FISHERY RESEARCH

DWORSHAK KOKANEE POPULATION AND RESERVOIR PRODUCTIVITY ASSESSMENT

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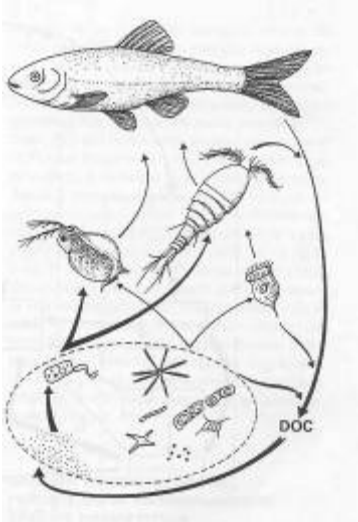

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Dworshak Kokanee Population and Reservoir Productivity Assessment

Project Progress Report

2004 Annual Report

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ABSTRACT

During 2004, we used midwater trawling to monitor the kokanee population in Dworshak Reservoir. Estimated abundance of kokanee has increased since 2003. Based on trawling, we estimated a total abundance of approximately 3,920,000 kokanee (90% CI ± 35.4%) in Dworshak Reservoir on July 2004. This included 3,137,892 age-0 (90% CI ± 42.2%), 692,348 age-1 (90% CI ± 24.2%), and 90,715 age-2 (90% CI ± 42.2%).

Entrainment sampling was conducted with fixed-site split-beam hydroacoustics a minimum of two days per month for a continuous 24 h period when dam operations permitted. The highest fish detection rates from entrainment assessments were found during nighttime periods and lowest during the day. Unlike previous assessments, fish detection rates were low during high discharges throughout the spring and summer and highest during low discharges in September and October.

Monthly hydroacoustic sampling showed fairly high densities of kokanee in the forebay of Dworshak Reservoir, likely a result of an increased kokanee abundance. Densities remained low but stable throughout the spring and summer despite high discharge, but increased substantially during the fall with low discharge. A total of 7,992 adult kokanee were counted in four tributary spawning streams in 2004. This data fit the previously developed relationship between spawner counts and adult kokanee abundance in the reservoir.

Overall, there has been little change in reservoir clarity or chlorophyll concentrations in the past 30 years, but both nitrate and orthophosphate concentrations have dropped substantially since 1973. Total zooplankton densities at most sites within the reservoir declined since initial assessments in 1974, and Cladoceran densities, the preferred forage of kokanee has declined.

Kokanee exhibited good monthly growth during 2004, and each age class obtained their respective maximum growth rates at different times of the year. However, there was no evidence of age-specific feeding habits. Kokanee diets were dominated by *Daphnia* sp. and diet composition was quite different from the zooplankton community composition in Dworshak Reservoir.

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INTRODUCTION

Kokanee *Oncorhynchus nerka* fisheries in the Pacific Northwest are very popular (Wydoski and Bennett 1981; Rieman and Myers 1992). Kokanee feed low on the food chain and may reach densities in excess of 150 harvestable-sized fish/ha even in relatively sterile waters (Maiolie et al. 1991). They also appear to be an ideal fish in many fluctuating reservoirs since they rear in the open pelagic zone and some strains spawn in tributary streams away from the potential impacts of water level fluctuations. When densities of kokanee are high, Dworshak Reservoir is one of the best kokanee fisheries in Idaho, accounting for a harvest of over 200,000 fish annually.

Kokanee, however, can exhibit behavioral tendencies to school and emigrate resulting in potentially large entrainment losses. Entrainment losses have been documented in Libby Reservoir in Montana (Skarr et al. 1996), Banks Lake, Washington (Stober et al. 1979), and Dworshak Reservoir (Maiolie and Elam 1998). At Dworshak Reservoir, it was estimated that 1.4 million kokanee (95% of the population) were lost through the dam in a period of five months in 1996 (Maiolie and Elam 1998).

Thus, entrainment loss of kokanee has been established as the single most important factor contributing to variability in the population. In 1996, losses of kokanee were severe enough that they strongly affected the angler's success in subsequent years, and years with high discharge have correlated with lower kokanee populations in the reservoir (Maiolie and Elam 1993).

Reduced reservoir productivity is another factor likely influencing the variability of the kokanee population. Declining reservoir productivity and limited food supply and nutrient levels were suggested by Berry-Martin (1975) and Bennett (1997) as critical limiting factors to stable fish populations in Dworshak Reservoir. Rieman and Meyers (1992) clearly demonstrated the positive relationship of reservoir productivity and kokanee yield. Bennett (1997) suggested this factor be addressed before emphasis was placed on intensive fisheries management.

The productivity of the North Fork Clearwater River ecosystem has been significantly reduced due to the loss of 'marine derived nutrients' from anadromous salmon and steelhead that no longer access the drainage (Cederholm et al. 2000). Kokanee now function as a surrogate for the historic anadromous fish runs, provide an important prey source for other resident fish, and contribute to the productivity of the reservoir and its tributaries. After spawning, all kokanee die, and the decomposition of their carcasses return phosphorous (P) and nitrogen (N) to their natal streams, which enhances primary and heterotrophic production, naturally fertilizing the rearing environment for their future progeny (Foerster 1968). However, extensive reservoir productivity sampling has not been performed on Dworshak since the early 1980s (Berry-Martin 1975; Falter 1982) and limnological sampling and kokanee population assessments have not coincided since the late 1980s (Maiolie et al. 1991).

This report describes the ongoing assessment of the Dworshak Reservoir kokanee population including entrainment assessment; kokanee age, growth, and density; and their relationship to reservoir productivity. During this contract, midwater trawl sampling was used to estimate the abundance and density of kokanee. Results from these surveys were used to determine the effects of the water year timing and magnitude and changes in dam operation (discharge) on the kokanee population in comparison to long-term population data. We also assessed the diel and seasonal susceptibility of kokanee to entrainment through dam intakes in

relation to varying discharge. Lastly, we conducted extensive limnological sampling and trawling to assess the effects of dam operations on primary and secondary production and influence on annual kokanee population stability (density, length-at-age, growth, and survival).

OBJECTIVE

1. To maintain kokanee densities of 30 to 50 adults (age-2 and older) per ha in Dworshak Reservoir by reducing entrainment losses.

DESCRIPTION OF STUDY AREA

Dworshak Dam is located on the North Fork of the Clearwater River in northern Idaho. At 219 m, it is the tallest straight-axis concrete dam in the United States. It was built in 1971 by the U.S. Army Corps of Engineers (USACE) for power production and flood control. Three turbines within the dam have a total operating capacity of 450 megawatts. The dam can discharge up to 283 m^3/s (10,000 cfs) through the turbines and an additional 420 m^3/s (15,000 cfs) through reservoir outlets and the spillway.

Dworshak Reservoir is 86 km long at full pool (Figure 1). Maximum and mean depths are 194 m and 56 m, respectively. Surface area at full pool is 6,644 ha with 5,400 ha of kokanee habitat (defined as the area over 15 m deep). Drawdowns for flood control may lower the surface elevation 47 m and reduce surface area by as much as 52%. The reservoir has a mean hydraulic retention time of 10.2 months and a mean annual discharge of 162 m^3/s (Falter 1982). High discharges from the reservoir occur during spring runoff, during the fall when the reservoir is lowered for flood control, and during late summer when water is released to benefit anadromous fish migration.

Kokanee were first stocked into Dworshak Reservoir in 1972 (Horton 1981). Four sources of fish were initially used, but the early spawning strain from Anderson Ranch Reservoir, Idaho now populates the reservoir (Winans et al. 1996). These fish spawn during September in tributary streams as far as 140 km upstream of the reservoir. They reach maturity primarily at age-2, although age-1 and age-3 spawners were occasionally found. Adults range in size from 200 to 400 mm in total length (TL), but generally average 300 mm TL during spawning (Maiolie and Elam 1995).

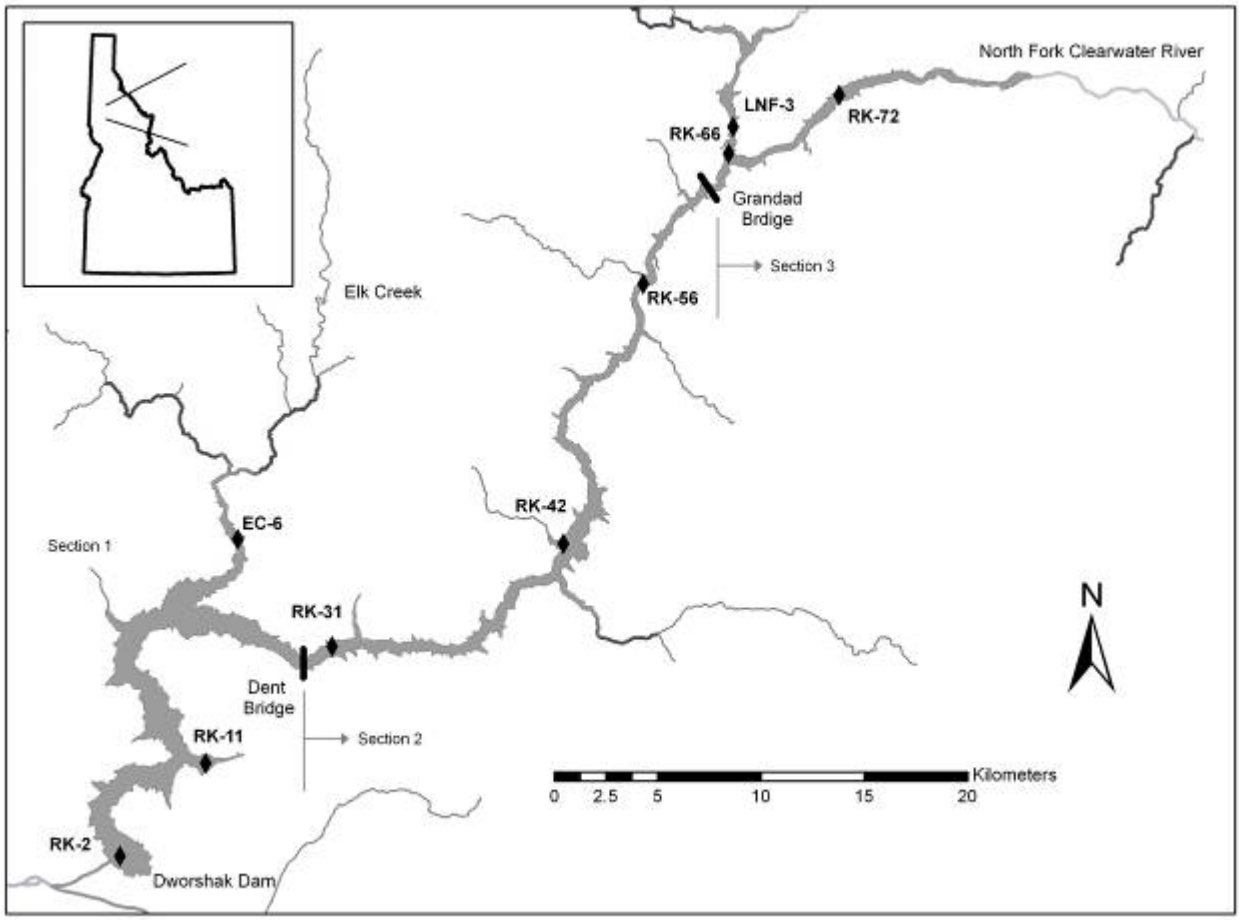


Figure 1. Map of Dworshak Reservoir, major tributaries, reservoir sections, and limnological sampling stations (represented with black diamonds), North Fork Clearwater River, Idaho.

METHODS

Kokanee Population

Abundance, Density, and Length-at-Age

In late June, we calibrated the trawler with different combinations of boat speeds and cable lengths. A second boat motoring behind the trawler and over the trawl net used a Furuno™ Model FCV-582 depth sounder with a 10° cone transom mounted transducer to locate the depth of the trawl net. Calibrated net depths were recorded and entered into a table and then used during sampling.

Midwater trawling was conducted during the evenings of July 12–14 throughout Dworshak Reservoir to estimate kokanee abundance and density. Sampling was conducted as near as possible to the dark phase of the moon, which optimized the capture efficiency of the trawl (Bowler et al. 1979). The reservoir was stratified into three sections: from the dam to Dent Bridge, Dent Bridge to Granddad Bridge, and Granddad Bridge to the beginning of slack water area (Figure 1). A stratified systematic sampling scheme was used to estimate kokanee abundance and density for the population estimate. Six transects were systematically selected within each section and one haul made along each transect.

Rieman (1992) described the midwater trawl and sampling procedure in detail. The net was 13.7 m long with a 3 m x 3 m mouth. Mesh sizes (stretch measure) graduated from 32, 25, 19, and 13 mm in the body of the net to 6 mm in the cod end. The trawl net was towed at a speed of 1.6 m/s by an 8.5 m boat. The vertical distribution of kokanee was determined with a Furuno™ Model FCV-582 depth sounder with a 10° cone angle transom mounted transducer. A stepwise oblique tow was conducted along each transect which sampled the entire vertical distribution of kokanee. Global positioning system (GPS) was used to determine distances traveled, and along with trawl net dimensions, was used to calculate trawl sample volumes.

During sampling, the reservoir elevation varied from 486.2 to 486.8 m (1,595 ft—1,597 ft), and the midpoint of the kokanee layer was at about the 18.4 m depth. Therefore, we used an area of 5,360 ha of kokanee habitat corresponding to an elevation of 468.2 m (1,536 ft). Fish from each trawl sample were counted, and total length (TL) and weight (g) were measured. Scales were also taken from 10 fish in each 10 mm size interval to determine kokanee age distribution.

The number of kokanee per age class in each trawl (haul) was divided by the transect volume to estimate age-specific density per haul. Mean kokanee age class densities in each reservoir section were then calculated and multiplied by the surface area of that section to obtain abundance estimates per reservoir section. Reservoir section abundance estimates were totaled to obtain total age class population estimates and the age class estimates totaled to obtain total kokanee abundance in the entire reservoir. Ninety percent confidence intervals were calculated on the age-0, age-1 and age-2 kokanee abundance estimates (Scheaffer et al. 1990).

Kokanee were aged by examining scales. Scales were collected dorsally to the lateral line and posterior to the dorsal fin using techniques described by Nielsen and Johnson (1985). Using a blunt knife, scales were loosened by scraping toward the head. Six to twelve scales were collected from each fish and sealed in a coin envelope labeled with total length (TL) and date collected. Scales were prepared by pressing them between two acetate slides. The slides were then viewed using a microfiche reader to examine patterns of growth from impressions of the scales on the slides. Areas of relatively slower growth signifying each winter season or the end of one year's growth (annuli) were counted to determine age. These aging techniques are described by Nielsen and Johnson (1985).

Entrainment

Entrainment sampling was conducted a minimum of two days per month (each for a continuous 24 h period) when the forebay area was accessible. This monitoring provided baseline information on time of day fish were susceptible to entrainment; detection rate immediately in front of the different turbine units and reservoir outlets; and the variability in fish susceptibility expected between varying times of day, seasons, and discharge rates. Secchi disc

transparencies, which were used to relate water clarity to discharge rate and entrainment susceptibility, were also measured during most hydroacoustic sample periods.

A wooden dock was secured to the trash racks of the turbine to be sampled (Figure 2). The hydroacoustic equipment was set up under a tent, which was attached to the dock. The echo sounder's transducer was attached to a pole, which was secured to the dock and pointed between 1° and 5° from vertical, outward from the face of the dam. This angle was adjusted for each sampling period depending upon the pool elevation and selector gate mode and depth. The outward angle and distance from the face of the dam were set to maximize the echogram coverage of the turbine unit opening area, yet still ensure that return echoes from the face of the dam did not interfere with detecting fish targets.

During sample periods when turbines were discharging in 'overshot mode' (meaning the selector gate was lowered in front of the turbine unit opening with water flowing over the top of the gate) only fish echoes in a zone from approximately 10.0 m above to 5.0 m below (15.0 m tall zone) the selector gate's top were counted. During sample periods when turbines were discharging in 'undershot mode' (meaning the selector gate was raised allowing water to flow straight into the turbine unit opening), only fish echoes within the depths of the opening were counted. The intake openings for turbine units 1 and 2 are located between 429.2 and 437.4 m above mean sea level (MSL), which results in an 8.2 m analysis zone when the turbines are operating in undershot. The opening for turbine unit 3 is located between 425.2 and 437.4 m above MSL, which results in a 12.2 m analysis zone when unit 3 is operating in undershot. The center of the analysis zone was considered the depth of the selector gate if in overshot mode or the center of the turbine opening (penstock) if in undershot mode.

We used the above echo sounder placement and sampling methods to estimate hourly rate of kokanee detection immediately in front of a single operating turbine unit or reservoir outlet. A BioSonics, Inc. DE-X™ split-beam scientific echo sounder with a 201 kHz transducer was used for all entrainment assessment sampling. The echo sounder was professionally calibrated by the manufacturer prior to the start sampling in March 2004. Then, prior to each sample period, we checked the calibration of the echo sounder by measuring the target strength (TS) of a 36 mm diameter standard calibration sphere, compared the TS against the known TS of the sphere at the sample water temperature, and adjusted the transducer gains if needed.

The echo sounder was set to ping at 5 pings per second with a pulse width of 0.3 milliseconds. The maximum beam compensation was set at 6.0 dB. In addition, the returned echo had to be greater than -45 dB (>100 mm; Love 1971) to be counted as a valid fish echo. This minimum threshold was necessary to avoid detection of echoes returning from the face of the dam, which would interfere with detection of small fish.

Analysis of fish echoes was then conducted on each hydroacoustic file using SonarData Echoview™ 3.0 post-processing software. We used Echoview minimum and maximum normalized pulse lengths of 0.3 and 1.8, respectively. We then manually counted fish echoes meeting the following track recognition criteria. We required a minimum of three single target detections, a minimum of three pings, and a maximum of one missing ping per track to qualify targets as a fish track. Fish tracks meeting these track criteria were counted as a single fish.

We divided the total number of fish detected by the number of hours sampled to estimate a detection rate (fish/h). This was determined for each of four time strata (dawn, day, dusk, and night). The diameter of the beam (B) at the depth of the center of the intake opening was also calculated with the following equation.

$$\text{Beam diameter (B)} = 2 \times R \times [\ \text{Tan}\ (\ \theta / 2\ )\ ]$$

where: R = range (depth of intake opening),
Tan = tangent of the angle,
θ = the nominal beam width, and
(6.6 degrees for the 201 kHz transducer).

The portion (%) of the intake sampled was calculated by dividing the diameter of the beam (B) by the width of the turbine opening (I). The original detection estimates were then expanded upon based on the percent coverage of the acoustic beam during each sample period, respectively.

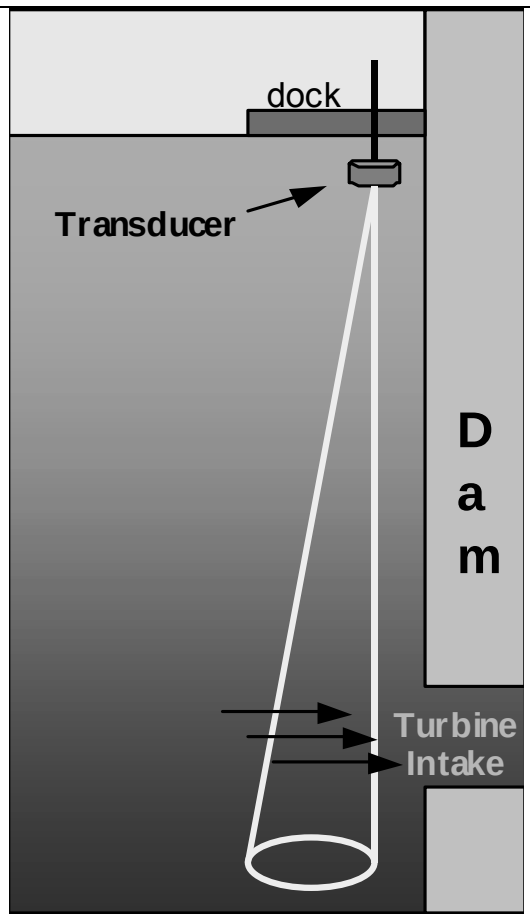


Figure 2. Location of the fixed-site echo sounding gear used to detect fish to determine their susceptibility to entrainment into turbine units and reservoir outlets of Dworshak Dam, Idaho.

Forebay Densities

Mobile hydroacoustic surveys were collected along five standardized transects within the forebay of Dworshak Reservoir, one night per month (Figure 3). Monthly estimates of kokanee densities in the forebay helped determine the seasonal changes in kokanee distribution and density near the dam and, therefore, when they may be more susceptible to entrainment.

The same BioSonics, Inc. DE-X™ split-beam scientific echo sounder with a 201 kHz transducer was also used for all forebay density sampling. The calibration procedure, pulse width, and maximum beam compensation were identical to those used during entrainment sampling. However, we used a 2.0 ping/s ping rate and a -60 dB minimum threshold for all forebay transect echograms.

Fish density estimates were calculated using BioSonics, Inc. Visual Analyzer™ software, version 4.0.2. We also used Visual Analyzer minimum and maximum normalized pulse lengths of 0.8 and 1.8, respectively. Only the pelagic region of each echogram was analyzed, generally from depths of 5 m to 50 m. Fish densities were calculated for each of five transects in the forebay outside of the log boom area and averaged together to obtain a monthly average kokanee density.

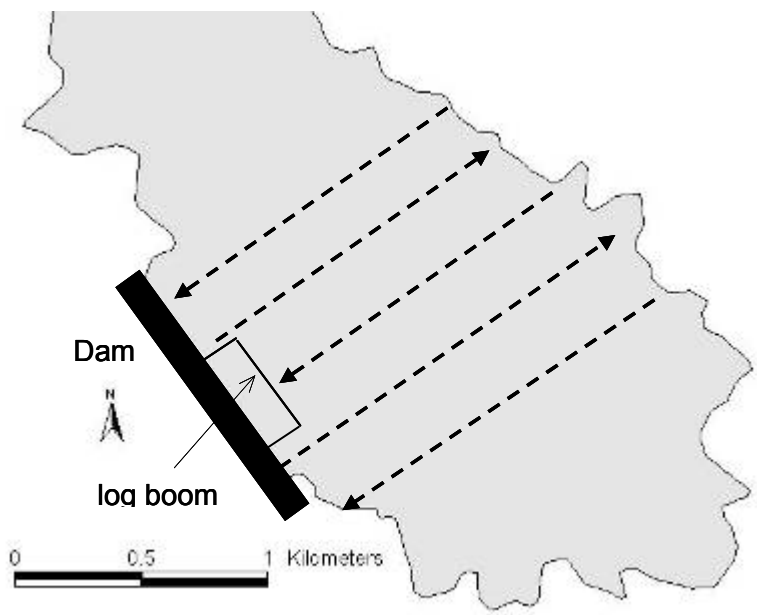


Figure 3. Map of Dworshak Reservoir forebay area and location of survey transects. Dashed arrows represent direction and location of hydroacoustic transects.

Discharge

Data on daily discharge, pool elevation, turbine units operating, reservoir outlets in use, and spillway operation for the year were obtained from the USACE Dworshak Project Control Room. The timing and magnitude of discharge from Dworshak Dam was used to examine correlations between entrainment potential and population abundances. All discharge values were measured in thousand cubic feet per second and were then converted to the metric unit of cubic meters per second (m^3/s). Pool elevation was measured as meters above MSL.

Spawner Counts

We counted kokanee in four tributaries of the North Fork of Clearwater upstream of Dworshak Reservoir on September 21 and 22, 2004. These spawner counts served as an additional relative index of the adult population abundance. Spawning kokanee were counted in Isabella Creek, Dog Creek, Skull Creek, and Quartz Creek. Streams were walked from their mouths to the furthest upstream reaches utilized by kokanee. These index tributaries had been surveyed annually since 1981 on or near September 25, which was determined to be the peak of kokanee spawning (Horton 1980). The total lengths (TL) of dead or near dead kokanee found along the tributaries were also measured to obtain an adult spawner length distribution.

Reservoir Productivity Assessment

Nine limnological stations were sampled monthly from May through November 2004 (Table 1). Three stations were sampled in each of three sections of Dworshak Reservoir (Figure 1). Stations were sampled in section 1 at river kilometers (RK) 2 and 11, and at RK 6 (EC-6) in the Elk Creek arm. The EC-6 station was kept separate from the reservoir section stations, since this site had been shown to have much different conditions (Berry-Martin 1975, Falter 1982, Maiolie et al. 1991). In section 2, sampling stations were located at RK 31, 42, and 56. Stations in section 3 were located at RK-66; and the last two additional stations within reservoir section 3 were located in the major tributary arms of the reservoir, at RK 3 in the Little North Fork arm (LNF-3) and at RK-72 in the North Fork Clearwater River arm in the upper reservoir. Sampling was conducted once per month on two consecutive days. This comprised a single sampling period.

Physical/Chemical

At each station, water depth was measured with a Furuno™ Model FCV-582 depth sounder with a 10° transom mounted transducer. A 20 cm standard Secchi disc was then vertically lowered from the shaded side of the boat until it just disappeared from sight, then raised until it reappeared. This depth was then recorded to the nearest 0.1 m as a measure of water transparency. Dissolved oxygen (DO) (mg/L) and temperature (°C) were then measured at the surface, 1 m depth, and at even meter depths to 60 m using a YSI™ model 58 oxygen/temperature meter. Reservoir elevation data was provided to the nearest 0.1 m by U.S. Army Corps of Engineers.

Table 1. Location and description of sampling stations used during Dworshak Reservoir limnological survey, May—November 2004.

River Mile	River Kilometer	Reservoir Section	Location Description
RM 2.5	NFC	0	In North Fork Clearwater (NFC) below Dworshak Dam, just downstream of 'no boats' sign.
RM 3	RK-2	1	At U.S. Army Corps water quality buoy.
RM 7	RK-11	1	At outhouse in Canyon Creek arm.
EC 4	EC-6	1	At no wake buoy in Elk Creek (EC) arm.
RM 19	RK-31	2	At swim platform upstream of Cranberry Creek.
RM 26	RK-42	2	At outhouse in Magnus Bay near mouth of Swamp Creek.
RM 35	RK-56	2	At U.S. Army Corps water quality buoy between Silver and Gold Creeks.
LNF 2	LNF-3	3	Little North Fork Clearwater (LNF) at wide spot (No-See-Um & Homestead Creeks).
RM 41	RK-66	3	At outhouse at Grandad (confluence of NFC & LNF).
RM 45	RK-72	3	At U.S. Army Corps water quality buoy between Benton and Anderson Creeks.

Water samples were collected from two depth strata at each station using a 2.2 L Kemmerer bottle. Water samples were collected from each of 1, 3, 6, and 12 m depths, but some depths were omitted if they fell below the thermocline. Approximately 1 L of water from each sample depth was then emptied into a splitter bucket and churned/mixed to comprise a single composite epilimnetic sample (EPI). A single 1 L Kemmerer bottle from 25 m comprised a hypolimnetic sample (HYPO).

The EPI and HYPO samples described above were then used to fill separate sample containers for each respective analyte of interest. Two 250 ml polyethylene sample containers were filled, one each from EPI and HYPO water. These samples were labeled as EPI- or HYPO-unfiltered with the appropriate station; date, time collected, and depth(s) sampled and immediately put on ice in a cooler. These samples were analyzed for total phosphorus (TP), nitrate nitrogen (NO_3-N), and total dissolved nitrogen (TDN) concentrations.

Two 1 L samples, one each from EPI and HYPO water, were manually filtered for total dissolved phosphorus (TDP) and total dissolved solids (TDS) analysis. The filter container and parts were rinsed in distilled water, and forceps were used to place a 47 mm Whatman™ GF/F filter on top of the analytical support. One L polyethylene sample containers and a funnel were rinsed with distilled water. The sample containers were then filled with the contents of the filtering container and labeled as EPI- or HYPO-filtered, with station, date, depth(s), and time collected.

