green)	0480553 5371938	Mouth of middle Creek	LMB	375	950	6/10/99	
580.21 (350 flo green)	0480553 5371938	Mouth of middle Creek	LMB	380	80	6/10/99	
580.32 (158 flo green)	0475028 5377864	slough with dead cottonwoods 1./4 mile u/s of Ruby Creek	LMB	400	730	6/10/99	
520.17 (157 flo green)	0475028 5377864	slough with dead cottonwoods 1./4 mile u/s of Ruby Creek	LMB	380	700	6/10/99	
580.03 (120 flo green)	0472080 538892	Tiger Slough (at earthen berm/penisula)	LMB (F)	400	1200	4/8/99	
540.15 (154 flo green)	0470655 5393034	Renshaw Cr. Slough	LMB (F)	475	1450	6/4/99	
520.18 (152 flo green)	0470652 5393037	Renshaw Cr. Slough	LMB (F)	390	1300	6/4/99	
560.05 (352 flo green)	0471576 5391474	Blue Canoe slough, south of Renshaw Cr, W bank	LMB (F)	405	1000	6/4/99	

Table 3. Cont.

FISH TAG#	UTM LOCATION	DESCRIPTION	SPECIES	LENGTH (mm)	WEIGHT (Grams)	DATE TAGGED	Comments
540.11 (354 flo green)	0471572 5391476	Blue Canoe slough, south of Renshaw Cr, W bank	LMB (F)	440	1300	6/4/99	
540.27 (106 flo green)	0472080 538892	Tiger Slough (at earthen berm/penisula)	LMB (M)	375	600	4/8/99	
540.28		Mouth of Skookum	MTW	307	260	10/27/98	
540.26	4831060 11717149	Left bank of Pend. 200' down from mouth of LeClerc Crk.	MTW	310	250	10/28/98	
580.31 (129 flo green)	0495709 5339377	West bank across from pioneer park	MTW	410		4/27/99	
580.10 (127 flo green)	0477548 5396453	West bank across and u/s 100 yds from Sierra club house	MTW	360	450	4/28/99	
560.06 (156 flo green)	0478289 5374258	Old ferry boat launch	MTW	300	400	6/10/99	
540.32	474092 5380121	N. of Ruby Crk. West side of river	RBW	377	1000	12/15/98	
560.29 (110 flo green)		Calispel Slough	WSC	321	350	4/7/99	

Fish movement varied greatly both within and between species. Brown trout and mountain whitefish showed the greatest tendency to "roam" the reservoir. Because only one individual rainbow trout and one westslope cutthroat trout were implanted with a radio tag, it was difficult to generalize any trend for either of these species. The majority of largemouth bass remained relatively close to their initial capture locations. Their primary movements appeared to be between shallow sloughs and flooded vegetation in the spring and early summer, and then to areas of deeper submerged aquatic macrophyte beds in the main river channel during late summer and early fall. Several bass did show significant migration (> 5 miles) but their movements tended to indicate a trend of leaving an area and then returning several weeks later. Table 4 shows the range of distances traveled by tagged fish.

Table 4. Relative distance traveled by species 1998-2000.

Distance (miles)	Brown Trout	Largemouth Bass	Mountain Whitefish	Rainbow Trout	Lake Whitefish	Westslope Cutthroat
0-2	11	12	1			
2.5-5	3	6				
5.5-8	3	8	1		1	1
8.5-15	2	3	1	1	1	
>15	2	0	1			

Comparison to Previous Radio Telemetry Studies

The results of the 1998-00 radio telemetry study done on the BCR were similar to results found by two previous radio telemetry studies done on the Pend Oreille River. Ashe and Scholz (1992) conducted an intensive survey of the Pend Oreille River from June 1990 through June 1991. Part of their work involved tagging largemouth bass with radio transmitters and following movements throughout the year. Results of their study were very similar to the results found in 1998-00 tracking study. These included bass utilizing similar habitats during various seasons (warm shallow sloughs in the spring; dense macrophyte beds in the main river during summer and early fall; and deeper channels in the main river channels during late fall). Ashe and Scholz (1992) also concluded that largemouth bass during non-winter periods were at preferred depths of approximately 3 meters and water temperatures of approximately 9-20° C. Lastly although their study results on bass movement differed somewhat, overall the findings indicated that bass did not have large migrations within the reservoir. Out of the 91 fish Ashe and Scholz (1992) had tagged, approximately 60 % showed no movement from their initial point of capture. Of the remaining fish, 15% moved 1-3 miles, 10% moved 3-6 miles and 15 % moved greater than 6 miles. Results indicated that 20% did not move, 27% moved 1-3 miles, 27% moved 3-6 miles and 23% moved greater than 6 miles.

Another radio telemetry study conducted on brown trout within Box Canyon Reservoir and its tributaries was done in 1992 and 1993 by Bennett and Garrett (1994). The results of the 1998-00 study were very similar to those found in the 1992-93 study. Bennett and Garrett (1994) found that in 1992 brown trout migrated into Skookum Creek when water temperatures in the main reservoir were above 19°C (June) and stayed there until after spawning (November). During the following year, main reservoir water temperatures were cooler in the summer and brown trout did not leave the reservoir until fall to spawn. We only tracked radio tagged trout for one full season, but 1999 appeared to have cooler reservoir water temperatures than 1998. As a result, radio tagged fish ascended tributaries (primarily Skookum and Cee Cee Ah creeks) in mid-September to mid-October to spawn. These results are further supported by the findings of the tributary trapping study, which was conducted from 1998-2000. This study confirmed that 1999 was a cooler water temperature year (both in the tributaries and the main reservoir) and that fish migration into the tributaries was much lower than observed migrations in 1998.

Discussion

Adfluvial migration patterns of Box Canyon tributary fish

The only salmonid captured in sufficient numbers and of the appropriate size/age class to suggest an adfluvial population exists in the Box Canyon Reservoir was the non-native brown trout. The number of brown trout captured made up nearly half of the entire salmonid catch. Of the 11 tributaries where traps were placed, 4 accounted for 97% of the brown trout captured. These 4 systems (Skookum, CCA, LeClerc and Indian Creeks) are the most southern tributaries that were trapped over the 3 year period and consistently produced higher numbers of brown trout over the study period.

The two triggering mechanisms for increased fish movement (water temperature and photoperiod) appeared to be related to two separate causative agents. The peak captures of fish when water temperatures ranged from 6-9° C (October-November) appeared to correspond to a brown trout spawning run. During this time most of the brown trout captured displayed pre-spawn or post-spawn condition. The second peak in captures occurred when water temperatures in the tributaries ranged from 13-16° (July-August) appeared to be a search for more tolerable water temperatures. During this same period the water temperatures in the reservoir rose above 20° C.

Although brook trout captures were responsible for nearly 40% of the total salmonid catch, their capture numbers and size/age class were so evenly distributed throughout the season's that no definitive migration can be assigned to a time or causal mechanism. However, the same 4 systems responsible for 97% of the brown trout catch were responsible for 70% of the brook trout catch.

Seven salmonid species were collected during the 3 year period. With the exception of brook and brown trout, none of the tributaries had more than 5 individuals of any other species captured in consecutive years. In fact, all remaining salmonid captures combined made up only 14% of the entire catch. Even though their individual numbers remained too low to suggest any clearcut patterns of migration, one general pattern did occur. The highest numbers of rainbow, westslope cutthroat, mountain whitefish, kokanee and bull trout (1 fish) were either captured in the southern most tributary (Indian Creek) or the two most northern tributaries (Cedar and Ruby Creeks).

Indian Creek is the first large tributary to the Box Canyon Reach below Albeni Falls Dam and it maintained the coolest water temperatures throughout the summer months. We suspect that the majority of fish captured, other than brook and brown trout, were entrained through Albeni Falls. In lieu of return fish passage to the Lake Pend Oreille system they sought temperature refuge in Indian Creek. The single bull trout that was captured was a large gravid female with an adipose fin clip. The only project to our knowledge in the system actively clipping bull trout is an IDFG project in Trestle Creek (Chip Corssi, IDFG pers. com.). Trestle Creek is a tributary in upper Lake Pend Oreille. During the trapping sessions 22 kokanee were captured in the Indian trap;

however, in 4 years of stream snorkel samples (1997-2000) not one kokanee was ever seen in any of the up-stream sample stations (Kalispel Resident Fish Project Annual Reports, 1997-2000). Brook trout and brown trout were not only the most common species captured during trapping sessions, they were also the most numerous species seen in snorkel stations throughout the stream during the same period.

Cedar and Ruby Creeks did produce the most mountain whitefish (38 and 23 fish respectively) and rainbow trout (24 and 21 fish respectively) during the trapping period. While these total numbers do not provide compelling evidence for adfluvial usage of these tributaries by these species, they do further illustrate the dichotomy in reservoir utilization. These two tributaries also had the fewest number of brown trout captured in the 11 streams fished.

These data suggest that the southern portion of the reservoir has four tributary systems that contain adfluvial brown trout populations of varying sizes. No native or potentially native salmonid species were captured in sufficient numbers to suggest with any clarity that adfluvial populations exist in the reservoir, with the exception of possible remnant runs in the northern portion of the reservoir.

The division in reservoir/tributary utilization for brown trout appears to follow the natural transition of physical characteristics in the drainage. The valley floor and floodplain is much broader in the southern portion of the reservoir. Residential and agricultural development is considerably higher for this portion. It appears that changes in the physical habitat from this development coupled with the natural landscape have created conditions that greatly favor non-native brown trout populations, while being detrimental to native salmonid species. As you move north through the reservoir the valley floor decreases to the point of the river channel itself. Development is, relatively speaking, greatly reduced. Under these conditions brown trout populations are greatly reduced.

Migration patterns of Box Canyon Reservoir fish

The radio telemetry tracking data provided preliminary information indicating salmonids exhibited active movement throughout the reservoir while largemouth bass remained in a relative generalized location. Brown trout appeared to move to areas that provide both preferred physical habitat and water temperatures. Cover ranged from nothing to large woody debris and sparse aquatic vegetation. Whitefish did not appear to fit any trend and moved throughout the reservoir over short periods of time. Tagged largemouth bass exhibited relatively limited distance movements, traveling between shallow vegetated areas to spawn and then deep dense submerged aquatic vegetation in post spawn periods.

Temperature

Nine individual brown trout and largemouth bass were fitted with tags that provided location information as well as ambient water temperatures at the fish's location. Temperatures recorded by the radio tags were similar to those temperatures recorded at the water's surface at the same time. Temperature tag monitoring data for these nine fish is shown in attachment 3.

The radio telemetry tagging data provides limited data on whether fish, particularly salmonids, sought refuge in the tributaries during the summer. One out of the four brown trout outfitted with a temperature tag left the river after early August 1999 and was confirmed upstream in a tributary (Skookum Creek) on September 12, 1999. On September 12th temperatures in Skookum Creek were 10° C while temperatures in the Pend Oreille River were 18° C. Three other tagged brown trout had joined this fish by September 17, 1999. During the warmest summer months, several brown trout were located near cooler tributary mouths (particularly Skookum and Indian creeks) or along the banks in areas where seeps and small springs were observed discharging. Other brown trout were located in the main river channel in deeper water with higher velocities but no recordable cold water differences. The majority of temperature tagged brown trout did not seem to be actively seeking cold water microhabitats within the Pend Oreille River.

Data from temperature-tagged largemouth bass showed very little trend. Movement for largemouth bass seemed more tied to preferred physical habitat than to preferred water temperatures except during the pre-spawning period in the spring. When collecting fish for tag insertion, pre-spawn bass were captured in warmer shallower water tight to vegetation. The five bass fitted with temperature tags appeared to prefer the same type of habitat regardless of where in the reservoir they were located. Since the entire reservoir took three days to track during a single tracking period, water temperatures varied slightly for the different fish locations. Bass clearly preferred the warmer shallow waters in the spring and these water temperatures were as much as 5° C higher than the main river channel. As water temperatures rose in the summer bass moved into deeper water near the main river channel. Little or no water temperature stratification was observed within the reservoir at any time of the year. Fall water temperatures did not seem to effect bass movement as much as the die-off of large submerged macrophyte beds.

Flow

Flows within Box Canyon reservoir undoubtedly cause fish to move. The radio telemetry tracking information showed all tagged fish species moving around more during periods of high flows. Whether fish were responding to increased velocities or a larger volume of water to move about in is unclear. Tracking information did indicate that when flows increased in the reservoir (mainly during runoff) that fish became more widely scattered and more difficult to locate. The opposite was true as water levels decreased. During the high spring flow period, water temperatures remained fairly constant throughout the main part of reservoir. However shallow flooded areas both in the sloughs and in adjacent low-lying uplands, likely warmed faster and these attracted particularly largemouth bass during the day. Migration in and out of these areas was most likely controlled by a combination of water levels and temperatures. As water levels rose bass moved farther laterally from the main river channel and as water levels fell, bass tended to move back towards the main river channel.

Brown trout and other salmonids were more difficult to track in the spring high flows because floating debris and underwater obstacles made travel over flooded areas difficult. Salmonids tended to remain deep in the submerged channels during high flows resulting in ineffective signal pick up by the receiver. Low water during the late summer and early fall appeared to be the most successful time for tag location due to more fish being concentrated into a smaller volume of reservoir.

Movement times throughout the year differed by species but generally appeared to be triggered more by water elevations than by water temperatures. The water temperatures did vary greatly during different times of the year, but on a daily basis they remained uniform throughout the entire length of the reservoir. Increased fish movements were more noticeable on changes in flows than with changes in temperatures. Spawning times for the various species also likely acted as a catalyst for movement of tagged fish.

Brown Trout

A total of 22 brown trout were captured and implanted with radio tags. The majority of tagged brown trout were captured in the upper portion of the reservoir from River Mile 90 (near Albeni Falls dam) downstream to the mid-portion at River Mile 54 (near Blueslide). Most all brown trout captured were either near tributary mouths or associated with cobble/boulder type substrate.

During the eleven-month tracking period, the 22 tagged fish averaged a biweekly movement of approximately 1.25 river miles. An overall maximum average distance traveled for these fish was 7.5 river miles. The greatest distance traveled by an individual brown trout was 48.5 river miles from its point of capture. This fish was tagged on April 27, 1999 near the Newport bridge.

Winter movement of brown trout appeared to be minimal. Several fish tagged in January and February remained within 300 ft of their capture location for nearly 2 months before showing any discernable movements. Spring brown trout movement appeared very random and showed no real trends. Some fish remained near tributary mouths while others moved up or down the main body of the reservoir. Nearly all fish remained in the reservoir during winter, spring and summer. Brown trout appeared to concentrate their movements during the summer to seek preferred water temperatures. These areas were either near creek mouths or in the vicinity of springs and seeps. These seasonal movements occurred with some consistency as the water temperatures in the main reservoir became elevated in July and August. It is believed that the greatest brown trout movement would occur during October and November coinciding with adfluvial spawning behavior. This theory has been supported by data collected during the multiple years of tributary trapping work done on the Pend Oreille River (1997 through 2000).

Four brown trout were implanted with radio tags able to give immediate surrounding water temperatures. Three of these fish were initially tagged in the mouth of Skookum Creek Slough and one near the Newport bridge. One fish from the Skookum Creek area traveled to the mouth of Indian Creek and is believed to be dead because no movement has occurred in 9 months. Two of the fish stayed within a one-mile range of their initial capture sites until mid to late July when they disappeared for several weeks. All three fish reappeared in early September 1999 in Skookum Creek near the LeClerc Road crossing.

Whitefish (Mountain and Lake)

A total of seven whitefish were captured and implanted with radio tags. Five of these fish were mountain whitefish and two were lake whitefish believed to have migrated from Lake Pend Oreille. The tagged mountain whitefish were captured in the upper portion of the river from River Mile 86 (near Pioneer Park) downstream to River Mile 54 (near Blueslide). The two tagged lake whitefish were captured near the Newport bridge at River Mile 89.

During the 11-month tracking period, the five tagged mountain whitefish averaged a biweekly movement of approximately 2.2 river miles and the two lake whitefish averaged 5 river miles. An overall maximum average distance traveled for the mountain whitefish was 13.1 river miles and for the lake whitefish 9.5 river miles. The greatest distance traveled by an individual mountain whitefish and lake whitefish, respectively, was 44.5 river miles and 12 river miles, from their points of capture.

Trends in whitefish movement were hard to detect because so few fish received tags. One fish was tagged in October 1998 and was never been detected in the 11 months of tracking in the main body of the reservoir or vehicle searches. Another whitefish was tagged in October 1998 and was not detected until late March 1999. By then it had traveled five river miles up reservoir and was holding in deep (>6.5 m) water. Two others have not ventured more than 6 river miles from their point of capture. One mountain whitefish was tagged in the upper river near Pioneer Park (River Mile 86.5) and stayed in the immediate area until early July 1999. Then in one 2-week period, it traveled some 45 river miles downstream and remained there. The two lake whitefish have both moved down reservoir from their points of capture; one 12 river miles and one 5 river miles. No real seasonal movement patterns have emerged from the radio telemetry tracking for whitefish. Information taken while attempting to collect specimens for radio tagging indicate that whitefish were much more common in the overall catch during the winter and early spring and catches dropped off by late spring and early summer.

Largemouth Bass

A total of 30 largemouth bass were captured and implanted with radio tags. This was the only species of fish that the target number of 30 tagged fish was reached. The bass were captured throughout the entire length of the reservoir and were the most widely ranging of the targeted fish. No bass were captured and tagged prior to March 31, 1999 and nearly all fish collected came from sloughs or flooded vegetated areas where spring water temperatures were slightly higher than the main body of the reservoir.

During the 11-month tracking period, the 30 tagged fish averaged a biweekly movement of approximately 1.1 river miles. An overall maximum average distance traveled for these fish was 4.5 river miles. The greatest distance traveled by an individual largemouth bass was 14 river miles from its point of capture. This fish was captured on June 4, 1999 in Renshaw slough (River Mile 42).

Winter movement of largemouth bass based on radio telemetry tracking remains unknown in the reservoir. Spring movements appeared to be driven by a combination of increasing water temperature and water elevation. Sloughs and areas of dark colored substrate attracted bass early in the spring as daytime water temperatures increased. As water levels rose with the spring runoff, bass were found moving farther and farther into flooded sloughs and tributary mouths. During this period, movement distances remained small (less than two river miles). By mid-summer when runoff flows began to recede, bass movements tended to be greater and were generally from sloughs to submerged aquatic macrophyte beds along the main river channel. Movements of three to six river miles became more common. Fish remained in these areas into early fall. Water level fluctuations appeared to have detrimental effects on some slough dwelling bass populations. One confirmed tagged fish was found dead in a dewatered slough. It is also believed that two other bass whose movements had not changed in nearly 2 months were likely mortalities stranded in nearly dry sloughs.

Five largemouth bass were implanted with temperature tags. The tagging locations of these fish ranged from the extreme southern end of the Reservoir near Pioneer Park to the northern end at Tiger slough. No clear trend temperature data was exhibited for largemouth bass.

Rainbow Trout

Only one rainbow trout meeting the size requirements was captured and tagged. Because of this, no trends about rainbow trout movements within the Box Canyon Reservoir can be determined. The lone rainbow trout was captured on December 15, 1998 at River Mile 52, just downstream of the mouth of Ruby Creek. The fish moved an average of 2.0 river miles per biweekly tracking period and moved a maximum of 14.5 river miles upstream from its point of capture. This fish was last located in late June 1999 in the Tacoma Creek slough. It has not been found since in either the main river or searched tributaries

Westslope Cutthroat Trout

Only one westslope cutthroat trout meeting the size requirements was captured and tagged. Because of this, no trends about cutthroat trout movements within the Box Canyon Reservoir can be determined. The single cutthroat trout was captured on April 7, 1999 at River Mile 70, in the mouth of Calispell Creek. The fish moved an average of 2.2 river miles per biweekly tracking period and moved a maximum of 7.0 river miles upstream from its point of capture. This fish was last located early September 1999 near the entrance of Tacoma Creek slough. This fish has not moved from its location in nearly three months and is believed to be dead.

Migration Below Box Canyon Dam

The seven antennae located below the dam recorded a number of tags coming within their field of detection. These antennae were in operation from December 1, 1998 through September 12, 1999. Several underwater antennae were knocked out of commission by high flows below the dam and as a result several time gaps exist in the fixed underwater antennae monitoring period; however, all above water antennae were monitoring during the entire monitoring period.

Examination of the data indicated that only one non-temperature tag was picked up by one or more of these antennae. This tag that was recorded, was implanted in a largemouth bass caught in Renshaw Creek slough (River Mile 42) in early June 1999. This fish has remained in the lower end of the Box Canyon Reservoir, moving between Tiger slough (River Mile 45) and the Box Canyon Dam (River Mile 34). In early September 1999, this fish swam close enough to the dam to be recorded by the fixed antennae. It was located two weeks later 4 miles upstream of the dam near Cedar Creek slough (River Mile 38). No other coded or temperature tags were recorded by the seven fixed antennae.

Summary

The findings for the radio-telemetry study seemed to corroborate the adfluvial trapping data. Brown trout were the most abundant salmonid species found in the reservoir and typically found in the most southern portion of the reservoir. Very few of the other salmonids could be found for transmitter implants and even fewer that were of the appropriate size. Although brown trout displayed active movement within the reservoir, most of their movement remained within close association of the 4 tributaries that showed adfluvial spawning migrations.

The limited numbers of native salmonids captured in the adfluvial trapping program and for transmitter implants suggests that the reservoir and the tributaries are two disjunct systems for native fish. Native salmonids appear to exist in viable population sizes only in the tributary resident form. Reservoir habitat conditions appear to be amenable only to non-native warm-water species and fisheries connectivity of the reservoir and its tributaries appear only to apply to non-native brown trout.

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Attachments

Attachment 1: 1998-2000 Salmonid capture results on Box Canyon reservoir tributaries, Pend Oreille River, WA.

Tributary		**Brook Trout**			**Brown trout**			**Rainbow trout**	
		1998 Up/Down	1999 Up/Down	2000 Up/Down	1998 Up/Down	1999 Up/Down	2000 Up/Down	1998 Up/Down	1999 Up/Down	2000 Up/Down
Indian										
	total caught	3 \ 54	3 \ 6	1 \ 5	5 \ 50	3 \ 25	9 \ 15	2 \ 2	0 \ 4	
	total tagged	1 \ 29	1 \ 3		2 \ 33	0 \ 2	1/0	2 \ 2	0 \ 4	
N.F. Skookum										
	total caught	3 \ 23	5 \ 7	1 \ 2	13 \ 93	18 \ 19	5 \ 18			
	total tagged	3 \ 10			9 \ 58	0 \ 2	0 \ 6			
Main Skookum										
	total caught	27 \ 13	12 \ 42	6 \ 26	24 \ 45	38 \ 37	12 \ 12	2 \ 0	0	0 \ 1
	total tagged	5 \ 5	1 \ 5	0 \ 10	1 \ 21	7 \ 11	1 \ 3	2 \ 0	0	0 \ 1
CCA										
	total caught	5 \ 15	0 \ 24	1 \ 13	5 \ 35	4 \ 63	6 \ 20			
	total tagged	1 \ 8	1 \ 6	0 \ 2	0 \ 25	1 \ 34	0 \ 8			
Mill										
	total caught	5 \ 6	N/O	N/O	1 \ 0	N/O	N/O		N/O	N/O
	total tagged		N/O	N/O	1 \ 0	N/O	N/O		N/O	N/O
Middle										
	total caught	12 \ 7	N/O	N/O	0 \ 1	N/O	N/O		N/O	N/O
	total tagged	4 \ 4	N/O	N/O	0 \ 1	N/O	N/O		N/O	N/O
EB LeClerc										
	total caught	5 \ 16	3 \ 12	3 \ 2	3 \ 16	4 \ 24	3 \ 8			0 \ 1
	total tagged	3 \ 11	0 \ 4	0 \ 2	2 \ 12	0 \ 12	0 \ 6		0 \ 1	
WB LeClerc										
	total caught	2 \ 12	0 \ 25	0 \ 7	5 \ 2	5 \ 12	3 \ 7	0 \ 3	0 \ 2	
	total tagged	2 \ 4	0 \ 5	0/3	5 \ 2	1 \ 7	1 \ 2	0 \ 1	0 \ 1	
Cedar										
	total caught	5 \ 9	3 \ 12	2 \ 6	0 \ 3	1 \ 2	5 \ 5	13 \ 5	3 \ 2	1 \ 0
	total tagged	1 \ 5	0 \ 1	0 \ 1	0 \ 2	0 \ 1		13 \ 2		
Big Muddy										
	total caught	9 \ 33	N/O	N/O	0 \ 1	N/O	N/O	1 \ 1	N/O	N/O
	total tagged	2 \ 1	N/O	N/O		N/O	N/O	0 \ 1	N/O	N/O
Ruby										
	total caught	0 \ 33	10 \ 20	2 \ 14	2 \ 2	0 \ 2	0 \ 1	1 \ 5	1 \ 0	13 \ 1
	total tagged	0 \ 17		0 \ 7	0 \ 1	0 \ 1		1 \ 1		4 \ 1
Totals up\down		**76 \ 221**	**36 \ 148**	**16 \ 75**	**58 \ 248**	**73 \ 184**	**43 \ 86**	**19 \ 16**	**4 \ 8**	**14 \ 3**
Total caught		**297**	**184**	**91**	**306**	**257**	**129**	**35**	**12**	**17**

Kalispel Tribe of Indians

Attachment 1: Cont.

Tributary	Westslope cutthroat			Mountain whitefish			Kokanee		
	1998 Up/Down	1999 Up/Down	2000 Up/Down	1998 Up/Down	1999 Up/Down	2000 Up/Down	1998 Up/Down	1999 Up/Down	2000 Up/Down
Indian									
total caught	4 \ 4	0 \ 3					7 \ 14		0 \ 1
total tagged	4 \ 4	0 \ 2							
N.F. Skookum									
total caught				0 \ 1					
total tagged									
Main Skookum									
total caught									
total tagged									
CCA									
total caught				0 \ 2					
total tagged				0 \ 2					
Mill									
total caught	1 \ 1	N/O	N/O		N/O	N/O		N/O	N/O
total tagged		N/O	N/O		N/O	N/O		N/O	N/O
Middle									
total caught	1 \ 6	N/O	N/O		N/O	N/O		N/O	N/O
total tagged	1 \ 3	N/O	N/O		N/O	N/O		N/O	N/O
EB LeClerc									
total caught	1 \ 1	1 \ 5		0 \ 1	0 \ 1	0 \ 1		0 \ 3	
total tagged	1 \ 1	0 \ 1		0 \ 1				0 \ 1	
WB LeClerc									
total caught	0 \ 2			0 \ 4	0 \ 1	0 \ 1		0 \ 1	
total tagged	0 \ 2			0 \ 4					
Cedar									
total caught	1 \ 2		2 \ 1	1 \ 20		14 \ 3	0 \ 1	2 \ 1	0 \ 1
total tagged	1 \ 2		0 \ 1	0 \ 4					
Big Muddy									
total caught	2 \ 0	N/O	N/O		N/O	N/O		N/O	N/O
total tagged		N/O	N/O		N/O	N/O		N/O	N/O
Ruby									
total caught	0 \ 4			0 \ 19	1 \ 0	0 \ 3			
total tagged	0 \ 3			0 \ 4					
Totals up\down	**10 \ 20**	**1 \ 8**	**2 \ 1**	**1 \ 47**	**1 \ 2**	**14 \ 8**	**7 \ 15**	**2 \ 5**	**0 \ 2**
Total caught	**30**	**9**	**3**	**48**	**3**	**22**	**22**	**7**	**2**

Attachment 2: 1998 - 2000 Non-salmonid capture results for Box Canyon Reservoir tributaries, Pend Oreille River, WA.

Tributary	**Sculpin**			**N. Pikeminnow**			**Bridgelip Sucker**			**Largescale Sucker**			**Yellow Perch**		
	1998	1999	2000	1998	1999	2000	1998	1999	2000	1998	1999	2000	1998	1999	2000
	U/D	U/D	U/D	U/D	U/D	U/D	U/D	U/D	U/D	U/D	U/D	U/D	U/D	U/D	U/D
Indian															
total caught	1 \ 9	2 \ 1				0/2	0 \ 1							0 \ 2	
total tagged															
N.F. Skookum															
total caught	0 \ 9	2 \ 0	3/2												
total tagged															
Main Skookum															
total caught	5 \ 33	5 \ 10	2/9		0 \ 2							0/3			
total tagged															
CCA															
total caught	5 \ 13	0 \ 3	2/5	0 \ 3	0 \ 2										
total tagged				0 \ 1											
Mill															
total caught		N/O			N/O			N/O			N/O			N/O	
total tagged		N/O			N/O			N/O			N/O			N/O	
Middle															
total caught	2 \ 4	N/O			N/O			N/O			N/O			N/O	
total tagged		N/O			N/O			N/O			N/O			N/O	
EB LeClerc															
total caught		1 \ 2	0/3	0 \ 1	0 \ 1										
total tagged				0 \ 1											
WB LeClerc															
total caught	2 \ 2	2 \ 1	3/3												
total tagged															
Cedar															
total caught	0 \ 3							0\1	0/2			0/1			
total tagged															
Big Muddy															
total caught	2 \ 10	N/O			N/O			N/O			N/O			N/O	
total tagged		N/O			N/O			N/O			N/O			N/O	
Ruby															
total caught	0 \ 1		1/0				0 \ 1	0 \ 1				0/1			
total tagged										0 \ 1					
Totals (caught)	**17 \ 84**	**12 \ 17**	**11/22**	**0 \ 4**	**0 \ 5**	**0/2**	**0 \ 2**	**0 \ 2**	**0/2**	**0 \ 1**		**0/5**		**0 \ 2**	
Totals up & down	**101**	**29**	**33**	**4**	**5**	**2**	**2**	**2**	**2**	**1**	**0**	**5**	**0**	**2**	**0**

Attachment 3: Migration monitoring data for nine temperature tagged fish in Box Canyon Reservoir.

Tag #, Species, Mile	Date	Depth (ft)	Tag Temp (C)	Surface temp (C)	River mile
149.059 **LMB** RMT:61.5	4/6/99	5	9	7	61.5
	4/19/99	3	15	12	61.5
	6/28/99	20	19	14	54
	7/27/99	25	23	18	54
	8/9/99	15	28	21	54
	8/24/99	18	28	20	54
	9/10/99	3	22	18	62.5
	9/13/99	Harvested by angler			62.5
149.109 **LMB** RMT:86.5	6/18/99	3	19	16	74.5
	6/30/99	15	20	15	73.5
	7/15/99	2	22	19	74
	7/29/99		27	19	74
	9/23/99	5	22	17	73
	10/5/99	3	18	13	74
	12/2/99	5	6	4	74
	1/12/00	3	4	2	73.5
	1/26/00	2	4	1	73.5
	2/9/00	4	5	2	73.5
	2/23/00	4	6	3	74
	3/8/00	4	7	4	73.5
	3/22/00	5	9	6	74
	4/5/00	2	15	11	74
	6/14/00	7	18	13	73.5
	7/26/00	2	27	22	73.5
	8/10/00		27		73.5
	8/24/00	9	27	21	73.5
	9/7/00	5	23	18	73.5
	9/19/00	3	21	17	73.5
	10/4/00	10	18	13	73.5
	10/25/00	2	14	10	73
	11/8/00	15	11	8	73.5

Tag #, Species, Mile	Date	Depth (ft)	Tag Temp (C)	Surface temp (C)	River mile
149.019 **LMB** RMT:73.5	09/17/99	9	16	17	75
	03/17/00		4		73.5
	04/05/00	2	25	7	75
	04/20/00	3	30	8	75
	06/14/00		21	13	75
	06/30/00	5	>30	18	75
	07/27/00	5	>30	22	75
	08/09/00	10		23	69
	08/10/00	4	>30	23	75
	08/24/00	10	24	21	75
	09/07/00	11	20	18	75
	09/19/00	5	16	17	75
	10/04/00	13	10	13	75
	10/25/00	13	8	10	75
	11/08/00	8	0	13	75
149.089 **LMB** RMT:44.5	4/19/99	8	15	11	44.5
	5/3/99			11	44.5
	5/17/99	6	13	9	48
	6/28/99	24	18	14	47.5
	8/24/99	19		21	48
	9/21/99	14	22	17	49
	10/19/99	23	15	11	46
	11/4/99	9	11	8	45.5
	11/15/99	4	12	9	46
	11/30/99	16	9	6	46
	12/21/99	10	7	3	46
	3/10/00		6		45
	3/21/00	10	7	4	45
	4/4/00	28	14	9	45
	4/18/00	5	17	14	43

Tag #, Species, Mile	Date	Depth (ft)	Tag Temp (C)	Surface temp (C)	River mile
149.049 **LMB** RMT:71.0	4/22/99	9	11	8	72
	5/18/99	10	16	9	72
	6/2/99	3	17	14	70
	6/18/99	2	18	16	74
	6/30/99	16	18	15	70
	7/15/99		20	18	74
	7/29/99	2	23	21	74
	8/11/99	3	24	21	73.5
	8/26/99	7	24	21	71.5
	9/8/99	8	20	18	72.5
	9/23/99	15	21	17	73.5
	10/5/99		16	14	72.5
	11/2/99	9	11	9	74
	11/17/99	16	11	9	74
	12/1/99	13	8	6	74
	12/22/99		6		74
	1/26/00	4	4	1	73.5
	2/9/00	3	4	2	73.5
	2/23/00	4	5	3	73.5
	3/8/00	2	6	4	73.5
	3/22/00		8		74
	4/5/00	2	13	11	74
	5/30/00		16		74
	6/14/00		19	13	73.5
	7/26/00	8	27	22	73
	8/10/00	5	28	23	72
	8/23/00	6	25	21	72
	9/7/00	14	18	18	73.5
	9/19/00	3	21	17	73.5
	10/4/00	2	16	13	73.5
	10/25/00	4	13	10	73.5
	11/8/00	2	8	8	73.5

Attachment 3: Cont.

Tag #, Species, Mile	Date	Depth (ft)	Tag Temp (C)	Surface temp (C)	River mile
149.069 BRN RMT:73.0	3/10/99	3	6		81.5
	4/5/99	6	9		81.5
	4/22/99	6	13	8	81.5
	5/4/99		11	7	81.5
	5/18/99		14	9	81.5
	6/2/99	10	15	10	81.5
	6/17/99	7	18	14	81.5
	6/28/99		18	14	81.5
	6/29/99	11	18	14	81.5
	7/15/99	3	21	17	81.5
	7/29/99	5	23	19	81.5
	8/11/99	4	21	21	81.5
	8/26/99	3	20	20	81.5
	9/8/99	2	20	18	81.5
	9/23/99	2	20	17	81.5
	10/5/99	2	18	13	81.5
	11/2/99	2	13	8	81.5
	11/17/99	3	13	9	81.5
	11/26/99	3	9	6	81.5
	12/22/99	3	7	4	81.5
	1/7/00	4	5	2	81.5
	1/21/00	4	4	1	81.5
	2/4/00		5	1	81.5
	2/9/00	3	5	2	81.5
	2/23/00	2	6	2	81.5
	3/8/00	4	7	4	81.5
	3/22/00	2	8	4	81.5
	4/5/00	3	11	7	81.5
	4/20/00	3	12	8	81.5
	5/18/00	4	16	12	81.5
	5/30/00	11	17	12	81.5
	6/14/00	5	18	13	81.5
	6/30/00	5	23	18	81.5
	7/27/00	10	23	22	81.5
	8/10/00	3	23	23	81.5
	8/24/00	2	20	21	81.5

Tag #, Species, Mile	Date	Depth (ft)	Tag Temp (C)	Surface temp (C)	River mile
149.069 Cont.	9/7/00	2	18	17	81.5
	9/19/00	3	19	16	81.5
	10/4/00	2	16	13	81.5
	10/25/00	2	14	10	81.5
	11/8/00	3	13	8	81.5
149.010 BRN RMT:87.5	5/4/99	10	10	7	88
	5/18/99	8	13	9	87.5
	6/2/99	16	15	11	87.5
	6/17/99	24	19	14	87.5
	6/29/99	9	19	14	87.5
	9/17/99	Sk. Cr	11		72.5
	10/1/99	Sk. Cr			72.5
	11/1/99	Sk. Cr	6		72.5
	11/12/00	Sk. Cr	11		72.5
	11/26/99	Sk. Cr	7		72.5
	1/12/00	4	5	2	88
	1/26/00	14	5	2	88
	2/9/00	11	5	2	87.5
	2/23/00	11	6	2	87.5
	3/8/00	15	7	4	87.5
	3/22/00	11		4	87.5
	6/14/00	8	19	14	88
	6/30/00	6	25	18	88
	7/27/00	4	29	22	88
	8/10/00	5	30	23	88
	8/22/00	2	25	23	88.5
	8/24/00	5	19	21	88.5
	9/7/00	6	20	18	88.5
	9/19/00	8	22	17	88.5
	10/4/00	5	20	13	88.5
	10/25/00		14		88.5

Tag #, Species, Mile	Date	Depth (ft)	Tag Temp (C)	Surface temp (C)	River mile
149.039 BRN RMT:73.0	5/18/99	10	13	9	74
	6/2/99		14	11	72
	7/15/99	15	22	18	73.5
	7/29/99			19	74
	9/3/99	slough	13		73.5
	9/17/99	slough	11		73.5
	10/1/99	slough	8		73.5
	11/1/99	slough	3		73.5
	11/12/99	slough	11		73.5
	11/26/99	slough	7		73.5
	12/21/99	slough	5		73.5
	1/7/00	slough	2		73.5
	1/21/00	slough	2		73.5
	2/4/00	slough	2		73.5
	2/18/00	slough	2		73.5
	3/10/00	slough	5		73.5
	3/17/00	slough	5		73.5
	3/31/00	slough	6		73.5
	4/28/00	slough	11		73.5
	5/31/00	slough	14		73.5
	6/16/00	slough	14		73.5
	6/30/00	slough			73.5
	7/27/00	slough			73.5
	9/22/00	slough	11		73.5
	10/3/00	slough			73.5
149.119 BRN RMT:73.0	09/17/99		4		72.5
	11/01/99		10		71
	11/17/99		7	6	71
	01/26/00	7	2	1	71
	02/09/00	5	3	2	71
	02/23/00	7	4	3	71
	03/08/00	3	6	4	71
	03/22/00	5	6	4	71
	04/05/00	3	8	7	71
	04/20/00	4	10	8	71

Appendix 1.

Zoological Investigation of Halfmoon and Yocum Lakes, Pend Oreille Co., Washington.

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Background:

This project was performed under the aegis of the Kalispel Tribe of Indians, the U.S. EPA and Eastern Washington University. It was intended to be a biological survey or inventory of Yocum and Halfmoon Lakes, Pend Oreille Co., Washington, including both benthic and pelagic components. The study included two sampling days at each lake: 10 July and 12 September, 2000.

Methods

Lakes Descriptions: The lakes studied include Yocum Lake (19.4 hectares) in section 23 of the township defined as T 36 N and R 43 E, and Halfmoon Lake (5.3 hectares) in sections 23 and 35 of the township defined as T 34 N and R 44 E. Both lakes exist east of the Pend Oreille River, north of the town *Usk*, and south of the town *Ione*, Pend Oreille County, Washington (see Washington Atlas and Gazetteer, 1998, DeLorme Mapping Co.). Both are small, deep, and mesotrophic montane lakes in the Selkirk Range of the Rocky Mountains

Sample Locations: Planktonic samples (zooplankton, phytoplankton, chlorophyll, D.O., and temperature) were collected from the water column above the deepest location within each lake. At Halfmoon Lake this was at about 8 m of depth in the south basin of the lake. Planktonic collecting in Yocum lake occurred in 18 meters of water in the deep north basin. Benthic invertebrates were collected at each of the deep water locations described above and at shallow water littoral site in each lake. Each shallow site was chosen to be at a depth which was 25-30% of the lakes maximum depth. And, in each case the shallow site existed within the lakes littoral zone. For Yocum Lake this was in 5 meters of water at the shallow south end. Within Halfmoon Lake, benthic sampling at the shallow site occurred in 3 meters of water at the north end of the lake.

Sampling and Collection Methods: Temperature and DO profiles were made for each lake, on each sample date, using a YSI 85 water quality meter. A three liter water bottle sampler (Aquatic Research Instruments, Lemhi ID) was used to collect water for determination of vertical chlorophyll profiles and for identification of phytoplankton. Replicate water collections for chlorophyll analysis were made at every two meters of depth, stored in 60 ml sample bottles in the dark and on ice, then assayed using a Turner 10-AU field fluorometer. Water for phytoplankton identification was collected from 5 m water depth, preserved with the addition of 3 mls of lugols preservative per liter of sample, and stored in one liter sample bottles for later identification and biovolume determination. Algal species identification was conducted as per Prescott (1954). Biovolume was estimated by Ms. Linda Sexton, Eastern Washington University, Department of Biology.

Three replicate zooplankton samples were collected from the deep basin within each lake, on each sample date. Each sample was collected with a 20 cm dia., 153 um mesh plankton net hauled 1 meter/second vertically, from within 1 meter of the lake bottom, to the lake surface. Vertical tow lengths were 15 meters in Yocum Lake, and 7 meters in Halfmoon Lake. Upon retrieval, contents were collected onto a 153 um seive, dipped into 95% EtOH for 30 seconds, then re-suspended in a 70%EtOH and stored in 60 ml sample bottles.

Zooplankton type specimens, mounted in Hoyer' mounting medium (Edmonson 1959), were identified using the taxonomic keys of Brooks (1959) for the Branchiopoda, and Wilson and Yeatman (1959) for the Calanoid and Cyclopoid copepods. Sample abundance was used to estimate density of each species. Body lengths of sample individuals were converted to body mass using the length-dry weight regressions of Dumont (1975) and Bottrell et al (1976) in an effort to estimate the biomass of each species present.

Benthic animals were collected using an Eckman Dredge and the Hester-Dendy plate incubation technique. Two replicate dredge samples were collected at the deep and littoral sample stations, and at a third location of intermediate depth. The contents of each sample were sifted through a 500 um filter to animals from substrate. Animals were fixed and stored in 70% EtOH. Hester-Dendie plates were placed August 17, 2000 and retrieved September 12, 2000 in each lake (plates placed 10 July and marked with buoys were stolen: 17 August plates were placed in each of the same locations and discretely tied to shore). Two sets of eight 100 cm^2 masonite plates were submerged at the deep and littoral stations of each lake. Upon retrieval, each set of plates was disassembled, and the aufwuchs on each plate scraped onto a 250 um mesh seive. The sieve contents were dipped in 95% ethanol for 1 minute, then suspended 70% EtOH in a single sample bottle. Benthic animals were identified using the keys of Merritt and Cummins (1996) and Thorp and Covich (1991), and enumerated.

Results and Discussion

The chlorophyll, dissolved oxygen, and temperature profiles of Yocum Lake are presented in Figure 1, and profiles of Halfmoon Lake are presented in Figure 2. Yocum Lake exhibited strong thermal stratification typical of a mountain lake in early summer. Maximum temperatures did not exceed 19 degrees, the thermocline rangeg from 4 to 10 meters and hypolimnion temperatures were below 10 degrees (figure 1). DO was abundant at all depths and chlorophyll profiles suggests high primary productivity in the thermocline and hypolimnion. September profiles illustrate a deep, cool and well circulated epilimnion with low phytoplankton biomass.

Halfmoon Lake (figure 2) and Yocum Lake exhibited markedly similar profiles. Figures 1 and 2 both illustrate cool epilimnetic waters of a mountain lake, abundant mixing (DO of the epilimnion is always above 5 mg l^{-1}), and low chlorophyll densities which increase in the thermocline.

Phytoplankton constituents of Yocum and Halfmoon lakes are presented in Tables 1 and 2, respectively. Both lakes possess a variety of species with at least one representative in five (Yocum) or six (Halfmoon) of the major taxonomic divisions. Species richness in Yocum lake included at least 17 species (Table 1), and although it is a much small water body, 26 species were observed in Halfmoon Lake (Table 2). In each case, most of the richness existed within the green algae (Chlorophyta) and diatoms (Chrysophyta, Bacillariophyceae) and phytoflagellates (Cryptophyta or Pyrrophyta). Biovolume estimates (Figure 3) indicate this pattern as well. July biovolume patterns in Yocum Lake indicate green algae, diatoms, and the flagellate *Ceratium* (Pyrrophyta) compose 11, 42, and 44 percent of the phytoplankton, respectively (figure 3). Late summer composition included 27 percent green algae, 38 percent diatoms, and 30 percent Cryptophyte flagellates (*Cryptomonas* and *Rhodomonas*).

Similar biovolume patterns were observed in Halfmoon Lake (figure 3). July biovolume primarily included 11 percent green algae (Chrysophyta), 60 percent diatoms (Crysophyta), and 26 percent flagellates (the Cryptophytes *Cryptomonas* and *Rhodomonas*). September composition includes the same three taxa representing 7, 66, and 16 percent of the biovolume respectively. Additionally the Euglenoid *Trachelomonas* represented 8 percent of the biovolume.

Halfmoon Lake appeared to have accumulated far more phytoplankton biomass (figure 3). Total biovolume in Halfmoon Lake was approximately twice the biovolume observed in Yocum Lake (0.64 $mm^3\ l^{-1}$ versus 0.37 $mm^3\ l^{-1}$, respectively). In September, total biovolume in Halfmoon Lake was approximately 6 times greater than in Yocum Lake (1.49 $mm^3\ l^{-1}$ versus 0.26 $mm^3\ l^{-1}$, respectively).

Zooplankton constituencies, abundance, and biomass are presented in figure 4. Species detected include the 1.8 mm maximum length herbivorous *Daphnia rosea*, seen in both lakes on both dates. *Ceriodaphnia reticulata* was observed in halfmoom lake samples collected on both sample dates. It is an herbivorous member of the family daphniidae and very small (< 1 mm). *Acanthodiaptomus*, an uncommon genus of the universal calanoid copepod family diaptomidae, was observed in Yocum lake samples from both dates. *Diaptomus* copepods are common herbivores world-wide. Finally, a very common omnivorous cyclopoid copepod, *Diacyclops thomasi*, was observed in both lakes from samples collected on both sample dates. *Diacyclops* consume phytoplankton and may prey upon the smaller members of the zooplankton community (copepod nauplii larvae and immature branchiopods).

Most of the plankton biomass in Yocum Lake was *Daphnia rosea* (figure 4). *D. rosea* also represented 60% or more of the Halfmoon Lake zooplankton biomass in July, while in September, *D. rosea* biomass had declined to just 15 percent of the total zooplankton biomass. In both lakes, zooplankton biomass was greater in July than in September. In Yocum Lake, total zooplankton biomass declined from 107 ug l^{-1} in July to 75 ug l^{-1} in September. In Halfmoon Lake total zooplankton biomass was 295 ug l^{-1} in July, and only 62 ug l^{-1} in September. The small size of the plankton constituents in both lakes, and the lack of any 2mm or larger invertebrate predator suggests vertebrate planktivores are important regulators of the plankton composition (Brooks and Dodson 1965, Zaret 1980), and that

Benthic animals collected within the two lakes included dipterans, amphipods, gastropods, bivalves, and oligochaetes. Families and genera identified from Yocum Lake samples included two dipterans (*Chaoborus* (chaoboridae) and a chironomid keyed to the family chironomidae), talitrid amphipods, gastropods of the genera *Physella* and *Valvata*, one species of bivalve in the family sphaeriidae, and oligochaetes. July dredge samples included *Chaoborus*, the talitrid, both gastropods, and the bivalve (figure 5). *Chaoborus* and the chironomid were the only organisms present in the dredge samples collected in September (figure 5). The talitrid amphipod and the sphaeriid bivalve were the only organisms that appeared to have colonized the Hester Dendy plates upon retrieval in September (figure 5). Densities of each taxa and for each sample technique are reported in figure 5. The benthic community appears to be more diversity and higher taxa densities in July. Although diptera are abundant in September, all other organisms are absent. The Hester-Dendy plate incubation technique does not carefully represent benthic community composition, diversity, or abundance of Yocum Lake.

Benthic organisms identified from Halfmoon Lake samples included *Chaoborus*, a chironomid belonging to the family tanypodinae, an amphipod belonging to the genus *Gammarus*, snails from the genus *Helisoma*, and sphaerid bivalves. Both July and September samples included diverse benthic communites. Animals from the *Chaoborus*, tanypodinae, Helisoma and sphaeriidae taxa were observed in July dredge samples (figure 5). *Chaoborus*, Tanypodinae, *Gammarus*, and *Helisoma* were present in September dredge samples. Hester-Dendy plate incubations estimated high densities of *Gammarus* and some of the tanypodinae chironomid. Estimated benthic animal densities are reported in figure 5. Variation in the conclusions drawn from among the two different sample techniques are similar to those mentioned above for Yocum Lake. Hester-Dendy plates do not collect the diversity of organisms that are caught using the Eckman Dredge sampler.

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Table 1. Phytoplankton identified from Yocum Lake, Pend Oreille Co., WA, 10 July and 12 September, 2000.

Division	Class	*Genus species*
Chlorophyta	Chlorophyceae	*Ankistrodesmus falcatus*
		Chlamydomonas sp.
		Mougeotia sp.
		Oocystis sp.
		Tetraedion minimum
Chrysophyta	Bacillariophyceae	*Acnanthes* sp.
		Asterionella formosa
		Cocconeis sp.
		Cyclotella sp.
		Fragilaria crotonensis
	Chrysophyceae	*Dinobryon bavaricum*
		Dinobryon sertularia
		Mallomonas sp.
Cryptophyta	Cryptophyceae	*Cryptomonas* sp.
		Rhodomonas sp.
Eubacteria	Cyanobacteria	*Aphanocapsa* sp.
Pyrrophyta	Dinophyceae	*Ceratium hirundella*

Table 2. Phytoplankton identified from Halfmoon Lake, Pend Oreille Co., WA, 10 July and 12 September, 2000.

Division	Class	*Genus species*
Chlorophyta	Chlorophyceae	*Ankistrodesmus falcatus*
		Chlamydomonas sp.
		Mougeotia sp.
		Oocystis sp.
		Pediastrum boryanum
		Scenedesmus bijuga
		Scenedesmun quadricauda
		Tetraedion minimum
Chrysophyta	Bacillariophyceae	*Acnanthes* sp.
		Amphora sp.
		Amphipleura sp.
		Asterionella formosa
		Cocconeis sp.
		Cyclotella sp.
		Fragilaria crotonensis
		Pinnularia sp.
		Synedra sp.
	Chrysophyceae	*Dinobryon sertularia*
Cryptophyta	Cryptophyceae	*Cryptomonas* sp.
		Rhodomonas sp.
Eubacteria	Cyanobacteria	*Anabaena* sp.
		Crucigenia sp.
		Gloecapsa sp.
Euglenophyta	Euglenophyceae	*Phacus* sp.
		Trachelomonas sp.
Pyrrophyta	Dinophyceae	*Ceratium hirundella*

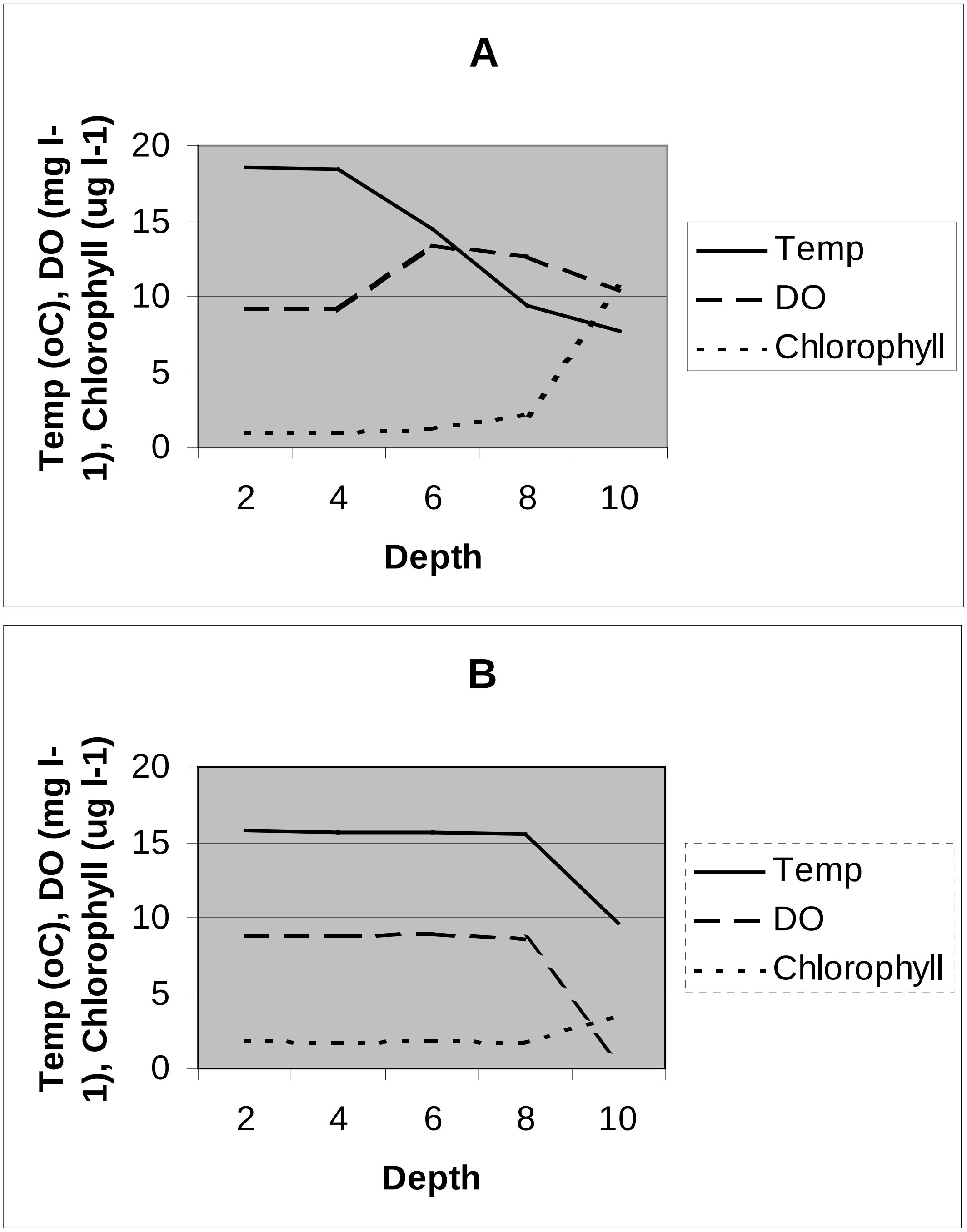
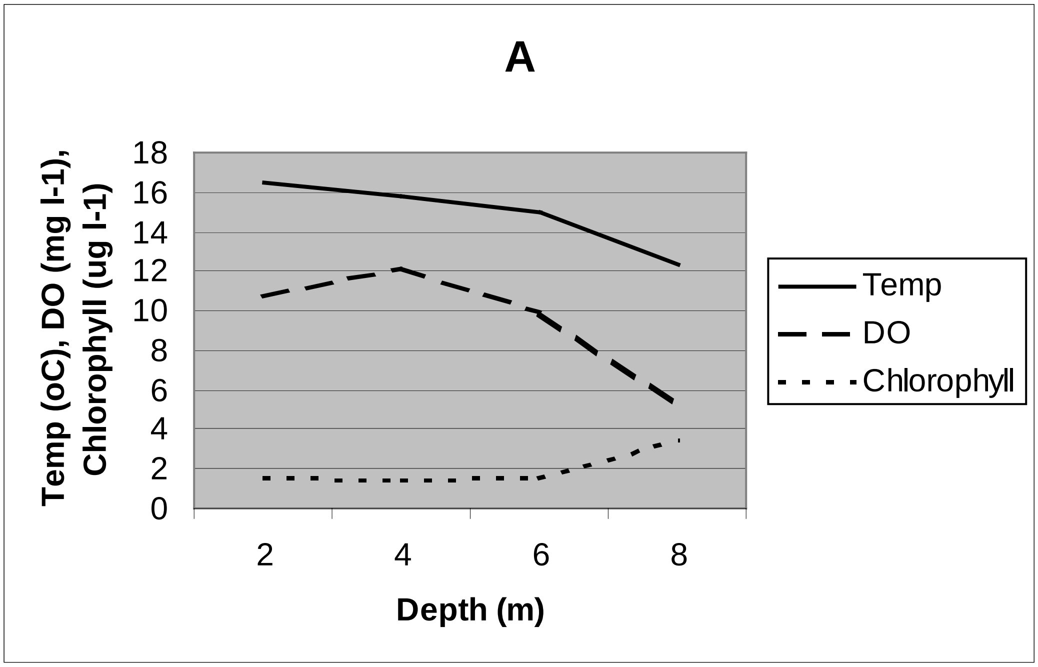


Figure 1. Temperature, dissolved oxygen, and chlorophyll profiles of Yocum Lake: A) 10 July, 2000; B) 12 September, 2000.



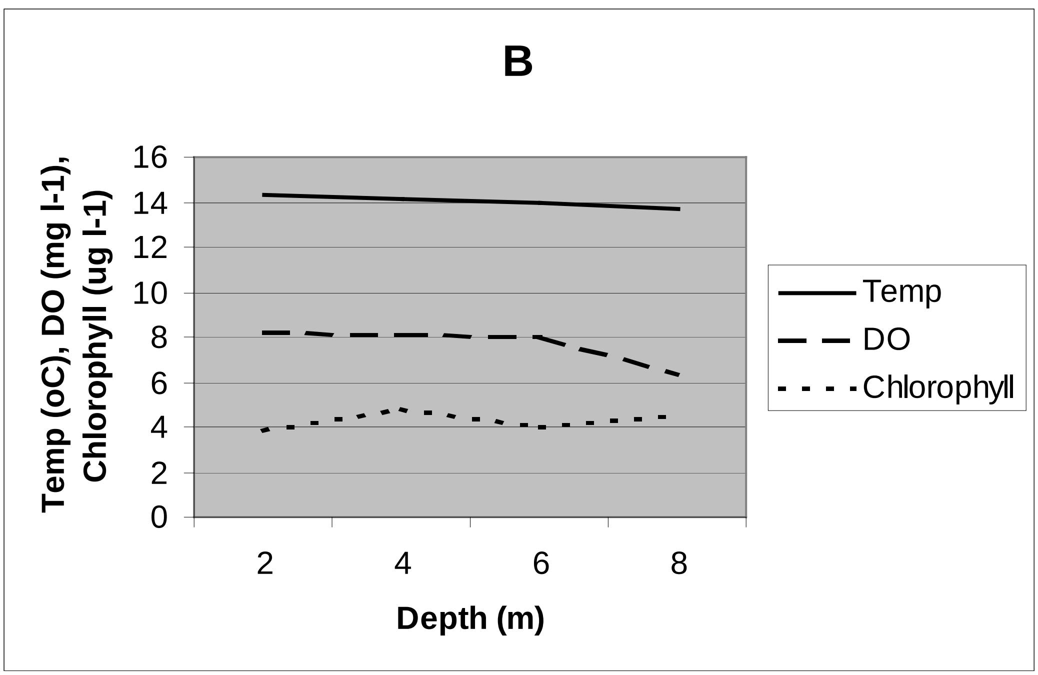


Figure 2. Temperature, dissolved oxygen, and chlorophyll profiles of Halfmoon Lake: A) 10 July, 2000; B) 12 September, 2000.

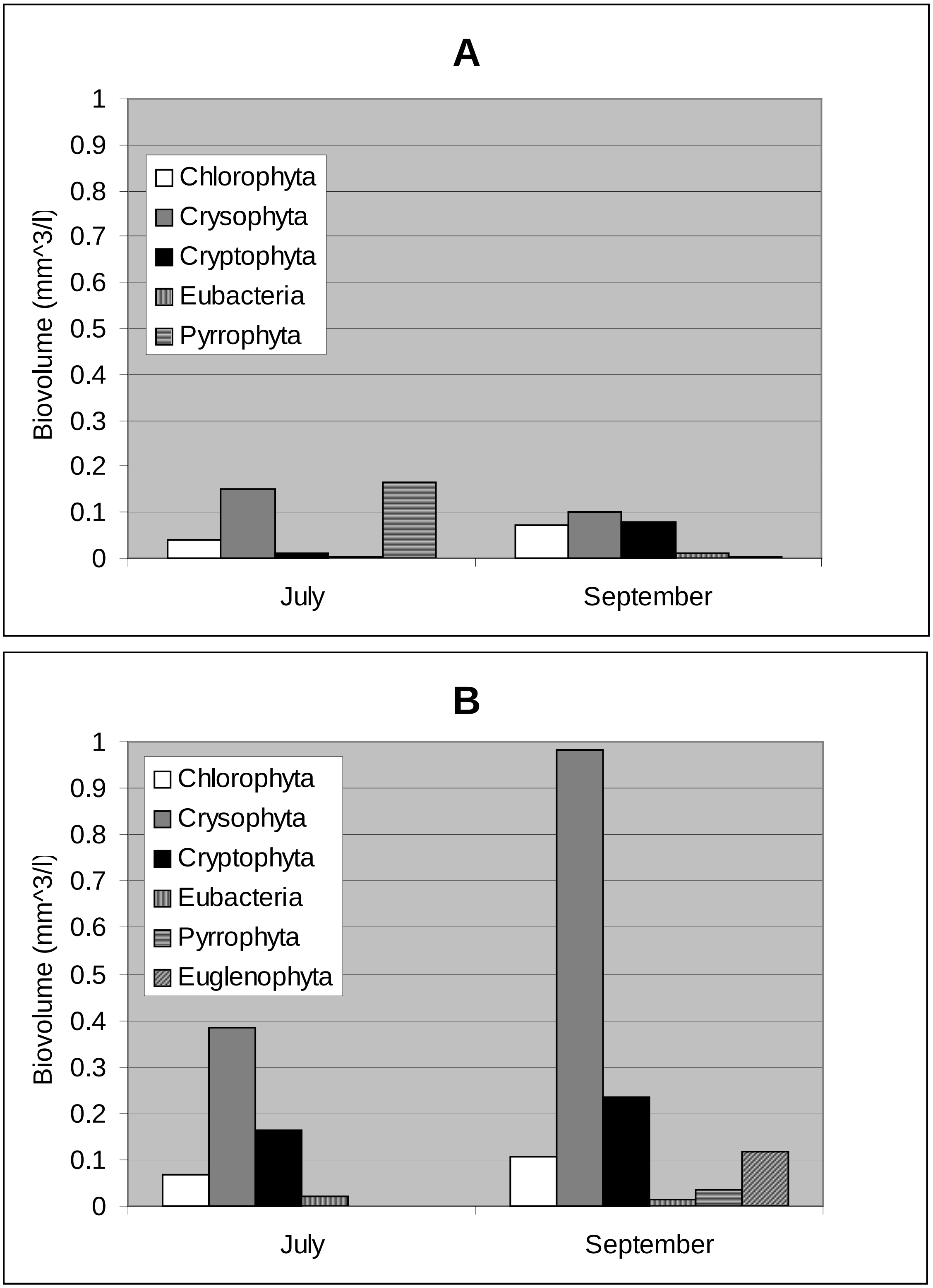
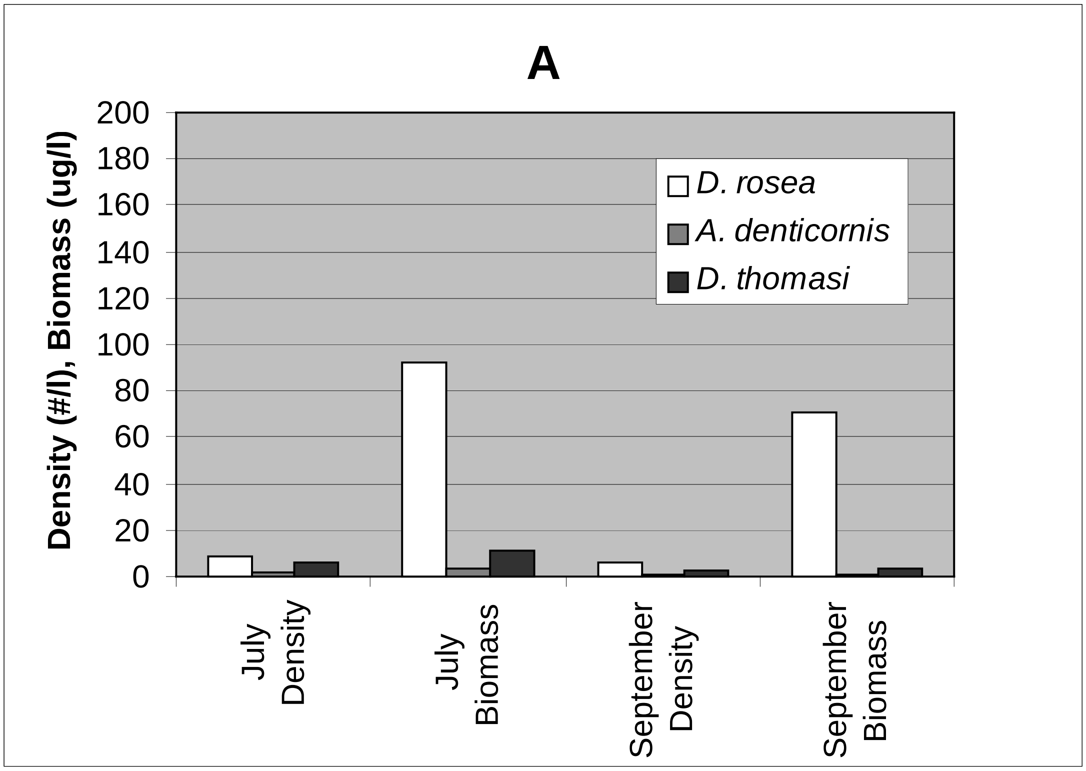


Figure 3. Phytoplankton biovolume by division for Yocum Lake (A) and Halfmoon Lake (B), 10 July and 12 September, 2000.