Samples were also collected for analysis of chlorophyll *a* concentration. An additional 500 ml of EPI water was filtered using the same methods as above except with a 47 mm diameter 0.45 µm cellulose acetate filters. After the water was filtered, the filter was lifted off the filter apparatus with forceps, carefully folded in half, and placed in the center of a 15 x 15 cm precut piece of aluminum foil. The foil was folded around the filter until as small as possible without folding the filter and placed in a zip-loc bag. This bag was labeled as Chl-A, with the date, station, and time and placed in a larger zip-loc bag and placed on ice in the cooler. The filters were frozen as soon as possible and kept frozen until submitted for analysis.

Water samples were then frozen and shipped to Anatek Labs, Incorporated.; Moscow, Idaho and analyzed for nitrate nitrogen (NO_3), orthophosphorus (OP), total phosphorus (TP), and chlorophyll a. Phytoplankton biomass from chlorophyll *a* samples will be reported as μg/L.

Bacteria

Bacteria and picocyanobacteria were sampled from Dworshak Reservoir in the forebay (RK-2), Elk Creek arm (EC-6), Magnus Bay (RK-42), and just upstream of Granddad bridge (RK-66), on November 1, 2004 (Figure 1). Water was collected with a 2.2 L Kemmerer bottle, which was rinsed with distilled water prior to each sampling.

At each station, one 25 ml vial was filled with unfiltered water from a composite epilimnion (EPI) sample from 1, 3, 5, and 7 m depths. Samples were preserved with 2 drops of gluteraldehyde and placed in a sterile capped test-tube. From each 25 ml bacteria sample, 15 ml was filtered through a prestained Irgalen black 0.2 μ polycarbonate Nuclepore© filter, placed in an envelope, and stored in a cool, dark location until microscopic analysis.

Bacteria and picocyanobacteria densities were enumerated by Eco-Logic Ltd., North Vancouver, British Columbia; using both the acridine orange and DAPI stained direct-count epifluorescence method (MacIsaac and Stockner 1981). Random fields were counted at 1250X magnification oil immersion after filtration of 10-15 ml samples onto 0.2 μ Irgalen black stained filters using a Zeiss epifluorescence microscope and blue-band excitation filter at wavelengths of 450-490 nm. APP was enumerated using the epifluorescence method described by MacIsaac and Stockner (1993). Up to 30 random fields were counted using a wideband filter excitation (397-560 nm). Results were reported as both abundance (cells/ml) and volume (mm^3/L).

Phytoplankton

Phytoplankton was sampled from Dworshak Reservoir at the same stations as described above for bacteria: in the forebay (RK-2), Elk Creek arm (EC-6), Magnus Bay (RK-42), and just upstream of Granddad bridge (RK-66), on November 1, 2004 (Figure 1). One 125 ml container was filled with unfiltered water from the composite EPI sample at each station. Each phytoplankton sample was preserved in acid Lugol's iodine preservative and stored in a cool location.

All samples were shipped in ice-filled coolers and analyzed within 72 hours of collection. Phytoplankton counts were conducted by Eco-Logic Ltd. using guidelines established by McQuaker (1994). Prior to quantitative enumeration by the Utermohl (1958) method, samples were gently shaken for 60 seconds, carefully poured into 25 ml settling chambers, and allowed to settle for a minimum of 8 hrs.

Counts were done using a Carl Zeiss inverted phase-contrast plankton microscope. Counting followed a 2-step process: first, random fields (5-10) were examined at 250X magnification (16X objective) and large microphytoplankton (20-200 μ), e.g., diatoms, dinoflagellates, filamentous blue-greens were enumerated; and secondly, all cells within a random transect (ranging from 10 to 15 mm) were counted at 1560X magnification (100X objective). This high magnification permitted quantitative enumeration of minute (less than 2 μ) autotrophic picoplankton cells (0.2-2.0 μ) [Class Cyanophyceae], and also of small auto-, mixo-, and heterotrophic nanoflagellates (2.0-20.0 μ) [Classes Chrysophyceae and Cryptophyceae]. In

total, 250-300 cells were enumerated in each sample to assure statistical accuracy (Lund et al. 1958). The compendium of Canter-Lund and Lund (1995) was used as the taxonomic reference. Phytoplankton was recorded as both densities (number/ml) and volume (mm^3/L).

Zooplankton

Zooplankton was sampled at each limnological station with 0.5 m diameter Wisconsin plankton nets with 130-150 micron mesh (size 10). A single vertical tow was taken from a depth of 2x the Secchi depth (euphotic zone) to the surface and the net was retrieved at 0.5 m/sec. Samples were preserved in 60% ethanol. In the laboratory, zooplankton were classified by family, enumerated, and recorded as organisms/liter. A subsample of 20 individuals per Cladoceran genera was measured to the nearest 1 µm with the ocular micrometer of a dissecting scope at 30x power.

Kokanee Growth and Diet

Trawl sampling was conducted once monthly from May though November 2004 to assess kokanee growth and food habits. Prior to the start of May sampling, daylight test trawls were conducted to calibrate the net as described above in the abundance, density, and length-at-age methods. Within each reservoir section, four transects were randomly selected near limnological sample stations and one haul made along each transect. Trawling was conducted as described above, except abundance and densities were not estimated. Therefore, recording the distance and duration of each step of the haul was not necessary.

All fish from each trawl sample were measured to the nearest mm TL and weighed to the nearest gram. Scales were collected from two fish in each 10 mm size interval from each trawl to verify kokanee ages. Stomach contents were also removed from up to nine kokanee per 50 mm size class per reservoir section. Stomach contents were squeezed into a small vial and preserved in 60% ethanol. In the laboratory, diet items were identified to genera and enumerated. A subsample of 20 individuals per Cladoceran genera was also measured to the nearest 1.0 µm with the ocular micrometer of a dissecting scope at 30x power.

During each trawl sample period, mean total lengths of each age class were calculated for each reservoir section and then weighted by the number sampled to obtain mean lengths of each age class for the entire reservoir. Monthly age class growth rates were then calculated by subtracting the weighted mean length from one trawl sample from the weighted mean from the next sample period for each age class.

RESULTS

Kokanee Population

Abundance, Density, and Length-at-Age

We estimated a total abundance of approximately 3,920,000 kokanee (90% CI ± 35.4%) in Dworshak Reservoir on July 2004. This included 3,137,892 age-0 (90% CI ± 42.2%), 692,348 age-1 (90% CI ± 24.2%), and 90,715 age-2 (90% CI ± 42.2%) (Figure 4).

The total density of all kokanee was estimated at 642 fish/ha, with 468 age-0/ha, 103 age-1/ha, and 14 age-2/ha (Figure 5). Both the total abundance (Figure 6) and total density (Figure 7) of kokanee was highest in section 2 and lowest in section 1. Both the abundance and density of age-0 and age-2 kokanee were highest in section 2, but the abundance and density of age-1 kokanee was highest in section 3 (Figure 7).

A total of 1,297 kokanee were captured during midwater trawls, with the largest measuring 333 mm (13.1 in) and smallest measuring 27 mm (1.1 in) (Figure 8). Trawled kokanee were comprised of three age classes: age-0, age-1, and age-2; no age-3 kokanee were captured. Based on a length-at-age frequency distribution of trawl caught fish, age-0 kokanee ranged from 27-81 mm TL (1.1–3.2 in), age-1+ fish ranged from 100 to 250 mm TL (3.9–9.8 in), and age-2+ kokanee ranged from 250 to 333 mm TL (9.8–13.1 in) (Table 2; Figure 8).

Table 2. Age-0, age-1, and age-2 kokanee total length ranges and corresponding ages.

	Age
24 – 99	0+
100 – 255	1+
256 – 375	2+

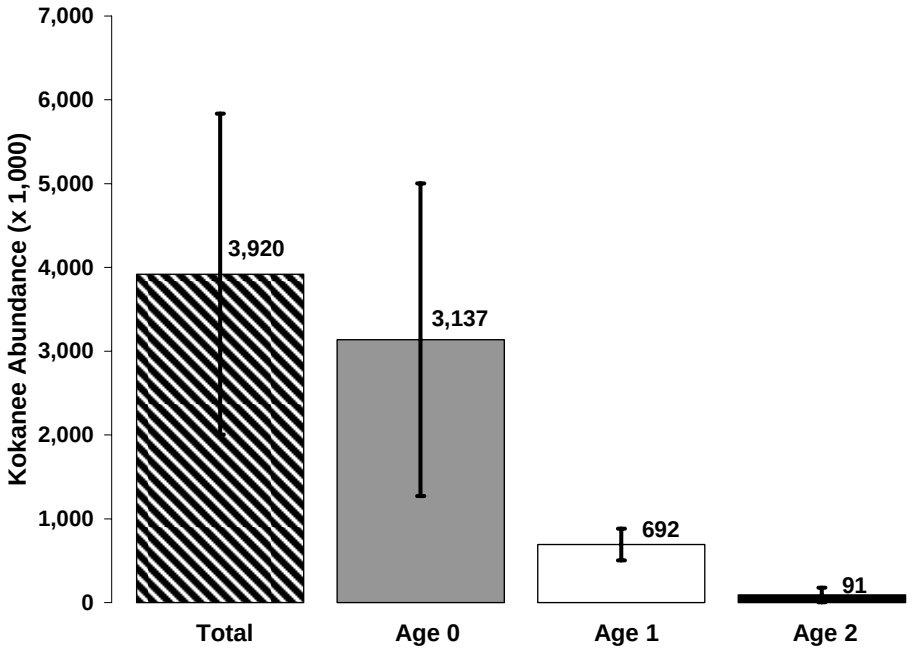


Figure 4. Abundance of kokanee in Dworshak Reservoir, July 12-14, 2004. Estimates were obtained by midwater trawling. Error bars represent 90% confidence intervals.

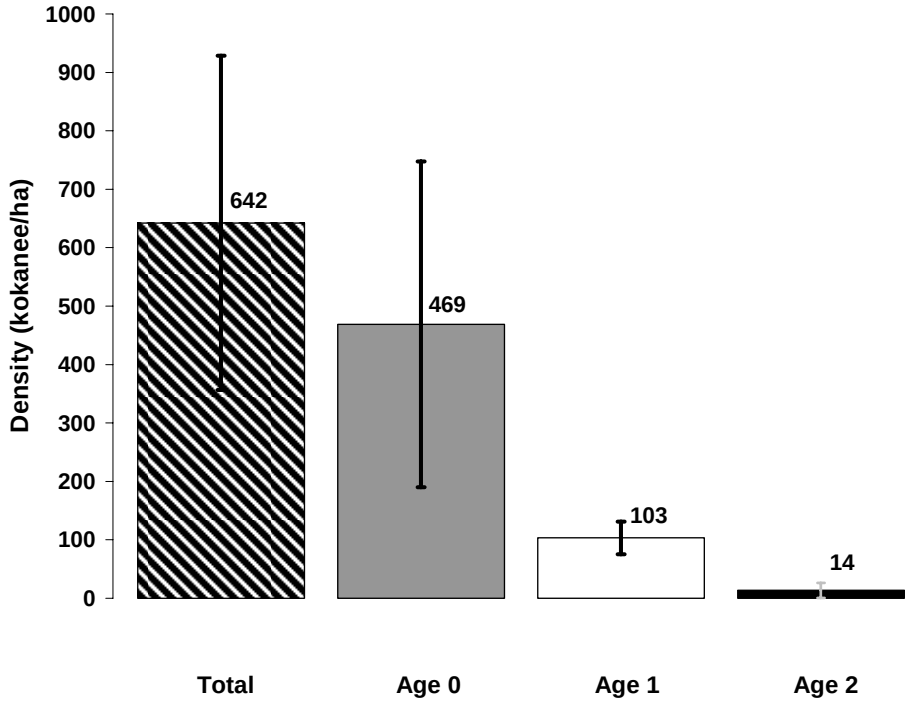


Figure 5. Density of kokanee in Dworshak Reservoir, July 12-14, 2004. Estimates were obtained by midwater trawling. Error bars represent 90% confidence intervals.

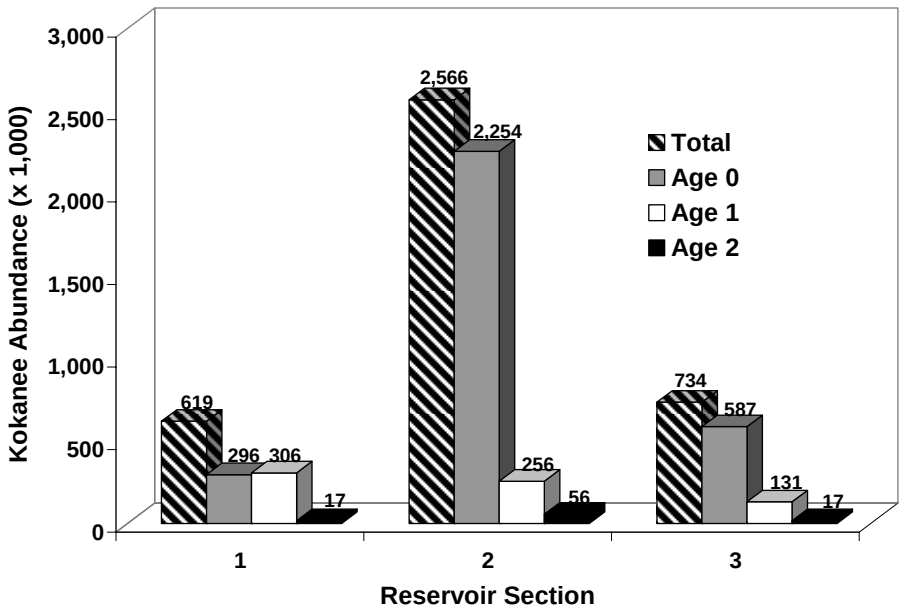


Figure 6. Abundance of kokanee by reservoir section and combined total abundance of kokanee in Dworshak Reservoir, July 12-14, 2004. Estimates were obtained by midwater trawling. See figure 1 for section locations.

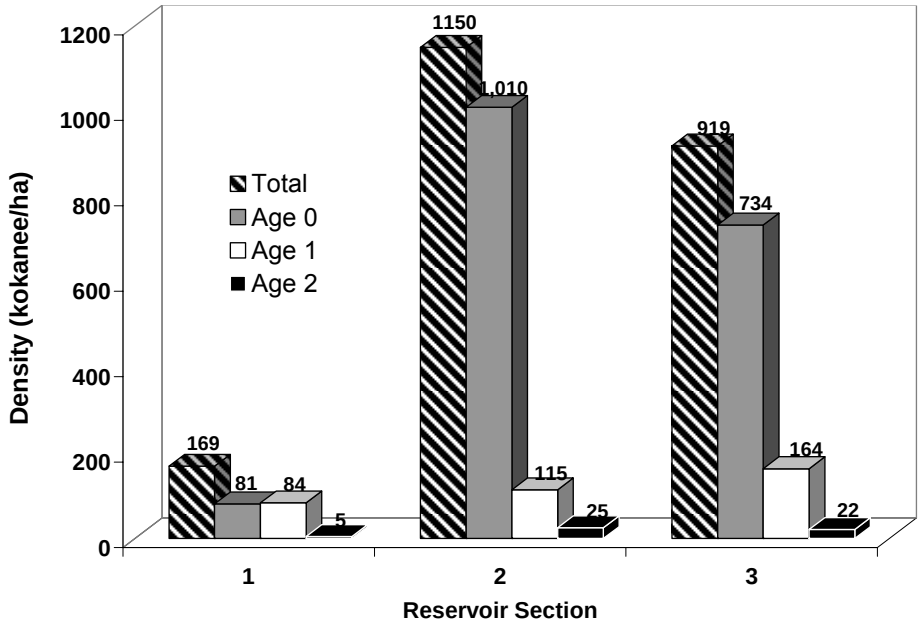


Figure 7. Density of kokanee by reservoir section and combined total density of kokanee in Dworshak Reservoir, July 12-14, 2004. Estimates were obtained by midwater trawling. See figure 1 for section locations.

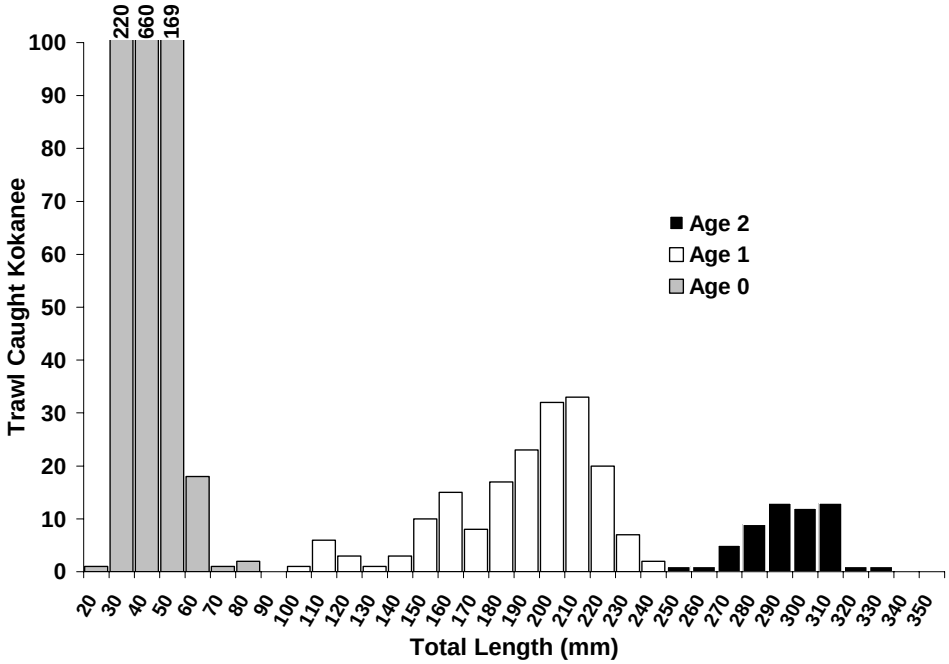


Figure 8. Length-frequency distribution of kokanee from midwater trawling in Dworshak Reservoir, July 12-14, 2004.

Entrainment

Fish detection rates during entrainment sampling in 2004 were quite variable. The highest 24 h fish detection rate (42.7 fish/h) was found at turbine 1 while discharging 45.3 m^3/s (Table 3) on October 19, 2004. Fish detection rates in general were low in front of all intakes from early spring through late summer then increased dramatically in the fall, irrespective of discharge rates.

Table 3. Sampling conditions and fish detection rate in front of operating turbines of Dworshak Dam. Fish detections were made using fixed location hydroacoustics between March 2004 and February 2005. Detection rates were expanded by the percent coverage to estimate potential entrainment across the entire turbine opening.

Date	Turbine	Discharge (m3/s)	Intake Depth (m)	Secchi Transparency (m)	Mean Detection Rate (fish/h)
3/23/2004	1	39.6	29.7	2.7	1.6
3/24/2004	1	39.6	29.7	2.7	3.4
4/20/2004	3	147.2	27.1	3.0	0.1
4/21/2004	3	147.2	27.1	3.0	0.0
5/25/2004	3	150.1	11.9	5.5	0.9
5/26/2004	3	150.1	11.9	5.5	4.6
6/14/2004	3	133.1	13.1	3.3	1.6
6/15/2004	3	133.1	13.4	3.3	1.7
6/22/2004	3	144.4	14.6	3.0	0.6
7/21/2004	1	59.5	30.5	3.4	0.2
7/22/2004	2	59.5	29.6	3.3	0.5
8/5/2004	3	155.7	46.0	2.6	1.3
8/9/2004	2	62.3	19.8	4.0	9.4
8/10/2004	1	62.3	41.9	3.6	0.2
8/30/2004	2	56.6	21.0	3.5	4.5
8/31/2004	3	161.4	36.3	3.4	2.6
9/27/2004	2	45.3	30.3	4.3	9.5
10/4/2004	1	45.3	30.3	4.9	22.5
10/18/2004	1	45.3	30.3	6.7	29.3
10/19/2005	1	45.3	30.3	6.7	42.7
10/25/2005	1	45.3	30.9	5.8	14.9
1/10/2005	3	158.6	19.8	6.1	0.6
1/25/2005	3	155.7	21.6	5.2	1.5
1/26/2005	3	155.7	19.8	5.2	5.3
2/15/2005	2	39.6	17.4	4.9	6.0

The highest mean fish detection rate among turbines was found in front of turbine 1 (14.5 fish/h) (Figure 9). Mean detection rate in front of turbine 2 was 6.2 fish/h; while the mean detection rate near turbine 3 was much lower (1.5 fish/h). Pairwise comparisons between detection rates in front of turbines found there 95% confidence intervals overlapped; therefore, locations could not be not statistically different from each other (Figure 9). Detection rates were generally lower with higher discharges (Figure 10). It appeared fish detection rate was generally greater with greater Secchi water transparency (Figure 11), and no real pattern was evident between intake depth and fish detection rate (Figure 12).

Fish were detected at all times of day in front of the turbines. The highest mean detection rate was found during night periods (14.7 fish/h), and was more than twice the dawn (6.9 fish/h) and dusk periods (2.3 fish/h) (Figure 13). The lowest mean detection rate across all three turbines occurred during day sample periods (0.8 fish/h).

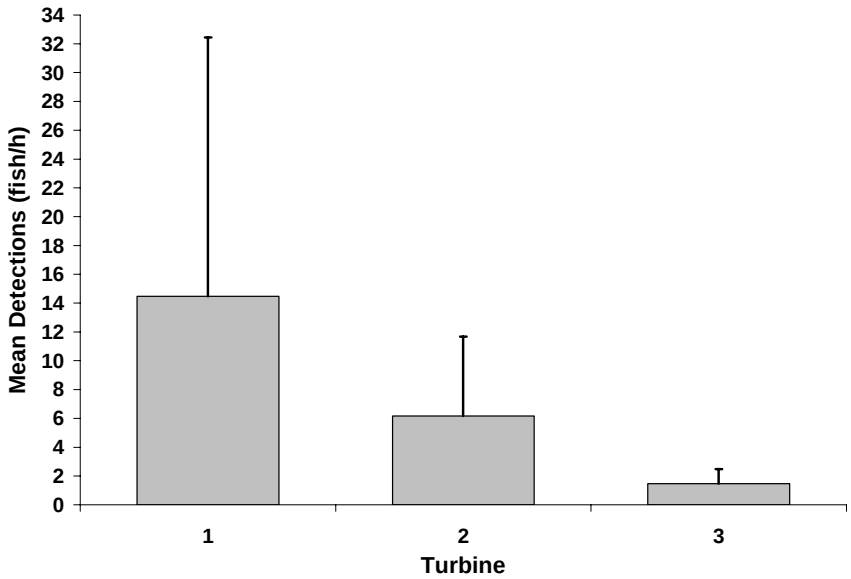


Figure 9. Mean fish detection rate in front of each of three turbines of Dworshak Dam, obtained from 24 h fixed-site hydroacoustic sampling, March 2004–February 2005. Rates were expanded based upon the percent coverage of the turbine openings by the acoustic beam. Vertical bar represents one standard deviation.

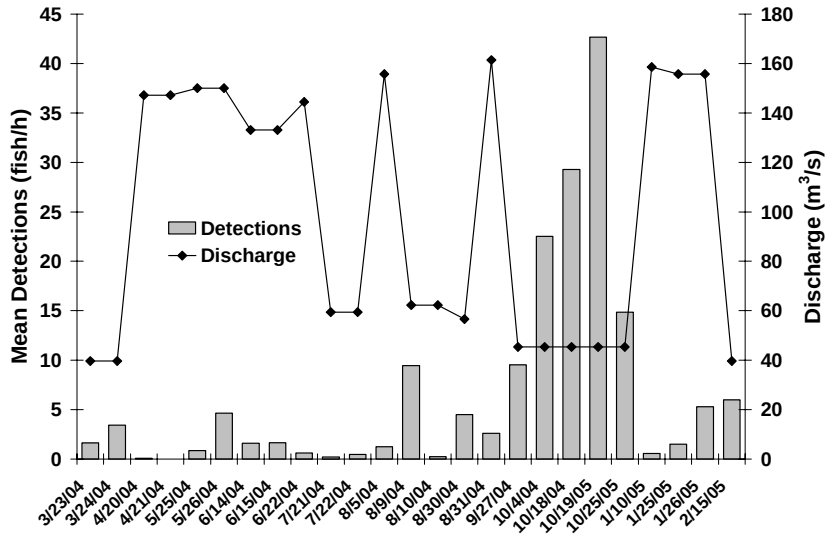


Figure 10. Mean fish detection rate in front of, and discharge rate of water through, the turbines of Dworshak Dam. Data were obtained from 24 h fixed-site hydroacoustic sampling, March 2004–February 2005. Rates were expanded based upon the percent coverage of the turbine openings by the acoustic beam.

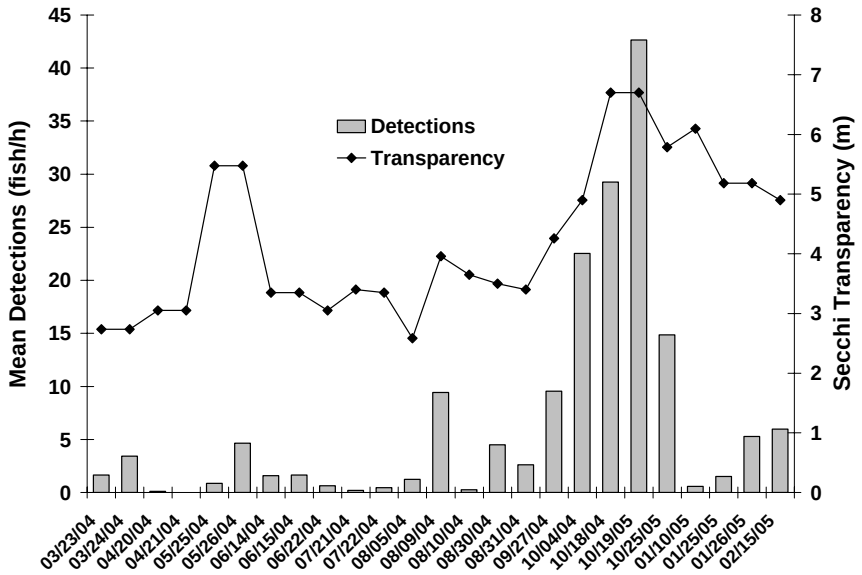


Figure 11. Mean fish detection rate in front of the turbines of Dworshak Dam and Secchi water transparency. Detection data were obtained from 24 h fixed-site hydroacoustic sampling, March 2004—February 2005. Rates were expanded based upon the percent coverage of the turbine openings by the acoustic beam.

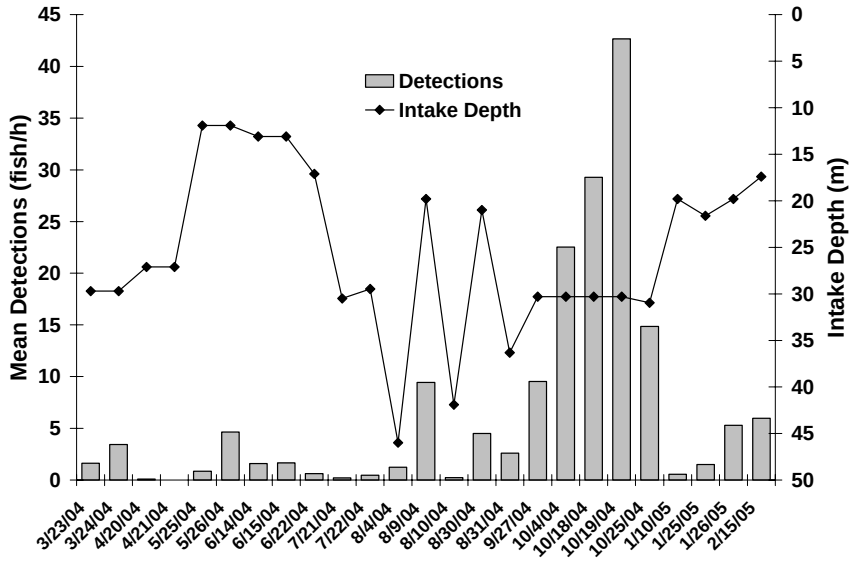


Figure 12. Mean fish detection rate and depth of water discharged through the turbines of Dworshak Dam. Data were obtained from 24 h fixed-site hydroacoustic sampling, March 2004–February 2005. Rates were expanded based upon the percent coverage of the turbine openings by the acoustic beam.

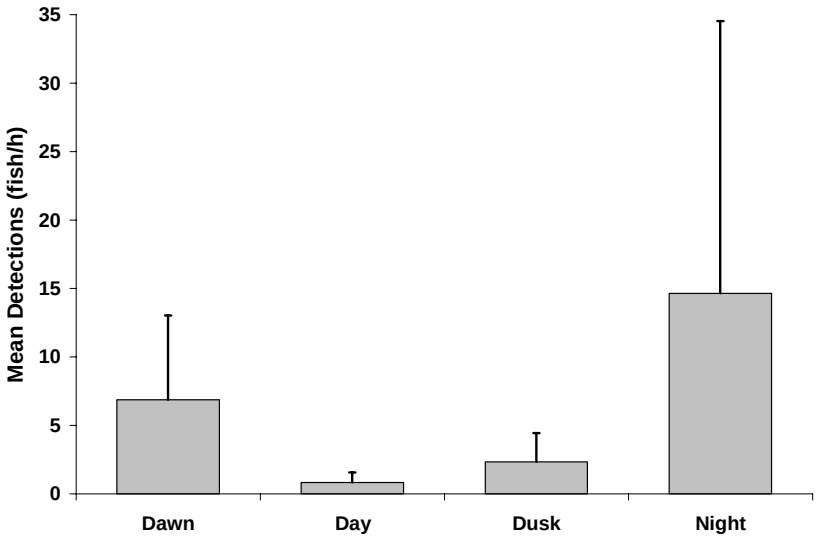


Figure 13. Mean fish detection rate in front of discharging turbines of Dworshak Dam, for each of four time of day strata (dawn, day, dusk, and night). Data were obtained from 24 h fixed-site hydroacoustic sampling, March 2004—February 2005. Rates were expanded based upon the percent coverage of the turbine openings by the acoustic beam. Vertical bars represent one positive standard deviation of the mean detection rates.

Forebay Densities

Kokanee densities near the dam were highest in October when they reached 1,374 fish/hectare and lowest in April when they dropped to only 70 fish/ha. During the rest of the year, densities remained low and relatively stable (Figure 14).

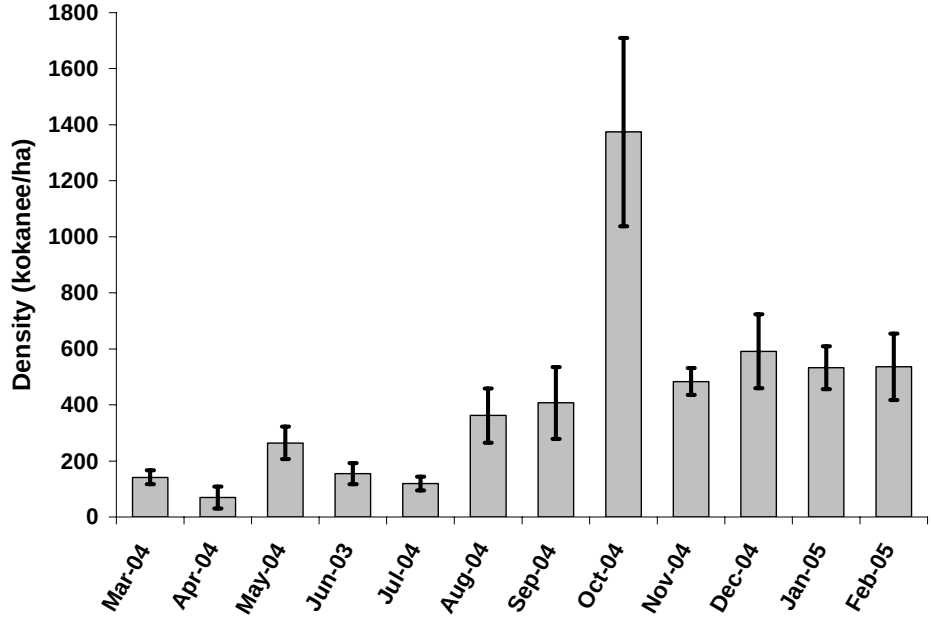


Figure 14. Mean kokanee densities in the forebay of Dworshak Reservoir, Idaho, obtained from monthly hydroacoustic sampling, March 2004–February 2005. Vertical error bars represent one standard deviation.

Discharge

During 2004, mean monthly discharge from Dworshak Dam varied from a low of 36.8 m^3/s throughout most of November and December to a high of 589 m^3/s during the beginning of June (Figure 15). Pool elevation varied from a low pool of 459.7 m on March 2, 2004 to a full pool of 487.6 m on June 30, 2004 (Figure 16). Water releases during summer months ('Salmon Flows') continued in 2004 and lasted from July 5 through September 22. These high discharges were intended to aid smolts by speeding up out-migration and cooling water temperatures in the Lower Snake River. Total discharge through Dworshak Dam was at or very near minimum discharge (36.8 m^3/s) for a total of 189 days. Secchi water transparencies generally decreased with greater discharge rates (Figure 17). Secchi transparency was lowest during August and highest in October.

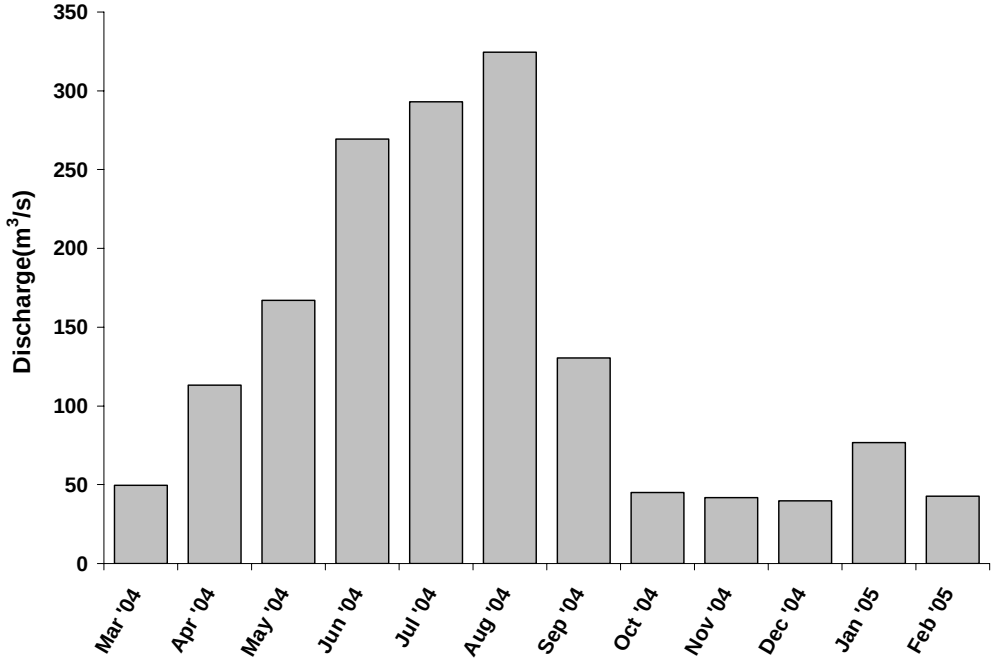


Figure 15. Mean monthly discharge through Dworshak Dam, March 2004—February 2005.

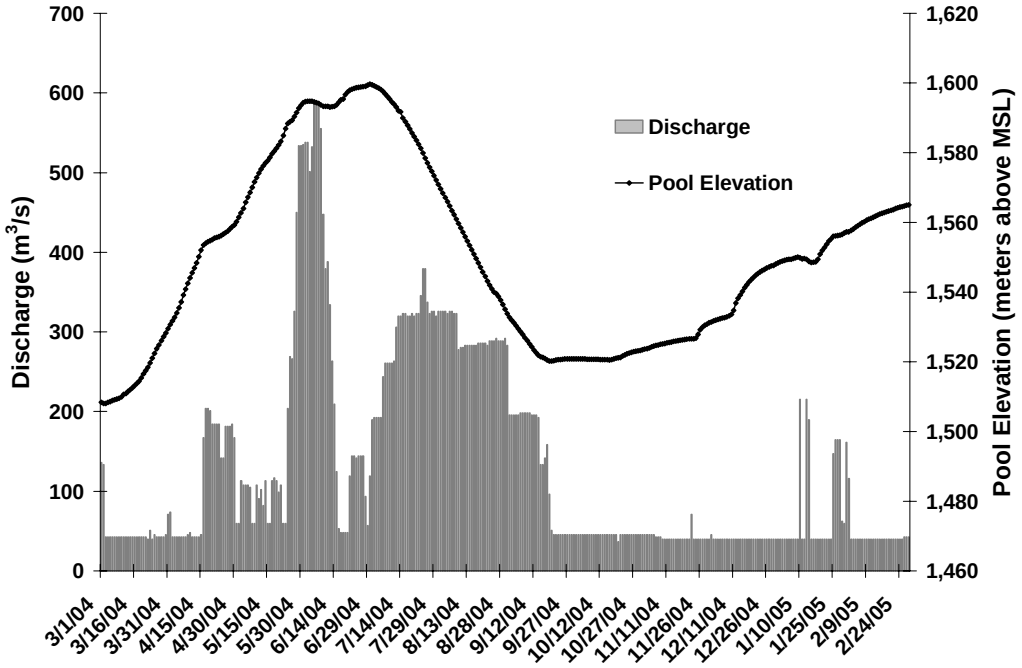


Figure 16. Total discharge through Dworshak Dam and Dworshak Reservoir pool elevation, March 2004—February 2005.

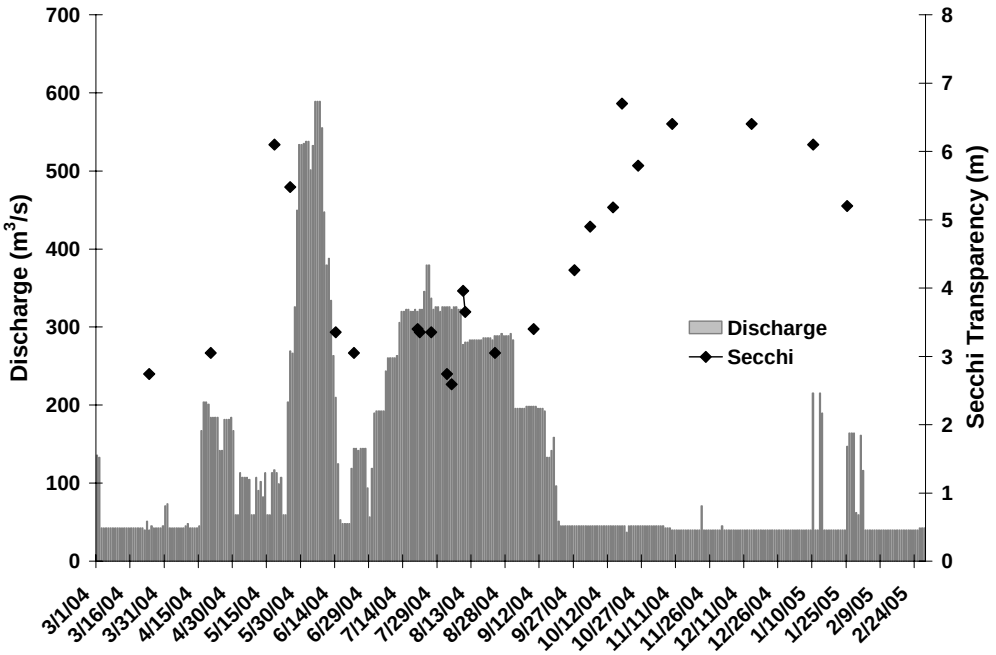


Figure 17. Total discharge through Dworshak Dam and Secchi water transparency, March 2004–February 2005.

Spawner Counts

We counted 9,466 spawning kokanee in three index streams in 2004 (Table 4). This was about 40% of the number of kokanee counted in the same streams in 2003 (23,612).

Kokanee distribution ended at 2.0, 2.2, 1.1, and 0.3 miles upstream of the mouths of Isabella Creek, Skull Creek, Quartz Creek, and Dog Creek, respectively. The same rockslide barrier was present again this year in Quartz Creek, which prevented further upstream movement. A significant impediment to upstream migration was also found on Skull Creek near river mile 2.2. In Isabella Creek, spawners were only observed up to river mile 2.0.

A subsample of 31 spawners was collected from the four tributaries during the counts. Fish ranged from 282 to 335 mm in length, with a mean of 308 mm (Figure 18). The sex ratio of measured spawners was two males for every female (2:1).

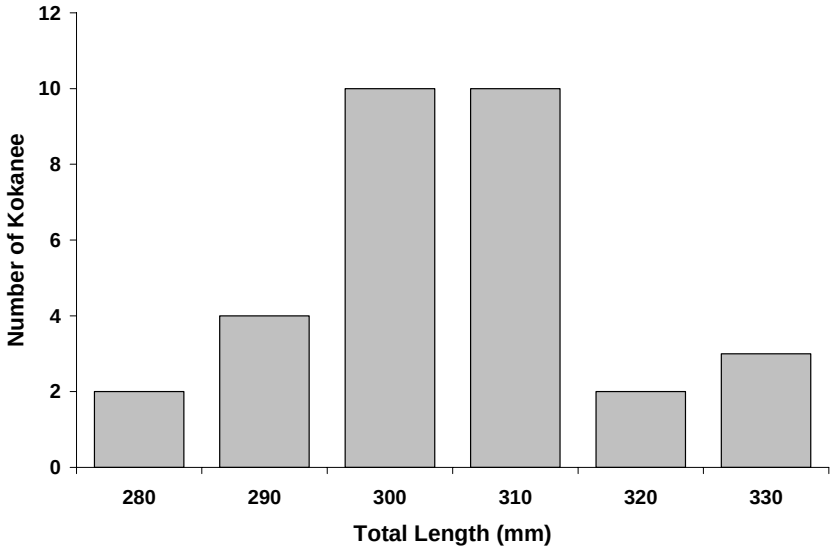


Figure 18. Length frequency distribution from a subsample of 31 kokanee spawners from Isabella, Quartz, and Skull Creeks, September 21–22, 2004. Mean total length was 308 mm.

Table 4. Number of kokanee spawners counted in selected tributaries to Dworshak Reservoir, Idaho during September 1981-2004.

Year	Isabella Creek	Skull Creek	Quartz Creek	Dog Creek	Total[a]
2004	6,922	2,094	450	1,474	9,466
2003	12,091	10,225	1,296	1,083	23,612
2002	15,933	7,065	2,016	1,367	25,014
2001	3751	1305	722	301	5,778
2000	3939	402	124	565	4,465
1999	10,132	361	827	2,207	11,320
1998	627	20	13	18	660
1997	144	0	0	0	144
1996	2,552	4	13	82	2,569
1995	12,850		2,780	1,160	15,630
1994	14,613	12,310	4,501	1,878	31,424
1993	29,171	7,574	2,476	6,780	39,221
1992	7,085	4,299	1,808	1,120	13,192
1991	4,053	1,249	693	590	5,995
1990	10,535	3,219	1,702	1,875	15,456
1989	11,830	5,185	2,970	1,720	19,985
1988	10,960	5,780	5,080	1,720	21,820
1987	3,520	1,351	1,477	700	6,348
1986	—	—	—	—	0
1985	10,000	8,000	2,000		20,000
1984	9,000	2,200	1,000		12,200
1983	2,250	135	66		2,451
1982	5,000	4,500	1,076		10,576
1981	4,000	3,220	850		8,070

[a] Total does not include Dog Creek because it was not censused until 1987.

Reservoir Productivity Assessment

Physical/Chemical

Dworshak Reservoir monthly mean water transparency in 2004 varied throughout the sampling period from 3.3 m in August to 6.0 m in November (Appendix A. Table 1). Station mean transparency was lowest at EC-6 in the Elk Creek arm (3.0 m) and highest at RK-72 (4.8 m) the farthest up-reservoir station.

Dworshak Reservoir mean water temperatures were highest during July followed by August then September (Appendix A. Tables 2-10); however, the epilimnion extended deeper in the water column during August than July. The maximum water temperature recorded during 2004 (27.2°C) was observed at the surface at RK-2 in July. Summer surface water temperatures exceeded 24°C during July and August 2004. Surface temperatures were coldest during November; however, overall mean epilimnetic water temperature was coldest during May followed by November then October. During August, hypolimnetic temperatures ranged from 4.3°C at 60 m and deeper up to 11.8°C at 20 m. The epilimnion did not extend below 25 m depth during 2004.

Nutrient concentrations were highly variable throughout limnological sampling in 2004 (Figure 19). Total phosphorus concentrations ranged from less than 5 µg/L at several sites in October and November up to 80 µg/L at RK-31 in May and RK-72 in June (Appendix A. Table 11). Mean monthly total phosphorus concentration peaked in September and was lowest in November (Appendix A. Table 12). The overall mean total phosphorus concentration was 16.2 µg/L.

Orthophosphorus concentrations varied from less than 0.001 mg/L at most sites in October up to 0.016 mg/L at RK-42 in June. Mean monthly orthophosphorus concentration peaked in June and was lowest in November. The overall mean orthophosphorus concentration was 0.005 mg/L.

Nitrate concentrations ranged from less than 0.001 mg/L at most sites in July and October up to 0.030 mg/L at LNF-3 in May. Mean monthly nitrate concentration peaked in May and was lowest in both July and October. The overall mean nitrate concentration was 0.006 mg/L.

Chlorophyll *a* concentrations varied from less than 0.001 mg/L at RK-72 in May, June, and July and at RK-11 and RK-2 in November, to 0.009 mg/L at RK-11 in July. Mean monthly chlorophyll *a* concentration peaked in September and was lowest in June. The overall mean chlorophyll *a* concentration was 0.003 mg/L.

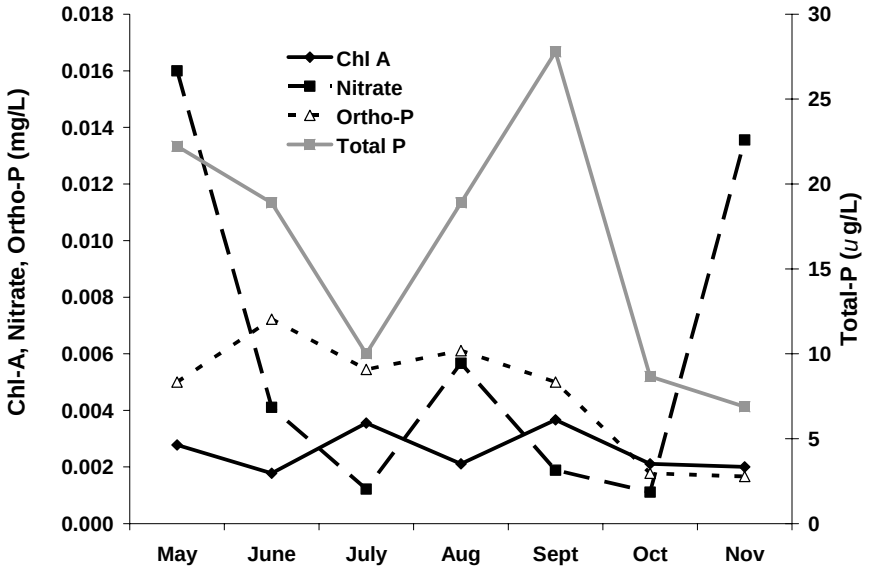


Figure 19. Mean concentration of chlorophyll *a*, nitrate, orthophosphorus, and total phosphorus sampled from nine limnological stations throughout Dworshak Reservoir, May–November 2004.

Bacteria

Bacteria counts varied from 380,000 at RK-2 to 715,000 at EC-6, and averaged 488,000. Counts of cyanobacteria varied from 16,000 at RK-42 to 37,000 at RK-2, and averaged 24,000 (Figure 20).

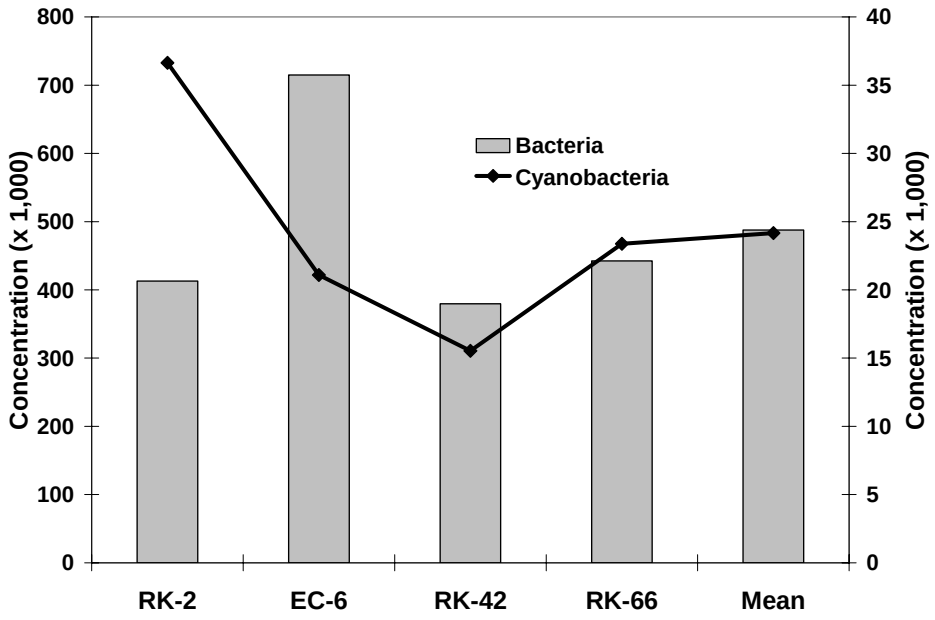


Figure 20. Concentration of bacteria and cyanobacteria at four stations in Dworshak Reservoir, November 1, 2004.

Phytoplankton

Total phytoplankton abundance in November 2004 varied from 2,696 cells/ml at RK-42 to 3,984 cells/ml at RK-66 (Figure 21), and averaged 3,368 cells/ml (Appendix A. Table 13). Total phytoplankton volume varied from 0.3024 mm^3/L at EC-6 to 0.5627 mm^3/L at RK-66, and averaged 0.3807 mm^3/L (Figure 22). Phytoplankton from Chrysophyceae and Cryptophyceae classes (flagellates) dominated both phytoplankton abundance and biovolume at all sites except RK-42 abundance in November 2004.

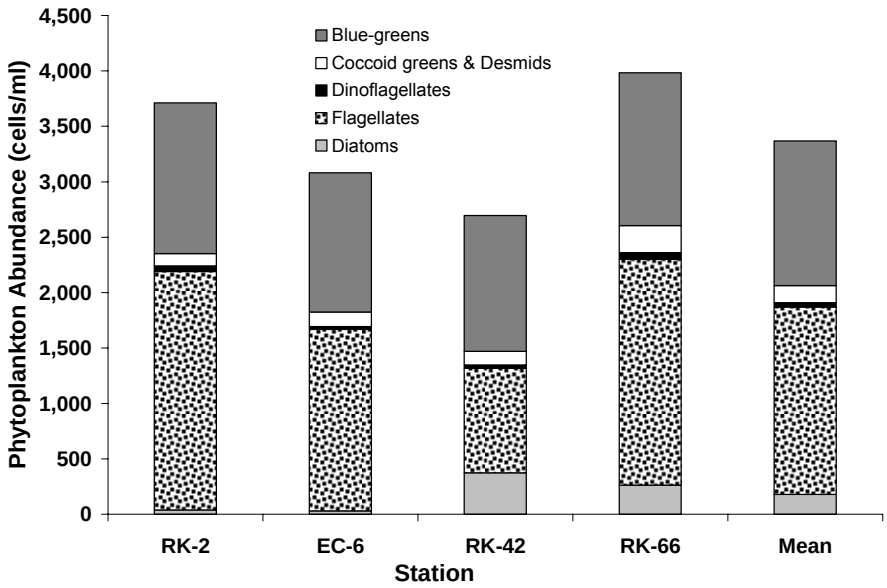


Figure 21. Abundance of phytoplankton sampled from four stations on Dworshak Reservoir, November 1, 2004. Each bar represents the contribution of each of five groups to the total phytoplankton abundance found at each site. RK = river kilometer, EC = Elk Creek Arm, numeral after abbreviation = kilometers from confluence of North Fork Clearwater and Clearwater Rivers, see figure 1 for station locations.

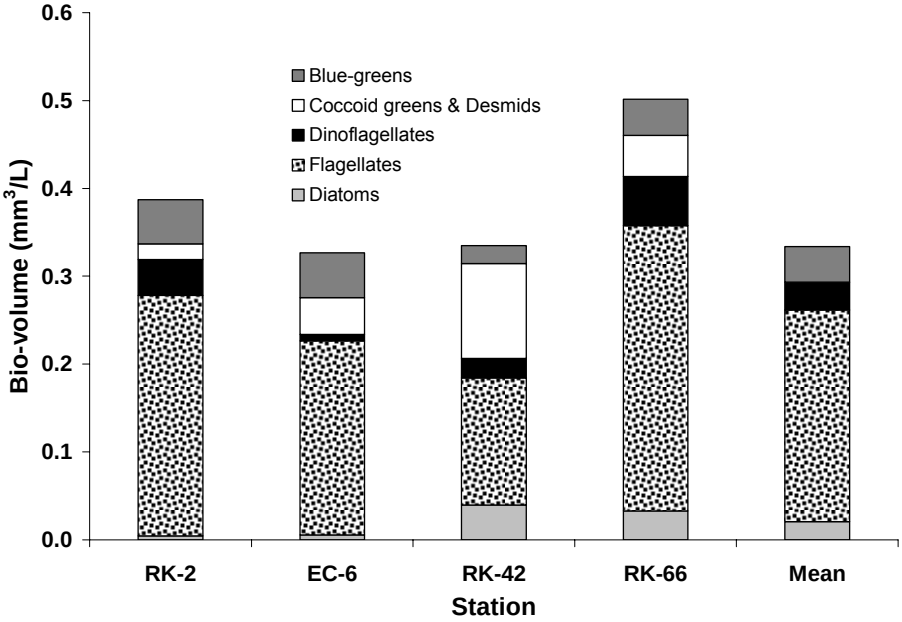


Figure 22. Biovolume of phytoplankton sampled from four stations on Dworshak Reservoir, November 1, 2004. Each bar represents the contribution of each of five groups to the total phytoplankton biovolume found at each site. RK = river kilometer, EC = Elk Creek Arm, numeral after abbreviation = kilometers from confluence of North Fork Clearwater and Clearwater Rivers; see Figure 1 for station locations.

Zooplankton

Monthly mean total zooplankton densities across all stations varied from 11.4/L in November to 19.4/L in September, with an overall mean of 16.9 zooplankton/L in Dworshak Reservoir during 2004 (Table 5). Mean total zooplankton densities remained high throughout late spring and summer but declined to 14.1/L in August (Figure 23).

Monthly mean taxonomic composition of the zooplankton community across all stations varied slightly more than total densities (Figure 23). *Cyclops* spp. Copepods dominated the community throughout most of the sampling in 2004 with the exception of July when *Daphnia* spp. comprised 48.8% of all zooplankton (Figure 24). *Cyclops* spp. made up 62.8% and 64% of the zooplankton density in June and November, respectively. *Diaphanosoma* spp. (Appendix A. Table 14) first appeared and became the third most abundant taxa in August and September but virtually disappeared by October. *Bosmina* spp. were more abundant and comprised a greater portion of the community in May and November. *Ergasilus* spp. consistently comprised 2-6% of the zooplankton throughout 2004 (Figure 24).