Kalispel Tribe of Indians



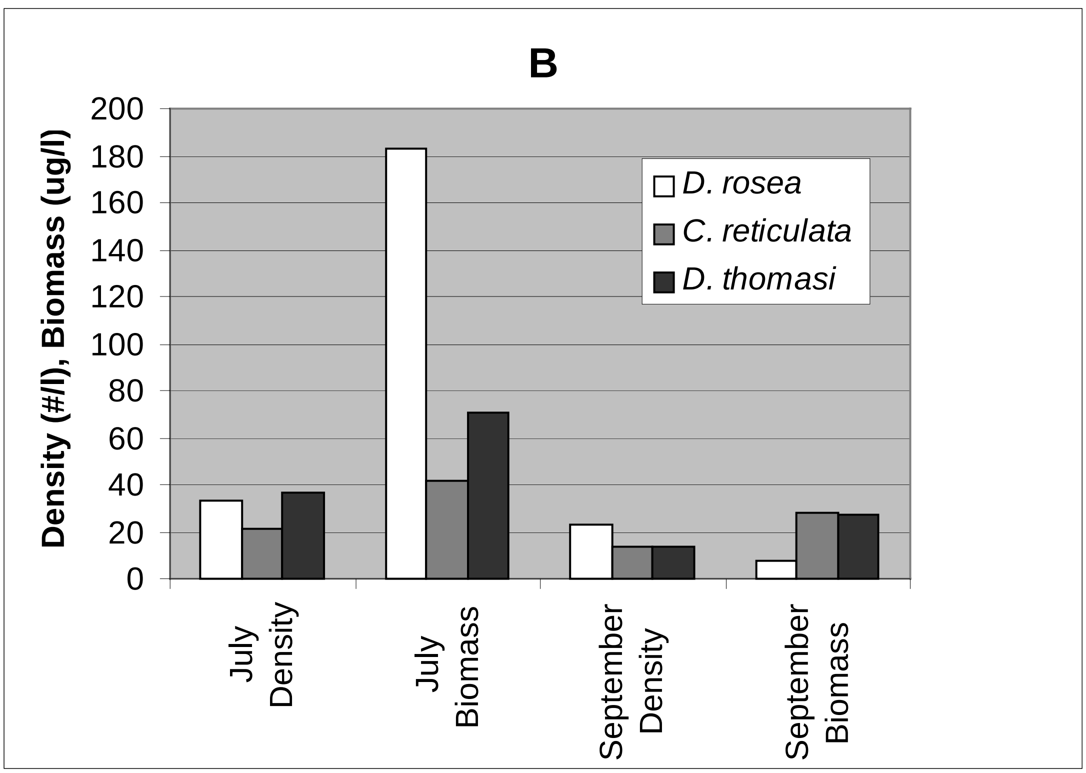


Figure 4. Zooplankton abundance and biomass in Yocum Lake (A) and Halfmoon Lake (B), 10 July and 12 September, 2000.

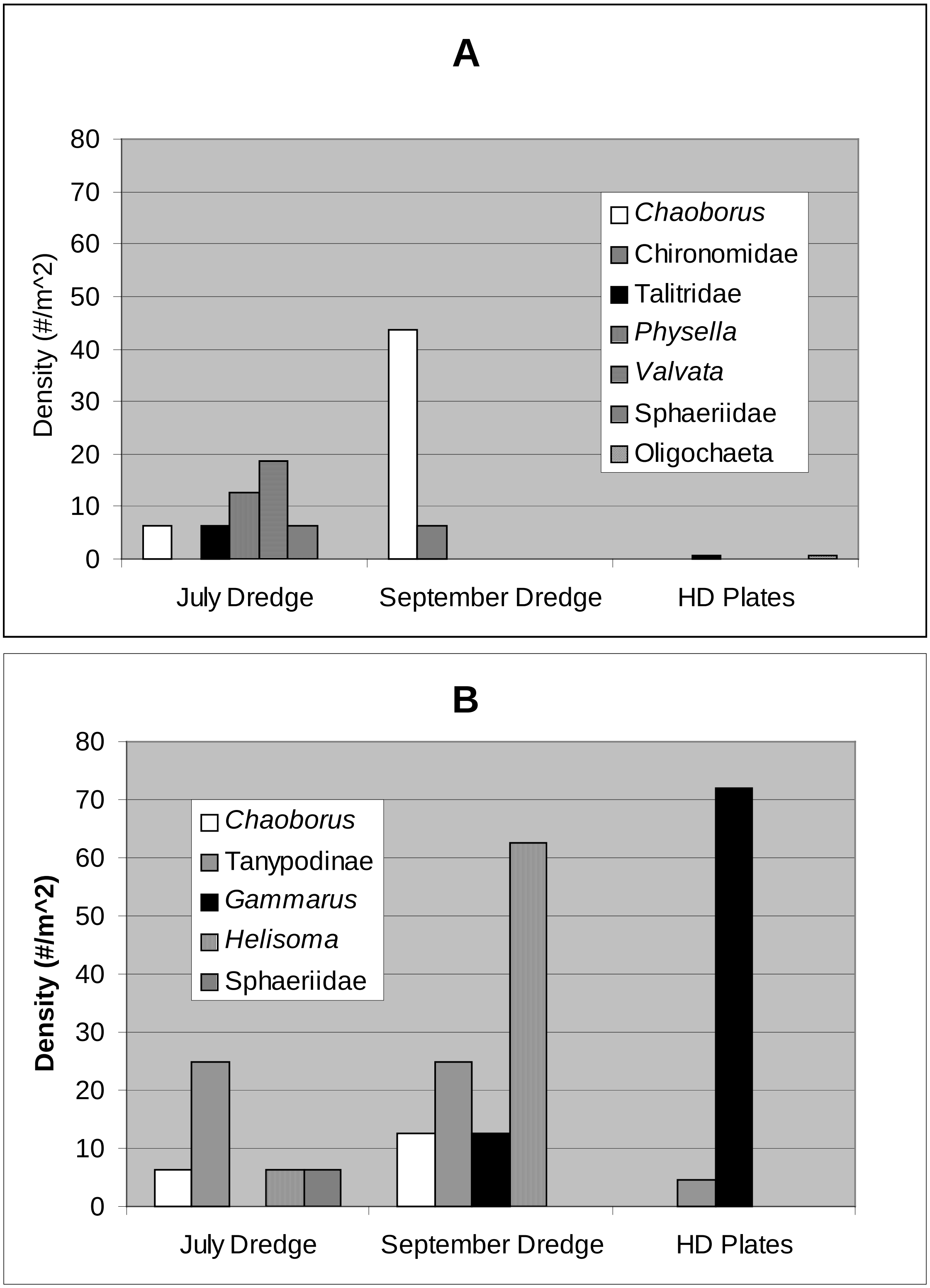


Figure 5. Eckman dredge and plate sampler estimates of zoobenthos density by taxa for Yocum (A) and Halfmoon (B) lakes. Dredge samples were collected on 10 July and 12 September, 2000. Benthic sample plates were placed on 17 August and retrieved 12 September.

2000 WDFW Annual Report for the Project RESIDENT FISH STOCK STATUS ABOVE CHIEF JOSEPH AND GRAND COULEE DAMS

Part I. Baseline Assessment of Boundary Reservoir,
Pend Oreille River, and its Tributaries

Part II. Coordination, Data Standards Development,
and Data Sharing Activities

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2000 WDFW Annual Report for the Project
RESIDENT FISH STOCK STATUS
ABOVE CHIEF JOSEPH AND GRAND COULEE DAMS

Part I. Baseline Assessment of Boundary Reservoir and its Tributaries

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March, 2001

Abstract

Boundary Reservoir and its tributaries were identified as water bodies in the "blocked area" behind Chief Joseph and Grand Coulee Dams that lacked fisheries data. A baseline fisheries assessment of the reservoir and its tributaries was conducted in 2000. The objectives of the study were to measure water quality, primary and secondary production, and fish species composition and relative densities in the reservoir, as well as describe fish habitat, species composition, and estimate densities in the main tributaries.

Temperature, dissolved oxygen, pH, specific conductivity, turbidity, chlorophyll *a*, phytoplankton, periphyton, zooplankton, and benthic macroinvertebrates were sampled in August and October. Boundary Reservoir was isothermal and temperatures ranged from 11 to 22 °C. Mean annual retention time for the reservoir was 1.9 days. The reservoir was classified as oligotrophic, with mean chlorophyll *a* levels of 1.05 μg/L, and mean annual density and bio-volume of phytoplankton of 1,140 org./L and 0.194 mm^3/L. Mean annual density and bio-volume of periphyton was 258 org./cm^2 and 130 mm^3/cm^2 and the mean annual density of zooplankton was 5.0 org./L. The mean annual density of macroinvertebrates and zooplankton that colonized the Hester-Dendy samplers was 76 org./m^2.

Fish were sampled in the reservoir in the spring, summer, and fall via electrofishing and gill netting. Largescale suckers had the highest electrofishing CPUE (45.3 fish/hr.), but northern pikeminnow had the highest horizontal gill net CPUE (12.2 fish/hr.). Smallmouth bass were the most abundant game fish collected in electrofishing surveys (12.1 fish/hr.) and yellow perch were the most abundant game fish collected in horizontal gillnet surveys (1.5 fish/night). Overall species composition (relative abundance) was dominated by the northern pikeminnow (33.4%), but largescale suckers comprised the greatest portion of the fish biomass (44.6%). Smallmouth bass were the most common game fish in the reservoir as indicated by the species composition (7.2%) and percent biomass (3.8%).

Limiting factors for the fishery in Boundary Reservoir were likely related to reservoir operations. Summer water temperatures were generally above the preferred range of most salmonids and below that of warmwater fish. Short retention times likely limited primary and secondary production, thus limiting fish production. Daily water level fluctuations may have reduced already limited littoral habitat.

Habitat and fish surveys were conducted on Slate, Sullivan, Sand, Flume, Sweet, Lunch, Pewee, and Lime Creeks. Habitat was described at each snorkel survey site. The highest fish densities were in Sand Creek (11 rainbow trout/100m^2) and the lowest were in Sullivan Creek (1 cutthroat trout/100m^2; <1 fish/100m^2 for all other species). The greatest diversity of fish was in Sullivan Creek (7 species) and the lowest was in Flume, Lime, and Lunch Creeks (1 species each). The only bull trout observed was located in lower Sweet Creek. Low densities of fish in Sullivan Creek, the largest stream surveyed, may have been the result of poor habitat, indicated by low densities of large woody debris and pool habitats, and/or high angling pressure. The amount of angling pressure should be measured.

Acknowledgements

We would like to thank the Kalispel Tribe for administration of the Joint Stock Assessment Project, in particular Neil Lockwood and Joe Maroney. We gratefully acknowledge John Whalen (WDFW) for advice and guidance in all aspects of the project design and implementation. We thank Al Solonsky and Seattle City Light for support of lower trophic level investigations. We thank Jim Lemieux for generating maps and watershed statistics. We thank the following individuals for their assistance with field collections: Leslie King, Heather Wohler, and Dick O'Connor (WDFW); Neil Lockwood, Ray Pierre, and Rod Haynes (Kalispel Tribe); and Holly McLellan, Dr. Al Scholz, Chuck Lee, and Randy Moffatt (Eastern Washington University). We would also like to thank Casey Baldwin (WDFW) for reviewing this report.

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Introduction

Project Background

The Joint Stock Assessment Project (JSAP), developed in 1997, is a cooperative project of the Washington Department of Fish and Wildlife (WDFW), Kalispel Tribe of Indians (KNRD; Kalispel Tribe Natural Resources Department), Spokane Tribe of Indians, Colville Confederated Tribes, and Coeur d'Alene Tribe of Indians. The primary objective of JSAP is to jointly perform stock assessment and generate a management plan for protection, mitigation, and enhancement of resident fish in the blocked area watersheds above Chief Joseph and Grand Coulee Dams. In order to perform joint stock assessment, the participants need to develop a central database of fisheries related data for the blocked area that would be accessible to all blocked area managers. Initial development of the database involved collecting all existing data. Using the historical database, data gaps are identified and new investigations are initiated to fill those gaps.

The lower Pend Oreille River was identified as a high priority watershed with little baseline water quality or fisheries data available for the JSAP database (Scott 1998). An initial baseline fisheries survey of Boundary Reservoir was conducted in the fall of 1999 by WDFW, in cooperation with KNRD. This sampling period was limited due to equipment failures and reservoir conditions (McLellan 2000a). The project was resumed in the spring of 2000 with the added support of Seattle City Light (SCL). Our objective was to determine baseline values of physical and physical water quality, primary and secondary production, fish species presence, and fish relative abundances and densities, and fish habitat for Boundary Reservoir and its tributaries.

Boundary Reservoir History

Boundary Reservoir was formed on the Pend Oreille River when SCL completed construction of Boundary Dam in 1967. Boundary Dam is a run-of-the-river project with the primary purpose of power production. The project currently provides 50% of the city of Seattle's electricity.

Prior to the construction of Boundary Dam, the Boundary reach of the Pend Oreille River was a fast, flowing river. Steep canyon walls, cascades, and waterfalls characterized the majority of the river channel, especially downstream from Metaline Falls through the Z Canyon to the current site of Boundary Dam. Fish composition in the Pend Oreille River prior to construction of dams consisted of salmon, resident trout, and native minnows (Barber et al. 1989; Ashe and Scholz 1992).

Following inundation, residents of Metaline and Metaline Falls expressed concern that the fish community shifted to high densities of native minnows, primarily northern pikeminnow (*Ptychocheilus oregonensis*), and low densities of salmonids. The residents of Metaline Falls conducted an 18-day northern pikeminnow derby in 1968 and captured 3,350 fish, of which only 27 were game fish (WDG 1968). In 1971 the residents of Metaline Falls requested that the Washington Department of Game (WDG) apply a piscicide to reduce the number of northern pikeminnow in the reservoir (WDG 1971a). The request was denied citing the low chance of success (WDG 1971b).

Prior to 1997, little fishery or limnological research had been conducted on Boundary Reservoir, but small amounts of data had been collected sporadically. The Washington State Pollution Control Commission collected basic water quality and periphyton data at the Metaline Falls Bridge and at the mouth of the Z Canyon above Boundary Dam on October 9th and 10th, 1962 (Pine and Clemetson 1962) and WDG biologists set a gill net at the mouth of Sand Creek and two gill nets at the mouth of Sweet Creek on July 26th, 1982 (WDG, unpublished data). Between 1994 and 1995 the Washington Department of Ecology (WDOE) collected water quality data at the Metaline Falls Bridge. Beginning in 1997, data was consistently collected on Boundary Reservoir by the WDOE and R2 Resource Consultants (R2). The WDOE began monthly monitoring of surface water quality at the Metaline Falls Bridge in 1997 (WDOE, unpublished data).

The most comprehensive fisheries work on Boundary Reservoir was conducted by R2, contracted by SCL (R2 1998). R2 and SCL attempted to determine the status of bull trout (*Salvelinus confluentus*) in the reservoir and its tributaries. Prior to R2's study, a bull trout population was present in Boundary Reservoir, and it was considered to be at high risk for extinction (Mongillo 1993). Temperature and dissolved oxygen profiles collected by R2 indicated that Boundary Reservoir did not stratify and that summer temperatures were outside of the preferred range for salmonids (R2 1998). Hydroacoustic, angling, and live-trapping surveys conducted by R2 in Boundary Reservoir had limited success and indicated fish densities in

Boundary Reservoir were relatively low and fish were distributed in the littoral habitats, primarily at the mouths of tributaries (R2 1998). We conducted a preliminary sample of the lower 2/3 of Boundary Reservoir in the fall of 1999. Our sample sizes were too small for conclusions (McLellan 2000a).

Historical fish and habitat surveys of tributaries to Boundary Reservoir were more extensive than those of the reservoir. The WDG conducted day creel surveys on Flume Creek in 1950, 1959, and 1960 and brook trout were the only fish captured (WDFW, unpublished data). The U.S. Forest Service (USFS) conducted fish surveys on Flume, Slate, and Styx Creeks in 1977 and 1978 (USFS, unpublished data). The USFS, Cascade Environmental Services (CES), SCL, and R2 conducted fish distribution surveys in Sullivan, North Fork Sullivan, Flume, Middle and South Forks Flume, Pewee, Sweet, Lunch, Slate, Styx, Slumber, Sand, Pass, Deemer, Leola, and Gypsy Creeks since 1993, all tributaries to Boundary Reservoir, with the primary objectives of determining bull trout presence (CES 1996, R2 1998; Terrapin 2000; USFS, unpublished data). The fish assemblages in the tributaries of Boundary Reservoir were mainly comprised of salmonids (CES 1996, R2 1998; Terrapin 2000; USFS, unpublished data). SCL operated a fish migration trap at the mouth of Slate Creek during the summer and fall of 1999, in which no fish were captured (Terrapin 2000).

Habitat enhancement work was conducted on Sullivan Creek by the USFS in the 1970's, which was comprised of removing large wood from the stream channel (T. Shuhda, Colville National Forest fish biologist, personal communication 2001). In the early 1980's the USFS implemented more habitat enhancements on Sullivan Creek. Five log weirs were placed in the stream channel, the majority of which no longer exist (T. Shuhda, Colville National Forest fish biologist, personal communication 2001). Monitoring of the structures was not conducted.

The USFS conducted Hankin and Reeves (1988) surveys on Slate, Flume, and Middle Fork Flume Creeks in 1991, Sand Creek in 1992, and Sullivan Creek in 1993 (USFS, unpublished data). R2 conducted habitat surveys at their fish survey locations on Flume, Slate, Sand, Sullivan, and Sweet Creeks in 1997. The WDOE conducted Benthic Index of Biotic Integrity surveys on North Fork Sullivan Creek and upper Slate Creek in 1996 (WDOE 2001).

Stocking History

Fish have been planted in the Pend Oreille River basin over the last 125 years. Several species of fish were planted, including rainbow trout, brown trout, cutthroat trout (westslope and Yellowstone subspecies), eastern brook trout, kokanee, walleye, and largemouth bass (Dr. A. Scholz, Eastern Washington University, personal communication; WDFW, unpublished hatchery records). The unpublished WDFW plant records for the Boundary Reservoir drainage from 1940 through 2000 are listed in Appendix A. The standard stocking regime for the Boundary Reservoir drainage between 1995 and 2000 included 30,000 rainbow trout in the net pens at Blue Slide Resort, Box Canyon Reservoir, and 10,000 rainbow trout in the Mill Pond (J. Ebel, WDFW Colville Hatchery, personal communication). Additional plants between 1995 and 2000 where 15,000 rainbow trout in a net pen at Boundary Dam in 1998, 15,000 rainbow trout in a net pen at Ione in 1998, 18,560 rainbow trout in Sullivan Lake in 1999, and 600 eastern brook trout in the Pend Oreille River in 1999 (J. Ebel, WDFW Colville Hatchery, personal communication).

Study Area

Boundary Reservoir occurs between Boundary Dam on its downstream end and Box Canyon Dam on the upstream end. The reservoir is 28.2 km (17.5 miles) long and has a surface area of 639 hectares (1,578 acres). Boundary Reservoir has a volume of 11,718 hectare-meters (95,000 acre-ft) at the full pool elevation of 607 m (1,990 ft.) above sea level.

Study Objectives

The objectives of the study were as follows:

- Measure physical and chemical water quality parameters in Boundary Reservoir including temperature, dissolved oxygen, pH, specific conductivity, turbidity, and secchi disk depth.
- Measure summer and fall primary production in Boundary Reservoir by describing the phytoplankton and periphyton species compositions, densities, bio-volumes and chlorophyll *a* levels.

- Measure summer and fall secondary production in Boundary Reservoir by describing the zooplankton and benthic macroinvertebrate species compositions and densities.
- Determine the fish species present in Boundary Reservoir and estimate their relative densities (CPUE and relative abundance).
- Describe the age structures and growth of the game fish populations in Boundary Reservoir and compare them with those of other waters throughout the northwest.
- Describe fish habitat at snorkel sites in Slate, Sullivan, Sand, Flume, Sweet, Lunch, Pewee, and Lime Creeks.
- Determine the fish species present in Slate, Sullivan, Sand, Flume, Sweet, Lunch, Pewee, and Lime Creeks and estimate their densities.

Methods

Reservoir Assessment

Physical Characteristics

Mean monthly and annual discharge (cfs) was calculated for water year 2000 (October 1, 1999 – September 30, 2000) and the last 25 years (1975-2000), using discharge data from the gauging station below Box Canyon Dam (USGS, Spokane, WA, unpublished data). Mean daily elevation (m) change in 2000 was calculated for each month from gauge heights (ft) recorded below Box Canyon Dam (USGS, Spokane, WA, unpublished data).

Water retention times (days) were calculated by dividing the reservoir volume (acre-feet) by the mean daily outflow (cfs). The reservoir volume was converted from the midnight reservoir elevation (ft) using the reservoir water storage table for Boundary Reservoir (provided by SCL). The mean daily outflows and reservoir elevations were provided by the USGS (Spokane, WA).

Water Quality

Summer and fall water column profiles of temperature (°C), dissolved oxygen (D.O.; mg/L), turbidity (NTU), specific conductivity (µS/cm), and pH were measured on August 22nd and October 24th, 2000. Measurements were taken at the deepest location in the forebay of Boundary Dam and at the Metaline Falls Bridge (Figure 1). Measurements were conducted at the surface, 7.6 m, 15.2 m, 30.5 m, 45.7 m, 61.0 m, and 76.2 m in the forebay. Measurements were conducted at the surface, 3 m, and 8 m at the Metaline Falls Bridge in July and at the surface, 3 m, 6 m and 9 m in October. In October, measurements were only taken to 30.5 m at the forebay and no turbidity data was collected at either site due to equipment failure. A YSI (Yellow Springs Instruments, OH) 6000 water quality meter was used for the summer water quality profiles. A YSI 63 meter and an Oxyguard® Handy MKII meter (Point Four Systems, British Columbia, Canada) were used for the fall water quality profiles. Secchi disk depth (m) was measured three times at each location, seasonally. The depth of the euphotic zone was determined by multiplying the mean secchi disk depth by three (Cole 1994).

Trophic Status

The trophic status of Boundary Reservoir was classified using the criteria established by the Organization for Economic Cooperation and Development (Table 1; OECD 1982). Total phosphorus measurements were provided by WDOE (unpublished data).

Trophic state values were calculated using the trophic state index (TSI; Carlson 1977). Index values were calculated for August and October, using the mean secchi disk depths (m) and chlorophyll *a* (mg/m^3) measured at both water quality stations, as well as surface total phosphorus (mg/m^3) levels measured at the Metaline Falls Bridge (WDOE, unpublished data).

Table 1. Selected OECD (1982) lake trophic classification values.

Trophic Classification	**Mean Annual TP (µg/L)**	**Mean Summer TP (µg/L)**	**Mean Summer Chl. *a* (µg/L)**	**Mean Summer Secchi Depth (m)**	**Mean Summer Phytoplankton bio-volume (mm^3/L)**
Oligotrophic (Max. likelihood)	8	-	-	-	-
Oligo-mesotrophic Threshold	14	15	3	6	1.5
Mesotrophic (Max. likelihood)	27	-	-	-	-
Meso-eutrophic Threshold	48	40	10	3	5
Eutrophic (Max. likelihood)	84	-	-	-	-

Primary Productivity

Water samples were collected in the summer and fall from the euphotic zone at both water quality stations to determine phytoplankton chlorophyll *a* (hereafter referred to as chlorophyll *a*), density, and bio-volume. Water samples were collected with an integrated core sampler, which was comprised of a 2.54 cm (inside diameter) tube, with a weight at the bottom end and a valve at the top end. Samples were collected by opening the valve on the upper end, lowering the weighted end to the bottom of the euphotic zone, and then closing the valve. The tube was then pulled up, the weighted end of the tube was inserted into a carboy, the valve was opened, and the water sample was emptied from the tube. After all three samples were emptied into the carboy, the contents were swirled gently and transferred to three 1 liter sample bottles.

The sample bottles were immediately placed on ice in an ice chest and taken directly to the Water Research Center at Eastern Washington University (EWU) for analysis.

Periphyton was sampled, during the summer, to estimate chlorophyll *a* (hereafter referred to as periphyton chlorophyll *a*), density, and bio-volume. Periphyton was sampled with two DuraSampler periphyton samplers floated at the reservoir surface at each water quality station. The samplers were set on August 22nd and retrieved on September 19th (28 days). When the samplers were collected they were placed in individual gallon zip-lock bags, put on ice, and taken directly to EWU for analysis.

Secondary Productivity

Assessment of secondary productivity consisted of determining zooplankton and benthic macroinvertebrate densities during the summer and fall at both of the water quality stations. Zooplankton were collected by vertical tows of the euphotic zone, with a Wisconsin-style zooplankton net (80 µm mesh; 18 cm diameter). Three tows were taken at each site on each occasion. Zooplankton were fixed in 10% ethanol and taken to EWU for analysis.

Benthic macroinvertebrates were collected with Hester-Dendy round plate samplers (0.13 m^2). Three samplers were set in the vicinity of each water quality station. The first set of samplers (summer) were set on August 22nd and retrieved on September 19th (28 days). The second set of samplers (fall) were set on September 19th and retrieved on October 24th (35 days). The two collection periods were designated as "summer" and "fall' samples because those were the seasons when the samples were collected. We did not contend that the samples represented the entire benthic macroinvertebrate communities during the entire summer or fall. After collection, the samplers were placed in individual gallon zip-lock bags and stored on ice. Once in the lab, all of the organisms colonized on the plates were removed and fixed in 90% ethanol. All of the organisms were identified to the lowest taxonomic level possible using Pennak (1989), Pennak (1978), and Merritt and Cummins (1996).

Reservoir Fisheries Surveys

Boundary Reservoir was sampled in the spring, summer, and fall of 2000. The reservoir was stratified into four reaches, based on physical habitat characteristics (Figure 1). A standard sampling strategy of two electrofishing transects per shoreline horizontal gill net survey was employed. We electrofished 10% of the reservoir shoreline, set horizontal gill nets at 5% of the remaining shoreline transects, and set four vertical gill nets in each reach. A minimum of two electrofishing transects and horizontal gill net sets were sampled per reach to allow for calculation of sampling variance.

A total of 16 shoreline transects (400 m) were electrofished per season. Two transects were electrofished in reaches one and three, eight transects were electrofished in reach two, and four transects were electrofished in reach 4. Each transect was randomly selected and all electrofishing was conducted at night, beginning at dusk. Supplemental day electrofishing surveys were conducted in reaches one and two, during the summer sample. The day electrofishing surveys were conducted in the same manner as the night surveys. Data collected from the day electrofishing was not used in calculation of relative abundance or catch-per-unit effort, however the data was included in age, growth, relative weight, and proportional stock density calculations.

A total of 10 horizontal experimental monofilament sinking gill nets (2.4 x 61.0 m; four 15.2 meter panels with square mesh sizes 1.3, 2.5, 3.8, and 5.1 cm) were set at randomly selected shoreline sites per season. Two horizontal gill nets were set in reaches one, three, and four, and four nets were set in reach two. The nets were set perpendicular to the shore, with the smallest mesh size closest to shore. A total of eight monofilament vertical gill nets were set per season, four in the pelagic zones of both reaches one and two, except during the spring when flows were too high the verticals were not set in the forebay. The nets (2.4 x 29.9 m), one of each mesh size (1.3, 2.5, 3.8, and 5.1 cm), were set in the upper 29.9 meters of the water column at randomly selected pelagic locations. During the summer, two additional horizontal nets were set in the pelagic zone of the forebay, one at the surface and one at the bottom (61 m). Data collected from the pelagic horizontal gill nets was not used in the relative abundance or catch-per-unit-effort calculations, however the data was included in age, growth, relative weight, and proportional stock density calculations. Gill nets in reaches two, three, and four were set at dusk and retrieved within 4 hours. The gill nets set in reach one were set in the early morning (approx. 2 a.m.) and retrieved within four hours. No nets were set near the mouths of Flume, Slate, or Sullivan Creeks to minimize fish mortalities.

Each fish collected was identified to species, measured (total length, TL; mm), weighed (grams), and recorded. Scale samples were obtained from all game fish. Catch-per-unit-effort (CPUE) by sampling method was determined for each fish species collected (number of fish/hour electrofishing, number of fish/horizontal gill net night, and number of fish/vertical gill net night). When calculating the CPUE for each gear type we used a standard 2:1 ratio of electrofishing sites to horizontal gill net sites. The CPUE for each fish species was calculated using all fish, including age 0 fish, as indices of relative density. Randomly chosen sample sections can contribute to high variability among samples, therefore, 80 percent confidence intervals (CI) were calculated for each mean CPUE by species and by sampling method. Species composition by weight (kg) and number were calculated from fish collected using boat electrofishing, horizontal gill netting, and vertical gill netting

Proportional stock density (PSD) was calculated for each game fish species collected. PSD's were calculated by dividing the number of fish ≥ the minimum quality length by the number of fish ≥ the minimum stock length, and multiplying by 100 (Anderson and Neuman 1996). Stock length was defined as the minimum length of fish with recreational value (20-26% of world record) and quality length was defined as the minimum size of fish that anglers would like to catch (36-41% of world record; Gabelhouse 1984). Relative stock densities were calculated to provide a proportion of stock length fish that were longer than quality length fish, relative to the world record. The three categories used for RSD were preferred, memorable, and trophy (Gabelhouse 1984). Preferred length was the minimum length of fish anglers would prefer to catch (45-55% of world record). Memorable length was the minimum length of fish anglers would remember catching (59-64% of world record). Trophy length was the minimum length of fish worthy of acknowledgement (74-80% of world record). RSD's were calculated by dividing the number of fish ≥ a specific length by the number of fish ≥ the minimum stock length, and multiplying by 100 (Anderson and Neuman 1996). Stock, quality, preferred, memorable, and trophy lengths were provided for fish collected in Boundary Reservoir (Table 2). Eighty percent confidence intervals were calculated, assuming a normal distribution, as an indication of precision.

Age and growth was evaluated from scale samples that were obtained from all game fish collected. Scale samples were pressed using acetate film and read according to the methods of Fletcher et al. (1993) and Jearld (1983). The Fraser-Lee method was used to back-calculate the total length at the formation of each annulus of warmwater game fish, and the direct proportional method was used for salmonids (Devries and Frie 1996). Standard intercept values, recommended by Carlander (1982), were used. The back-calculation equation was,

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

where, L_i was the back-calculated TL of the fish at the formation of the i^{th} annulus, L_c was the TL of the fish at capture, S_c was the length from the focus to the outermost edge of the scale at capture, S_i was the length from focus of the scale to the outer edge of the i^{th} annulus, and a was the y-intercept of the body length-scale length regression line. The direct proportional method assumed the intercept value, a, was equal to 0.

Relative weight (W_r) index was used to evaluate the condition of fish in Boundary Reservoir. The index was calculated as,

$$W_r = \frac{W}{W_s} x100$$

where, W is the weight (g) of an individual fish and W_s is the standard weight of a fish of the same length (Murphy and Willis 1991). W_s was calculated from the standard log_{10}weight-log_{10}length relationship defined for the species of interest (Andersen and Neuman 1996). A W_r value of 100 generally indicates that a fish is in good condition (Anderson and Gutreuter 1983).

In addition to relative weights, condition factors (K_{TL}) were calculated as an index of how fish add weight in relation to increasing length (Anderson and Neuman 1996). Mean condition factor was calculated for all game fish age 1 or older and ≥100 mm TL using the formula,

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

where, WT is the weight (g) and TL is the total length (mm) of an individual fish.

Table 2. Length categories used for PSD and RSD calculations. The lengths listed represent total lengths (mm; Anderson and Neuman 1996). Numbers in parentheses are the percent of the world record (Gabelhouse 1984).

	Standard Length Categories				
Species	**Stock (20-26)**	**Quality (36-41)**	**Preferred (45-55)**	**Memorable (59-64)**	**Trophy (74-80)**
Black crappie	130	200	250	300	380
Brown trout	150	230	300	380	460
Burbot	200	380	530	670	820
Cutthroat trout	200	350	450	600	750
Lake trout	300	500	650	800	1000
Largemouth bass	200	300	380	510	630
Pumpkinseed	80	150	200	250	300
Rainbow trout	250	400	500	650	800
Smallmouth bass	180	280	350	430	510
Yellow perch	130	200	250	300	380

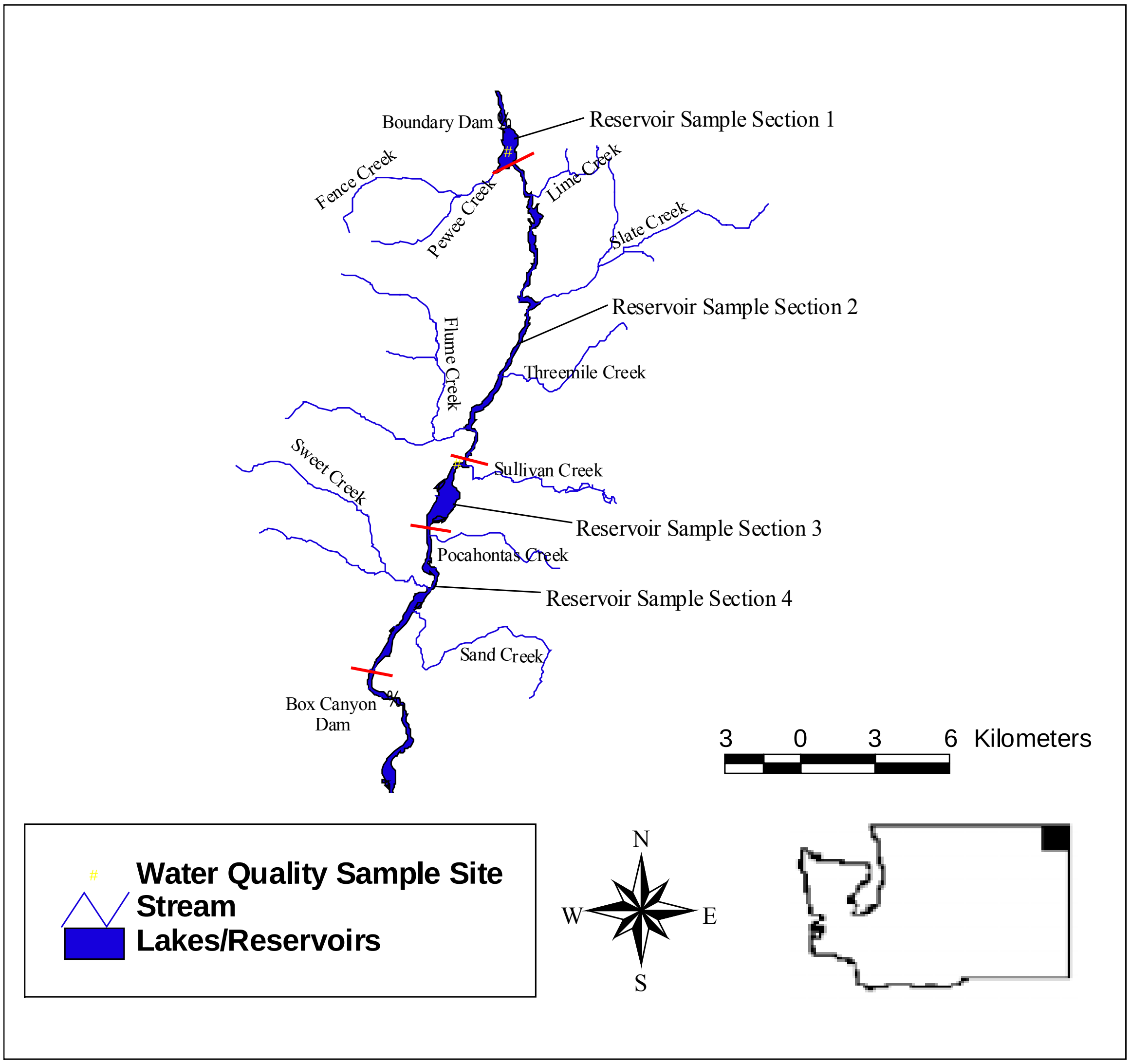

Figure 1. Fish sampling sections and water quality sampling locations on Boundary Reservoir, Pend Oreille River.

Tributary Assessments

Habitat

Each stream was stratified into reaches using a USGS topographic map (1:24,000 scale; Figure 2; Appendix G). Reaches were defined as portions of streams with similar gradient between confluences with tributaries and road crossings. Sample sites for habitat and fish distribution were selected every 500 m, beginning 500 m upstream of the mouth. A minimum of two sites were sampled per reach, regardless of the reach length. Each sample site was 30 m long. Survey site lengths were measured with a hip chain. The previously described sampling design was conducted on all of the streams surveyed except Slate Creek. Habitat surveys were conducted every 90 m for the entire length of Slate Creek, beginning at the crossing of USFS Road #208. Due to the large amount of time required to conduct habitat surveys at 90 m intervals, the stream survey protocol was modified to emphasize fish surveys and ensure that all of the major tributaries to Boundary Reservoir were surveyed.

Stream habitat surveys were always completed following fish sampling. The total numbers of large pools (LP) and acting large woody debris (LWD) in the 30 m transect were counted to estimate their mean densities per reach, as well as the entire stream. Densities were calculated as the number of LP per km and the number of LWD per 100 m. LP's were defined as a pool habitat that had a length or width that was equal to or greater than the mean wetted width of the reach. Acting LWD were considered any piece of organic debris with a diameter >10 cm and a length >1 m that intruded into the stream (KNRD 1997). Exposed root wads of live trees were only counted if they were intruding the stream. Large debris dams causing one particular effect on the stream were counted as a single piece of LWD (KNRD 1997).

Habitat parameters were measured or visually estimated along a transect line that was perpendicular to the flow of the stream at the end of each 30 m site. Parameters included, habitat type, habitat width, dominant substrate in each habitat type, stream wetted width, bankfull width, mean stream depth, maximum stream depth, gradient, air and water temperature, and pool maximum and tailout depths. Mean values and standard deviations of each habitat parameter were calculated.

Habitat types were divided into two categories, pool and riffle. A pool was defined as a portion of the stream with reduced current velocity and usually deeper than a riffle (KNRD 1997). A riffle was a shallow rapid where the water flowed swiftly over completely or partially submerged obstructions to produce surface agitation (KNRD 1997). Runs, stream segments with intermediate characteristics between pools and riffles, were combined with riffles for analysis because they were difficult to differentiate (Platts et al. 1983). The wetted width of stream was defined as the distance from the edge of the water on each shoreline, perpendicular to the flow of the stream. If the channel was braided the wet width of each braid was measured and summed to provide a total wetted width. Wetted width was measured to the nearest tenth of a meter. If a transect had two segments of a similar habitat type, their widths were summed to provide a single width for that habitat type. The dominant substrate in each habitat type was estimated visually (Table 3).

The bankfull width (or channel) was defined as the cross section of the stream valley containing the stream that was distinct from the surrounding area due to breaks in the general slope of the land, lack of terrestrial vegetation, and changes in the composition of the substrate material (Platts et al. 1983). The bankfull width contains the stream bottom and stream bank and a bankfull flow fills the channel with water to the point just prior to the its spreading onto the flood plain (Platts et al. 1983). The bankfull width was measured to the nearest tenth of a meter.

Mean stream depth was determined from summing the depth measurements (cm) taken at ¼, ½, and ¾ the wetted width along the transect line and dividing them by four to account for the zero depth values at each shoreline (Platts et al. 1983). Maximum stream depths (cm) were measured at each transect. The maximum depths provide the thalweg depth, or the line connecting the deepest points along the stream bed (KNRD 1997).

Stream channel gradient was defined as the change in vertical elevation per unit horizontal distance of the channel (Platts et al. 1983; KNRD 1997). Gradient (%) was measured at each transect with a clinometer (Suunto Corp.). When measuring gradient, the observer stood at water level and measured from one end of the 30 m transect to the other.

Water and air temperatures (°C) were measured at each transect. Water temperatures were measured in the middle of the thalweg. Air temperatures were measured away from the waters surface and out of direct sunlight.

The maximum and tailout depths (cm) were measured in each pool that was bisected by a transect (KNRD 1997). The residual pool depth was calculated by summing the maximum and tailout depths and dividing by 2 (KNRD 1997).

Definite and potential natural and man-made fish barriers were identified on each stream surveyed. Natural fish barriers were described as falls or chutes. Falls were vertical overflow portions of the stream (Orsborn and Powers 1985). Chutes were defined as steep, sloping, open channels with high velocities (Orsborn and Powers 1985). Human made barriers consisted of culverts and dams. A falls or culvert was determined to be a definite barrier if it had a vertical height of 3.4 m (11.0 ft), which exceeded the maximum leaping height of the healthiest steelhead (610-792 mm TL) with a maximum burst speed of 8.1 m/s (26.5 ft/s; Powers and Orsborn 1985). We assumed the swimming abilities of steelhead exceeded those of resident trout. A good takeoff pool is required for fish to leap any height, so a relatively low fall without a good take off pool may act as a total barrier (Powers and Orsborn 1985). Waterfalls with vertical heights ≥1.5 m, without a plunge pool were considered a potential barrier. Culverts with a vertical height of ≥2.5 m were reported as potential barriers because they lacked landing pools. The lack of good landing pools reduces the chance of passage (Powers and Orsborn 1985). A chute was considered a potential barrier if it had a smooth bedrock substrate and a slope ≥15% and a length ≥10.0 m.

Discharge (Q; m^3/s) was estimated at the mouth of each stream following the habitat and fish surveys, according to the method described by Platts et al. (1983). Velocity (m/s) was measured with a Global Flow Probe®.

Temperatures (^{o}C) of the streams were monitored with Tidbit® temperature loggers (Onset Corp., MA) between June 28th and October 19th, 2000. The temperature logging interval was every 2 hours for 24 hours. The loggers were fixed with identification tags and were attached to logs or root wads near the stream bottom, out of direct sunlight. Loggers were placed near the mouth of all of the streams monitored, except Lime and Sand Creeks, which had loggers placed near their midpoints (Figure 3). Slate, Flume, and Sullivan Creeks had additional loggers placed near the headwaters, and Sullivan Creek had a third logger placed near its midpoint (Figure 3). The temperature logging interval was every 2 hours for 24 hours.

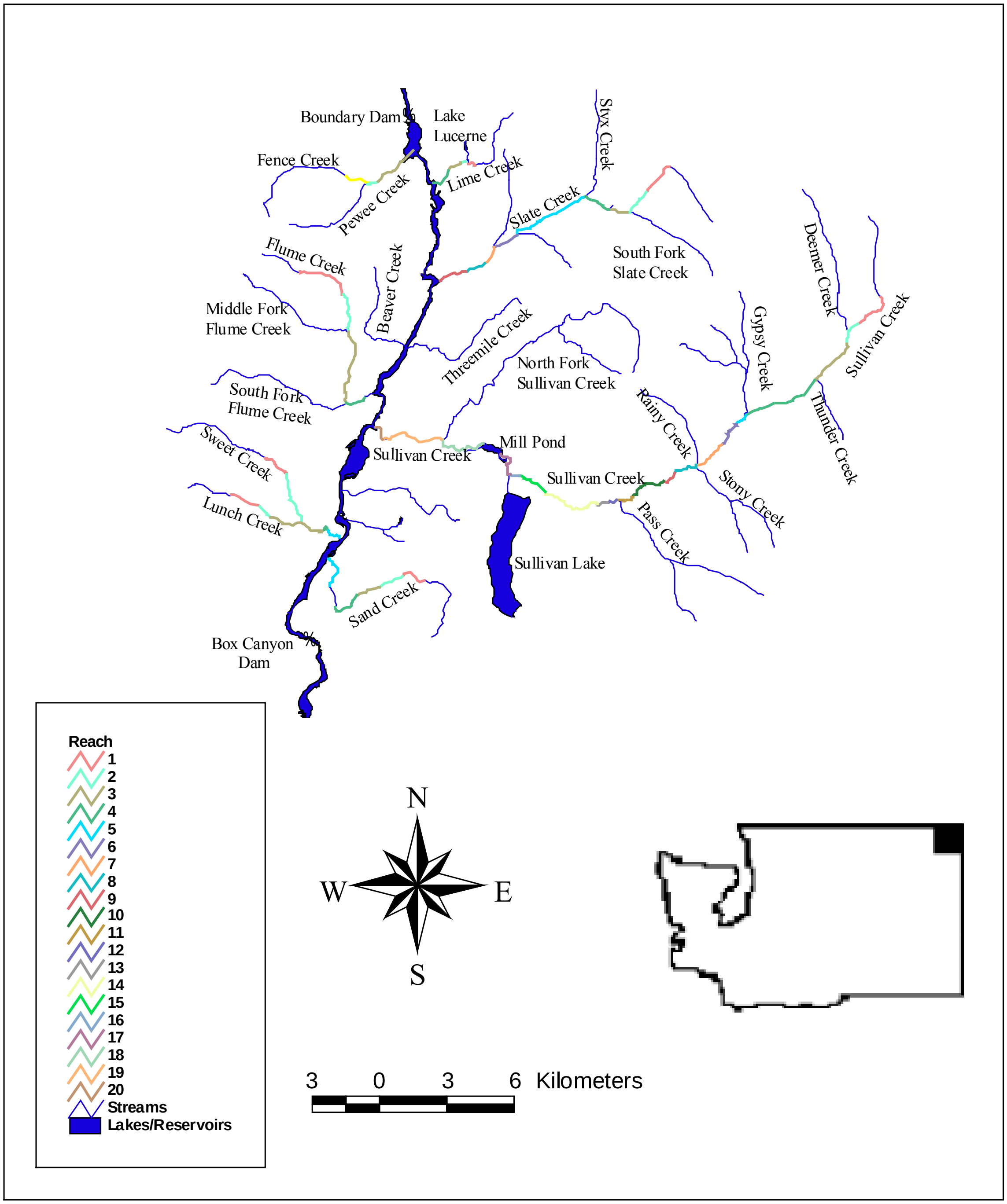

Figure 2. Sampling reaches on the tributaries to Boundary Reservoir that were surveyed in 2000.

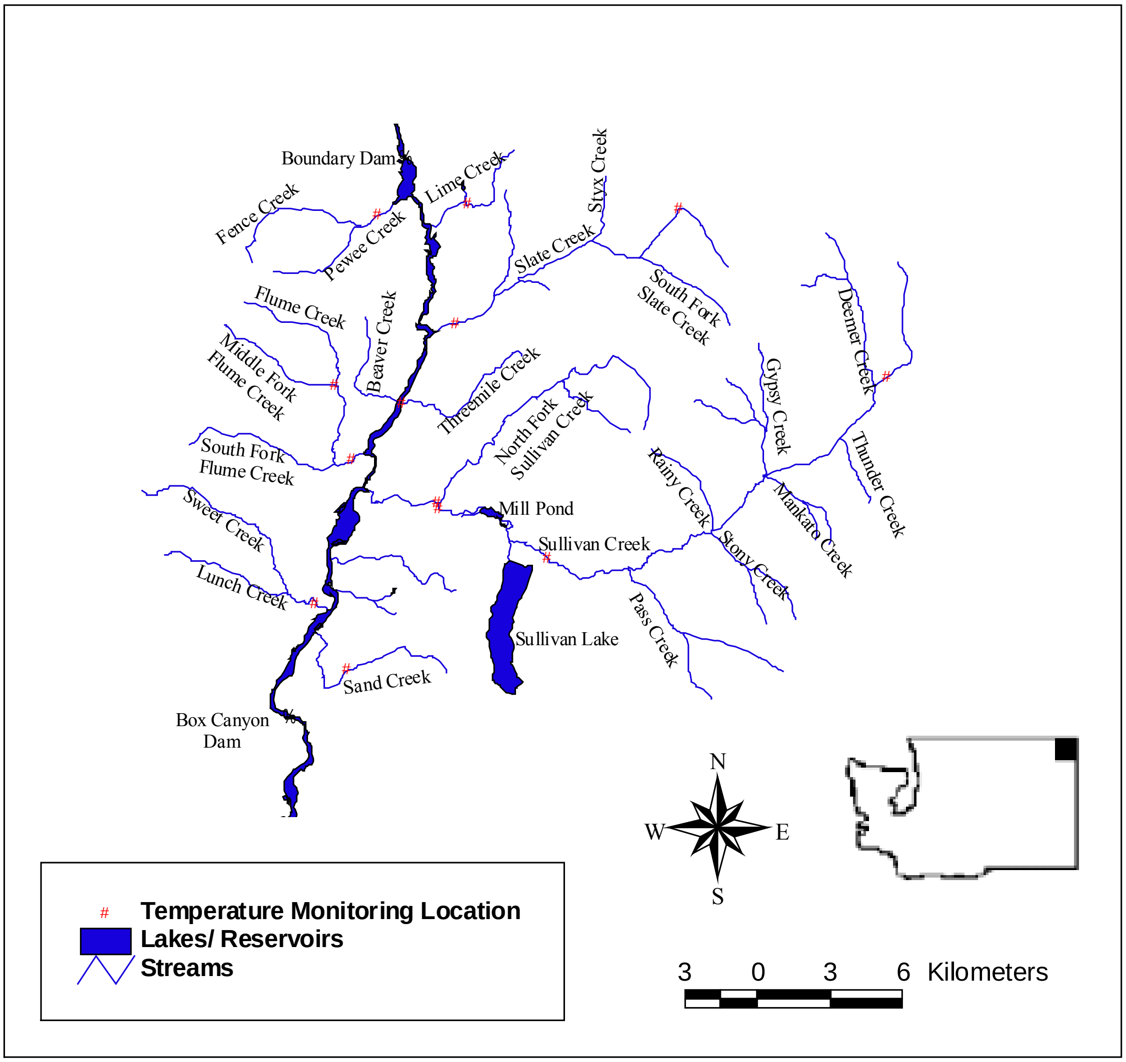

Figure 3. Map of temperature monitoring locations.

Table 3. Description of substrate classification used for stream habitat assessments (modified from KNRD 1997).

Substrate Type	Description
Bedrock	Large masses of solid rock
Boulder	>30.5 cm (>12.0 in.)
Rubble	15.2 - 30.5 cm (6.0 in. - 12.0 in.)
Cobble	7.6 - 15.2 cm (3.0 in. - 6.0 in.)
Gravel	0.6 - 7.6 cm (0.25 in. - 3.0 in.)
Sand	<0.6 cm (<0.25 in.)
Silt	Fine sediments with little grittiness.
Muck	Decomposed organic material, usually black in color.
Organic Debris	Undecomposed herbaceous material.

Tributary Fisheries Surveys

Fish presence, relative abundance, and density was estimated by snorkeling a 30 m transect at each sample site during the day. Occasionally, the length of a snorkel transect was extended to ensure that a pool was not bisected. Snorkeling was conducted moving upstream, except in the lower portions of Sullivan Creek where flows were too high. Data from a single observer was used in all calculations. All fish observed were identified, counted, and their total length (mm) was estimated using a wrist cuff marked with 100 mm increments. The fish were divided into length groups. The length groups were ≤100 mm TL, 101-200 mm, TL 201-300 mm TL, and >300 mm TL. The length groups were broad and designed to provide a general size distribution of a population, not an age distribution. Mean densities (number of fish/100 m^2) of fish observed were estimated for each species and size class, in each reach and stream. Densities were calculated by dividing the number of fish observed in a survey, by the surface area (m^2) of the survey site. The surface area of the transect was determined by multiplying the wetted width (m) of the stream at the site, by the length of the survey.

Results

Reservoir Assessment

Physical Characteristics

The mean annual discharge in water year 2000 was 22,773 (± 11,153 SD) cfs compared to the 25 year average of 25,192 (± 16,744) cfs (Figure 4; USGS, unpublished data). Boundary Reservoir had daily water level fluctuations as a result of power production operations. The mean daily elevation change in water year 2000 was 2.4 (± 1.6) m (Figure 5; USGS, unpublished data).

The mean annual water retention time in water year 2000 was 1.9 (± 1.0) days, from 325 days sampled (Table 4). Midnight reservoir surface elevations were only recorded twice in December (December 16th and 17th, 1999) and after January 13th, 2000. The minimum water retention time was 0.6 days on April 21st and the maximum was 5.9 days on August 27th.

Water Quality

Water temperatures, dissolved oxygen, pH, specific conductivity, and turbidity values measured in Boundary Reservoir during the summer and fall were similar at each sample site, regardless of depth (Figures 6 through 8). Mean temperature was 17.2 ^{o}C (± 0.2). Mean dissolved oxygen was 9.3 mg/L (± 0.7). Mean pH was 8.4 (± 0.3). Mean specific conductivity was 147 µS/cm (± 10). Mean turbidity was 3.3 NTU (± 0.6). Mean secchi disk depth at the Metaline Falls Bridge was 3.2 m (± 0.2) in the summer and 2.5 m (± 0.2) in the fall. The estimated euphotic zone depth at the Metaline Falls Bridge was 9.5 m in the summer and 7.6 m in the fall. Mean secchi disk depth at the Boundary Dam forebay was 3.9 (± 0.2) m in the summer and 2.7 (± 0.0) m in the fall. The estimated euphotic zone depth at the Boundary Dam forebay was 11.6 m in the summer and 8.2 m in the fall.

Trophic Status

Boundary Reservoir was classified as oligotrophic according to the OECD criteria (1982), using mean annual total phosphorus (11 µ/L), mean summer total phosphorus (11 µ/L), mean summer chlorophyll a (1.01 µ/L), and mean summer phytoplankton bio-volume (0.189 mm^3/L). According to mean summer secchi disk depths, which were 3.9 m at the forebay of Boundary Dam and 3.2 m at the Metaline Falls Bridge, Boundary Reservoir was eutrophic.

Secchi disk TSI's were 42 and 46 in August and October. Chlorophyll *a* TSI's were 31 in August and October. Total phosphorus TSI's were 41 and 37 in August and October.

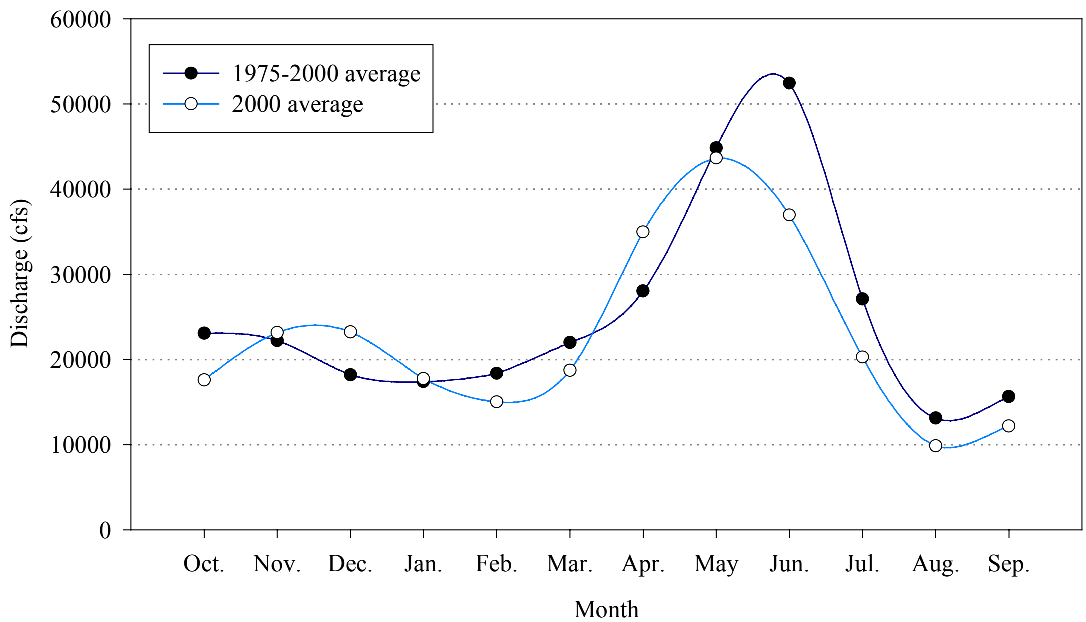

Figure 4. Mean monthly discharge at the USGS gaging station below Box Canyon Dam in water year 2000 compared to the 25-year average (USGS, unpublished data).

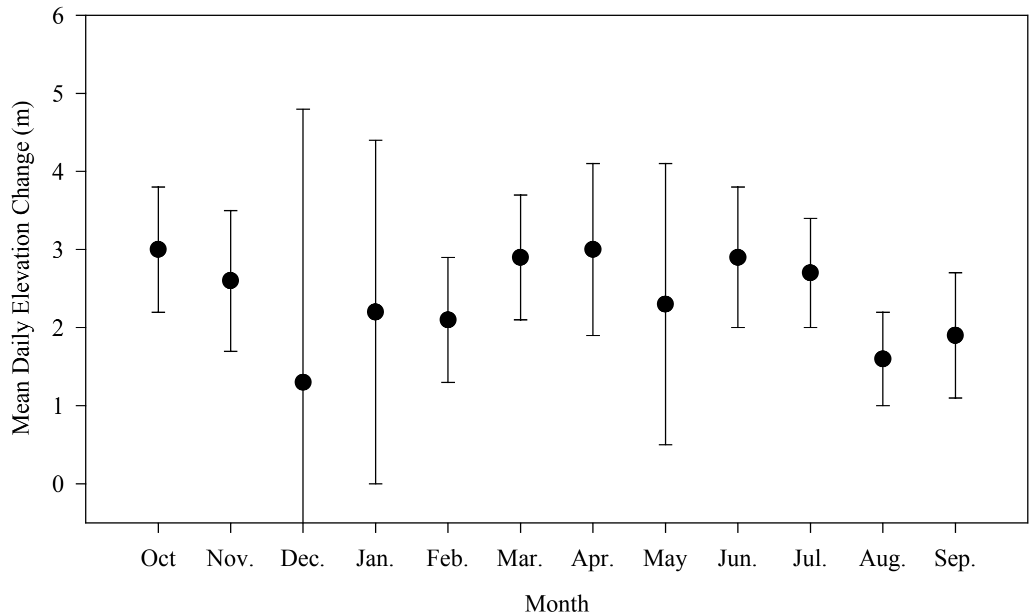

Figure 5. Mean daily surface elevation change (m) of Boundary Reservoir in water year 2000 (Oct. 1, 1999-Sep. 30, 2000; USGS, unpublished data).

Table 4. Mean monthly and annual water retention times (days) for Boundary Reservoir during water year 2000 (October 1st, 1999 – September 30th, 2000).

Month	**n**	**Mean**	**Minimum**	**Maximum**
October	31	2.1 (± 0.7)	1.4	4.4
November	30	1.5 (± 0.3)	1.1	2.7
December	2	1.4 (± 0.0)	1.4	1.4
January	19	2.1 (± 0.4)	1.4	3.0
February	29	2.3 (± 0.4)	1.5	3.2
March	31	1.8 (± 0.4)	1.3	2.8
April	30	1.1 (± 0.3)	0.6	1.7
May	31	0.8 (± 0.1)	0.7	1.0
June	30	0.9 (± 0.2)	0.7	1.5
July	31	1.8 (± 0.5)	1.2	2.9
August	31	3.8 (± 1.0)	2.2	5.9
September	30	3.0 (± 1.0)	1.7	5.6
Total	**325**	**1.9 (± 1.0)**	**0.6**	**5.9**

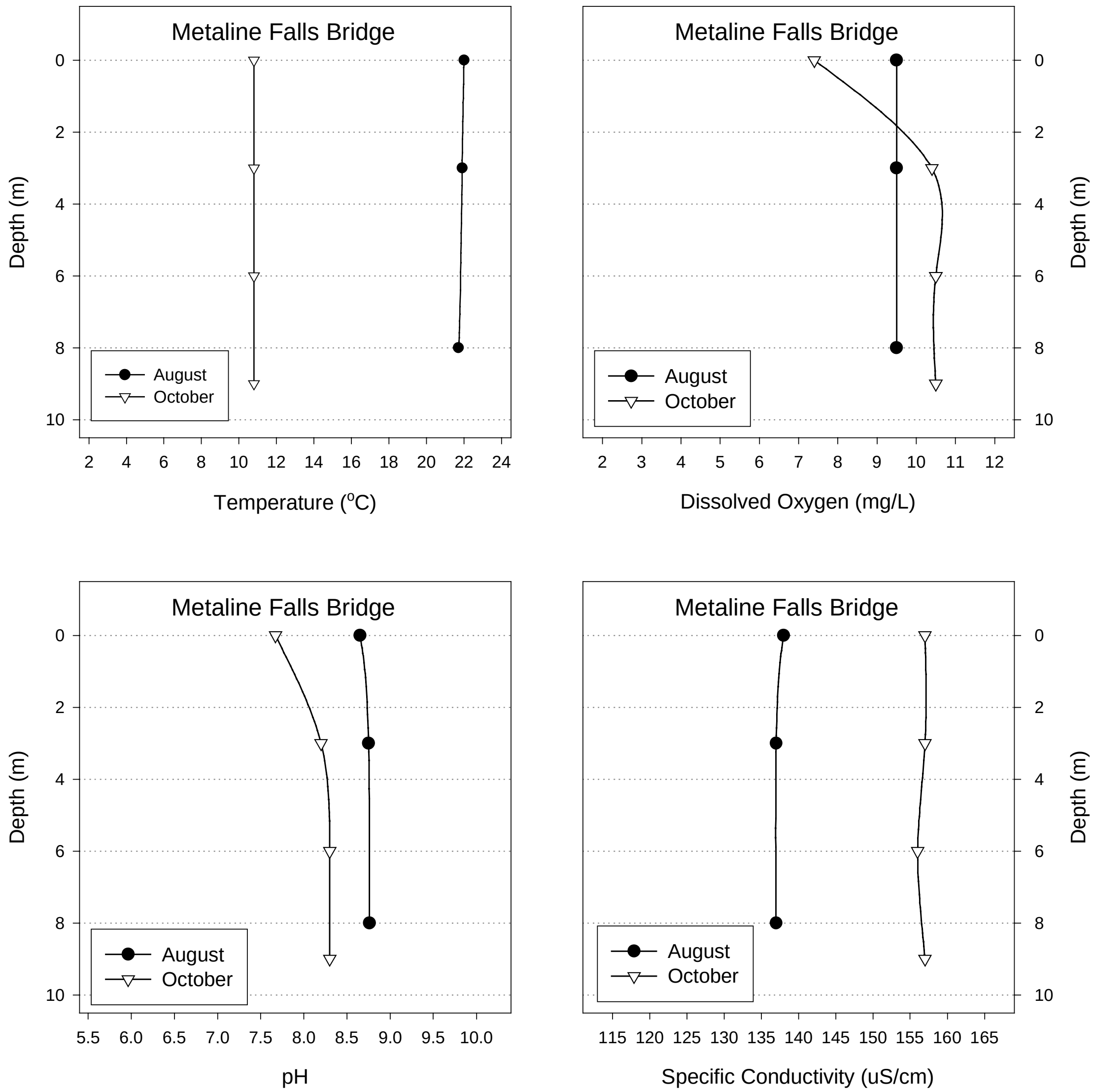

Figure 6. Depth profiles of temperature, dissolved oxygen, pH and specific conductivity measured at the Metaline Falls Bridge in the summer and fall.