Table 5. Monthly mean zooplankton densities collected from nine stations throughout Dworshak Reservoir during limnological survey, May–November 2004.

	Zooplankton Mean Densities (number/L)							Mean Percent Daphnia
	Cladocerans				Copepods			
Date	**Daphnia**	**Bosmina**	**Holop**	**Diaphan**	**Cyclops**	**Erga**	**Total**	
May	7.49	1.27	0.03	0.00	9.20	0.66	18.7	40.1%
June	5.13	0.11	0.42	0.00	11.38	1.07	18.1	28.2%
July	9.46	0.07	0.10	0.05	8.99	0.64	19.3	48.8%
Aug	4.65	0.16	0.04	3.31	5.47	0.52	14.1	32.8%
Sept	5.35	0.21	0.03	3.55	9.36	0.90	19.4	27.4%
Oct	6.32	0.18	1.80	0.06	8.24	0.86	17.5	36.1%
Nov	2.99	0.86	0.02	0.00	7.31	0.25	11.4	25.8%
Mean	5.91	0.41	0.35	1.00	8.56	0.70	16.9	34.2%

Holop = *Holopedium spp.*
Diaph = *Diaphanosoma spp.*
Erga = *Ergasilus* spp.

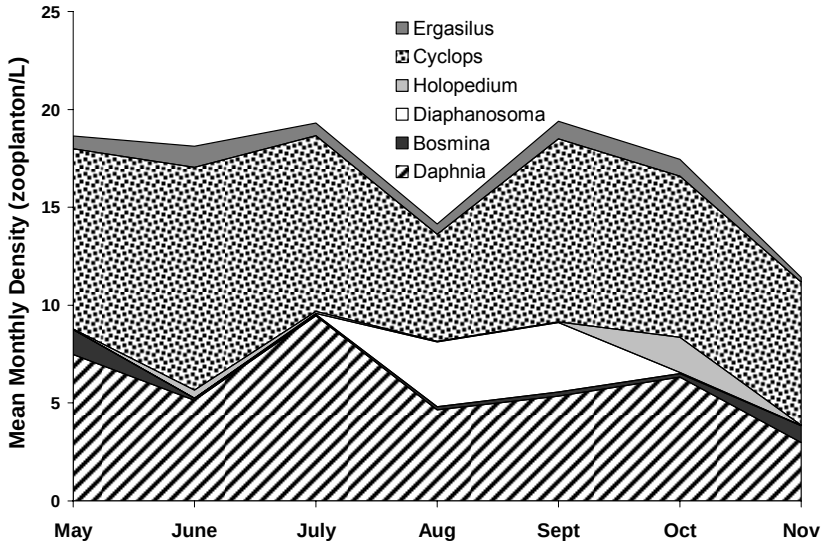


Figure 23. Mean monthly zooplankton density from nine stations on Dworshak Reservoir, collected May through November 2004. Stacked data represents the contribution of each of six major zooplankton genera to the total mean zooplankton density for each month.

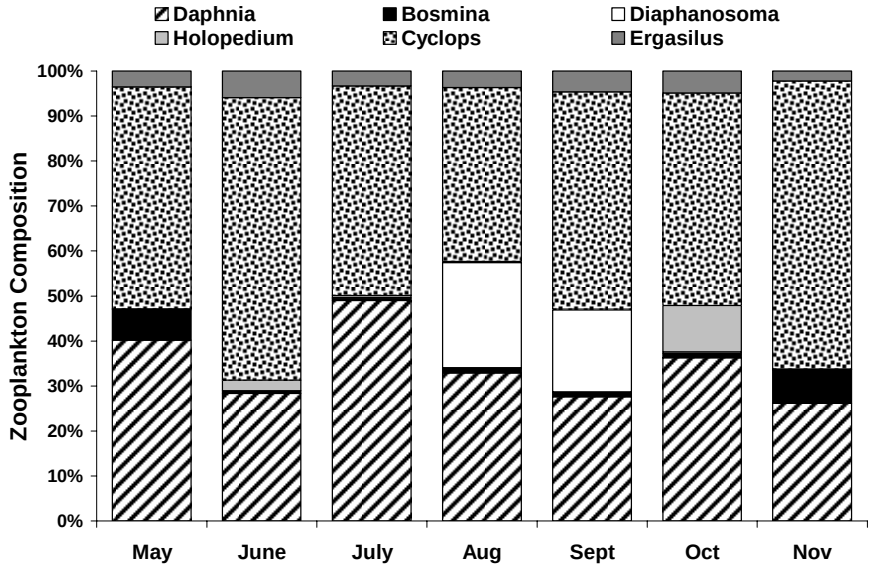


Figure 24. Mean monthly zooplankton composition from nine stations on Dworshak Reservoir, collected May through November 2004. Stacked data represents the contribution by percent of each of six major zooplankton genera to the total zooplankton assemblage for each month.

Mean zooplankton density and composition varied significantly between stations (Table 6). Mean total density was highest at EC-6 (25.6/L) and lowest at RK-72 (10.9/L) (Figure 25). *Daphnia* spp. were found at their highest mean densities at the LNF-3 station (7.9/L), but comprised a greater percentage of the zooplankton assemblage at RK-66 (50%, 7.6/L) (Figure 26). *Daphnia* spp. mean densities were lowest at station RK-42 (4.5/L, 31.1%), but comprised even less of the population at EC-6 (25.7%, 6.58/L).

Density and composition was even more variable both between stations each month and between months at each station (Appendix A. Table 15). The largest within site variability was observed at LNF-3, where total density of zooplankton varied from only 3.4/L (lowest total density) in May to 42.9/L in July. The greatest variability within a given month was found during July when total zooplankton density ranged from 8.2/L at RK-72 to 42.9 at LNF-3. The highest total zooplankton density was 43.2/L at RK-11 in May. Zooplankton densities at most stations declined in August, especially for *Daphnia* spp.

Table 6. Station mean zooplankton densities collected from nine stations throughout Dworshak Reservoir during limnological survey, May–November 2004.

	Zooplankton Densities (number/L)							
	Cladocerans				**Copepods**			**Percent**
Station	**Daphnia**	**Bosmina**	**Holop**	**Diaphan**	**Cyclops**	**Erga**	**Total**	**Daphnia**
RK-72	4.86	0.34	0.28	0.11	4.65	0.47	10.85	44.8%
LNF-3	7.85	0.26	0.32	0.19	8.22	0.92	17.84	44.0%
RK-66	7.60	0.22	0.42	0.09	6.21	0.52	15.18	50.0%
RK-56	5.42	0.31	1.05	0.45	6.37	0.76	14.38	37.7%
RK-42	4.54	0.23	0.29	3.28	5.56	0.66	14.60	31.1%
RK-31	5.66	0.44	0.50	1.36	8.98	0.67	17.65	32.1%
EC-6	6.58	0.47	0.06	1.11	16.22	1.07	25.61	25.7%
RK-11	5.69	1.00	0.11	0.60	12.21	0.78	20.45	27.8%
RK-2	5.01	0.40	0.11	1.78	8.64	0.46	16.46	30.4%

Holop = *Holopedium spp.*
Diaph = *Diaphanosoma spp.*
Erga = *Ergasilus* spp.

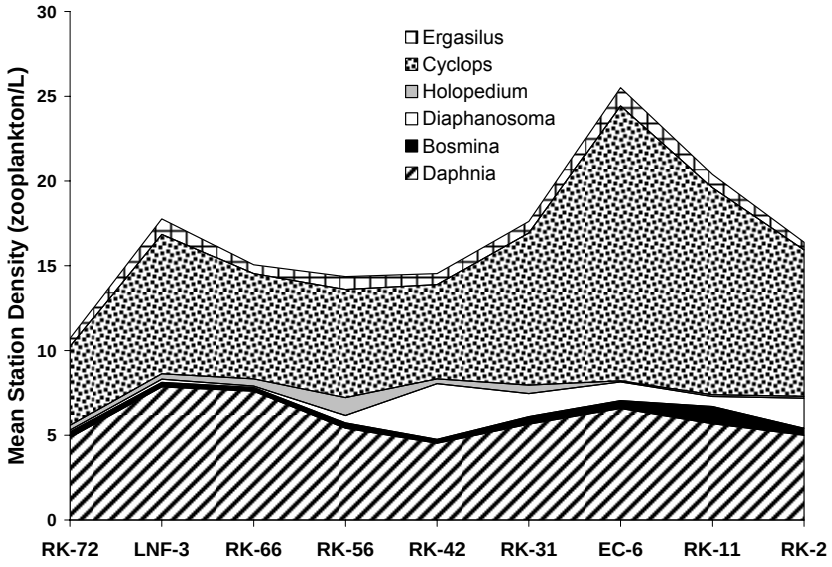


Figure 25. Mean zooplankton density from nine stations on Dworshak Reservoir, collected May through November 2004. Stacked data represents the contribution of each of six major zooplankton genera to the total mean zooplankton density for each station.

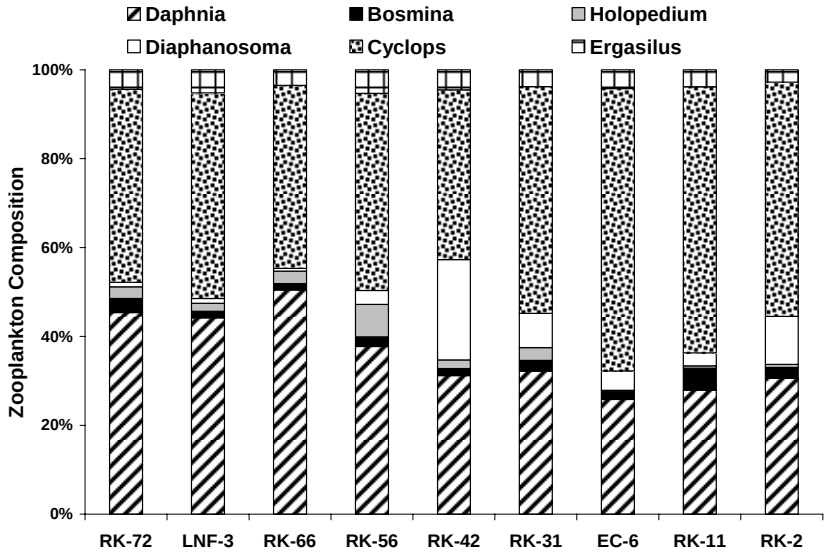


Figure 26. Mean zooplankton composition at each of nine stations on Dworshak Reservoir, collected May through November 2004. Stacked data represents the contribution by percent of each of six major zooplankton genera to the total zooplankton assemblage for each station.

Daphnia spp. mean total length varied between months but exhibited little variation between stations (Figure 27). Overall, total lengths ranged from 533 to 1567 µm with a mean of 1167 µm. Mean total length by month was shortest in May (986 µm) and longest in June (1331 µm); (Appendix A. Table 16). Mean total length by station was shortest at EC-6 (1128 µm) and longest at RK-11 (1219 µm) (Appendix A. Table 17).

Bosmina spp. mean total length varied significantly between months, but exhibited little variation between stations. Overall, lengths ranged from 167 to 667 µm and a mean of 333 µm. Mean total length by month was shortest in October (311 µm) and longest in June (365 µm), and by station was shortest at LNF-3 (340 µm) and longest at RK-2 (365 µm) (Appendix A. Tables 16-17).

Cyclops spp. mean total length varied significantly between months, but exhibited little variation between stations. Overall, total lengths varied from 367 to 1467 µm and averaged 833 µm. Mean total length by month was shortest in November (740 µm) and longest in October (922 µm), and by station was shortest at RK-31 (811 µm) and longest at RK-11 (878 µm); (Appendix A. Table 16-17).

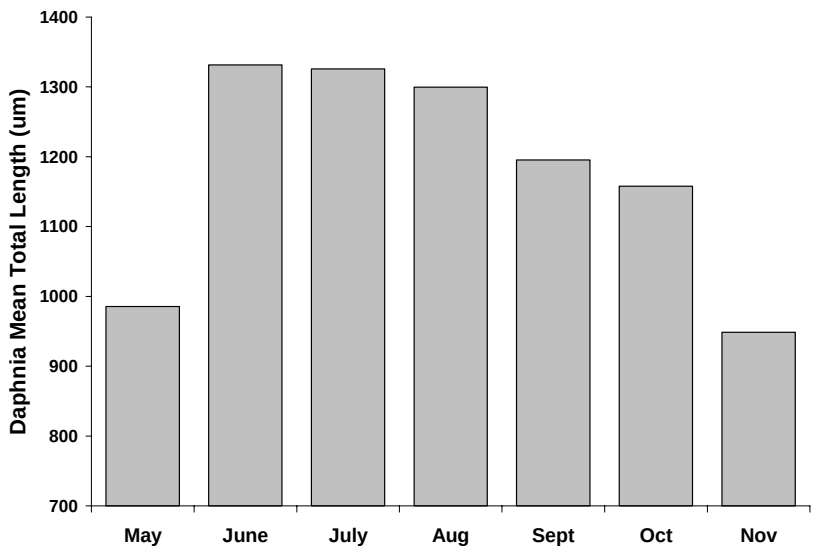


Figure 27. Mean monthly length (µm) of *Daphnia* spp. zooplankton collected at each of nine stations on Dworshak Reservoir 2004.

Kokanee Growth and Diet

During monthly trawl sampling in May-November 2004, we captured 4,434 kokanee ranging from 22 to 354 mm TL. This included 3,660 age-0 from 22 to 133 mm, 634 age-1 between 104 and 267 mm, and 140 age-2 kokanee from 251 to 354 mm TL. Total catch was highest in July (1297 kokanee) and lowest in May (221 kokanee) (Appendix A. Table 18).

Mean growth of all fish (age-0, -1, and -2) obtained from trawl sampling in 2004 was 12.5 mm per month. Mean length of age-0 kokanee increased from 24 mm in May to 93 mm in November (Figure 28). Growth of age-0 kokanee averaged 11.5 mm per month, with their fastest growth (18.3 mm) achieved between September and October trawl periods (Figure 29), and growth was slowest (4.5 mm) between May and June (Appendix A. Table 19).

Age-1 kokanee mean length increased from 145 mm in May to 232 mm in November (Figure 28). Mean growth of age-1 kokanee was 14.5 mm per month; they grew fastest (24.5 mm) between May and June trawl periods (Figure 29) and slowest (4.5 mm) between September and October (Appendix A. Table 19).

Mean length of age-2 kokanee increased from 273 mm in May to 311 mm in August (Figure 28). Growth of age-2 kokanee averaged 12.6 mm per month; their fastest growth (16.1 mm) was achieved between July and August trawl periods (Figure 29), and growth was slowest (4.5 mm) between June and July (Appendix A. Table 19).

Kokanee diet composition was enumerated from 98 stomachs collected from trawl caught kokanee from May through November 2004 (Appendix A. Table 20). *Daphnia* spp. zooplankton comprised the majority of all kokanee stomach contents, averaging 75.6% percent of all diet items by number. The next most abundant (23.4%) group of organisms was unidentifiable items we termed as 'unknown' (Table 7). The remaining identifiable organisms combined comprised slightly more than 1% of all kokanee stomach contents by abundance. This group consisted of *Bosmina* spp. and *Leptodora kindti* Cladocerans and *Cyclops* spp. and *Ergasilus* spp. Copepods, with *Leptodora kindti* most abundant (0.549%) followed by *Cyclops* spp. (0.465%), *Bosmina* spp. (0.051%), and *Ergasilus* spp. (0.005%).

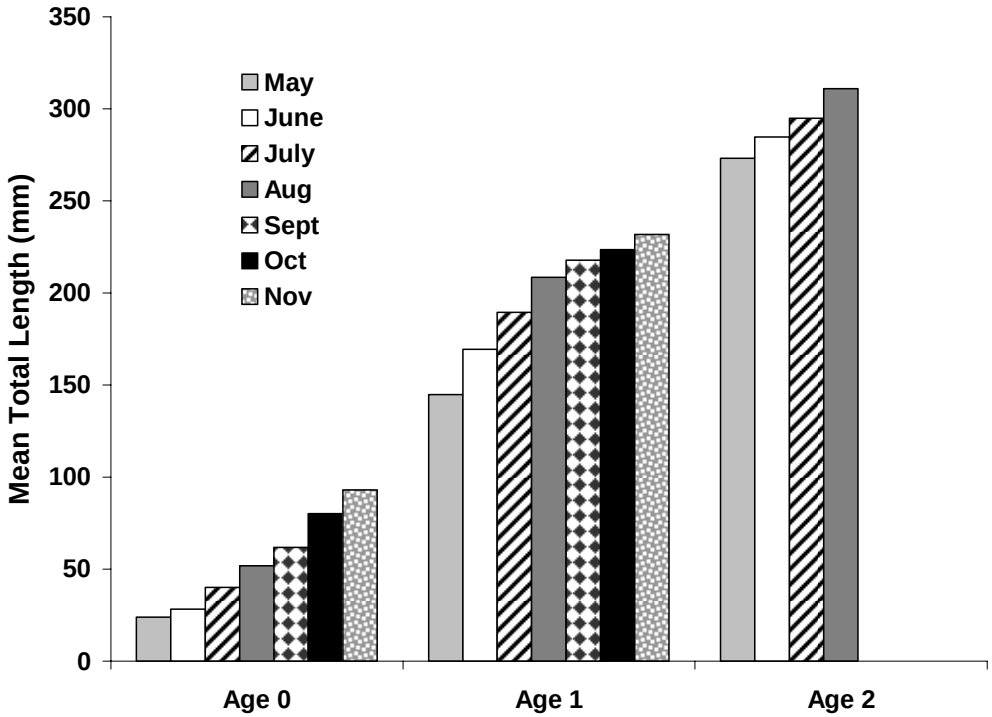


Figure 28. Mean total length of age-0, age-1, and age-2 kokanee collected from monthly midwater trawling on Dworshak Reservoir, May–November 2004.

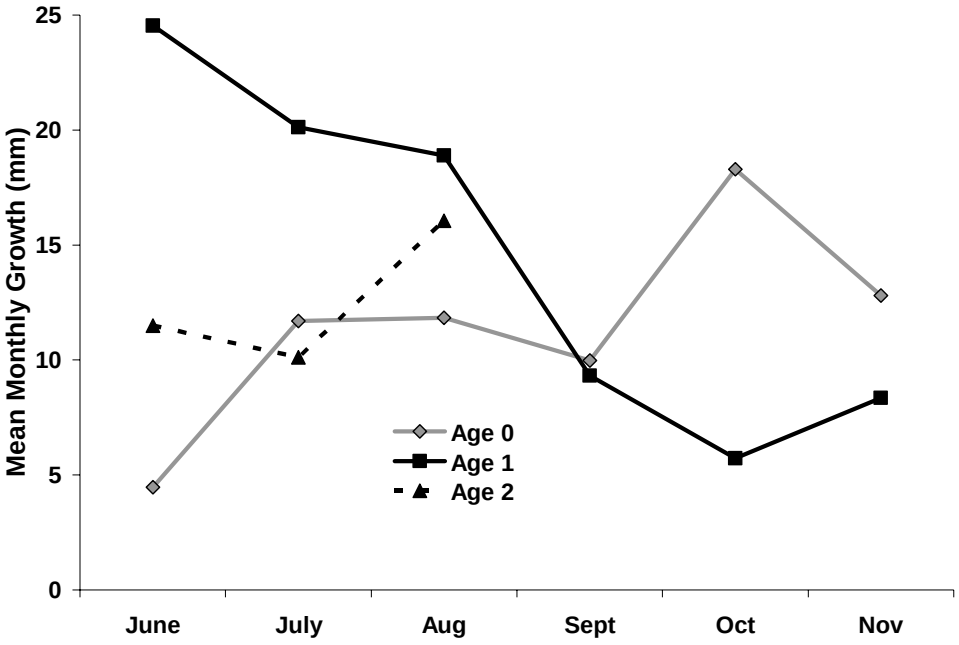


Figure 29. Mean monthly growth of age-0, age-1, and age-2 kokanee collected from monthly midwater trawling on Dworshak Reservoir, May–November 2004.

Table 7. Mean abundance and composition of diet items collected from kokanee stomachs collected during monthly midwater trawling on Dworshak Reservoir, May–November 2004.

	Kokanee Stomach Contents (zooplankton/stomach)					
	Cladocerans			Copepods		
	Daphnia	**Bosmina**	**Leptodora**	**Cyclops**	**Ergasilus**	**Unknown**
Mean Number	338.15	0.23	2.46	2.08	0.02	104.47
Percent Composition	75.579%	0.051%	0.549%	0.465%	0.005%	23.351%

DISCUSSION

Kokanee Population

Abundance, Density, and Length-at-Age

Population estimates indicated kokanee abundance increased nearly 4-fold from 2003 (1.1 million) to 2004 (3.9 million). However, adult (age-2) density declined substantially from 42 adults/ha in 2003 to only 14 adults/ha in 2004 (Table 8). In fact, age-2 kokanee in 2004 incurred nearly 80% annual mortality between 2003 and 2004, despite the fact they were fairly abundant (434,586) in 2003 (Figure 30).

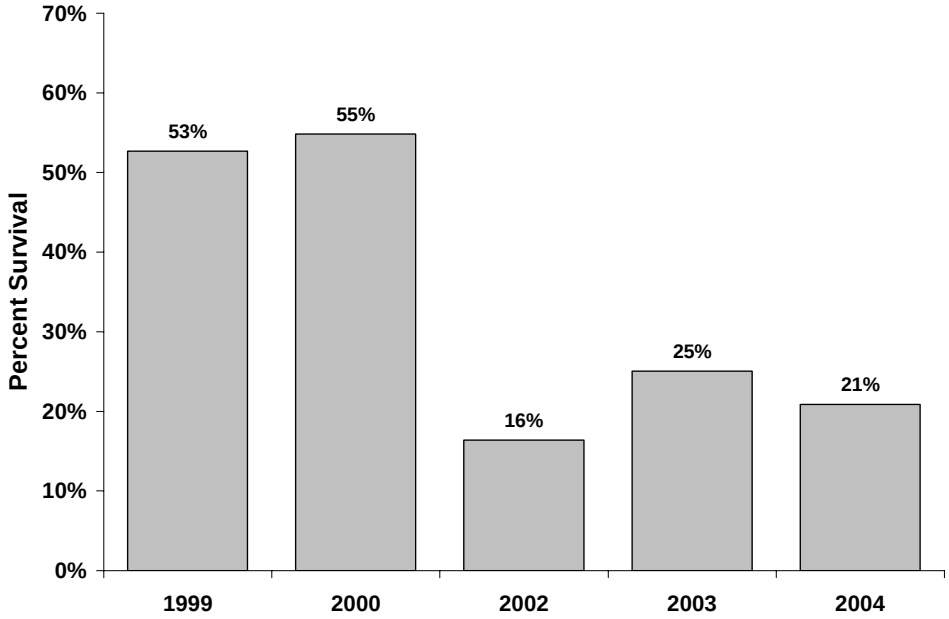


Figure 30 Percent survival of kokanee in Dworshak Reservoir from age-1 to -2 during 1999-2004. Survival rates are based upon population estimates for each age from annual hydroacoustic surveys (99-03) and from trawl survey in 2004.

We would have expected 40-50% annual survival rates for a population with little or no predation (Maiolie and Elam 1995). Thus, the low survival observed in 2004 suggests other sources of mortality in addition to natural mortality. However, 2004 may have also had fairly high fishing mortality contributing to the overall annual mortality. High fish mortality was especially evident between the ages of 1 and 2, which had only 21% annual survival (Figure 30). Part of this low survival could be attributed to entrainment losses for these fish. Low survival rates typically coincided with years in which age-2 densities were low. Although abundance of age-2 kokanee declined in 2004 (Table 8), age-0 abundance increased. Age-0 density in 2004 (468 fish/ha) was more than 3 times higher than age-0 density in 2003 (129 fish/ha).

Table 8. Estimated abundance of kokanee age classes and density of adults (age-2) in Dworshak Reservoir, Idaho, 1988-2004.

Year	Sampling Method	Kokanee Abundance					Adult Density (fish/ha)
		Age-0	Age-1	Age-2	Age-3	Total	
2004	Trawling	3,136,892	692,348	90,715	0	3,919,956	14
2003	Hydroacoustic	439,580	434,586	276,055	0	1,150,222	42
2002	Hydroacoustic	1,246,959	1,101,232	127,933	0	2,476,124	24
2001	Hydroacoustic	1,962,000	781,000	405,000	0	3,150,000	75
2000	Hydroacoustic	1,894,857	303,680	199,155	0	2,397,691	37
1999	Hydroacoustic	1,143,634	363,250	38,464	0	1,545,347	7
1998	Hydroacoustic	537,000	73,000	39,000	0	649,000	7
1997	Trawling	65,000	0	0	0	65,000	0
1996	Hydroacoustic	231,000	43,000	29,000	0	303,000	5
1995[b]	Hydroacoustic	1,630,000	1,300,000	595,000	0	3,539,000	110
1994	Hydroacoustic	156,000	984,000	304,000	9,000	1,457,000	69
1993	Trawling	453,000	556,000	148,000	6,000	1,163,000	33
1992	Trawling	1,040,000	254,000	98,000	0	1,043,000	22
1991	Trawling	132,000	208,000	19,000	6,000	365,000	5
1990[a]	Trawling	978,000	161,000	11,000	3,000	1,153,000	3
1989[b]	Trawling	148,000	148,000	175,000	0	471,000	32
1988	Trawling	553,000	501,000	144,000	12,000	1,210,000	29

[a] September trawling likely resulted in underestimation of the mature fish.
[b] June sampling likely resulted in underestimation of age 0 kokanee.

Average size of age-2 kokanee was substantially larger in 2004 (294 mm, 11.6 in) than in 2003 when the mean total length was about 259 mm (10.2 in). The larger age-2 kokanee in 2004 could be partially attributed to density dependent growth, since age-2 density declined between 2203 and 2004. We did not conduct angler checks to obtain age-at-length data, but instead conducted trawling again this year to obtain this data; therefore, comparison of mean TL was valid. The age-1 abundance estimate was likely an overestimation since there could not have been more age-1 kokanee in 2004 than we had age-0 kokanee in 2003. Alternatively, 2003's estimate of age-0 kokanee was too low (Table 8).

Trawling, although more time and labor intensive, was much more effective at obtaining smaller kokanee than creel surveys. Trawl sampling provided extensive age-at-length data and resulted in more accurate age class-specific population estimates than using hydroacoustics because it provided definitive data on the size break between age-0 and age-1 fish. Sampling scales and total length measurements from angler caught kokanee provided an efficient way to obtain kokanee age-at-length data. However, smaller kokanee are less vulnerable to angling and, therefore, are underrepresented. Ancillary age-at-length data obtained from creel surveys would only provide additional age frequency distribution data for age-1 and -2 kokanee.

Entrainment

Fish detection rates from entrainment assessment sampling were highly variable in 2004 with mostly findings different from previous years, but one pattern was observed again during 2004. We again found the highest detection rate during nighttime periods (14.7 fish/h), with more than twice the rate of the dawn period (6.9 fish/h), and nearly 20 times the detection rate observed during the day (0.8 fish/h) (Figure 13). On average, nighttime detections comprised

60% of all detections, and time of day was the only variable that has remained consistently predictable throughout all entrainment sampling. Therefore, we feel prospective deterrent efforts should be focused on the nighttime periods to keep fish away from Dworshak Dam and effectively reduce entrainment on a population level.

However, several different patterns in fish detections were observed during 2004 than the during previous entrainment assessments in 2002 and 2003. Mean fish detection rates remained low throughout the spring high discharge period from April through June 2004 (Table 3). Low detection rates were also observed throughout July and August sampling during high discharge periods (Figure 10), unlike previous assessments. Conversely, low discharge during September and October resulted in our highest detection rates. However, kokanee densities in the forebay were at their highest during this same period, particularly in October 2004 (Figure 14). Thus, there was no clear relationship between detection rates and discharge (Figure 31). Our highest fish detection rates also occurred during higher water transparencies (Figure 11). The above patterns were opposite those observed in previous assessments, where we found higher detection rates with greater discharge and lower water transparency (Stark and Maiolie 2004, 2007).

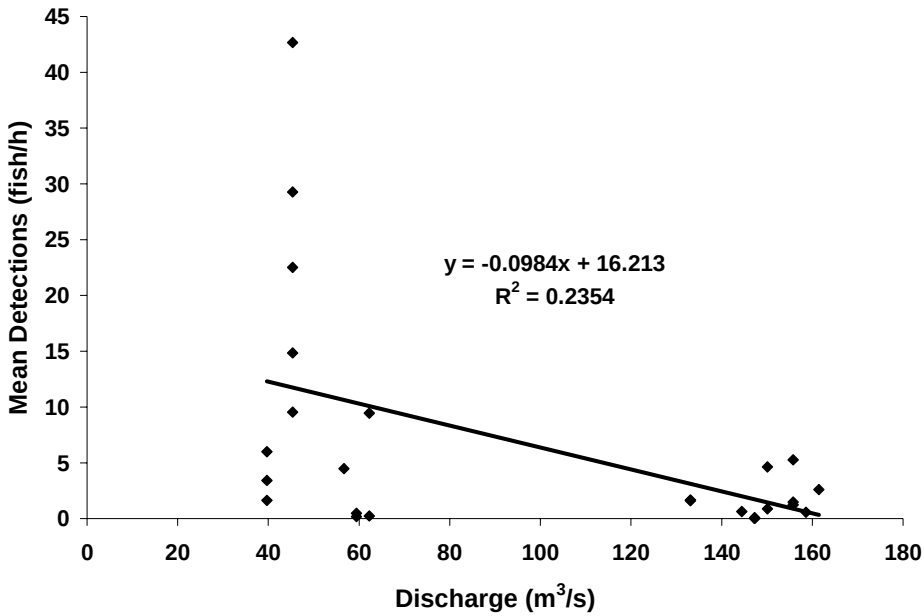


Figure 31. Relationship between fish detection rate and discharge rate of water through the turbines of Dworshak Dam obtained from 24 h fixed-site hydroacoustic sampling, March 2004–February 2005. Rates were expanded based upon the percent coverage of the turbine openings by the acoustic beam.

Maiolie and Elam (1998) documented seasonal movements of kokanee throughout the reservoir. They also found that kokanee entrainment was low during the August drawdowns largely because kokanee (mostly age-2 fish) were further up the reservoir. Thus, seasonal fish distribution and density of kokanee near the dam likely influenced entrainment potential, along with the influence of discharge rate.

Unlike 2002 and 2003, we found greater entrainment potential (fish detection rate) in front of turbine 1 than turbine 2, and more in front of turbine 2 than turbine 3 (Figure 9). However, turbine 3 was typically only operated during periods of high discharge in the spring and mid-summer, as was turbine 2, although to a lesser extent. Turbine 1 was operated almost year-round and mostly at or near minimum discharge rates. Thus, turbine unit entrainment potential was not mutually exclusive of discharge rate. In addition, comparisons between turbines were also likely influenced by the time of the year turbines were operated. For instance, turbine units 1 and 2 were more likely to be discharging during the spring when forebay densities of kokanee were greater.

Unlike 2003, though, we did not find a strong relationship between intake depth and fish detection rate (Figure 32). However, withdrawal depth again was not independent of discharge rate, season, or intake unit. Lastly, we did not find a relationship between detection rate (kokanee entrainment susceptibility) and Secchi transparency (water clarity). Again, water clarity was not independent of season and discharge rate.

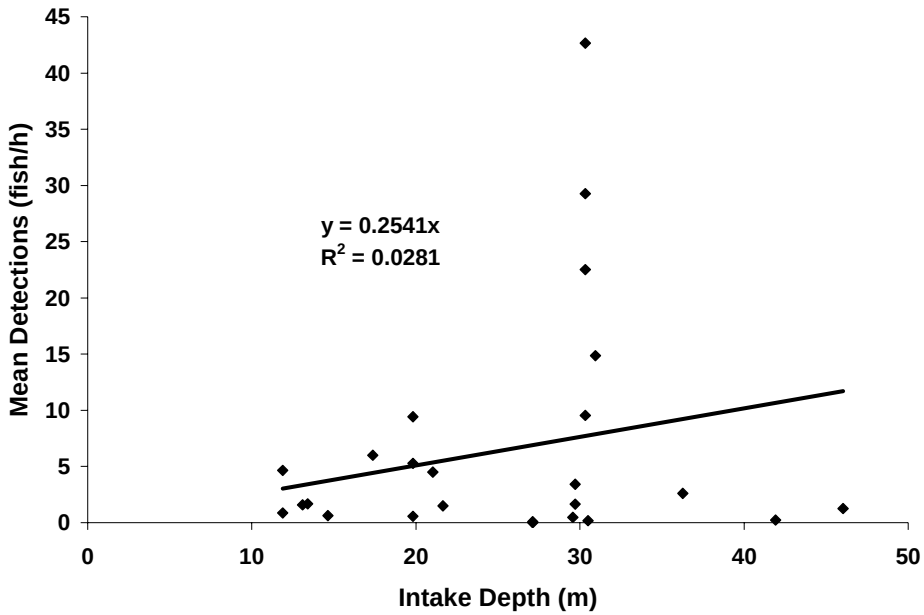


Figure 32. Relationship between fish detection rate and intake depth of water discharged through the turbines of Dworshak Dam obtained from 24 h fixed-site hydroacoustic sampling, March 2004–February 2005. Rates were expanded based upon the percent coverage of the turbine openings by the acoustic beam.

The percent of the turbine opening covered by our hydroacoustic sampling was highly variable (Table 9). Changes in depth of discharge through dam intakes, as affected by pool elevation and selector gate operation, changed our sampling efficiency. The fixed-site hydroacoustic transducer used for fish detection immediately in front of turbine intake openings had side lobes that detect the face of the dam. This detection resulted in severe noise intrusion into entrainment assessment echograms, especially within the 15-30 m depth range. More efficient coverage of the intakes was obtainable when the reservoir was closer to full pool since

the intake depths were deeper, below the side-lobe noise band. Relatively noise free entrainment sampling was attainable when the intakes were quite shallow (<15 m deep), yet the acoustic coverage was drastically reduced since the acoustic beam was narrow near the surface.

An increase in sampling effort would allow us to obtain enough hours of fish detections (sample size) to allow for statistically valid tests of the effects of time of day, seasons, discharge rate, and depth of withdrawal. Sample sizes must be large enough to statistically test for the effects of one factor while controlling for the remaining factors.

Lastly, transducers installed inside the turbine intake monoliths (inside and downstream of the selector gates and trash racks) remains the best option to increase the sampling efficiency (beam coverage), reduce noise intrusion into echograms, increase detection sample size, and most importantly obtain 'true' estimates of the number of entrained fish per hour.

Table 9 Conditions, settings, acoustic beam coverage, and proximities to the turbine units of Dworshak Dam during entrainment sampling, March 2004–February 2005. Beam diameter, portion of intake sampled, and distance from beam to dam were values at the center of the openings.

Date	Turbine	Intake Width (m)	Offset Angle (deg°)	Analysis Depths (m)	Beam Diameter (m)	Acoustic Beam Coverage (%)	Distance from Beam Edge to Dam (m)
3/23/2004	1.0	3.7	3.0	25.6-33.8	3.4	93.7%	0.8
3/24/2004	1.0	3.7	3.0	25.6-33.8	3.4	93.7%	0.8
4/20/2004	3.0	6.1	3.5	22.1-32.1	3.1	51.3%	1.1
4/21/2004	3.0	6.1	3.5	22.1-32.1	3.1	51.3%	1.1
5/25/2004	3.0	6.1	2.5	6.9-16.9	1.4	22.5%	0.7
5/26/2004	3.0	6.1	2.5	6.9-16.9	1.4	22.5%	0.7
6/14/2004	3.0	6.1	2.5	8.1-18.1	1.5	24.8%	0.7
6/15/2004	3.0	6.1	2.5	8.1-18.1	1.5	25.4%	0.6
6/22/2004	3.0	6.1	3.0	9.6-19.6	1.7	27.7%	0.8
7/21/2004	1.0	3.7	15.0	25.5-35.5	3.5	96.1%	7.3
7/22/2004	2.0	3.7	17.0	24.5-34.5	3.4	100.0%	8.4
8/4/2004	3.0	6.1	5.0	39.9-52.1	5.3	87.1%	2.7
8/9/2004	2.0	3.7	5.0	14.8-24.8	2.3	62.5%	1.7
8/10/2004	1.0	3.7	5.0	37.8-46.0	4.8	132.1%	2.6
8/30/2004	2.0	3.7	4.0	16.0 -26.0	2.4	66.3%	1.2
8/31/2004	3.0	6.1	3.0	30.2-42.4	4.2	68.6%	1.5
9/27/2004	2.0	3.7	4.0	26.2-34.4	3.5	95.6%	1.4
10/4/2004	1.0	3.7	4.0	26.2-34.4	3.5	95.6%	1.4
10/18/2004	1.0	3.7	3.0	26.2-34.4	3.5	95.6%	0.7
10/19/2004	1.0	3.7	3.0	26.2-34.4	3.5	95.6%	0.7
10/25/2004	1.0	3.7	3.5	26.8-35.1	3.6	97.5%	1.1
1/10/2005	3.0	6.1	5.5	14.8-24.8	2.3	37.5%	1.9
1/25/2005	3.0	6.1	5.0	16.6-26.6	2.5	40.9%	1.8
1/26/2005	3.0	6.1	5.0	15.8-24.8	2.3	37.5%	1.7
2/15/2005	2.0	3.7	3.5	12.4-22.4	2.0	54.8%	1.0

Forebay Densities

Densities remained fairly low and stable throughout the spring and summer, but increased substantially during the fall. During the spring of 2004 fish densities in the forebay did not increase as in 2003, when newly emerged young-of-year kokanee moved down-reservoir toward the dam. Densities remained low in June and July despite high discharge rates through the dam. Kokanee densities were high in August and September even when most adult kokanee were found in the upper reservoir and in the North Fork Clearwater River staging for spawning.

In 2004, kokanee densities were at their lowest again in 2004 during high discharge conditions from April through July but increased in August and September; discharge increased to aid smolt migration and cool water temperatures in the Lower Snake River. However, chronic entrainment still occurred even at the lowest of discharges as evidenced by injured kokanee in the dam spillway area on a regular basis. Discharge was increased periodically throughout January and February 2005 (Figure 16), and unlike previous years, kokanee densities remained high throughout the fall and into winter, thereby increasing the likelihood of acute entrainment during these periods.

Monthly hydroacoustic sampling in 2004 showed much higher densities of kokanee in the forebay area of Dworshak Reservoir than in 2003 (Figure 33), likely as a result of higher overall densities in the reservoir (Table 8). Moreover, the density of kokanee in the forebay area of Dworshak Reservoir was lower during some of the higher discharge periods of typical annual dam operations (Figure 34); however, periods of high susceptibility to entrainment still occurred.

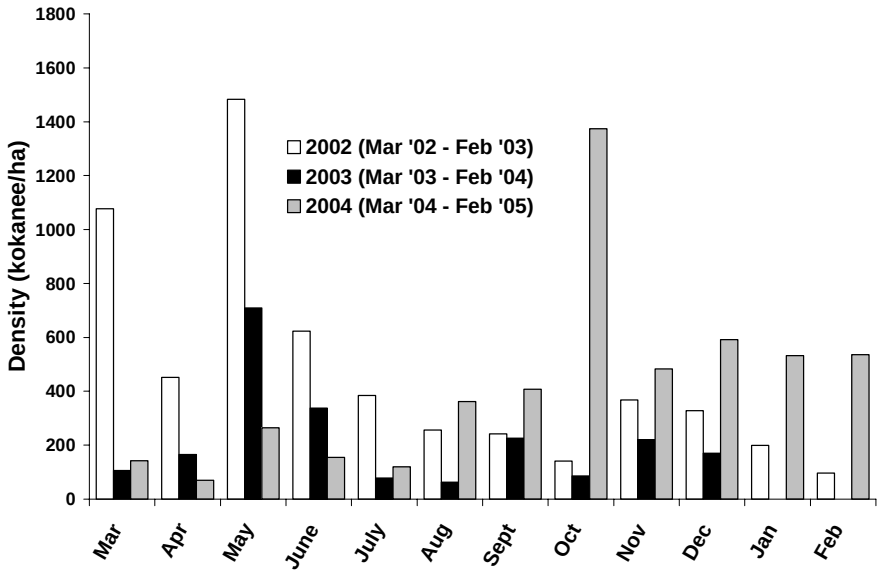


Figure 33. Average kokanee densities in the forebay of Dworshak Reservoir, Idaho, obtained from monthly hydroacoustic sampling, 2002—2004.

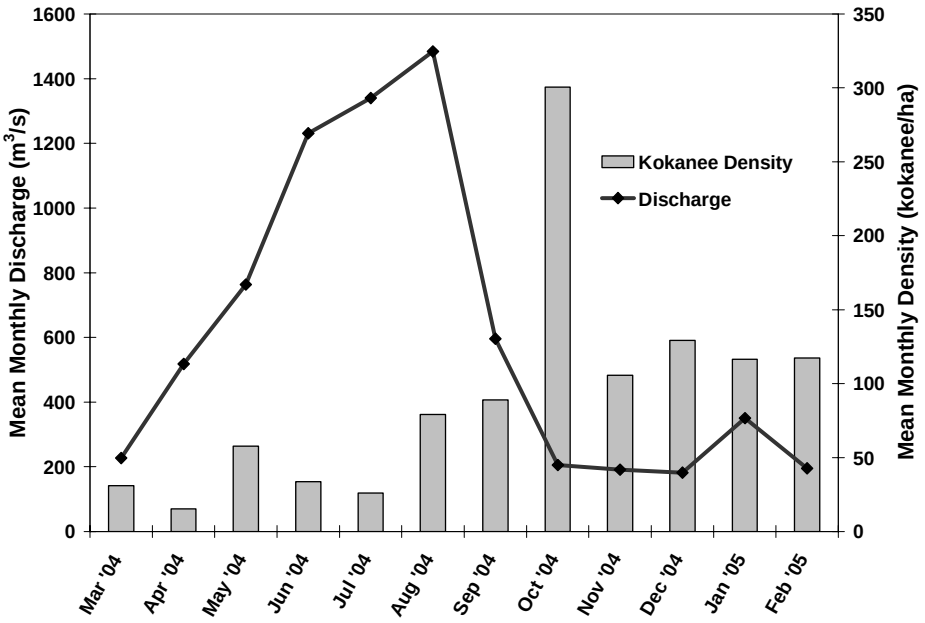


Figure 34. Comparison between mean monthly discharge through Dworshak Dam and mean monthly kokanee densities in the forebay of Dworshak Reservoir, Idaho, March 2004–February 2005. Forebay kokanee densities were obtained from monthly hydroacoustic surveys.

Discharge

The 2004 water year was about average when compared to the 1999- 2003 period, with a mean annual discharge through Dworshak Dam of 132 m^3/s (Figure 35). However, the high discharge period was shorter in duration than in 2003 and peaked at a higher mean total discharge (Figure 36). Therefore, the opportunity for large entrainment losses was reduced during the spring of 2004 relative to previous years, since discharge was lower during March and April while kokanee densities were typically still high in the forebay of Dworshak Reservoir. Despite lower discharges in 2004, entrainment sampling and population estimates suggest even low entrainment rates were taking a large toll on kokanee abundance over time.

Discharge of water through Dworshak Dam during 2004 appeared to have adversely impacted kokanee abundance, since age-2 fish had particularly poor survival (Figure 30). However, entrainment assessments during July through September revealed high discharge 'Salmon Flows' were not likely impacting kokanee abundance severely since very few fish were detected. Additionally, few fish were detected during entrainment assessments during high discharges earlier in the spring (Figure 10). Similarly, forebay kokanee densities were also low during the early spring (Figure 14). Unlike previous years' findings, 2004 results indicated the majority of fish losses likely occurred during low discharge periods during the fall and winter instead of high discharge periods during spring and summer.

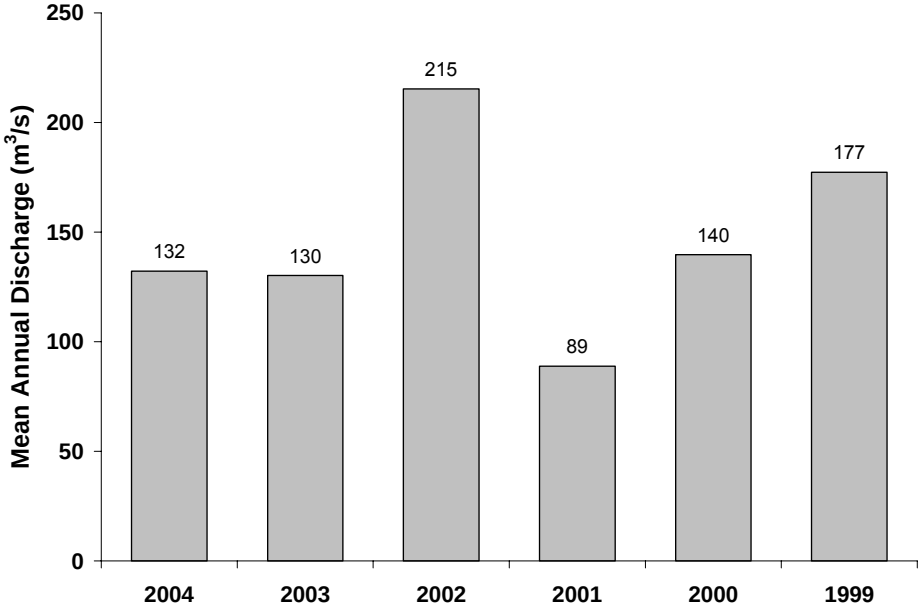


Figure 35 Mean annual discharge through Dworshak Dam, 1999-2004.

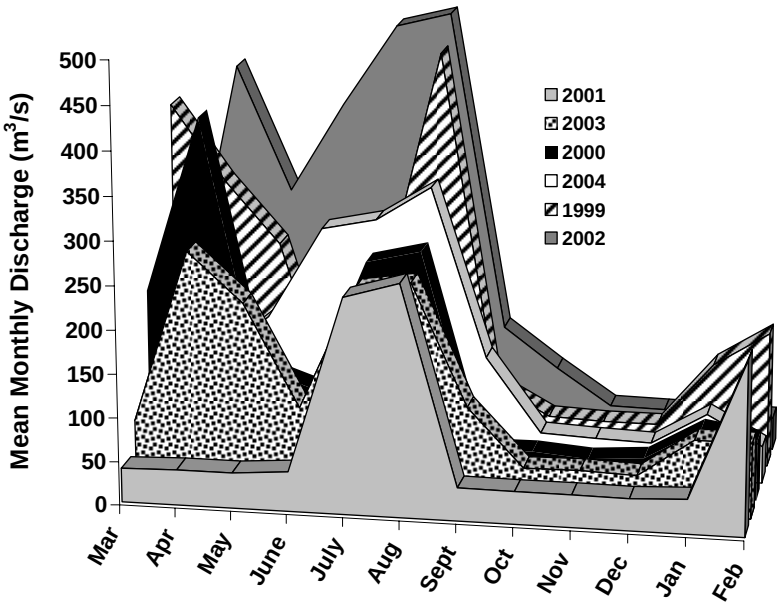


Figure 36 Mean monthly discharge through Dworshak Dam, 1999-2004.

Spawner Counts

Kokanee spawner counts were substantially lower in 2004, less than one-third the 2003 counts. However, we expected counts to be lower since estimated age-2 abundance was also approximately one-third of the 2003 abundance (Table 8). In fact, the 2004 results closely fit the previous relationship between spawner counts and reservoir adult abundance (Figure 37). The mean length of adult spawners was also 30 mm larger in 2004 than in 2003.

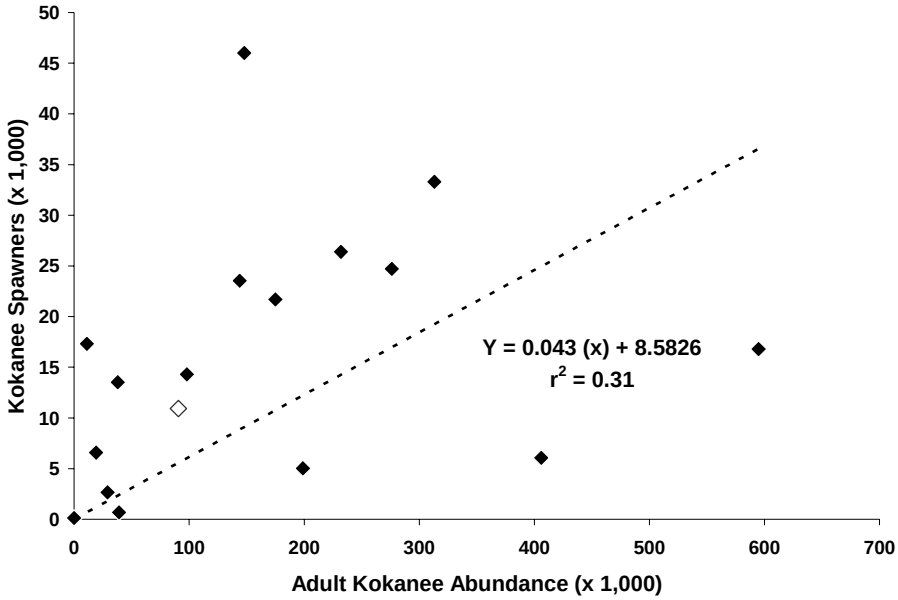


Figure 37. Relationship between adult kokanee abundance in Dworshak Reservoir and kokanee spawner abundance in tributaries to the North Fork Clearwater River, 1988–2004. The dotted trend line represents the linear regression equation for the relationship between adult and spawner abundances. The white diamond represents 2004 values.

Kokanee were able to access slightly more spawning gravels during the 2004 survey because of higher than normal water. However, this higher water may have negatively influenced our ability to accurately count all spawners, therefore likely resulting in a slight underestimation of the true abundance of spawners.

The previous barrier to upstream movement in Quartz Creek at river kilometer 1.3 appeared to have been obliterated since 2003. However, the Quartz Creek landslide at RK 2.3 was still a barrier to upstream migration. Significant impediments to upstream migration were found at river kilometers 3.2 (logjam) and 0.6 (large drops) on Isabella and Dog Creeks, respectively. Fish have migrated past these impediments in the past but stayed below them in 2004.

Lastly, our counts of spawning kokanee could also be supplemented with additional spawner count data collected as part of ongoing research on bull trout in the North Fork Clearwater River above Dworshak Reservoir. Although the bull trout ancillary data is collected differently (randomized 100 m transects), it may still provide some insight on the annual variability in counts and upstream spawning distribution.

Reservoir Productivity Assessment

Physical/Chemical

The upper reservoir typically has the highest water clarity with a maximum Secchi depth of 7.6 m recorded in August 1974. The area of the reservoir with the lowest water clarity continues to be the Elk Creek arm (Appendix A. Table 1-10). Mean water transparency increased during fall 2004, from 3.7 m in September to 5.8 m by October.

Overall, there has been little change in reservoir water clarity in the past 30 years. Mean reservoir water clarity for the months of March through November was approximately 3 m in 1972-1974, 3.2 m in 1993-1996 (Table 10), and in 2004 the mean increased to 3.9 m. Minimum Secchi disc depths did not approach the 1 meter depth recorded in 1972, 1974, and 1995 (Falter et al. 1979; Juul and Funk 1996).

Table 10. Minimum, maximum, and mean Secchi disk water transparency measurements collected from Dworshak Reservoir, 1972-1974, 1993-1996, and 2004.

	1972–1974*		1993–1996		2004	
	Secchi Depth (m)	Sample Date	Secchi Depth (m)	Sample Date	Secchi Depth (m)	Sample Date
Minimum	<1.0	Jul-72 May-74	1.0	Mar-95	2.1	Aug-04
Mean	3		3.2		3.9	
Maximum	7.6	Aug-74	7.2	Nov-93	6.7	Oct-04

* Values estimated from Falter et al. (1979).

Dworshak Reservoir thermally stratified starting in April, with a strong thermocline by June that intensified through August (Figure 38). The reservoir was monomictic for the lower 30 kilometers. The water temperature remained warm (>20°C) for the upper 6-8 meters during the summer. The epilimnion averaged 10 m to 13 m below the water surface and constituted 20% to 22% of the total reservoir volume during summer months. The hypolimnion made up the majority (70%) of the water volume in the reservoir. Reservoir water is typically released from the hypolimnion, which results in a longer residence time for the epilimnetic water and likely benefits plankton production.

The dissolved oxygen profile during 2004 indicated little oxygen depletion in the hypolimnion, which was very similar to that found by Juul and Funk in 1995. Although dissolved oxygen concentrations were not collected below 60 m in 2004, it is likely that dissolved oxygen conditions in the hypolimnion were similar to those found in 1995. Thus, dissolved oxygen concentrations in Dworshak Reservoir should not be a limiting factor to the aquatic community, and there appears to be a large buffer before reductions in dissolved oxygen would be a concern.

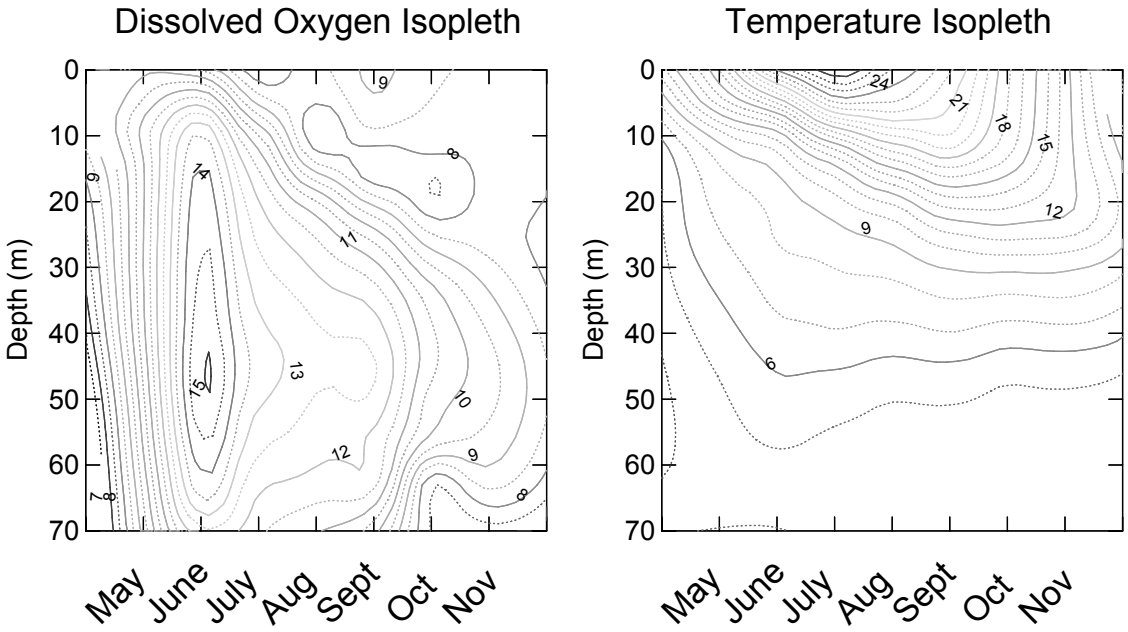


Figure 38. Dissolved oxygen and temperature isopleths at RK-2 during 2004.