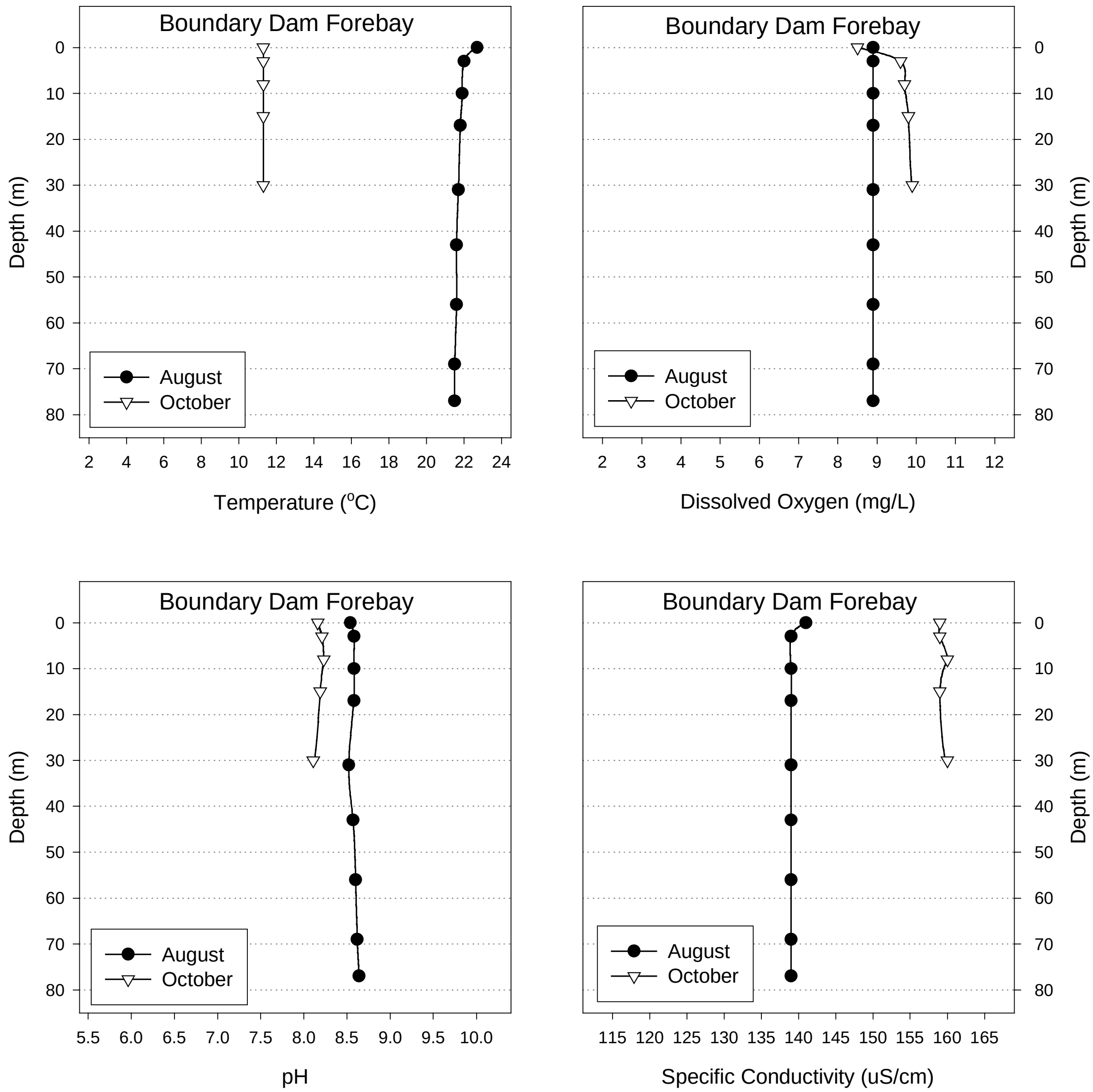

Figure 7. Depth profiles of temperature, dissolved oxygen, pH and specific conductivity measured at the Boundary Dam forebay in the summer and fall.

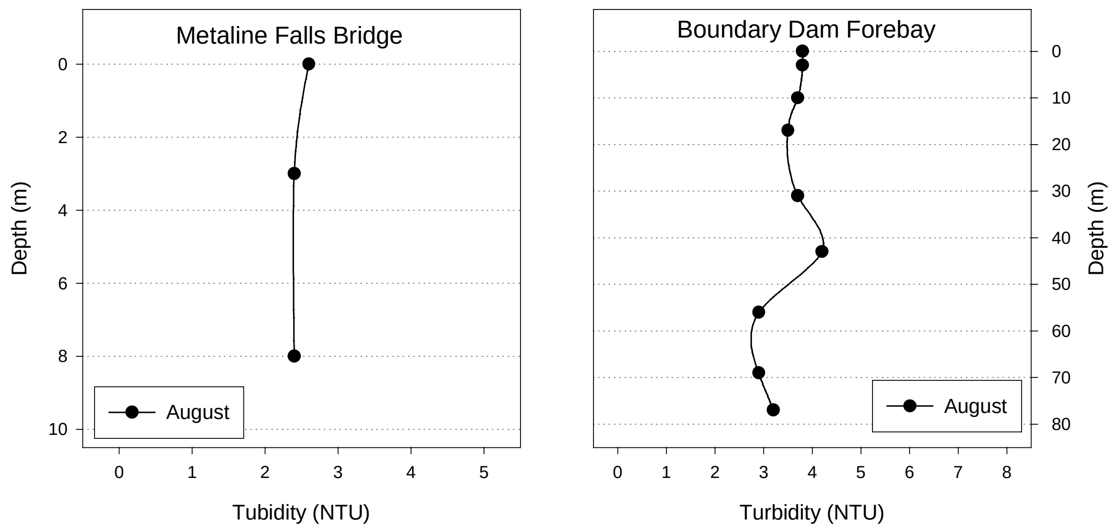

Figure 8. Depth profiles of turbidity measured at the Metaline Falls Bridge and the Boundary Dam forebay in the summer.

Primary Productivity

Mean annual chlorophyll *a* in Boundary Reservoir was 1.05 µg/L (± 0.83; Table 5). Summer chlorophyll *a* values were highest at the Metaline Falls Bridge, while fall values were greatest at the Boundary Dam forebay (Table 5). Mean periphyton chlorophyll *a* was 5.70 µg/L (± 1.61; Table 6). Mean periphyton chlorophyll *a* was highest at the Metaline Falls Bridge (6.28 µg/L ± 2.53; Table 6).

There were 18 species of phytoplankton, representing 5 Divisions, identified from samples collected from Boundary Reservoir (Table 7; Appendix B). Mean annual density and bio-volume of phytoplankton were 1,140 org./ml (± 436) and 0.194 mm^3/L (± 0.053; Table 9). Mean annual phytoplankton densities and bio-volumes were greatest at Metaline Falls Bridge (Table 9). Chryptophyceae were the most abundant phytoplankton overall, but Chlorophyceae had the highest density at the Boundary Dam forebay and Bacillariophyceae had the highest bio-volume at the Boundary Dam forebay (Table 9).

There were 16 species of periphyton, representing 2 Divisions, identified from samples collected from Boundary Reservoir (Table 8; Appendix C). Mean density of periphyton in Boundary Reservoir was 258 $org./cm^2$ (± 325) and mean bio-volume was 130 mm^3/cm^2 (± 143; Table 10). Periphyton densites were greatest at the Boundary Dam forebay (Table 10). Of the two Divisions, the Bacillariophyceae were the most abundant by density and bio-volume at the Boundary Dam forebay and the entire reservoir, and bio-volume at the Metaline Falls Bridge (Table 10). Chlorophyceae had the greatest density at the Metaline Falls Bridge (Table 10).

Table 5. Seasonal phytoplankton chlorophyll *a* levels in Boundary Reservoir, 2000.

Season	Boundary Forebay Chlorophyll a (µg/L)	Metaline Falls Bridge Chlorophyll a (µg/L)	Mean
Summer	<0.01	2.01	1.01 (± 1.41)
Fall	1.26	0.92	1.09 (± 0.24)
Mean	**0.64 (± 0.88)**	**1.47 (± 0.77)**	**1.05 (± 0.83)**

Table 6. Mean periphyton chlorophyll *a* levels in Boundary Reservoir, 2000.

Location	Mean Periphyton Chlorophyll a (µg/L)
Boundary Forebay	5.12 (± 0.21)
Metaline Falls Bridge	6.28 (± 2.53)
Total	**5.70 (± 1.61)**

Table 7. Synoptic list of phytoplankton collected in Boundary reservoir, 2000.

Division Chlorophyta
- Class Chlorophyceae
  - *Ankistrodesmus falcatus* (Corda) Ralfs
  - *Chlamydomonas* sp. Ehr.
  - *Scenedesmus quadricauda* (Turp.) Breb.
  - *Scenedesmus bijuga*

Division Chrysophyta
- Class Bacillariophyceae
  - *Amphora* sp. Ehr.
  - *Asterionella formosa* Hass.
  - *Melosira italica* (Ehr.) Kützing
  - *Navicula* sp. Bory
  - *Rhizosolenia* sp. Ehr.
  - *Synedra* sp. Ehr.
- Class Chrysophyseae
  - *Dinobryon bavaricum* Imhof
  - *Dinobryon sertularia* Ehr.
  - *Mallomonas* sp. Perty

Division Cryptophyta
- Class Cryptophyceae
  - *Cryptomonas* sp. Ehr.
  - *Rhodomonas* sp. Karsten

Division Eubacteria
- Class Cyanobacteria
  - *Aphanotheca* sp. Nägeli
  - *Oscillatoria* sp. Vaucher

Table 8. Synoptic list of periphyton collected in Boundary Reservoir, 2000.

Division Chlorophyta		
	Class Chlorophyceae	
		Cladophora sp. Kützing
		Cosmarium sp. Corda
		Mougeotia sp. (C.A. Agardh) Wittrock
		Scenedesmus quadricauda (Turp.) Breb.
Division Chrysophyta		
	Class Bacillariophyceae	
		Achnanthes sp. Bory
		Amphipleura sp. Kutzing
		Amphora sp. Ehr.
		Cymbella sp. Agardh.
		Cocconeis sp. Ehr.
		Fragilaria sp. Lyngbye
		Gomphonema sp. Ehr.
		Melosira varians Agarh.
		Melosira italica (Ehr.) Kutzing
		Navicula sp. Bory
		Pinnularia sp. Ehr.
		Synedra sp. Ehr.

Table 9. Mean annual density (#/ml; ± standard deviation) and bio-volume (mm^3/L; ± standard deviation) of phytoplankton collected in Boundary Reservoir, 2000.

	Boundary Forebay			Metaline Falls Bridge			Mean Totals		
Organism	**n**	**Density (#/ml)**	**Bio-volume (mm^3/L)**	**n**	**Density (#/ml)**	**Bio-volume (mm^3/L)**	**n**	**Density (#/ml)**	**Bio-volume (mm^3/L)**
Bacillariophyceae	32	132 (± 150)	0.051 (± 0.049)	23	91 (± 60)	0.040 (± 0.011)	55	111 (± 96)	0.045 (± 0.030)
Chlorophyceae	37	271 (± 153)	0.049 (± 0.004)	43	322 (±18)	0.038 (±0.005)	80	297 (± 94)	0.043 (± 0.007)
Chrysophyceae	4	11 (± 15)	0.016 (± 0.022)	13	35 (±18)	0.027 (±0.009)	17	23 (± 20)	0.021 (± 0.015)
Cryptophyceae	94	248 (± 141)	0.039 (± 0.024)	206	544 (±260)	0.099 (±0.050)	300	396 (± 242)	0.069 (± 0.047)
Cyanophyceae	53	170 (± 240)	0.004 (± 0.006)	10	86 (±122)	0.008 (±0.011)	63	128 (± 163)	0.006 (± 0.007)
microplankton	14	121 (± 73)	0.007 (± 0.004)	29	250 (±158)	0.014 (±0.008)	43	185 (± 125)	0.011 (± 0.007)
Total	**234**	**952 (± 596)**	**0.165 (± 0.056)**	**324**	**1,328 (± 274)**	**0.224 (± 0.042)**	**558**	**1,140 (± 436)**	**0.194 (± 0.053)**

Table 10. Mean annual density ($\#/cm^2$; ± standard deviation) and bio-volume (mm^3/cm^2; ± standard deviation) of periphyton collected in Boundary Reservoir, 2000.

	Boundary Forebay			Metaline Falls Bridge			Mean Totals		
Organism	**n**	**Density ($\#/cm^2$)**	**Bio-volume (mm^3/ cm^2)**	**n**	**Density ($\#/cm^2$)**	**Bio-volume (mm^3/ cm^2)**	**n**	**Density ($\#/cm^2$)**	**Bio-volume (mm^3/ cm^2)**
Bacillariophyceae	373	606 (± 512)	307 (± 150)	292	149 (± 68)	122 (± 165)	665	378 (± 398)	214 (± 167)
Chlorophyceae	58	40 (± 8)	47 (± 6)	8	237 (± 331)	46 (± 59)	66	138 (± 223)	46 (± 34)
Total	**431**	**323 (± 441)**	**177 (± 173)**	**300**	**193 (± 202)**	**84 (± 110)**	**731**	**258 (± 325)**	**130 (± 143)**

Secondary Productivity

There were 20 species of zooplankton collected from Boundary Reservoir with a mean annual density of 5.0 org./L (± 7.3; Tables 11 and 12). Copepods had the highest density (12.6 org./L ± 11.2) of which the majority were nauplii (9.5 org./L ± 8.8; Table 12). Zooplankton densities were greatest at the Boundary Dam forebay (Table 12). Copepods had the highest density at both sample sites in the summer and rotifers were the most abundant at both sample sites in the fall (Appendix D).

There were 2,240 macroinvertebrates and zooplankton that colonized the Hester-Dendy samplers, representing 6 Phyla, 10 Classes, and 16 Orders (Table 13; Appendix E). The mean annual density of organisms collected on the Hester-Dendy samplers was 76 org./m^2 (± 249; Table 14). Gastropods had the highest density of the macroinvertebrates collected at the Boundary Dam forebay (430 org./m^2 ± 380; Table 14). Diptera had the highest density of the macroinvertebrates collected at the Metaline Fall Bridge (369 org./m^2 ± 278; Table 14). Cladocerans had the highest density of the organisms collected on the samplers at the Metaline Falls Bridge (803 org./m^2 ± 1,134; Table 14). The cladoceran *Sida crystallina* and Harpacticoid copepods were only collected on Hester-Dendy samplers. *Sida crystallina* were collected at both sample locations and during both sampling periods, unlike the Harpacticoid copepods which were only collected at the Boundary Dam forebay. Three *Alona* sp. were collected at the Metaline Falls Bridge in the fall and one *Diacyclops bicuspidatus thomasi* was collected at the Boundary Dam forebay in the fall.

Table 11. Synoptic list of zooplankton collected in vertical zooplankton tows in Boundary Reservoir, 2000.

- Phylum Arthropoda
  - Class Crustacea
    - Subclass Branchiopoda
      - Order Cladocera
        - *Alona* sp. Baird
        - *Bosmina longirostris* (Müller)
        - *Daphnia galeata mendotae* (Sars) Birge
        - *Daphnia pulex* Leydig
        - *Daphnia rosea* (Sars) Richard
    - Subclass Copepoda
      - Order Eucopepoda
        - nauplii
        - Suborder Calanoida
          - Calanoid copepodid
          - *Epischura nevadensis* Lilljeborg
          - *Hesperodiaptomus franciscanus* (Lillj.)
        - Suborder Cyclopoida
          - Cyclopoid copepodid
          - *Diacyclops bicuspidatus thomassi* Forbes
          - *Mesocyclops edax* (Forbes)
- Phylum Rotifera
  - Class Monogononta
    - Order Flosculariacea
      - *Conochilus* sp. (Ehrenberg)
    - Order Ploima
      - *Asplancha brightwelli* Gosse
      - *Kellicottia longispina* Kellicott
      - *Keratella cochlearis* (Gosse)
      - *Lecane* sp. Nitzsch
      - *Notholca* sp. Gosse
      - *Polyarthra vulgaris* Carlin
      - *Synchaeta pectinata* Ehrenberg
      - *Trichocerca* sp. (Lamarck)

Table 12. Mean density (#/L; ± standard deviation) of zooplankton collected in vertical tows in Boundary Reservoir, 2000.

	Boundary Forebay		Metaline Falls		Total	
Organism	**n**	**Density (#/L)**	**n**	**Density (#/L)**	**n**	**Density (#/L)**
Cladocera	**64**	**0.9 (± 1.0)**	**46**	**0.8 (± 0.8)**	**110**	**0.8 (± 0.9)**
Daphnia galeata mendotae	63	0.9 (± 1.0)	44	0.7 (± 0.9)	107	0.8 (± 0.9)
Daphnia pulex	1	<0.1 (± 0.0)	0	0	1	<0.1 (± 0.0)
Daphnia rosea	0	0	2	<0.1 (± 0.1)	2	<0.1 (± 0.1)
other Cladocera	**174**	**2.8 (± 0.7)**	**159**	**2.7 (± 1.3)**	**333**	**2.8 (± 1.0)**
Alona sp.	3	0.1 (± 0.1)	7	0.1 (± 0.2)	10	0.1 (± 0.1)
Bosmina longirostris	171	2.8 (± 0.7)	152	2.6 (± 1.4)	323	2.7 (± 1.1)
Copepoda	**1,116**	**14.2 (± 13.2)**	**666**	**11.1 (± 9.9)**	**1,782**	**12.6 (± 11.2)**
Calanoid copepodid	47	0.6 (± 0.7)	35	0.6 (± 0.6)	82	0.6 (± 0.6)
Cyclopoid copepodid	86	1.2 (± 1.1)	89	1.5 (± 1.1)	175	1.4 (± 1.1)
Diacyclops bicuspidatus thomasi	5	0.1 (± 0.1)	3	0.1 (± 0.1)	8	0.1 (± 0.1)
Epischura nevadensis	54	0.7 (± 0.8)	40	0.7 (± 0.7)	94	0.7 (± 0.8)
Hesperodiaptomus franciscanus	19	0.3 (± 0.1)	30	0.5 (± 0.5)	49	0.4 (± 0.3)
Mesocyclops edax	1	<0.1 (± 0.0)	0	0	1	<0.1 (± 0.0)
nauplii	904	11.2 (± 10.6)	469	7.8 (± 7.2)	1373	9.5 (± 8.8)
Rotifera	**177**	**3.4 (± 3.5)**	**208**	**4.0 (± 3.8)**	**385**	**3.7 (± 3.5)**
Asplanchna brightwelli	0	0	1	<0.1 (± 0.0)	1	<0.1 (± 0.0)
Conochilus sp.	14	0.3 (± 0.4)	37	0.7 (± 0.9)	51	0.5 (± 0.7)
Kellicottia longispina	101	1.9 (± 2.0)	69	1.3 (± 1.4)	170	1.6 (± 1.7)
Keratella cochlearis	19	0.4 (± 0.4)	28	0.5 (± 0.8)	47	0.5 (± 0.6)
Lecane sp.	1	0	5	0.1 (± 0.1)	6	0.1 (± 0.1)
Notholca sp.	0	0	1	<0.1 (± 0.0)	1	<0.1 (± 0.0)
Polyarthra vulgaris	33	0.6 (± 0.7)	52	1.0 (± 0.8)	85	0.8 (± 0.7)
Synchaeta pectinata	0	0	1	<0.1 (± 0.0)	1	<0.1 (± 0.0)
Trichocerca sp.	9	0.2 (± 0.2)	14	0.3 (± 0.3)	23	0.2 (± 0.2)
Total	**1,531**	**5.3 (± 8.3)**	**1,079**	**4.6 (± 6.4)**	**2,610**	**5.0 (± 7.3)**

Table 13. Synoptic list of macroinvertebrates and zooplankton collected on Hester-Dendy samplers set in Boundary Reservoir, 2000.

Phylum Arthropoda
- Class Crustacea
  - Subclass Branchiopoda
    - Order Cladocera
      - *Alona* sp. Baird
      - *Sida crystallina* (Müller)
    - Order Copepoda
      - Suborder Harpacticoida
        - Harpacticoid copepodid
      - Suborder Cyclopoida
        - *Diacyclops bicuspidatus thomasi* Forbes
  - Subclass Ostracoda
    - Ostracod sp.
  - Subclass Malacostraca
    - Order Amphipoda
      - Family Gammaridae
        - *Gammarus lacustris* Sars
      - Family Talitridae
        - *Hyalella azteca* (Saussure)
- Class Arachnoidea
  - Order Hydracarina
    - Hydracarina sp.
    - Family Limnesiidae
      - *Kawamuracarus* sp.
- Class Insecta
  - Subclass Pterygota
    - Order Ephemeroptera
      - Family Caenidae
        - *Caenis* sp.
      - Family Heptageniidae
        - *Stenonema* sp.
    - Order Odonata
      - Family Coenagrionidae
        - *Enallagma* sp.
    - Order Plecoptera
      - Family Perlodidae
        - *Skwala* sp.
    - Order Trichoptera
      - Trichoptera sp.
      - Family Hydropsychidae
        - *Cheumatopsyche* sp.
      - Family Hydroptilidae
        - Hydroptilid sp.
        - *Agraylea* sp.
        - *Ochrotrichia* sp.
      - Family Leptoceridae
        - *Oecetis* sp.
        - *Nectopsyche* sp.
      - Family Polycentropodidae

Table 13. Continued.

Polycentropus sp.
Order Coleoptera
Family Elmidae
Dubiraphia sp.
Order Diptera
Family Ceratopogonidae
Ceratopogonid sp.
Bezzia sp.
Stilobezzia sp.
Family Chironomidae
Chironomid sp.
Phylum Nematoda
Nematode sp.
Phylum Bryozoa
Class Phylactolaemata
Family Cristatellidae
Cristatella mucedo Cuvier
Phylum Coelenterata
Class Hydrozoa
Order Hydroida
Family Hydridae
Hydra sp.
Phylum Annelida
Class Hirudinea
Order Pharyngobdella
Family Erpobdellidae
Erpobdella punctata (Leidy)
Order Rhynchobdella
Family Glossiphoniidae
Helobdella fusca Castle
Helobdella stagnalis (L.)
Class Oligochaeta
Order Haplotaxida
Family Naididae
Naidid sp.
Phylum Mollusca
Class Gastropoda
Order Limnophila
Family Lymnaeidae
Lymnaeid sp.
Fisherola sp.
Family Physidae
Physid sp.
Family Planorbidae
Planorbid sp.
Menetus sp.
Grayulus sp.
Class Pelecypoda
Order
Family Sphaeriidae
Sphaeriid sp.

Table 14. Annual mean density (#/m^2; ± standard deviation) of macroinvertebrates and zooplankton collected on Hester-Dendy samplers set in Boundary Reservoir, 2000.

	Boundary Forebay		Metaline Falls Bridge		Mean Totals	
Organism	**n**	**Density (#/m^2)**	**n**	**Density (#/m^2)**	**n**	**Density (#/m^2)**
Amphipoda	26	33 (± 29)	0	0	26	17 (± 26)
Bryozoa	0	0	1	1 (± 3)	1	1 (± 2)
Cladocera	48	62 (± 128)	626	803 (± 1,134)	674	432 (± 861)
Coleoptera	0	0	7	9 (± 22)	7	5 (± 16)
Copepoda	64	82 (± 123)	2	3 (± 4)	66	42 (± 93)
Diptera	145	186 (± 105)	288	369 (± 278)	433	278 (± 222)
Ephemeroptera	1	1 (± 3)	13	17 (± 8)	14	9 (± 10)
Gastropoda	335	430 (± 380)	98	126 (± 120)	433	278 (± 312)
Haplotaxida	61	78 (± 131)	130	167 (± 239)	191	122 (± 190)
Hydracarina	62	80 (± 180)	26	33 (± 30)	88	56 (± 125)
Hydroida	86	110 (± 227)	72	92 (± 89)	158	101 (± 164)
Nematoda	1	1 (± 3)	0	0	1	1 (± 2)
Odonota	0	0	1	1 (± 3)	1	1 (± 2)
Ostracoda	77	99 (± 103)	4	5 (± 6)	81	52 (± 85)
Pelecypoda	2	3 (± 4)	0	0	2	1 (± 3)
Pharyngobdella	2	3 (± 4)	0	0	2	1 (± 3)
Plecoptera	0	0	1	1 (± 3)	1	1 (± 2)
Rhynchobdellida	9	12 (± 16)	0	0	9	6 (± 12)
Trichoptera	8	10 (± 13)	44	56 (± 45)	52	33 (± 40)
Total	**927**	**63 (± 153)**	**1,313**	**89 (± 317)**	**2,240**	**76 (± 249)**

Reservoir Fisheries Surveys

There were 18 species of fish collected in Boundary Reservoir during 2000 (Table 15). CPUE and species composition were calculated for each species, gear type, reservoir section, and season (Tables 16 and 17; Appendices F and G). Largescale suckers were the most abundant species in boat electrofishing surveys (45.3 fish/hr.), but northern pikeminnow were the most abundant in horizontal gill net surveys (12.2 fish/night; Table 16). Smallmouth bass were the most abundant game fish collected in electrofishing surveys (12.1 fish/hr.) and yellow perch were the most abundant game fish collected in horizontal gillnet surveys (1.5 fish/night; Table 16). The species composition by percent number (relative abundance) was dominated by the northern pikeminnow (33.4%), but largescale suckers comprised the greatest portion of the fish biomass (44.6%; Table 17). Smallmouth bass were the dominant game fish in the reservoir as indicated by the species composition by percent number (7.2%) and percent biomass (3.8%; Table 17).

During the supplemental day electrofishing surveys there were 13 smallmouth bass, 12 northern pikeminnow, 10 redside shiners, 6 largescale suckers, 6 mountain whitefish, 4 rainbow trout, 1 yellow perch, 1 cutthroat trout, 1 longnose sucker, and 1 peamouth collected. Electrofishing effort totaled 1.33 hours (n=8). There were four fish captured in the bottom horizontal gill net that was set at the forebay of Boundary Dam in the summer. Three of the fish were northern pikeminnow and the other one was a longnose sucker. One peamouth was caught in the surface horizontal gill net that was set at the Boundary Dam forebay in the summer.

Proportional stock densities (PSD) and relative stock densities (RSD) were calculated for each game fish species collected. Sample sizes were too small for interpretation, except for smallmouth bass and yellow perch. Smallmouth bass had PSD's of 21 by electrofishing and 38 by gill netting (Tables 18 and 19). Yellow perch had PSD's of 28 by electrofishing and 55 by gill netting (Tables 18 and 19).

Ages were determined for 79 smallmouth bass, 55 yellow perch, 35 mountain whitefish, 15 rainbow trout, 7 largemouth bass, 6 black crappie, 6 brown trout, 5 pumpkinseed, 3 cutthroat trout, and 2 lake trout. Mean back-calculated total lengths at the formation of each annulus were calculated for smallmouth bass, yellow perch, mountain whitefish, and rainbow trout (Tables 20 through 23). Mean back-calculated total lengths were calculated for the game fish species that had small sizes (Table 24).

Smallmouth bass W_r's were greater than the national standard (100) until 250 mm TL, after which the majority had relative weights below the national standard (Figure 9). Yellow perch W_r values were clustered near the national standard (100) but appeared to decline with increased total length (Figure 9). W_r's of mountain whitefish were generally low when compared to the national standard of 100 (Figure 9). Rainbow trout W_r's were low when compared to the national standard (Figure 9). Largemouth bass W_r's were greater than the national standard (100) until 400 mm TL (Figure 10). Black crappie and pumpkinseed W_r's were generally greater than the national standard of 100 (Figure 10). The relative weights of brown trout, cutthroat trout, lake trout, and burbot were relatively low when compared to the national standard (Figures 10 and 11).

Mean total length, mean weight, and mean K_{TL} were calculated for each age of smallmouth bass, yellow perch, mountain whitefish, and rainbow trout collected in Boundary Reservoir (Tables 25 through 28). Mean total length, mean weight, and mean K_{TL} were calculated for largemouth bass, black crappie, brown trout, pumpkinseed, cutthroat trout, and lake trout collected in Boundary Reservoir (Table 29).

Table 15. Common and scientific names of fish species captured in Boundary Reservoir.

Common Name	**Species Name**
Black crappie*	*Poxomis nigromaculatus* (Lesueur)
Brown bullhead*	*Ameiurus nebulosus* (Lesueur)
Brown trout*	*Salmo trutta* Linnaeus
Burbot*	*Lota lota* (Linnaeus)
Cutthroat trout*	*O. clarki* (Richardson)
Lake trout*	*S. namaycush* (Walbaum)
Largemouth bass*	*Micropterus salmoides* (Lacepede)
Largescale sucker	*Catostomus macrocheilus* (Girard)
Longnose sucker	*C. catostomus* (Forster)
Mountain whitefish*	*Prosopium williamsoni* (Girard)
Northern pikeminnow*	*Ptychocheilus oregonensis* (Richardson)
Peamouth	*Mylocheilus caurinus* (Richardson)
Pumpkinseed*	*Lepomis gibbosus* (Linnaeus)
Rainbow trout*	*Oncorhynchus mykiss* (Walbaum)
Redside shiner	*Richardsonius balteatus* (Richardson)
Smallmouth bass*	*M. dolomieui* (Lacepede)
Tench	*Tinca tinca* (Linnaeus)
Yellow perch*	*Perca flavescens* (Mitchill)

*Game fish species.

Table 16. Mean annual catch-per-unit-effort (CPUE; ± 80% CI) of fish collected in Boundary Reservoir, 2000.

	Gear Type					
	Electrofishing		Horizontal Gill Netting		Vertical Gill Netting	
Species	**#/ hour**	**n**	**#/GN night**	**n**	**#/VGN night**	**n**
Black crappie	0.1 (± 0.2)	48	0.2 (± 0.1)	29	0	20
Brown bullhead	1.6 (± 1.3)	48	0.3 (± 0.3)	29	0	20
Brown trout	0.6 (± 0.4)	48	<0.1 (± <0.1)	29	0	20
Burbot	0.5 (± 0.4)	48	0	29	0	20
Cutthroat trout	0.3 (± 0.3)	48	0	29	0	20
Lake trout	0	48	0.1 (± 0.1)	29	0	20
Largemouth bass	1.0 (± 0.5)	48	<0.1 (± <0.1)	29	0	20
Largescale sucker	45.3 (± 8.6)	48	4.5 (± 2.0)	29	0	20
Longnose sucker	2.9 (± 1.3)	48	0.3 (± 0.2)	29	0	20
Mountain whitefish	4.6 (± 1.6)	48	0.2 (± 0.1)	29	0	20
Northern pikeminnow	31.9 (± 8.1)	48	12.2 (± 2.5)	29	0.1 (± 0.1)	20
Peamouth	2.8 (± 1.4)	48	3.5 (± 1.0)	29	0.1 (± 0.1)	20
Pumpkinseed	0.4 (± 0.3)	48	0.1 (± 0.1)	29	0	20
Rainbow trout	1.13 (± 0.5)	48	0.1 (± 0.1)	29	0	20
Redside shiner	22.0 (± 6.0)	48	0.7 (± 0.4)	29	0	20
Smallmouth bass	12.1 (± 4.4)	48	1.2 (± 0.6)	29	0	20
Tench	2.8 (± 1.5)	48	0.2 (± 0.2)	29	0	20
Yellow perch	7.8 (± 3.9)	48	1.5 (± 0.7)	29	0	20

Table 17. Annual species composition, by number and weight, and the size range of fish collected in Boundary Reservoir, 2000.

	Species Composition					
	by Number		by Weight		Size Range (mm TL)	
Species	**(#)**	**(%n)**	**(kg)**	**(%w)**	**Min**	**Max**
Black crappie	6	0.3	0.7	0.2	135	218
Brown bullhead	21	1.2	5.7	1.4	231	292
Brown trout	6	0.3	3.0	0.7	271	452
Burbot	4	0.2	0.7	0.2	241	431
Cutthroat trout	2	0.1	0.5	0.1	312	375
Lake trout	2	0.1	1.0	0.2	318	474
Largemouth bass	8	0.4	3.4	0.8	81	432
Largescale sucker	489	26.8	185.5	44.6	32	552
Longnose sucker	31	1.7	12.8	3.1	68	434
Mountain whitefish	42	2.3	9.3	2.2	91	411
Northern pikeminnow	609	33.4	118.4	28.5	50	550
Peamouth	126	6.9	20.5	4.9	70	357
Pumpkinseed	5	0.3	0.3	0.1	110	167
Rainbow trout	11	0.6	4.3	1.0	182	480
Redside shiner	197	10.8	3.6	0.9	43	180
Smallmouth bass	131	7.2	15.7	3.8	55	402
Tench	29	1.6	22.3	5.4	145	460
Yellow perch	103	5.7	8.1	1.9	52	252

Table 18. Annual PSD and RSD values (± 80% CI) for fish collected by electrofishing in Boundary Reservoir, 2000.

Species	# Stock Length	PSD	RSD-P	RSD-M	RSD-T
Brown trout	5	100 (± 0)	60 (± 28)	60 (± 28)	0
Burbot	4	25 (± 28)	0	0	0
Cutthroat trout	3	67 (± 35)	0	0	0
Largemouth bass	4	75 (± 28)	50 (± 32)	0	0
Pumpkinseed	3	33 (± 35)	0	0	0
Rainbow trout	10	30 (± 19)	10 (± 12)	10 (± 12)	0
Smallmouth bass	21	29 (± 13)	14 (± 10)	0	0
Yellow perch	28	43 (± 12)	0	0	0

Table 19. Annual PSD and RSD values (± 80% CI) for fish collected by horizontal gill netting in Boundary Reservoir, 2000.

Species	# Stock Length	PSD	RSD-P	RSD-M	RSD-T
Black crappie	5	60 (± 28)	0	0	0
Lake trout	2	0	0	0	0
Pumpkinseed	2	0	0	0	0
Rainbow trout	2	0	0	0	0
Smallmouth bass	32	38 (± 11)	22 (± 9)	0	0
Yellow perch	42	55 (± 10)	2 (± 3)	0	0

Table 20. Mean back-calculated total lengths (± standard deviation) at the formation of each annulus for smallmouth bass collected in Boundary Reservoir during 2000.

		Mean Total Length (mm) at the Formation of Each Annulus						
Cohort	**n**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
1999	14	78 (± 13)						
1998	35	87 (± 10)	137 (± 18)					
1997	13	81 (± 11)	138 (± 17)	189 (± 36)				
1996	5	77 (± 13)	135 (± 31)	199 (± 47)	247 (± 44)			
1995	8	88 (± 12)	144 (± 19)	220 (± 29)	276 (± 42)	319 (± 52)		
1994	3	100 (± 10)	142 (± 19)	229 (± 23)	283 (± 32)	326 (± 29)	364 (± 11)	
1993	1	79 (nc)	118 (nc)	149 (nc)	195 (nc)	268 (nc)	321 (nc)	372 (nc)
Grand Mean	79	84 (± 12)	138 (± 19)	202 (± 38)	264 (± 44)	317 (± 46)	353 (± 23)	372 (nc)
Mean Annual Growth		84 (± 12)	52 (± 16)	63 (± 23)	53 (± 16)	45 (± 17)	42 (± 17)	51 (nc)

nc= not calculable.

Table 21. Mean back-calculated total lengths (± standard deviation) at the formation of each annulus for yellow perch collected in Boundary Reservoir during 2000.

		Mean Total Length (mm) at the Formation of Each Annulus			
Cohort	**n**	**1**	**2**	**3**	**4**
1999	10	71 (± 7)			
1998	14	74 (± 8)	124 (± 12)		
1997	23	67 (± 10)	123 (± 19)	168 (± 22)	
1996	8	69 (± 10)	126 (± 16)	171 (± 13)	202 (± 20)
Grand Mean	55	70 (± 9)	124 (± 16)	168 (± 20)	202 (± 20)
Mean Annual **Growth**		70 (± 9)	55 (± 13)	44 (± 10)	31 (± 13)

Table 22. Mean back-calculated total lengths (± standard deviation) at the formation of each annulus for mountain whitefish collected in Boundary Reservoir during 2000.

		Mean Total Length (mm) at the Formation of Each Annulus						
Cohort	**n**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
1999	2	96 (± 1)						
1998	3	78 (± 9)	228 (± 18)					
1997	12	78 (± 14)	196 (± 34)	276 (± 27)				
1996	4	76 (± 6)	165 (± 46)	225 (± 42)	269 (± 37)			
1995	7	71 (± 19)	168 (± 30)	252 (± 24)	301 (± 33)	342 (± 23)		
1994	5	64 (± 11)	143 (± 54)	214 (± 54)	261 (± 24)	296 (± 42)	328 (± 34)	
1993	2	64 (± 6)	123 (± 3)	194 (± 21)	256 (± 16)	283 (± 18)	313 (± 29)	343 (± 34)
Grand **Mean**	35	75 (± 14)	177 (± 44)	248 (± 42)	278 (± 39)	317 (± 39)	324 (± 31)	343 (± 34)
Mean Annual **Growth**		75 (± 14)	103 (± 40)	76 (± 20)	49 (± 18)	37 (± 13)	31 (± 9)	29 (± 5)

Table 23. Mean back-calculated total lengths (± standard deviation) at the formation of each annulus for rainbow trout collected in Boundary Reservoir during 2000.

		Mean Total Length (mm) at the Formation of Each Annulus					
Cohort	**n**	**1**	**2**	**3**	**4**	**5**	**6**
1999	1	73 (nc)					
1998	2	63 (± 15)	153 (± 80)				
1997	8	92 (± 23)	173 (± 39)	284 (± 46)			
1996	3	116 (± 43)	209 (± 59)	288 (± 73)	372 (± 76)		
1995	0	-	-	-	-	-	
1994	1	111 (nc)	282 (nc)	354 (nc)	448 (nc)	526 (nc)	614 (nc)
Grand Mean	15	93 (± 29)	186 (± 54)	291 (± 52)	391 (± 73)	526 (nc)	614 (nc)
Mean Annual Growth		93 (± 29)	92 (± 35)	100 (± 34)	87 (± 18)	77 (nc)	89 (nc)

nc= not calculable.

Table 24. Mean back-calculated total lengths (mm) at the formation of each annulus (± standard deviation) of sport fish, with small sample sizes, collected in Boundary Reservoir 2000.

		Mean Total Length (mm) at the Formation of Each Annulus									
Species	**n**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Largemouth Bass	7	62 (±5)	135 (± 24)	181 (± 54)	257 (± 62)	269 (± 4)	290 (± 3)	342 (± 16)	367 (± 17)	390 (± 11)	414 (nc)
Black Crappie	6	59 (± 7)	111 (± 23)	170 (± 30)	153 (nc)						
Brown Trout	6	85 (± 29)	195 (± 33)	321 (± 66)	380 (± 57)						
Pumpkinseed	5	45 (± 5)	72 (± 12)	81 (± 5)	107 (± 18)	120 (± 13)	133 (± 22)	144 (± 20)			
Cutthroat Trout	3	97 (± 27)	167 (± 40)	254 (± 72)							
Lake Trout	2	112 (± 27)	199 (± 4)	292 (± 16)	393 (nc)						

nc= not calculable.

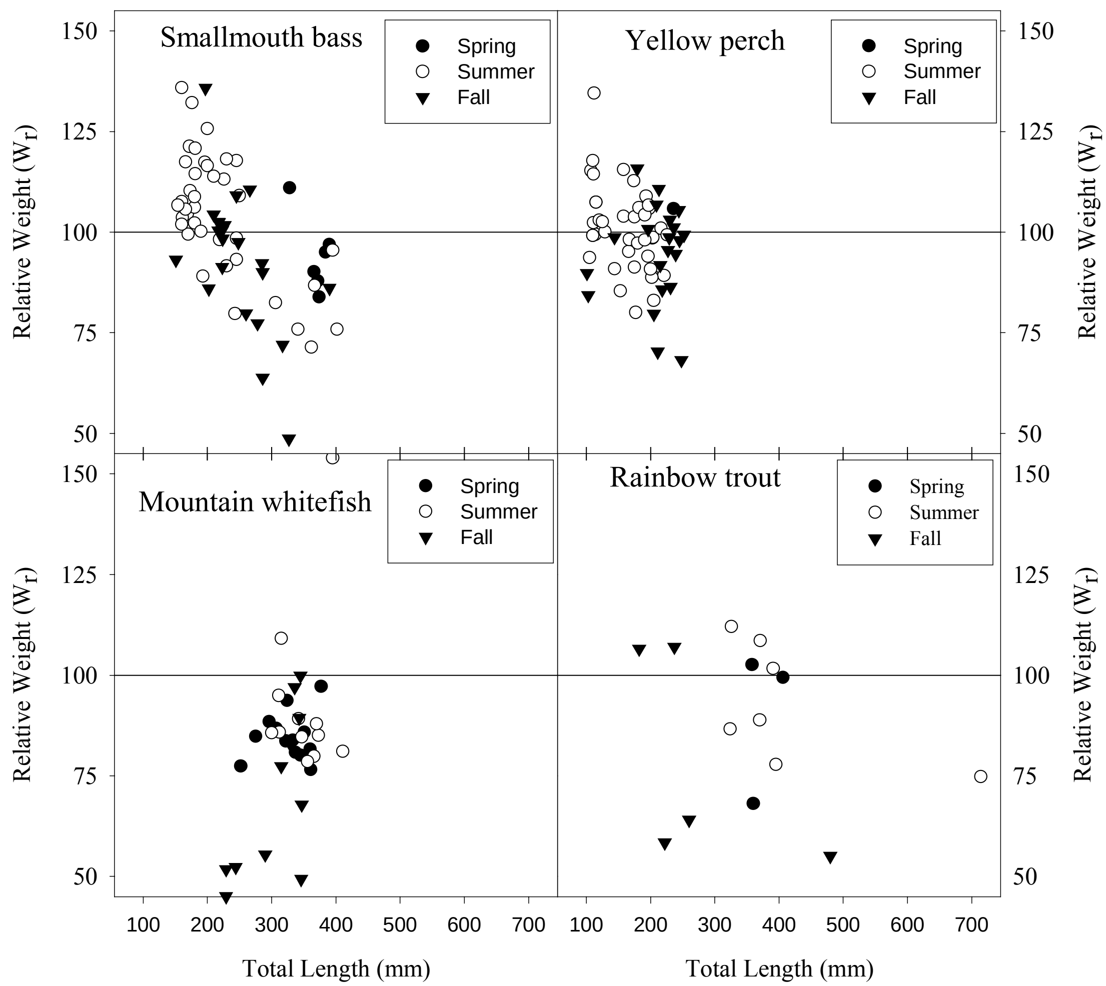

Figure 9. Relative weights of smallmouth bass, yellow perch, mountain whitefish, and rainbow trout collected in Boundary Reservoir, 2000. The national standard of 100 generally indicates good condition.

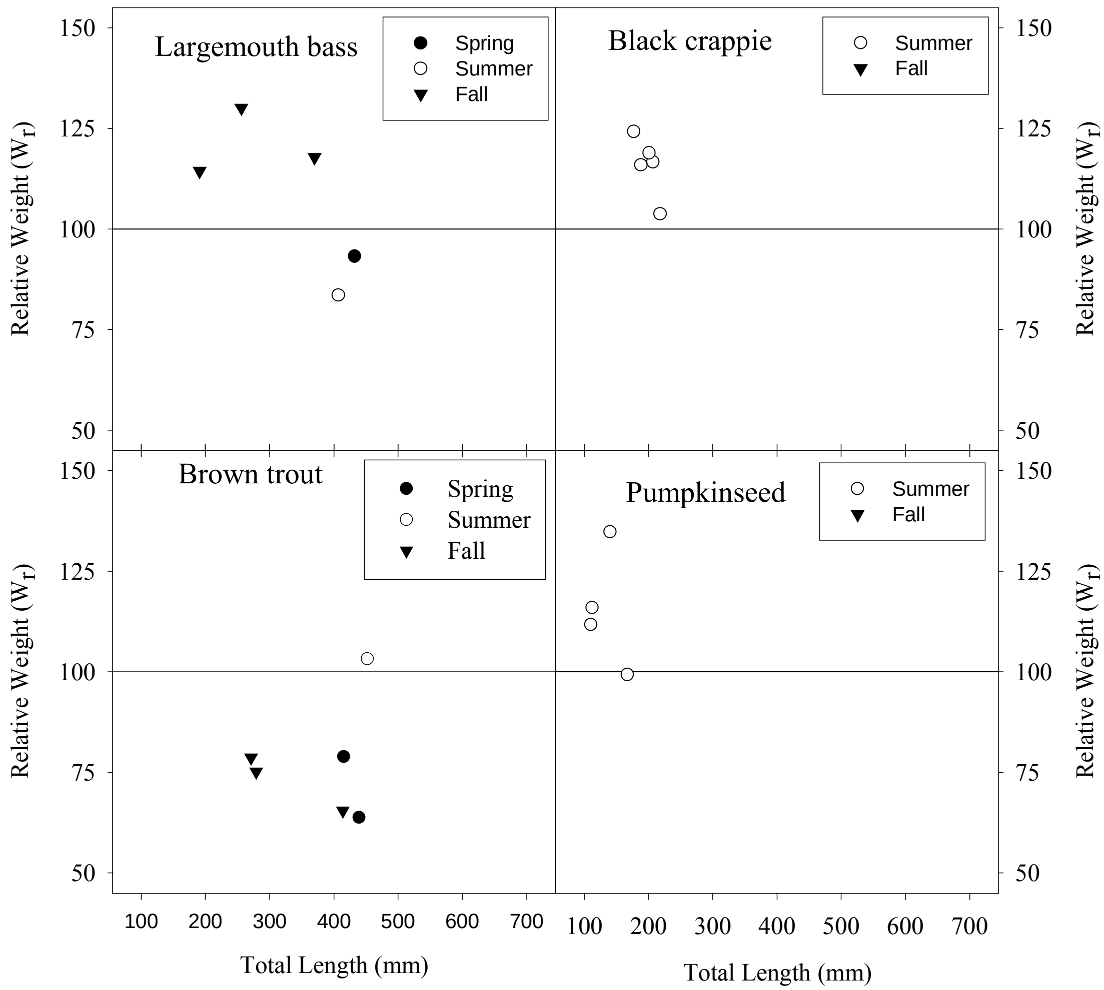

Figure 10. Relative weights of largemouth bass, black crappie, brown trout, and pumpkinseed collected in Boundary Reservoir, 2000. The national standard of 100 generally indicates good condition.

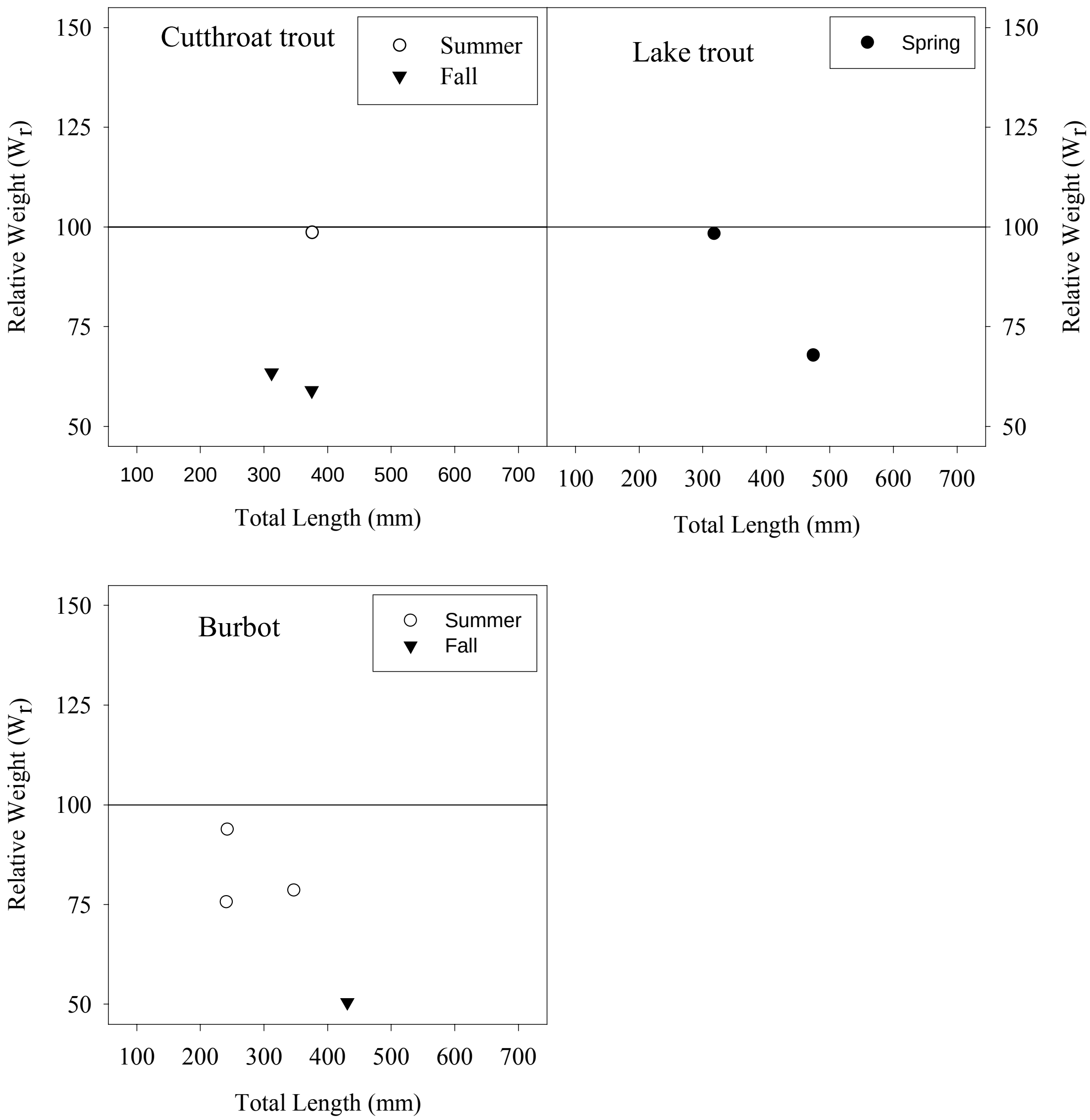

Figure 11. Relative weights of cutthroat trout, lake trout, and burbot collected in Boundary Reservoir, 2000. The national standard of 100 generally indicates good condition.

Table 25. Mean total length, weight, and condition factor (K_{TL}) of smallmouth bass collected in Boundary Reservoir, 2000.

Age	n	Mean TL (mm)	Mean WT (g)	Mean K_{TL}
1	8	108 (± 6)	19 (± 5)	1.49 (± 0.21)
2	35	189 (± 33)	105 (± 58)	1.41 (± 0.15)
3	13	229 (± 45)	181 (± 85)	1.40 (± 0.21)
4	5	281 (± 46)	288 (± 170)	1.25 (± 0.40)
5	8	341 (± 48)	551 (± 224)	1.30 (± 0.12)
6	3	396 (± 6)	823 (± 78)	1.33 (± 0.15)
7	1	390 (n/c)	889 (n/c)	1.50 (n/c)
Total	**73**	**222 (± 81)**	**211 (± 233)**	**1.39 (± 0.19)**

nc= not calculable.

Table 26. Mean total length, weight, and condition factor (K_{TL}) of yellow perch collected in Boundary Reservoir, 2000.

Age	n	Mean TL (mm)	Mean WT (g)	Mean K_{TL}
1	10	118 (± 12)	22 (± 7)	1.31 (± 0.13)
2	14	174 (± 29)	76 (± 37)	1.31 (± 0.15)
3	23	208 (± 24)	126 (± 45)	1.35 (± 0.16)
4	7	226 (± 18)	159 (± 50)	1.33 (± 0.19)
Total	**54**	**186 (± 43)**	**98 (± 59)**	**1.33 (± 0.16)**

Table 27. Mean total length, weight, and condition factor (K_{TL}) of mountain whitefish collected in Boundary Reservoir, 2000.

Age	n	Mean TL (mm)	Mean WT (g)	Mean K_{TL}
1	2	123 (± 3)	11 (± 2)	0.59 (± 0.11)
2	3	263 (± 40)	144 (± 101)	0.70 (± 0.22)
3	12	309 (± 31)	268 (± 96)	0.86 (± 0.17)
4	4	297 (± 45)	217 (± 112)	0.76 (± 0.16)
5	7	357 (± 23)	456 (± 230)	0.96 (± 0.28)
6	5	358 (± 18)	380 (± 125)	0.81 (± 0.18)
7	2	386 (± 36)	480 (± 132)	0.83 (± 0.00)
Total	**35**	**314 (± 64)**	**303 (± 180)**	**0.83 (± 0.20)**

Table 28. Mean total length, weight, and condition factor (K_{TL}) of rainbow trout collected in Boundary Reservoir, 2000.

Age	n	Mean TL (mm)	Mean WT (g)	Mean K_{TL}
1	1	182 (n/c)	69 (n/c)	1.14 (n/c)
2	2	241 (± 27)	96 (± 37)	0.66 (± 0.04)
3	8	351 (± 51)	466 (± 160)	1.05 (± 0.17)
4	3	403 (± 78)	573 (± 221)	0.88 (± 0.25)
5	-	-	-	-
6	1	714 (n/c)	3,023 (n/c)	0.83 (n/c)
Total	**15**	**360 (± 126)**	**582 (± 711)**	**0.95 (± 0.21)**

nc= not calculable.

Table 29. Mean total length, weight, and condition factor (K_{TL}) of game fish species with small sample sizes, collected in Boundary Reservoir, 2000.

Species	n	Mean TL (mm)	Mean WT (g)	Mean K_{TL}
Largemouth Bass	6	268 (± 137)	556 (± 474)	1.53 (± 0.21)
Black Crappie	6	188 (± 30)	125 (± 38)	1.89 (± 0.41)
Brown Trout	6	378 (± 81)	506 (± 314)	0.83 (± 0.15)
Pumpkinseed	5	130 (± 24)	60 (± 31)	2.59 (± 0.45)
Cutthroat Trout	3	354 (± 37)	366 (± 181)	0.79 (± 0.23)
Lake Trout	2	396 (± 110)	479 (± 293)	0.74 (± 0.14)

Tributary Assessments
Flume Creek

Flume Creek was divided into 4 sampling reaches that were sampled on September 6th and 7th (Figure 4; Appendix G). A total of 13 sites were surveyed (Appendix H). The mean of each habitat parameter was calculated for each reach and the entire stream (Table 30). The dominant substrate was cobble (Table 30) and the dominant habitat type was riffle (86%; Table 31). The discharge of Flume Creek on September 6th was 0.25 m^3/sec.

Three fish migration barriers were identified on Flume Creek (Figure 12; Appendix I). A 13.0 m vertical waterfall was located near the mouth of Flume Creek. Two additional potential human made barriers were identified. A culvert was located where the creek goes under Boundary Road. The culvert mouth was approximately 2.5 m vertically above the surface of the plunge pool. A second culvert was located where USFS Road #350 crossed the creek. The culvert mouth was 1.5 m high and there was no plunge pool below it.

The temperature of upper Flume Creek was measured 1,338 times with the thermograph, between June 28th and October 17th. Daily average, maximum, and minimum temperatures were determined (Figure 13). Mean temperature (± standard deviation) was 8.54 (± 2.02) °C with a maximum of 12.68 °C on August 9th and a minimum of 2.88 °C on October 6th.

The temperature of lower Flume Creek was measured 1,338 times with the thermograph, between June 28th and October 17th. Daily average, maximum, and minimum temperatures were determined (Figure 14). Total mean temperature was 9.02 (± 2.30) °C with a maximum of 14.71 °C on July 21st and 29th and a minimum of 3.19 °C on October 6th.

Eastern brook trout were the only species of fish observed (n=165; Table 32). No fish were observed in reach 1. The mean density of brook trout in Flume Creek was 9 fish/100m^2. The majority of the fish observed were in reach 3 (73%; n=120) and were <100 mm TL (79%; n=130).

Lime Creek

Lime Creek was divided into 4 sampling reaches that were sampled on September 26th (Figure 4; Appendix G). A total of 8 sites were surveyed (Appendix H). The mean of each habitat parameter measured was calculated for each reach and the entire stream (Table 33). The dominant substrate was gravel (Table 33) and riffles were the dominant habitat type observed (60%; Table 34). The discharge of Lime Creek on September 26th was 0.08 m^3/sec.

A natural fish passage barrier was identified on Lime Creek, where the stream went underground for approximately 100 m, downstream of State Highway 31 (Figure 12; Appendix I).

The temperature of Lime Creek was measured 1,340 times with the thermograph, between June 28th and October 17th. Daily average, maximum, and minimum temperatures were determined (Figure 15). Mean temperature (± standard deviation) was 8.78 (± 1.54) °C with a maximum of 11.87 °C on August 9th and a minimum of 4.27 °C on October 6th.

Eastern brook trout were the only species of fish observed (n=35; Table 35). The mean density of brook trout was 5 fish/100m^2. No fish were observed in reach 1, which was the stretch upstream of where the stream went sub-terminal. Fish were distributed evenly among the reaches 2 through 4. The majority of fish observed were <100 mm TL (54%; n=19), and no fish >300 mm TL were observed.

Pewee Creek

Pewee Creek was divided into 3 sampling reaches that were sampled on September 25th (Figure 4; Appendix G). A total of 6 sites were surveyed (Appendix H). Reach 1 was on Fence Creek, a tributary of Pewee Creek, which was larger than Pewee Creek. Upstream of the confluence with Fence Creek, Pewee Creek was a large wetland with out enough surface water to support fish. The mean of each habitat parameter was calculated for each reach and the entire stream (Table 36). The dominant substrate was rubble (Table 36) and riffles were the dominant habitat type (83%; Table 37). The discharge of Pewee Creek on September 25th was 0.01 m^3/sec.

A 50.0 m vertical waterfall occurred at the mouth of Pewee Creek and it was considered a fish passage barrier (Figure 12; Appendix H).

The temperature of Pewee Creek was measured 1,338 times with the thermograph, between June 28th and October 17th. Daily average, maximum, and minimum temperatures were determined (Figure 16). Mean temperature (± standard deviation) was 8.59 (± 1.75) °C with a maximum of 12.04 °C on August 9th and a minimum of 2.76 °C on October 6th.

Cutthroat (40%; n=2) and eastern brook trout (60%; n=3) were the fish species observed in Pewee Creek (Table 38). The mean densities of both cutthroat and brook trout were 1 fish/100m^2. Fish densities were similar between all of the reaches, except no cutthroat trout were observed in reach 2. The majority of fish observed were 100-200 mm TL (80%; n=4), and no fish >201 mm TL were observed.

Sand Creek

Sand Creek was divided into 5 sampling reaches that were sampled on August 28th and September 7th (Figure 4; Appendix G). A total of 12 sites were surveyed (Appendix H). There was a portion of Sand Creek between reaches 4 and 5 that could not be sampled, because private landowners would not allow access. The mean of each habitat parameter was calculated for each reach and the entire stream (Table 39). The dominant substrate was sand (Table 39) and riffles were the dominant habitat type observed (69%; Table 40). The discharge of Sand Creek on September 7th was 0.01 m^3/sec.

Two fish passage barriers were identified on Sand Creek (Figure 12; Appendix I). The first barrier was a culvert (2.0 m vertical, 75.0 m long) where the railroad track crossed the creek near USFS Road #3669. The second barrier was a waterfall (5.0 m vertical) 2 km upstream from the mouth.

The temperature of Sand Creek was measured 1,363 times with the thermograph, between June 28th and October 19th. Daily average, maximum, and minimum temperatures were determined (Figure 17). Mean temperature (± standard deviation) was 9.65 (± 3.01) °C with a maximum of 16.26 °C on August 23rd and a minimum of 2.53 °C on October 6th.

Cutthroat (6%; n=11) and rainbow trout (94%; n=54) were observed (Table 41). The mean density of cutthroat trout was 2 fish/100m^2. The mean density of rainbow trout was 11 fish/100m^2. The majority of the fish were observed in reaches 5 (46%; n=30) and 1 (28%; n=18). No rainbow trout were observed in reaches 2 and 4. All fish observed were <201 mm TL. The majority of fish observed were rainbow trout <100 mm TL (74%; n=48).

Table 30. Mean values (± standard deviation) of habitat parameters measured on Flume Creek, 2000.

Reach	n	Wet Width (m)	Bankfull Width (m)	Mean Depth (cm)	Mean Max. Depth (cm)	Gradient (%)	Water Temp. (°C)	No. LP/km	No. LWD/100 m	Dominant Substrate
1	2	4.5 (± 0.8)	7.8 (± 1.8)	10 (± 2)	25 (± 1)	17 (± 4)	7 (± 1)	0	37 (± 9)	Cobble
2	4	3.0 (± 0.9)	4.7 (± 1.4)	10 (± 4)	25 (± 18)	10 (± 3)	8 (± 1)	25 (± 17)	38 (± 9)	Cobble
3	5	5.1 (± 1.6)	29.2 (± 44.1)	10 ± (± 3)	21 (± 5)	3 (± 2)	9 (± 0)	53 (± 30)	21 (± 17)	Cobble
4	2	6.0 (± 1.0)	9.7 (± 1.1)	13 (± 2)	32 (± 4)	3 (± 2)	8 (± 0)	17 (± 24)	22 (± 2)	Cobble
Total	**13**	**4.5 (± 1.6)**	**15.4 (± 28.0)**	**11 (± 3)**	**24 (± 10)**	**7 (± 6)**	**8 (± 1)**	**31 (± 29)**	**29 (± 14)**	**Cobble**

Table 31. Mean width, maximum depth, and residual depth (± standard deviation) and percent occurrence of each habitat type observed on Flume Creek, 2000.

	Riffle Habitat			Pool Habitat				
Reach	**n**	**Width (m)**	**Occurrence (%)**	**n**	**Width (m)**	**Occurrence (%)**	**Mean Max. Depth (cm)**	**Residual Depth (cm)**
1	2	4.5 (± 0.8)	100	0	-	0	-	-
2	3	2.6 (± 0.7)	75	1	4.1 (nc)	25	52 (nc)	16 (nc)
3	5	4.9 (± 1.6)	83	1	1.0 (nc)	17	22 (nc)	20 (nc)
4	2	6.0 (± 1.0)	100	0	-	0	-	-
Total	**12**	**4.5 (± 1.6)**	**86**	**2**	**2.6 (± 2.2)**	**14**	**37 (± 21)**	**18 (± 3)**

nc=not calculable.

Table 32. The number of fish of each species observed during snorkel surveys of Flume Creek, and their estimated densities (#/100m^2; ± standard deviation).

	<100 mm		100-200 mm		201-300 mm		>300 mm		Total	
Reach	**n**	**Density**	**n**	**Density**	**n**	**Density**	**n**	**Density**	**n**	**Density**
1										
No Fish										
2										
E. brook trout	10	3 (± 4)	3	1 (± 1)	0	0	0	0	13	4 (± 3)
3										
E. brook trout	120	17 (± 20)	25	3 (± 1)	5	1 (± 1)	1	<1 (± 0)	151	20 (± 21)
4										
E. brook trout	0	0	1	<1 (± 0)	0	0	0	0	1	<1 (± 0)
Total										
E. brook trout	130	7 (± 14)	29	1 (± 2)	5	<1 (± 0)	1	<1 (± 0)	165	9 (± 15)

Table 33. Mean values (± standard deviation) of habitat parameters measured on Lime Creek, 2000.

Reach	n	Wet Width (m)	Bankfull Width (m)	Mean Depth (cm)	Mean Max. Depth (cm)	Gradient (%)	Water Temp. (°C)	No. LP/km	No. LWD/100 m	Dominant Substrate
1	2	6.2 (± 0.6)	9.6 (± 1.1)	17 (± 1)	48 (± 11)	9 (± 5)	8 (± 0)	150 (± 71)	35 (± 26)	Gravel
2	2	2.7 (± 0.3)	5.6 (± 2.7)	8 (± 2)	14 (± 6)	5 (± 3)	9 (± 1)	0	47 (± 19)	Gravel
3	2	4.4 (± 0.1)	10.5 (± 3.0)	10 (± 1)	21 (± 2)	5 (± 1)	8 (± 0)	83 (± 24)	60 (± 19)	Cobble
4	2	2.4 (± 0.4)	3.4 (± 0.4)	15 (± 2)	29 (± 1)	7 (± 2)	7 (± 0)	67 (± 47)	50 (± 9)	Gravel
Total	**8**	**3.9 (± 1.6)**	**7.3 (± 3.5)**	**13 (± 4)**	**28 (± 14)**	**6 (± 3)**	**8 (± 1)**	**75 (± 66)**	**48 (± 17)**	**Gravel**

Table 34. Mean width, maximum depth, and residual depth (± standard deviation) and percent occurrence of each habitat type observed on Lime Creek, 2000.

	Riffle Habitat			Pool Habitat				
Reach	**n**	**Width (m)**	**Occurrence (%)**	**n**	**Width (m)**	**Occurrence (%)**	**Mean Max. Depth (cm)**	**Residual Depth (cm)**
1	1	1.3 (nc)	33	2	5.6 (± 1.5)	67	48 (± 11)	28 (± 6)
2	2	2.7 (±0.3)	100	0	-	0	-	-
3	2	4.4 (±0.1)	100	0	-	0	-	-
4	0	(±)	0	2	2.4 (± 0.4)	100	29 (± 1)	21 (± 1)
Total	**5**	**3.1 (±1.3)**	**60**	**4**	**4.0 (± 2.0)**	**30**	**38 (± 13)**	**24 (± 5)**

nc=not calculable.

Table 35. The number of fish of each species observed during snorkel surveys of Lime Creek, and their estimated densities (#/100m^2; ± standard deviation).

	<100 mm		100-200 mm		201-300 mm		>300 mm		Total	
Reach	**n**	**Density**	**n**	**Density**	**n**	**Density**	**n**	**Density**	**n**	**Density**
1										
No Fish										
2										
E. brook trout	6	4 (± 0)	2	1 (± 2)	2	1 (± 0)	0	0	10	6 (± 2)
3										
E. brook trout	8	3 (± 2)	6	2 (± 0)	0	0	0	0	14	5 (± 2)
4										
E. brook trout	5	3 (± 2)	3	2 (± 1)	3	2 (± 1)	0	0	11	7 (± 3)
Total										
E. brook trout	19	2 (± 2)	11	1 (± 1)	5	1 (± 1)	0	0	35	5 (± 3)

Table 36. Mean values (± standard deviation) of habitat parameters measured on Pewee Creek, 2000.