Mean chlorophyll *a* concentrations in 2004 were low and varied little between stations. However, chlorophyll *a* exhibited a slight longitudinal gradient with decreased concentrations at upper reservoir stations (Figure 39). Mean chlorophyll *a* concentrations were low for the moderate total phosphorus values found, but a few higher concentrations were observed at several lower reservoir stations (Appendix A. Table 11). This was indicative of a system with a large amount of unavailable particulate or colloidal P present. Comparisons of 2004 values with historic data also indicate that chlorophyll *a* concentrations were similar between 1992-1995 (Juul and Funk 1996) and 2004 (Figure 40; Appendix A. Table 21).

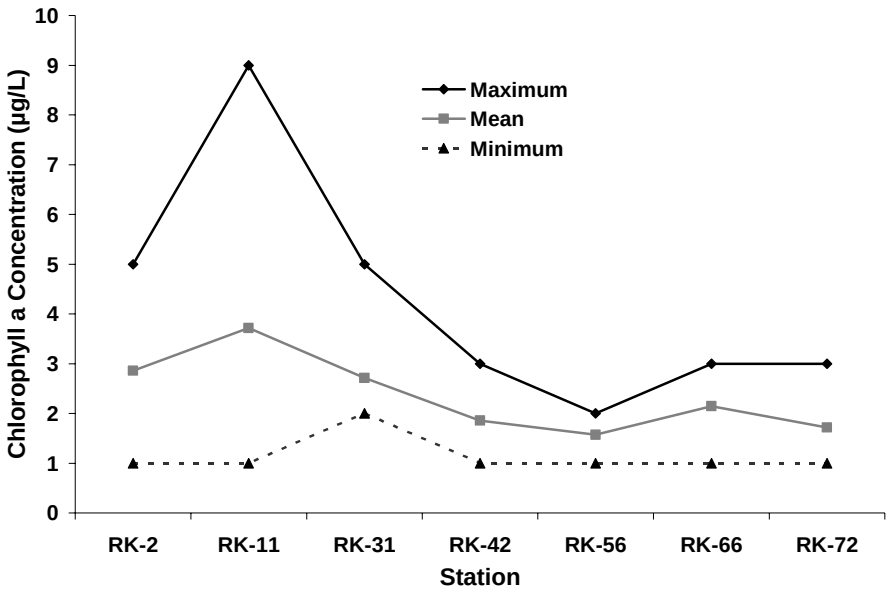


Figure 39. Minimum, mean, and maximum chlorophyll *a* concentrations at each of seven main reservoir stations collected during limnological sampling on Dworshak Reservoir, May–November, 2004.

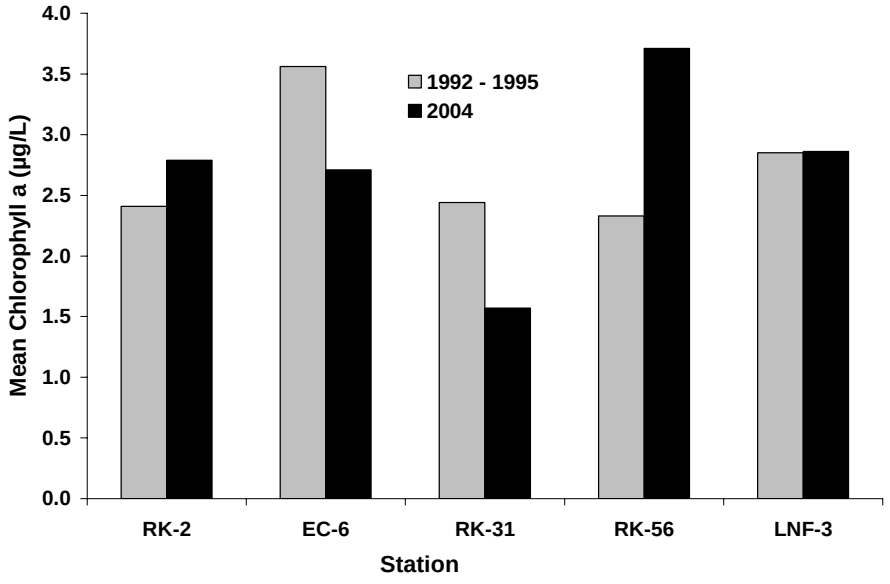


Figure 40. Mean chlorophyll a concentrations at select stations collected during limnological sampling on Dworshak Reservoir, 1992-1995 and 2004.

During our sampling in 2004 and from other surveys between 1972 and 1974 (Falter et al. 1979), nitrate was used to indicate nitrogen availability within the reservoir. However, Juul and Funk (1996) collected Nitrite + Nitrate, yet due to the transitory nature of nitrite in surface water, we felt comparisons of their 1995 Nitrite + Nitrate values with 1973 and 2004 Nitrate values were acceptable (Appendix A. Table 22). Nitrate concentrations dropped significantly since the 1973 and 1995 studies (Figure 41). During the first several years following creation of the reservoir, the area submerged consisted of recently harvested coniferous forest, but a considerable amount of biomass from slash and undecomposed duff was left in place. Thus, higher nitrate concentrations early in the reservoir's history were likely a result of the large amount of organic matter submerged and its subsequent decay. However, nitrate concentrations have continued to decline even since limnological surveys in 1995.

The only type of phosphorus collected consistently in the same studies above was orthophosphate. Therefore, we used orthophosphate as the indicator of the changes in phosphorus concentration through the history of the reservoir (Appendix A. Table 23). Orthophosphate concentrations have also dropped considerably since the 1973 study (Figure 42), yet concentrations have increased since 1995. We contend that this is due to the inability of laboratories to accurately measure orthophosphate concentrations in the values found in Dworshak Reservoir. We suspect that during 2004 sampling, true orthophosphate levels were significantly lower than those we reported.

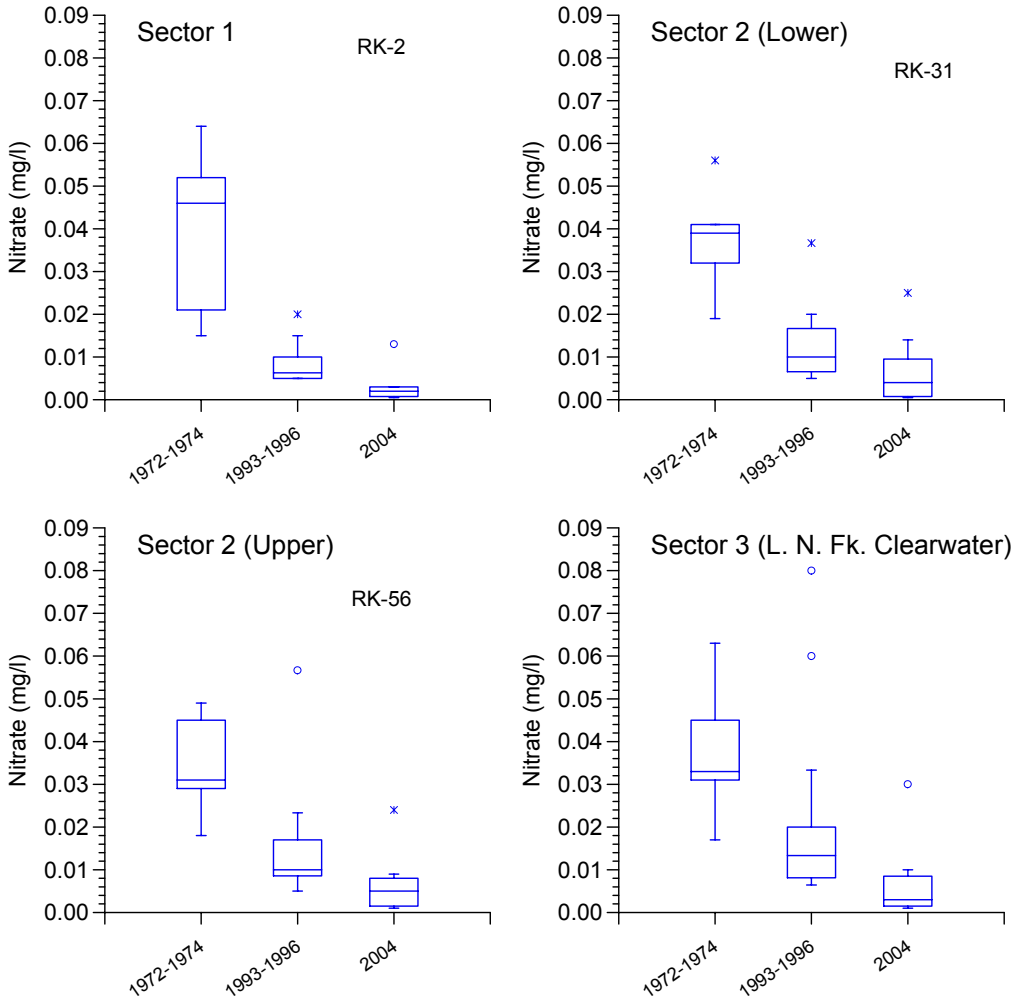


Figure 41. Comparison of epilimnetic nitrate concentrations from four stations collected during each of three study periods; 1972–1974, 1993–1996, and 2004. Each box and whisker plot displays the minimum, mean, maximum, and ± one standard deviation of the mean nitrate concentration values.

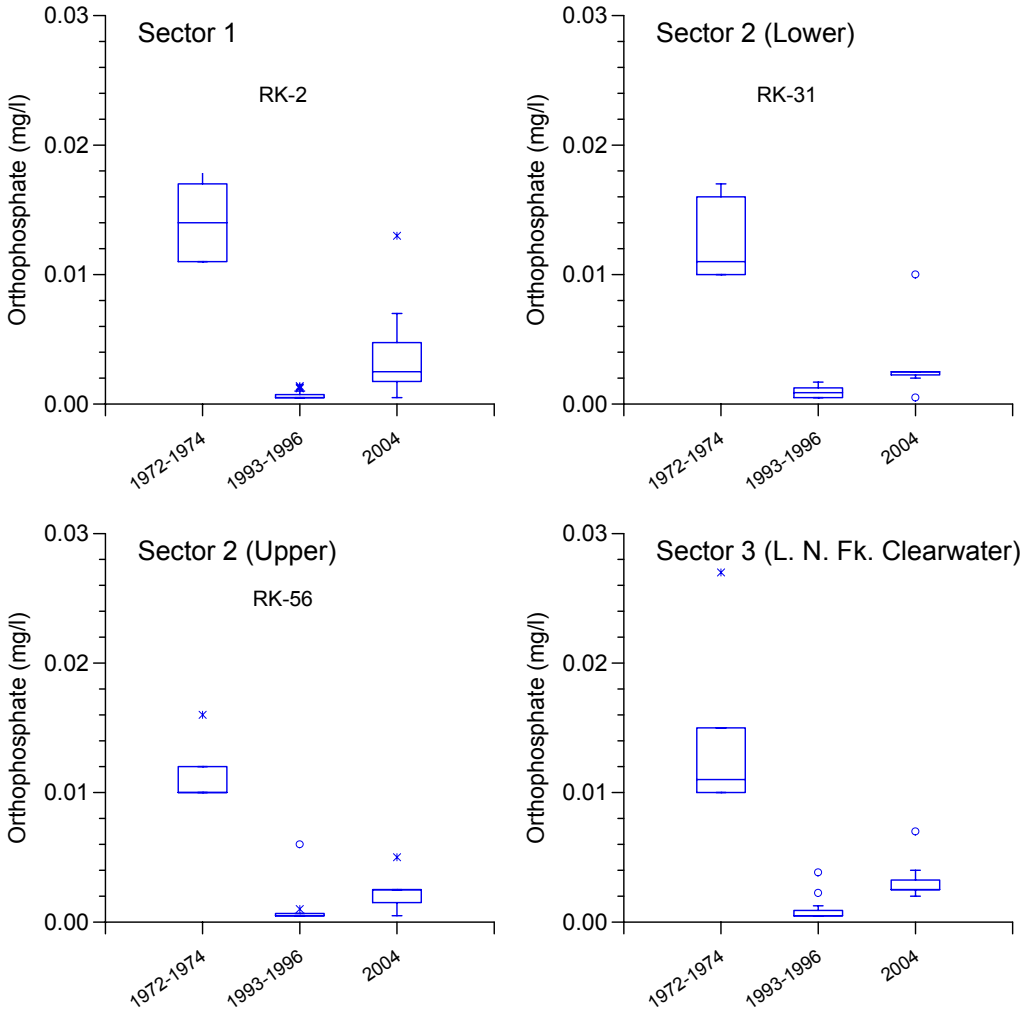


Figure 42. Comparison of epilimnetic (12 m) orthophosphate concentrations from four stations collected during each of three study periods; 1972–1974, 1993–1996, and 2004. Each box and whisker plot displays the minimum, mean, maximum, and ± one standard deviation of the mean nitrate concentration values.

Bacteria

The average density of free-living bacteria populations in Dworshak Reservoir in November 2004 was about 488,000 cells/ml. These values were close to estimates from several fertilized and untreated British Columbia coastal lakes, where average population densities ranged from 500,000–600,000 cells/ml (MacIssac and Stockner 1981), densities well within the oligotrophic range for Canadian Boreal lakes (Bird and Kalff 1986). The highest concentration of bacteria was found at EC-6 in the Elk Creek arm.

The highest picocyanobacteria populations in Dworshak were found at RK-2 near Dworshak Dam where densities exceeded 37,000 cells/ml. Picocyanobacteria belonging to the

Class Cyanobacteracae were the largest component of the Dworshak picoplankton community, and these were composed largely of the two single-celled coccoid species-*Synechococcus* and *Synechocystis* spp. There were also small *Chlorella*-like green algae in the reservoir, albeit at very low population densities (<2-3000 cells/ml), but by virtue of their small size (<2 μ) they were also a component of the picoplankton community. Comparisons with other reservoir abundances, biovolume, and composition would be more meaningful with bacteria sampling conducted throughout the growing season, March through November.

Phytoplankton

Phytoplankton abundance and biovolume were fairly similar between stations in November 2004; however, some patterns were evident. The mid-reservoir station RK-42 had the lowest phytoplankton abundance (Figure 21), and the EC-6 station the lowest biovolume (Figure 22). The highest abundance and biovolume was found at RK-66, which is located just up-reservoir of Granddad Bridge at the confluence of the Little North Fork Clearwater and North Fork Clearwater arms of the reservoir. With the exception of RK-66 station, there was a slight gradient in phytoplankton abundance with lowest values up reservoir near RK-42 and highest at RK-2, although this was based on just one sampling period in November (Appendix A. Table 13).

Phytoplankton concentrations and assemblage diversity in November were typical of oligomesotrophic ecosystems in interior lakes and reservoirs of western North America. Many flagellates, particularly *Rhodomonas* sp. and mostly edible phytoplankton, dominated the samples with no apparent carbon sinks apart from some long, inedible *Fragilaria crotonensis* chains (diatoms). Biomass (volume) estimates were similar to those found in Kootenay (Stockner and Shortreed 1991) and Arrow Reservoir (Pieters et al. 2000) in British Columbia, Canada.

Phytoplankton abundance from selected stations in each section of the reservoir showed a diverse assemblage of colonial diatoms (e.g., *Fragilaria crotonensis, F. capucina, F. acus, Asterionella formosa*), flagellates (*Rhodomonas*, *Chryptomonas, Chroomonas, Chrysochromulina*), small but abundant picophytoplankters (*Synechococcus*), and a moderate density of blue-green algae (*Oscillatoria* sp2.). The phytoplankton species composition and abundance were also within the normal range of values seen in large, interior BC and Yukon Territory lakes (Stockner and Shortreed 1991).

Zooplankton

Zooplankton densities throughout Dworshak Reservoir were moderately high during 2004; however, several genera and stations strongly influenced densities and, therefore, mean composition as well. Total mean zooplankton density was 16.9/L in 2004 (Table 5); however, over 50% of all zooplankton were *Cyclops* sp. Copepods. Omitting *Cyclops*, total mean density of zooplankton was only 8.3/L. Lower Reservoir stations, particularly EC-6, were dominated by *Cyclops* sp. especially during June and November and more so than upper reservoir stations (Table 6). Conversely, high densities of *Daphnia* sp. were found at several upper reservoir stations, LNF-3 and RK-66 (Appendix A. Table 14). In fact, particularly high *Daphnia* densities in July at LNF-3 (28.4/L) and RK-66 (20.2/L) alone greatly inflated the mean density of zooplankton and the mean percent *Daphnia* accordingly (Appendix A. Table 15).

There was no apparent explanation for declines in zooplankton densities at most stations during August sampling. Chlorophyll and nutrient concentrations did not appear to increase or decrease drastically during August. However, zooplankton declines may have been influenced

by a shift in phytoplankton abundance and taxonomic composition unfavorable to most genera particularly *Daphnia*. Unfortunately, neither bacteria nor phytoplankton were collected throughout 2004 to support this hypothesis.

Total zooplankton densities for most sites within the reservoir have seen marked reductions since the initial assessment in 1974 (Table 11; Figure 43). The most pronounced declines in zooplankton density occurred between 1974 and 1988; however, densities continued to decline for most stations from 1988 to 2004. Two exceptions to declining zooplankton densities were the EC-6 and LNF-3 sites. However, as described above, EC-6 was dominated by *Cyclops* and LNF-3 by *Daphnia*, but only during abundance peaks in July and September. The fact that these arms did not decline may have been a result of activities within the drainage basins feeding these arms of the reservoir.

Land uses within the Elk Creek watershed included cattle grazing and forest fertilization. In addition to these sources, the city of Elk River discharges wastewater into Elk Creek. The Little North Fork arm of the reservoir also had several drainages with elevated sediment and nutrient levels compared to an unimpacted watershed. These activities likely increased sediment erosion and associated nutrients, and could account for the high zooplankton densities in these sections of the reservoir.

Table 11. Zooplankton density and percent Cladocerans for select stations collected during limnological studies on Dworshak Reservoir, 1972–1974, 1988, and 2004.

	Mean Density (zooplankton/L)			Percent Cladoceran (%)		
Station	**1972-1974**	**1988***	**2004**	**1972-1974**	**1988**	**2004**
RK-2	39.8	11.3	5.7	60%	23%	42%
EC-6	25.1	10.6	28.9	77%	33%	18%
RK-31	17	7.4	3.7	73%	29%	34%
RK-56	11.3	7.1	6.5	72%	41%	52%
LNF-3	8.8	8	8.5	81%	42%	31%
Mean	**18.9**	**8.9**	**10.7**	**78%**	**35%**	**35%**

***** Numbers are estimated from Figure 7 in Mauser et al. (1989).

The zooplankton community within the reservoir also shifted since 1974 (Figure 44), and the percent cladocerans declined since the early life of the reservoir. The mean percent of cladocerans within the reservoir fell from 78% in 1973-1975 to 35% for 1988 and 2004. There seems to be little change in the percent of cladocerans in the zooplankton community since 1988. However, the reduction in Cladoceran species likely resulted in a decline in the zooplankton density available to kokanee. Zooplankton samples were only taken in the euphotic zone; therefore, the late summer tows were considerably longer than the spring tows. However, comparisons of densities and community composition were still viable.

The summer period between June and August produced larger *Daphnia* than other periods, and with the exception of August, abundance was also high during this period (Appendix A. Table 16). Both *Daphnia* and *Cyclops* were largest at RK-11. *Daphnia* were smallest at EC-6 where *Cyclops* was most abundant (Appendix A. Table 17).

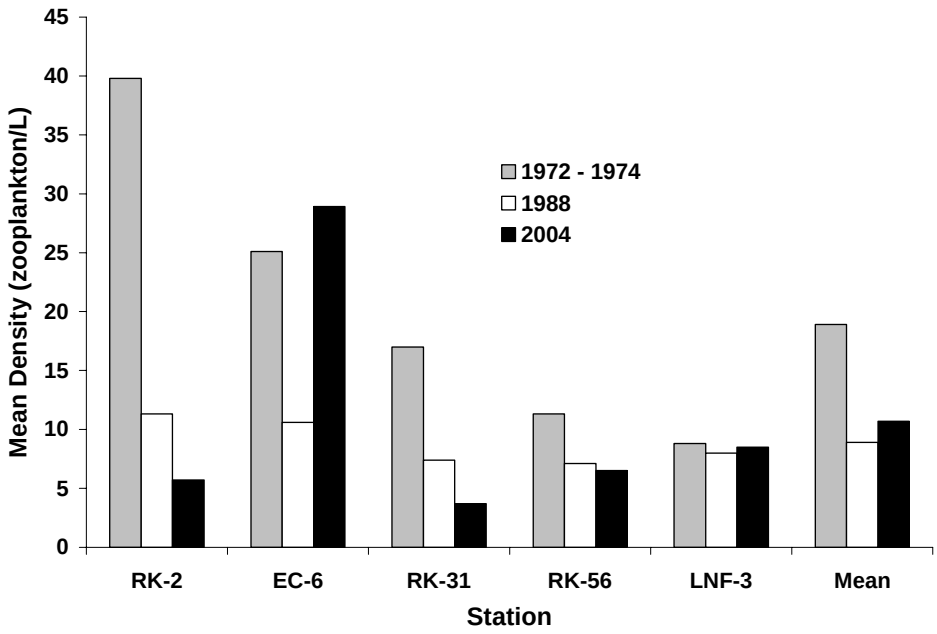


Figure 43. Mean total zooplankton density at six select sites on Dworshak Reservoir, collected during limnological sampling, 1972–1974, 1998, and 2004.

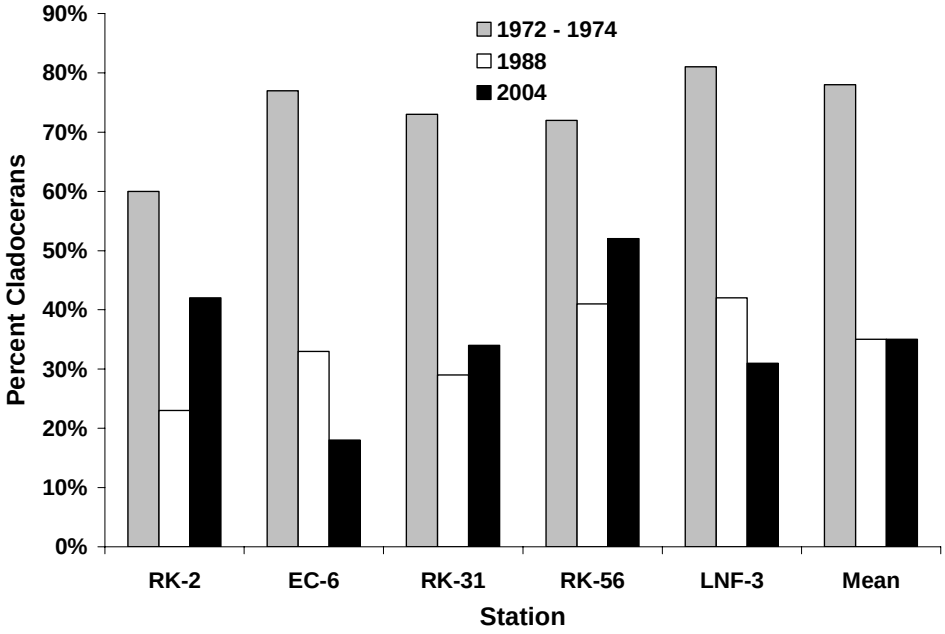


Figure 44. Mean percent cladocerans of zooplankton assemblage at six select sites on Dworshak Reservoir, collected during limnological sampling, 1972–1974, 1998, and 2004.

Kokanee Growth and Diet

Each age class of kokanee obtained from trawl sampling obtained their respective maximum growth rates at different times of the year. For example, age-0 kokanee grew slowest in June when age-1 kokanee grew fastest. Age-0 kokanee obtained their fastest growth in October, when age-1 grew slowest. Lastly, age-2 reached their fastest growth rate during August, when both age-0 and age-1 kokanee were at moderate growth rates (Appendix A. Table 19). However, there was no evidence of age-specific feeding habits, since we found no relationship between kokanee size (TL) and the mean length of *Daphnia* they ingested (Figure 45).

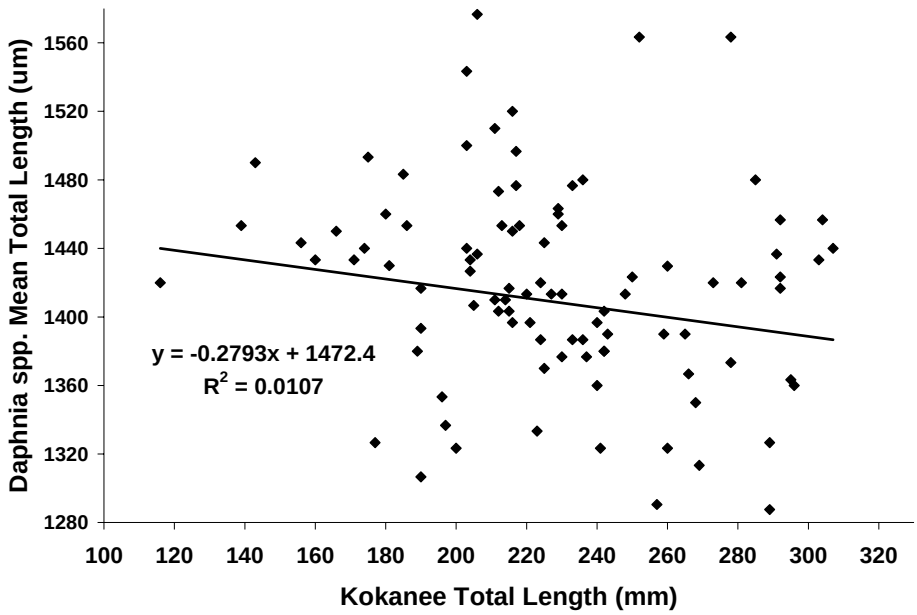
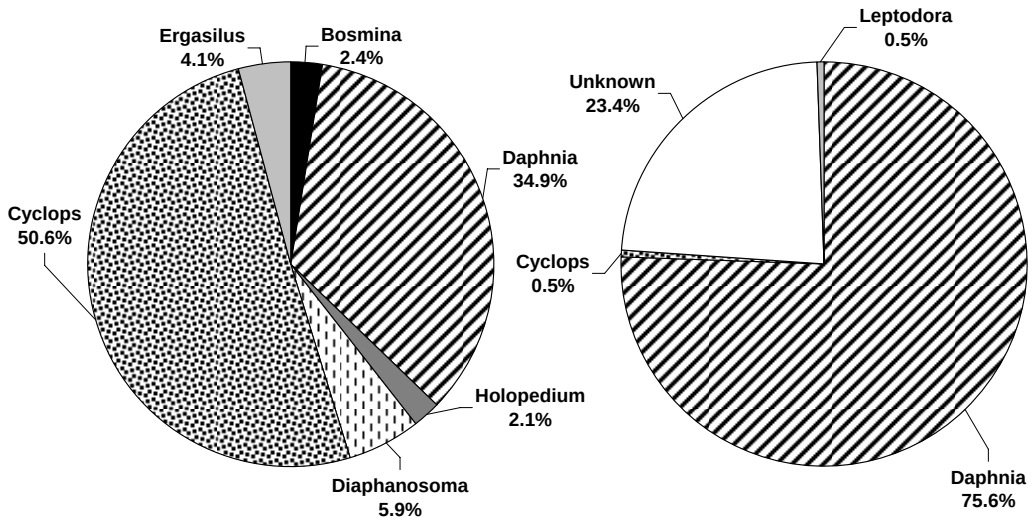


Figure 45. Relationship between kokanee total length (mm) and total length of Daphnia spp. zooplankton from their stomach contents, collected during trawl sampling, May-November 2004.

Kokanee diets were dominated by *Daphnia* sp., and composition was quite different from the zooplankton community composition in Dworshak Reservoir in 2004. Based on abundance, *Daphnia* on average comprised over 75% of the diet items of kokanee, yet *Daphnia* made up only about 35% of the zooplankton community (Figure 46). The most abundant zooplankton group in the reservoir, *Cyclops* (50%), comprised less than 1% of kokanee diets (Appendix A. Table 20). These results suggested kokanee select for and prefer *Daphnia* to all other zooplankton in the reservoir.

Our diet data was qualitative, since we were not certain we collected the entire contents of each stomach. It is possible we missed some diet items, particularly smaller zooplankton. In addition, it is likely most of the diet items categorized as unknown were also *Daphnia*, despite being unidentifiable parts of organisms; thus, kokanee diets were likely dominated by *Daphnia* even more than our sampling suggested.



Spp. composition in Dworshak Reservoir Kokanee diet composition

Figure 46. Mean zooplankton community composition during limnological sampling (left pie chart) and mean kokanee stomach content composition collected from monthly midwater trawling (right pie chart) on Dworshak Reservoir, May–November 2004.

CONCLUSIONS

Total kokanee abundance increased in 2004, but densities of harvestable-size kokanee dropped below Dworshak Reservoir management goals. Kokanee catch rates and yield would reach these goals if densities of harvestable kokanee doubled. Discharge of water through Dworshak Dam during 2004 appeared to have adversely impacted kokanee abundance, since age-1 to age-2 survival was very poor. Average or slightly above average mean monthly discharge appeared to affect the population.

The highest fish detection rates from entrainment assessments were again found during nighttime periods and lowest during the day. Unlike previous assessments, fish detection rates were low during high discharges throughout the spring and summer and highest during low discharges in September and October. Similarly, densities of kokanee in the forebay of Dworshak Reservoir were fairly low but stable throughout the spring and summer despite high discharge rates, but increased substantially during the fall when discharge was low.

Overall, there has been little change in reservoir clarity or chlorophyll concentrations in the past 30 years, but both nitrate and orthophosphate concentrations have dropped significantly since 1973. Total zooplankton densities for most sites within the reservoir have seen marked reductions since initial assessments in 1974, and the community has also shifted to one with fewer Cladocerans, which are the preferred forage of kokanee.

Kokanee exhibited good monthly growth during 2004, but each age class obtained their respective maximum growth rates at different times of the year. However, there was no evidence of age-specific feeding habits. Lastly, kokanee diets were dominated by Daphnia sp. and composition was quite different from the zooplankton community composition in Dworshak Reservoir in 2004.

RECOMMENDATIONS

1. We recommend increasing adult kokanee density to 30–50 fish/ha to improve the fishery. Densities could be increased by using strobe lights at night near operating turbines whenever kokanee densities in the forebay are high (Stark and Maiolie 2004). Monitoring of fish entrainment rates with installed hydroacoustic transducers inside dam intakes performed throughout the year could provide an estimate of entrainment mortality with and without strobes operating.

2. We recommend conducting a nutrient enhancement experiment on Dworshak Reservoir as a means to counter ongoing oligotrophication, thereby increasing reservoir productivity to benefit fish populations, especially kokanee. Monthly or seasonal trawl sampling would be needed to assess pre- and post-nutrient enhancement effects on age-specific abundance and growth of kokanee.

ACKNOWLEDGMENTS

The authors would like to thank Charlie Craig and the Bonneville Power Administration for their help in funding and contracting this project. Many Clearwater Hatchery personnel also provided assistance with trawling and limnological sampling; their help was greatly appreciated. We also wish to acknowledge Pete Rust and Brian Leth for editing drafts of this report. Lastly, we would especially like to thank Dworshak Project research data tech Josh Goodwin and fisheries technician Ric Downing for their continued hard work and long hours.

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APPENDICES

Appendix A. Table 1. Secchi disc water transparency measurements collected at nine stations during Dworshak Reservoir limnological survey, May–November 2004.

Sampled Date	Secchi Depth (m)										Pool Elevation (m)
	RK-72	LNF-3	RK-66	RK-56	RK-42	RK-31	EC-6	RK-11	RK-2	Mean	
5/17/2004	2.7	2.7	3.0	3.7	3.4	4.3	3.4	4.6	6.1	3.8	481.9
6/21/2004	5.8	3.7	5.5	3.7	2.7	3.0	2.7	3.0	3.0	3.7	487.1
7/19/2004	5.8	4.0	4.1	4.0	2.4	3.0	2.4	2.7	3.4	3.5	483.1
8/18/2004	2.7	3.0	3.7	4.0	4.0	4.3	2.1	2.4	3.4	3.3	471.8
9/8/2004	4.9	3.7	4.0	4.3	4.0	3.4	3.0	2.7	3.4	3.7	465.4
10/6/2004	6.7	5.5	6.4	6.1	5.8	5.2	4.6	5.8	6.4	5.8	463.6
11/8/2004	6.1	6.4	5.8	6.4	6.1	6.1	5.2	5.5	6.4	6.0	464.8
Mean	4.8	3.8	4.4	4.3	3.7	3.9	3.0	3.6	4.3	4.0	475.5

Appendix A. Table 2. Dissolved oxygen concentration and water temperatures at river kilometer 72 (RK-72) during Dworshak Reservoir limnological survey, May–November 2004. Measurements taken at surface, 1 m, and every even meter to 60 m or bottom.

Depth (m)	Dissolved Oxygen (mg/L)							Water Temperature (°C)						
	May	June	July	Aug	Sept	Oct	Nov	May	June	July	Aug	Sept	Oct	Nov
0	12.1	12.6	8.0	10.5	10.1	10.8	9.3	14.2	18.6	25.6	24.8	20.2	17.0	11.8
1	12.4	13.3	8.1	10.7	10.1	10.8	9.1	12.8	16.5	24.9	24.8	20.2	17.0	11.7
2	12.3	14.3	8.4	10.7	10.2	10.7	9.1	12.4	14.6	24.3	24.7	20.0	17.0	11.7
4	12.9	14.6	7.9	10.6	10.2	10.7	9.1	10.3	12.5	23.0	24.5	19.9	17.0	11.7
6	12.9	15.0	7.5	9.5	9.4	9.4	9.1	9.0	11.9	20.4	22.0	19.6	16.4	11.7
8	13.0	15.1	7.5	8.5	8.5	9.8	9.1	8.5	11.6	19.4	20.8	19.0	15.9	11.7
10	13.0	15.2	8.2	7.8	8.7	10.0	9.1	8.2	11.3	17.2	20.0	18.4	15.8	11.5
12	12.9	15.3	8.6	7.8	8.8	10.0	9.1	8.2	11.0	15.6	19.2	17.7	15.4	11.1
14	13.1	15.5	9.0	7.9	8.3	10.0	9.4	7.9	10.9	14.1	18.0	16.6	15.2	10.7
16	13.0	15.6	10.3	8.7	8.9	10.3	11.4	7.8	10.7	12.0	15.2	15.5	14.1	6.5
18	12.9	15.6	11.6	8.2	9.3	11.3	11.8	7.7	10.6	10.1	12.7	14.8	12.0	6.1
20	12.9	15.7	12.0	8.4	9.3	11.3	11.9	7.6	10.2	9.5	11.1	14.3	11.5	5.9
22	12.7	15.8	12.3	7.9	9.4	11.1	12.0	7.6	9.9	9.0	10.2	14.1	11.3	5.8
24	12.8	15.7	12.2	8.5	9.2			7.4	9.6	8.9	9.6	13.8		
26	13.0	15.8	12.3	8.4				7.2	9.3	8.8	9.2			
28	13.0	16.0	12.4	5.9				7.1	9.0	8.5	8.8			
30	13.0	16.1	12.5					7.0	8.9	7.9				
32	13.1	16.2	12.5					6.7	8.7	7.7				
34	13.1	16.4	12.7					6.4	7.4	7.5				
36	13.0	16.5	12.5					6.3	6.4	7.4				
38	12.2	16.8	10.9					6.1	5.1	7.3				
40		16.2	9.5						4.8	7.1				
42		16.2	8.6						4.7	6.9				
44		16.0	5.1						4.6	6.6				
46		15.7							4.5					
48		15.6							4.5					
50		15.5							4.5					
52		15.1							4.7					
54		14.9							4.7					
56		14.3							4.7					
58		14.1							4.8					
60		13.9							4.8					

Appendix A. Table 3. Dissolved oxygen concentration and water temperatures at river kilometer 66 (RK-66) during Dworshak Reservoir limnological survey, May–November 2004. Measurements taken at surface, 1 m, and every even meter to 60 m or bottom.

Depth (m)	Dissolved Oxygen (mg/L)							Water Temperature (°C)						
	May	June	July	Aug	Sept	Oct	Nov	May	June	July	Aug	Sept	Oct	Nov
0	10.9	13.0	8.5	9.6	9.9	10.2	9.2	16.4	20.4	24.9	25.3	20.9	17.0	12.3
1	11.6	15.2	8.5	9.6	10.1	10.0	9.2	14.7	15.1	24.8	25.3	20.4	16.9	11.9
2	11.8	14.8	8.7	9.6	10.0	10.8	9.2	13.2	14.8	24.1	25.2	20.1	16.9	11.9
4	12.3	15.4	8.7	9.8	9.9	10.8	9.2	10.1	12.6	21.8	24.5	20.0	16.9	11.8
6	12.4	15.4	8.1	10.6	9.6	10.1	9.2	9.3	11.8	20.7	22.0	19.8	16.8	11.8
8	12.2	15.2	9.4	8.6	8.3	9.3	9.1	8.7	11.4	19.5	20.8	18.9	16.5	11.7
10	12.0	15.2	9.3	8.2	8.5	9.2	9.1	8.2	11.3	17.5	20.0	18.2	16.2	11.7
12	12.0	15.5	9.5	7.9	8.7	9.5	9.1	8.0	10.8	16.5	19.0	17.5	15.7	11.7
14	12.1	15.7	9.8	8.3	8.7	9.7	9.2	7.7	10.6	14.6	17.9	16.7	15.4	11.1
16	12.2	15.6	11.9	9.0	8.8	9.7	9.3	7.5	10.3	9.9	15.1	15.8	15.0	10.8
18	12.2	15.7	12.1	10.2	9.0	9.8	9.3	7.4	10.0	10.0	12.5	15.1	14.5	10.6
20	12.3	15.8	12.4	11.0	9.3	10.0	9.6	7.4	9.7	9.4	11.5	14.3	13.4	9.9
22	12.3	15.8	12.6	11.1	9.3	10.2	10.0	7.2	9.5	9.0	10.1	14.1	12.9	9.2
24	12.3	16.0	12.6	11.6	8.1	10.2	10.3	7.2	9.3	8.8	9.5	13.6	12.6	8.3
26	12.4	15.8	12.7	11.9		10.1	10.5	7.2	9.3	8.4	9.1		12.3	7.9
28	12.4	16.1	13.0	10.6		9.8	10.5	7.1	9.1	7.9	8.6		12.0	7.5
30	12.4	15.8	12.9	10.5		9.9	10.8	7.0	8.9	7.7	8.4		11.7	7.0
32	12.4	15.8	13.0	10.1		11.1	10.9	6.7	8.8	7.5	8.1		11.5	6.8
34	12.5	15.9	13.1	8.9			11.0	6.6	8.7	7.3	7.8			6.8
36	12.5	15.9	13.1	8.9			7.6	6.5	8.2	7.2	7.6			6.8
38	12.6	16.3	13.1	8.5			5.2	6.5	7.0	7.2	7.3			6.8
40	12.6	16.4	13.0	8.1			4.6	6.4	5.4	7.1	7.1			6.8
42	12.6	16.2	13.0	8.4			3.9	6.3	4.7	6.9	6.6			6.8
44	12.6	16.2	12.8	8.5				6.3	4.6	6.7	6.1			
46	12.5	16.1	10.6	7.9				6.3	4.5	6.1	5.8			
48	12.5	15.9	10.7	7.4				6.3	4.4	6.1	5.7			
50	12.5	15.8	10.4	7.2				6.3	4.3	5.9	5.7			
52	12.5	15.7	10.5					6.2	4.3	5.7				
54	12.5	15.6	10.9					5.0	4.3	5.5				
56	10.8	15.5	11.1					4.4	4.3	5.4				
58	10.0	15.2	11.0					4.5	4.3	5.1				
60	2.0	15.3	10.0					4.5	4.3	5.1				

Appendix A. Table 4. Dissolved oxygen concentration and water temperatures at river kilometer 3 in the Little North Fork arm (LNF-3) during Dworshak Reservoir limnological survey, May–November 2004. Measurements taken at surface, 1 m, and every even meter to 60 m or bottom.

Depth (m)	Dissolved Oxygen (mg/L)							Water Temperature (°C)						
	May	June	July	Aug	Sept	Oct	Nov	May	June	July	Aug	Sept	Oct	Nov
0	11.2	13.1	8.3	9.6	9.9	10.7	9.6	16.0	18.9	24.5	25.3	20.3	16.7	11.9
1	11.9	13.4	8.4	9.8	10.1	10.2	9.3	13.5	18.4	24.4	25.0	20.0	16.7	11.8
2	12.1	15.3	8.4	9.7	10.2	10.1	9.3	12.4	15.7	24.0	24.8	19.8	16.7	11.8
4	12.8	16.2	8.7	11.1	10.1	10.1	9.2	9.9	13.0	21.6	23.1	19.6	16.7	11.7
6	12.7	16.2	9.0	10.1	10.1	10.1	9.1	8.8	11.8	20.5	21.4	19.6	16.7	11.7
8	12.3	16.0	9.7	8.8	9.4	9.4	9.1	8.4	11.3	19.1	20.3	18.9	16.4	11.6
10	12.3	16.0	9.5	8.3	9.5	9.7	9.1	8.1	10.9	17.7	19.6	18.2	16.0	11.6
12	12.3	16.0	9.7	8.2	9.5	9.8	9.1	7.8	10.6	16.1	19.0	17.5	15.7	11.4
14	12.3	16.0	9.9	8.7	9.3	9.9	9.2	7.7	10.4	15.0	18.0	16.8	15.5	11.0
16	12.3	15.7	10.7	8.6	9.4	10.0	9.4	7.6	10.1	12.4	16.8	16.2	15.0	10.5
18	12.4	15.8	11.9	9.3	9.6	10.5	9.7	7.4	9.9	10.3	13.6	15.4	14.2	10.1
20	12.5	15.8	12.3	10.0	9.7	10.9	10.2	7.3	9.7	9.4	11.8	14.6	13.3	8.3
22	12.6	16.0	12.6	10.3	9.6	11.0	10.6	7.1	9.5	9.0	10.6	14.2	12.8	7.8
24	12.5	16.1	12.7	9.6	8.4	10.9	8.0	7.0	9.3	8.8	10.0	13.6	12.0	7.7
26	12.6	16.2	12.9	10.3		10.0		6.9	9.1	8.5	9.3		11.8	
28	12.6	16.1	12.8	9.6				6.8	9.0	8.1	9.0			
30	12.7	16.3	12.8	8.6				6.7	8.8	7.8	8.5			
32	12.7	16.2	12.8	7.1				6.5	8.7	7.6	8.2			
34	12.8	16.4	12.8					6.3	8.1	7.4				
36	12.8	16.6	12.5					6.2	6.7	7.3				
38	12.7	16.9	12.5					6.0	5.8	7.2				
40	12.4	16.4	12.8					5.9	5.3	7.1				
42	12.4	16.4	12.8					5.8	4.9	6.9				
44		16.4	11.9						4.6	6.5				
46		16.0	6.9						4.5	6.1				
48		15.6							4.5					
50		15.5							4.4					
52		13.9							4.6					
54		13.8							4.6					
56		12.3							4.6					
58		12.1							4.6					
60		11.8							4.6					

Appendix A. Table 5. Dissolved oxygen concentration and water temperatures at river kilometer 56 (RK-56) during Dworshak Reservoir limnological survey, May–November 2004. Measurements taken at surface, 1 m, and every even meter to 60 m or bottom.

Depth (m)	Dissolved Oxygen (mg/L)							Water Temperature (°C)						
	May	June	July	Aug	Sept	Oct	Nov	May	June	July	Aug	Sept	Oct	Nov
0	10.9	13.4	8.2	9.4	9.2	10.1	9.3	14.4	20.4	24.7	24.9	21.7	17.1	12.5
1	11.1	14.3	8.2	9.3	9.5	10.0	9.2	14.3	18.0	24.7	24.8	20.7	17.1	12.4
2	11.1	14.6	8.2	9.3	9.5	10.0	9.1	14.0	17.4	24.3	24.8	20.3	17.1	12.2
4	11.4	15.8	9.2	9.5	9.4	10.0	9.1	12.8	14.8	22.5	24.0	20.0	17.0	12.1
6	12.1	17.2	9.5	9.7	9.3	10.0	9.0	9.7	11.6	20.2	22.5	20.0	17.0	12.1
8	11.9	17.1	9.7	8.9	9.0	9.9	9.0	8.6	10.4	18.5	21.2	19.9	16.9	12.1
10	11.8	17.1	9.7	7.7	7.7	9.7	8.9	8.3	10.3	16.9	20.0	18.6	16.8	12.1
12	11.8	17.2	9.7	7.2	7.6	9.2	8.8	8.1	9.8	15.6	19.0	17.8	16.2	12.1
14	11.8	17.0	10.1	7.2	7.9	9.2	8.8	8.0	9.6	14.0	17.6	16.8	15.7	12.1
16	11.8	16.6	11.4	8.5	8.2	9.3	8.9	7.9	9.4	11.8	15.7	16.0	15.3	11.6
18	11.8	16.5	12.3	10.0	8.5	9.6	9.1	7.7	9.3	10.3	12.8	15.0	14.7	11.1
20	12.0	16.5	12.8	11.1	8.4	9.9	9.2	7.3	9.1	9.6	11.5	14.2	13.7	10.7
22	12.0	16.4	12.8	12.1	8.1	9.9	9.5	7.2	9.0	9.3	10.3	13.4	12.9	10.1
24	12.0	16.4	13.0	12.9	7.4	9.4	9.7	7.0	8.8	8.9	9.3	11.0	12.7	9.7
26	12.0	16.3	13.1	13.1	9.3	9.4	9.8	7.0	8.7	8.6	9.1	9.8	12.6	9.2
28	12.0	16.4	13.3	13.2	10.2	9.4	10.0	7.0	8.4	8.3	8.6	9.2	12.3	8.7
30	12.1	16.5	13.3	13.3	10.4	9.5	10.3	6.6	8.1	8.0	8.3	8.8	11.6	8.1
32	12.2	16.7	13.4	13.3	9.9	6.6	10.4	6.5	7.6	7.8	8.1	8.5	10.1	7.9
34	12.1	16.9	13.5	13.3	9.9	8.1	10.5	6.5	7.2	7.6	7.8	8.1	8.7	7.7
36	12.1	16.9	13.5	13.1	9.9	8.5	10.5	6.4	7.1	7.5	7.5	7.9	8.2	7.7
38	12.1	17.0	13.5	12.9	10.0		10.5	6.3	6.8	7.3	7.4	7.5		7.7
40	12.2	16.9	13.5	12.7	9.9		10.5	6.1	6.4	7.0	7.0	7.2		7.6
42	12.1	17.2	13.4	12.2	9.8		10.4	5.8	5.8	6.7	6.7	6.8		7.6
44	12.0	17.1	13.5	12.2	9.9		10.3	5.4	5.5	6.5	6.4	6.4		7.5
46	11.9	17.2	13.4	12.1	9.8		10.2	5.0	5.3	6.2	6.1	5.9		7.4
48	11.9	17.1	13.3	12.1	9.7		9.4	4.6	5.2	5.9	5.5	5.7		7.0
50	11.9	17.0	13.1	12.1	9.4		6.6	4.4	5.1	5.7	5.3	5.4		5.5
52	11.7	16.9	13.1	12.0	9.4		6.3	4.2	5.0	5.4	5.0	5.2		5.1
54	11.6	16.9	13.0	11.8	9.3		6.3	4.2	4.8	5.3	5.0	5.1		5.1
56	11.6	16.8	12.7	11.8	9.4		6.2	4.1	4.7	5.0	4.9	5.0		5.0
58	11.5	16.8	12.6	12.0	9.4		6.3	4.1	4.6	5.0	4.8	5.0		5.0
60	11.4	16.7	12.6	12.0	9.6		6.3	4.1	4.4	5.0	4.7	4.9		5.0

Appendix A. Table 6. Dissolved oxygen concentration and water temperatures at river kilometer 42 (RK-42) during Dworshak Reservoir limnological survey, May–November 2004. Measurements taken at surface, 1 m, and every even meter to 60 m or bottom.

Depth (m)	Dissolved Oxygen (mg/L)							Water Temperature (°C)						
	May	June	July	Aug	Sept	Oct	Nov	May	June	July	Aug	Sept	Oct	Nov
0	10.6	8.7	9.2	10.1	9.4	10.3	9.2	15.3	18.4	26.1	24.3	21.8	17.4	12.6
1	10.8	10.5	9.3	9.9	9.7	10.1	9.0	15.3	17.9	25.4	24.4	21.7	17.4	12.6
2	10.8	10.8	9.2	9.7	9.8	10.1	9.0	15.3	17.2	25.2	24.4	20.8	17.2	12.4
4	10.9	11.3	9.7	9.7	9.7	10.1	8.9	14.9	15.5	24.2	24.4	20.5	17.2	12.3
6	11.5	12.6	11.2	9.8	9.1	10.1	8.9	12.8	11.2	19.9	23.6	20.3	17.1	12.3
8	12.0	13.0	11.0	8.7	8.6	10.1	8.8	9.7	10.0	18.2	21.2	20.2	17.1	12.3
10	11.8	12.9	11.2	8.2	6.4	10.0	8.8	8.6	9.7	16.6	19.9	19.0	17.0	12.3
12	11.6	12.9	11.4	7.9	6.4	7.9	8.8	8.0	9.5	14.9	18.4	18.1	16.2	12.2
14	11.5	12.9	12.7	8.5	7.0	8.2	8.8	7.8	9.3	12.7	16.6	17.0	15.7	12.2
16	11.5	13.0	13.8	10.1	7.8	8.3	8.8	7.6	9.1	10.7	13.4	15.9	15.3	12.2
18	11.5	13.0	14.1	11.6	8.4	8.7	8.5	7.6	9.0	9.7	11.5	15.2	14.7	11.9
20	11.6	13.1	13.9	12.6	8.1	9.0	8.5	7.5	8.8	9.4	10.4	14.0	14.0	11.2
22	11.6	13.3	14.3	13.3	8.1	9.3	8.3	7.4	8.7	9.1	9.5	13.2	13.2	10.7
24	11.7	13.3	14.0	13.6	8.6	9.5	8.8	7.4	8.5	8.9	9.0	11.7	12.9	10.3
26	11.6	13.4	14.1	14.0	10.5	9.6	9.1	7.3	8.2	8.5	8.8	10.1	12.7	9.9
28	11.7	13.6	14.3	13.9	11.2	9.2	9.1	7.0	8.0	8.1	8.4	9.3	11.8	9.5
30	11.7	13.7	14.5	14.0	11.5	8.3	9.4	6.7	7.7	7.8	8.1	8.9	11.0	8.9
32	11.8	13.9	14.5	14.3	11.7	9.9	9.6	6.4	7.5	7.6	7.9	8.4	9.3	8.7
34	11.7	14.0	14.5	14.3	11.9	10.2	9.5	6.3	7.4	7.5	7.6	8.1	8.7	8.3
36	11.9	13.8	14.4	14.4	12.1	10.5	9.5	5.9	7.2	7.3	7.4	7.8	8.2	8.2
38	12.0	13.8	14.5	14.2	12.2	10.6	9.3	5.7	7.1	7.1	7.2	7.5	7.9	8.1
40	11.9	13.9	14.6	14.2	12.2	10.7	9.1	5.4	6.8	6.9	6.9	7.2	7.4	7.9
42	11.9	14.0	14.6	14.3	12.2	10.7	8.6	5.1	6.6	6.6	6.6	6.9	7.0	7.8
44	11.9	14.0	14.7	14.4	12.3	10.8	8.1	4.8	6.4	6.4	6.0	6.4	6.5	6.8
46	11.8	14.1	14.6	14.6	12.3	10.9	8.2	4.6	6.1	6.2	5.6	6.0	5.8	6.2
48	11.8	14.1	14.7	14.1	12.4		8.3	4.5	5.8	5.9	5.3	5.6		5.6
50	11.6	14.3	14.7	14.3	12.3		8.3	4.4	5.5	5.6	5.1	5.3		5.2
52	11.6	14.4	14.5	14.2	12.1		8.7	4.3	5.4	5.3	4.9	5.0		4.8
54	11.8	14.3	14.4	14.0	12.0		8.9	4.4	5.1	5.2	4.8	4.9		4.7
56	11.7	14.2	14.5	14.1	11.9		8.9	4.2	5.0	5.0	4.8	4.8		4.6
58	11.6	14.2	14.3	13.9	11.9			4.2	4.9	4.9	4.7	4.7		
60	11.5	14.2	14.3	13.9	11.9			4.2	4.8	4.8	4.6	4.5		

Appendix A. Table 7. Dissolved oxygen concentration and water temperatures at river kilometer 31 (RK-31) during Dworshak Reservoir limnological survey, May–November 2004. Measurements taken at surface, 1 m, and every even meter to 60 m or bottom.

Depth (m)	Dissolved Oxygen (mg/L)							Water Temperature (°C)						
	May	June	July	Aug	Sept	Oct	Nov	May	June	July	Aug	Sept	Oct	Nov
0	10.9	11.6	8.8	9.4	9.9	10.3	9.2	14.7	19.2	25.3	24.0	20.4	17.3	12.5
1	10.9	11.9	8.8	9.4	10.0	10.2	8.9	14.6	18.6	25.2	24.0	20.4	17.3	12.6
2	10.9	12.0	8.9	9.4	9.9	10.1	8.7	14.5	18.3	24.6	24.0	20.4	17.3	12.5
4	11.0	12.1	9.3	9.3	10.0	10.1	8.7	13.9	18.1	24.1	24.0	20.4	17.2	12.4
6	11.5	12.9	10.0	9.3	10.0	9.9	8.6	12.1	16.3	21.6	23.9	20.4	17.2	12.4
8	12.0	14.3	9.9	9.3	9.7	10.0	8.6	9.4	12.3	19.2	23.6	20.4	17.2	12.3
10	12.1	15.0	9.9	8.2	9.9	9.9	8.5	8.6	10.1	16.6	19.7	20.4	17.1	12.3
12	12.1	15.1	10.3	8.2	6.3	10.0	8.5	8.1	9.5	14.8	18.6	18.8	17.1	12.3
14	12.1	15.2	11.7	8.9	6.4	9.9	8.5	8.0	9.2	12.4	16.3	17.6	17.1	12.3
16	11.9	15.3	12.1	9.9	6.6	7.5	8.5	7.9	9.0	11.1	14.3	16.3	15.6	12.3
18	12.0	15.4	12.6	11.4	6.9	7.6	8.5	7.7	8.9	9.8	12.1	15.4	15.0	12.3
20	12.1	15.4	12.8	12.4	7.4	7.5	8.4	7.5	8.6	9.4	10.8	14.2	14.3	12.3
22	12.1	15.4	13.0	12.8	8.4	7.7	8.3	7.1	8.2	9.0	9.8	13.0	13.5	12.2
24	12.2	15.4	13.1	13.2	9.7	8.4	7.6	6.7	8.0	8.8	9.2	11.5	12.7	11.2
26	12.2	15.4	13.3	13.6	10.7	8.3	7.8	6.5	7.9	8.4	8.8	9.9	12.0	10.3
28	12.1	15.4	13.2	13.8	11.3	8.4	8.0	6.3	7.7	8.1	8.5	9.2	11.2	9.7
30	12.2	15.4	13.3	13.9	11.7	10.0	8.2	5.9	7.6	7.9	8.2	8.8	9.7	9.1
32	12.2	15.4	13.4	14.2	11.9	10.4	8.4	5.7	7.5	7.7	8.0	8.5	9.1	8.9
34	12.2	15.4	13.3	14.1	12.1	10.7	8.3	5.6	7.4	7.6	7.7	8.2	8.5	8.3
36	12.2	15.5	13.4	14.1	12.1	11.0	8.2	5.5	7.1	7.3	7.5	7.8	8.1	8.1
38	12.1	15.6	13.6	14.4	12.3	11.2	9.1	5.5	6.9	7.0	7.2	7.5	7.7	7.3
40	12.1	15.7	13.7	14.3	12.2	11.3	9.2	5.4	6.6	6.7	7.0	7.2	7.3	6.7
42	12.1	15.8	13.9	14.5	12.4	11.4	9.4	5.1	6.1	6.2	6.7	6.9	6.8	6.4
44	12.0	15.9	13.9	14.6	12.5	11.5	9.5	5.0	5.8	6.1	6.2	6.5	6.3	5.9
46	11.8	16.0	14.1	14.6	12.6	11.7	9.5	4.8	5.6	5.7	6.0	5.9	5.9	5.5
48	11.7	15.8	14.0	14.7	12.7	11.7	9.6	4.7	5.4	5.4	5.6	5.6	5.5	5.2
50	11.5	15.7	14.0	14.7	12.7	11.8	9.6	4.6	5.3	5.3	5.5	5.4	5.2	5.0
52	11.6	15.6	14.0	14.6	12.6	11.9	9.6	4.6	5.2	5.3	5.0	4.9	4.9	4.8
54	11.5	15.5	13.9	14.6	12.6	11.9	9.5	4.4	5.0	4.9	4.9	4.8	4.8	4.7
56	11.5	15.3	13.8	14.7	12.6	12.4	9.5	4.3	4.8	4.7	4.7	4.7	4.6	4.6
58	11.4	15.3	13.7	14.5	12.5	12.0	9.5	4.3	4.8	4.6	4.6	4.6	4.5	4.5
60	11.3	15.2	13.6	14.4	12.5	11.7	9.3	4.2	4.7	4.6	4.5	4.5	4.5	4.4

Appendix A. Table 8. Dissolved oxygen concentration and water temperatures at river kilometer 6 in the Elk Creek arm (EC-6) during Dworshak Reservoir limnological survey, May–November 2004. Measurements taken at surface, 1 m, and every even meter to 60 m or bottom.