Reach	n	Wet Width (m)	Bankfull Width (m)	Mean Depth (cm)	Mean Max. Depth (cm)	Gradient (%)	Water Temp. (°C)	No. LP/km	No. LWD/100 m	Dominant Substrate
1	2	2.0 (± 0.8)	7.6 (± 7.0)	18 (± 8)	35 (± 12)	9 (± 4)	6 (± 0)	50 (± 71)	25 (± 16)	Cobble
2	2	3.0 (± 0.7)	9.3 (± 8.0)	12 (± 1)	25 (± 4)	6 (± 1)	6 (± 0)	33 (± 47)	23 (± 14)	Boulder
3	2	3.4 (± 2.6)	6.0 (± 1.0)	6 (± 2)	18 (± 3)	8 (± 0)	6 (± 0)	0	13 (± 5)	Rubble
Total	**6**	**2.8 (± 1.4)**	**7.6 (± 5.0)**	**12 (± 6)**	**26 (± 9)**	**8 (± 2)**	**6 (± 0)**	**28 (± 44)**	**21 (± 11)**	**Rubble**

Table 37. Mean width, maximum depth, and residual depth (± standard deviation) and percent occurrence of each habitat type observed on Pewee Creek, 2000.

	Riffle Habitat			Pool Habitat				
Reach	**n**	**Width (m)**	**Occurrence (%)**	**n**	**Width (m)**	**Occurrence (%)**	**Mean Max. Depth (cm)**	**Residual Depth (cm)**
1	1	1.4 (nc)	50	1	2.6 (nc)	50	43 (nc)	10 (nc)
2	2	3.0 (± 0.7)	100	0	-	0	-	-
3	2	3.4 (± 2.6)	100	0	-	0	-	-
Total	**5**	**2.8 (± 1.6)**	**83**	**1**	**2.6 (nc)**	**17**	**43 (nc)**	**10 (nc)**

nc=not calculable.

Table 38. The number of fish of each species observed during snorkel surveys of Pewee Creek, and their estimated densities (#/100m^2; ± standard deviation).

	<100 mm		100-200 mm		201-300 mm		>300 mm		Total	
Reach	**n**	**Density**	**n**	**Density**	**n**	**Density**	**n**	**Density**	**n**	**Density**
1										
Cutthroat trout	0	0	1	1 (± 2)	0	0	0	0	1	1 (± 2)
E. brook trout	0	0	1	1 (± 1)	0	0	0	0	1	1 (± 1)
2										
E. brook trout	1	1 (± 2)	0	0	0	0	0	0	1	1 (± 2)
3										
Cutthroat trout	0	0	1	1 (± 1)	0	0	0	0	1	1 (± 1)
E. brook trout	0	0	1	<1 (± 1)	0	0	0	0	1	<1 (± 1)
Total										
Cutthroat trout	0	0	2	1 (± 1)	0	0	0	0	2	1 (± 1)
E. brook trout	1	<1 (± 1)	2	<1 (± 1)	0	0	0	0	3	1 (± 1)

Table 39. Mean values (± standard deviation) of habitat parameters measured on Sand Creek, 2000.

Reach	n	Wet Width (m)	Bankfull Width (m)	Mean Depth (cm)	Mean Max. Depth (cm)	Gradient (%)	Water Temp. (°C)	No. LP/km	No. LWD/100 m	Dominant Substrate
1	3	1.4 (± 0.5)	3.6 (± 1.4)	10 (± 7)	22 (± 19)	6 (± 5)	9 (± 1)	44 (± 51)	31 (± 7)	Boulder
2	2	3.0 (± 0.9)	6.7 (± 0.7)	12 (± 2)	28 (± 12)	7 (± 4)	9 (± 1)	17 (± 24)	20 (± 19)	Sand
3	2	2.7 (± 0.5)	5.4 (± 2.9)	5 (± 4)	15 (± 4)	11 (± 10)	9 (± 0)	83 (± 24)	30 (± 24)	Cobble
4	2	2.1 (± 0.1)	10.5 (± 2.1)	8 (± 2)	16 (± 3)	6 (± 0)	10 (± 1)	33 (± 0)	55 (± 31)	Sand
5	3	1.7 (± 0.9)	6.5 (± 2.7)	7 (± 3)	19 (± 13)	6 (± 1)	10 (± 1)	56 (± 51)	43 (± 30)	Cobble
Total	**12**	**2.1 (± 0.8)**	**6.3 (± 2.9)**	**8 (± 4)**	**20 (± 11)**	**7 (± 4)**	**10 (± 1)**	**47 (± 39)**	**36 (± 22)**	**Sand**

Table 40. Mean width, maximum depth, and residual depth (± standard deviation) and percent occurrence of each habitat type observed on Sand Creek, 2000.

	Riffle Habitat			Pool Habitat				
Reach	**n**	**Width (m)**	**Occurrence (%)**	**n**	**Width (m)**	**Occurrence (%)**	**Mean Max. Depth (cm)**	**Residual Depth (cm)**
1	2	1.1 (± 0.1)	67	1	2.0 (nc)	33	44 (nc)	24 (nc)
2	1	0.6 (nc)	33	2	2.7 (± 1.3)	67	29 (± 10)	18 (± 2)
3	2	2.7 (± 0.5)	100	0	-	0	-	-
4	2	2.1 (± 0.1)	100	0	-	0	-	-
5	2	1.2 (± 0.3)	67	1	2.7 (nc)	33	33 (nc)	21 (nc)
Total	**9**	**1.6 (± 0.8)**	**69**	**4**	**2.5 (± 0.8)**	**31**	**34 (± 9)**	**20 (± 3)**

nc=not calculable.

Table 41. The number of fish of each species observed during snorkel surveys of Sand Creek, and their estimated densities (#/100m^2; ± standard deviation).

	<100 mm		100-200 mm		201-300 mm		>300 mm		Total	
Reach	**n**	**Density**	**n**	**Density**	**n**	**Density**	**n**	**Density**	**n**	**Density**
1										
Cutthroat trout	0	0	1	1 (± 2)	0	0	0	0	1	1 (± 2)
Rainbow trout	12	11 (± 19)	5	5 (± 6)	0	0	0	0	17	16 (± 25)
2										
Cutthroat trout	1	1 (± 1)	1	<1 (± 1)	0	0	0	0	2	1 (± 0)
3										
Cutthroat trout	0	0	3	2 (± 1)	0	0	0	0	3	2 (± 1)
Rainbow trout	8	4 (± 6)	0	0	0	0	0	0	8	4 (± 6)
4										
Cutthroat trout	3	3 (± 4)	1	1 (± 1)	0	0	0	0	4	3 (± 5)
5										
Cutthroat trout	0	0	1	1 (± 1)	0	0	0	0	1	1 (± 1)
Rainbow trout	24	23 (± 29)	5	4 (± 2)	0	0	0	0	29	27 (± 32)
Total										
Cutthroat trout	4	1 (± 1)	7	1 (± 1)	0	0	0	0	11	2 (± 2)
Rainbow trout	44	9 (± 18)	10	2 (± 3)	0	0	0	0	54	11 (± 21)

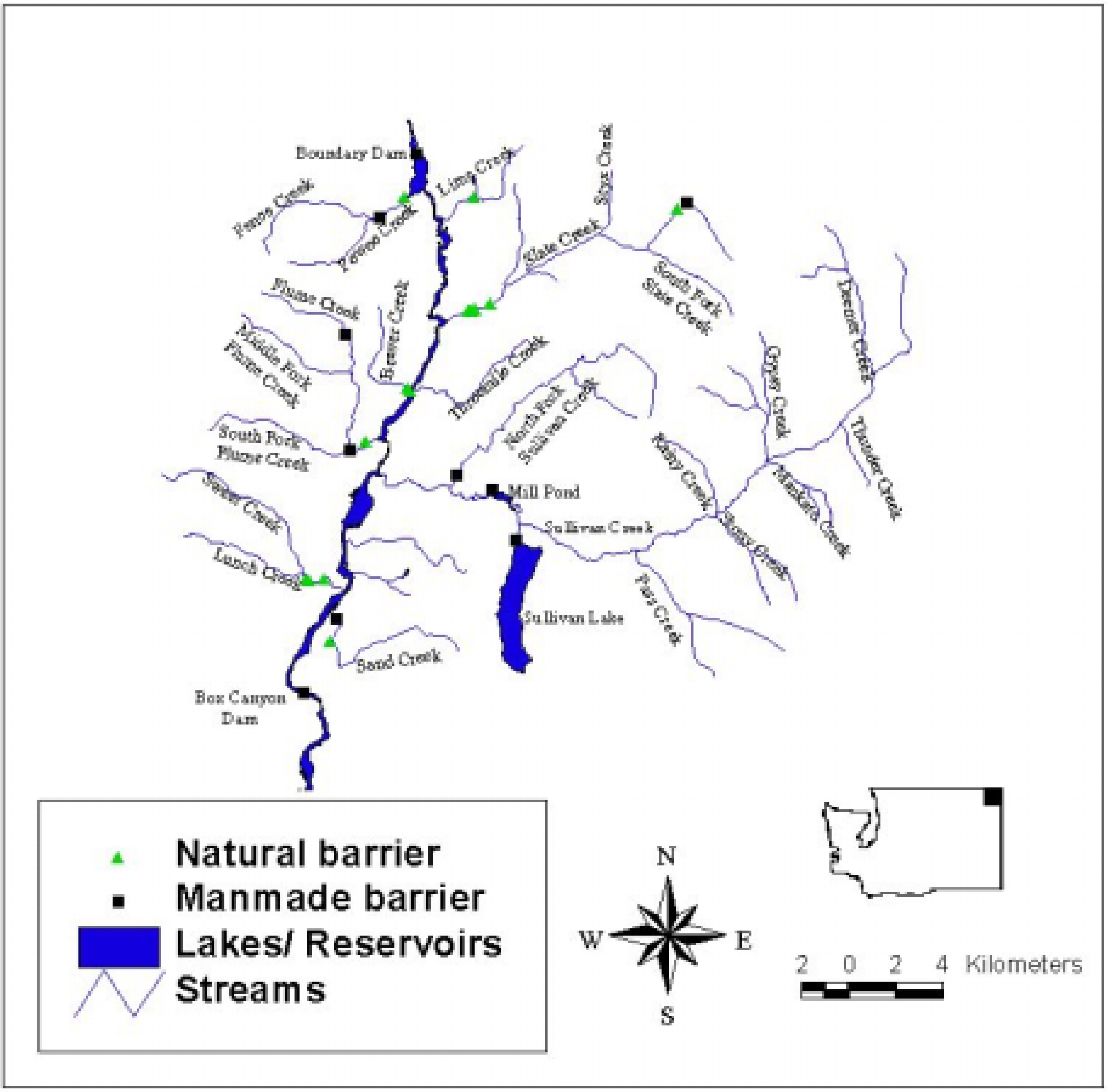

Figure 12. Locations of manmade and natural fish passage barriers, identified during surveys in 2000. Latitude and longitude coordinates provided in Appendix H.

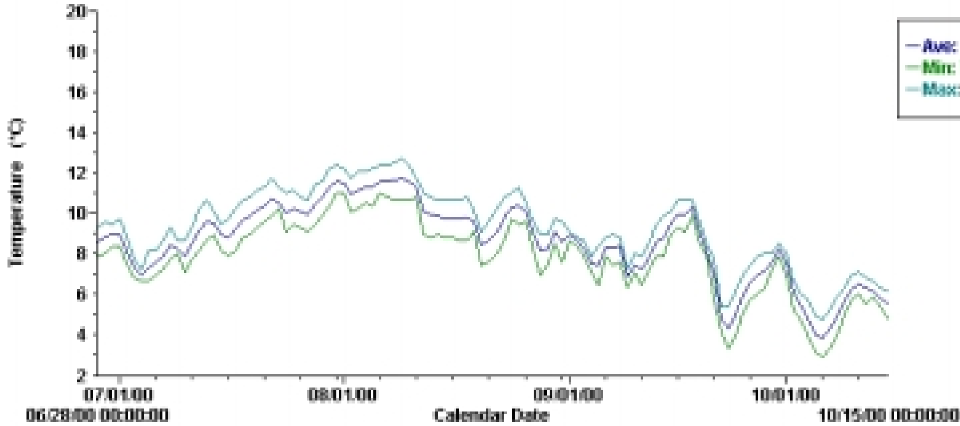

Figure 13. Mean, maximum, and minimum daily temperatures recorded on upper Flume Creek.

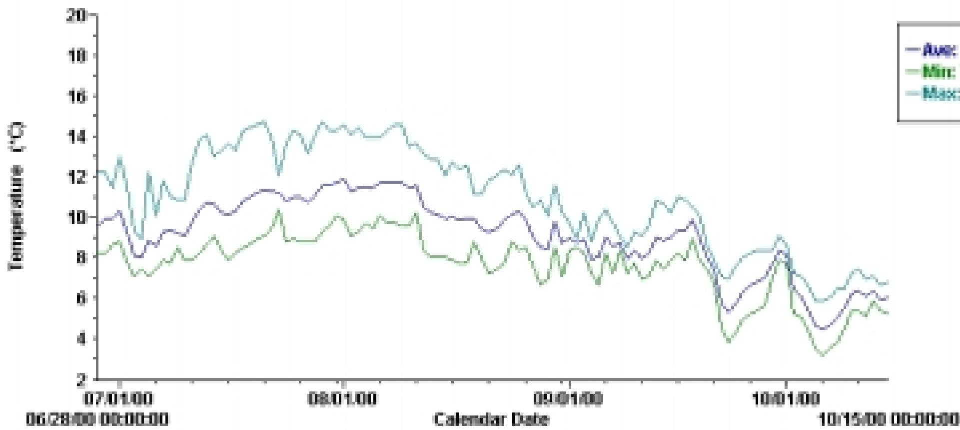

Figure 14. Mean, maximum, and minimum daily temperatures recorded on lower Flume Creek.

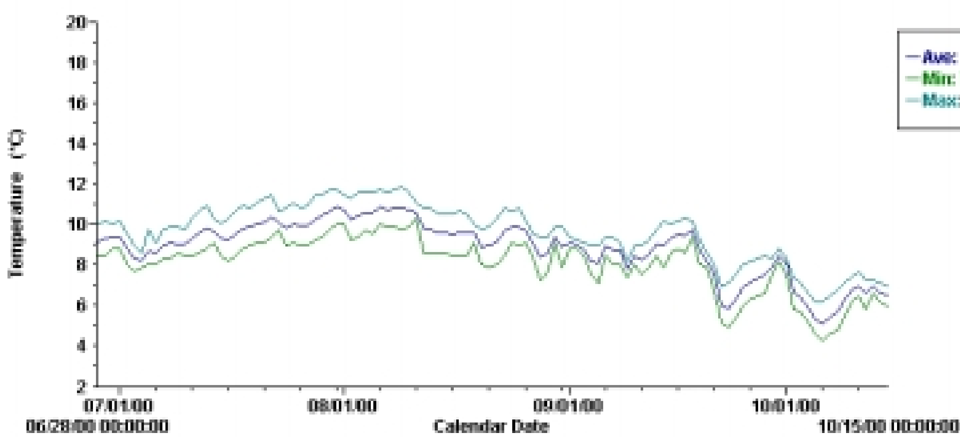

Figure 15. Mean, maximum, and minimum daily temperatures recorded on Lime Creek.

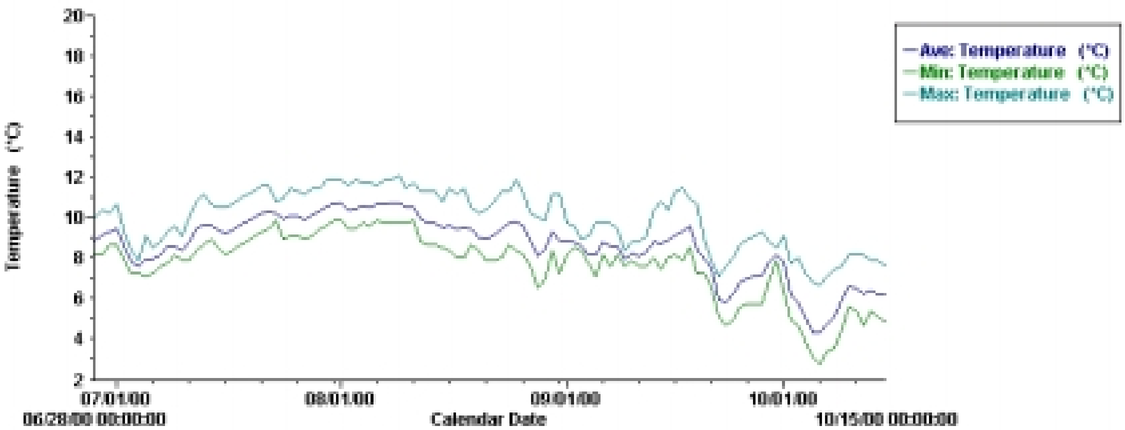

Figure 16. Mean, maximum, and minimum daily temperatures recorded on Pewee Creek.

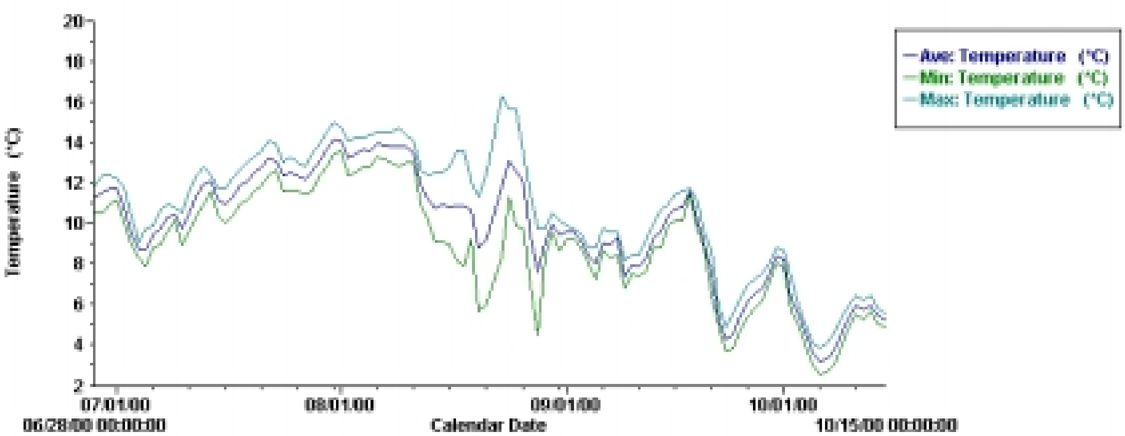

Figure 17. Mean, maximum, and minimum daily temperatures recorded on Sand Creek.

Slate Creek

Slate Creek was divided into 9 sampling reaches (Figure 4; Appendix G). A total of 24 sites were surveyed (Appendix H). Habitat sampling was conducted between July 6th through July 20th and fish sampling occurred between July 31st and August 2nd. The mean of each habitat parameter was calculated for each reach and the entire stream (Table 42). The dominant substrate was cobble (Table 42) and riffles were the dominant habitat type (58%; Table 43). The mean composition (%) of each substrate type, as well as substrate embeddedness, was calculated for each reach and the stream (Table 44). The discharge of Slate Creek on July 31st was 0.31 m^3/sec.

Moving in an upstream direction, there were a series of four waterfalls and a chute on Slate Creek that were considered fish barriers (Figure 12; Appendix I). They were located near the break between reaches 8 and 9. The first waterfall was the largest with a vertical height of 6.0 m. The second waterfall was approximately 4.0 m tall. The third waterfall was 5.0 m high and the stream narrowed to 1 m before plunging through a crack in the bedrock. The water plunged through the crack, away from the concave face of the cliff. The fourth waterfall was 2.8 m high. The final barrier in this 800 m stretch of Slate Creek was a chute. The chute was 30 m long, 2 m wide, and had a gradient of 38% with uninterrupted flow.

There were two additional fish migration barriers identified on Slate Creek (Figure 12; Appendix H). The first was a waterfall/chute located approximately 400 m upstream from the State Highway 31 bridge. Facing upstream, there was a 3.0 m waterfall on the right side and a chute that was 10 m long, 1 m wide, and had a gradient of 24% on the left side. The most upstream barrier on the creek was a chute (27.5 m long, 1 m wide, 18% gradient) located 300 m downstream from the USFS Road #209 crossing.

The temperature of upper Slate Creek was measured 1,231 times with the thermograph, between July 7th and October 17th. Daily average, maximum, and minimum temperatures were determined (Figure 18). Mean temperature (± standard deviation) was 5.93 (± 1.89) °C with a maximum of 9.46 °C on July 31st and a minimum of 1.54 °C on October 6th.

The temperature of lower Slate Creek was measured 1,339 times with the thermograph, between June 28th and October 17th. Daily average, maximum, and minimum temperatures were determined (Figure 19). Mean temperature (± standard deviation) was 9.00 (± 2.29) °C with a maximum of 13.34 °C on August 8^{th} and 9^{th}, and a minimum of 2.80 °C on October 6^{th}.

Three fish species were observed in Slate Creek; cutthroat trout (85%; n=130), eastern brook trout (14%; n=25), and rainbow trout (1%; n=2; Table 45). The mean density of cutthroat trout was 4 fish/100m^2. The mean density of brook trout was 1 fish/100m^2. The mean density of rainbow trout was <1 fish/100m^2. Cutthroat trout were observed in all reaches, except reach 1 where no fish of any species were observed. Brook trout were in reaches 4 through 7. Rainbow trout were only observed in reach 9, which was below a waterfall assumed to be a fish migration barrier. The majority of fish observed were 100-200 mm TL (56%; n=99).

Table 42. Mean values (± standard deviation) of habitat parameters measured on Slate Creek, 2000.

Reach	n	Wet Width (m)	Bankfull Width (m)	Mean Depth (cm)	Mean Max. Depth (cm)	Gradient (%)	Water Temp. (°C)	No. LP/km	No. LWD/100 m	Dominant Substrate
1	17	3.4 (± 0.9)	5.2 (± 2.4)	17 (± 8)	32 (± 16)	9 (± 3)	6 (± 1)	58 (± 23)	36 (± 12)	Cobble
2	14	3.6 (± 0.9)	5.9 (± 3.0)	18 (± 9)	38 (± 25)	9 (± 3)	7 (± 0)	56 (± 22)	39 (± 12)	Gravel
3	11	5.9 (± 1.9)	10.3 (± 5.8)	13 (± 5)	34 (± 9)	7 (± 2)	8 (± 0)	80 (± 24)	42 (± 10)	Cobble
4	12	6.1 (± 2.2)	12.0 (± 4.2)	18 (± 5)	35 (± 11)	6 (± 3)	10 (± 1)	59 (± 19)	49 (± 9)	Cobble
5	42	5.4 (± 1.8)	10.9 (± 6.6)	22 (± 8)	46 (± 18)	6 (± 2)	10 (± 1)	61 (± 17)	37 (± 11)	Cobble
6	13	6.4 (± 2.2)	9.6 (± 4.1)	22 (± 8)	47 (± 12)	6 (± 3)	10 (± 1)	67 (± 25)	46 (± 18)	Cobble
7	9	6.4 (± 1.9)	12.4 (± 3.6)	27 (± 9)	53 (± 20)	5 (± 3)	11 (± 1)	86 (± 20)	52 (± 12)	Cobble
8	11	7.9 (± 2.7)	11.8 (± 4.0)	28 (± 14)	60 (± 25)	7 (± 3)	10 (± 0)	42 (± 10)	25 (± 12)	Boulder
9	13	6.0 (± 1.7)	9.6 (± 3.7)	25 (± 12)	47 (± 22)	7 (± 5)	11 (± 1)	35 (± 14)	25 (± 22)	Boulder
Total	**142**	**5.5 (± 2.1)**	**9.7 (± 5.3)**	**21 (± 10)**	**44 (± 20)**	**7 (± 3)**	**9 (± 2)**	**60 (± 23)**	**38 (± 15)**	**Cobble**

Table 43. Mean width, maximum depth, and residual depth (± standard deviation) and percent occurrence of each habitat type observed on Slate Creek, 2000.

	Riffle Habitat			Pool Habitat				
Reach	**n**	**Width (m)**	**Occurrence (%)**	**n**	**Width (m)**	**Occurrence (%)**	**Mean Max. Depth (cm)**	**Residual Depth (cm)**
1	11	2.5 (± 1.4)	48	12	2.5 (± 1.3)	52	40 (± 16)	27 (± 10)
2	10	2.8 (± 1.6)	59	7	3.2 (± 1.1)	41	55 (± 27)	33 (± 15)
3	11	5.4 (± 1.5)	79	3	1.9 (± 1.8)	21	40 (± 11)	32 (± 10)
4	12	3.8 (± 2.2)	60	8	3.5 (± 1.8)	40	49 (± 10)	31 (± 6)
5	34	3.7 (± 1.9)	54	29	3.5 (± 2.1)	46	53 (± 22)	35 (± 13)
6	12	5.0 (± 1.8)	60	8	3.0 (± 3.0)	40	50 (± 12)	34 (± 9)
7	6	4.8 (± 2.1)	55	5	5.9 (± 2.0)	45	64 (± 21)	42 (± 11)
8	8	7.0 (3.4)	57	6	5.2 (± 3.4)	43	62 (± 28)	42 (± 20)
9	13	4.1 (2.0)	68	6	3.5 (± 1.5)	32	53 (± 28)	37 (± 19)
Total	**117**	**4.1 (± 2.2)**	**58**	**84**	**3.5 (± 2.2)**	**42**	**52 (± 21)**	**34 (± 13)**

Table 44. Mean substrate embeddedness and percent composition of each substrate type (± standard deviation) observed on Slate Creek, 2000.

			Mean Composition (%) of Each Substrate Type						
Reach	**n**	**Embeddedness (%)**	Silt	**Sand**	**Gravel**	**Cobble**	**Rubble**	**Boulder**	**Bedrock**
1	17	4 (± 13)	0	11 (± 28)	20 (± 17)	60 (± 25)	1 (± 3)	5 (± 14)	3 (± 12)
2	14	1 (± 3)	0	4 (± 10)	52 (± 25)	29 (± 25)	3 (± 6)	12 (± 16)	0
3	11	2 (± 4)	0	2 (± 4)	27 (± 20)	46 (± 22)	6 (± 8)	17 (± 22)	0
4	12	7 (± 10)	8 (± 24)	13 (± 20)	28 (± 15)	42 (± 26)	3 (± 4)	7 (± 15)	0
5	42	4 (± 7)	2 (± 13)	11 (± 23)	31 (± 25)	41 (± 28)	6 (± 10)	7 (± 15)	1 (± 10)
6	13	11 (± 14)	0	20 (± 29)	32 (± 27)	35 (± 28)	8 (± 13)	6 (± 8)	0
7	9	12 (± 11)	1 (± 5)	20 (± 22)	24 (± 20)	44 (± 25)	9 (± 10)	2 (± 3)	0
8	11	3 (± 6)	1 (± 3)	5 (± 16)	18 (± 28)	17 (± 17)	18 (± 17)	26 (± 26)	14 (± 34)
9	13	4 (± 11)	<1 (± 1)	3 (± 8)	14 (± 22)	16 (± 15)	15 (± 20)	38 (± 31)	12 (± 27)
Total	**142**	**5 (± 10)**	**2 (± 10)**	**10 (± 21)**	**28 (± 24)**	**38 (± 27)**	**7 (± 12)**	**12 (± 20)**	**3 (± 15)**

Table 45. The number of fish of each species observed during snorkel surveys of Slate Creek, and their estimated densities (#/100m^2; ± standard deviation).

	<100 mm		100-200 mm		201-300 mm		>300 mm		Total	
Reach	**n**	**Density**	**n**	**Density**	**n**	**Density**	**n**	**Density**	**n**	**Density**
1										
No Fish										
2										
Cutthroat trout	1	<1 (± 1)	10	5 (± 1)	4	2 (± 0)	0	0	15	7 (± 0)
3										
Cutthroat trout	2	<1 (± 0)	18	4 (± 3)	2	<1 (± 0)	0	0	22	5 (± 3)
4										
Cutthroat trout	0	0	4	1 (± 1)	0	0	0	0	4	1 (± 1)
E. brook trout	1	<1 (± 1)	0	0	0	0	0	0	1	<1 (± 1)
5										
Cutthroat trout	6	<1 (± 0)	20	2 (± 3)	5	<1 (± 1)	3	<1 (± 0)	34	3 (± 4)
E. brook trout	0	0	12	1 (± 1)	6	1 (± 1)	0	0	18	2 (± 2)
6										
Cutthroat trout	2	1 (± 0)	6	2 (± 0)	7	2 (± 1)	0	0	15	4 (± 1)
E. brook trout	0	0	2	1 (± 0)	1	<1 (± <1)	0	0	3	1 (± 0)
7										
Cutthroat trout	1	<1 (± 0)	10	3 (± 3)	11	3 (± 2)	3	1 (± 1)	25	8 (± 5)
E. brook trout	1	<1 (± 1)	1	<1 (± 1)	1	<1 (± 1)	0	0	3	1 (± 2)
8										
Cutthroat trout	0	0	1	<1 (± 0)	0	0	0	0	1	<1 (± 0)
9										
Cutthroat trout	5	1 (± 1)	13	2 (± 1)	13	2 (± 1)	3	<1 (± 0)	34	5 (± 1)
Rainbow trout	0	0	2	1 (± 1)	0	0	0	0	2	1 (± 1)
Total										
Cutthroat trout	17	<1 (± 0)	82	2 (± 2)	42	1 (± 1)	9	<1 (± 0)	150	4 (± 3)
E. brook trout	2	<1 (± 0)	15	<1 (± 1)	8	<1 (± 1)	0	0	25	1 (± 2)
Rainbow trout	0	0	2	1 (± 1)	0	0	0	0	2	<1 (± 0)

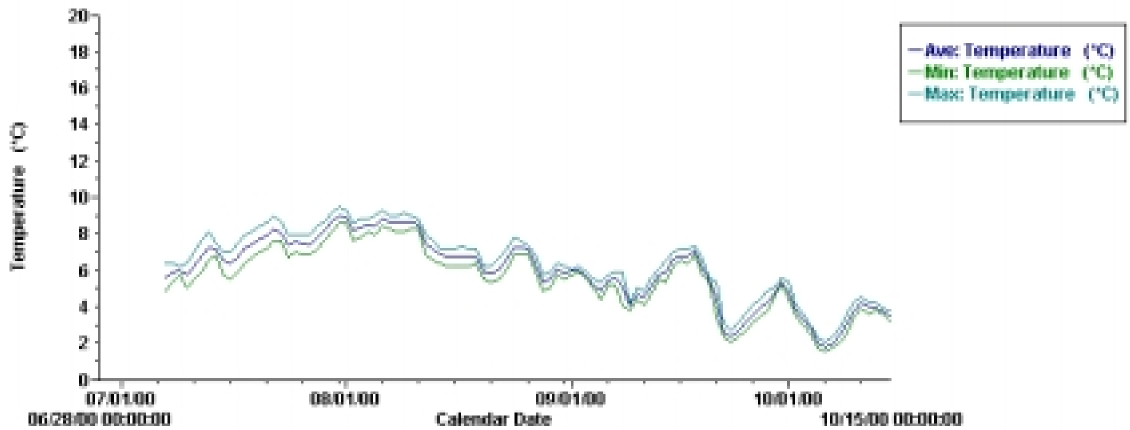

Figure 18. Mean, maximum, and minimum daily temperatures recorded on upper Slate Creek.

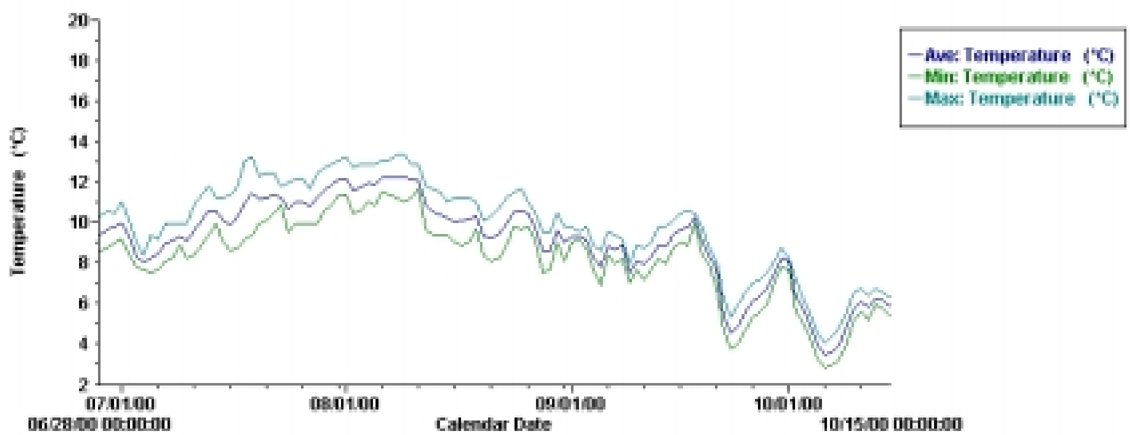

Figure 19. Mean, maximum, and minimum daily temperatures recorded on lower Slate Creek.

Sullivan Creek

Sullivan Creek was divided into 20 reaches that were sampled between August 7th and August 16th (Figure 4; Appendix G). A total of 55 sites were surveyed (Appendix H). The mean of each habitat parameter was calculated for each reach and the entire stream (Table 46). The dominant substrate in Sullivan Creek was rubble (Table 46) and riffles were the dominant habitat type (69%; Table 47). The discharge of upper Sullivan Creek, measured just upstream of the confluence with Outlet Creek, was 1.17 m^3/sec on August 16th. The discharge of lower Sullivan Creek, measured near the mouth on August 16th, was 2.20 m^3/sec.

The only barrier on Sullivan Creek was the Mill Pond Dam, which divided sampling reaches 17 and 18 (Figure 12; Appendix I). Reaches 1 through 17 were upstream of the Mill Pond. Reaches 18, 19, and 20 were downstream of the Mill Pond Dam. There was also a dam at the outlet of Sullivan Lake, which prevented fish movements between Sullivan Lake and Sullivan Creek above the Mill Pond, via Outlet Creek (Figure 12; Appendix H).

The temperature of upper Sullivan Creek was measured 763 times with the thermograph, between August 17th and October 19th. Daily average, maximum, and minimum temperatures were determined (Figure 20). Mean temperature was 5.83 (± 2.22) °C with a maximum of 10.56 °C on August 25th and a minimum of 1.02 °C on October 6th.

The temperature of middle Sullivan Creek was measured 1,363 times with the thermograph, between June 28th and October 19th. Daily average, maximum, and minimum temperatures were determined (Figure 21). Mean temperature was 8.92 (± 2.63) °C with a maximum of 14.60 °C on August 9th and a minimum was 2.45 °C on October 6th.

The temperature of lower Sullivan Creek was measured 1,363 times with the thermograph, between June 28th and October 19th. Daily average, maximum, and minimum temperatures were determined (Figure 22). Mean temperature was 13.10 (± 2.53) °C with a maximum of 18.86 °C on August 9th and a minimum of 4.93 °C on September 23rd.

Seven species of fish were observed in Sullivan Creek; cutthroat trout (37%; n=154), eastern brook trout (14%; n=57), rainbow trout (26%; n=119), brown trout (2%; n=9), largescale suckers (9%; n=39), mountain whitefish (11%; n=48), and sculpins (1%; n=4; Table 48). The mean density of cutthroat trout was 1 fish/100m^2 (Table 49). The mean densities of brook trout, rainbow trout, brown trout, largescale suckers, mountain whitefish, and sculpins were <1 fish/100m^2 (Table 49). All species of fish were observed above and below the Mill Pond Dam, except largescale suckers and eastern brook trout (Tables 48 and 49). Largescale suckers were only found in lower Sullivan Creek near the confluence with the Pend Oreille River (reach 20) and brook trout were only observed upstream of the Mill Pond Dam. Fish were observed in all reaches sampled. Cutthroat trout were present from the lowest to the uppermost reaches. Brook trout were observed from the lowest reach above the Mill Pond (reach 17) upstream to reach 2. Rainbow trout were observed as far upstream as reach 8. Brown trout, mountain whitefish, and sculpin were usually observed in reaches just upstream of the larger water bodies of the Mill Pond and Pend Oreille River. The majority of the cutthroat trout (52%; n=80), brook trout (63%; n=36), rainbow trout (52%; n=56), and mountain whitefish (56%; n=27) were 100-200 mm TL. The majority (67%; n=6) of the brown trout were <200 mm TL, but three brown trout observed near the confluence with Outlet Creek were >500 mm TL. Most of the largescale suckers (90%; n=35) and sculpins (75%; n=3) were <100 mm TL.

Table 46. Mean values (± standard deviation) of habitat parameters measured on Sullivan Creek, 2000.

Reach	n	Wet Width (m)	Bankfull Width (m)	Mean Depth (cm)	Mean Max. Depth (cm)	Gradient (%)	Water Temp. (°C)	No. LP/km	No. LWD/100 m	Dominant Substrate
1	3	4.8 (± 1.4)	8.3 (± 2.0)	12 (± 5)	35 (± 15)	7 (± 3)	9 (± 1)	78 (± 19)	21 (± 7)	Boulder
2	2	5.7 (± 2.3)	9.5 (± 2.0)	11 (± 3)	23 (± 8)	9 (± 9)	8 (± 1)	33 (± 0)	20 (± 5)	Cobble
3	4	5.5 (± 1.8)	10.7 (± 2.8)	18 (± 10)	39 (± 22)	2 (± 2)	9 (± 1)	50 (± 33)	17 (± 24)	Cobble
4	5	7.2 (± 2.1)	12.1 (± 3.0)	21 (± 11)	44 (± 14)	6 (± 1)	9 (± 0)	27 (± 15)	13 (± 7)	Boulder
5	2	7.7 (± 1.2)	19.7 (± 0.6)	19 (± 5)	41 (± 8)	3 (± 1)	9 (± 0)	33 (± 47)	18 (± 7)	Cobble
6	2	9.6 (± 3.6)	31.9 (± 19.4)	18 (± 5)	38 (± 6)	1 (± 0)	12 (± 1)	67 (± 47)	40 (± 24)	Cobble
7	3	7.7 (± 2.2)	19.3 (± 3.2)	26 (± 7)	58 (± 12)	2 (± 0)	12 (± 1)	44 (± 19)	20 (± 7)	Cobble
8	2	9.0 (± 0.7)	15.9 (± 3.1)	28 (± 1)	84 (± 51)	2 (± 0)	10 (± 0)	17 (± 24)	15 (± 12)	Rubble
9	2	10.4 (± 1.5)	15.5 (± 2.3)	24 (± 1)	37 (± 16)	1 (± 0)	9 (± 0)	17 (± 24)	8 (± 2)	Cobble
10	3	9.2 (± 3.1)	22.6 (± 5.7)	28 (± 7)	63 (± 10)	3 (± 1)	9 (± 0)	22 (± 38)	17 (± 6)	Rubble
11	2	9.7 (± 0.2)	16.3 (± 0.1)	25 (± 6)	56 (± 6)	3 (± 1)	13 (± 0)	17 (± 24)	5 (± 2)	Rubble
12	2	11.3 (± 2.1)	23.4 (± 6.3)	24 (± 1)	56 (± 6)	3 (± 2)	11 (± 0)	0	12 (± 2)	Rubble
13	2	12.7 (± 1.2)	14.4 (± 3.1)	25 (± 5)	49 (± 16)	1 (± 0)	11 (± 0)	33 (± 47)	7 (± 5)	Cobble
14	7	10.4 (± 1.8)	30.0 (± 10.9)	31 (± 10)	61 (± 14)	1 (± 0)	13 (± 2)	20 (± 18)	12 (± 9)	Rubble
15	2	12.6 (± 4.6)	19.3 (± 3.3)	29 (± 11)	47 (± 13)	1 (± 0)	14 (± 1)	0	10 (± 0)	Rubble
16	2	10.9 (± 4.7)	33.8 (± 2.1)	26 (± 1)	44 (± 3)	2 (± 1)	14 (± 1)	0	8 (± 2)	Rubble
17	3	15.1 (± 4.3)	28.2 (± 11.9)	28 (± 5)	58 (± 11)	1 (± 0)	13 (± 1)	0	13 (± 12)	Rubble
18	4	17.3 (± 2.7)	22.3 (± 1.1)	32 (± 9)	63 (± 10)	2 (± 1)	17 (± 1)	17 (± 19)	8 (± 6)	Rubble
19	3	14.4 (± 2.9)	17.6 (± 4.4)	40 (± 9)	138 (± 98)	4 (± 0)	18 (± 1)	33 (± 0)	3 (± 0)	Boulder
20	2	22.1 (± 8.8)	35.9 (± 19.1)	32 (± 1)	53 (± 7)	1 (± 0)	18 (± 1)	0	2 (± 2)	Rubble
Total	**55**	**10.5 (± 4.8)**	**20.0 (± 9.8)**	**25 (± 9)**	**55 (± 32)**	**3 (± 3)**	**12 (± 3)**	**27 (± 28)**	**13 (± 11)**	**Rubble**

Table 47. Mean width, maximum depth, and residual depth (± standard deviation) and percent occurrence of each habitat type observed on Sullivan Creek, 2000.

	Riffle Habitat			Pool Habitat				
Reach	**n**	**Width (m)**	**Occurrence (%)**	**n**	**Width (m)**	**Occurrence (%)**	**Mean Max. Depth (cm)**	**Residual Depth (cm)**
1	1	6.1 (nc)	33	2	4.2 (± 1.3)	67	44 (± 1)	30 (± 1)
2	2	4.8 (± 3.6)	67	1	1.9 (nc)	33	34 (nc)	22 (nc)
3	3	5.8 (± 2.0)	75	1	4.7 (nc)	25	71 (nc)	58 (nc)
4	3	8.1 (± 2.0)	60	2	5.8 (± 1.8)	40	58 (± 6)	39 (± 4)
5	2	7.7 (± 1.2)	100	0	-	0	-	-
6	1	12.1 (nc)	50	1	7.0 (nc)	50	75 (nc)	51 (nc)
7	1	7.0 (nc)	33	2	8.1 (± 3.0)	67	89 (± 16)	56 (± 8)
8	1	9.5 (nc)	50	1	8.5 (nc)	50	120 (nc)	79 (nc)
9	2	9.0 (± 0.5)	67	1	2.8 (nc)	33	63 (nc)	44 (nc)
10	2	7.2 (± 5.7)	50	2	6.6 (± 5.8)	50	69 (± 2)	52 (± 2)
11	2	9.7 (± 0.2)	100	0	-	0	-	-
12	2	11.3 (± 2.1)	100	0	-	0	-	-
13	1	13.5 (nc)	50	1	11.8 (nc)	50	88 (nc)	54 (nc)
14	4	11.0 (± 1.5)	80	1	8.1 (nc)	20	95 (nc)	78 (nc)
15	2	12.6 (± 4.6)	100	0	-	0	-	-
16	2	10.9 (± 4.7)	100	0	-	0	-	-
17	4	10.4 (± 4.4)	80	1	3.6 (nc)	20	68 (nc)	50 (nc)
18	4	10.6 (± 9.2)	67	2	13.4 (± 1.3)	33	72 (± 1)	52 (± 3)
19	2	13.0 (± 2.1)	67	1	17.2 (nc)	33	250 (nc)	149 (nc)
20	2	22.1 (± 8.8)	100	0	-	0	-	-
Total	**43**	**10.1 (± 5.0)**	**69**	**19**	**7.5 (± 4.3)**	**31**	**80 (± 46)**	**55 (± 27)**

Table 48. Relative abundance (%) of fish collected in Sullivan Creek. Lower Sullivan Creek was the section of stream between the mouth and the Mill Pond Dam (Reaches 18, 19, and 20). Upper Sullivan Creek was the section of stream between the Mill Pond and the headwaters (Reaches 1 through 17).

Species	Lower Sullivan Creek		Upper Sullivan Creek		Total	
	n	**Relative Abundance (%n)**	**n**	**Relative Abundance (%n)**	**n**	**Relative Abundance (%n)**
Cutthroat trout	2	1	152	61	154	37
E. brook trout	0	0	57	23	57	14
Rainbow trout	81	48	27	11	108	26
Brown trout	5	3	4	2	9	2
Largescale sucker	39	23	0	0	39	9
Mountain whitefish	39	23	9	4	48	11
Sculpin spp.	2	1	2	1	4	1
Total	168	100	251	100	419	100

Table 49. The number of fish of each species observed during snorkel surveys of Sullivan Creek, and their estimated densities (#/100m^2; ± standard deviation).

	<100 mm		100-200 mm		201-300 mm		>300 mm		Total	
Reach	**n**	**Density**	**n**	**Density**	**n**	**Density**	**n**	**Density**	**n**	**Density**
1										
Cutthroat trout	3	1 (± 1)	11	3 (± 2)	4	1 (± 1)	0	0	18	5 (± 4)
2										
Cutthroat trout	4	1 (± 1)	6	2 (± 1)	2	<1 (± 1)	3	1 (± 1)	15	4 (± 4)
E. brook trout	1	<1 (± 0)	11	3 (± 4)	4	1 (± 1)	1	<1 (± 0)	17	4 (± 5)
3										
Cutthroat trout	7	1 (± 1)	21	3 (± 3)	7	1 (± 1)	0	0	35	5 (± 4)
E. brook trout	0	0	5	1 (± 0)	0	0	0	0	5	1 (± 0)
4										
Cutthroat trout	2	<1 (± 0)	16	2 (± 1)	9	1 (± 0)	1	<1 (± 0)	28	3 (± 1)
5										
Cutthroat trout	1	<1 (± 0)	5	1 (± 1)	1	<1 (± 0)	0	0	7	2 (± 1)
E. brook trout	0	0	4	1 (± 1)	0	0	0	0	4	1 (± 1)
6										
Cutthroat trout	2	<1 (± 0)	4	1 (± 1)	4	1 (± 1)	1	<1 (± 0)	11	2 (± 2)
E. brook trout	4	1 (± 1)	8	2 (± 2)	2	<1 (± 1)	1	<1 (± 0)	15	3 (± 3)
7										
Cutthroat trout	4	<1 (± 0)	7	1 (± 1)	2	<1 (± 0)	0	0	13	2 (± 1)
E. brook trout	3	<1 (± 0)	4	<1 (± 0)	2	<1 (± 0)	0	0	9	1 (± 1)
8										
Rainbow trout	0	0	1	<1 (± 0)	0	0	0	0	1	<1 (± 0)
9										
Rainbow trout	0	0	1	<1 (± 0)	0	0	0	0	1	<1 (± 0)
10										
Cutthroat trout	0	0	0	0	0	0	1	<1 (± 1)	1	<1 (± 1)
E. brook trout	1	<1 (± 0)	1	<1 (± 0)	0	0	0	0	2	<1 (± 0)
Rainbow trout	0	0	2	<1 (± 0)	3	<1 (± 0)	0	0	5	1 (± 1)

Table 48. Continued.

Reach	<100 mm n	<100 mm Density	100-200 mm n	100-200 mm Density	201-300 mm n	201-300 mm Density	>300 mm n	>300 mm Density	Total n	Total Density
11										
Cutthroat trout	3	1 (± 0)	3	1 (± 1)	0	0	0	0	6	1 (± 1)
E. brook trout	1	<1 (± 0)	0	0	0	0	0	0	1	<1 (± 0)
12										
Cutthroat trout	0	0	3	<1 (± 0)	3	<1 (± 0)	0	0	6	1 (± 0)
E. brook trout	0	0	1	<1 (± 0)	0	0	0	0	1	<1 (± 0)
Rainbow trout	0	0	0	0	1	<1 (± 0)	0	0	1	<1 (± 0)
13										
E. brook trout	0	0	1	<1 (± 0)	0	0	0	0	1	<1 (± 0)
Brown trout	0	0	1	<1 (± 0)	0	0	0	0	1	<1 (± 0)
Rainbow trout	0	0	1	<1 (± 0)	0	0	0	0	1	<1 (± 0)
14										
Cutthroat trout	0	0	3	<1 (± 0)	7	<1 (± 0)	0	0	10	1 (± 0)
E. brook trout	0	0	1	<1 (± 0)	0	0	0	0	1	<1 (± 0)
Rainbow trout	1	<1 (± 0)	12	1 (± 1)	3	<1 (± 0)	4	<1 (± 0)	26	1 (± 1)
Sculpin spp.	1	<1 (± 0)	0	0	0	0	0	0	1	<1 (± 0)
15										
Sculpin spp.	1	<1 (± 0)	0	0	0	0	0	0	1	<1 (± 0)
16										
Cutthroat trout	0	0	0	0	2	<1 (± 1)	0	0	2	<1 (± 1)
Brown trout	0	0	0	0	0	0	1	<1 (± 0)	1	<1 (± 0)
17										
E. brook trout	0	0	0	0	0	0	1	<1 (± 0)	1	<1 (± 0)
Rainbow trout	0	0	0	0	1	<1 (± 0)	1	<1 (± 0)	2	<1 (± 0)
Brown trout	0	0	0	0	0	0	2	<1 (± 0)	2	<1 (± 0)
Mountain whitefish	2	<1 (± 0)	0	0	4	<1 (± 0)	3	<1 (± 0)	9	1 (± 1)
18										
Cutthroat trout	0	0	1	<1 (± 0)	0	0	0	0	1	<1 (± 0)
Rainbow trout	1	<1 (± 0)	18	1 (± 0)	3	<1 (± 0)	4	<1 (± 0)	26	1 (± 1)

Table 48. Continued.

	<100 mm		100-200 mm		201-300 mm		>300 mm		Total	
Reach	**n**	**Density**	**n**	**Density**	**n**	**Density**	**n**	**Density**	**n**	**Density**
19										
Cutthroat trout	0	0	0	0	1	<1 (± 0)	0	0	1	<1 (± 0)
Rainbow trout	11	1 (± 1)	12	1 (± 0)	7	1 (± 0)	7	1 (± 0)	37	3 (± 0)
Sculpin spp.	0	0	1	<1 (± 0)	0	0	0	0	1	<1 (± 0)
20										
Rainbow trout	4	<1 (± 0)	9	1 (± 1)	5	<1 (± 0)	0	0	18	1 (± 1)
Brown trout	3	<1 (± 0)	2	<1 (± 0)	0	0	0	0	5	<1 (± 1)
Largescale sucker	35	4 (± 5)	0	0	0	0	4	<1 (± 0)	39	<1 (± 1)
Mountain whitefish	9	1 (± 1)	27	2 (± 2)	2	<1 (± 0)	1	<1 (± 0)	39	3 (± 0)
Sculpin spp.	1	0	0	0	0	0	0	0	1	<1 (± 0)
Total										
Cutthroat trout	26	<1 (± 1)	80	1 (± 1)	42	<1 (± 1)	6	<1 (± 0)	154	1 (± 2)
E. brook trout	10	<1 (± 0)	36	<1 (± 1)	8	<1 (± 0)	3	<1 (± 0)	57	<1 (± 1)
Rainbow trout	17	<1 (± 0)	56	<1 (± 0)	23	<1 (± 0)	12	<1 (± 0)	108	<1 (± 1)
Brown trout	3	<1 (± 0)	3	<1 (± 0)	0	<1 (± 0)	3	<1 (± 0)	9	<1 (± 0)
Largescale sucker	35	<1 (± 1)	0	0	0	0	4	<1 (± 0)	39	<1 (± 1)
Mountain whitefish	11	<1 (± 0)	27	<1 (± 0)	6	<1 (± 0)	4	<1 (± 0)	48	<1 (± 1)
Sculpin spp.	3	<1 (± 0)	1	<1 (± 0)	0	0	0	0	4	<1 (± 0)

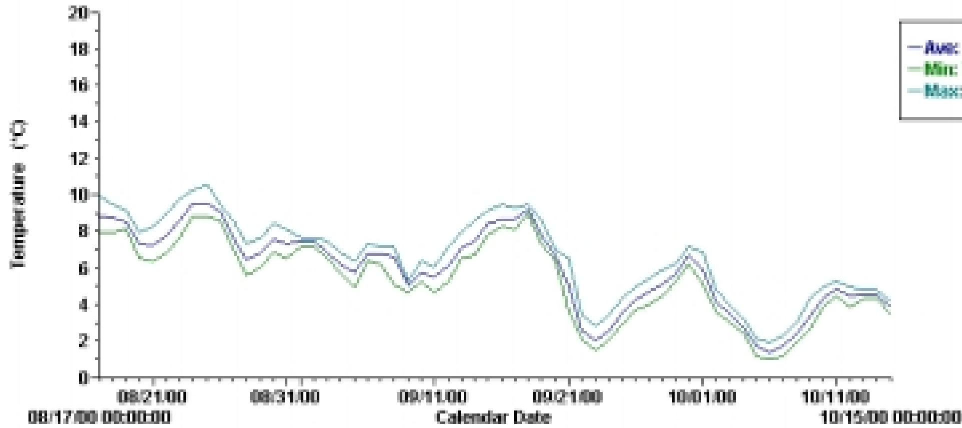

Figure 20. Mean, maximum, and minimum daily temperatures recorded on upper Sullivan Creek.

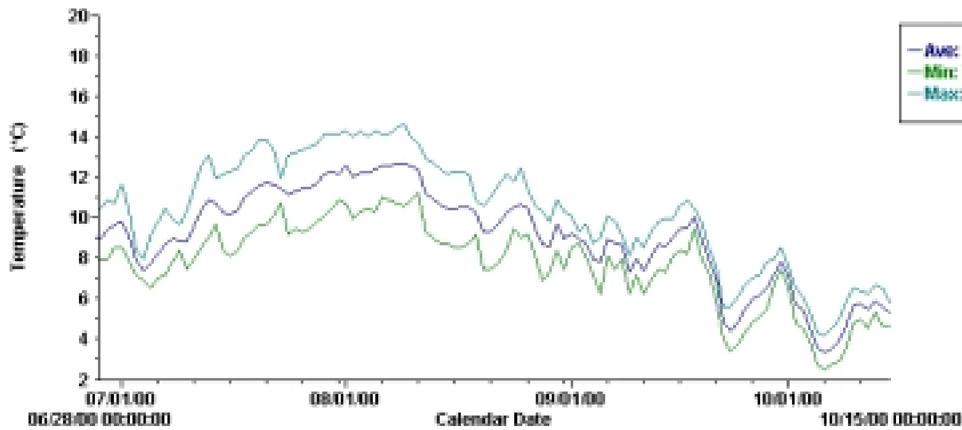

Figure 21. Mean, maximum, and minimum daily temperatures recorded on middle Sullivan Creek.

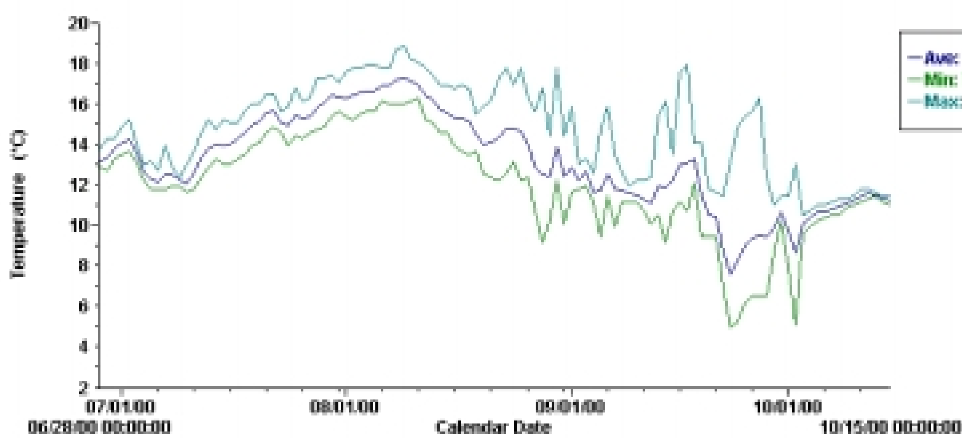

Figure 22. Mean, maximum, and minimum daily temperatures recorded on lower Sullivan Creek.

Sweet Creek

Sweet Creek was divided into 5 reaches that were sampled between September 11th and 13th (Figure 4; Appendix G). A total of 14 sites were surveyed (Appendix H). The mean of each habitat parameter was calculated for each reach and the entire stream (Table 50). The dominant substrate in Sweet Creek was boulder (Table 50) and the dominant habitat type was riffle (81%; Table 51). The discharge of Sweet Creek on September 11th was 0.15 m^3/sec.

Sweet Creek had four waterfalls that were fish passage barriers (Figure 12; Appendix I). Moving in an upstream direction, the first waterfall (6.0 m) was located 200 m upstream from the State Highway 31 bridge. The second waterfall (6.0 m) was 20 m upstream of the first waterfall. The third waterfall (6.0 m) was 500 m upstream from the second. The fourth waterfall was 150 m upstream from the third waterfall and had a vertical height of 8.2 m.

The temperature of Sweet Creek was measured 1,338 times with the thermograph, between June 28th and October 17th. Daily average, maximum, and minimum temperatures were determined (Figure 23). Mean temperature was 9.88 (± 2.80) °C with a maximum of 15.63 °C on August 6th, 7th, and 9th, and a minimum of 2.26 °C on October 6th.

Six species of fish were observed in Sweet Creek; cutthroat trout (44%; n=73), eastern brook trout (5%; n=8), rainbow trout (49%; n=81), brown trout (2%; n=3), bull trout (1%; n=1), and mountain whitefish (1%; n=1; Table 52). The mean densities of both cutthroat and rainbow trout were 4 fish/100m^2. The mean density of brook trout was 1 fish/100m^2. The mean densities of brown trout, bull trout, and mountain whitefish were <1 fish/100m^2. Cutthroat trout were observed in all reaches, the majority of which were 100-200 mm TL (45%; n=33). Brook trout were observed from the lowest reach (reach 5) upstream to reach 2. Most brook trout were 100-200 mm TL (75%; n=6). Rainbow trout and brown trout were observed in reaches 4 and 5, which were below the first barrier waterfall. The majority of rainbow trout were <100mm TL (87%; n=71) and all of the brown trout were <100mm TL (n=3). A single bull trout (300 mm TL) was observed in reach 4, in the plunge pool below the barrier waterfall. One mountain whitefish (100-200 mm TL) was present in reach 5 just upstream of the confluence with the Pend Oreille River.

Lunch Creek

Lunch Creek was divided into 3 reaches that were sampled between September 11th and 13th (Figure 4; Appendix G). A total of 7 sites were surveyed (Appendix H). The mean of each habitat parameter was calculated for each reach and the entire stream (Table 53). The dominant substrate in Lunch Creek was rubble (Table 53) and riffles were the dominant habitat type observed (75%; Table 54).

Cutthroat trout were the only fish species observed in Lunch Creek (Table 55). The mean density of cutthroat trout was 2 fish/100m^2 (± 1). The majority of the fish observed were 100-200 mm TL (53%; n=8), and no fish >300 mm TL were observed.

Other Creeks

Fish passage barriers were identified on three streams that were not surveyed during the study (Figure 12; Appendix I). There was a 25.0 m waterfall at the mouth of Beaver Creek. Threemile Creek had a 5.0 m waterfall at its mouth. North Fork Sullivan Creek has a dam approximately 400 m upstream from its mouth.

Temperatures were monitored with thermographs near the mouths of Threemile and North Fork Sullivan Creeks (Figure 5). The temperature of Threemile Creek was measured 1,338 times, between June 28th and October 17th. Daily average, maximum, and minimum temperatures were determined (Figure 24). Mean temperature was 8.07 (± 1.29) °C with a maximum of 10.59 °C on August 8th and 9th, and a minimum of 4.21 °C on October 6th.

The temperature of North Fork Sullivan Creek was measured 1,364 times, between June 28th and October 19th. Daily average, maximum, and minimum temperatures were determined (Figure 25). Mean temperature was 8.28 (± 2.00) °C with a maximum of 11.98 °C on July 30th and 31st, August 6th, 8th, and 9th, and a minimum of 3.12 °C on October 6th.

Table 50. Mean values (± standard deviation) of habitat parameters measured on Sweet Creek, 2000.

Reach	n	Wet Width (m)	Bankfull Width (m)	Mean Depth (cm)	Mean Max. Depth (cm)	Gradient (%)	Water Temp. (°C)	No. LP/km	No. LWD/100 m	Dominant Substrate
1	2	4.1 (± 1.0)	7.3 (± 1.1)	11 (± 3)	31 (± 0)	10 (± 0)	9 (± 1)	33 (± 0)	10 (± 0)	Boulder
2	5	4.3 (± 1.2)	7.5 (± 1.6)	13 (± 4)	28 (± 12)	5 (± 2)	9 (± 1)	40 (± 15)	15 (± 7)	Cobble
3	3	4.2 (± 1.3)	17.4 (± 4.3)	17 (± 5)	40 (± 22)	7 (± 1)	8 (± 0)	67 (± 0)	28 (± 22)	Bedrock
4	2	4.5 (± 0.2)	10.0 (± 1.3)	21 (± 4)	41 (± 3)	4 (± 1)	8 (± 0)	17 (± 24)	20 (± 5)	Boulder
5	2	4.6 (± 0.1)	10.9 (± 2.4)	11 (± 1)	25 (± 3)	2 (± 0)	8 (± 0)	50 (± 24)	18 (± 2)	Cobble
Total	**14**	**4.3 (± 0.9)**	**10.4 (± 4.5)**	**14 (± 5)**	**33 (± 13)**	**5 (± 3)**	**8 (± 0)**	**43 (± 20)**	**18 (± 11)**	**Boulder**

Table 51. Mean width, maximum depth, and residual depth (± standard deviation) and percent occurrence of each habitat type observed on Sweet Creek, 2000.

	Riffle Habitat			Pool Habitat				
Reach	**n**	**Width (m)**	**Occurrence (%)**	**n**	**Width (m)**	**Occurrence (%)**	**Mean Max. Depth (cm)**	**Residual Depth (cm)**
1	2	4.1 (± 1.0)	100	0	-	0	-	-
2	5	4.3 (± 1.2)	100	0	-	0	-	-
3	3	2.8 (± 1.9)	75	1	4.1 (nc)	25	65 (nc)	41 (nc)
4	1	2.0 (nc)	33	2	3.5 (± 1.2)	67	46 (± 4)	29 (± 0)
5	2	4.6 (± 0.1)	100	0	-	0	-	-
Total	**13**	**3.8 (± 1.4)**	**81**	**3**	**3.7 (± 0.9)**	**19**	**52 (± 11)**	**33 (± 7)**

nc=not calculable.

Table 52. The number of fish of each species observed during snorkel surveys of Sweet Creek, and their estimated densities (#/100m^2; ± standard deviation).

	<100 mm		100-200 mm		201-300 mm		>300 mm		Total	
Reach	**n**	**Density**	**n**	**Density**	**n**	**Density**	**n**	**Density**	**n**	**Density**
1										
Cutthroat trout	0	0	1	<1 (0)	4	2 (0)	1	<1 (0)	6	3 (1)
2										
Cutthroat trout	8	1 (1)	14	2 (1)	8	1 (1)	1	<1 (0)	31	5 (2)
E. brook trout	1	<1 (0)	2	<1 (0)	1	<1 (0)	0	0	4	1 (1)
3										
Cutthroat trout	0	0	5	1 (1)	7	2 (2)	0	0	12	4 (3)
E. brook trout	0	0	2	1 (1)	0	0	0	0	2	1 (1)
4										
Cutthroat trout	0	0	11	4 (3)	6	2 (3)	5	2 (1)	22	7 (7)
E. brook trout	0	0	1	<1 (0)	0	0	0	0	1	<1 (0)
Rainbow trout	42	15 (2)	2	1 (1)	1	1 (1)	3	1 (1)	48	17 (2)
Brown trout	2	1 (0)	0	0	0	0	0	0	2	1 (0)
Bull trout	0	0	0	0	0	0	1	<1 (0)	1	<1 (0)
5										
Cutthroat trout	0	0	2	1 (1)	0	0	0	0	2	1 (1)
E. brook trout	0	0	1	<1 (1)	0	0	0	0	1	<1 (1)
Rainbow trout	29	10 (2)	3	1 (0)	1	<1 (1)	0	0	33	12 (2)
Brown trout	1	<1 (0)	0	0	0	0	0	0	1	<1 (0)
Mountain whitefish	0	0	1	<1 (1)	0	0	0	0	1	<1 (1)
Total										
Cutthroat trout	8	<1 (0)	33	2 (2)	25	1 (1)	7	<1 (1)	73	4 (3)
E. brook trout	1	<1 (0)	6	<1 (0)	1	<1 (0)	0	0	8	1 (1)
Rainbow trout	71	4 (6)	5	<1 (1)	2	<1 (0)	3	<1 (1)	81	4 (7)
Brown trout	3	<1 (0)	0	0	0	0	0	0	3	<1 (0)
Bull trout	0	0	0	0	0	0	1	<1 (0)	1	<1 (0)
Mountain whitefish	0	0	1	<1 (0)	0	0	0	0	1	<1 (0)

Table 53. Mean values (± standard deviation) of habitat parameters measured on Lunch Creek, 2000.

Reach	n	Wet Width (m)	Bankfull Width (m)	Mean Depth (cm)	Mean Max. Depth (cm)	Gradient (%)	Water Temp. (°C)	No. LP/km	No. LWD/100 m	Dominant Substrate
1	2	4.2 (± 1.1)	9.9 (± 0.1)	18 (± 15)	36 (± 31)	18 (± 0)	8 (± 0)	17 (± 24)	22 (± 2)	Cobble
2	2	2.5 (± 0.8)	7.0 (± 4.0)	13 (± 5)	26 (± 11)	11 (± 4)	8 (± 0)	17 (± 24)	12 (± 2)	Rubble
3	3	3.8 (± 0.2)	7.1 (± 1.4)	8 (± 1)	19 (± 3)	8 (± 3)	8 (± 1)	22 (± 19)	30 (± 10)	Boulder/Rubble
Total	**7**	**3.5 (± 0.9)**	**7.9 (± 2.3)**	**12 (± 8)**	**26 (± 16)**	**12 (± 5)**	**8 (± 0)**	**19 (± 18)**	**21 (± 9)**	**Rubble**

Table 54. Mean width, maximum depth, and residual depth (± standard deviation) and percent occurrence of each habitat type observed on Lunch Creek, 2000.

	Riffle Habitat			Pool Habitat				
Reach	**n**	**Width (m)**	**Occurrence (%)**	**n**	**Width (m)**	**Occurrence (%)**	**Mean Max. Depth (cm)**	**Residual Depth (cm)**
1	1	3.4 (nc)	50	1	5.0 (nc)	50	58 (nc)	35 (nc)
2	2	2.1 (± 0.3)	67	1	0.7 (nc)	33	33 (nc)	23 (nc)
3	3	3.8 (± 0.2)	100	0	-	0	-	-
Total	**6**	**3.2 (± 0.9)**	**75**	**2**	**2.9 (± 3.0)**	**25**	**46 (± 18)**	**29 (± 8)**

nc=not calculable.

Table 55. The number of fish of each species observed during snorkel surveys of Lunch Creek, and their estimated densities (#/100m^2; ± standard deviation).

	<100 mm		100-200 mm		201-300 mm		>300 mm		Total	
Reach	**n**	**Density**	**n**	**Density**	**n**	**Density**	**n**	**Density**	**n**	**Density**
1										
Cutthroat trout	0	0	2	1 (± 0)	1	<1 (± 1)	0	0	3	1 (± 1)
2										
Cutthroat trout	0	0	1	1 (± 1)	2	2 (± 2)	0	0	3	2 (± 2)
3										
Cutthroat trout	3	1 (± 0)	5	1 (± 0)	1	<1 (± 1)	0	0	9	3 (± 0)
Total										
Cutthroat trout	3	<1 (± 0)	8	1 (± 1)	4	1 (± 1)	0	0	15	2 (± 1)

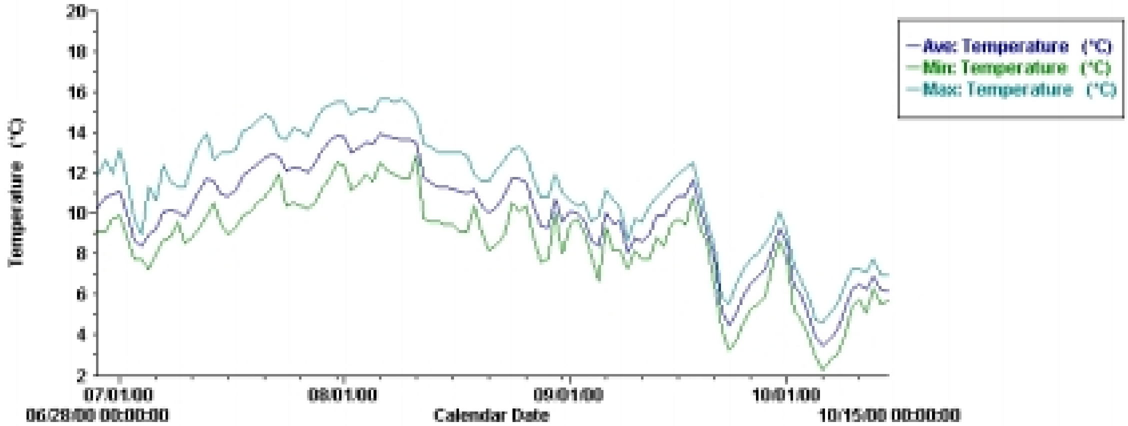

Figure 23. Mean, maximum, and minimum daily temperatures recorded on Sweet Creek.

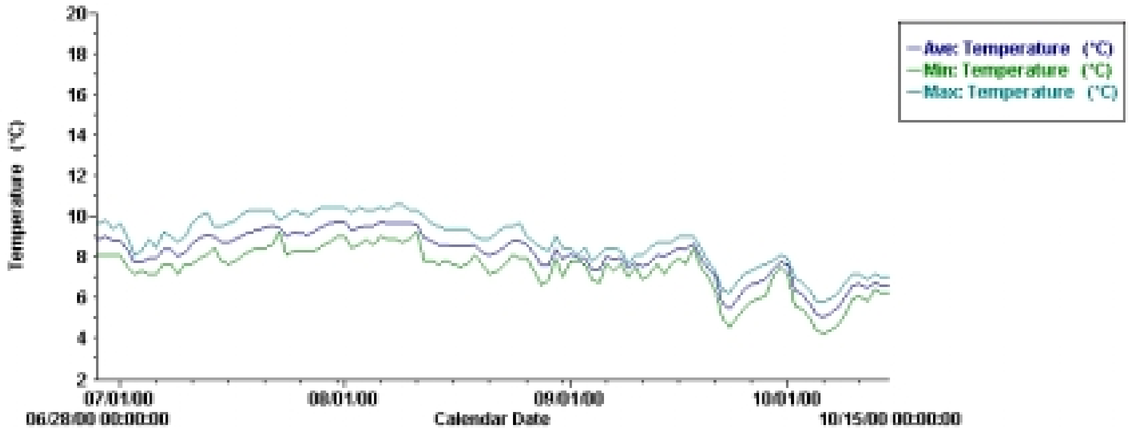

Figure 24. Mean, maximum, and minimum daily temperatures recorded on Threemile Creek.

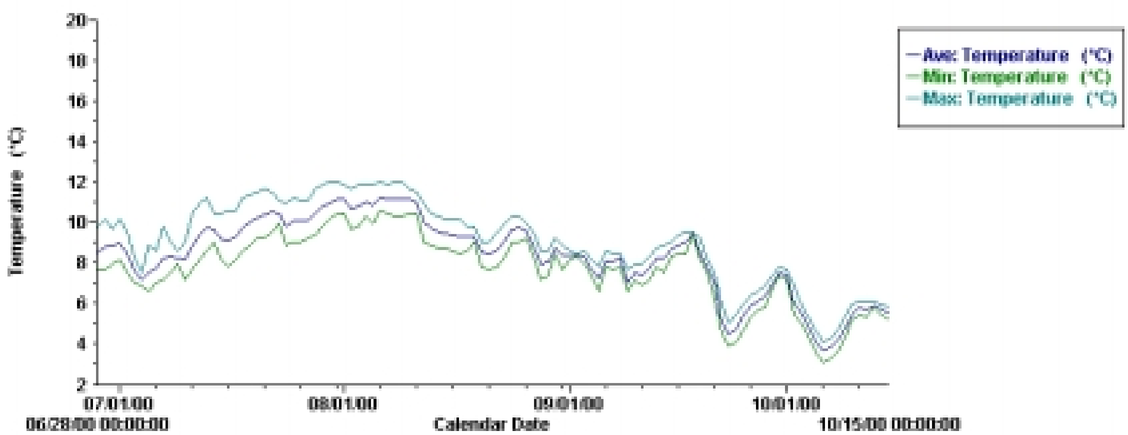

Figure 25. Mean, maximum, and minimum daily temperatures recorded on North Fork Sullivan Creek.

Discussion

Reservoir Assessment

Water Quality

Boundary Reservoir was isothermal in 2000, and its maximum temperature was 22°C, which appeared to be typical of the reservoir. R2 reported that Boundary Reservoir was isothermal and that the maximum water temperature was 22°C (R2 1998). The maximum surface temperature measured at the Metaline Falls Bridge was near 22°C each year from 1997 through 2000 (WDOE, unpublished data). Temperatures may limit fish production in Boundary Reservoir by exceeding the optimal temperatures for salmonids during the summer and by being too cold for warmwater fish, resulting in delayed spawning time and/or slow growth rates. Other water quality parameters were within the ranges necessary for healthy aquatic life.

Temperature may limit salmonid production in Boundary Reservoir by limiting available summer habitat. Water temperatures were equal to or greater than the upper avoidance temperatures reported for most salmonids. Rainbow, brown, brook, and lake trout avoid water temperatures above 22°C (Coutant 1977; Garrett and Bennett 1995). Brown trout in Box Canyon Reservoir, just upstream of Boundary Reservoir, moved into cooler tributary streams when reservoir water temperatures reached 19°C (Garrett and Bennett 1995). Salmonids were likely limited to tributary mouths during the summer months, while they sought refuge from the warm water in the reservoir. Proportionally, tributary mouths provided a small amount of habitat in the reservoir.

Water temperatures may limit warmwater game fish production by delaying spawning time and/or causing slow growth rates. Smallmouth bass, largemouth bass, black crappie, and pumpkinseed all spawn at temperatures 13°C or greater (Wydoski and Whitney 1979), which did not occur until mid-June in Boundary Reservoir (Figure 26; WDOE, unpublished data). The maximum temperature observed in Boundary Reservoir was at the low end or below the preferred temperature of all of the warmwater fish species collected, except yellow perch. Reservoir temperatures never reached the optimal temperatures for growth of smallmouth bass, largemouth bass, black crappie, or pumpkinseed (Coutant 1977). The average growth rates of age 0 smallmouth and largemouth bass were generally low at 15.2 and 20.1°C (Coutant and DeAngelis 1983). The growing season for warmwater fish in Boundary Reservoir was short as well. Maximum daily temperatures declined below 20°C by the beginning of September and were below 15°C by the beginning of October (R2 1998). Late spawning and slow summer growth may result in smaller individuals at the onset of winter, which may result in low over-winter survival and poor recruitment. Size of largemouth bass was positively related to over-winter survival and negatively related to energy depletion, especially in cases where food was limited (Fullerton et al. 2000). The thermal regime of Boundary Reservoir appeared to be optimal for yellow perch. The preferred temperatures of yellow perch in lakes were 20 to 21°C (Coutant 1977).

Mean annual water retention time in Boundary Reservoir was short when compared to other northwest reservoirs and lakes (Figure 56). Low water retention may result in decreased temperatures, as well as primary, secondary, and fish production through rapid transfer of nutrients and entrainment of organisms. Rapid movement of nutrients through the reservoir may limit the ability for assimilation by primary producers. All types of organisms, particularly planktonic organisms such as phytoplankton, zooplankton, and larval fish, may be subject to physical removal from the reservoir. Cichosz et al. (1999), Tilson and Scholz (1998), and McLellan et al. (1998) reported entrainment losses of adult rainbow trout, kokanee, and walleye over Grand Coulee Dam. Above average year classes of largemouth bass have been shown to coincide with longer water retention times (Maceina and Bettolli 1998). The shorter retention time and corresponding year class strength was likely the result of increased food production and decreased entrainment (Maceina and Bettolli 1998). Losses and gains of phytoplankton, zooplankton, and fish due to entrainment need to be quantified for Boundary Reservoir.

The surface elevation of Boundary Reservoir fluctuated an average of 2.4 m a day, due to power peaking operations at Boundary Dam. Daily water level fluctuations may limit fish production by reducing periphyton and macrophyte growth, macroinvertebrate colonization, and littoral habitat, as well as dewatering fish nests. Littoral habitat along much of the reservoir was rare (R2 1998). The drawdowns dewatered large areas of the shoreline for several hours, exposing aquatic organisms to drying in the summer and freezing in the winter. The water level fluctuations also dewatered large portions of the littoral habitat that was available at full pool, possibly limiting habitat for larval and juvenile fish. Young fish forced into the main reservoir were likely more vulnerable to entrainment, predation, or starvation. Fluctuating water levels may have dewatered eggs of warmwater fish that typically spawn in littoral areas. Future research should be conducted to determine the impacts of water level fluctuations on periphyton, macrophyte, benthic macroinvertebrate, and fish production.

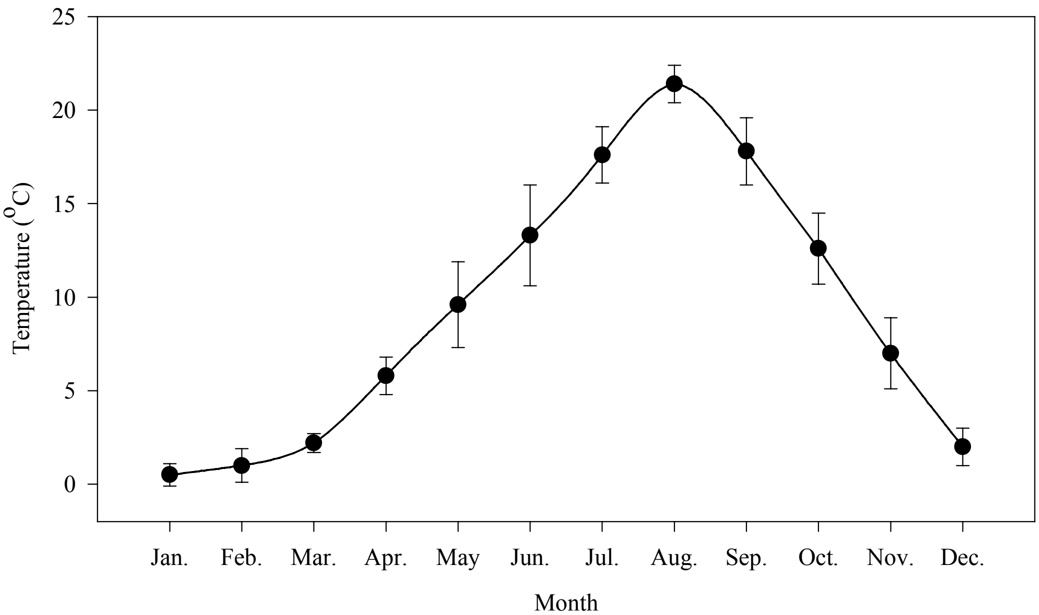

Figure 26. Mean monthly surface temperatures (± standard deviation) for Boundary Reservoir between 1994 and 2000 (WDOE, unpublished data).

Trophic Status

Boundary Reservoir was considered oligotrophic according to OECD (1982) criteria. Secchi disk depth (m) was the only measurement that resulted in a different trophic classification (eutrophic). The trophic classification based on the secchi disk depths was disregarded, because low secchi disk depths could be the result of suspended solids instead of primary production (Carlson 1977).

TSI values typically range from 0 to 100, with lower values indicating less production (Carlson 1977). TSI values based on chlorophyll a, total phosphorus, and secchi disk depth ranged from 31 to 46. The lowest value (31) was calculated from chlorophyll *a* and the highest from secchi disk depth (42 and 47).

Primary Production

Primary production, as indicated by chlorophyll *a* values, was low when compared to other northwest reservoirs and lakes (Table 57). The low production of phytoplankton was likely related to retention times that were too fast to allow for nutrient assimilation by phytoplankton. Soballe and Kimmel (1987) reported that a minimum retention time of 75 days was needed for full biotic expression of nutrients. Phytoplankton production in Boundary Reservoir may have been virtually nonexistent. With the rapid retention times, the majority of the phytoplankton in the reservoir may have been produced in upstream reservoirs and was just passing through on its way downstream. Enclosure experiments should be conducted to determine how phytoplankton species composition and production is affected by water retention.

Phytoplankton species composition and bio-volumes were dominated by cryptophytes, greens, and diatoms, which was consistent with those described for populations early in succession, prior to high grazing pressure (Sterner 1989). In situations with heavy grazing by cladocerans, phytoplankton species composition shifted from small edible species to large inedible species and blue-greens (Sommer 1989; Post and McQueen 1987). *Chlamydomonas* sp. and *Rhodomonas* sp. were the most abundant genera collected, and both of these genera were often consumed by cladocerans (Sterner 1989). Phytoplankton species composition suggested that grazing by zooplankton in Boundary Reservoir was low.

Periphyton production, according to periphyton chlorophyll *a* values, was greater than phytoplankton production. Comparative periphyton chlorphyll *a* values and bio-volumes were virtually non-existent, so we did not know what impact the periphyton production was having on the higher trophic levels. Future research should be conducted on the role of periphyton in Boundary Reservoir and the impact reservoir operations.

Secondary Productivity

Zooplankton densities in Boundary Reservoir were low when compared to other northwest reservoirs and lakes (Table 58). Zooplankton densities appeared to be greater in Boundary Reservoir than in Rock Lake and Lake Roosevelt, however those studies did not include rotifers or juvenile zooplankton in their calculations (McLellan 2000b; Cichosz et al. 1999). Juvenile copepods (nauplii) had the highest density of all zooplankton collected and if these and Rotifers were removed the zooplankton density for Boundary Reservoir would have been lower.

The short retention times probably caused the low densities of zooplankton observed. The short retention times did not allow for assimilation of nutrients by phytoplankton, reducing the amount of available food for zooplankton. Chlorophyll *a* has been positively correlated with zooplankton biomass (Canfield and Jones 1996), indicating that the low primary production in Boundary Reservoir may be limiting zooplankton production. Possessing poor swimming abilities, many zooplankton were likely entrained out of the reservoir without having time to reproduce. Calanoid and cyclopoid copepod and cladoceran generation times were greater (range=7.50-26.72 days @ 20 °C; Gillooly 2000) than the longest retention times measured in Boundary Reservoir (5.9 days). There were likely areas of refuge from the main flow of the reservoir that had longer retention times and greater zooplankton production, but embayment and backwater habitats were rare and often dewatered. The Pewee Falls embayment of the Boundary Dam forebay probably had the highest potential for zooplankton production. The majority of zooplankton in the reservoir may have been produced in upstream lakes and reservoirs, and entrained into the reservoir. Enclosure experiments should be conducted to determine how zooplankton species composition, density, and biomass are affected by water retention.

Daphnia sp. had the lowest densities of the four zooplankton groups. The low densities of *Daphnia* sp. were representative of a population that had been subject to heavy predation (Brooks and Dodson 1965; Galbraith 1967; Post and McQueen 1987). Eight fish were collected in the pelagic zone of the reservoir in the summer and *Daphnia* densities were higher in the summer than the in fall, suggesting that fish were preying on the few *Daphnia* in the reservoir. However, the general low abundance of pelagic fish indicated that *Daphnia* were not abundant despite some predation. Fish diets should be analyzed monthly to determine the extent of zooplankton exploitation.

Macroinvertebrate densities were low when compared to densities in Rock Lake (Table 59). Few studies have documented reservoir macroinvertebrate densities from collections on artificial substrates, so comparisons were limited. Our data indicated that benthic macroinvertebrate production was low, but the number of samples collected was small and isolated to two different reservoir locations that may or may not have had macroinvertebrate communities that were representative of the entire reservoir. Artificial substrates were used, so it was assumed that the species colonizing the samplers represented the true community, which was unlikely. Zooplankton levels were very low, so benthic macroinvertebrates may be the primary food source for many adult and juvenile fish in Boundary Reservoir. Attempts should be made to quantify benthic macroinvertebrate production in the reservoir, as well as the impacts of reservoir operations. Future research should include sampling of all habitat types in the reservoir using multiple gears. Analysis of fish diets should be conducted to quantify the importance of benthic macroinvertebrates to fish production.

Table 56. Comparison of mean annual retention times of northwest lakes and reservoirs with that of Boundary Reservoir in 2000.

Location	Retention Time	**Source**
Rock Lake, WA	8.15 years	McLellan (2000b)
West Medical Lake, WA	3.86 years	Soltero et al. (1995)
Deer Lake, WA	9.00 years	Soltero et al. (1991)
Sacheen Lake, WA	328.5 days	Soltero et al. (1991)
Spirit Lake, ID	6.13 years	Soltero and Hall (1985)
Hayden Lake, ID	37.10 years	Soltero et al. (1986)
Long Lake, WA	26.08 days	Soltero et al. (1992)
Lake Roosevelt, WA	29.2 days	Cichosz et al. (1999)
Boundary Reservoir, WA	1.9 days	Current study

Table 57. Comparison of the mean annual chlorophyll *a* concentration in Boundary Reservoir, with those of other northwest lakes and reservoirs.

Location	**Concentration (µg/L)**	**Source**
Sprague Lake, WA 1999	36.3	Taylor (2000)
Rock Lake, WA 1999	19.63	McLellan (2000b)
Lake Roosevelt, WA 1997	3.74	Cichosz et al. (1997)
Box Canyon Reservoir, WA 1990	1.02	Falter et al. (1991)
Deer Lake, WA 1990	2.00	Soltero et al. (1991)
Boundary Reservoir, WA 2000	1.05	Current study

Table 58. Comparison of the mean zooplankton densities in Boundary Reservoir, with those of other northwest lakes and reservoirs.

Location	Density (org./L)	Source
Rock Lake, WA 1999	2	McLellan (2000b)
Sprague Lake, WA 1999	40	Taylor (2000)
Lake Roosevelt, WA 1997	2	Cichosz et al. (1999)
Box Canyon Reservoir, WA 1990	13	Ashe et al. (1991)
Deer Lake, WA 1990	109	Soltero et al. (1991)
West Medical Lake, WA 1994	204	Soltero et al. (1995)
Boundary Reservoir, WA 2000	5	Current study

Table 59. Comparison of the mean macroinvertebrate densities in Boundary Reservoir, with those of Rock Lake.

Location	Density (org./m^2)	Source
Rock Lake, WA 1999	311	McLellan (2000b)
Boundary Reservoir, WA 2000	76	Current study

Reservoir Fish

Native cyprinids and catostomids, particularly northern pikeminnow and largescale suckers, dominated the fish community in Boundary Reservoir. R2 reported that northern pikeminnow were the most abundant fish species in the reservoir, but they did not indicate the high abundance of largescale suckers (R2 1998). Smallmouth bass and yellow perch were the two most abundant game fish species in the reservoir. R2 found that rainbow trout were the most abundant game fish in the reservoir, second in overall abundance behind northern pikeminnow, in creel, angling, and live trapping samples (R2 1998). The differences were likely related to different sampling techniques. Angling, which includes creel surveys, was probably more selective than randomly set gill nets and electrofishing surveys. The species composition from this study was more representative of the actual fish community structure in Boundary Reservoir.

Few fish were in the pelagic zone of the reservoir, as indicated by low vertical gill net catch rates. Fish were only captured in one vertical gill net set in the forebay of Boundary Dam in the summer. Two northern pikeminnow and two peamouth were captured within the upper 3 m of the net. Northern pikeminnow and peamouth were captured in two horizontal gill nets set at the same time and location as the vertical gill net that captured fish. One of the nets was on the surface and the other was on the bottom (60 m). Hydroacoustic surveys of Boundary Reservoir also indicated few fish in the pelagic zone (R2 1998). The data indicated that most fish in Boundary Reservoir were occupying littoral habitats during all seasons. The low catch rates in vertical gill nets may have been the result of net inefficiency or avoidance. During higher flows, particularly in the spring, the tops of the nets were pushed downstream, stretching the nets, and possibly compressing the mesh so that they were ineffective. Fish may have avoided the nets while they were fishing, because of large amounts of organic debris that accumulated in the nets, particularly in the spring.

Ranges of PSD values have been determined to represent balanced populations for some fish species (Andersen and Neumann 1996). The range of PSD values that represent a balanced yellow perch population were 30-60 (Andersen and Neumann 1996). PSD values calculated for the yellow perch in Boundary Reservoir (43 by electrofishing and 55 by gill netting) were within the range, indicating that the population was balanced. RSD values indicated that a small proportion of the yellow perch population was large. No range of PSD values has been reported for balanced smallmouth bass populations, but the PSD values of those from Boundary Reservoir were lower than the 40-70 range for largemouth bass, and the PSD of smallmouth captured by electrofishing was less than the 30-60 range for other coolwater fish, such as yellow perch, walleye (*Stizostedion vitreum*), and northern pike (*Esox lucius*; Andersen and Neumann 1996). Smallmouth bass of preferred size (RSD-P) were collected; 14% of stock size fish collected by electrofishing and 22% of stock size fish collected by gill netting. All brown trout collected were of stock size and there were brown and rainbow trout that were of memorable size (RSD-M) in Boundary Reservoir. Caution should be used when making inferences from the PSD and RSD values calculated in this study, because sample sizes were small.

Smallmouth bass growth in Boundary Reservoir was better than average when compared to other northwest lakes and reservoirs (Table 60). Smallmouth bass W_r's generally declined with increasing length. Smaller fish had W_r values better than the national standard of 100, but larger fish had W_r values below the standard. When compared to smallmouth bass from Loon and Sprague Lakes, K_{TL} were higher for smallmouth bass from Boundary Reservoir (Table 64).

Growth of yellow perch in Boundary Reservoir was better than average when compared to other northwest lakes and reservoirs (Table 61). Yellow perch growth was faster in Boundary Reservoir than in Box Canyon Reservoir (Table 61). Yellow perch were the most abundant species of fish in Box Canyon Reservoir and the population was considered stunted (Ashe and Scholz 1992). Growth rates of yellow perch in Boundary Reservoir exceeded those reported for Sprague Lake, which was considered to have a good perch fishery. However, yellow perch in Sprague Lake reached lengths 80 mm longer than those in Boundary Reservoir (Taylor 2000). Yellow perch W_r's were distributed around the national standard of 100, indicating good growth. Yellow perch from Boundary Reservoir had a mean K_{TL} that was average when compared to other eastern Washington lakes, indicating average growth (Table 65).

Mountain whitefish growth in Boundary Reservoir was slow when compared to other mountain whitefish waters (Table 62). The growth of mountain whitefish from Boundary Reservoir and the averages from Montana lakes and reservoirs were similar (Table 62). Mountain whitefish condition was generally below average as indicated by W_r. Mean K_{TL} of mountain whitefish in Boundary Reservoir (0.83) was higher than the mean of those in Box Canyon Reservoir (0.76=weighted mean from 1988-90; Ashe and Scholz 1992).

Growth of rainbow trout in Boundary Reservoir was appeared to be slow, when compared to rainbow trout in other northwest waters (Table 63). Rainbow trout growth was faster in Boundary Reservoir than in Box Canyon Reservoir, however a few large rainbow trout have been captured in both reservoirs. Barber et al. (1990) captured a rainbow trout in Box Canyon reservoir that was > 817 mm TL and a 710 mm TL rainbow trout was captured in Boundary Reservoir during this study. The large rainbow trout may have been entrained Kamloops strain rainbow trout from Lake Pend Oreille. The condition of some rainbow trout in Boundary Reservoir was below average and some above, as indicated by W_r. Rainbow trout growth was average, as indicated by mean K_{TL}, when compared to other northwest lakes and reservoirs (Table 66).

Growth rates and condition (K_{TL}) of the other game fish collected in Boundary Reservoir were not discussed, due to the small sample sizes. The W_r's of salmonids and burbot were generally lower than the national standard of 100 and the W_r's of warmwater fish were generally above the national standard. The data suggests that reservoir conditions may favor growth of warmwater fish, although the sample sizes were small.

Table 60. Comparison of mean back-calculated total lengths (mm) of smallmouth bass in northwest lakes and reservoirs.

		Mean Total Length (mm) at Each Annulus									
Location	n	1	2	3	4	5	6	7	8	9	Source
Laramie River, WY 1991-92	148	87	124	167	209	249	285	316	346	371	Patton and Hubert (1996)
Salmon River, ID	-	82	137	180	221	249	268	288	306		Carlander (1969)
Clearwater River, ID	166	83	142	193	241	269	295	315	325	338	Carlander (1969)
Lower Snake River, ID	155	84	145	206	239	267	292	310	322		Carlander (1969)
Upper Snake River, ID	162	87	150	211	249	272	297	310	325		Carlander (1969)
Lake Roosevelt, WA 1997	59	89	144	199	253	308	329	382	413		EWU, unpublished data
Lake Roosevelt, WA 1999	439	91	140	199	255	325	368	407	439		EWU, unpublished data
Sprague Lake, WA 1999	20	101	145	188	238	285	328	361	384	402	Taylor (2000)
Boundary Reservoir, 2000	79	84	138	202	264	317	353	372			Current study

Table 61. Comparison of mean back-calculated total lengths (mm) of yellow perch in northwest lakes and reservoirs.

		Mean Total Length (mm) at Each Annulus							
Location	n	1	2	3	4	5	6	7	8	Source
Liberty Lake, WA 1998	23	75	160	188						Phillips et al. (1999)
Jump Off Joe Lake, WA 1998	28	62	105	152	176					Divens and Phillips (1999)
Sprague Lake, WA 1999	83	68	101	138	174	215	248	277	286	Taylor (2000)
Box Canyon Reservoir, WA 1988-90	2,555	75	114	135	151	164	194	197	211	Ashe and Scholz (1992)
Boundary Reservoir, WA 2000	55	70	124	168	202					Current study

Table 62. Comparison of mean back-calculated total lengths (mm) of mountain whitefish in northwest lakes and reservoirs.

		Mean Total Length (mm) at Each Annulus								
Location	**n**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Source**
Montana Reservoirs	232	86	183	246	290	312	335	351	371	Carlander (1969)
Montana Rivers	1,212	86	180	246	292	328	353	368	419	Carlander (1969)
Wyoming Average	-	99	206	262	290	318	338			Carlander (1969)
Okanogan lake, BC	33	135	221	292	323					Carlander (1969)
Madison River, WY	36	130	226	305	348	388	429			Carlander (1969)
Box Canyon Reservoir, WA 1988-90	1,540	149	206	250	285	341	381	413	435	Ashe and Scholz (1992)
Boundary Reservoir, WA 2000	35	75	177	248	278	317	324	343		Current study

Table 63. Comparison of mean back-calculated total lengths (mm) of rainbow trout in northwest lakes and reservoirs.

		Mean Total Length (mm) at Each Annulus						
Location	**n**	**1**	**2**	**3**	**4**	**5**	**6**	**Source**
Montana Lakes	2,905	89	206	323	406	465	495	Wydoski and Whitney (1979)
Lake Roosevelt, WA 1997	35	136	248	332	367			Cichosz et al. (1999)
Rock Lake, WA 1999	87	141	313	369	407			McLellan (2000b)
Box Canyon Reservoir, WA 1988-90	29	96	156	256	369	538	817	Ashe and Scholz (1992)
Boundary Reservoir, 2000	15	91	186	291	391	526	614	Current study

Table 64. Comparison of smallmouth bass condition factors from northwest lakes and reservoirs.

Location	n	K_{TL}	Source
Loon Lake, WA 1985	12	1.10	Scholz et al. (1988)
Lake Roosevelt, WA 1997-99	485	1.46	EWU, unpublished data
Sprague Lake, WA 1999	22	1.31	Taylor (2000)
Boundary Reservoir, WA 2000	73	1.39	Current study

Table 65. Comparison of yellow perch condition factors from northwest lakes and reservoirs.

Location	n	K_{TL}	Source
Deer Lake, WA 1985	29	1.19	Scholz et al. (1988)
Loon Lake, WA 1985	25	0.99	Scholz et al. (1988)
Box Canyon Reservoir, WA 1988-90	2,555	1.08	Ashe and Scholz (1992)
Sprague Lake, WA 1999	247	1.41	Taylor (2000)
Boundary Reservoir, WA 2000	54	1.33	Current study

Table 66. Comparison of rainbow trout condition factors from northwest lakes and reservoirs.

Location	n	K_{TL}	Source
Deer Lake, WA 1985	32	1.08	Scholz et al. (1988)
Loon Lake, WA 1985	15	0.93	Scholz et al. (1988)
Box Canyon Reservoir, WA 1988-90	29	0.93	Ashe and Scholz (1992)
Lake Roosevelt, WA 1997	35	1.22	Cichosz et al. (1999)
Rock Lake, WA 1999	266	0.98	McLellan (2000b)
Boundary Reservoir, WA 2000	15	0.95	Current study

Tributary Assessments

Sullivan Creek was the largest stream surveyed, as indicated by wetted and bankfull widths and mean depth. The mean wetted width of Sullivan Creek (10.5 m) was almost twice that of Slate Creek (5.5 m), the second largest stream measured. The wetted width of Slate Creek was ≥ 1 m wider than the other streams surveyed, excluding Sullivan Creek. The mean depth of Slate Creek was 4 cm less than the mean depth of Sullivan Creek and 7 cm deeper than next deepest stream. Flume and Sweet Creeks were similar in mean wetted width and depth, as were Lime, Lunch, and Pewee Creeks. Sand Creek was the smallest stream surveyed.

In general, streams with the fewest number of LP/km had the lowest numbers of LWD/100m. Lunch, Sullivan, Pewee, and Flume Creeks had the lowest numbers of LP/km, as well as low percent occurrence of pool habitats. Slate and Lime Creeks had high LP/km, LWD/100m, and percent occurrence of pool habitat. Sweet Creek was the exception, with an intermediate number of LP/km, low LWD/100m, and low percent occurrence of pool habitat. The percent occurrence of pool habitat should be interpreted with caution, because it included all categories of pool habitat, such as pocket water, that may have different levels of quality for various fish species and life stages.

Similar to our results, R2 found that Slate Creek had higher numbers of LWD when compared to Sweet, Sullivan, Sand, and Flume Creeks (R2 Resource Consultants 1998). However, the USFS data indicated that Slate Creek had low numbers of LWD (44/100m) when compared to Sand (124/100m) and Flume Creeks (67/100m; USFS, unpublished data)). The USFS found that Sullivan Creek had the lowest densities of LWD of the four (17/100m; USFS, unpublished data). The differences between the results in this study and those of the USFS were likely the result of differences in the definition of acting LWD. The USFS considered LWD to be pieces of wood ≥15 cm in diameter 6.1 m from the base, within the bankfull channel (USFS 1998). LWD in this study were >10 cm in diameter, >1 m long, and acting in the current wetted channel. The smaller sizes of wood counted in this study would have resulted in higher numbers of LWD, but the USFS method of counting wood in the bankfull channel would have also resulted in higher counts. The degree of difference between the two methods could not be determined. Nonetheless, both studies indicated that LWD densities in Sullivan Creek were low when compared to other streams in the area. The low amounts of LWD may have been due to natural hydraulic conditions preventing LWD retention, human removal of LWD from the stream, human removal of large trees from the riparian zone that could have recruited to the stream, or some combination of these factors.

There has been some debate as to the occurrence of two fish passage barriers on lower Sullivan Creek approximately 0.97 and 1.04 km upstream from the mouth. The first has been described as a turbulent cascade and the second as a chute (CES 1996). Neither of them was identified as a barrier during this study. CES conducted an extensive analysis of both features and indicated that fish passage over either would be difficult, but they could not rule out the possibility of passage (CES 1996).

The mean and maximum temperatures in lower Sullivan Creek were higher than the other streams monitored (13.10 °C ave. and 18.86 °C max.). The warmer temperatures in lower Sullivan Creek were likely the result of surface inflow from Sullivan Lake and the Mill Pond.
Large temperature fluctuations in Sand Creek between approximately August 10th and August 28th were the result of the thermograph being dewatered. The stream channel shifted, leaving the thermograph exposed to the air. The maximum temperature (16.26 °C) was recorded while the thermograph was out of the water, so the actual maximum temperature was likely lower. The thermograph was placed in the channel on August 28th.

Large temperature fluctuations in lower Sullivan Creek between approximately August 20th and October 5th were likely the result of the thermograph being dewatered. The thermograph was never observed out of the water (checked Aug. 7th), but the fluctuations resemble those of a thermograph recording air temperature. According to Pend Oreille County PUD (personal communication), the discharge from Sullivan Lake was decreased on August 17th (from 17 cfs to 16.3 cfs) that may have been enough to lower the stream to a level that dewatered the thermograph. Discharge was increased to 17 cfs on September 6th and remained at that level until September 11th, when it was decreased to 14.6 cfs, which corresponded with a short period of low temperature fluctuations (see Figure 20 in results). The maximum temperature in 2000 (18.86 °C) was still lower than the maximum observed by R2 (19.4 °C; 1998) in 1997.

Maximum temperatures recorded by R2 (1998) in 1997, were slightly warmer than those in 2000, although they were generally within 0.54 °C. Lower Slate Creek was the exception, with maximum temperatures of 13.34 °C in 2000 and 15.4 °C in 1997 (R2 1998), a difference of more than 2 °C.

The maximum temperatures of the streams monitored did not exceed the ranges preferred by rainbow, brown, and brook trout (Coutant 1977). Maximum water temperatures exceeded 15 °C in lower Sullivan Creek (18.86 °C), Sweet Creek (15.63 °C), and Sand Creek (16.26 °C), possibly limiting their use for bull trout. In general, maximum water temperatures exceeding 15°C were thought to limit bull trout distribution (Baxter et al. 1997). However, the only bull trout observed in the study was in Sweet Creek.

All of the streams surveyed for fish in 2000 had been previously surveyed on at least one occasion, except Lime Creek (Terrapin 2000; R2 Resource Consultants 1998; CES 1996; USFS, unpublished data). Sampling methods used in all of the studies were not exactly the same, so comparisons were made using relative abundance (%), to provide general distributions and relative density.

In two previous surveys of Flume Creek, brook trout were the only species observed, except in 1997 when two cutthroat trout were observed (R2 1998). The USFS collected cutthroat trout at one location on Pewee Creek (USFS, unpublished data). Rainbow trout, cutthroat trout, and rainbow x cutthroat hybrids had the highest relative abundance in 1 of each the 3 previous fish surveys on Sand Creek (Figure 27). The high abundance of cutthroat observed in the electrofishing survey by R2 may have been due to small sample size (4 sample sites; R2 1998). The high incidence of hybrids observed during R2 snorkel surveys was suspect. Rainbow x cutthroat hybrids have been confirmed to inhabit Sand Creek (USFS, unpublished genetic data), however the ability to distinguish hybrids from pure rainbow or cutthroat trout during snorkeling was thought to be extremely difficult and inaccurate. The virtual inability to distinguish hybrid fish from pure fish may have also resulted in an underestimate of hybrid densities in 2000. During the previous 3 studies brown trout, eastern brook trout, and mountain whitefish were observed below the barrier falls (R2 1998; USFS, unpublished data).

Similar to previous studies, rainbow trout, eastern brook trout, and cutthroat trout were observed in Slate Creek in 2000 (R2 1998; USFS, unpublished data). Unlike the previous two surveys, cutthroat trout had the highest relative abundance in 2000 (Figure 28). Two surveys by R2 (1998) indicated that brook trout were most abundant in 1996 and brook trout and cutthroat occurred in approximately the same density in 1997. Both of these surveys were limited by sample size (3 sites each), when compared to the 24 sites surveyed in 2000. The USFS surveyed approximately the same amount of Slate Creek in 1997 as was surveyed in 2000, but fish densities were recorded in categories of sparse (<10 fish), moderate (10-50 fish), and dense (>50 fish) preventing comparisons of relative abundance (USFS, unpublished data).

There were 7 species of fish observed in Sullivan Creek in 2000, which was more than in the other streams surveyed. Sullivan Creek also had the lowest densities of fish. The low densities may have been due to limited habitat, such as LWD and pool habitat (previously discussed). Low densities may have also been related to harvest. High susceptibility of cutthroat trout to angling has been implicated, among other factors, as contributing to the general decline of the species throughout its native range through over harvest (Behnke 1992). The majority of Sullivan Creek was easily accessible to anglers via a forest road that ran along it for the majority of its length and several campsites located on the stream. Sullivan Creek was the only stream surveyed which had the majority of its length accessible to anglers and that had evidence of angling on the bank and in the stream, such as intestines from cleaned fish, line, and lures. Future research of Sullivan Creek should include a creel survey to estimate the angler impact on the fishery.

Sullivan Creek was divided into two sections for comparisons with other studies, the portion below Mill Pond Dam (lower Sullivan Creek) and the portion above Mill Pond Dam (upper Sullivan Creek). In all studies of lower Sullivan Creek rainbow trout were the most abundant species, as indicated by relative abundance (Figure 29). Differences in 2000 were that no brook trout were observed and there were high densities of mountain whitefish and largescale suckers (Figure 29). The high densities of mountain whitefish and largescale suckers were the result of large numbers of juveniles observed at the site just upstream of the confluence with the Pend Oreille River.

In the studies of upper Sullivan Creek by CES (1996) and the USFS (unpublished data), cutthroat trout were the most abundant fish species observed, similar to the results in 2000 (Figure 30). Limited surveys by R2 (1998) and Pend Oreille County PUD (CES 1996), indicated high densities of sculpins, brown trout, and dace (Figure 30). These results were likely related to small sample sizes, location, and method. Only 1 site was sampled by R2 and 2 sites by the PUD, both PUD sites were between Sullivan Dam and Mill Pond, and sampling in both surveys was conducted by electrofishing. Electrofishing likely resulted in higher collection rates of bottom oriented sculpins and dace (*Rhinchthys* spp.), when compared to snorkeling.

Unlike our results, cutthroat trout were the most abundant species in three previous studies of Sweet Creek (Figure 32). The high density of rainbow trout in 2000 was the result of large numbers of juveniles observed in the lower reaches of Sweet Creek, below the barrier falls. Cutthroat trout were the only species of fish observed in Lunch Creek, similar to the results of R2 (1998). The steep gradient (12%) of Lunch Creek may have slowed or prevented invasion by brook trout. Select tributaries to Sullivan, Slate, and Flume Creeks have been surveyed and the results were summarized in Terrapin (2000) and CES (1996).

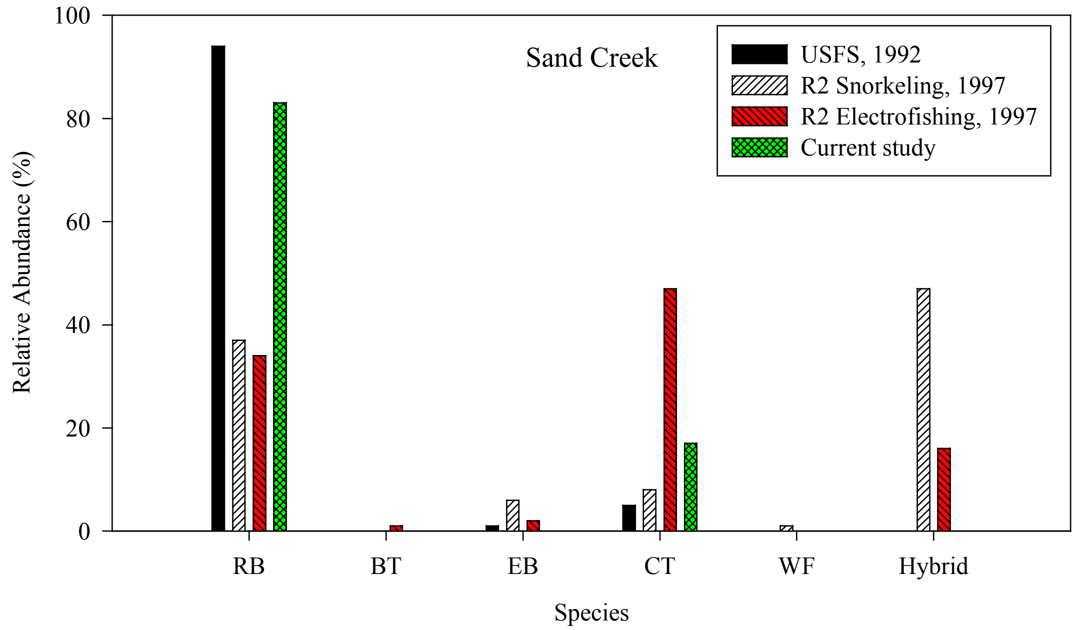

Figure 27. Relative abundance (%) of fish observed in Sand Creek in 2000, compared to those of previous studies. RB=rainbow trout, BT=brown trout, EB=eastern brook trout, CT=cutthroat trout, WF=mountain whitefish, and Hybrid=rainbow x cutthroat trout hybrid.

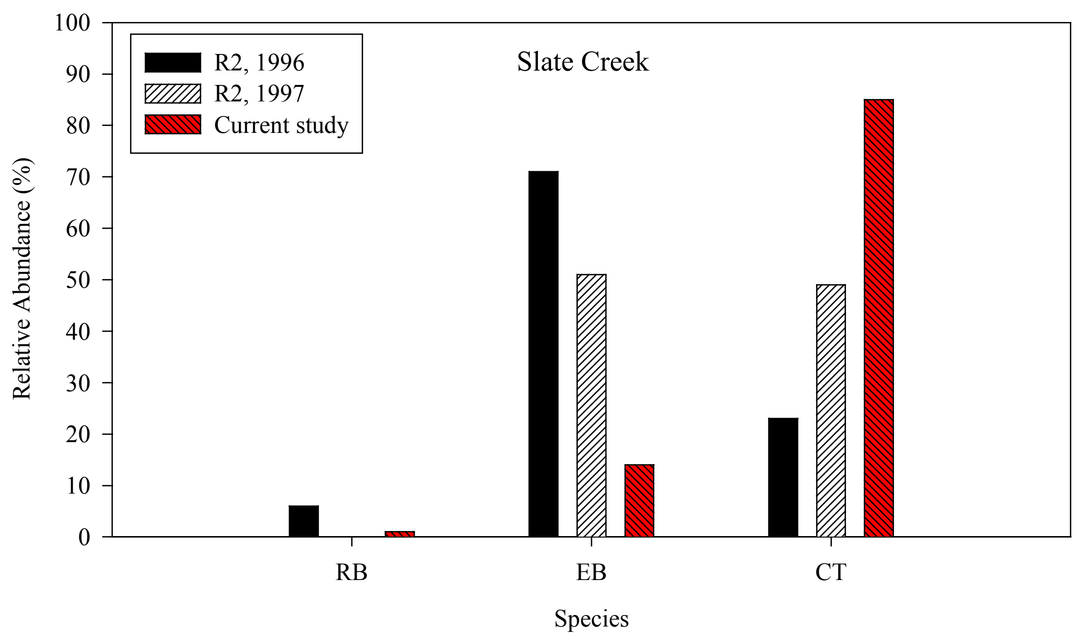

Figure 28. Relative abundance (%) of fish observed in Slate Creek in 2000, compared to those of previous studies. RB=rainbow trout, EB=eastern brook trout, CT=cutthroat trout.

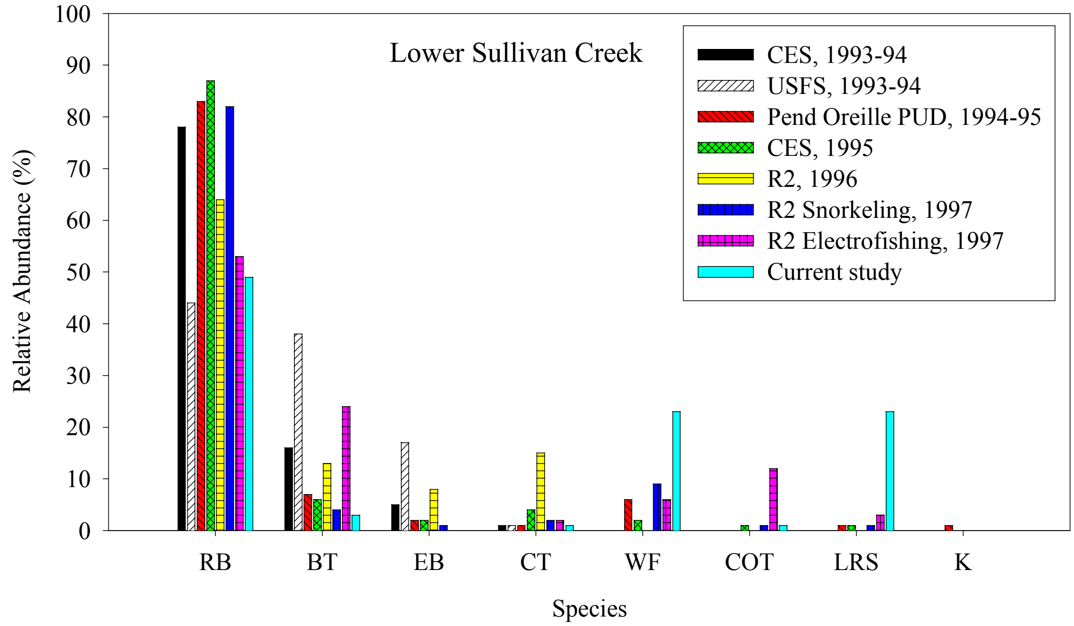

Figure 29. Relative abundance (%) of fish observed in lower Sullivan Creek in 2000, compared to those of previous studies. RB=rainbow trout, BT=brown trout, EB=eastern brook trout, CT=cutthroat trout, WF=mountain whitefish, COT=sculpin spp., LRS=largescale suckers, and K=kokanee.

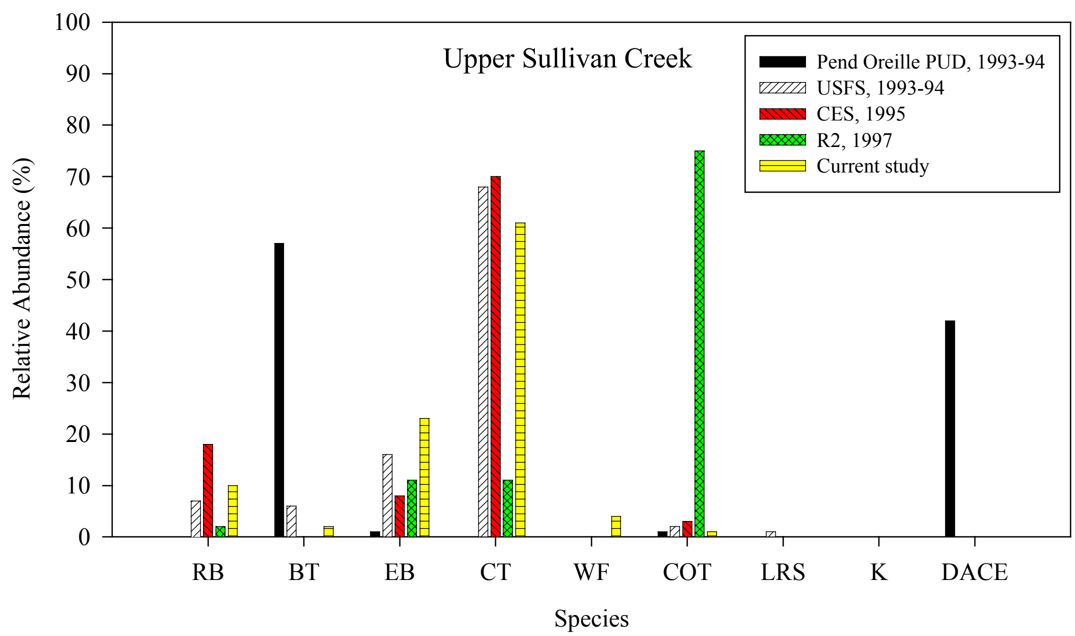

Figure 30. Relative abundance (%) of fish observed in upper Sullivan Creek in 2000, compared to those of previous studies. Species codes as in Figure 29 and DACE=dace spp.

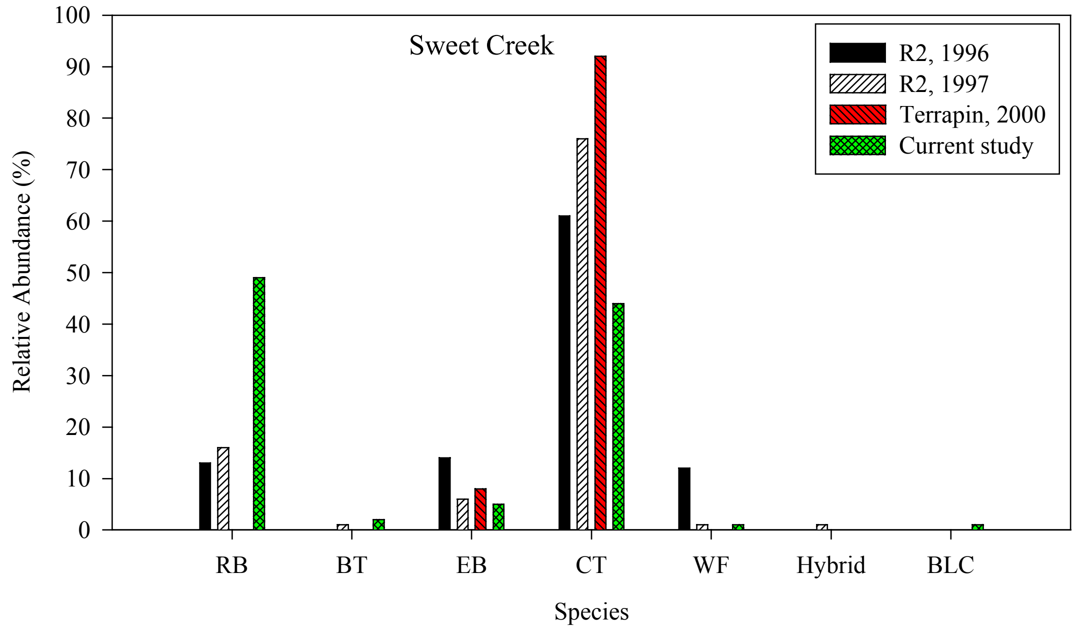

Figure 31. Relative abundance (%) of fish observed in Sweet Creek in 2000, compared to those of previous studies. RB=rainbow trout, BT=brown trout, EB=eastern brook trout, CT=cutthroat trout, WF=mountain whitefish, Hybrid=rainbow x cutthroat trout hybrid, and BLC=bull trout.

Conclusions

Boundary Reservoir was classified as oligotrophic reservoir. Nutrient levels, primary productivity, and secondary productivity were low in Boundary Reservoir. Low nutrient levels and short retention times were likely limiting primary production. Short retention times and/or low primary production were limiting zooplankton production. Retention time was likely the principle cause of low zooplankton densities by entraining large numbers before they could reproduce in the reservoir. Macroinvertebrate production appeared low, but requires further investigation.

The fish species composition in Boundary Reservoir was dominated by native catostomids and cyprinids, particularly largescale suckers and northern pikeminnow. Relatively few game fish were collected, but smallmouth bass had the greatest species composition. Low game fish densities were likely the result of conditions created by hydropower production, such as elevated water temperatures, short retention time, entrainment, and dewatered littoral habitat. Overall, it appeared that the opportunities for game fish management in Boundary Reservoir were limited. We do not have a full understanding of all of the limiting factors in the system and how they are related to each other. We do have an indication that the major limiting factors were related to water temperature, retention times, and daily water level fluctuations. The effects of reservoir operations on aquatic organisms need to be quantified, so that fishery improvement opportunities can be explored.

Pool habitat and LWD occurred in low densities in Sullivan Creek. All of the tributaries to Boundary Reservoir contained wild trout populations. Individual streams were dominated by cutthroat trout, eastern brook trout, or rainbow trout. Cutthroat trout densities were generally greater in upper stream reaches, while rainbow trout were most dense in lower stream reaches. Unless they were the only species in a stream, brook trout densities were generally greatest in the middle reaches of a stream. Habitat partitioning, habitat enhancement opportunities, and angler impacts on the trout population of Sullivan Creek should be investigated. Genetic purity and relation to other wild and hatchery populations should be determined for each population of cutthroat trout. The feasibility of brook trout removal above migration barriers to reduce competition with native species should be investigated. Griffith (1982) indicated that brook trout have the potential to out compete cutthroat trout. Brook trout may also out compete and hybridize with bull trout.

Recommendations

- Coordinate with the USGS to obtain hydrologic information to calculate water retention times and water level fluctuations to be related to primary, secondary, and fish production data.
- Monthly water profile measurements of temperature, dissolved oxygen, turbidity, pH, and conductivity in Boundary Reservoir to determine seasonal changes in the reservoir limnology to be related to reservoir operations and production information.

- Monthly measurements of chlorophyll *a*, phytoplankton species composition, and phytoplankton bio-volume to determine seasonal changes in primary productivity and algal succession, related to reservoir conditions and zooplankton production.
- Monthly measurements of zooplankton species composition, density, and biomass to determine seasonal changes in secondary productivity to be related to reservoir conditions, primary productivity, and fish feeding habits.
- Monthly measurements of benthic macroinvertebrate species composition and density, using all gear types and in all habitat types, to determine seasonal macroinvertebrate production related to reservoir operations and fish diets.
- Conduct fish stomach analysis, monthly and for all age/size classes of each species, to quantify prey consumption, determine prey electivity, and diet overlaps between species and age classes.
- Quantify fish entrainment into and out of Boundary Reservoir.
- Determine the effects of daily water level changes on periphyton production, macrophyte production, macroinvertebrate production, littoral habitat availability, larval and juvenile fish production, and fish spawning habitat.
- Investigate potential habitat improvements to Sullivan Creek, with a statistically valid evaluation plan to be conducted prior to and following any improvements.
- Conduct a comprehensive creel survey of Sullivan Creek, to quantify angler harvest to help with management.
- Microsatellite DNA characterization of the cutthroat stocks that have not been evaluated to determine purity and distinction from other stocks. Emphasize two sets of collections per stream, one from above any barriers and one from below.
- Explore feasibility of eastern brook trout removal from stream reaches above fish migration barriers.
- Conduct adfluvial trapping at the mouth of Sweet Creek to determine the extent of its use by bull trout.
- Monitor habitat conditions in Sweet Creek, due to timber harvest operations being conducted in the watershed.

- Identify the human made fish migration barriers that should be removed or improved to restore passage.

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Appendices

Appendix A.

Table A1. Fish plants in the Boundary Reservoir drainage by WDFW. Data from unpublished hatchery records. EB = eastern brook trout, CT = cutthroat trout, RB = rainbow trout, WE = walleye, K = kokanee, and BT = brown trout.

Location	Date	Species	# Planted	no./lb.
Beaver Creek	6/6/46	EB	13,800	2,311
Beaver Creek	6/13/46	EB	11,375	875
Beaver Creek	6/13/46	EB	2,185	875
Fence Creek	6/14/78	EB	1,125	75
Flume Creek	6/9/82	EB	1,560	98
Lucerne Lake	5/12/47	EB	17,400	1,516
Lucerne Lake	5/13/49	EB	12,000	1,612
Lucerne Lake	5/17/50	EB	15,400	2,200
Lucerne Lake	4/26/51	EB	14,300	2,050
Lucerne Lake	5/22/52	EB	15,600	1,735
Lucerne Lake	5/11/53	EB	15,025	1,582
Lucerne Lake	5/10/54	EB	15,050	800
Lucerne Lake	5/20/55	EB	15,600	650
Lucerne Lake	5/28/57	EB	10,000	800
Lucerne Lake	5/22/58	EB	5,060	460
Lucerne Lake	5/22/59	EB	5,220	475
Lunch Creek	7/25/47	CT	7,500	2,500
Lunch Creek	8/16/48	CT	4,200	2,107
Lunch Creek	9/21/49	CT	7,335	815
Mill Pond (Sull. Lake)	4/30/46	RB	15,000	28
Mill Pond (Sull. Lake)	7/3/51	RB	9,300	9
Mill Pond (Sull. Lake)	7/5/51	RB	8,170	9
Mill Pond (Sull. Lake)	5/29/52	RB	17,115	17.5
Mill Pond (Sull. Lake)	5/1/53	RB	10,000	20
Mill Pond (Sull. Lake)	5/4/53	RB	10,090	12
Mill Pond (Sull. Lake)	6/1/54	RB	20,320	21
Mill Pond (Sull. Lake)	6/11/65	RB	15,000	100
Mill Pond (Sull. Lake)	5/14/73	RB	18,966	87
Mill Pond (Sull. Lake)	5/20/74	RB	10,027	88
Mill Pond (Sull. Lake)	5/13/75	RB	10,560	96
Mill Pond (Sull. Lake)	5/19/76	RB	10,000	80
Mill Pond (Sull. Lake)	5/10/77	RB	10,010	77
Mill Pond (Sull. Lake)	5/17/78	RB	10,080	90
Mill Pond (Sull. Lake)	5/14/80	RB	10,030	85
Mill Pond (Sull. Lake)	5/19/81	RB	10,010	70
Mill Pond (Sull. Lake)	5/11/82	RB	10,050	75
Mill Pond (Sull. Lake)	5/6/83	RB	5,040	80
Mill Pond (Sull. Lake)	5/7/84	RB	10,010	65
Mill Pond (Sull. Lake)	5/9/85	RB	10,010	70
Mill Pond (Sull. Lake)	5/13/86	RB	11,200	90
Mill Pond (Sull. Lake)	5/24/88	RB	10,010	55
Mill Pond (Sull. Lake)	5/9/89	RB	10,050	67
Mill Pond (Sull. Lake)	5/4/90	RB	9,996	68
Mill Pond (Sull. Lake)	5/11/91	RB	9,990	74

Table A1. Continued.

Location	Date	Species	# Planted	no./lb.
Mill Pond (Sull. Lake)	5/21/92	RB	10,000	50
Mill Pond (Sull. Lake)	5/29/93	RB	10,000	50
Mill Pond (Sull. Lake)	5/23/94	RB	10,000	50
Mill Pond (Sull. Lake)	5/1/95	RB	10,005	87
Mill Pond (Sull. Lake)	1996	RB	10,000	70-80
Mill Pond (Sull. Lake)	1997	RB	10,000	70-80
Mill Pond (Sull. Lake)	1998	RB	10,000	70-80
Mill Pond (Sull. Lake)	1999	RB	10,000	70-80
Mill Pond (Sull. Lake)	2000	RB	10,000	70-80
North Fork Sullivan Creek	9/23/49	CT	3,980	663
Pewee Creek	6/9/82	EB	1,176	98
Pend Oreille River	Aug-99	EB	600	
Pend Oreille River	7/9/46	RB	7,500	25
Pend Oreille River	7/9/46	RB	7,500	25
Pend Oreille River	7/10/46	RB	6,300	21
Pend Oreille River	7/10/46	RB	6,300	21
Pend Oreille River	7/11/46	RB	6,300	21
Pend Oreille River	7/11/46	RB	7,500	25
Pend Oreille River	7/12/46	RB	7,500	25
Pend Oreille River	7/12/46	RB	4,937	25
Pend Oreille River	7/12/46	RB	5,125	50
Pend Oreille River	7/13/46	RB	12,500	60
Pend Oreille River	7/13/46	RB	12,500	60
Pend Oreille River	7/14/46	RB	12,500	60
Pend Oreille River	7/14/46	RB	13,900	60
Pend Oreille River	7/15/46	RB	12,500	60
Pend Oreille River	7/15/46	RB	13,500	50
Pend Oreille River	7/16/46	RB	10,000	40
Pend Oreille River	7/16/46	RB	4,800	40
Pend Oreille River	7/7/47	RB	12,000	30
Pend Oreille River	7/7/47	RB	12,000	30
Pend Oreille River	7/8/47	RB	12,000	30
Pend Oreille River	7/8/47	RB	12,000	30
Pend Oreille River	7/9/47	RB	11,320	28
Pend Oreille River	7/9/47	RB	11,200	28
Pend Oreille River	7/10/47	RB	11,200	28
Pend Oreille River	7/10/47	RB	11,200	28
Pend Oreille River	7/11/47	RB	11,200	28
Pend Oreille River	7/11/47	RB	18,000	45
Pend Oreille River	7/12/47	RB	18,000	45
Pend Oreille River	7/12/47	RB	18,000	45
Pend Oreille River	7/14/47	RB	18,000	45
Pend Oreille River	7/14/47	RB	15,750	45
Pend Oreille River	7/15/47	RB	15,750	45
Pend Oreille River	7/15/47	RB	15,750	45
Pend Oreille River	7/16/47	RB	15,750	45
Pend Oreille River	7/21/47	RB	16,200	45

Table A1. Continued.

Location	Date	Species	# Planted	no./lb.
Pend Oreille River	6/22/51	RB	13,501	23
Pend Oreille River	6/23/51	RB	18,285	23
Pend Oreille River	6/23/51	RB	13,776	28
Pend Oreille River	7/9/51	RB	10,150	11
Pend Oreille River	7/10/51	RB	14,200	17
Pend Oreille River	7/11/51	RB	7,800	17
Pend Oreille River	8/20/89	RB	37,841	4.5
Pend Oreille River	7/23/91	RB	3,000	20
Pend Oreille River	8/12/91	RB	22,000	16
Pend Oreille River	10/28/91	RB	15,868	2.2
Pend Oreille River	8/21/92	RB	25,000	7
Pend Oreille River	10/2/93	RB	38,126	3
Pend Oreille River	10/2/93	RB	18,563	3
Pend Oreille River	10/24/93	RB	500	3
Pend Oreille River – Blue Slide Net Pen	1995	RB	30,000	
Pend Oreille River – Blue Slide Net Pen	1996	RB	30,000	
Pend Oreille River – Blue Slide Net Pen	1997	RB	30,000	
Pend Oreille River – Blue Slide Net Pen	1998	RB	30,000	
Pend Oreille River – Ione Net Pen	1998	RB	15,000	
Pend Oreille River – Boundary Dam Net Pen	1998	RB	15,000	
Pend Oreille River – Blue Slide Net Pen	1999	RB	30,000	
Pend Oreille River – Blue Slide Net Pen	1999	RB	30,000	
Pend Oreille River – Blue Slide Net Pen	2000	RB	30,000	
Pend Oreille River	4/20/83	WE	500,000	10,000
Pend Oreille River	4/25/84	WE	253,000	11,000
Pocahontas Creek	9/19/49	CT	4,880	814
Sand Creek	9/19/49	CT	11,530	900
Sand Creek	10/4/54	CT	4,500	1,500
Slate Creek	8/9/45	CT		
Slate Creek	9/28/54	CT	11,125	1,500
Slate Creek	7/1/48	EB	9,550	355
Slate Creek	6/5/81	EB	2,000	100
Slumber Creek	6/4/81	EB	1,000	100
Sullivan Creek	8/31/43	CT		
Sullivan Creek	Jul-45	CT		
Sullivan Creek	8/31/45	CT		
Sullivan Creek	9/28/47	CT	20,000	2,000
Sullivan Creek	8/17/48	CT		
Sullivan Creek	8/20/48	CT		
Sullivan Creek	9/20/49	CT	17,094	814
Sullivan Creek	7/1/39	RB		
Sullivan Creek	4/30/46	RB		
Sullivan Lake	8/8/46	CT	108,000	3,055
Sullivan Lake	7/28/47	CT	31,000	2,000
Sullivan Lake	7/28/47	CT	90,000	3,500
Sullivan Lake	8/17/48	CT	40,300	1,975
Sullivan Lake	8/20/48	CT	55,350	2,520
Sullivan Lake	10/26/49	CT	55,940	746

Table A1. Continued.

Location	Date	Species	# Planted	no./lb.
Sullivan Lake	9/22/59	CT	111,900	418
Sullivan Lake	10/11/60	CT	19,125	625
Sullivan Lake	10/11/60	CT	48,750	650
Sullivan Lake	10/11/60	CT	86,240	880
Sullivan Lake	10/11/60	CT	26,000	1,000
Sullivan Lake	10/11/60	CT	19,125	625
Sullivan Lake	10/11/60	CT	48,750	650
Sullivan Lake	10/11/60	CT	86,420	880
Sullivan Lake	10/11/60	CT	26,000	1,000
Sullivan Lake	6/6/84	CT	37,800	42
Sullivan Lake	6/6/84	CT	16,638	18.8
Sullivan Lake	6/7/84	CT	36,120	42
Sullivan Lake	6/8/84	CT	16,450	18.8
Sullivan Lake	6/11/84	CT	16,450	18.8
Sullivan Lake	6/12/84	CT	33,600	42
Sullivan Lake	5/23/85	CT	25,900	35
Sullivan Lake	5/24/85	CT	21,175	35
Sullivan Lake	5/29/85	CT	25,200	35
Sullivan Lake	5/30/85	CT	25,900	35
Sullivan Lake	5/31/85	CT	27,650	35
Sullivan Lake	6/30/73	EB	86,400	160
Sullivan Lake	9/30/80	BT	20,103	18.7
Sullivan Lake	5/4/76	K	197,960	1,800
Sullivan Lake	6/10/65	RB	70,000	100
Sullivan Lake	6/11/65	RB	55,000	100
Sullivan Lake	6/14/65	RB	170,000	850
Sullivan Lake	6/14/65	RB	60,150	85
Sullivan Lake	6/17/65	RB	16,100	700
Sullivan Lake	6/17/65	RB	79,570	73
Sullivan Lake	6/17/65	RB	11,400	164
Sullivan Lake	6/17/65	RB	95,940	113
Sullivan Lake	6/8/71	RB	77,000	110
Sullivan Lake	6/10/71	RB	80,000	100
Sullivan Lake	6/11/71	RB	80,000	100
Sullivan Lake	6/14/71	RB	40,000	100
Sullivan Lake	6/20-22/73	RB	194,700	150
Sullivan Lake	5/17/74	RB	75,000	150
Sullivan Lake	5/23/74	RB	58,080	88
Sullivan Lake	5/24/74	RB	50,000	100
Sullivan Lake	5/27/74	RB	68,870	95
Sullivan Lake	6/4/75	RB	4,930	85
Sullivan Lake	6/1/76	RB	85,600	80
Sullivan Lake	6/8/76	RB	6,250	50
Sullivan Lake	5/10/77	RB	32,956	428
Sullivan Lake	6/15/78	RB	36,750	75
Sullivan Lake	6/16/80	RB	18,750	75
Sullivan Lake	6/2/82	RB	36,946	98

Table A1. Continued.

Location	Date	Species	# Planted	no./lb.
Sullivan Lake	5/29/84	RB	14,300	65
Sullivan Lake	5/29/84	RB	14,300	65
Sullivan Lake	5/30/84	RB	14,300	65
Sullivan Lake	5/30/84	RB	14,300	65
Sullivan Lake	5/30/84	RB	14,300	65
Sullivan Lake	5/21/85	RB	48,000	80
Sullivan Lake	5/22/85	RB	44,000	80
Sullivan Lake	5/20-21/86	RB	92,500	100
Sullivan Lake	1999	RB	18,560	64
Sweet Creek	7/25/47	CT	7,500	2,500
Sweet Creek	8/16/48	CT	10,500	2,107
Sweet Creek	9/21/49	CT	4,890	815
Sweet Creek	9/28/54	CT	8,925	1,500
Sweet Creek	6/10/82	EB	1,176	98
Three Mile Creek	9/15/59	CT	1,050	300

Appendix B.

Table B1. Mean density (#/ml) and bio-volume (mm^3/L) of phytoplankton collected in Boundary Reservoir in the summer, 2000.

	Boundary Forebay			Metaline Falls Bridge			Mean Totals (± standard deviation)		
Organism	n	Density (#/ml)	Bio-volume (mm^3/L)	n	Density (#/ml)	Bio-volume (mm^3/L)	n	Density (#/ml)	Bio-volume (mm^3/L)
Bacillariophyceae	**5**	**26**	**0.016**	**7**	**48**	**0.032**	**12**	**37 (± 16)**	**0.024 (± 0.011)**
Amphora sp.	0	0	0.000	0	0	0.000	0	0	0.000
Asterionella formosa	0	0	0.000	0	0	0.000	0	0	0.000
Melosira italica	4	21	0.012	0	0	0.000	4	11 (± 15)	0.006 (± 0.008)
Navicula sp.	0	0	0.000	1	5	0.008	1	3 (± 4)	0.004 (± 0.006)
Rhizosolenia sp.	1	5	0.004	5	26	0.023	6	16 (± 15)	0.014 (± 0.013)
Synedra sp.	0	0	0.000	1	17	0.001	1	9 (± 12)	0.001 (± 0.001)
Chlorophyceae	**15**	**163**	**0.046**	**25**	**335**	**0.034**	**40**	**249 (± 122)**	**0.040 (± 0.008)**
Ankistrodesmus falcatus	4	21	0.001	2	34	0.000	6	28 (± 9)	0.001 (± 0.001)
Chlamydomonas sp.	7	121	0.020	11	190	0.031	18	156 (± 49)	0.026 (± 0.008)
Cryptomonas sp.	4	21	0.025	0	0	0.000	4	11 (± 15)	0.013 (± 0.018)
Scenedesmus bijuga	0	0	0.000	4	69	0.001	4	35 (± 49)	0.001 (± 0.001)
Scenedesmus quadricauda	0	0	0.000	8	42	0.002	8	21 (± 30)	0.001 (± 0.001)
Chrysophyceae	**4**	**21**	**0.031**	**9**	**48**	**0.033**	**13**	**35 (± 19)**	**0.032 (± 0.001)**
Dinobryon bavaricum	0	0	0.000	0	0	0.000	0	0	0.000
Dinobryon sertularia	0	0	0.000	6	32	0.008	6	16 (± 23)	0.004 (± 0.006)
Mallomonas sp.	4	21	0.031	3	16	0.025	7	19 (± 4)	0.028 (± 0.004)
Cryptophyceae	**28**	**148**	**0.022**	**138**	**728**	**0.134**	**166**	**438 (± 410)**	**0.078 (±0.079)**
Cryptomonas sp.	0	0	0.000	5	26	0.031	5	13 (± 18)	0.016 (± 0.022)
Rhodomonas sp.	28	148	0.022	133	702	0.103	161	425 (± 392)	0.063 (± 0.057)
Cyanophyceae	**0**	**0**	**0.000**	**0**	**0**	**0.000**	**0**	**0**	**0.000**
Aphanotheca sp.	0	0	0.000	0	0	0.000	0	0	0.000
Oscillatoria sp.	0	0	0.000	0	0	0.000	0	0	0.000
microplankton	**10**	**172**	**0.010**	**21**	**362**	**0.020**	**31**	**267 (± 134)**	**0.015 (± 0.007)**

Table B2. Mean density (#/ml) and bio-volume (mm^3/L) of phytoplankton collected in Boundary Reservoir in the fall, 2000.

	Boundary Forebay			Metaline Falls Bridge			Mean Totals (± standard deviation)		
Organism	n	Density (#/ml)	Bio-volume (mm^3/L)	n	Density (#/ml)	Bio-volume (mm^3/L)	n	Density (#/ml)	Bio-volume (mm^3/L)
Bacillariophyceae	**27**	**238**	**0.085**	**16**	**133**	**0.047**	**43**	**186 (± 74)**	**0.066 (± 0.027)**
Amphora sp.	1	5	0.009	0	0	0.000	1	3 (± 4)	0.005 (± 0.006)
Asterionella formosa	8	42	0.022	6	32	0.028	14	37 (± 7)	0.025 (± 0.004)
Melosira italica	0	0	0.000	0	0	0.000	0	0	0.000
Navicula sp.	0	0	0.000	0	0	0.000	0	0	0.000
Rhizosolenia sp.	10	53	0.046	6	32	0.016	16	43 (± 15)	0.031 (± 0.021)
Synedra sp.	8	138	0.008	4	69	0.003	12	104 (± 49)	0.006 (± 0.004)
Chlorophyceae	**22**	**378**	**0.051**	**18**	**309**	**0.041**	**40**	**344 (± 49)**	**0.046 (± 0.007)**
Ankistrodesmus falcatus	4	69	0.00	2	34	0.00	6	52 (± 25)	0.00 (± 0.000)
Chlamydomonas sp.	18	310	0.051	14	241	0.040	32	276 (± 49)	0.046 (± 0.008)
Cryptomonas sp.	0	0	0.000	0	0	0.000	0	0	0.000
Scenedesmus bijuga	0	0	0.000	0	0	0.000	0	0	0.000
Scenedesmus quadricauda	0	0	0.000	2	34	0.001	2	17 (± 24)	0.001 (± 0.001)
Chrysophyceae	**0**	**0**	**0.00**	**4**	**22**	**0.020**	**4**	**11 (± 16)**	**0.010 (± 0.014)**
Dinobryon bavaricum	0	0	0.000	2	11	0.003	2	6 (± 8)	0.002 (± 0.002)
Dinobryon sertularia	0	0	0.000	0	0	0.000	0	0	0.000
Mallomonas sp.	0	0	0.000	2	11	0.017	2	6 (± 8)	0.009 (± 0.012)
Cryptophyceae	**66**	**348**	**0.056**	**68**	**360**	**0.063**	**134**	**241 (± 151)**	**0.060 (± 0.005)**
Cryptomonas sp.	1	5	0.006	2	11	0.012	3	8 (± 4)	0.009 (± 0.004)
Rhodomonas sp.	65	343	0.050	66	349	0.051	131	346 (± 4)	0.051 (± 0.001)
Cyanophyceae	**53**	**339**	**0.008**	**10**	**172**	**0.015**	**63**	**256 (± 118)**	**0.012 (± 0.005)**
Aphanotheca sp.	48	253	0.001	0	0	0.000	48	127 (179)	0.001 (± 0.001)
Oscillatoria sp.	5	86	0.007	10	172	0.015	15	129 (61)	0.011 (± 0.006)
microplankton	**4**	**69**	**0.004**	**8**	**138**	**0.008**	**12**	**104 (± 49)**	**0.006 (± 0.003)**

Appendix C.

Table C1. Mean number and density (#/L; ± standard deviation) of zooplankton collected in the summer, 2000.

	Boundary Forebay		**Metaline Falls**		**Total**	
Organism	**n**	**Density (#/L)**	**n**	**Density (#/L)**	**n**	**Density (#/L)**
Cladocera	**63**	**1.7 (± 0.5)**	**43**	**1.4 (± 0.7)**	**106**	**1.6 (± 0.6)**
Daphnia galeata mendotae	63	1.7 (± 0.5)	43	1.4 (± 0.7)	106	1.6 (± 0.6)
Daphnia pulex	0	0	0	0	0	0
Daphnia rosea	0	0	0	0	0	0
other Cladocera	**100**	**2.7 (± 0.7)**	**114**	**3.7 (± 1.2)**	**214**	**3.2 (± 1.1)**
Alona sp.	0	0	2	0.1 (± 0.1)	2	<0.1 (± 0.1)
Bosmina longirostris	100	2.7 (± 0.7)	112	3.7 (± 1.2)	212	3.2 (± 1.0)
Copepoda	**1,058**	**26.0 (± 3.2)**	**608**	**19.8 (± 3.8)**	**1,666**	**22.9 (± 4.6)**
Calanoid copepodid	46	1.3 (± 0.2)	30	1.0 (± 0.5)	76	1.1 (± 0.4)
Cyclopoid copepodid	76	2.1 (± 1.1)	75	2.4 (± 0.5)	151	2.3 (± 0.8)
Diacyclops bicuspidatus thomasi	4	0.1 (± 0.1)	2	0.1 (± 0.1)	6	0.1 (± 0.1)
Epischura nevadensis	54	1.5 (± 0.4)	40	1.3 (± 0.2)	94	1.4 (± 0.3)
Hesperodiaptomus franciscanus	13	0.4 (± 0.1)	27	0.9 (± 0.4)	40	0.6 (± 0.4)
Mesocyclops edax	1	<0.1 (± 0.0)	0	0	1	<0.1 (± 0.0)
nauplii	864	20.8 (± 2.2)	434	14.2 (± 2.7)	1,298	17.5 (4.2)
Rotifera	**8**	**0.2 (± 0.1)**	**18**	**0.6 (± 0.4)**	**26**	**0.4 (± 0.3)**
Asplanchna brightwelli	0	0	1	<0.1 (± 0.1)	1	<0.1 (± 0.0)
Conochilus sp.	0	0	0	0	0	0
Kellicottia longispina	7	0.2 (± 0.1)	6	0.2 (± 0.1)	13	0.2 (± 0.1)
Keratella cochlearis	0	0	0	0	0	0
Lecane sp.	0	0	0	0	0	0
Notholca sp.	0	0	0	0	0	0
Polyarthra vulgaris	1	<0.1 (± 0.0)	11	0.4 (± 0.4)	12	0.2 (± 0.3)
Synchaeta pectinata	0	0	0	0	0	0
Trichocerca sp.	0	0	0	0	0	0
Total	**1,229**	**7.7 (± 11.2)**	**783**	**6.4 (± 8.4)**	**2,012**	**7.0 (± 9.7)**

Table C2. Mean number and density (#/L; ± standard deviation) of zooplankton collected in the fall, 2000.

	Boundary Forebay		Metaline Falls		Total	
Organism	**n**	**Density (#/L)**	**n**	**Density (#/L)**	**n**	**Density (#/L)**
Cladocera	**1**	**<0.1 (± 0.1)**	**3**	**0.1 (± 0.1)**	**4**	**0.1 (± 0.1)**
Daphnia galeata mendotae	0	0	1	<0.1 (± 0.1)	1	<0.1 (± 0.0)
Daphnia pulex	1	<0.1 (± 0.1)	0	0	1	<0.1 (± 0.0)
Daphnia rosea	0	0	2	0.1 (± 0.1)	2	<0.1 (± 0.1)
other Cladocera	**74**	**2.9 (± 0.9)**	**45**	**1.8 (± 0.4)**	**119**	**2.3 (± 0.9)**
Alona sp.	3	0.1 (± 0.1)	5	0.2 (± 0.2)	8	0.2 (± 0.1)
Bosmina longirostris	71	2.8 (± 0.9)	40	1.6 (± 0.5)	111	2.2 (± 0.9)
Copepoda	**58**	**2.3 (± 1.0)**	**58**	**2.3 (± 0.8)**	**116**	**2.3 (± 0.8)**
Calanoid copepodid	1	<0.1 (± 0.1)	5	0.2 (± 0.3)	6	0.1 (± 0.2)
Cyclopoid copepodid	10	0.4 (± 0.2)	14	0.6 (± 0.4)	24	0.5 (± 0.3)
Diacyclops bicuspidatus thomasi	1	<0.1 (± 0.1)	1	<0.1 (± 0.1)	2	<0.1 (± 0.1)
Epischura nevadensis	0	0	0	0	0	0
Hesperodiaptomus franciscanus	6	0.2 (± 0.0)	3	0.1 (± 0.0)	9	0.2 (± 0.1)
Mesocyclops edax	0	0	0	0	0	0
nauplii	40	1.6 (± 0.7)	35	1.4 (± 0.6)	75	1.5 (± 0.6)
Rotifera	**169**	**6.6 (± 0.6)**	**190**	**7.4 (± 0.4)**	**359**	**7.0 (± 0.6)**
Asplanchna brightwelli	0	0	0	0	0	0
Conochilus sp.	14	0.6 (± 0.4)	37	1.5 (± 0.5)	51	1.0 (± 0.6)
Kellicottia longispina	94	3.7 (± 0.9)	63	2.5 (± 0.9)	157	3.1 (± 1.0)
Keratella cochlearis	19	0.7 (± 0.2)	28	1.1 (± 0.7)	47	0.9 (± 0.5)
Lecane sp.	1	<0.1 (± 0.1)	5	0.2 (± 0.1)	6	0.1 (± 0.1)
Notholca sp.	0	0	1	<0.1 (± 0.1)	1	<0.1 (± 0.0)
Polyarthra vulgaris	32	1.3 (± 0.1)	41	1.6 (± 0.4)	73	1.4 (± 0.3)
Synchaeta pectinata	0	0	1	<0.1 (± 0.1)	1	<0.1 (± 0.0)
Trichocerca sp.	9	0.4 (± 0.0)	14	0.6 (± 0.1)	23	0.5 (± 0.1)
Total	**302**	**3.0 (± 2.6)**	**296**	**2.9 (± 2.9)**	**598**	**2.9 (± 2.7)**

Appendix D.

Table D1. Mean number and density (#/m^2; ± standard deviation) of macroinvertebrates collected on Hester-Dendy samplers set in Boundary Reservoir in the summer and fall, 2000.

	Boundary Forebay		Metaline Falls Bridge		Mean Totals	
Organism	**n**	**Density (#/m^2)**	**n**	**Density (#/m^2)**	**n**	**Density (#/m^2)**
Summer						
Amphipoda	13	33 (± 40)	0	0	13	17 (± 31)
Bryozoa	0	0	0	0	0	0
Cladocera	43	110 (± 184)	588	1,508 (± 1,304)	631	809 (± 1,131)
Coleoptera	0	0	0	0	0	0
Copepoda	3	8 (± 8)	0	0	3	3.8 (± 6.4)
Diptera	56	144 (± 112)	185	474 (± 385)	241	309 (± 312)
Ephemeroptera	1	3 (± 4)	8	21 (± 9)	9	12 (± 12)
Gastropoda	127	326 (± 284)	74	190 (± 138)	201	258 (± 213)
Haplotaxida	15	39 (± 43)	74	190 (± 329)	89	114 (± 225)
Hydracarina	59	151 (± 255)	14	36 (± 39)	73	94 (± 175)
Hydroida	3	8 (± 13)	18	46 (± 40)	21	27 (± 34)
Nematoda	1	3 (± 4)	0	0	1	1 (± 3)
Odonota	0	0	0	0	0	0
Ostracoda	21	54 (± 56)	1	3 (± 4)	22	28 (± 45)
Pelecypoda	1	3 (± 4)	0	0	1	1 (± 3)
Pharyngobdella	0	0	0	0	0	0
Plecoptera	0	0	0	0	0	0
Rhynchobdellida	8	21 (± 19)	0	0	8	10 (± 17)
Trichoptera	2	5 (± 9)	26	67 (± 54)	28	36 (± 48)
Total	**353**	**48 (± 118)**	**988**	**133 (± 437)**	**1,341**	**91 (± 321)**
Fall						
Amphipoda	13	33 (± 24)	0	0	13	17 (± 24)
Bryozoa	0	0	1	3 (± 4)	1	1 (± 3)
Cladocera	5	13 (± 9)	38	97 (± 149)	43	55 (± 105)
Coleoptera	0	0	7	18 (± 31)	7	9 (± 22)
Copepoda	61	156 (± 145)	2	5 (± 9)	63	81 (± 124)
Diptera	89	228 (± 97)	103	264 (± 112)	192	246 (± 96)
Ephemeroptera	0	0	5	13 (± 4)	5	6 (± 8)
Gastropoda	208	533 (± 498)	24	62 (± 67)	232	297 (± 410)
Haplotaxida	46	118 (± 191)	56	144 (± 184)	102	131 (± 168)
Hydracarina	3	8 (± 8)	12	31 (± 28)	15	19 (± 22)
Hydroida	83	213 (± 311)	54	139 (± 109)	137	176 (± 212)
Nematoda	0	0	0	0	0	0
Odonota	0	0	1	3 (± 4)	1	1 (± 3)
Ostracoda	56	144 (± 132)	3	8 (± 8)	59	76 (± 112)
Pelecypoda	1	3 (± 4)	0	0	1	1 (± 3)
Pharyngobdella	2	5 (± 4)	0	0	2	3 (± 4)
Plecoptera	0	0	1	3 (± 4)	1	1 (± 3)
Rhynchobdellida	1	3 (± 4)	0	0	1	1 (± 3)
Trichoptera	6	15 (± 15)	18	46 (± 43)	24	31 (± 33)
Total	**574**	**78 (± 182)**	**325**	**44 (± 89)**	**899**	**61 (± 143)**

Appendix E.

Table E1. Mean catch-per-unit-effort (CPUE) of fish collected in Section 1 in the Spring, 2000.

	Gear Type					
	Electrofishing		Horizontal Gill Netting		Vertical Gill Netting	
Species	**#/hour**	**n**	**#/GN night**	**n**	**#/VGN night**	**n**
Brown bullhead	0	2	1.0 (± 1.3)	2	0	0
Longnose sucker	0	2	0.5 (± 0.6)	2	0	0
Largescale sucker	6.0 (± 0.0)	2	2.5 (± 0.6)	2	0	0
Lake trout	0	2	0.5 (± 0.6)	2	0	0
Northern pikeminnow	0	2	8.0 (± 5.1)	2	0	0
Peamouth	3.0 (± 3.8)	2	3.0 (± 3.8)	2	0	0
Redside shiner	6.0 (± 0.0)	2	1.5 (± 1.9)	2	0	0
Smallmouth bass	0	2	1.0 (± 1.3)	2	0	0

Table E2. Mean catch-per-unit-effort (CPUE) of fish collected in Section 2 in the Spring, 2000.

	Gear Type					
	Electrofishing		Gill Netting		Vertical Gill Netting	
Species	**#/hour**	**n**	**#/GN night**	**n**	**#/VGN night**	**n**
Largescale sucker	15.8 (± 7.4)	8	4.3 (± 2.6)	4	0	4
Lake trout	0	8	0.3 (± 0.3)	4	0	4
Northern pikeminnow	15.8 (± 9.0)	8	7.8 (± 3.5)	4	0	4
Peamouth	2.3 (± 2.9)	8	2.5 (± 1.5)	4	0	4
Rainbow trout	0.8 (± 1.0)	8	0	4	0	4
Redside shiner	9.0 (± 5.2)	8	2.8 (± 2.0)	4	0	4
Smallmouth bass	0.8 (± 1.0)	8	0.8 (± 1.0)	4	0	4
Mountain whitefish	1.5 (± 1.3)	8	0	4	0	4
Yellow perch	0	8	0.3 (± 0.3)	4	0	4

Table E3. Mean catch-per-unit-effort (CPUE) of fish collected in Section 3 in the Spring, 2000.

	Gear Type					
	Electrofishing		Horizontal Gill Netting		Vertical Gill Netting	
Species	**#/hour**	**n**	**#/GN night**	**n**	**#/VGN night**	**n**
Largescale sucker	33.0 (± 26.9)	2	2.0 (± 0)	1	0	0
Northern pikeminnow	3.0 (± 3.8)	2	9.0 (± 0)	1	0	0
Peamouth	0	2	7.0 (± 0)	1	0	0
Mountain whitefish	3.0 (± 3.8)	2	0	1	0	0

Table E4. Mean catch-per-unit-effort (CPUE) of fish collected in Section 4 in the Spring, 2000.

	Gear Type					
	Electrofishing		**Horizontal Gill Netting**		**Vertical Gill Netting**	
Species	**#/hour**	**n**	**#/GN night**	**n**	**#/VGN night**	**n**
Brown trout	3.0 (± 2.2)	4	0	2	0	0
Largemouth bass	1.5 (± 1.9)	4	0	2	0	0
Largescale sucker	46.5 (± 11.5)	4	0.5 (± 0.6)	2	0	0
Northern pikeminnow	24.0 (± 15.7)	4	0.5 (± 0.6)	2	0	0
Peamouth	16.5 (± 12.3)	4	0.5 (± 0.6)	2	0	0
Rainbow trout	3.0 (± 2.2)	4	0	2	0	0
Mountain whitefish	15.0 (± 8.0)	4	0	2	0	0

Table E5. Mean catch-per-unit-effort (CPUE) of fish collected in all sections in the Spring, 2000.

	Gear Type					
	Electrofishing		**Horizontal Gill Netting**		**Vertical Gill Netting**	
Species	**#/hour**	**n**	**#/GN night**	**n**	**#/VGN night**	**n**
Brown bullhead	0	16	0.2 (± 0.3)	9	0	4
Brown trout	0.8 (± 0.7)	16	0	9	0	4
Largemouth bass	0.4 (± 0.5)	16	0	9	0	4
Longnose sucker	0	16	0.1 (± 0.1)	9	0	4
Largescale sucker	24.4 (± 7.0)	16	2.8 (± 1.3)	9	0	4
Lake trout	0	16	0.2 (± 0.2)	9	0	4
Northern pikeminnow	14.3 (± 6.2)	16	6.3 (± 2.2)	9	0	4
Peamouth	5.6 (± 3.7)	16	2.7 (± 1.2)	9	0	4
Rainbow trout	1.1 (± 0.8)	16	0	9	0	4
Redside shiner	5.3 (± 2.9)	16	1.6 (± 1.0)	9	0	4
Smallmouth bass	0.4 (± 0.5)	16	0.6 (± 0.5)	9	0	4
Mountain whitefish	4.9 (± 2.7)	16	0	9	0	4
Yellow perch	0	16	0.1 (± 0.1)	9	0	4

Table E6. Mean catch-per-unit-effort (CPUE) of fish collected in Section 1 in the Summer, 2000.

	Gear Type					
	Electrofishing		**Horizontal Gill Netting**		**Vertical Gill Netting**	
Species	**#/hour**	**n**	**#/GN night**	**n**	**#/VGN night**	**n**
Longnose sucker	0	2	2.0 (± 1.3)	2	0	4
Largescale sucker	87.0 (± 3.8)	2	22.0 (± 20.5)	2	0	4
Northern pikeminnow	48.0 (± 30.8)	2	22.5 (± 17.3)	2	0.5 (± 0.6)	4
Peamouth	3.0 (± 3.8)	2	3.5 (± 1.9)	2	0.5 (± 0.6)	4
Rainbow trout	3.0 (± 3.8)	2	0	2	0	4
Redside shiner	3.0 (± 3.8)	2	1.5 (± 1.9)	2	0	4
Smallmouth bass	30.0 (± 15.4)	2	3.0 (± 3.8)	2	0	4
Tench	0	2	0.5 (± 0.6)	2	0	4
Yellow perch	0	2	8.0 (± 2.6)	2	0	4

Table E7. Mean catch-per-unit-effort (CPUE) of fish collected in Section 2 in the Summer, 2000.

	Gear Type					
	Electrofishing		Horizontal Gill Netting		Vertical Gill Netting	
Species	#/hour	n	#/GN night	n	#/VGN night	n
Black crappie	0	8	0.3 (± 0.3)	4	0	4
Longnose sucker	0.8 (± 1.0)	8	0	4	0	4
Largescale sucker	33.8 (± 13.5)	8	1.0 (± 0.9)	4	0	4
Northern pikeminnow	18.0 (± 8.1)	8	5.0 (± 2.5)	4	0	4
Peamouth	0	8	0.8 (± 0.6)	4	0	4
Redside shiner	34.5 (± 16.4)	8	0.5 (± 0.4)	4	0	4
Smallmouth bass	6.0 (± 3.3)	8	0.8 (± 0.6)	4	0	4
Mountain whitefish	3.0 (± 2.5)	8	0.3 (± 0.3)	4	0	4
Yellow perch	3.8 (± 2.9)	8	0	4	0	4

Table E8. Mean catch-per-unit-effort (CPUE) of fish collected in Section 3 in the Summer, 2000.

	Gear Type					
	Electrofishing		Horizontal Gill Netting		Vertical Gill Netting	
Species	#/hour	n	#/GN night	n	#/VGN night	n
Brown bullhead	30.0 (± 15.4)	2	0.5 (± 0.7)	2	0	0
Black crappie	3.0 (± 3.8)	2	0	2	0	0
Brown trout	0	2	0.1 (± 0.1)	2	0	0
Largemouth bass	6.0 (± 0.0)	2	0	2	0	0
Longnose sucker	21.0 (± 19.2)	2	0.1 (± 0.1)	2	0	0
Largescale sucker	150.0 (± 161.5)	2	0.1 (± 0.1)	2	0	0
Northern pikeminnow	30.0 (± 23.1)	2	2.7 (± 0.2)	2	0	0
Peamouth	0	2	0.8 (± 0.8)	2	0	0
Pumpkinseed	6.0 (± 0.0)	2	0.1 (± 0.1)	2	0	0
Redside shiner	6.0 (± 0.0)	2	0	2	0	0
Smallmouth bass	3.0 (± 3.8)	2	0.1 (± 0.1)	2	0	0
Tench	24.0 (± 7.7)	2	0.2 (± 0.2)	2	0	0
Yellow perch	12.0 (± 0.0)	2	0.1 (± 0.1)	2	0	0

Table E9. Mean catch-per-unit-effort (CPUE) of fish collected in Section 4 in the Summer, 2000.

	Gear Type					
	Electrofishing		Horizontal Gill Netting		Vertical Gill Netting	
Species	#/hour	n	#/GN night	n	#/VGN night	n
Brown bullhead	4.5 (± 5.8)	4	0	2	0	0
Black crappie	0	4	1.5 (± 1.9)	2	0	0
Burbot	4.5 (± 3.7)	4	0	2	0	0
Longnose sucker	13.5 (± 6.6)	4	0	2	0	0
Largescale sucker	46.5 (± 21.4)	4	0	2	0	0
Northern pikeminnow	54.0 (± 28.9)	4	20.5 (± 19.9)	2	0	0
Peamouth	0	4	1.0 (± 1.3)	2	0	0
Pumpkinseed	1.5 (± 1.9)	4	0	2	0	0
Rainbow trout	0	4	1.0 (± 1.3)	2	0	0
Redside shiner	15.0 (± 12.0)	4	0	2	0	0
Smallmouth bass	0	4	1.0 (± 1.3)	2	0	0
Tench	4.5 (± 3.7)	4	0.5 (± 0.6)	2	0	0
Mountain whitefish	12.0 (± 7.0)	4	0.5 (± 0.6)	2	0	0
Yellow perch	40.5 (± 32.0)	4	5.5 (± 7.1)	2	0	0

Table E10. Mean catch-per-unit-effort (CPUE) of fish collected in all sections in the Summer, 2000.

	Gear Type					
	Electrofishing		Horizontal Gill Netting		Vertical Gill Netting	
Species	**#/hour**	**n**	**#/GN night**	**n**	**#/VGN night**	**n**
Brown bullhead	4.9 (± 3.7)	16	0.6 (± 0.8)	10	0	8
Black crappie	0.4 (± 0.5)	16	0.4 (± 0.4)	10	0	8
Brown trout	0	16	0.1 (± 0.1)	10	0	8
Burbot	1.1 (± 1.0)	16	0	10	0	8
Largemouth bass	1.1 (± 0.8)	16	0	10	0	8
Longnose sucker	6.4 (± 3.5)	16	0.5 (± 0.4)	10	0	8
Largescale sucker	58.1 (± 21.1)	16	4.9 (± 4.8)	10	0	8
Northern pikeminnow	32.3 (± 9.8)	16	13.8 (± 5.2)	10	0.3 (± 0.3)	8
Peamouth	0.4 (± 0.5)	16	2.2 (± 1.1)	10	0.3 (± 0.3)	8
Pumpkinseed	1.1 (± 0.8)	16	0.1 (± 0.1)	10	0	8
Rainbow trout	0.4 (± 0.5)	16	0.2 (± 0.3)	10	0	8
Redside shiner	22.1 (± 9.4)	16	0.5 (± 0.4)	10	0	8
Smallmouth bass	7.1 (± 3.6)	16	1.3 (± 0.9)	10	0	8
Tench	4.1 (± 2.8)	16	0.4 (± 0.3)	10	0	8
Mountain whitefish	4.5 (± 2.5)	16	0.2 (± 0.2)	10	0	8
Yellow perch	13.5 (± 9.0)	16	2.8 (± 1.8)	10	0	8

Table E11. Mean catch-per-unit-effort (CPUE) of fish collected in Section 1 in the Fall, 2000.

	Gear Type					
	Electrofishing		Horizontal Gill Netting		Vertical Gill Netting	
Species	**#/hour**	**n**	**#/GN night**	**n**	**#/VGN night**	**n**
Longnose sucker	0	2	0.5 (± 0.6)	2	0	4
Largescale sucker	9.0 (± 3.8)	2	20.0 (± 2.6)	2	0	4
Northern pikeminnow	21.0 (± 3.8)	2	19.5 (± 7.0)	2	0	4
Peamouth	0	2	5.0 (± 5.1)	2	0	4
Pumpkinseed	0	2	0.5 (± 0.6)	2	0	4
Redside shiner	15.0 (± 3.8)	2	0.5 (± 0.6)	2	0	4
Smallmouth bass	0	2	6.5 (± 5.8)	2	0	4
Yellow perch	0	2	2.5 (± 1.9)	2	0	4

Table E12. Mean catch-per-unit-effort (CPUE) of fish collected in Section 2 in the Fall, 2000.

	Gear Type					
	Electrofishing		Horizontal Gill Netting		Vertical Gill Netting	
Species	**#/hour**	**n**	**#/GN night**	**n**	**#/VGN night**	**n**
Longnose Sucker	0.8 (± 1.0)	8	0.3 (± 0.3)	4	0	4
Largescale Sucker	53.1 (± 12.6)	8	1.5 (± 1.5)	4	0	4
Northern Pikeminnow	17.2 (± 5.9)	8	8.3 (± 2.7)	4	0	4
Peamouth	3.7 (± 3.2)	8	2.5 (± 1.5)	4	0	4
Redside Shiner	56.1 (± 22.9)	8	0.3 (± 0.3)	4	0	4
Smallmouth Bass	26.2 (± 9.7)	8	0.5 (± 0.6)	4	0	4
Tench	0.7 (± 1.0)	8	0	4	0	4
Mountain Whitefish	1.5 (± 1.9)	8	0	4	0	4
Yellow Perch	12.7 (± 13.3)	8	1.3 (± 1.6)	4	0	4

Table E13. Mean catch-per-unit-effort (CPUE) of fish collected in Section 3 in the Fall, 2000.

	Gear Type					
	Electrofishing		Horizontal Gill Netting		Vertical Gill Netting	
Species	**#/hour**	**n**	**#/GN night**	**n**	**#/VGN night**	**n**
Cutthroat trout	6.0 (± 7.7)	2	0	2	0	0
Longnose sucker	6.0 (± 7.7)	2	0	2	0	0
Largescale sucker	66.0 (± 30.8)	2	3.5 (± 4.5)	2	0	0
Northern pikeminnow	108.0 (± 130.7)	2	22.0 (± 11.5)	2	0	0
Peamouth	0	2	9.5 (± 5.8)	2	0	0
Rainbow trout	9.0 (± 3.8)	2	0	2	0	0
Redside shiner	9.0 (± 3.8)	2	0	2	0	0
Tench	9.0 (± 11.5)	2	0	2	0	0
Mountain whitefish	21.0 (± 19.2)	2	1.0 (± 1.3)	2	0	0

Table E14. Mean catch-per-unit-effort (CPUE) of fish collected in Section 4 in the Fall, 2000.

	Gear Type					
	Electrofishing		Horizontal Gill Netting		Vertical Gill Netting	
Species	**#/hour**	**n**	**#/GN night**	**n**	**#/VGN night**	**n**
Black crappie	0	4	0.5 (± 0.6)	2	0	0
Brown trout	4.5 (± 3.7)	4	0	2	0	0
Burbot	1.5 (± 1.9)	4	0	2	0	0
Largemouth bass	3.0 (± 3.8)	4	0.5 (± 0.6)	2	0	0
Longnose sucker	4.5 (± 3.7)	4	0	2	0	0
Largescale sucker	69.0 (± 28.2)	4	1.5 (± 1.9)	2	0	0
Northern Pikeminnow	97.5 (± 39.6)	4	21.5 (± 17.3)	2	0	0
Peamouth	1.5 (± 1.9)	4	8.5 (± 9.6)	2	0	0
Rainbow trout	1.5 (± 1.9)	4	0	2	0	0
Redside shiner	30.0 (± 16.9)	4	0	2	0	0
Smallmouth bass	36.0 (± 38.6)	4	0.5 (± 0.6)	2	0	0
Tench	10.5 (± 13.5)	4	1.5 (± 1.9)	2	0	0
Mountain whitefish	4.5 (± 5.8)	4	0.5 (± 0.6)	2	0	0
Yellow perch	9.0 (± 16.9)	4	1.5 (± 1.9)	2	0	0

Table E15. Mean catch-per-unit-effort (CPUE) of fish collected in all sections in the Fall, 2000.

	Gear Type					
	Electrofishing		Horizontal Gill Netting		Vertical Gill Netting	
Species	#/hour	n	#/GN night	n	#/VGN night	n
Black crappie	0	16	0.1 (± 0.1)	10	0	8
Brown trout	1.1 (± 1.0)	16	0	10	0	8
Burbot	0.4 (± 0.5)	16	0	10	0	8
Cutthroat trout	0.8 (± 1.0)	16	0	10	0	8
Largemouth bass	1.5 (± 1.1)	16	0.1 (± 0.1)	10	0	8
Longnose sucker	2.3 (± 1.4)	16	0.2 (± 0.2)	10	0	8
Largescale sucker	53.3 (± 11.0)	16	5.6 (± 3.2)	10	0	8
Northern pikeminnow	49.1 (± 20.2)	16	15.9 (± 4.3)	10	0	8
Peamouth	2.3 (± 1.7)	16	5.6 (± 2.3)	10	0	8
Pumpkinseed	0	16	0.1 (± 0.1)	10	0	8
Rainbow trout	1.8 (± 1.2)	16	0	10	0	8
Redside shiner	38.6 (± 13.3)	16	0.2 (± 0.2)	10	0	8
Smallmouth bass	28.9 (± 11.1)	16	1.6 (± 1.4)	10	0	8
Tench	4.1 (± 3.6)	16	0.3 (± 0.4)	10	0	8
Mountain whitefish	4.5 (± 3.2)	16	0.3 (± 0.3)	10	0	8
Yellow perch	9.8 (± 7.1)	16	1.3 (± 0.8)	10	0	8

Appendix F.

Table F1. Species composition, by number and weight, and the size range of fish collected in Section 1 in the Spring, 2000.

	Species Composition					
	by Number		**by Weight**		**Size Range (mm TL)**	
Species	**(#)**	**(%n)**	**(kg)**	**(%w)**	**Min**	**Max**
Brown bullhead	2	4.9	0.5	4.8	231	279
Longnose sucker	1	2.4	0.4	3.9	346	346
Largescale sucker	7	17.1	2.6	24.4	221	456
Lake trout	1	2.4	0.3	2.5	318	318
Northern pikeminnow	16	39.0	3.9	36.4	234	386
Peamouth	7	17.1	1.6	14.7	141	357
Redside shiner	5	12.2	0.1	0.9	116	141
Smallmouth bass	2	4.9	1.3	12.5	366	374

Table F2. Species composition, by number and weight, and the size range of fish collected in Section 2 in the Spring, 2000.

	Species Composition					
	by Number		**by Weight**		**Size Range (mm TL)**	
Species	**(#)**	**(%n)**	**(kg)**	**(%w)**	**Min**	**Max**
Largescale sucker	38	28.1	13.0	36.0	218	505
Lake trout	1	0.7	0.7	1.9	474	474
Northern pikeminnow	52	38.5	16.1	44.7	179	492
Peamouth	13	9.6	1.8	5.1	234	340
Rainbow trout	1	0.7	0.3	1.0	360	360
Redside shiner	23	17.0	0.4	1.1	112	156
Smallmouth bass	4	3.0	3.0	8.3	328	390
Mountain whitefish	2	1.5	0.5	1.3	275	322
Yellow perch	1	0.7	0.2	0.6	236	236

Table F3. Species composition, by number and weight, and the size range of fish collected in Section 3 in the Spring, 2000.

	Species Composition					
	by Number		**by Weight**		**Size Range (mm TL)**	
Species	**(#)**	**(%n)**	**(kg)**	**(%w)**	**Min**	**Max**
Largescale sucker	13	41.9	6.9	69.8	263	442
Northern pikeminnow	10	32.3	1.9	19.3	239	328
Peamouth	7	22.6	0.9	9.6	244	267
Mountain whitefish	1	3.2	0.1	1.3	252	252

Table F4. Species composition, by number and weight, and the size range of fish collected in Section 4 in the Spring, 2000.

	Species Composition					
	by Number		by Weight		Size Range (mm TL)	
Species	**(#)**	**(%n)**	**(kg)**	**(%w)**	**Min**	**Max**
Brown trout	2	2.6	1.2	3.2	415	439
Largemouth bass	1	1.3	1.2	3.2	432	432
Largescale sucker	32	42.1	21.2	57.9	226	495
Northern pikeminnow	17	22.4	6.6	18.0	264	418
Peamouth	12	15.8	1.8	5.0	235	349
Rainbow trout	2	2.6	1.2	3.4	358	406
Mountain whitefish	10	13.2	3.4	9.3	296	377

Table F5. Species composition, by number and weight, and the size range of fish collected in all sections in the Spring, 2000.

	Species Composition					
	by Number		by Weight		Size Range (mm TL)	
Species	**(#)**	**(%n)**	**(kg)**	**(%w)**	**Min**	**Max**
Brown bullhead	2	0.7	0.5	0.6	231	279
Brown trout	2	0.7	1.2	1.3	415	439
Largemouth bass	1	0.4	1.2	1.2	432	432
Longnose sucker	1	0.4	0.4	0.5	346	346
Largescale sucker	90	31.8	43.7	46.8	218	505
Lake trout	2	0.7	1.0	1.0	318	474
Northern pikeminnow	95	33.6	28.6	30.6	179	492
Peamouth	39	13.8	6.2	6.6	141	357
Rainbow trout	3	1.1	1.6	1.7	358	406
Redside shiner	28	9.9	0.5	0.5	112	156
Smallmouth bass	6	2.1	4.3	4.7	328	390
Mountain whitefish	13	4.6	4.0	4.3	252	377
Yellow perch	1	0.4	0.2	0.2	236	236

Table F6. Species composition, by number and weight, and the size range of fish collected in Section 1 in the Summer, 2000.

	Species Composition					
	by Number		by Weight		Size Range (mm TL)	
Species	**(#)**	**(%n)**	**(kg)**	**(%w)**	**Min**	**Max**
Longnose sucker	4	2.1	2.3	4.9	356	396
Largescale sucker	73	38.6	18.9	41.2	98	476
Northern pikeminnow	63	33.3	18.5	40.3	200	526
Peamouth	10	5.3	1.7	3.7	237	343
Rainbow trout	1	0.5	0.4	0.9	326	326
Redside shiner	4	2.1	0.1	0.2	125	135
Smallmouth bass	17	9.0	1.4	3.1	90	245
Tench	1	0.5	0.8	1.8	390	390
Yellow perch	16	8.5	1.7	3.7	180	226

Table F7. Species composition, by number and weight, and the size range of fish collected in Section 2 in the Summer, 2000.

	Species Composition					
	by Number		by Weight		Size Range (mm TL)	
Species	**(#)**	**(%n)**	**(kg)**	**(%w)**	**Min**	**Max**
Black crappie	1	0.6	0.1	0.3	177	177
Longnose sucker	1	0.6	0.1	0.4	230	230
Largescale sucker	49	29.3	18.9	58.3	205	472
Northern pikeminnow	44	26.3	7.8	24.2	192	475
Peamouth	3	1.8	0.5	1.5	241	270
Redside shiner	48	28.7	0.8	2.5	58	180
Smallmouth bass	11	6.6	1.6	5.1	160	362
Mountain whitefish	5	3.0	2.3	7.2	300	411
Yellow perch	5	3.0	0.2	0.6	105	177

Table F8. Species composition, by number and weight, and the size range of fish collected in Section 3 in the Summer, 2000.

	Species Composition					
	by Number		by Weight		Size Range (mm TL)	
Species	**(#)**	**(%n)**	**(kg)**	**(%w)**	**Min**	**Max**
Brown bullhead	16	10.5	4.4	6.8	240	292
Black crappie	1	0.7	0.1	0.2	188	188
Brown trout	1	0.7	1.0	1.6	452	452
Largemouth bass	2	1.3	0.9	1.4	107	407
Longnose sucker	8	5.3	4.1	6.4	353	396
Largescale sucker	51	33.6	32.6	50.5	350	497
Northern pikeminnow	41	27.0	10.4	16.1	218	548
Peamouth	10	6.6	1.4	2.2	247	272
Pumpkinseed	3	2.0	0.2	0.3	112	167
Redside shiner	2	1.3	0.1	0.1	76	170
Smallmouth bass	2	1.3	1.2	1.9	341	402
Tench	10	6.6	7.7	12.0	347	415
Yellow perch	5	3.3	0.5	0.7	158	202

Table F9. Species composition, by number and weight, and the size range of fish collected in Section 4 in the Summer, 2000.

	Species Composition					
	by Number		by Weight		Size Range (mm TL)	
Species	**(#)**	**(%n)**	**(kg)**	**(%w)**	**Min**	**Max**
Brown bullhead	3	1.6	0.7	1.8	243	260
Black crappie	3	1.6	0.5	1.2	201	218
Burbot	3	1.6	0.4	1.1	241	347
Longnose sucker	9	4.7	2.9	7.5	107	419
Largescale sucker	29	15.1	13.5	34.3	32	469
Northern pikeminnow	77	40.1	12.2	31.0	50	461
Peamouth	2	1.0	0.3	0.7	251	269
Pumpkinseed	1	0.5	0.0	0.1	110	110
Rainbow trout	2	1.0	1.2	3.0	391	395
Redside shiner	10	5.2	0.1	0.4	68	155
Smallmouth bass	2	1.0	1.6	4.0	367	395
Tench	4	2.1	2.9	7.4	365	423
Mountain whitefish	9	4.7	0.4	1.0	91	315
Yellow perch	38	19.8	2.6	6.5	52	221

Table F10. Species composition, by number and weight, and the size range of fish collected in all sections in the Summer, 2000.

	Species Composition					
	by Number		by Weight		Size Range (mm TL)	
Species	**(#)**	**(%n)**	**(kg)**	**(%w)**	**Min**	**Max**
Brown bullhead	19	2.7	5.1	2.8	240	292
Black crappie	5	0.7	0.7	0.4	177	218
Brown trout	1	0.1	1.0	0.6	452	452
Burbot	3	0.4	0.4	0.2	241	347
Largemouth bass	2	0.3	0.9	0.5	107	407
Longnose sucker	22	3.1	9.5	5.2	107	419
Largescale sucker	202	28.9	83.9	46.0	32	497
Northern pikeminnow	225	32.1	48.9	26.8	50	548
Peamouth	25	3.6	3.9	2.1	237	343
Pumpkinseed	4	0.6	0.2	0.1	110	167
Rainbow trout	3	0.4	1.6	0.9	326	395
Redside shiner	64	9.1	1.1	0.6	58	180
Smallmouth bass	32	4.6	5.9	3.2	90	402
Tench	15	2.1	11.5	6.3	347	423
Mountain whitefish	14	2.0	2.7	1.5	91	411
Yellow perch	64	9.1	4.9	2.7	52	226

Table F11. Species composition, by number and weight, and the size range of fish collected in Section 1 in the Fall, 2000.

	Species Composition					
	by Number		by Weight		Size Range (mm TL)	
Species	**(#)**	**(%n)**	**(kg)**	**(%w)**	**Min**	**Max**
Longnose sucker	1	0.8	0.3	1.1	377	377
Largescale sucker	43	34.4	13.1	46.7	226	445
Northern pikeminnow	46	36.8	9.4	33.4	222	424
Peamouth	10	8.0	2.2	7.8	259	320
Pumpkinseed	1	0.8	0.1	0.2	120	120
Redside shiner	6	4.8	0.2	0.5	128	146
Smallmouth bass	13	10.4	2.2	8.0	197	327
Yellow perch	5	4.0	0.6	2.3	196	248

Table F12. Species composition, by number and weight, and the size range of fish collected in Section 2 in the Fall, 2000.

	Species Composition					
	by Number		by Weight		Size Range (mm TL)	
Species	**(#)**	**(%n)**	**(kg)**	**(%w)**	**Min**	**Max**
Largemouth bass	1	0.3	0.0	0.0	103	103
Longnose sucker	2	0.7	0.5	1.3	235	381
Largescale sucker	77	26.6	22.4	53.8	48	478
Northern pikeminnow	56	19.4	9.0	21.7	53	422
Peamouth	15	5.2	1.9	4.6	70	274
Rainbow trout	1	0.3	0.2	0.4	237	237
Redside shiner	76	26.3	1.5	3.7	43	176
Smallmouth bass	37	12.8	2.5	6.1	55	390
Tench	1	0.3	1.1	2.6	432	432
Mountain whitefish	2	0.7	0.7	1.7	330	345
Yellow perch	21	7.3	1.6	4.0	70	245

Table F13. Species composition, by number and weight, and the size range of fish collected in Section 3 in the Fall, 2000.

	Species Composition					
	by Number		by Weight		Size Range (mm TL)	
Species	**(#)**	**(%n)**	**(kg)**	**(%w)**	**Min**	**Max**
Cutthroat trout	2	1.2	0.5	2.2	312	375
Largemouth bass	1	0.6	0.0	0.0	81	81
Longnose sucker	2	1.2	0.4	1.6	68	337
Largescale sucker	29	17.0	6.7	27.2	46	552
Northern pikeminnow	79	46.2	10.1	41.0	114	550
Peamouth	19	11.1	3.1	12.5	254	280
Rainbow trout	3	1.8	0.3	1.1	182	260
Redside shiner	3	1.8	0.1	0.4	97	170
Smallmouth bass	18	10.5	0.1	0.5	59	101
Tench	3	1.8	2.1	8.6	381	404
Mountain whitefish	9	5.3	1.2	4.7	109	346
Yellow perch	3	1.8	0.0	0.1	87	103

Table F14. Species composition, by number and weight, and the size range of fish collected in Section 4 in the Fall, 2000.

	Species Composition					
	by Number		**by Weight**		**Size Range (mm TL)**	
Species	**(#)**	**(%n)**	**(kg)**	**(%w)**	**Min**	**Max**
Black crappie	1	0.4	0.1	0.1	135	135
Brown trout	3	1.2	0.8	1.8	271	414
Burbot	1	0.4	0.3	0.6	431	431
Largemouth bass	3	1.2	1.3	2.8	191	370
Longnose sucker	3	1.2	1.7	3.6	375	434
Largescale sucker	48	18.9	15.7	34.2	44	517
Northern pikeminnow	108	42.5	12.4	27.1	96	438
Peamouth	18	7.1	3.2	7.1	155	332
Rainbow trout	1	0.4	0.7	1.5	480	480
Redside shiner	20	7.9	0.2	0.5	88	165
Smallmouth bass	25	9.8	0.6	1.2	58	266
Tench	10	3.9	7.6	16.5	145	460
Mountain whitefish	4	1.6	0.7	1.5	121	347
Yellow perch	9	3.5	0.6	1.4	70	252

Table F15. Species composition, by number and weight, and the size range of fish collected in all sections in the Fall, 2000.

	Species Composition					
	by Number		**by Weight**		**Size Range (mm TL)**	
Species	**(#)**	**(%n)**	**(kg)**	**(%w)**	**Min**	**Max**
Black crappie	1	0.1	0.1	0.0	135	135
Brown trout	3	0.4	0.8	0.6	271	414
Burbot	1	0.1	0.3	0.2	431	431
Cutthroat trout	2	0.2	0.5	0.4	312	375
Largemouth bass	5	0.6	1.3	0.9	81	370
Longnose sucker	8	1.0	2.9	2.1	68	434
Largescale sucker	197	23.5	57.9	41.3	44	552
Northern pikeminnow	289	34.4	40.9	29.2	53	550
Peamouth	62	7.4	10.5	7.5	70	332
Pumpkinseed	1	0.1	0.1	0.0	120	120
Rainbow trout	5	0.6	1.1	0.8	182	480
Redside shiner	105	12.5	2.0	1.4	43	176
Smallmouth bass	93	11.1	5.5	3.9	55	390
Tench	14	1.7	10.8	7.7	145	460
Mountain whitefish	15	1.8	2.6	1.8	109	347
Yellow perch	38	4.5	2.9	2.1	70	252

Appendix G.

Table G1. Starting and ending Latitude and Longitude (decimal degrees, DD) for the tributary reaches surveyed in 2000.

Stream	Reach	Start Lat. (DD)	Start Long. (DD)	End Lat. (DD)	End Long. (DD)
Fence Creek	1	48.96485	117.38711	48.96247	117.37329
Flume Creek	1	48.92667	117.41411	48.91770	117.38896
Flume Creek	2	48.91770	117.38896	48.90279	117.38563
Flume Creek	3	48.90279	117.38563	48.87396	117.38634
Flume Creek	4	48.87396	117.38634	48.87679	117.37598
Lime Creek	1	48.97001	117.30856	48.97046	117.31253
Lime Creek	2	48.97195	117.31415	48.97088	117.31769
Lime Creek	3	48.97088	117.31769	48.96819	117.32494
Lime Creek	4	48.96819	117.32494	48.96277	117.33338
Lunch Creek	1	48.83749	117.45478	48.83251	117.43824
Lunch Creek	2	48.83251	117.43824	48.82834	117.43132
Lunch Creek	3	48.82834	117.43132	48.82621	117.41358
Pewee Creek	1	48.96243	117.37334	48.96371	117.36708
Pewee Creek	2	48.96371	117.36708	48.97098	117.35489
Sand Creek	1	48.80349	117.33858	48.80580	117.35172
Sand Creek	2	48.80580	117.35172	48.80135	117.36543
Sand Creek	3	48.80135	117.36543	48.79776	117.37895
Sand Creek	4	48.79776	117.37895	48.79289	117.39262
Sand Creek	5	48.80081	117.39605	48.81172	117.39642
Slate Creek	1	48.96907	117.19105	48.95962	117.20512
Slate Creek	2	48.95962	117.20512	48.95111	117.21595
Slate Creek	3	48.95111	117.21595	48.95221	117.22794
Slate Creek	4	48.95221	117.22794	48.95734	117.24296
Slate Creek	5	48.95734	117.24296	48.94232	117.28376
Slate Creek	6	48.94232	117.28376	48.93695	117.29757
Slate Creek	7	48.93695	117.29757	48.93084	117.30252
Slate Creek	8	48.93084	117.30252	48.92767	117.31362
Slate Creek	9	48.92767	117.31362	48.92336	117.32504
Sullivan Creek	1	48.91707	117.06336	48.90688	117.07685
Sullivan Creek	2	48.90688	117.07685	48.89865	117.08383
Sullivan Creek	3	48.89865	117.08383	48.88433	117.10304
Sullivan Creek	4	48.88433	117.10304	48.87113	117.14437
Sullivan Creek	5	48.87113	117.14437	48.86692	117.15047
Sullivan Creek	6	48.86692	117.15047	48.85865	117.15945
Sullivan Creek	7	48.85865	117.15945	48.85038	117.17415
Sullivan Creek	8	48.85038	117.17415	48.84732	117.18784
Sullivan Creek	9	48.84732	117.18784	48.84336	117.19357
Sullivan Creek	10	48.84336	117.19357	48.83761	117.21325
Sullivan Creek	11	48.83761	117.21325	48.83609	117.22220
Sullivan Creek	12	48.83609	117.22220	48.83551	117.22756
Sullivan Creek	13	48.83551	117.22756	48.83410	117.23391
Sullivan Creek	14	48.83410	117.23391	48.83923	117.26655
Sullivan Creek	15	48.83923	117.26655	48.84568	117.28099
Sullivan Creek	16	48.84568	117.28099	48.84602	117.28655
Sullivan Creek	17	48.84602	117.28655	48.85420	117.29361
Sullivan Creek	18	48.85868	117.30301	48.86002	117.32822

Table G1. Continued.

Stream	Reach	Start Lat. (DD)	Start Long. (DD)	End Lat. (DD)	End Long. (DD)
Sullivan Creek	19	48.86002	117.32822	48.86033	117.36374
Sullivan Creek	20	48.86033	117.36374	48.86454	117.36796
Sweet Creek	1	48.85193	117.43501	48.84594	117.42258
Sweet Creek	2	48.84594	117.42258	48.82625	117.41353
Sweet Creek	3	48.82625	117.41353	48.82405	117.39974
Sweet Creek	4	48.82405	117.39974	48.82288	117.39725
Sweet Creek	5	48.82288	117.39725	48.82027	117.39033

Appendix H.

Table H1. Locations of habitat and fish survey sites in tributaries to Boundary Reservoir. Lat.=latitude, Long.=longitude, and DD=decimal degrees.

Stream	Reach	Lat. (DD)	Long. (DD)
Fence Creek	1	48.96264	117.37418
Fence Creek	1	48.96761	117.39274
Flume Creek	1	48.92465	117.39550
Flume Creek	1	48.92639	117.41135
Flume Creek	2	48.90697	117.38474
Flume Creek	2	48.91276	117.38521
Flume Creek	2	48.91732	117.38843
Flume Creek	2	48.92035	117.39005
Flume Creek	3	48.87920	117.38789
Flume Creek	3	48.88482	117.38466
Flume Creek	3	48.89310	117.38174
Flume Creek	3	48.89807	117.38137
Flume Creek	3	48.90021	117.38439
Flume Creek	4	48.87406	117.38160
Flume Creek	4	48.87610	117.37613
Lime Creek	1	48.96991	117.30940
Lime Creek	1	48.97057	117.31211
Lime Creek	2	48.97108	117.31722
Lime Creek	2	48.97157	117.31519
Lime Creek	3	48.96939	117.32186
Lime Creek	3	48.97067	117.31811
Lime Creek	4	48.96329	117.32916
Lime Creek	4	48.96716	117.32602
Lunch Creek	1	48.83350	117.44385
Lunch Creek	1	48.83629	117.45114
Lunch Creek	2	48.82896	117.43350
Lunch Creek	2	48.83206	117.43751
Lunch Creek	3	48.82559	117.41930
Lunch Creek	3	48.82639	117.41467
Lunch Creek	3	48.82779	117.42736
Pewee Creek	1	48.96240	117.37222
Pewee Creek	1	48.96322	117.36818
Pewee Creek	2	48.96612	117.36432
Pewee Creek	2	48.96757	117.35884
Sand Creek	1	48.80356	117.34258
Sand Creek	1	48.80359	117.33889
Sand Creek	1	48.80637	117.34896
Sand Creek	2	48.80275	117.36070
Sand Creek	2	48.80473	117.35401
Sand Creek	3	48.79900	117.37343
Sand Creek	3	48.80100	117.36771
Sand Creek	4	48.79267	117.38421
Sand Creek	4	48.79635	117.37985
Sand Creek	5	48.80139	117.39642
Sand Creek	6	48.80718	117.39085

Table H1. Continued.

Stream	Reach	Lat. (DD)	Long. (DD)
Sand Creek	6	48.80945	117.39335
Slate Creek	1	48.96359	117.20027
Slate Creek	1	48.96907	117.19397
Slate Creek	2	48.95404	117.21288
Slate Creek	2	48.95745	117.20756
Slate Creek	3	48.95100	117.21735
Slate Creek	3	48.95100	117.21621
Slate Creek	4	48.95331	117.23122
Slate Creek	4	48.95559	117.23719
Slate Creek	5	48.94426	117.28068
Slate Creek	5	48.94501	117.27568
Slate Creek	5	48.94791	117.26916
Slate Creek	5	48.95001	117.26374
Slate Creek	5	48.95157	117.25816
Slate Creek	5	48.95377	117.25258
Slate Creek	5	48.95700	117.24499
Slate Creek	6	48.93857	117.29241
Slate Creek	6	48.94008	117.28798
Slate Creek	7	48.93150	117.30137
Slate Creek	7	48.93601	117.29773
Slate Creek	8	48.92832	117.31070
Slate Creek	8	48.92925	117.30622
Slate Creek	9	48.92491	117.32791
Slate Creek	9	48.92639	117.32316
Slate Creek	9	48.92736	117.31727
Sullivan Creek	1	48.90757	117.07498
Sullivan Creek	1	48.91218	117.06372
Sullivan Creek	1	48.91531	117.06247
Sullivan Creek	2	48.90350	117.08310
Sullivan Creek	2	48.90646	117.07831
Sullivan Creek	3	48.88281	117.10517
Sullivan Creek	3	48.88842	117.09809
Sullivan Creek	3	48.89355	117.08909
Sullivan Creek	3	48.89765	117.08362
Sullivan Creek	4	48.87241	117.13785
Sullivan Creek	4	48.87348	117.13303
Sullivan Creek	4	48.87472	117.12842
Sullivan Creek	4	48.87520	117.11999
Sullivan Creek	4	48.87806	117.11281
Sullivan Creek	5	48.86827	117.14724
Sullivan Creek	5	48.87099	117.14479
Sullivan Creek	6	48.86065	117.15653
Sullivan Creek	6	48.86499	117.15256
Sullivan Creek	7	48.85027	117.17332
Sullivan Creek	7	48.85289	117.16764
Sullivan Creek	7	48.85695	117.16182
Sullivan Creek	8	48.84833	117.18612
Sullivan Creek	8	48.84977	117.17970

Table H1. Continued.

Stream	Reach	Lat. (DD)	Long. (DD)
Sullivan Creek	9	48.84456	117.19143
Sullivan Creek	9	48.84613	117.18833
Sullivan Creek	10	48.83961	117.21097
Sullivan Creek	10	48.84225	117.19805
Sullivan Creek	10	48.84284	117.20372
Sullivan Creek	11	48.83606	117.21642
Sullivan Creek	11	48.83612	117.21963
Sullivan Creek	12	48.83530	117.22480
Sullivan Creek	12	48.83541	117.22621
Sullivan Creek	13	48.83530	117.23110
Sullivan Creek	13	48.83535	117.22928
Sullivan Creek	14	48.83241	117.24911
Sullivan Creek	14	48.83305	117.24150
Sullivan Creek	14	48.83420	117.23459
Sullivan Creek	14	48.83502	117.25470
Sullivan Creek	14	48.83764	117.26062
Sullivan Creek	15	48.84074	117.26835
Sullivan Creek	15	48.84371	117.27491
Sullivan Creek	16	48.84595	117.28381
Sullivan Creek	16	48.84597	117.28178
Sullivan Creek	17	48.84631	117.28763
Sullivan Creek	17	48.84909	117.28912
Sullivan Creek	17	48.85309	117.28784
Sullivan Creek	18	48.85740	117.31206
Sullivan Creek	18	48.85768	117.32790
Sullivan Creek	18	48.85837	117.30551
Sullivan Creek	18	48.86044	117.32908
Sullivan Creek	19	48.86013	117.36166
Sullivan Creek	19	48.86064	117.33363
Sullivan Creek	19	48.86102	117.35906
Sullivan Creek	20	48.86095	117.36635
Sullivan Creek	20	48.86340	117.36554
Sweet Creek	1	48.84808	117.42747
Sweet Creek	1	48.85176	117.43232
Sweet Creek	2	48.82708	117.41353
Sweet Creek	2	48.83042	117.41577
Sweet Creek	2	48.83427	117.41826
Sweet Creek	2	48.84006	117.42123
Sweet Creek	2	48.84371	117.42211
Sweet Creek	3	48.82343	117.40006
Sweet Creek	3	48.82381	117.40869
Sweet Creek	3	48.82515	117.41119
Sweet Creek	4	48.82384	117.39790
Sweet Creek	4	48.82443	117.39922
Sweet Creek	5	48.82140	117.39199
Sweet Creek	5	48.82220	117.39673

Appendix I.

Table I1. Locations of potential fish passage barriers in tributaries to Boundary Reservoir. Lat.=latitude, Long.=longitude, and DD=decimal degrees.

Stream	Type	Lat. (DD)	Long. (DD)	Height (m)	Gradient (%)	Length (m)
Sullivan Creek	Mill Pond Dam	48.85861	117.30280	15.0		
Outlet Creek	Sullivan Lake Dam	48.83936	117.28900	20.0		
Flume Creek	Culvert	48.87404	117.38526	2.5		
Flume Creek	Culvert	48.91777	117.38787	1.5		
Sand Creek	Culvert	48.80918	117.39272	2.0		
North Fork Sullivan Creek	Dam	48.86407	117.32350	4.0		
Slate Creek	Chute	48.96662	117.19574		18	27.5
Slate Creek	Waterfall/chute	48.93019	117.30382	3.0	24	10
Slate Creek	Chute	48.92812	117.31263		38	30
Slate Creek	Waterfall	48.92777	117.31357	2.8		
Slate Creek	Waterfall	48.92736	117.31477	5.0		
Slate Creek	Waterfall	48.92736	117.31623	4.0		
Slate Creek	Waterfall	48.92743	117.31685	6.0		
Sand Creek	Waterfall	48.80067	117.39595	5.0		
Flume Creek	Waterfall	48.87699	117.37582	13.0		
Sweet Creek	Waterfall	48.82436	117.39948	6.0		
Sweet Creek	Waterfall	48.82426	117.39964	6.0		
Sweet Creek	Waterfall	48.82360	117.40833	6.0		
Sweet Creek	Waterfall	48.82422	117.40963	8.2		
Pewee Creek	Waterfall	48.97109	117.35370	50.0		
Lime Creek	Subterminal	48.97098	117.31326	3.0		
Beaver Creek	Waterfall	48.89745	117.35216	25.0		
Threemile Creek	Waterfall	48.89677	117.35012	5.0		

2000 WDFW Annual Report for the Project
RESIDENT FISH STOCK STATUS
ABOVE CHIEF JOSEPH AND GRAND COULEE DAMS

Part II. Coordination, Data Standards Development, and Data Sharing Activities

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March, 2001

Introduction

The Resident Fish Stock Status Project, also referred to as the Joint Stock Assessment Project (JSAP), was started in 1998 at the request of tribal and state fish management agencies in the blocked area (that part of the Columbia Basin above Chief Joseph and Grand Coulee Dams**).** The primary objective is to jointly perform stock assessment and generate a management plan for protection, mitigation, and enhancement of blocked area resident fish. To perform joint stock assessment, participants need a common database, and early reviews of available data identified both useful collections and major gaps in the biological data record for resident fish.

This project, then, has two main emphases. The "field research" part prioritizes identified data gaps, plans and conducts studies to gather needed baseline data, and provides the analysis required to fully address these gaps. The "data sharing" part of the project coordinates development of common data codes, formats, and standards for priority data categories, and facilitates sharing of these data among not only project participants but Columbia Basin interests at large via a direct connection with the StreamNet Project.

The following summary covers activities from March 1, 2000 through February 28, 2001.

Coordination and Data Standards Development

On May 17 and November 9 the JSAP Steering Committee met in Spokane.

During the May meeting, we met the new Project Manager, reviewed progress to date, and began describing a minimum set of standards for shared data. The initial areas of data focus are Population Composition, Habitat, and Migration Tracking. Fish collection and habitat description data will be the focus of the field samplers, while hatchery stocking data will be the first priority for historical data "mining" from state, tribal, federal and other entities. WDFW will begin a review of available data and determine if a standardized format can be generated for resident fish stocking data. Committee members discussed distinctions between fish sightings data and extrapolated distribution based on those data, and affirmed the need to keep both as distinct but connected datasets. There were also discussions on whether all of the previously listed habitat variables were in fact necessary to collect, store, and share for the purpose of this (stock assessment) project.

In November, Committee members provided updates on work plan and budget activities for the current year. Discussions on future work and spending plans for 2001 were held, as well as some generalized discussion about the "out-years" (2002-2004). In 2001, WDFW field staff will concentrate on sampling activities on the Little Spokane River system. Genetic analysis of collected fish tissues, data entry of historical data (particularly stocking records and fish sightings from field surveys), and development of standard formats and routines to accommodate StreamNet formats are other major objectives. Some differences between agencies in sampling protocols were discussed, based on practical issues that arose during the summer, 2000 sampling season. There is some sense that differences between historical data collections and our current sampling results may interfere with database creation and assimilation, so more research will be needed here in 2001.

Data Sharing Activities

WDFW headquarters staff (Dick O'Connor, Cynthia Burns) participated in a series of activities supporting compilation, standardization, and sharing of data relevant to the JSAP effort:

- O'Connor generated a summary of all historical resident fish sightings data from the WDFW Stream, Lake, and Fish Database (SLFD) and provided copies to the JSAP Data Manager as well as other WDFW JSAP staff;
- O'Connor supplied an update on JSAP-area coverage of resident fish distribution data (including "minor" species) to the JSAP Data Manager in order to demonstrate StreamNet Project standards for spatial data fields and data codes;
- O'Connor assisted in field sampling of Sullivan Creek for three days to gain first-hand experience with the data fields and protocols currently in use;
- Burns worked with WDFW Region 1 staff to enter and verify bull trout data presence and use (spawning, rearing) data for the JSAP area as part of an official agency-sanctioned statewide update to that spatial/tabular dataset;
- O'Connor assessed differences found between JSAP-area SLFD bull trout sightings, the "old" bull trout presence data, and the "newly updated" bull trout data and shared them with WDFW Region 1 staff for their comment on apparent discrepancies;
- Burns reviewed the StreamNet-standard LLID codes for 100K streams in the JSAP area and attempted to link each code with the corresponding Washington State "Stream Catalog" code to facilitate assimilation of historical data. 495 streams were identified and linked, which represents 46% of the named streams and 11% of the streams overall in WRIAs 49 through 62;
- Burns added JSAP-area information to the database of fish distribution mapping "contacts" she is managing, in order to document fish distribution data for sharing with StreamNet;
- Burns spent some time reviewing spatial data (GIS) coverages available on USFS Web sites, particularly the Okanogan Forest's Tonasket District, and reviewed the contents of a comprehensive fish and habitat data CD provided by the Colville National Forest, in search of datasets relevant to JSAP work.

Resident Fish Stock Status above Chief Joseph And Grand Coulee Dams

Spokane Indian Reservation

2000 Annual Report

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ABSTRACT

The "Resident Fish Stock Status Above Chief Joseph and Grand Coulee Dams" project began allocating funds to the Spokane Tribe of Indians in 1998 to begin collecting data on the fish stock status within and around the Spokane Indian Reservation. In addition to Sand Creek and the four inland lakes, this report contains data collected on Blue Creek, Castle Rock Creek, Oyachen Creek, Little Tshimikain Creek, Deep Creek and Cottonwood Creek.

A baseline habitat and fish survey was conducted in all or part of the streams identified above. Habitat and fish surveys were conducted in the lakes to assess available habitat and existing species. Fish surveys, to complete Sand Creek, were completed by snorkeling transects in the lower two reaches. Large numbers of brook trout and one rainbow trout were found in the pools below the falls. Questions were asked as to whether fish could enter lower Sand Creek due to the gradient and bedrock flows at the mouth. Depending upon the lake elevation in the spring, the presence of a rainbow trout may suggest that movement from Lake Roosevelt into the lower reach of Sand Creek is possible although it is not known to what extent.

Blue Creek average temperatures were less near the mouth than below the mine effluent. The water treatment plant is adding warmer water than is found naturally in the stream. The majority of the summer flow comes from the effluent tributary, which decreases the maximum monthly temperatures while increasing the monthly average. Habitat surveys were conducted on the first two reaches using the TFW ambient monitoring protocol while the third and fourth reaches were completed using the standard protocol. Heavy beaver activity was occurring in the lower portion of reach 1 and in reach 3. High beaver dams and low flows create passage barriers to fall migrating fish. The lower portion of Blue Creek has the least amount of overstory, which could be attributed to the historical lack of flow. Reach 2, from Oyachen Creek to the mine effluent tributary, has an average gradient of 4.6% and the lowest pool:riffle ratio. Reach 4, with a 2% average gradient, is spring-like and has the highest pool:riffle ratio. Fish were observed in all reaches of Blue Creek and will be reported in 2001.

Oyachen Creek was surveyed for 3,150 meters of which rainbow trout were sampled. Although flows were sub-surface, fish densities were relatively good and temperatures remained

low. The large number of small rainbow trout indicate that Oyachen an important rearing and spawning area.

Little Tshimikain Creek was surveyed for 7 habitat reaches of which 5 of them were sampled for fish. Except for temperature, the first 3 reaches exhibit the relatively best habitat for salmonids. Densities of fish are high throughout Little Tshimikain but densities of salmonids are approximately 1fish per100m^2. Although alder and hawthorn are present, there is limited overstory canopy in the first 3 reaches. Suppression of riparian vegetation by grazing, and beaver activity has negatively impacted all the reaches surveyed. Reach 3 ends at a 25-foot vertical fall that is currently a passage barrier. Above the falls, in reaches 4 through 7 flows diminish, along with the overstory vegetation. Densities of dace, shiners, and suckers are high whereas rainbow trout were only sampled occasionally. The gradient is 1% or less in reaches 4 through 7 and is dominated by a contiguous series of beaver ponds. Substrate size in reaches 4 through 7 decreases while sediment and embeddedness increase.

Four reaches were surveyed in Cottonwood Creek from the confluence with Little Tshimikain to the Cottonwood road crossing. These four reaches are contained by steep side slopes with occasional talus slopes extending to the waters edge. The majority of the substrate is unconsolidated, which causes the loss of surface flow. Fish were observed and are known to exist above these reaches. Cottonwood creek suffers from elevated temperatures do to effects of heavy beaver activity, low gradients, grazing, and logging.

Deep Creek, a tributary to Sheep Creek, was surveyed for one reach extending past Drum Road. Deep Creek is a low gradient beaver dominated channel characterized by deep pools with sandy substrate. A transect will be electroshocked in 2001 to determine if fish are present.

Castle Rock Creek (Fox Creek), although having adequate flows for fish, has gradients averaging 10.1%, and very few primary pools. Although fish passage into lower Castle Rock Creek may be possible during high flows, the deposition bar and debris at the mouth inhibit fish passage during most of the year. No fish were observed while surveying the stream or while shocking transects. Past mining and logging/road building continue to be sources of sediment in the stream.

Benjamin, Mathews, McCoy, and Turtle Lakes were sampled for fish species composition and relative abundance using electroshocking and gillnets. The lakes were also sampled for zooplankton in spring, summer and fall. Benjamin Lake is dominated by pumpkinseed and large mouth bass with rainbow trout being sampled in the pelagic zone. The bass and pumpkinseed are naturally reproducing while the rainbow trout are stocked from the Spokane Tribal Hatchery. Fall zooplankton densities and biomass showed a sharp increase in 2000 when compared to 1999 in all groups except Copepoda. *Daphnia* species are the most prevalent and contribute the most biomass in the three seasons sampled.

Brook trout and pumpkinseed were the only species sampled in Mathews Lake although additional sampling would be necessary to fully evaluate the species composition and relative abundance. Zooplankton samples revealed that the group "Copepoda" made up 76% of the density and 85% of the biomass. Dissolved oxygen is the largest limiting factor for fish health in Mathews Lake.

McCoy Lake dropped 2.61 meters from full pool by November. Largemouth bass and rainbow trout were sampled in the lake. Largemouth bass were recently introduced by an unknown source evident by the uniform sample lengths. McCoy Lake suffers from super eutriphication and high temperatures. Algal blooms in combination with water loss and decreases the amount of dissolved oxygen. The observed stomachs of the stocked rainbow trout were empty, which suggests that the water was too warm for feeding activities. Rainbow trout from previous year stocking had a low condition factor. Adult rainbow trout are attempting to spawn in McCoy Creek, and have historically, although success has not been determined. Densities of *Daphnia* species increased in the fall of 2000 when compared to the fall of 1999 while densities of "other Cladocera", and "Copepoda" decreased.

Approximately 90% of the littoral habitat was electroshocked in Turtle Lake. The relative abundance of rainbow and brown trout, the only species collected, was 94.7% and 5.2% respectively. Although Turtle Lake has the most desirable temperatures, there is a lack of dissolved oxygen in the areas of those temperatures. Water samples revealed high amounts of iron below 12 meters, which may contribute to the incomplete mixing of the lake at turnover. The "Copepod" group had the highest mean density and biomass in the lake. *L. ashlandi* and *D. rosea* are the most likely species to be used for fish consumption.

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1.0 INTRODUCTION

1.1 OBJECTIVES

The Spokane Tribe is one of four organizations that currently are working under the "Resident Fish Stock Status Above Chief Joseph and Grand Coulee Dams" project. The Spokane Tribe, under this project, will compile and analyze historical fish and fish habitat data on all water bodies within and near the Spokane Indian Reservation (SIR). Current baseline habitat and fisheries data will be collected on all fish bearing waters on or near the SIR. A comprehensive coverage of fish distribution and habitats will be kept in a central database and linked with Geographic Information System (GIS) coverages for all areas surveyed. Data collected by other projects such as Lake Roosevelt Monitoring will be gradually incorporated into the central database.

The first data collected by the Spokane Indian Tribe for this project is reported in the 1999 Annual Report of the project, "Resident Fish Stock Status Above Chief Joseph and Grand Coulee Dams" project #199700400. Annual reports may contain only partial data on a stream or lake. Refer to prior and/or subsequent reports to obtain all data available that was collected under this project.

1.2 DESCRIPTION OF STUDY AREA

Data collection activities in 2000 were concentrated within the Spokane Indian Reservation. The Spokane Indian Reservation (SIR) is located in Stevens County Washington. The borders of the SIR are Franklin D Roosevelt Lake to the west, the Spokane River arm of Lake Roosevelt to the south, the 48° parallel to the north, and Tshimikain Creek to the west (Figure 1). The streams of focus for this report are Sand Creek, Castle Rock Creek, Oyachen Creek, and Little Tshimikain Creek. Data was also collected on the lakes: Turtle, Benjamin, McCoy, and Mathews. Partial surveys were completed on Blue Creek, Deep Creek, and Cottonwood Creek, which will be completed in 2001 and reported in the 2001 Annual Report.

Figure 1 Overview map of the Spokane Indian Reservation with major highways, roads, streams, and lakes.

2.0 METHODS

2.1 STREAM HABITAT SURVEY

The stream habitat methodology in 2000 was a subset of parameters measured in 1999. In fiscal year 2000, 90-meter transects were taken, while walking directly in the channel, using a hip-chain. The information collected at each transect was: habitat identification (i.e. riffle, pool, run), wetted width to the nearest tenth of a meter, water depths at ¼, ½, and ¾ width to the nearest cm, substrate size (Table 2.1), and an ocular estimate of substrate embeddedness. Channel gradients were obtained using a Suunto clinometer with % scale at locations permitting visibility of flagging. The number of primary pools and large woody debris (LWD) were recorded the entire length between transects. Primary pools were considered those pools where the length or width of the pool was greater than the average stream width. Primary pools also had a maximum depth at least two times the tail-out depth. Large woody debris was tallied if it was at least a meter in length, and 10 cm diameter. Bankfull widths and depths were measured at representative sites within each reach.

The length of each reach averaged 20 transects (1,800 meters). Reach breaks were made at 20 transects or at significant changes in stream habitat. Data for each reach and stream was summarized. General observations were recorded in a field notebook and representative pictures were taken of each reach and special features.

Blue Creek, from the mouth to the mine effluent tributary, was surveyed using both the above methodology as well as the TFW ambient monitoring by the Lake Roosevelt Habitat Improvement Project. Reach 2 was surveyed only using the TFW monitoring while reach 1 was surveyed using both methodologies. Riffles and pools, the only habitats identified, were measured for length and average width under the TFW protocol. Pebble counts, at random habitats, did not distinguish rubble (6”-12”) or small gravel (0.25”-1”).

2.2 RELATIVE FISHERIES ABUNDANCE

Within each reach delineated during the habitat survey, a minimum of one site was randomly selected to collect relative fisheries abundance. Sampling procedures included either snorkeling or backpack electrofishing. Fish sample sites were selected not to bisect habitats. Transects included both pool and riffle habitats, and were a minimum of 30 meters in length.

Snorkeling was the method used in sites where water depth and clarity permitted the enumeration and classification of fish. Snorkeling was only used in lower Sand Creek in 2000. Fish species were identified and their total length was estimated to the nearest inch. Data was recorded by a person on the stream bank or was written on a "cuff tube" and later transferred to standard data sheets.

Table 2.1 Substrate classifications according to Epinosa (1988).

Organic debris:	undecomposed sticks, leaves, logs, or other woody and herbaceous material
Muck:	decomposed organic material, usually black in color
Silt:	fine sediments with little grittiness
Sand:	< 0.25 inches in diameter
Small Gravel:	0.25 – 1 inches
Coarse Gravel:	1 – 3 inches
Cobble:	3 – 6 inches
Rubble:	6 – 12 inches
Boulders:	> 12 inches
Bedrock:	large masses of solid rock

Backpack electroshocking was used at a majority of the sites sampled in 2000. A Smith Root model VII, adjusted to the specific water depth and conductivity, was used to sample streams that could not be snorkeled. A single pass was made on transects with a width only 2-4 times the width of the electrofishing wand. Double-pass electrofishing was performed in reaches that were wider than four times the width of the wand and too shallow or turbid to snorkel effectively.

Fish per 100/m^2 was calculated based on the length of the sample site as well as the average width. Standard deviation was calculated for those sites where the double-pass depletion method was used.

The following size/age classes for salmonid species were determined according to Clearwater National Forest guidelines (Epinosa 1988). The size classifications are general guidelines that were found applicable in other northeastern Washington streams.

Table 2.2 Size/age classifications for certain species of fish according to Epinosa (1988).

Species	**Group**	**Size Range**
Rainbow Trout	age 0+	< 65 mm FL
Cutthroat Trout	age 1+	65-110 mm FL
	age 2+	111-150 mm FL
	age 3+	151-200 mm FL
	age 4+	201-305 mm FL
	BIG	> 305 mm FL
Bull Trout	age 0+	< 65 mm FL
Brown Trout	age 1+	65-115 mm FL
Brook Trout	age 2+	116-165 mm FL
	age 3+	166-210 mm FL
	age 4+	211-305 mm FL
	BIG	> 305 mm FL
Sculpin: Record total number of sculpin; by species if possible.		
Sucker: Record total number of suckers; by species if possible.		
Other: Record total number; by species if possible.		

2.3 STREAM TEMPERATURES

Optic StowAway Temp data loggers (accuracy ±0.2 °C) were placed in all major streams on the reservation in order to obtain current temperature regimes. Loggers were placed in the streams based on flow, location, and possible mine effluent effects. Temperature loggers were placed in the streams July 6, 2000 and removed by October 19, 2001 and recorded temperatures every hour. Maximum, minimum, and average temperatures were calculated for each month. Overall maximums and minimums were calculated with their corresponding date. Relative air temperatures were collected from the forestry weather station at Wellpinit, WA. Maximum and minimum daily temperatures were used to calculate maximum and minimum monthly values as well as averages (Table 3.4).

2.4 INLAND LAKE WATER QUALITY

Water quality data was collected at McCoy, Turtle, Benjamin, and Mathews Lakes. Monthly surveys were taken to assess limiting factors and available fish habitat on the inland lakes. Samples were taken at the estimated maximum depth to gain a profile for the entire lake. A Hydrolab Surveyor 4 was used to collect depth, temperature, percent dissolved oxygen, dissolved oxygen, conductivity, turbidity, total dissolved gases, pH, and oxidation-reduction potential. Hydrolab measurements were taken at 1-meter intervals from the surface to a depth of 6-meters and 3-meter intervals from 6-meters to the bottom of the lake. At each location general weather conditions were recorded, transparency was measured using a Secchi disk, and the depth of the euphotic zone was calculated by multiplying Secchi depth by 1.7 (Wetzel, 1983). Samples were taken once a month although the specific day varied. Due to conditions limiting access or logistic problems with sampling equipment no samples were taken for the months of January, March, and June.

2.5 ZOOPLANKTON

Zooplankton was collected at the four inland lakes using a Wisconsin vertical tow plankton net with 80 µm silk mesh and a radius of 10 cm. Triplicate tows were made from 5 meters depth to the surface at each lake. Samples were taken in April, July, and October. Zooplankton collected from each tow were rinsed into a 63 µm mesh screen and submersed in 95% ethanol. Organisms were then rinsed into a 60 ml sample bottle with 70% ethanol for preservation and further analysis.

Sorting, counting and identification to species or lowest practical taxon was completed in the laboratory using taxonomic keys by Brooks (1957), Edmondson (1959), Pennak (1989), Thorp and Covitch (1991) and Ruttner and Kolisko (1974). The species identified as *Ceriodaphnia reticulata* in 1999 was correctly identified as *Ceriodaphnia quadrangula* in both 1999 and 2000 samples. Samples were split, using a Motodo 1.5 liter plankton splitter, to a level where approximately 100 organisms of the most prevalent species were remaining in the sample. A Leica MZ-8 compound microscope fitted with an optical micrometer was used to identify zooplankton. Zooplankton lengths were taken from the first 20 organisms of each species after which organisms were simply counted. Lengths for Branchiopoda (i.e. *Daphnia* and "other Cladocera") were taken from the anterior most region of the head to the posterior base of the carapace while organism lengths for copepod taxa were taken from the anterior most region of the head to the base of the caudal ramus. Zooplankton lengths are displayed in millimeters.

Zooplankton density and biomass were calculated for each tow. The volume of water sampled by the plankton net was calculated using the equation:

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

Where:

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

The number of zooplankton per cubic meter of water sampled was calculated by the equation:

$$D = ((TC*SF)/V)*1000$$

Where:

D = density of organisms
TC = the total number of organisms measured and counted
SF = the analyzed split fraction of the original sample
V = the volume of water sampled (liters)

Biomass of predominant zooplankton taxa was determined using the length to dry weight regressions by species as determined by Dumont et al. (1976), Bottrel et al. (1976) and summarized by Downing and Rigler (1984).

Zooplankton densities and biomass were calculated for each individual tow and the results of the three tows were averaged to arrive at a single location density and biomass value. The dry weight and biomass estimates for each observed zooplankton species were calculated using the equation:

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

Where:

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

And:

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

Where:

B = biomass (µg/m^3)
ln W = log of the dry weight estimate by species (µg); and
D = density (# organisms/m^3).

Taxonomically related zooplankton species were grouped into the following categories: *Daphnia pulex,* and *Daphnia rosea* were grouped as "Daphnia sp.", while *Alona quadrangularis, Bosmina longirostris, Ceriodaphnia reticulata,* and *Diaphanosoma brachyurum* were grouped as "other Cladocera". *Leptodiaptomus ashlandi, Diacyclops bicuspidatus thomasi, Mesocyclops edax, Epischura nevadensis,* Harpacticoid sp. and juvenile copepods (Calanoid/Cyclopoid copepodids and nauplii) were grouped as "Copepod sp." *Daphnia* sp. and "other Cladocera" were examined separately due to their differing importance in the diets of both kokanee salmon and rainbow trout (Underwood et al. 1996 and 1997; Griffith and Scholz 1991)

Hrbacek (1962) and Brooks and Dodson (1965) first suggested that planktonic herbivores show competitive superiority of large-bodied species. Small-bodied zooplankton are more abundant in the presence of planktivorous fish because they are less vulnerable to visually oriented predators (Kerfoot and Sih 1987; Gilwicz and Pizanowska 1989). In the absence of planktivorous fish, large-bodied species dominate due to more efficient feeding abilities (Hall et al. 1976). Size classifications of zooplankton are: large > 2.0 mm, medium 1.0 – 2.0 mm, and small < 1.0 mm.

2.6 Inland Lake Fish

The four inland lakes, Mathews, McCoy, Benjamin, and Turtle, of the SIR were sampled in June 2000 to obtain relative abundance of the fish assemblages. Sampling was performed using a combination of electrofishing and a gillnet. Mathews Lake was sampled using only a gillnet due to limited access for the electroshocking boat. Fish were sampled using a 24-foot Smith-Root Electrofisher with the adjusted voltage to produce the desired galvanotaxis as outlined by Reynolds (1983). Fish were dip-netted and placed into a live-well where they were later examined. Electrofishing was concentrated in the littoral zones at night to increase sampling efficiency. Sampling time was recorded for each shocking pass to calculate the catch per unit of effort (CPUE) and there were no overlapping passes. Fish were identified to species, measured to the nearest millimeter (total length), and weighed to the nearest gram. Scales were taken on the first 5 fish of each 10-millimeter size class for age determination and back calculation.

An 8 x 100-foot gill net with varying 25-foot mesh sizes was set perpendicular to the shore for 3.5 to 6 hours at night. Although a 24-hour set would be desirable, the Spokane Tribal Wildlife Committee was concerned about the unnecessary loss of fish due to the small size of the lakes and the circling behavior of salmonids within the lakes. The nets were set near the surface because of the limited oxygen supply in the meta and hypolimnion.

Scales were collected from the area between the lateral line and the dorsal fin. Scales were not taken on rainbow trout because of their hatchery origin and the difficulty in aging them based on the scale annuli. 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 age and measure the annuli for back calculation of length at age. The number of annuli were counted to determine the age of each fish (Jearld, 1983). The distance (mm) of each annuli from the focus was measured along a constant axis, and using constant magnification.

Lee's back-calculation method was used to determine the length of the fish at the formation of each annulus (Carlander 1950, 1981; Hile 1970).

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 rainbow trout (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).

Relative weight (Wr), is a calculation to determine the ratio of the weight of the fish to the weight of a "standard" fish of the same length. The following equations, defined by Wege and Anderson (1978), and Anderson (1980) were used to calculate the relative weights for largemouth bass and pumpkinseed respectively.

$$Wr = \text{Log } W_S = -5.316 + 3.191 * \log L$$

And

$$Wr = \log W_S = -5.374 + 3.316 * \log L$$

Where:

Wr = relative weight (%)
W_S = standard weight
L = Length of fish at capture

3.0 RESULTS AND DISCUSSION

3.1 SAND CREEK

3.1a Relative Fisheries Abundance

Except for one rainbow trout sampled in reach 11, brook trout was the only species sampled in Sand Creek. Tables 3.1 through 3.3 include fish sampled in both 1999 and 2000. The occurrence of a rainbow trout in reach 11 may suggest that fish are entering from Lake Roosevelt. The rainbow trout was sampled just below the Sand Creek falls.

The lowest density ($6.69/100m^2$) of fish was observed in reach 10. Reach 10 and 11 were sampled in early August and fish were predominately confined to primary pools. The average depth was only 10 cm in reach 10, and 8.7 cm in reach 11. The average wetted width decreased in reaches 10 and 11 when compared to reaches 4 through 9 (Crossley 1999).

Only 6 fish were sampled in reach 10, 4 of which were considered age 0+, and 2 at age 1+. Below the falls, in reach 11, the only age 4+ fish were sampled in large pools. The majority of the fish sampled in reach 11 were age 3+, accounting for 57% of the total number sampled (Table 3.3). The rainbow trout sampled in reach 11 was 152 mm long and considered to be an age 3+. The density of fish in reach 11 was $21.15/100m^2$ including the rainbow trout.

Table 3.1 Number of fish observed in 1999and 2000 in Sand Creek by habitat type and reach.

Reaches	Pool	Riffle	Run
1	16	1	6
3	17	0	0
4	11	0	0
5	7	0	0
6	14	1	0
7	19	1	5
8	12	0	0
10	6	0	0
11	60	1	0
Totals	**162**	**4**	**11**

Table 3.2 Sand Creek Brook Trout Abundance by Reach in 1999

Date (1999)	Reach	Method	N	Area(m^2)	Density (#/100m^2)	Depletion Calculation (#/100m^2)	Pop. Conf. Intervals (#/100m^2)
10/18/99	1	Shock	23	55.28	41.61		
10/18/99	2	shock/depletion	41	58.80	69.73	71.43	64.80 / 78.05
9/8/99	3	Snorkel	17	37.73	45.06		
9/9/99	4	Snorkel	11	51.64	21.30		
9/8/99	5	Snorkel	7	68.08	10.28		
10/20/99	6	Shock	15	103.20	14.53		
10/20/99	7	Shock	25	77.03	32.45		
10/20/99	8	Shock	12	107.70	11.14		
10/8/99	9	shock/depletion	21	127.71	16.44	17.8	12.70 / 22.96
8/2/00	10	Snorkel	6	89.72	6.69		
8/1/00	11	Snorkel	60	288.38	20.81		
Sum			237	1065.27	290.04		
Average					**26.36**		

Table 3.3 Age class (Epinosa 1988) and number of fish sampled by reach in Sand Creek 1999.

Age Class

	0+	**1+**	**2+**	**3+**	**4+**
1	1	7	12	3	
2	1	21	15	4	
3	7		7	3	
4			9	2	
5			4	3	
6			9	6	
7		3	19	3	
8		1	8	3	
9		1	15	5	
10	4	2			
11	0	13	34	9	4
Totals	**13**	**48**	**132**	**41**	**4**

Table 3.4 Stream temperature comparisons for the summers of 1999 and 2000. Temperatures are displayed in °C.

	Lower Blue Creek		Upper Blue Creek		McCoy Creek		Lower Sand Creek		Upper Sand Creek	
	1999	**2000**	**1999**	**2000**	**1999**	**2000**	**1999**	**2000**	**1999**	**2000**
July Max		19.65		19.05		20.64		20.01		19.38
July Min		11.74		11.63		11.14		10.38		8.72
July Avg		15.32		15.56		15.81		14.62		13.46
August Max	21.56	20.46	20.18	19.86	dewatered	dewatered	20.98	20.49	22.17	20.03
August Min	12.17	9.73	12.87	10.86	11.29	9.12	11.93	9.14	10.42	7.17
August Avg	16.12	14.69	16.76	15.78	17.5	17.56	16.01	14.94	15.27	13.27
September Max	13.56	15.48	15.21	16.32	15.97	n/a	15.04	15.52	14.91	14.59
September Min	4.26	4.3	7.61	6.67	2.26	n/a	5.42	5.27	2.96	2.8
September Avg	10.35	10.81	12.51	12.36	10.64	n/a	11.19	11.07	9.71	9.35
October Max	11.39	12.06	12.09	13.18	11.76	n/a	11.16	11.62	9.96	10.58
October Min	1.89	3.05	5.12	6.05	0.34	n/a	3.23	3.86	0.73	1.69
October Avg	6.42	7.29	8.78	9.36	6.07	n/a	7.4	7.44	5.61	5.78
Total Avg Temp	11.64	12.57	13.25	13.73	12.35	n/a	12.26	12.56	10.99	11.01
Max Temp	21.56	20.46	20.18	19.86	dewatered	dewatered	20.98	20.49	22.17	20.03
Max Date	8/4/99	8/1/00	8/4/99	8/1/00	8/26-28/99	8/28/00	8/4/99	8/1,10/00	8/4/99	8/6/00
Min Temp	1.89	3.05	5.12	6.05	0.34	9.12	3.23	3.86	0.73	1.69
Min Date	10/16/99	10/6/00	10/16/99	10/6/00	10/19/99	8/27/00	10/16/99	10/6/00	10/16/99	10/6/00
Logger Start	7/30/99	7/6/00	7/30/99	7/6/00	7/30/99	7/6/00	7/30/99	7/6/00	7/30/99	7/6/00
Logger End	10/21/99	10/17/00	10/21/99	10/17/00	10/19/99	8/28/00	10/19/99	10/17/00	10/19/99	10/17/00

Table 3.4 Continued.

	Upper Little Tshimikain	Lower Little Tshimikain		Upper Tshimikain	Tshimikain at Ford		Lower Tshimikain	Air at Wellpinit	
	2000	**1999**	**2000**	**2000**	**1999**	**2000**	**1999**	**1999**	**2000**
July Max	25.64		25.41	24.81		20.83			33.89
July Min	13.87		13.96	15.47		13.03			6.67
July Avg	20.43		19.16	19.76		16.37			19.39
August Max	25.98	26.46	26.46	25.67	20.99	20.99	23.29	35.56	35.56
August Min	13.1	13.5	11.33	14.04	11.47	9.92	11.59	3.89	5
August Avg	19.11	18.74	17.64	19.16	14.97	14.53	16.23	20.31	19.61
September Max	17.66	18.41	19.06	17.84	15.99	15.99	17.39	29.44	32.22
September Min	7.07	5.6	5.76	5.66	6.83	7.29	5.86	-6.67	-3.33
September Avg	12.9	12.73	12.88	12.4	11.48	11.66	12.02	13.9	12.93
October Max	12.48	12.42	14.43	12.81	15.68	13.49	12.68	21.11	24.44
October Min	5.36	3.72	4.35	4.25	6.05	7.14	4.46	-6.67	-4.44
October Avg	8.32	8.76	9.1	7.97	9.51	9.97	9.17	7.93	8.53
Total Avg Temp	15.9	14.06	15.3	15.55	12.33	13.44	12.93	14.05	15.115
Max Temp	25.98	26.46	26.46	25.67	20.99	20.99	23.29	35.56	35.56
Max Date	8/1/00	8/5/99	8/1/00	8/1/00	8/5/99	8/1/00	8/5/99	8/2-3/99	8/9/00
Min Temp	5.36	3.72	4.35	4.25	6.05	7.14	4.46	-6.67	-4.44
Min Date	10/6/00	10/16/99	10/6/00	10/7/00	10/16/99	10/6/00	10/16/99	10/21/99	10/5,23/00
Logger Start	7/7/00	8/2/99	7/6/00	7/7/00	8/2/99	7/6/00	8/2/99	8/1/99	7/1/00
Logger End	10/17/00	10/19/99	10/17/00	10/17/00	10/19/99	10/17/00	10/19/99	10/31/99	10/31/00

3.2 BLUE CREEK

3.2a Stream Habitat Survey

Blue Creek was partially sampled in 2000 but due to the ongoing sampling of a related project it could not be completed. Blue Creek sampling will be concluded in the 2001 field season and reported in the 2001 annual report.

Table 3.5 summarizes the data collected in Blue Creek. Reach 1 is from full pool on Lake Roosevelt (1290 ft) to the mouth of Oyachen Creek (Figure 2). Reach 2 continues to the mouth of the Midnight Mine water treatment effluent. Reach 3 was terminated below the Blue Creek campground and reach 4 continued 540 meters until no flow was observed.

The lower portion of reach 1 as well as a good portion of reach 3 is dominated by beaver dams. Very little large woody debris (LWD) was observed in reach 1. There is a large percentage of sand in reaches 1 through 3 due to the sandy valley slopes and the road adjacent the stream. Although the number of primary pools in reach 1 was lower, the size was greater. Sand is constantly entering the stream from the upper slopes. Although grazing may have been present in the past, no cattle activity was observed in the lower reaches. Average bankfull width/depth ratios were 4.95 in reach 1, 3.86 in reach 2, 9.26 in reach 3, and 13.77 in reach 4. High average bankfull ratios recorded in reaches 3 and 4 is attributed to the lack of channel confinement by stream banks and the relative width of the valley bottom.

Reach 2 has the highest average gradient and is confined by steep valley side slopes, which explains the lower pool/riffle ratio as well as the lowest bankfull width/depth ratio (3.86). Large substrate (cobble/rubble) is prevalent in reaches 1 and 2 but sparse in reaches 3 and 4. Large substrate, as opposed to gravel, will provide better fish habitat by increasing the complexity.

Recorded temperatures were less than in 1999 although temperatures at the mouth continue to be less than those below the mine effluent (Table 3.4). Lower temperatures near the mouth could be contributed to ground water influence or the relative higher temperatures from the mine water treatment.

3.2b Relative Fisheries Abundance

Fish sampling was completed in reaches 3 and 4 and will be combined with data collected in 2001 and reported.

Table 3.5 Habitat data collected on Blue Creek in 2000.

Reach	1	2	3	4	Combined
Length (m)	2790	3845	2520	540	9695.00
Mean Embeddedness (%)	52.3	N/A	43.4	37.5	44.40
Min	25		15	15	15.00
Max	100		100	100	100.00
Pool-Riffle Ratio	0.53 : 1	0.22 : 1	0.7 : 1	4 : 1	1.4 : 1
LWD (#/100m)	0.6	N/A	6.3	6.9	4.6
Primary Pools (#/Km)	25.09	N/A	40.5	63	42.9
Mean Stream Width (m)	2.38	2.11	1.7	1.2	1.85
Mean Stream Depth (cm)	22	N/A	15.2	11.4	16.20
Mean Gradient (%)	2.7	4.6	3.2	2	3.13
Min	1.5	0.5	2	1	1.00
Max	4	8	7.5	3	7.50
Substrate (% Occurrence)					
Bedrock					
Boulders	23.77	15.72	0	0	9.87
Rubble	27.99	28.11	7.1	0	21.00
Cobble			1.9	18.9	
Gravel	13.89	24.18	36.2	0	38.69
Small Gravel			17	63.5	
Sand	34.36	31.99	22.9	17.6	26.71
Silt	0	0	15	0	3.75
Habitat Types					
Pool (% Occurrence)	**23.7**	**18.36**	**45.7**	**71.6**	**39.84**
Mean Width (m)	2.85	2.34	2.2	1.3	2.17
Min Width (m)	1.5	1.8	1.5	1.2	1.20
Max Width (m)	8.3	3.5	3.9	1.4	8.30
Riffle (% Occurrence)	**43.9**	**81.64**	**39.9**	**16.2**	**45.41**
Mean Width (m)	1.91	1.88	1.4	1.2	1.60
Min Width (m)	0.5	1	0.9	1.2	0.50
Max Width (m)	4.8	3	2.1	1.2	4.80
Run (% Occurrence)	**32.3**	**N/A**	**14.3**	**12.2**	**19.60**
Mean Width (m)	2.2		1.7	0.9	1.60
Min Width (m)	1.5		1.2	0.9	0.90
Max Width (m)	3		2.2	0.9	3.00

Figure 2. Reaches 1 and 2 surveyed in Blue Creek and Oyachen Creek in 2000.

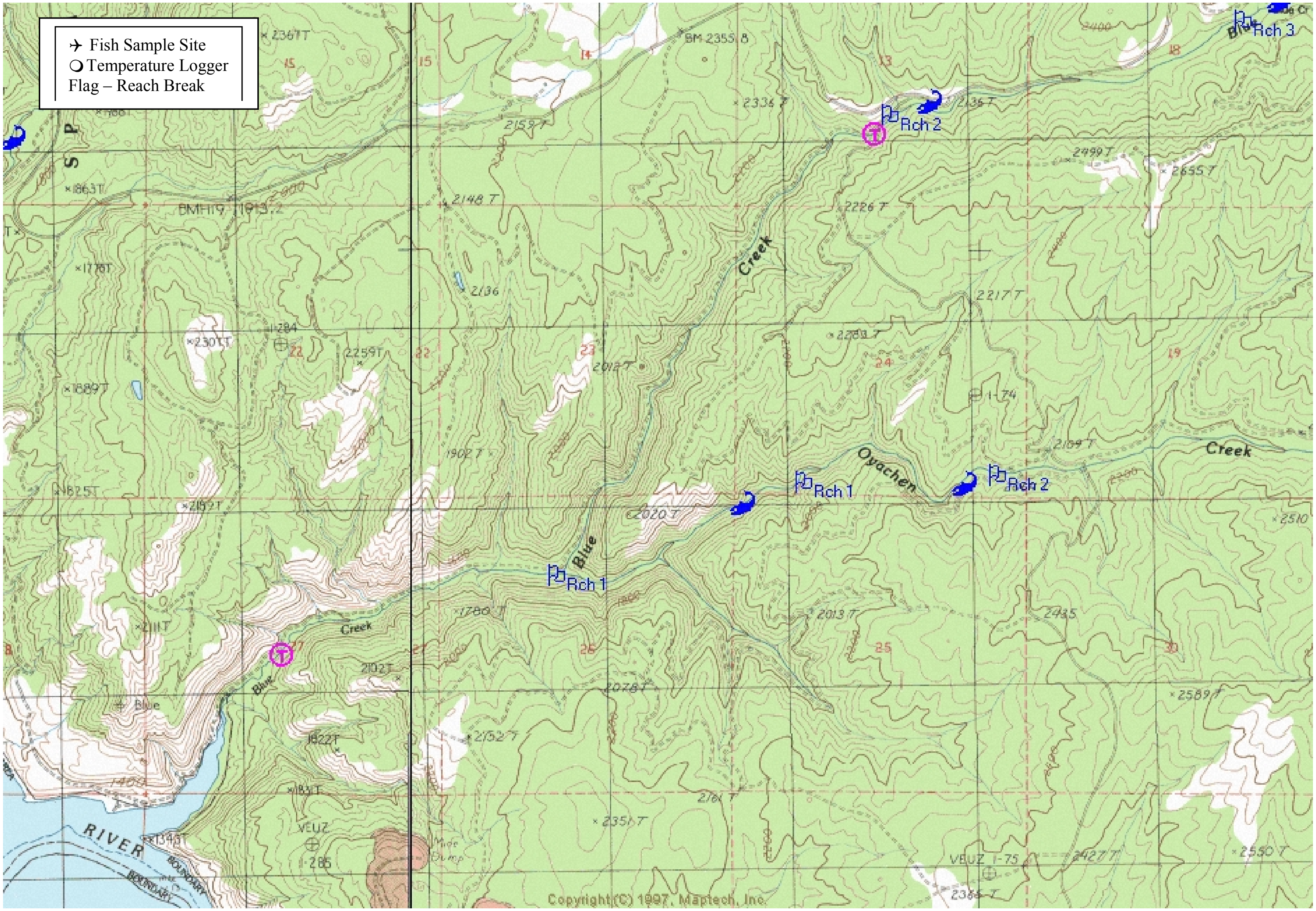
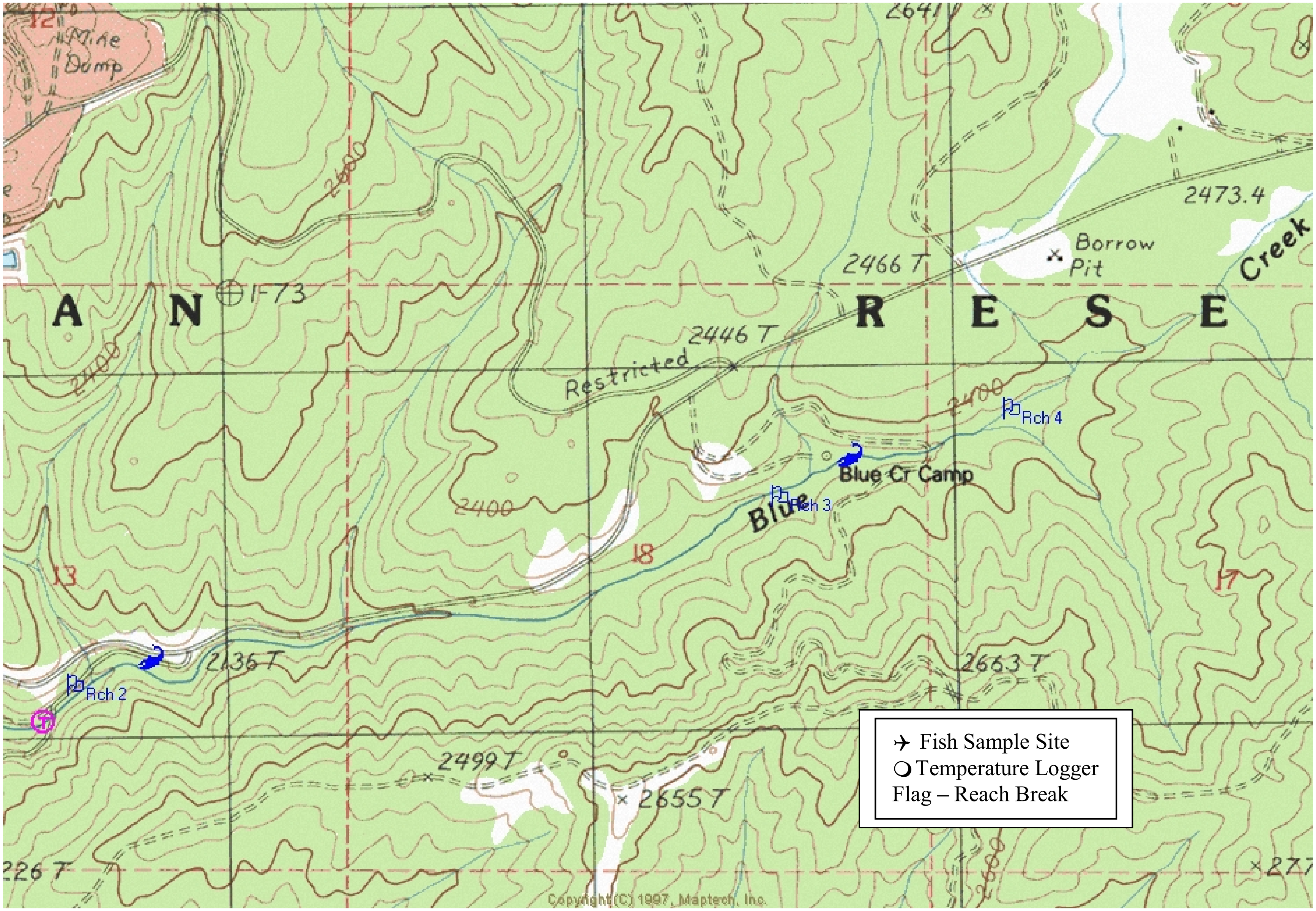


Figure 3. Blue Creek reaches 3 and 4 surveyed in 2000.



3.3 OYACHEN CREEK

3.3a Stream Habitat Survey

Oyachen Creek, a tributary to Blue Creek, was surveyed for 3,150 meters beginning at the confluence with Blue Creek (Figure 2). There was very little flow from Oyachen at the confluence but flows increased upstream. The first reach was 1,980 meters long and had a pool/riffle ratio of 0.9:1. There were 8.9 pieces of large woody debris (LWD) per 100 meters in reach 1. Average embeddedness was 41.7% in this first reach (Table 3.6). Average bankfull width/depth ratios were 4.74 in reach 1 and 8.33 in reach 2. According to Rosgen, reach 1 would be classified as a B4 and reach 2 would be classified as a B4/B3 with exception of the low width/depth ratios.

The second reach was 1,170 meters long and had a pool/riffle ratio of 1:1. There was only 1 LWD/100 meters and average embeddedness was 47.7%. Reach 2 was truncated where flows diminished and there was a large portion of dry streambed. Oyachen Creek, usually dry at the mouth, sustained flows into Blue Creek in 2000.

3.3b Relative Fisheries Abundance

Rainbow trout was the only species found in the two single pass electroshocking transects on September 7th. In reach 1, 40 rainbow trout were sampled in 29.66 m^2 for a density of 134.86 fish per 100 m^2. Ninety-eight percent of those fish sampled were in pools, many of them landlocked. Decreased flows could cause fish to be concentrated in the pools due to the loss of other habitats. Reach 2, after electroshocking, produced 10 rainbow trout in 18.55 m^2 for a density of 53.91 fish/100 m^2. All fish in reach 2 were sampled in pool habitat. Of the fish observed in both reaches, 81% were 65 mm or less (Age 0+). Three electrofishing samples were taken at various locations approximately 2 miles above the reach break where water was present but no fish were observed. Spring spawning may occur above the reach break as no fish barriers were observed. Sampling earlier in the year may provide useful information as to the extent of fish usage within the drainage. Oyachen Creek is a key area for rearing fry even though it experiences diminishing mid-summer flows.

Table 3.6 Habitat summary for Oyachen Creek in 2000.

	Oyachen Creek		
Reach	**1**	**2**	**Combined**
Length (m)	1170	1980	3150
Mean Embeddedness (%)	47.7	41.7	43.9
Min	15	15	15
Max	65	70	70
Pool-Riffle Ratio	1 : 1	0.9 : 1	0.9 : 1
LWD (#/100m)	1	8.8	6
Primary Pools (#/Km)	6	42.9	29.2
Mean Stream Width (m)	1.7	1.2	1.4
Mean Stream Depth (cm)	11.8	6.5	8.5
Mean Gradient (%)	2.7	2.8	2.8
Min	2	1	1
Max	4	6	6
Substrate (% Occurrence)			
Bedrock			
Boulders		18	10
Rubble	4.2	19.2	12.4
Cobble	13.9	22.6	18.7
Gravel	14.8	9.4	11.8
Small Gravel	30.1	24.4	27
Sand	37	6.4	20.1
Silt			
Habitat Types			
Pool (% Occurrence)	**31.9**	**47.7**	**40.7**
Mean Width (m)	2.3	1.4	1.6
Min Width (m)	1.9	0.7	0.7
Max Width (m)	2.8	2.1	2.8
Riffle (% Occurrence)	**12**	**28.9**	**21.4**
Mean Width (m)	0.9	1	0.9
Min Width (m)	0.8	0.5	0.5
Max Width (m)	0.9	1.4	1.4
Run (% Occurrence)	**56**	**23.3**	**38**
Mean Width (m)	1.7	1.6	1.7
Min Width (m)	0.8	0.8	0.8
Max Width (m)	2.7	3.4	3.4

3.4 LITTLE TSHIMIKAIN CREEK

3.4a Stream Habitat Survey

Seven reaches in Little Tshimikain were surveyed for habitat parameters in 2000 (Figures 4 and 5). Surveying began at the little falls impoundment and extended to Lanham's field, approximately 1 mile above the Ford-Wellpinit Hwy crossing Little Tshimikain Creek. There is a falls (~10 meters vertical) located at the end of reach 3, which is a fish passage barrier. There is a productive spring 400 meters above the falls and subsurface flows are prevalent for almost 1000 meters above the spring with only occasional pools. The subsurface trend continues for the first half of reach 5 before large pools enhanced by beaver activity became the dominant habitat. Heavy beaver activity was observed in reaches 4 through 7 where removal and suppression have greatly reduced the amount of overstory vegetation along the stream. Coupled with the lack of overstory vegetation, the beaver ponds allow water temperatures to rise through irradiation and increased water retention times. Although deep pools exist (> 1.5 m max depth), most are long, wide, and shallow. Habitat data collected in reaches 1-7, as well as the combined averages are displayed in Table 3.7.

Little Tshimikain recorded the highest temperatures of all streams on the SIR (Table 3.4). The maximum temperature of 26.46°C was recorded on August 1st at BIA road #14. The upper temperature logger was placed in the stream approximately ¾ mile downstream of Ford Wellpinit Rd crossing. The upper logger recoded a maximum temperature of 25.98 °C on August 1st and a July maximum of 25.64 °C. In July, August, and September; the average temperature was higher at the upstream site than that of the lower sampling site (Table 3.4).

Large woody debris was low throughout Little Tshimikain with the maximum of 3.7 pieces per 100 meters found in reach 2. Stream gradient was between 0.5% and 2% in reaches 1 through 3 while the range was 0.5 to 1 in reaches 4 through 7. There were generally more pools per riffles in all reaches, which made up 95% of the habitat in reaches 5 and 6. Cobble embeddedness was the lowest in reaches 7 and 2 that were those areas with the least number of beaver dams. Reaches 1, 5, and 6 had the highest embeddedness percentages and also the highest amount of silt and sand as substrate (Table 3.7).

Figure 4 Reaches 1 through 3 of Little Tshimikain Creek surveyed in 2000.

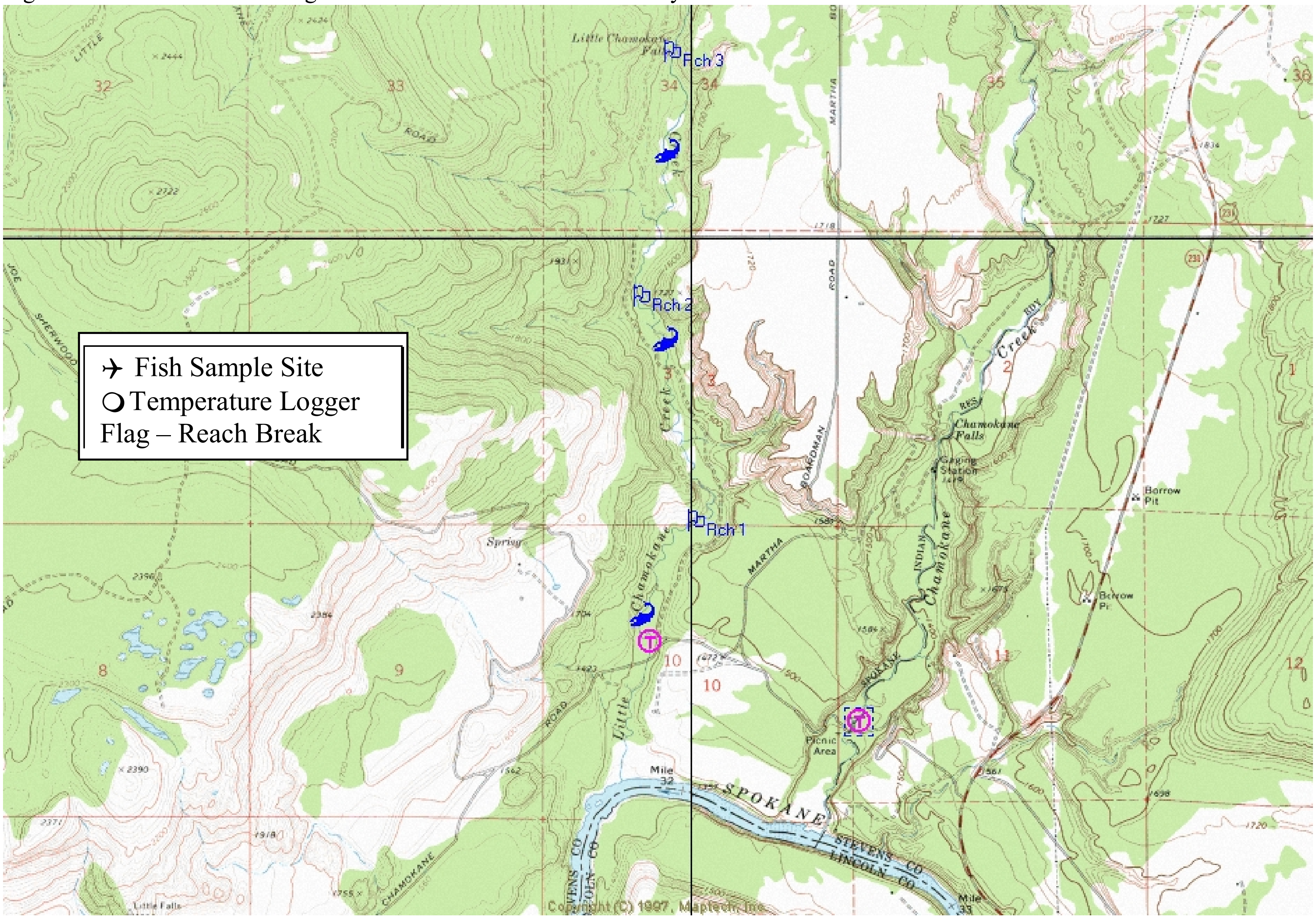


Figure 5 Reaches 4 through 7 of Little Tshimikain Creek and Reach 1 of Cottonwood Creek surveyed in 2000.

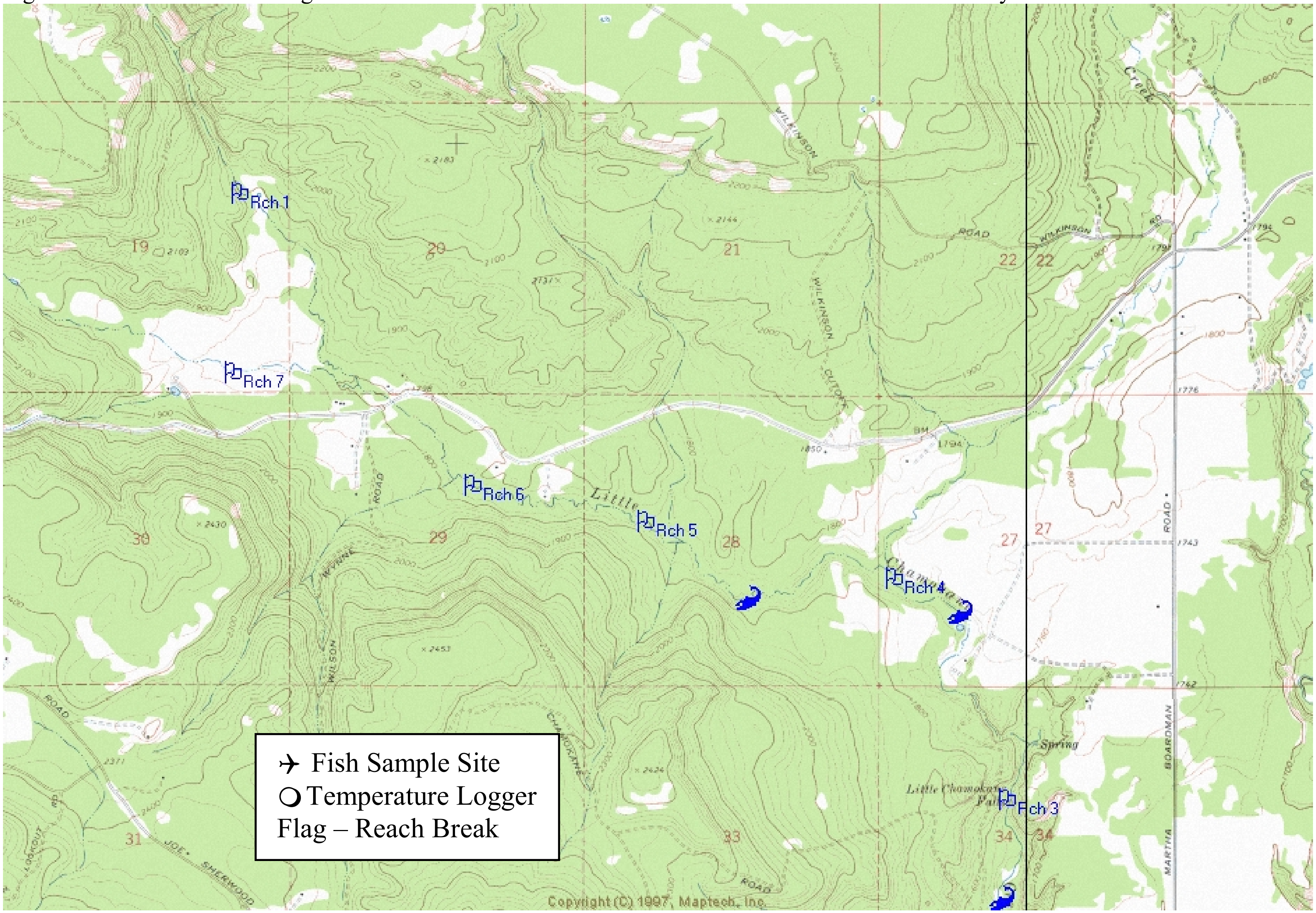


Table 3.7 Habitat data collected on 7 reaches in Little Tshimikain Creek in 2000.

Reach	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Combined**
Length (m)	1,800	1,800	1,710	2,160	1,980	1,620	1,800	12,870
Mean Embeddedness (%)	54.1	36.5	50.3	43.5	70.9	64.4	33.8	50.4
Min	10	10	0	0	20	20	10	0
Max	100	60	90	100	100	100	70	100
Pool-Riffle Ratio	1.5 : 1	1.4 : 1	1.6 : 1	2.5 : 1	15 : 1	8 : 1	3.5 : 1	2.6 : 1
LWD (#/100m)	3.6	3.7	3.3	1.8	2.9	3.1	0.4	2.6
Primary Pools (#/Km)	21.7	23.9	19.3	18.5	27.3	28.4	24.4	23.2
Mean Stream Width (m)	5.1	3.8	4.4	1.8	3.1	3.7	3.6	3.6
Mean Stream Depth (cm)	22.1	16.2	28.2	13.3	24.3	42	32.4	24.9
Mean Gradient (%)	1.8	1.3	1	0.7	0.5	0.5	1	1
Min	1.5	1	0.5	0.5	0.5	0.5	1	0.5
Max	2	1.5	2	1	0.5	0.5	1	2
Substrate (% Occurrence)								
Bedrock				33.3				5.8
Boulders	4.8	3.2	18.4	5.5				1.9
Rubble		13.5	15.9	6.4		7	4	6.6
Cobble	33.4	54.3	37.4	3.9	17	30.9	17.7	29.9
Gravel	5.9	15.5	10	5.5	16.4	14.9	33.4	14.4
Small Gravel			11.2		4.6		11	4
Sand	27.9	7.9	4.8	45.3	36.3	23.3	33.8	24
Silt	28.1	5.7	2.4		25.7	23.9		13.4
Habitat Types								
Pool (% Occurrence)	**68.2**	**53**	**53**	**71**	**96.5**	**95.4**	**46.5**	**67.8**
Mean Width (m)	7	4	4.4	3.1	4.5	3.9	4.8	4.5
Min Width (m)	2.6	2.4	2	1	2.4	1.4	3.8	1
Max Width (m)	18.5	6.7	8.4	4.8	6.8	5.5	7.2	18.5
Riffle (% Occurrence)	**28.6**	**33.8**	**26.6**	**22.5**	**3.5**	**4.6**	**4.2**	**18.8**
Mean Width (m)	3.7	3.7	4.4	2.5	2.3	1.5	1.5	3.3
Min Width (m)	1.7	1.6	2.7	0.5	2.3	1.3	1.3	0.5
Max Width (m)	6	5.6	7.1	4.5	2.3	1.7	1.7	7.1
Run (% Occurrence)	**3.1**	**13.2**	**20.4**	**6.4**	**0**	**0**	**49.3**	**13.5**
Mean Width (m)	3.2	3.3	4.3	2.8			3.2	3.4
Min Width (m)	3.2	2.8	3.4	2.8			1.5	1.5
Max Width (m)	3.2	4.2	5	2.8			6.8	6.8

Cattle were observed in reaches 1 through 3 although sign was present in all reaches. Suppression of vegetation was observed from grazing as the cattle were congregating in the riparian area.

3.4b Relative Fisheries Abundance

Five of the seven reaches in Little Tshimikain were sampled in 2000. Species include: rainbow trout (*Salmo gairdneri*), brown trout (*Salmo trutta*), bridgelip sucker (*Catostomus columbianus*), speckled dace (*Rhinichthys osculus*), piute sculpin (*Cottus leiopomus*), chiselmouth (*Acrocheilus alutaceus*), northern pikeminnow (*Ptychocheilus oregonensis*), and redside shiner (*Richardsonius balteatus*). Overall, densities of rainbow and brown trout were very low, and densities of all other fish were very high (Table 3.8). Although recruitment to the electroshocker was good, only a single electroshocking pass was made at each transect due to the lack of salmonid presence. A single electroshocking pass will underestimate the actual fish density. The low number of salmonids could be directly attributed to the high temperatures in Little Tshimikain. Although most sculpin prefer colder water, the piute sculpin is common in waters with a range of 12°C to 25°C (Wydoski and Whitney 1979). The high temperatures are attributed to the lack of overstory, and the numerous beaver dams reaching into the headwaters. Above the falls, the species observed by highest density was bridgelip suckers, speckled dace, redside shiners, and rainbow trout. Currently sculpin have only been found below the falls in reaches 1 through 3. Bridgelip sucker, speckled dace, and redside shiners, which are all native fish, were found above the falls. Densities of fish were high in reaches 4 and 5 due to the receding flows and concentration of fish in pools.

Table 3.8 Densities (#/100m^2) of fish in Little Tshimikain in reaches 1 through 5.

Date	Reach	Method	N	Area(m^2)	Brown Trout Density	Rainbow Trout Density	Sculpin Density	Other Density	Overall Density (#/100m^2)
09/07/00	1	shock	240	174.30	0.00	0.00	50.49	87.21	137.69
09/07/00	2	shock	211	174.18	0.00	1.15	67.75	52.25	121.14
09/11/00	3	shock	479	305.70	0.33	2.29	53.32	100.75	156.69
09/11/00	4	shock	388	63.99	0.00	1.56	0.00	604.78	606.34
09/11/00	5	shock	504	136.89	0.00	0.00	0.00	368.18	368.18
Sum			1822	855.06	0.33	5.00	171.55	1213.16	1390.05
Average			**364.40**	**171.01**	**0.07**	**1.00**	**34.31**	**242.63**	**278.01**

3.5 COTTONWOOD CREEK

3.5a Stream Habitat Survey

Four reaches beginning at Little Tshimikain and ending at Cottonwood road were surveyed for habitat in 2000 (Figures 5 and 6). No fish surveys were conducted in 2000 although fish were observed. Completion of the habitat survey along with the respective fish survey will be concluded in 2001. Habitat data collected on Cottonwood Creek is summarized in Table 3.9. Reach 1, which had the highest number of primary pools, had the widest valley bottom as it entered Little Tshimikain. Reach 1 had the highest average depth as well as the highest percentage of sand and muck. Reaches 2 through 4 are characterized with shallow runs as the dominant habitat with low embeddedness and gravel/cobble substrate. Of the 73 transects taken in all reaches, 13 of them were dry. Average bankfull width/depth ratios in reaches 1 through 4 were 5.64, 9.43, 18.64, and 7.44 respectively.

3.6 DEEP CREEK

3.6a Stream Habitat Survey

Deep Creek was surveyed for habitat in 2000 but no fish sampling was performed. Fish sampling will conclude in 2001 and be reported in the 2001 annual report. Deep creek habitat data is summarized in Table 3.9. Deep Creek was surveyed from the confluence with Sheep Creek to just above Cottonwood road (Figure 6). Sustained flow comes from the springs above Cottonwood Road whereas the stream is intermittent above that point. Deep creek is a low gradient stream dominated by deep pools and a sandy substrate (Table 3.9). Water temperature was 18.5°C at 1:00 pm when the air temperature was 24.5°C. High temperatures are attributed to lack of overstory and the direct irradiance of the numerous pools.

Figure 6. Reaches 2 through 4 of Cottonwood Creek, and Reach 1 of Deep Creek surveyed in 2000.

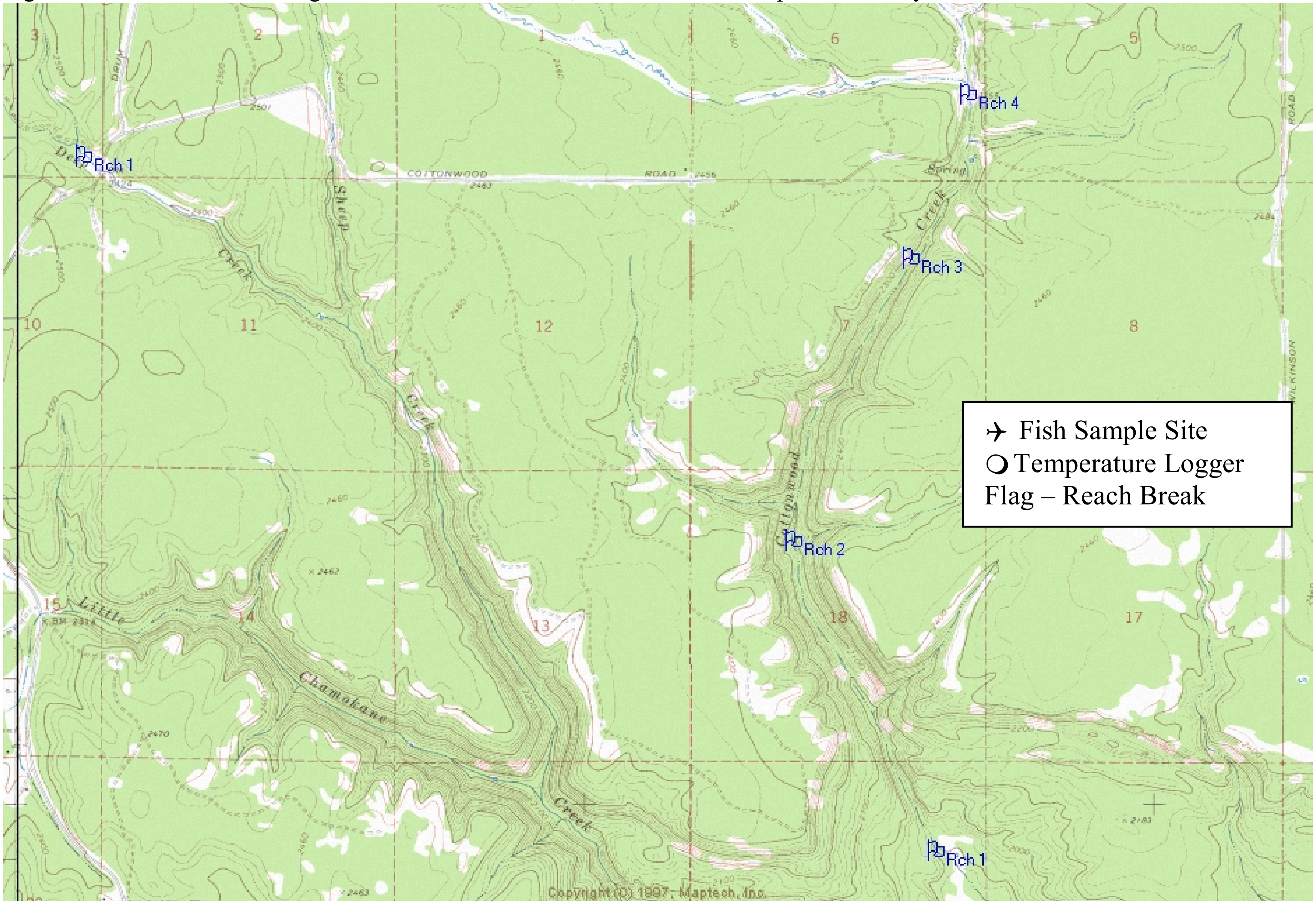


Table 3.9 Habitat summary data collected on Deep Creek and Cottonwood Creek in 2000.

	Deep Creek	Cottonwood Creek				
Reach	**1**	**1**	**2**	**3**	**4**	**Combined**
Length (m)	1800	1800	1800	1980	990	6570
Mean Embeddedness (%)	52	45.5	34.6	41.6	25.9	38.8
Min	30	20	20	30	10	10
Max	70	70	45	60	50	70
Pool-Riffle Ratio	13 : 1	2.3 : 1	1 : 0	5 : 1	2 : 0	3.8 : 1
LWD (#/100m)	4.4	1.4	3.2	1.4	1	1.8
Primary Pools (#/Km)	32.2	26.7	5.6	9.1	5.1	12.3
Mean Stream Width (m)	2.7	2.5	1.2	2.3	1.4	1.9
Mean Stream Depth (cm)	35.1	25.7	9.3	12.9	9.5	14.9
Mean Gradient (%)	1.4	1.6	1.7	1.6	2.3	1.7
Min	1	1	1	1	2	1
Max	2	2.5	2.5	2.5	3	3
Substrate (% Occurrence)						
Rubble	4.6					
Cobble	10.6	25.1	50	31.8	27.3	30
Gravel	14.1	32.7	40	54.5	63.6	45.5
Small Gravel	1.8			9.1	9.1	7.4
Sand	68.9	28.3	10			10.1
Silt						
Muck		13.9				4.9
Organic Debris				4.5		2
Habitat Types						
Pool (% Occurrence)	**84.4**	**50.2**	**7.7**	**26.3**	**25**	**35.2**
Mean Width (m)	3.5	3.6	2.2	3.6	1.95	3.3
Min Width (m)	1.7	2.3	2.2	2.9	1.5	1.5
Max Width (m)	7.2	6.9	2.2	3.9	2.4	6.9
Riffle (% Occurrence)	**0**	**7.8**	**0**	**5.3**	**0**	**3.8**
Mean Width (m)		1.3		1.4		1.3
Min Width (m)		1		1.4		1
Max Width (m)		1.7		1.4		1.7
Run (% Occurrence)	**15.6**	**42**	**92.3**	**68.4**	**75**	**61**
Mean Width (m)	1.2	2.1	1.8	2.4	2	2.1
Min Width (m)	1	1.4	0.8	0.9	1.7	0.8
Max Width (m)	1.7	4.8	3.2	3.6	2.2	4.8

3.7 CASTLE ROCK CREEK

3.7a Stream Habitat Survey

Castle Rock Creek was surveyed from the mouth (1290 ft) to 2070 feet (Figure 7). Castle Rock Creek is characterized by a deep-V valley type, and high gradient stream with very little pool habitat. Reach 1 would be classified as an A3 stream bordering on an A3+ according to Rosgen stream classification. Reach 2 would be an A4+ according to Rosgen. Mid-day temperature was recorded as 16.5°C on July 12th. The deep canyon has dense timber on the north slope, while the south facing slope is a mixture of bitterbrush/bunchgrass with sparse ponderosa pine. Habitat data for the two reaches are summarized in Table 3.10.

There has been mining activity in the drainage evident by the tailings piles on stream banks, barrels, equipment, and piping in the stream. Tailings were transported down to the creek via mine carts where they were processed using sluices. Tailings are exposed (45 m long) to the waters edge and are contributing to the bed load approximately 1700 meters above the mouth.

Reach 2 was terminated at the confluence of the tributary below the pond, which is 180 meters above the road crossing. There was minimal flow above this point in both the tributary and main channel. Historic timber harvest is present within the riparian area and some abandoned roads are sloughing into the channel. The culvert, 180 meters below the end of reach 2, has been restricted by debris causing the stream to flow over the road surface. Small gullies are present from surface flows down the road entering the creek.

3.7b Relative Fisheries Abundance

No fish were observed in the stream while conducting the habitat survey. Electrofishing was conducted in the lower 200 meters of the stream in the best available habitats. Sixty meters in reach 1 was electroshocked (Figure 7). No fish were sampled during either electrofishing effort. Lack of fish presence could be primarily related to the high gradient, lack of pool habitat, diminishing downstream flow, and debris jams and deposition bars at the mouth.

Figure 7 Reaches 1 and 2 of Castle Rock Creek surveyed in 2000.

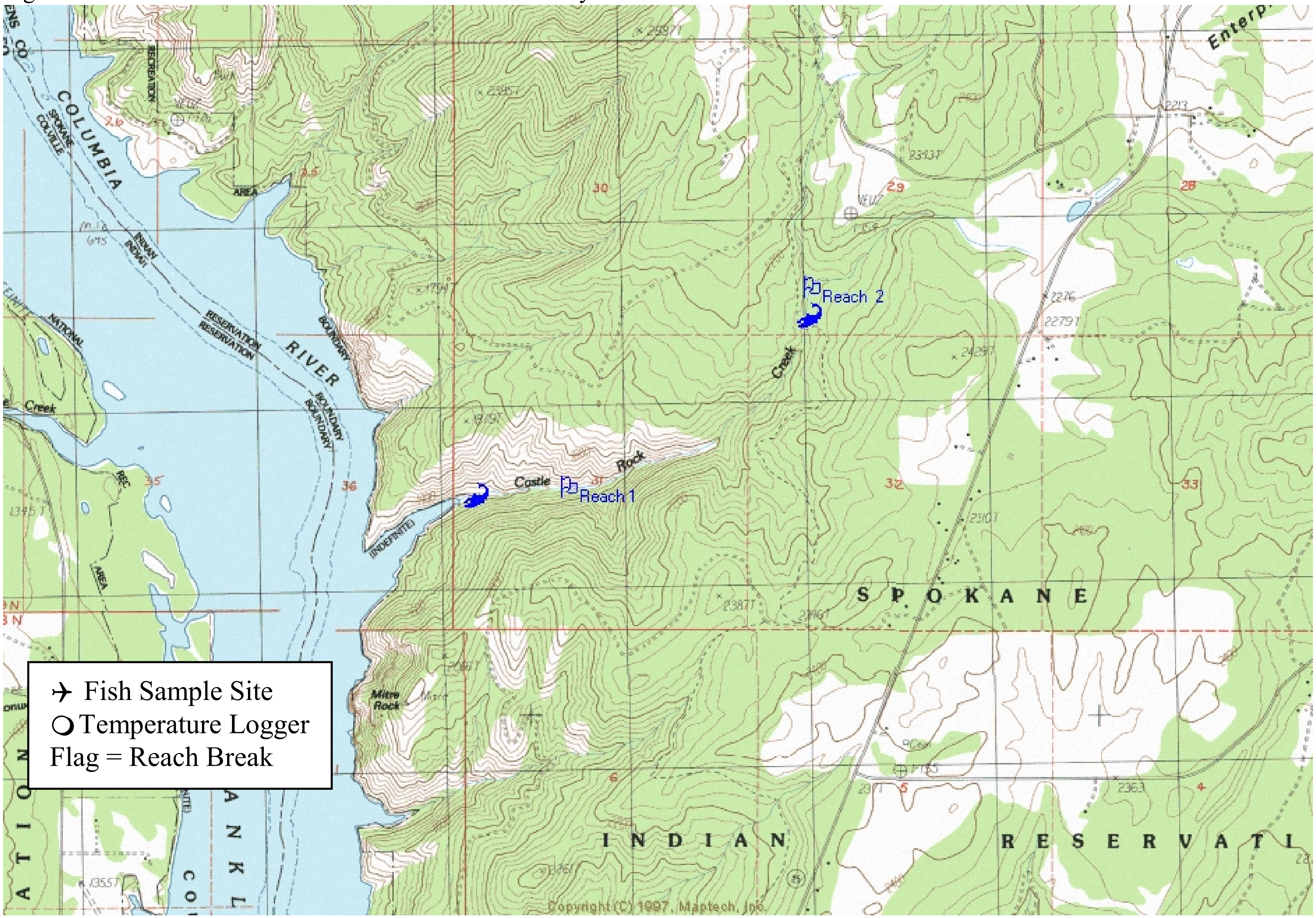


Table 3.10 Habitat summary data collected from Castle Rock Creek in 2000.

Reach	1	2	Combined
Length (m)	810	1890	2700
Mean Embeddedness (%)	33.9	40.7	38.7
Min	0	0	0
Max	45	100	100
Pool-Riffle Ratio	0 : 1	0.3 : 1	0.2 : 1
LWD (#/100m)	5.7	8.5	7.7
Primary Pools (#/Km)	12.3	39.2	31.1
Mean Stream Width (m)	1.3	1.2	1.3
Mean Stream Depth (cm)	7.1	9	8.5
Mean Gradient (%)	9.8	10.3	10.1
Min	9	5	5
Max	10.5	14	14
Substrate (% Occurrence)			
Bedrock	14.4	13.1	13.5
Boulders	24.6	4.6	10.9
Rubble	32.2	2.7	11.9
Cobble	18.6	18.9	18.8
Gravel		47.9	32.9
Small Gravel	10.2	10	10.1
Sand			
Silt		2.7	1.9
Habitat Types			
Pool (% Occurrence)	**0**	**27**	**18.6**
Mean Width (m)		1.4	1.4
Min Width (m)		1.2	1.2
Max Width (m)		1.8	1.8
Riffle (% Occurrence)	**89.9**	**68.7**	**75.3**
Mean Width (m)	1.3	1.2	1.2
Min Width (m)	1	0.7	0.7
Max Width (m)	1.7	1.8	1.8
Run (% Occurrence)	**10.2**	**4.2**	**6.1**
Mean Width (m)	1.2	1.1	1.2
Min Width (m)	1.2	1.1	1.1
Max Width (m)	1.2	1.1	1.2

3.8 BENJAMIN LAKE

Benjamin Lake, located within the South Slopes Basin, had a surface area of 22.7 acres and a maximum depth of 10 meters in 1973 (Woodward).

Densities and biomass of each group of zooplankton are displayed in Tables 3.12 and 3.13. Samples in 2000, as opposed to 1999, indicate that *Daphnia spp*. densities and biomass are higher than all other categories. Total zooplankton density and biomass are highest in April and the lowest in October. Average species length for each month is displayed in Table 3.14. The species more likely to contribute directly to the fish diets, based on size, are the larger *Daphnia spp*. as well as *Leptodiaptomus ashlandi* (Table 3.15). *Daphnia rosea* were only sampled in October, although a large number were sampled. *D. rosea* were present in small numbers in the fall samples taken in 1999. Of the three groups sampled *Daphnia spp*. increased from 420/m^3 in October 1999 to 7,402/m^3 in October of 2000. In October 1999 densities of "Other Cladocera" and Copepoda were 5,220/m^3 and 10,394/m^3 respectively (Crossley, 1999) compared to 3,565/m^3 and 6,960/m^3 in 2000. High numbers of zooplankton are expected in eutrophic lakes although zooplankton blooms could explain the high densities in specific months.

The largest sources of biomass (µg/m^3) are the *Daphnia spp*. and Coepoda groups. *Daphnia* spp. biomass was 2,039/m^3 in October 1999 and increased to 36,552/m^3 in October 2000. Biomass of "Other Cladocera" and Copepoda in October 1999 was 9,327/m^3 and 64,462/m^3 respectively and 17,274/m^3 and 64,300/m^3 in 2000.

Monthly mean zooplankton lengths by species and group are in Table 3.14. Combined mean zooplankton lengths, standard deviation, number sampled, and observed range are displayed in Table 3.15. Species of identified zooplankton are listed in Table 3.19. The large numbers of "small" zooplankton suggests there are large amounts of food, however inter and intra species competition is high for those resources. High zooplankton densities should provide available forage for larger predatory species, however there was none found in the months sampled. Although the oxygen is low below 5 meters in all the lakes, the larger predatory zooplankton may be sampled at depths greater than 5 meters.

Water quality measurements are summarized by parameter, date and depth in Tables 3.16. Limiting factors, common to eutrophic lakes, are dissolved oxygen and temperature. Mid-day surface temperatures were as high as 22.57°C in July. Dissolved oxygen was below 5 mg/l in August and September in the upper 3 meters of the lake. Spring and fall mixing occurred in March and October respectively. Secchi disk measurements were the highest in April and the lowest in October and averaged 4.22 meters (Table 3.36).

The fish assemblages in Benjamin Lake were sampled on June 28th. A total of 0.49 hours were spent electrofishing and 5.58 hours of gill net sampling to collect 225 fish (Tables 3.17 and 3.18). The total combined CPUE was 442.43 in Benjamin Lake: 287.76 for pumpkinseed (*Lepomis gibbosus*), 153.06 for largemouth bass (*Micropterus salmoides*), and 1.61 for rainbow trout. Due to high conductivity the electroshocker was adjusted after the first 10-minute transect, which increased sampling efficiency in subsequent transects. The average condition factor for rainbow trout was 0.93. Average relative weights for pumpkinseed and largemouth bass were 99% and 88% respectively. Relative weights for largemouth bass ranged from 59% to 109%. The lower relative weight of largemouth bass may be related to the short growing season. The largest bass sampled had a relative weight of 109%, which may suggest that younger bass are competing directly with the pumpkinseed. Relative abundance of fish species in Benjamin Lake is identified in Table 3.20. Back-calculated lengths of largemouth bass sampled in Benjamin Lake are displayed in Table 3.11. Except for age 1 fish, the largemouth bass growth in Benjamin Lake is below Washington State's average according to Wydoski and Whitney (1979)(Table 3.11).

Table 3.11 Largemouth bass mean back-calculated lengths (mm) at annulus with standard deviation for fish sampled in Benjamin Lake in June, 2000.

	MEAN ± BACK-CALCULATED LENGTH AT ANNULUS						
N	**1**	**2**	**3**	**4**	**5**	**6**	**7**
3	85 ± 14.9						
36	72.4 ± 10.1	134 ± 10.7					
10	76.4 ± 10.7	120 ± 15.8	155 ± 14.1				
4	77.2 ± 8.1	116 ± 18.7	147 ± 13	178 ± 29			
1	62	98	136	180	225	253	289
Grand Mean	N = 54 74 ± 10.6	N = 51 129 ± 14.7	N = 15 151 ± 14.1	N = 174 178 ± 25.1	N = 1 225	N = 1 253	N = 1 289
Mean Annual Growth Increment	74	55	22	27	47	28	36
Washington State's Average Growth	71	135	213	257	302	343	381

Table 3.12 Zooplankton density (#/m^3) and standard deviation (S.D.) sampled in 2000 from Benjamin Lake.

Sample Date	Daphnia	S.D	Other Cladocera	S.D.	Copepoda	S.D.	Total Zooplankton	S.D.
April 21	61,115.50	41,350.30	4,889.24	3,259.49	21,458.33	12,632.73	87,463.07	56,996.49
July 17	3,531.12	3,085.06	39,113.92	5,876.13	32,730.74	12,899.30	75,375.78	19,839.28
Oct. 31	7,401.77	1,756.39	3,565.07	1,234.98	6,960.38	878.20	17,927.21	3,335.01
Mean	**24,016.13**		**15,856.08**		**20,383.15**		**60,255.35**	
Percentage	**39.9%**		**26.3%**		**33.8%**			

Table 3.13 Zooplankton biomass (µg/m^3) and standard deviation (S.D.) sampled in 2000 from Benjamin Lake.

Sample Date	Daphnia	S.D.	Other Cladocera	S.D.	Copepoda	S.D.	Total Zooplankton	S.D.
April 21	289,161.78	140,423.05	12,389.97	5,197.78	111,493.50	129,656.19	413,045.24	269,771.09
July 17	6,075.79	5,508.13	94,237.17	15,516.02	109,500.57	71,200.40	209,813.54	89,129.29
Oct. 31	36,552.20	10,160.54	17,274.29	5,454.75	64,300.20	9,348.09	118,126.69	24,963.34
Mean	**110,596.59**		**41,300.48**		**95,098.09**		**246,995.16**	
Percentage	**44.8%**		**16.7%**		**38.5%**			

Table 3.14 Average length (mm) and standard deviation (S.D.) of zooplankton species sampled from Benjamin Lake in April, July, and October 2000.

Species	April Mean Length	S.D.	July Mean Length	S.D.	October Mean Length	S.D.
Daphnia						
Daphnia pulex	0.97 (n=60)	0.32	0.67 (n=13)	0.12	0.88 (n=65)	0.27
Daphnia rosea	--		--		1.06 (n=49)	0.17
Other Cladocera						
Chydorus sphaericus	0.29 (n=2)	0.12	--		--	
Ceriodaphnia quadrangula	--		0.51 (n=61)	0.12	0.75 (n=60)	0.09
Diaphanosoma brachyurum	--		0.60 (n=2)	0.31		
Bosmina longirostris	--				0.36 (n=9)	0.07
Copepoda						
Diacyclops bicus. thomasi	0.49 (n=2)	0.13	--		0.54 (n=19)	0.14
Leptodiaptomus ashlandi	1.18 (n=14)	0.70	0.99 (n=43)	0.38	1.18 (n=60)	0.33
Nauplii	0.21 (n=41)	0.06	0.19 (n=61)	0.06	0.21 (n=29)	0.06

Table 3.15 Combined mean zooplankton length (mm), standard deviation (S.D.), number sampled, and observed range from samples taken in 2000 from Benjamin Lake.

Species	Combined Mean Length	Average S.D.	n	Observed Range
Daphnia				
Daphnia pulex	0.84	0.24	138	(0.49-1.67)
Daphnia rosea	1.06	0.17	49	(0.65-1.35)
Other Cladocera				
Chydorus sphaericus	0.29	0.12	2	(0.21-0.38)
Ceriodaphnia quadrangula	0.63	0.10	121	(0.34-0.93)
Diaphanosoma brachyurum	0.60	0.31	2	(0.38-0.82)
Bosmina longirostris	0.36	0.07	9	(0.21-0.44)
Copepoda				
Diacyclops bicus. thomasi	0.52	0.14	21	(0.32-0.84)
Leptodiaptomus ashlandi	1.12	0.47	117	(0.38-2.09)
Nauplii	0.20	0.06	131	(0.10-0.36)

Tables 3.16 Water quality measurements taken with a Hydrolab Surveyor 4 at Benjamin Lake in 2000.

Temperature (°C)									
Depth (m)	**2/9/00**	**4/21/00**	**5/30/00**	**7/17/00**	**8/28/00**	**9/28/00**	**10/31/00**	**11/30/00**	**12/27/00**
0	0.68	13.99	17.45	22.57	20.35	14.03	8.83	3.42	1.74
1	--	13.25	17.28	22.22	19.88	13.95	8.83	--	3.32
2	--	11.39	16.14	20.94	19.82	13.92	8.84	--	3.44
3	3.35	8.28	13.99	18.93	19.76	13.9	8.85	--	3.47
4	--	6.11	10.23	14.9	17.97	13.87	8.86	--	3.52
5	--	4.61	7.75	11.89	14.41	13.84	8.85	--	3.54
6	3.47	4.21	6.55	9.34	10.43	11.57	8.85	--	3.57
9	3.74	4.13	5	6.26	6.63	7.14	8.34	--	3.91

% Dissolved Oxygen									
Depth (m)	**2/9/00**	**4/21/00**	**5/30/00**	**7/17/00**	**8/28/00**	**9/28/00**	**10/31/00**	**11/30/00**	**12/27/00**
0	65	95.1	105.5	92.8	51.2	38.6	57.7	45.5	37.4
1	--	91.5	101.8	90.8	51.3	38.7	57.7	--	40.7
2	--	86.5	102.9	65.5	52.1	38.7	57	--	33.5
3	52.6	79.9	106.3	94.8	53	37.9	55.6	--	31.5
4	--	70.2	75.1	130.6	63.6	38.1	55.9	--	29
5	--	27.7	46.3	105.9	60.6	38.9	56	--	28
6	41.7	12.6	20.4	60.3	39.3	26.1	54.3	--	28.1
9	21.7	5.8	5.5	13.8	9.1	9.7	13.7	--	11.2

Dissolved Oxygen (mg/L)									
Depth (m)	**2/9/00**	**4/21/00**	**5/30/00**	**7/17/00**	**8/28/00**	**9/28/00**	**10/31/00**	**11/30/00**	**12/27/00**
0	8.55	9.82	9.26	7.38	4.26	3.68	6.82	6.08	5.33
1	--	9.61	8.97	7.29	4.3	3.69	6.78	--	5.56
2	--	9.42	9.28	5.44	4.38	3.69	6.71	--	4.56
3	6.47	9.38	10.05	8.08	4.46	3.61	6.49	--	4.29
4	--	8.76	7.73	12.07	5.57	3.63	6.57	--	3.94
5	--	3.64	5.07	10.74	5.67	3.8	6.57	--	3.8
6	5.11	1.7	2.29	6.45	4.05	2.62	6.53	--	3.81
9	2.7	0.79	0.63	1.59	1.04	1.09	1.7	--	1.51

Conductivity (mmho/cm)									
Depth (m)	**2/9/00**	**4/21/00**	**5/30/00**	**7/17/00**	**8/28/00**	**9/28/00**	**10/31/00**	**11/30/00**	**12/27/00**
0	443	401	419	425	440	440	449	443	453
1	--	400	420	424	440	440	448	--	451
2	--	406	424	427	439	440	449	--	452
3	445	444	434	438	439	440	449	--	452
4	--	457	458	452	457	440	449	--	453
5	--	459	464	458	461	440	449	--	453
6	450	460	466	460	464	466	448	--	454
9	456	461	464	462	477	481	468	--	458

Total Dissolved Gases (mmHg)									
Depth (m)	**2/9/00**	**4/21/00**	**5/30/00**	**7/17/00**	**8/28/00**	**9/28/00**	**10/31/00**	**11/30/00**	**12/27/00**
0	630	727	714	691	668	652	645	699	673
1	--	728	721	691	673	655	645	--	672
2	--	725	723	687	674	656	645	--	672
3	634	719	726	684	675	657	645	--	665
4	--	712	728	675	675	657	645	--	652
5	--	685	701	667	667	658	645	--	649
6	638	664	652	657	659	655	645	--	646
9	639	655	635	645	644	646	645	--	645

pH									
Depth (m)	**2/9/00**	**4/21/00**	**5/30/00**	**7/17/00**	**8/28/00**	**9/28/00**	**10/31/00**	**11/30/00**	**12/27/00**
0	8.44	8.08	8.16	8	8.23	8.45	7.58	7.65	7.76
1	--	8.1	8.23	7.98	8.26	8.48	7.6	--	7.75
2	--	8.02	8.15	7.66	8.28	8.47	7.6	--	7.76
3	8.4	8.06	8.27	7.83	8.27	8.48	7.61	--	7.76
4	--	8.02	8.12	8.24	8.23	8.49	7.61	--	7.76
5	--	7.76	7.95	8.09	8.2	8.5	7.62	--	7.76
6	8.3	7.7	7.86	7.8	7.94	7.96	7.62	--	7.76
9	8.18	7.66	7.75	7.59	7.59	7.67	7.25	--	7.66

Oxidation Reduction Potential (mV)									
Depth (m)	**2/9/00**	**4/21/00**	**5/30/00**	**7/17/00**	**8/28/00**	**9/28/00**	**10/31/00**	**11/30/00**	**12/27/00**
0	288	336	332	403	320	318	98	264	68
1	--	333	293	406	319	319	105	--	68
2	--	332	271	411	320	321	110	--	69
3	287	332	258	413	322	322	115	--	73
4	--	332	243	413	325	323	119	--	79
5	--	332	235	415	330	325	122	--	82
6	288	332	212	417	336	332	126	--	85
9	284	332	204	215	63	10	57	--	88

Table 3.17 Electrofishing catch per unit effort (CPUE) calculated for each lake sampled in 2000.

	Benjamin Lake			McCoy Lake			Turtle Lake		
	hours sampled		0.49	hours sampled		0.50	hours sampled		0.27
Species	**Total**	**Percent**	**CPUE (hrs)**	**Total**	**Percent**	**CPUE (hrs)**	**Total**	**Percent**	**CPUE (hrs)**
brook trout	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00
brown trout	0	0.0	0.00	0	0.0	0.00	1	5.3	3.70
rainbow trout	0	0.0	0.00	121	91.0	242.00	18	94.7	66.67
pumpkinseed	141	65.3	287.76	0	0.0	0.00	0	0.0	0.00
largemouth bass	75	34.7	153.06	12	9.0	24.00	0	0.0	0.00
TOTALS	**216**		**440.82**	**133**		**266.00**	**19**		**70.37**

Table 3.18 Gillnet catch per unit effort (CPUE) calculated for each lake sampled in 2000.

	Benjamin Lake			McCoy Lake			Turtle Lake			Mathews Lake		
	hours sampled		5.58	hours sampled		4.00	hours sampled		3.92	hours sampled		4.83
Species	**Total**	**Percent**	**CPUE (hrs)**	**Total**	**Percent**	**CPUE (hrs)**	**Total**	**Percent**	**CPUE (hrs)**	**Total**	**Percent**	**CPUE (hrs)**
brook trout	0	0.0	0.00	0		0.00	0		0.00	1	25.0	0.21
brown trout	0	0.0	0.00	0		0.00	0		0.00	0	0.0	0.00
rainbow trout	9	100.0	1.61	0		0.00	0		0.00	0	0.0	0.00
pumpkinseed	0	0.0	0.00	0		0.00	0		0.00	3	75.0	0.62
largemouth bass	0	0.0	0.00	0		0.00	0		0.00	0	0.0	0.00
TOTALS	**9**		**1.61**	**0**		**0.00**	**0**		**0.00**	**4**		**0.83**

Table 3.19 Zooplankton taxa identified in Benjamin, Mathews, McCoy, and Turtle Lakes during 1999 and 2000.

Phylum Anthropoid
- Class Crustacea
  - Subclass Branchiopoda
    - Order Cladocera
      - Family Daphnidae
        1. *Ceriodaphnia quadrangula* (B, M, Mc, T)
        2. Daphnia pulex *(B, M, Mc, T)*
        3. Daphnia rosea *(B, M, Mc, T)*
      - Family Chydoridae
        4. *Alona quadrangularis* (B, Mc)
        5. *Chydorus sphaericus (B)*
      - Family Sididae
        6. *Diaphanosoma brachyurum* (B, M, Mc, T)
      - Family Bosmina
        7. *Bosmina longirostris* (B, M, T)
  - Subclass Copepoda
    - Order Eucopepoda
      - Suborder Calanoida
        - Family Diaptomidae
          8. *Leptodiaptomus ashlandi* (B, M, Mc, T)
        - Family Temoridae
          9. *Epischura nevadensis* (T)
      - Suborder Cyclopoida
        - Family Cyclopoidae
          10. *Diacyclops bicuspidatus thomasi* (B, M, Mc, T)
          11. *Mesocyclops edax* (B, M, T)
      - Suborder Harpacticoida
        - Family Harpacticoidae
          12. *Harpacticoid spp.* (M)

B – Benjamin Lake
M – Mathews Lake
Mc – McCoy Lake
T – Turtle Lake

3.9 MATHEWS LAKE

Mathews Lake has a surface area of 2.7 acres of open water with approximately 11 acres of adjacent wetland. The maximum depth of the lake is 6 meters. The group “Copepoda” made up 76% of the zooplankton density and 85% of the zooplankton biomass in Mathews Lake (Tables 3.21 and 3.22). The highest zooplankton densities and biomass were observed in July. All zooplankton species are relatively small which could be due to the fierce competition for food and the lack of predatory species. All species of zooplankton in Mathews Lake averaged less than 1.0 mm in length (Table 3.23). Lengths greater than 1.0 mm were measured in *Daphnia rosea* and *L. ashlandi* (Table 3.24).

Water quality measurements are displayed in Tables 3.25, by parameter, depth, and month. Dissolved oxygen is the largest limiting factor for fish in Mathews Lake. The highest dissolved oxygen measurement was less than 4 mg/l in 5 of the 9 months sampled. Dissolved oxygen was below 3.5 mg/l below 2 meters in all months sampled. At turnover, in October, dissolved oxygen remained low and did not rejuvenate until February. Secchi disk measurements averaged 2.77 meters, was 4 meters in September and 1.8 meters in April and October (Table 3.36).

Fish sampling was done only by gillnet due to the inaccessibility of shocking equipment. One experimental gillnet was set for 4.83 hours and produced 3 pumpkinseed and a brook trout (Table 3.18). Additional sampling would be required to adequately assess the relative fish abundance and species present.

Table 3.20 Relative abundance of fish species sampled from the lakes in 2000.

Species	Benjamin Lake	Mathews Lake	McCoy Lake	Turtle Lake
brook trout	0.00%	25.00%	0.00%	0.00%
brown trout	0.00%	0.00%	0.00%	5.26%
rainbow trout	4.00%	0.00%	90.98%	94.74%
pumpkinseed	62.67%	75.00%	0.00%	0.00%
largemouth bass	33.33%	0.00%	9.02%	0.00%
	(n = 225)	(n = 4)	(n = 133)	(n = 19)

Table 3.21 Zooplankton density (#/m^3) and standard deviation (S.D.) sampled in 2000 from Mathews Lake.

Sample Date	Daphnia	S.D	Other Cladocera	S.D.	Copepoda	S.D.	Total Zooplankton	S.D.
April 21	0.00	0.00	5,432.49	3,763.74	178,185.63	19,647.29	183,618.12	23,124.80
July 17	2,716.24	2,489.48	77,684.59	9,267.13	247,178.24	69,724.46	327,579.07	80,056.90
Oct. 31	611.15	538.99	53,374.20	14,481.21	26,890.82	7,952.85	80,876.18	21,696.72
Mean	**1,109.13**		**45,497.09**		**150,751.56**		**197,357.79**	
Percentage	**0.6%**		**23.1%**		**76.4%**			

Table 3.22 Zooplankton biomass (µg/m^3) and standard deviation (S.D.) sampled in 2000 from Mathews Lake.

Sample Date	Daphnia	S.D.	Other Cladocera	S.D.	Copepoda	S.D.	Total Zooplankton	S.D.
April 21	0.00	0.00	8,883.24	7,816.95	415,575.30	45,677.21	424,458.54	53,494.16
July 17	8,484.47	9,384.02	79,080.86	11,610.84	462,533.79	119,509.35	550,099.12	140,504.21
Oct. 31	1,612.10	1,862.92	68,318.25	22,864.10	81,642.99	29,547.23	151,573.33	54,274.25
Mean	**3,365.52**		**52,094.12**		**319,917.36**		**375,377.00**	
Percentage	**0.9%**		**13.9%**		**85.2%**			

Table 3.23 Average length (mm) and standard deviation (S.D.) of zooplankton species sampled from Mathews Lake in April, July, and October 2000.

Species	April Mean Length	S.D	July Mean Length	S.D.	October Mean Length	S.D.
Daphnia						
Daphnia pulex	--		0.66 (n=3)	0.19	0.61 (n=1)	n/a
Daphnia rosea	--		1.0 (n=2)	0.23	0.83 (n=7)	0.09
Other Cladocera						
Ceriodaphnia quadrangula	0.65 (n=5)	0.23	0.53 (n=61)	0.09	0.59 (n=60)	0.07
Diaphanosoma brachyurum	--		0.59 (n=22)	0.15	0.70 (n=2)	0.03
Bosmina longirostris	--		0.30 (n=11)	0.08	0.37 (n=62)	0.06
Copepoda						
Diacyclops bicus. thomasi	0.62 (n=49)	0.14	0.59 (n=22)	0.20	0.70 (n=2)	0.11
Leptodiaptomus ashlandi	0.84 (n=4)	0.44	0.77 (n=59)	0.20	0.69 (n=62)	0.17
Mesocyclops edax	0.82 (n=8)	0.04	--		--	
Nauplii	0.22 (n=62)	0.05	0.17 (n=66)	0.04	0.20 (n=56)	0.05

Table 3.24 Combined mean zooplankton length (mm), standard deviation (S.D.), number sampled, and observed range from samples taken in 2000 from Mathews Lake.

Species	Combined Mean Length	Average S.D.	n	Observed Range
Daphnia				
Daphnia pulex	0.63	0.04	4	(0.53-0.87)
Daphnia rosea	0.92	0.16	9	(0.76-1.16)
Other Cladocera				
Ceriodaphnia quadrangula	0.59	0.13	126	(0.32-0.86)
Diaphanosoma brachyurum	0.65	0.09	24	(0.25-0.78)
Bosmina longirostris	0.33	0.07	73	(0.21-0.48)
Copepoda				
Diacyclops bicus. thomasi	0.64	0.15	87	(0.38-0.95)
Leptodiaptomus ashlandi	0.77	0.27	125	(0.38-1.29)
Mesocyclops edax	0.82	0.04	8	(0.76-0.87)
Nauplii	0.20	0.05	184	(0.10-0.32)

Tables 3.25 Water quality measurements taken with a Hydrolab Surveyor 4 at Mathews Lake in 2000.

Temperature (°C)

Depth (m)	2/18/00	4/21/00	5/30/00	7/17/00	8/28/00	9/28/00	10/31/00	11/30/00	12/27/00
0	1.29	13.27	16.45	21.31	20.12	13.57	8.19	3.27	1.03
1		10.12	15.29	20.07	19	13.43	8.2		2.53
2		7.96	13.88	18.3	18.9	13.27	8.21		3.42
3	3.57	6.25	10.26	12.82	15.62	13.18	8.21		3.48
4		4.81	7.39	9.86	10.41	11.65	8.19		3.69
5		4.6	5.21	7.02	7.28	8	8.2		3.88
6	3.85			5.78	6.39				

% Dissolved Oxygen

Depth (m)	2/18/00	4/21/00	5/30/00	7/17/00	8/28/00	9/28/00	10/31/00	11/30/00	12/27/00
0	105.9	105.2	72.3	63.9	45.7	33.5	27.4	18	14.3
1		101.4	60.5	20.8	43.3	31.7	26.9		8.9
2		99.6	64.3	8.9	40.7	31.8	26.2		7.2
3	25.2	8.5	3	5.3	17.1	31.3	26.2		6.9
4		4.8	1.6	5.4	9.8	11.6	25.8		4.7
5		3.3	1	5.2	6.2	8.9	17		4.5
6	12.2			6.6	5.3				

Dissolved Oxygen (mg/L)

Depth (m)	2/18/00	4/21/00	5/30/00	7/17/00	8/28/00	9/28/00	10/31/00	11/30/00	12/27/00
0	13.91	11.1	6.48	5.23	3.82	3.23	3.27	2.41	2.05
1		11.43	5.58	1.9	3.72	3.05	3.2		1.24
2		11.82	6.09	0.78	3.48	3.08	3.12		0.99
3	3.05	1.05	0.31	0.52	1.59	3.03	3.13		0.93
4		0.61	0.18	0.55	1.01	1.2	3.08		0.64
5		0.46	0.11	0.57	0.69	0.97	2.11		0.6
6	1.46			0.75	0.6				

Conductivity (mmho/cm)

Depth (m)	2/18/00	4/21/00	5/30/00	7/17/00	8/28/00	9/28/00	10/31/00	11/30/00	12/27/00
0	306	267	273	275	292	295	302	304	308
1		262	271	272	290	295	302		306
2		272	272	272	290	295	302		308
3	315	292	289	300	302	295	302		309
4		314	307	307	312	307	302		314
5		352	365	362	401	425	304		334
6	330			444	519				

Total Dissolved Gases (mmHg)

Depth (m)	2/18/00	4/21/00	5/30/00	7/17/00	8/28/00	9/28/00	10/31/00	11/30/00	12/27/00
0	628	724	696	680	679	651	639	657	668
1		744	687	678	677	655	641		663
2		735	685	675	677	655	641		662
3	633	701	652	669	668	656	642		658
4		664	647	655	654	655	642		649
5		659	669	645	647	646	642		642
6	637			639	641				

pH

Depth (m)	2/18/00	4/21/00	5/30/00	7/17/00	8/28/00	9/28/00	10/31/00	11/30/00	12/27/00
0	8.48	8.01	7.84	7.51	7.72	7.85	7.08	7.17	7.27
1		7.75	7.74	7.23	7.69	7.81	7.08		7.25
2		7.75	7.63	7.13	7.66	7.82	7.09		7.26
3	8.03	7.25	7.48	7.18	7.3	7.81	7.09		7.26
4		7.31	7.44	7.19	7.24	7.49	7.09		7.25
5		7.32	7.5	7.23	7.38	7.46	7.07		7.18
6	7.84			7.15	7.27				

Oxidation Reduction Potential (mV)

Depth (m)	2/18/00	4/21/00	5/30/00	7/17/00	8/28/00	9/28/00	10/31/00	11/30/00	12/27/00
0	455	373	278	421	260	243	95	258	101
1		368	275	423	269	248	97		99
2		361	275	425	273	251	98		97
3	457	272	270	429	200	256	101		94
4		227	268	405	282	261	102		-14
5		201	112	184	40	72	24		-79
6	330			105	22				

3.10 MCCOY LAKE

McCoy Lake has a surface area of 37.2 acres at full pool and a maximum depth of 16 meters. McCoy Creek, the inlet, flows from the west side of the Huckleberry Mountains and there is no outlet. The lake level was 2.61 meters below the full pool level in November 2000.

Density in October 1999 of *Daphnia spp*. was 543/m^3, 48,892/m^3 for "other Cladocera", and 8,420/m^3 for the group "Copepoda" (Crossley 1999). Although densities of *Daphnia spp*. increased in 2000, "other Cladocera" and "Copepoda" decreased. *D. Rosea* and *L. ashlandi* were the largest zooplankton species averaging over 1 mm in October and *L. ashlandi* was the most abundant (Tables 3.29, 3.28, and 3.26).

Temperature, dissolved oxygen, and pH are the three largest limiting water quality factors affecting fish and fish growth (Tables 3.30). Although the highest temperature recorded in Tables 3.30 was 22.89°C at mid-day on the surface in July, 27.6°C was recorded at 8:45 pm in June. The thermocline was between 3 and 4 meters throughout the summer and early fall months. Dissolved oxygen was a below 5 mg/l at 4 meters from April through September. The pH, in the top 3 meters, was above 8.82 from April through September. Secchi disk measurements averaged 3.8 meters and were the highest in August and October (Table 3.36).

Rainbow trout and largemouth bass were sampled while electrofishing in McCoy Lake). No fish were sampled in the gill net that was set for 4 hours (Table 3.18). During 0.5 hours of electroshocking, 133 fish were captured (10 largemouth bass, 122 rainbow trout), (Table 3.17). The average condition factor for the rainbow trout was 0.82, which suggest sub-optimal conditions for growth. The average largemouth bass relative weight was 105%, which may be attributed to the recent introduction of bass into the lake (unknown source).

Table 3.26 Zooplankton density (#/m^3) and standard deviation (S.D.) sampled in 2000 from McCoy Lake.

Sample Date	Daphnia	S.D	Other Cladocera	S.D.	Copepoda	S.D.	Total Zooplankton	S.D.
April 21	3,259.49	4,609.62	814.87	1,152.40	24,446.20	2,304.81	28,520.57	8,066.83
Oct. 31	3,904.60	2,098.23	18,334.65	5,659.37	4,278.08	1,324.17	26,517.34	8,800.26
Mean	**3,582.05**		**9,574.76**		**14,362.14**		**27,518.95**	
Percentage	**13.0%**		**34.8%**		**52.2%**			

Table 3.27 Zooplankton biomass (μg/m^3) and standard deviation (S.D.) sampled in 2000 from McCoy Lake.

Sample Date	Daphnia	S.D.	Other Cladocera	S.D.	Copepoda	S.D.	Total Zooplankton	S.D.
April 21	7,951.65	11,245.33	441.22	623.98	118,066.43	6,948.85	126,459.30	4,920.46
Oct. 31	14,142.83	7,844.02	87,596.55	25,502.54	26,914.68	15,002.81	128,654.06	42,194.84
Mean	**11,047.24**		**44,018.89**		**72,490.55**		**127,556.68**	
Percentage	**8.7%**		**34.5%**		**56.8%**			

Table 3.28 Average length (mm) and standard deviation (S.D.) of zooplankton species sampled from McCoy Lake in April, and October 2000.

Species	April Mean Length	S.D.	October Mean Length	S.D.
Daphnia				
Daphnia pulex	0.76 (n=4)	0.12	0.85 (n=59)	0.20
Daphnia rosea			1.09 (n=2)	0.26
Other Cladocera				
Ceriodaphnia quadrangula	--		0.71 (n=63)	0.11
Diaphanosoma brachyurum	0.40 (n=1)	n/a	0.61 (n=1)	n/a
Copepoda				
Diacyclops bicus. thomasi	0.57 (n=2)	0.24	--	
Leptodiaptomus ashlandi	0.90 (n=17)	0.43	1.06 (n=44)	0.53
Nauplii	0.22 (n=11)	0.09	0.25 (n=43)	0.08

Table 3.29 Combined mean zooplankton length (mm), standard deviation (S.D.), number sampled, and observed range from samples taken in 2000 from McCoy Lake.

Species	Combined Mean Length	Average S.D.	n	Observed Range
Daphnia				
Daphnia pulex	0.81	0.16	63	(0.46-1.37)
Daphnia rosea	1.09	0.26	2	(0.91-1.27)
Other Cladocera				
Ceriodaphnia quadrangula	0.71	0.11	63	(0.44-0.86)
Diaphanosoma brachyurum	0.50	0.1477853	2	(0.40-0.61)
Copepoda				
Diacyclops bicus. thomasi	0.57	0.24	2	(0.40-0.74)
Leptodiaptomus ashlandi	0.98	0.48	61	(0.44-1.97)
Nauplii	0.24	0.09	54	(0.13-0.46)

Tables 3.30 Water quality measurements taken with a Hydrolab Surveyor 4 at McCoy Lake in 2000.

Temperature (°C)

Depth (m)	2/9/00	4/26/00	5/31/00	7/18/00	8/28/00	9/28/00	10/30/00	12/4/00	12/27/00
0	1.7	14.75	17.28	22.89	20.07	14.08	9.33	2.26	1.27
1		13.73	17.08	22.52	20.09	14.05	9.15		
2		12.81	16.97	22.02	20.08	14.04	9.1		
3	3.52	8.68	12.59	17.02	20.05	14.02	9.08		
4		5.38	8.6	12.1	15.81	13.87	9.06		
5		4.36	6.4	9.37	11.09	13	9.04		
6	3.38	3.78	4.91	6.78	9.32	9.56	9		
9	3.48	3.75	4.11	4.51	4.75	5	4.99		
12	4.23	3.92	4.05	4.26	4.31	4.43	4.46		
15	4.9	4.05	4.16	4.22	4.36	4.43	4.49		

% Dissolved Oxygen

Depth (m)	2/9/00	4/26/00	5/31/00	7/18/00	8/28/00	9/28/00	10/30/00	12/4/00	12/27/00
0	70.9	125.6	116	133.4	63.4	36.7	80.8	57.4	46.7
1		123.4	118.9	130.8	67.6	37.2	78		
2		131.8	115.6	140.9	68.3	37.4	79.3		
3	57.8	136.7	131.6	155.8	68.7	38.5	77.7		
4		47.2	65.6	76.1	60.3	39.2	75.3		
5		10.8	29.6	31	23.3	26.2	75.1		
6	47.4	4.6	4.7	12.3	11.3	10.7	73.6		
9	38.4	2.3	2	8.2	6.3	8.7	4.1		
12	11.5	1.6	1.2	7.3	5.7	7.5	3.3		
15	8.8	1.2	0.8	7.1	5.3	7.3	3.1		

Dissolved Oxygen (mg/L)

Depth (m)	2/9/00	4/26/00	5/31/00	7/18/00	8/28/00	9/28/00	10/30/00	12/4/00	12/27/00
0	9.43	12.72	10.3	10.58	5.35	3.49	9.39	7.86	6.7
1		12.7	10.53	10.32	5.67	3.52	9.24		
2		13.91	10.25	11.2	5.73	3.55	9.28		
3	7.23	15.92	13.19	13.7	5.73	3.65	9.07		
4		5.95	7.04	7.5	5.54	3.74	8.87		
5		1.4	3.34	3.26	2.35	2.57	8.78		
6	5.81	0.6	0.54	1.39	1.22	1.12	8.47		
9	4.88	0.3	0.24	0.98	0.75	1.02	0.52		
12	1.43	0.21	0.15	0.88	0.68	0.9	0.43		
15	1.04	0.16	0.09	0.83	0.62	0.88	0.39		

Conductivity (mmho/cm)

Depth (m)	2/9/00	4/26/00	5/31/00	7/18/00	8/28/00	9/28/00	10/30/00	12/4/00	12/27/00
0	320	304	308	266	268	281	297	303	321
1		304	308	265	268	282	298		
2		302	308	270	268	282	298		
3	325	298	313	317	268	282	298		
4		315	324	334	340	282	298		
5		327	328	340	345	322	299		
6	333	334	339	346	351	353	299		
9	343	344	353	354	372	367	387		
12	399	371	376	389	408	423	440		
15	497	395	409	411	461	455	478		

Total Dissolved Gases (mmHg)

Depth (m)	2/9/00	4/26/00	5/31/00	7/18/00	8/28/00	9/28/00	10/30/00	12/4/00	12/27/00
0	634	762	714	684	675	655	646	748	663
1		767	733	686	678	657	645		
2		772	769	686	678	657	645		
3	633	778	771	680	679	657	645		
4		710	721	663	667	658	645		
5		656	670	654	659	656	645		
6	635	640	643	647	647	647	645		
9	636	635	639	638	635	636	635		
12	638	651	660	637	633	633	632		
15	640	686	720	637	634	632	632		

pH

Depth (m)	2/9/00	4/26/00	5/31/00	7/18/00	8/28/00	9/28/00	10/30/00	12/4/00	12/27/00
0	8.38	9.19	9.24	9.14	9.12	9.08	8.17	8.11	7.65
1		9.24	9.23	9.11	9.12	9.1	8.12		
2		9.25	9.23	9.08	9.13	9.09	8.09		
3	8.3	9.04	9.06	8.82	9.14	9.11	8.08		
4		8.03	8.29	8.18	8.57	9.09	8.09		
5		7.88	8.02	7.84	8.05	8.35	8.1		
6	8.29	7.68	7.85	7.71	7.9	8.01	8.09		
9	8.23	7.67	7.74	7.55	7.7	7.82	7.08		
12	7.72	7.56	7.61	7.39	7.52	7.59	6.9		
15	7.56	7.47	7.48	7.3	7.36	7.5	6.82		

Oxidation Reduction Potential (mV)

Depth (m)	2/9/00	4/26/00	5/31/00	7/18/00	8/28/00	9/28/00	10/30/00	12/4/00	12/27/00
0	303	261	214	401	426	466	146	254	242
1		261	228	398	425	464	146		
2		261	241	399	424	464	146		
3	301	266	252	406	423	463	144		
4		273	261	415	432	462	140		
5		275	264	420	432	469	135		
6	302	275	262	423	440	475	120		
9	303	274	262	187	60	108	120		
12	90	167	135	70	-13	34	132		
15	23	134	93	36	-22	8	132		

3.11 TURTLE LAKE

Turtle Lake is located at the headwaters of Blue Creek and accessible from the Wellpinit-WestEnd Highway. Turtle, with a surface area of 11.7 acres, has a maximum depth of 18 meters (Woodward, 1973).

Species of zooplankton found in Turtle Lake are listed in Table 3.19. The group "Copepoda", similar to October 1999, has the highest mean density and biomass (Tables 3.31 and 3.32). Sampling zooplankton in April and July showed an increased density and biomass of *Daphnia spp*. from the fall sampling of 1999 (Crossley, 1999). *Daphnia rosea* had a mean length of 1.08 mm and ranged from 0.63 to 1.71mm (Table 3.34). The largest zooplankton species sampled were *Leptodiaptomus ashlandi* (2.35mm). Turtle Lake has the lowest densities of zooplankton when compared to the other lakes on the SIR.

Mid-day maximum temperature was recorded on the surface of Turtle Lake in July (22.57°C) (Tables 3.35). In August of 1999, surface temperature was 22.2°C. The summer thermocline was recorded at 4 meters and turnover in November. Incomplete mixing occurred at fall turnover and has been documented in 1999 (Crossley), and 1993 (Heaton) due to a chemocline near 13 meters. Elevated levels of iron were found below 12 meters that may explain the incomplete mixing, the high conductivity, and the overall color of the lake. Dissolved oxygen was below 5 mg/l in the entire profiles of August and September. Dissolved oxygen was 5.4 mg/l at three meters in August of 1999. Low dissolved oxygen may be attributed to algae decomposition or, because similar results were found in McCoy and Benjamin Lakes, an error in the calibration of the Hydrolab. Secchi disk measurements averaged 4.06 meters and was measured at 5 meters during August and September (Table 3.36).

Electrofishing was conducted in Turtle Lake and 19 fish were captured in 0.27 hours of shock time (Table 3.17). Except the area between the 2 docks closest the highway, the entire lake was electrofished. Electrofishing CPUE was 70.37, while the gill net set for 3.92 hours caught nothing (Table 3.18). All fish sampled were rainbow trout except for one large brown trout. The average condition factor for the trout was 0.93, whereas 1 is desirable.

Table 3.31 Zooplankton density (#/m^3) and standard deviation (S.D.) sampled in 2000 from Turtle Lake.

Sample Date	Daphnia	S.D	Other Cladocera	S.D.	Copepoda	S.D.	Total Zooplankton	S.D.
April 21	3,259.49	1,077.98	135.81	235.23	22,137.39	4,687.00	25,532.70	3,915.07
July 17	10,253.82	1,045.40	2,105.09	715.44	9,438.95	1,004.92	21,797.86	2,740.75
Oct. 31	3,819.72	1,487.46	305.58	397.77	5,364.58	427.12	9,489.88	1,232.17
Mean	**5,777.68**		**848.83**		**12,313.64**		**18,940.15**	
Percentage	**30.5%**		**4.5%**		**65.0%**			

Table 3.32 Zooplankton biomass (μg/m^3) and standard deviation (S.D.) sampled in 2000 from Turtle Lake.

Sample Date	Daphnia	S.D.	Other Cladocera	S.D.	Copepoda	S.D.	Total Zooplankton	S.D.
April 21	13,486.09	11,584.01	53.12	92.00	49,721.55	20,456.96	63,260.76	29,816.00
July 17	46,781.38	6,765.83	2,778.09	513.27	45,677.91	11,706.16	95,237.37	18,669.19
Oct. 31	21,544.98	9,084.99	1,482.29	1,999.43	17,247.07	383.95	40,274.33	6,801.60
Mean	**27,270.81**		**1,437.83**		**37,548.84**		**66,257.49**	
Percentage	**41.2%**		**2.2%**		**56.7%**			

Table 3.33 Average length (mm) and standard deviation (S.D.) of zooplankton species sampled from Turtle Lake in April, July, and October 2000.

Species	April Mean Length	S.D.	July Mean Length	S.D.	October Mean Length	S.D.
Daphnia						
Daphnia pulex	0.77 (n=24)	0.39	0.83 (n=64)	0.27	0.96 (n=58)	0.24
Daphnia rosea	--		1.12 (n=23)	0.31	1.04 (n=59)	0.21
Other Cladocera						
Ceriodaphnia quadrangula	--		0.47 (n=5)	0.06	0.76 (n=15)	0.04
Diaphanosoma brachyurum	0.34 (n=1)	n/a	0.54 (n=18)	0.22	0.61 (n=3)	0.05
Copepoda						
Diacyclops bicus. thomasi	0.46 (n=6)	0.07	0.38 (n=8)	0.02	0.51 (n=4)	0.11
Leptodiaptomus ashlandi	0.83 (n=43)	0.46	1.01 (n=53)	0.34	0.72 (n=72)	0.31
Mesocyclops edax	--		--		0.63 (n=2)	0.24
Nauplii	0.21 (n=61)	0.08	0.20 (n=47)	0.05	0.20 (n=58)	0.05

Table 3.34 Combined mean zooplankton length (mm), standard deviation (S.D.), number sampled, and observed range from samples taken in 2000 from Turtle Lake.

Species	Combined Mean Length	Average S.D.	n	Observed Range
Daphnia				
Daphnia pulex	0.85	0.30	146	(0.38-1.71)
Daphnia rosea	1.08	0.26	82	(0.63-1.71)
Other Cladocera				
Ceriodaphnia quadrangula	0.62	0.05	20	(0.42-0.57)
Diaphanosoma brachyurum	0.50	0.14	22	(0.25-0.89)
Copepoda				
Diacyclops bicus. thomasi	0.45	0.07	18	(0.34-0.67)
Leptodiaptomus ashlandi	0.85	0.37	158	(0.38-2.35)
Mesocyclops edax	0.63	0.24	2	(0.46-0.80)
Nauplii	0.20	0.06	166	(0.10-0.53)

Tables 3.35 Water quality measurements taken with a Hydrolab Surveyor 4 at Turtle Lake in 2000.

Temperature (°C)

Depth (m)	**2/9/00**	**4/26/00**	**5/31/00**	**7/17/00**	**8/28/00**	**9/28/00**	**10/31/00**	**11/30/00**	**12/27/00**
0	0.6	12.27	15.37	22.57	18.9	12.57	7.23	3.37	1.26
1		11.86	15.2	21.67	18.75	12.44	7.24	3.66	3.37
2		10.6	14.97	20.63	18.72	12.4	7.24	3.67	3.42
3	3.35	7.59	11.42	18.23	18.6	12.39	7.26	3.67	3.5
4		6.13	8.54	13.14	14.25	12.35	7.25	3.68	3.59
5		4.96	6.31	9.44	11.2	12.01	7.24	3.67	3.64
6	3.64	4.44	5.1	6.48	7.76	8.63	7.23	3.67	3.7
9	3.77	4.09	4.34	4.89	5.03	5.17	5.38	3.76	3.78
12	3.89	3.9	4.06	4.31	4.38	4.48	4.55	3.83	3.95
15	4.6	4.39	4.37	4.22	4.63	4.63	4.66		4.61
18		5.06	5.03	5.08	5.08	5.04	5.03		

% Dissolved Oxygen

Depth (m)	**2/9/00**	**4/26/00**	**5/31/00**	**7/17/00**	**8/28/00**	**9/28/00**	**10/31/00**	**11/30/00**	**12/27/00**
0	52.8	95.7	84.7	95.4	47.8	35.4	61.2	57.1	36.1
1		93.4	81.2	99.6	48.9	34.8	61.8	51.8	33.8
2		90.3	77.5	91.6	50.3	34.8	60.2	51.7	36.7
3	36.9	67.3	67	94.1	50.6	34.6	60.4	51.2	36
4		42.6	39.3	64.4	26.6	34.5	59.9	44.3	35.2
5		19.7	18.2	28.4	19.4	30.8	58.8	42.7	33.2
6	32.9	12.6	2.6	14.4	12	20.3	58.4	40.3	34.1
9	26.4	5.5	1.3	9.7	8.4	12.9	5.4	35.8	26.2
12	19.7	2	0.8	8.4	6.7	8.2	4.2	30.1	6.4
15	9.2	1.6	0.5	15.9	5.7	6.8	4.2		4.1
18		1.4	0.3	11.3	5.4	5.05	4		

Dissolved Oxygen (mg/L)

Depth (m)	**2/9/00**	**4/26/00**	**5/31/00**	**7/17/00**	**8/28/00**	**9/28/00**	**10/31/00**	**11/30/00**	**12/27/00**
0	7.31	10.25	7.79	7.61	4.1	3.48	7.51	7.71	5.24
1		10.04	7.49	7.55	4.2	3.44	7.55	6.93	4.65
2		10.03	7.19	7.59	4.33	3.43	7.36	6.92	5.02
3	4.58	8.05	6.74	8.13	4.35	3.41	7.42	6.86	4.89
4		5.37	4.26	6.3	2.52	3.41	7.32	5.98	4.65
5		2.52	2.06	2.93	2	3.09	7.17	5.71	4.51
6	4.03	1.69	0.3	1.64	1.33	2.18	7.13	5.39	4.62
9	3.28	0.71	0.13	1.14	1.02	1.51	0.69	4.6	3.54
12	2.38	0.27	0.09	1.01	0.81	0.98	0.54	4	0.86
15	1.1	0.2	0.06	1.91	0.69	0.81	0.51		0.54
18		0.18	0.04	1.31	0.63	0.78	0.51		

Conductivity (mmho/cm)

Depth (m)	2/9/00	4/26/00	5/31/00	7/17/00	8/28/00	9/28/00	10/31/00	11/30/00	12/27/00
0	103	93	96	99	103	102	101	105	111
1		92	96	99	103	102	101	104	104
2		93	96	99	103	102	101	104	104
3	104	93	95	97	103	102	101	104	104
4		94	96	98	100	102	101	104	104
5		97	98	99	100	102	101	104	104
6	105	99	100	101	103	104	101	104	104
9	106	101	102	103	104	107	109	104	105
12	107	107	110	118	128	130	137	106	111
15	243	272	275	136	306	319	309		274
18		582	594	582	593	582	587		

Total Dissolved Gases (mmHg)

Depth (m)	2/9/00	4/26/00	5/31/00	7/17/00	8/28/00	9/28/00	10/31/00	11/30/00	12/27/00
0	638	708	682	682	668	649	635	661	659
1		711	684	690	671	650	636	662	661
2		707	684	687	673	651	637	663	658
3	632	703	680	684	673	652	637	664	655
4		695	661	673	668	653	638	665	649
5		687	645	656	657	653	638	666	642
6	634	682	605	649	651	649	638	666	641
9	635	679	605	643	641	641	635	667	643
12	636	675	603	640	636	635	633	667	642
15	637	741	849	645	635	633	633		645
18		1025	1400	641	636	634	634		

pH

Depth (m)	2/9/00	4/26/00	5/31/00	7/17/00	8/28/00	9/28/00	10/31/00	11/30/00	12/27/00
0	7.86	7.09	7.8	7.55	7.77	7.91	7.16	7.2	7.21
1		7.26	7.78	7.55	7.72	7.82	7.11	7.09	7.14
2		7.24	7.72	7.39	7.69	7.78	7.1	7.05	7.12
3	7.64	7.05	7.5	7.29	7.62	7.76	7.09	7.05	7.13
4		6.93	7.31	7.14	7.22	7.74	7.09	7.03	7.12
5		6.82	7.17	7	7.1	7.61	7.09	7.01	7.12
6	7.58	6.78	7.12	6.93	7.09	7.36	7.08	7	7.12
9	7.52	6.76	7.07	7.02	7.09	7.29	7.78	6.99	7.11
12	7.49	6.78	7.01	6.94	7.06	7.24	6.67	6.95	7.04
15	7.22	6.83	7.21	7.28	7.18	7.34	6.76		6.92
18		6.88	7.18	6.95	7.23	7.34	6.81		

Oxidation Reduction Potential (mV)

Depth (m)	2/9/00	4/26/00	5/31/00	7/17/00	8/28/00	9/28/00	10/31/00	11/30/00	12/27/00
0	417	360	254	345	291	313	243	258	243
1		350	262	356	292	318	245	261	245
2		347	269	368	295	321	244	263	246
3	415	345	275	373	297	324	244	263	247
4		343	285	376	303	325	244	265	248
5		340	290	379	304	327	244	267	249
6	414	338	290	383	305	330	244	268	250
9	415	336	289	183	303	331	116	270	250
12	416	290	244	133	157	82	93	273	248
15	196	169	121	89	78	65	88		-78
18		112	65	93	30	36	109		

Table 3.36 Secchi Disk measurements (m) taken from the 4 interior lakes in the respective months.

	Benjamin Lake	Mathews Lake	McCoy Lake	Turtle Lake
April	5.4	1.8	3.1	3
May	4	3.5	3.2	4.25
July	4	3	3.5	2.6
August	4.4	2.5	4.5	5
September	4.25	4	4	5
October	3.25	1.8	4.5	4.5

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