Depth (m)	Dissolved Oxygen (mg/L)							Water Temperature (°C)						
	May	June	July	Aug	Sept	Oct	Nov	May	June	July	Aug	Sept	Oct	Nov
0	10.3	10.8	8.4	9.9	10.3	10.5	8.8	16.0	21.3	26.7	24.9	20.2	17.3	12.1
1	10.9	10.9	8.5	9.9	10.2	10.6	8.7	15.9	21.1	26.6	24.6	20.2	17.2	12.2
2	10.9	11.6	8.9	10.1	10.0	10.6	8.6	15.9	18.7	26.0	24.1	20.2	17.1	12.2
4	11.2	12.8	9.8	9.9	9.8	10.4	8.6	13.7	16.7	23.8	23.9	20.1	17.0	12.2
6	11.1	13.2	9.1	8.9	9.8	10.5	8.6	11.5	14.8	21.6	23.5	20.1	16.9	12.2
8	10.8	13.5	8.1	7.9	9.7	10.4	8.6	9.3	12.9	18.1	23.0	20.1	16.9	12.2
10	10.7	13.6	10.0	6.0	9.5	10.4	8.6	8.6	10.5	15.6	20.3	20.0	16.9	12.2
12	10.6	14.1	10.2	5.9	9.3	10.3	8.5	8.4	9.3	14.3	18.4	19.7	16.9	12.2
14	10.8	14.1	10.4	6.5	7.9	10.3	8.5	8.0	9.2	12.2	16.6	18.0	16.9	12.2
16	10.9	14.2	10.9	7.3	6.6	10.4	8.5	7.8	8.8	10.9	14.4	17.1	16.3	12.2
18	11.0	14.3	11.1	9.1	6.2	10.4	8.5	7.5	8.5	10.0	12.8	15.7	15.5	12.2
20	10.9	14.3	11.5	9.7	6.5	10.3	8.5	7.2	8.3	9.4	11.4	14.6	14.8	11.9
22	11.1	14.4	11.7	10.7	6.0	7.3	8.8	7.0	8.1	9.1	10.2	13.6	14.0	10.9
24	11.0	14.6	11.7	10.9	6.0		8.7	6.7	8.0	8.8	9.6	12.2		10.3
26	11.0	14.7	11.6	11.4	6.0		7.8	6.7	7.9	8.6	9.1	10.7		9.8
28	11.1	14.8	11.6	11.6	6.3		7.5	6.2	7.8	8.3	8.8	9.8		9.1
30	11.0	14.8	11.7	11.0	6.5		7.1	6.1	7.7	8.0	8.5	9.3		8.7
32	11.0	14.8	11.9	10.9	6.7		6.5	5.9	7.7	7.9	8.2	8.8		8.4
34	11.0	14.7	12.1	10.8	6.8		5.5	5.9	7.6	7.6	7.9	8.4		7.9
36	10.9	14.6	11.9	10.7	8.1		5.4	5.8	7.4	7.4	7.7	8.0		7.8
38	10.9	14.6	11.9	11.5	8.4		4.7	5.6	7.4	7.2	7.4	7.7		7.1
40	10.9	14.0	11.3	11.6	8.3		4.6	5.6	7.2	7.0	7.1	7.4		6.4
42	10.8	13.9	11.3	11.1	8.3		4.7	5.5	7.0	6.6	6.9	6.8		5.7
44	10.8	13.6	11.2	11.3	8.4		4.8	5.4	6.6	6.2	6.4	6.4		5.5
46	10.7	13.4	11.3	11.1	8.4			5.3	6.3	5.9	6.1	6.0		
48	10.7	13.6	11.5	11.2	8.4			5.1	5.9	5.5	5.9	5.6		
50	10.7	13.5	11.4	10.9	8.3			5.0	5.7	5.4	5.5	5.3		
52	10.6	13.5	11.5	11.0	8.3			4.9	5.5	5.2	5.3	5.2		
54	10.7	13.5	11.4	11.1	8.4			4.8	5.4	5.1	5.1	5.0		
56	10.7	13.5	11.4	11.2	8.1			4.7	5.2	5.0	4.9	5.1		
58	10.6	13.6	11.5	11.2	7.8			4.7	5.1	4.9	4.8	5.1		
60	10.6	13.5	11.4	11.2	7.2			4.5	4.9	4.8	4.8	5.1		

Appendix A. Table 9. Dissolved oxygen concentration and water temperatures at river kilometer 11 (RK-11) during Dworshak Reservoir limnological survey, May–November 2004. Measurements taken at surface, 1 m, and every even meter to 60 m or bottom.

Depth (m)	Dissolved Oxygen (mg/L)							Water Temperature (°C)						
	May	June	July	Aug	Sept	Oct	Nov	May	June	July	Aug	Sept	Oct	Nov
0	10.0	10.1	8.0	9.0	9.5	8.5	8.3	16.2	22.0	26.9	25.8	21.3	17.0	12.6
1	10.0	10.8	8.2	9.0	9.5	8.6	8.2	16.2	20.0	26.7	25.6	21.2	16.8	12.6
2	10.1	11.6	8.5	9.3	9.6	8.6	8.1	15.7	19.5	26.0	25.1	20.9	16.7	12.6
4	10.3	12.1	8.8	9.1	9.5	8.4	8.1	15.2	17.7	24.8	24.7	20.8	16.6	12.6
6	10.8	12.3	8.6	8.4	9.4	8.4	8.1	13.4	16.8	23.4	24.2	20.8	16.6	12.6
8	11.3	13.8	8.4	7.8	9.3	8.4	8.1	10.3	13.8	22.1	23.6	20.8	16.6	12.6
10	11.1	14.5	10.2	7.1	8.7	8.4	8.1	9.1	10.4	17.0	21.0	20.6	16.6	12.6
12	10.7	14.3	10.9	7.8	8.8	8.4	8.1	8.8	9.6	12.5	18.2	20.5	16.6	12.6
14	10.6	14.0	11.2	8.8	6.2	6.0	8.1	8.2	9.0	11.3	16.4	18.0	14.8	12.6
16	10.7	14.4	11.5	9.7	6.7	6.2	8.1	7.8	8.7	10.0	14.7	16.7	14.2	12.6
18	10.9	14.7	11.7	10.4	7.2	6.3	8.1	7.6	8.5	9.5	13.6	15.3	13.6	12.6
20	10.9	14.7	11.9	11.4	8.3	7.0	8.1	7.5	8.4	9.1	11.1	13.8	12.6	12.5
22	10.9	14.8	11.7	11.9	9.3	7.9	7.8	7.2	8.2	8.9	10.2	12.3	11.8	12.4
24	11.0	14.8	11.7	12.5	9.6	7.9	7.0	7.0	8.1	8.7	9.3	11.3	10.6	11.8
26	11.0	14.8	11.6	12.8	10.2	8.5	7.1	6.8	8.0	8.4	9.0	10.0	9.6	11.0
28	10.8	14.9	11.8	12.9	10.5	8.5	7.6	6.7	7.9	8.2	8.7	9.4	8.9	10.3
30	10.7	14.9	12.4	13.4	10.8	9.1	8.1	6.4	7.9	7.9	8.4	10.8	8.4	9.5
32	10.6	14.9	12.4	13.7	10.9	9.1	8.3	6.3	7.8	7.7	8.2	10.9	7.9	8.9
34	10.8	15.0	12.4	12.4	11.0	9.4	8.6	6.2	7.8	7.6	7.8	11.0	7.5	8.3
36	10.8	15.0	12.5	12.1	11.4	9.3	8.9	5.9	7.6	7.3	7.5	11.4	7.1	7.8
38	10.7	14.9	12.4	12.3	11.6	9.4	8.6	5.8	7.5	7.1	7.2	11.6	6.6	7.5
40	10.8	14.8	12.6	12.3	11.6	9.3	8.6	5.7	7.3	6.8	7.2	11.6	6.0	6.8
42	10.7	14.7	12.8	12.2	11.5	9.2	8.7	5.6	7.2	6.5	6.8	11.5	5.5	6.3
44	10.5	14.9	12.8	12.3	11.6	8.9	8.2	5.5	6.7	6.2	6.3	11.6	5.2	5.8
46	10.5	15.1	12.6	12.4	11.7	9.3	8.2	5.4	6.4	6.0	6.0	11.7	5.0	5.4
48	10.5	15.1	12.5	12.1	11.5	8.9	8.1	5.2	6.1	5.8	5.7	11.5	4.9	5.1
50	10.2	14.8	12.2	12.1	10.9	8.8	8.0	5.1	5.9	5.4	5.5	10.9	4.7	4.9
52	10.0	14.8	11.8	11.6	10.9	8.8	8.3	4.9	5.8	5.2	4.9	10.9	4.6	4.7
54	9.9	14.7	12.0	11.4	10.7	8.8	8.3	4.8	5.7	5.1	4.8	10.7	4.5	4.7
56	9.8	14.6	11.8	11.3	10.6	8.8	8.3	4.6	5.6	5.0	4.6	10.6	4.5	4.5
58	9.8	14.5	11.8	11.2	10.5	8.7	8.1	4.5	5.3	4.9	4.5	10.5	4.5	4.5
60	9.6	14.0	11.6	11.1	10.5	8.7	8.0	4.4	5.0	4.7	4.4	10.5	4.4	4.5

Appendix A. Table 10. Dissolved oxygen concentration and water temperatures at river kilometer 2 (RK-2) during Dworshak Reservoir limnological survey, May–November 2004. Measurements taken at surface, 1 m, and every even meter to 60 m or bottom.

Depth (m)	Dissolved Oxygen (mg/L)							Water Temperature (°C)						
	May	June	July	Aug	Sept	Oct	Nov	May	June	July	Aug	Sept	Oct	Nov
0	10.0	8.7	7.6	8.5	9.1	8.5	8.3	15.3	26.4	27.2	24.3	22.1	17.1	12.5
1	10.1	10.5	7.7	8.4	9.2	8.6	8.3	15.3	20.9	27.2	24.2	21.9	17.0	12.5
2	10.1	11.0	7.7	8.4	9.4	8.6	8.2	15.2	20.2	27.1	24.1	21.3	17.0	12.5
4	10.2	11.3	8.0	8.3	9.2	8.5	8.2	15.0	19.3	25.7	24.1	21.2	16.9	12.5
6	10.5	12.7	9.0	8.2	9.2	8.5	8.2	14.0	15.6	22.8	24.0	21.1	16.9	12.5
8	11.6	14.1	9.8	6.5	9.1	8.5	8.2	10.2	11.6	19.8	21.4	21.1	16.9	12.5
10	11.6	14.3	11.0	7.0	8.8	8.4	8.2	8.8	9.9	15.6	18.6	21.0	16.8	12.5
12	10.9	14.4	11.1	7.2	8.0	8.4	8.2	8.3	9.3	13.2	17.4	20.7	16.8	12.5
14	10.7	14.4	11.4	7.8	6.5	8.4	8.2	7.9	8.9	11.4	16.0	17.5	16.8	12.5
16	10.8	14.5	11.7	8.9	6.7	6.6	8.2	7.8	8.7	10.4	14.3	16.5	14.8	12.5
18	10.9	14.6	11.9	10.1	8.0	7.0	8.2	7.5	8.5	9.9	12.2	14.9	14.1	12.5
20	10.8	14.7	11.9	10.9	8.6	7.3	8.2	7.6	8.2	9.5	10.3	13.9	13.5	12.5
22	10.9	14.8	12.1	11.2	9.6	7.6	8.2	7.1	8.1	9.1	9.7	12.3	12.8	12.5
24	11.0	14.8	12.3	11.4	10.2	8.1	8.1	7.3	8.0	8.8	9.3	11.2	12.0	12.5
26	10.8	14.8	12.2	11.6	10.5	8.5	8.1	6.9	8.9	8.5	9.0	10.4	11.1	10.6
28	11.0	14.9	12.4	11.7	11.1	9.2	8.4	6.8	7.8	8.2	8.7	9.4	9.9	9.6
30	11.0	15.0	12.5	11.9	11.2	9.5	8.7	6.5	7.7	8.1	8.3	9.0	9.0	8.9
32	10.9	15.0	12.6	12.1	11.7	9.9	8.9	6.3	7.5	7.9	7.9	8.6	8.4	8.7
34	10.9	15.0	12.8	12.2	11.7	10.6	9.0	6.2	7.4	7.7	7.7	8.2	7.9	8.2
36	10.9	15.0	12.8	12.4	12.1	10.3	9.2	5.9	7.3	7.5	7.4	7.8	7.5	7.7
38	10.9	15.0	12.9	12.4	12.3	10.4	9.4	5.7	7.1	7.4	7.1	7.6	7.1	7.2
40	10.8	15.1	13.0	12.6	12.3	10.5	9.4	5.6	6.7	7.2	6.8	7.2	6.4	6.8
42	10.8	15.3	13.2	12.7	12.6	10.7	9.7	5.4	6.5	6.6	6.3	6.5	6.0	6.2
44	10.6	15.4	13.3	12.8	12.9	10.8	9.7	5.2	6.2	6.1	5.8	6.0	5.5	5.5
46	10.5	15.5	13.2	12.7	12.7	10.5	9.7	5.1	6.1	6.0	5.4	5.7	5.1	5.3
48	10.5	15.5	13.3	12.4	12.8	10.2	9.7	4.9	5.9	5.7	5.2	5.5	4.8	5.0
50	10.4	15.3	13.0	12.4	12.5	10.0	9.7	4.9	5.8	5.4	5.0	5.1	4.7	4.8
52	10.2	15.2	12.8	12.3	12.5	9.8	9.6	4.7	5.7	5.1	4.8	4.9	4.6	4.7
54	10.1	15.1	12.5	12.2	12.3	10.6	9.4	4.7	5.5	5.0	4.7	4.6	4.5	4.6
56	10.2	15.0	12.6	12.2	11.3	9.8	9.4	4.6	5.2	4.9	4.5	4.4	4.4	4.5
58	9.9	14.6	12.4	12.2	12.1	9.9	9.2	4.5	4.9	4.7	4.4	4.3	4.3	4.4
60	9.9	14.3	12.3	12.0	12.1	7.6	9.1	4.5	4.8	4.6	4.3	4.3	4.3	4.4

Appendix A. Table 11. Concentration of chlorophyll *a*, nitrate, orthophosphorus, and total phosphorus collected at nine stations during Dworshak Reservoir limnological survey, May–November 2004.

Sample Date	Station	Nutrient Concentrations (mg/L)			
		Chlorophyll A (Chl-A)	Nitrate (NO_3-N)	Orthophosphorus (OP)	Total Phosphorus (TP)
17-May	RK-72	0.002	0.015	0.005	0.02
	LNF-3	0.006	0.030	0.005[a]	0.02
	RK-66	0.003	0.034	0.005[a]	0.01
	RK-56	0.002	0.024	0.005[a]	0.01[a]
	RK-42	0.002	0.024	0.005[a]	0.01
	RK-31	0.002	0.014	0.005[a]	0.08
	EC-6	0.003	0.001	0.005[a]	0.01
	RK-11	0.003	0.001[a]	0.005[a]	0.03
	RK-2	0.002	0.001[a]	0.005[a]	0.01
	Mean	0.003	0.020	0.005	0.02
21-Jun	RK-72	0.001[a]	0.005	0.005	0.08
	LNF-3	0.002	0.003	0.007	0.01[a]
	RK-66	0.001	0.004	0.005[a]	0.01[a]
	RK-56	0.001	0.005	0.005	0.02
	RK-42	0.001	0.010	0.016	0.01[a]
	RK-31	0.002	0.005	0.010	0.01
	EC-6	0.002	0.001	0.007	0.01[a]
	RK-11	0.003	0.001	0.005[a]	0.01[a]
	RK-2	0.003	0.003	0.005[a]	0.01[a]
	Mean	0.002	0.004	0.008	0.04
19-Jul	RK-72	0.001[a]	0.001	0.005[a]	0.01[a]
	LNF-3	0.002	0.001	0.005[a]	0.01[a]
	RK-66	0.002	0.001	0.007	0.01[a]
	RK-56	0.002	0.001	0.005[a]	0.01
	RK-42	0.002	0.001	0.005[a]	0.01
	RK-31	0.005	0.001	0.005[a]	0.01[a]
	EC-6	0.006	0.002	0.005[a]	0.01[a]
	RK-11	0.009	0.001	0.005[a]	0.01[a]
	RK-2	0.003	0.002	0.007	0.01[a]
	Mean	0.004	0.001	0.007	0.01
18-Aug	RK-72	0.001[a]	0.007	0.005[a]	0.01[a]
	LNF-3	0.002	0.007	0.005[a]	0.01
	RK-66	0.002	0.007	0.005[a]	0.01
	RK-56	0.002	0.007	0.005[a]	0.01[a]
	RK-42	0.001	0.006	0.005[a]	0.03
	RK-31	0.002	0.004	0.005[a]	0.02
	EC-6	0.001	0.008	0.006	0.02
	RK-11	0.004	0.002	0.006	0.05
	RK-2	0.004	0.003	0.013	0.01[a]
	Mean	0.002	0.006	0.008	0.02
8-Sep	RK-72	0.003	0.002	0.005[a]	0.01
	LNF-3	0.003	0.001	0.005[a]	0.01[a]
	RK-66	0.003	0.002	0.005[a]	0.01[a]
	RK-56	0.002	0.002	0.005[a]	0.02
	RK-42	0.003	0.002	0.005[a]	0.05
	RK-31	0.003	0.001[a]	0.005[a]	0.03
	EC-6	0.007	0.005	0.005[a]	0.06
	RK-11	0.004	0.001	0.005[a]	0.01[a]
	RK-2	0.005	0.001[a]	0.005[a]	0.05
	Mean	0.004	0.002	0.005	0.04

Appendix A. Table 11. Continued.

Sample Date	Station	Nutrient Concentrations (mg/L)			
		Chlorophyll A (Chl-A)	Nitrate (NO_3-N)	Orthophosphorus (OP)	Total Phosphorus (TP)
6-Oct	RK-72	0.002	0.001	0.001	0.015
	LNF-3	0.002	0.002	0.004	0.010
	RK-66	0.001	0.001	0.004	0.009
	RK-56	0.001	0.001	0.001[a]	0.005
	RK-42	0.002	0.001[a]	0.002	0.006
	RK-31	0.002	0.001[a]	0.001[a]	0.005
	EC-6	0.005	0.001[a]	0.001	0.009
	RK-11	0.002	0.001	0.001[a]	0.006
	RK-2	0.002	0.001	0.001	0.013
	Mean	0.002	0.001	0.002	0.009
8-Nov	RK-72	0.002	0.008	0.001[a]	0.007
	LNF-3	0.003	0.010	0.002	0.005[a]
	RK-66	0.003	0.010	0.001	0.006
	RK-56	0.001	0.009	0.001[a]	0.006
	RK-42	0.002	0.015	0.002	0.007
	RK-31	0.003	0.025	0.002	0.005
	EC-6	0.002	0.012	0.003	0.011
	RK-11	0.001[a]	0.020	0.002	0.005
	RK-2	0.001[a]	0.013	0.001[a]	0.01
	Mean	0.002	0.014	0.002	0.01

[a] Below detection limit, detection limit value listed was used in averaging.

Appendix A. Table 12. Monthly mean concentrations of chlorophyll *a*, nitrate, orthophosphorous, and total phosphorus during Dworshak Reservoir limnological survey, May–November 2004.

Month	Monthly Mean Nutrient Concentrations (mg/L)			
	Chlorophyll A (Chl-A)	Nitrate (NO_3-N)	Orthophosphorus (OP)	Total Phosphorus (TP)
May	0.003	0.016	0.005	0.022
June	0.002	0.004	0.007	0.019
July	0.004	0.001	0.005	0.010
Aug	0.002	0.006	0.006	0.019
Sept	0.004	0.002	0.005	0.028
Oct	0.002	0.001	0.002	0.009
Nov	0.002	0.014	0.002	0.007
Overall Mean	0.003	0.006	0.005	0.016

Appendix A. Table 13. Abundance and bio-volume of phytoplankton collected from single 2 m deep epilimnetic sample at four stations during Dworshak Reservoir limnological survey, May–November 2004.

		RK-2		EC-6		RK-42		RK-66		Mean	
Class	**Species**	**Count (cells/ml)**	**Bio Volume (mm^3/L)**	**Count (cells/ml)**	**Bio Volume (mm^3/L)**	**Count (cells/ml)**	**Bio Volume (mm^3/L)**	**Count (cells/ml)**	**Bio Volume (mm^3/L)**	**Count (cells/ml)**	**Bio Volume (mm^3/L)**
Bacillariophyceae (diatoms)	*Asterionella formosa var1*	0	0.0000	0	0.0000	193	0.0193	61	0.0061	63	0.0064
	Cyclotella comta	0	0.0000	10	0.0035	0	0.0000	0	0.0000	3	0.0009
	Cyclotella glomerata	0	0.0000	0	0.0000	10	0.0005	0	0.0000	3	0.0001
	Fragilaria acus	10	0.0010	20	0.0020	30	0.0030	30	0.0030	23	0.0023
	Fragilaria capucina	0	0.0000	0	0.0000	0	0.0000	30	0.0030	8	0.0008
	Fragilaria crotonensis	30	0.0036	0	0.0000	142	0.0170	132	0.0158	76	0.0091
	Tabellaria fenestrata	0	0.0000	0	0.0000	0	0.0000	10	0.0051	3	0.0013
	Group total	41	0.0047	30	0.0055	375	0.0398	264	0.0330	177	0.0207
Chryso- & Cryptophyceae (flagellates)	*Bitrichia sp.*	0	0.0000	0	0.0000	10	0.0020	0	0.0000	3	0.0005
	Chromulina sp1	71	0.0014	61	0.0012	61	0.0012	61	0.0012	63	0.0013
	Chroomonas acuta	193	0.0289	142	0.0213	41	0.0061	112	0.0167	122	0.0183
	Chryptomonas sp.	203	0.1014	182	0.0912	182	0.0912	365	0.1825	233	0.1166
	Chrysochromulina sp.	142	0.0106	112	0.0084	71	0.0053	112	0.0084	109	0.0082
	Kephyrion sp.	10	0.0005	0	0.0000	0	0.0000	0	0.0000	3	0.0001
	Rhodomonas sp.	1,267	0.1267	963	0.0963	355	0.0355	1,115	0.1115	925	0.0925
	Small microflagellates	264	0.0040	182	0.0027	223	0.0033	274	0.0041	236	0.0035
	Group total	2,149	0.2735	1,642	0.2211	943	0.1446	2,038	0.3244	1,693	0.2409
Dinophyceae (dinoflagellates)	*Peridinium sp1*	30	0.0106	20	0.0071	20	0.0071	30	0.0106	25	0.0089
	Gymnodinium sp2	20	0.0304	0	0.0000	10	0.0152	30	0.0456	15	0.0228
	Group total	51	0.0410	20	0.0071	30	0.0223	61	0.0562	41	0.0317
Chlorophyceae (coccoid greens, desmids, etc.)	*Ankistro-desmus sp.*	30	0.0024	41	0.0032	30	0.0024	41	0.0032	35	0.0028
	Chlorella	30	0.0006	41	0.0008	30	0.0006	41	0.0008	35	0.0007
	Clamydocapsa sp.	10	0.0101	0	0.0000	0	0.0000	20	0.0203	8	0.0076
	Cosmarium sp.	0	0.0000	10	0.0051	0	0.0000	10	0.0051	5	0.0026
	Elakatothrix sp3	10	0.0025	10	0.0025	0	0.0000	10	0.0025	8	0.0019
	Oocystis sp.	0	0.0000	10	0.0051	0	0.0000	0	0.0000	3	0.0013
	Planctonema sp.	0	0.0000	0	0.0000	10	0.0035	0	0.0000	3	0.0009
	Plancto-sphaeria	0	0.0000	0	0.0000	30	0.0304	30	0.0304	15	0.0152
	Tetraedron	10	0.0005	10	0.0005	0	0.0000	0	0.0000	5	0.0003
	Scenedesmus sp.	10	0.0006	10	0.0006	0	0.0000	0	0.0000	5	0.0003
	Spondylosium sp.	10	0.0025	0	0.0000	20	0.0051	61	0.0152	23	0.0057
	Staurastrum sp.	0	0.0000	0	0.0000	0	0.0000	30	0.0304	8	0.0076
	Group total	112	0.0192	132	0.0178	122	0.0420	243	0.1079	152	0.0467
Cyanophyceae (blue-greens)	*Anabaena circinalis*	10	0.0091	10	0.0091	0	0.0000	10	0.0091	8	0.0068
	Aphanothecae sp.	10	0.0010	30	0.0030	0	0.0000	0	0.0000	10	0.0010
	Coelosphaeria sp.	30	0.0228	30	0.0228	0	0.0000	0	0.0000	15	0.0114
	Microcystis sp.	0	0.0000	0	0.0000	10	0.0051	30	0.0152	10	0.0051
	Oscillatoria sp2	720	0.0144	669	0.0134	608	0.0122	679	0.0136	669	0.0134
	Synechococcus sp. (<2 um)	588	0.0029	517	0.0026	608	0.0030	659	0.0033	593	0.0030
	Group total	1,358	0.0502	1,257	0.0509	1,227	0.0203	1,379	0.0412	1,305	0.0407
	GRAND TOTAL	3,710	0.3885	3,082	0.3024	2,696	0.2690	3,984	0.5627	3,368	0.3807

Appendix A. Table 14. Zooplankton densities collected from nine stations during Dworshak Reservoir limnological survey, May–November 2004.

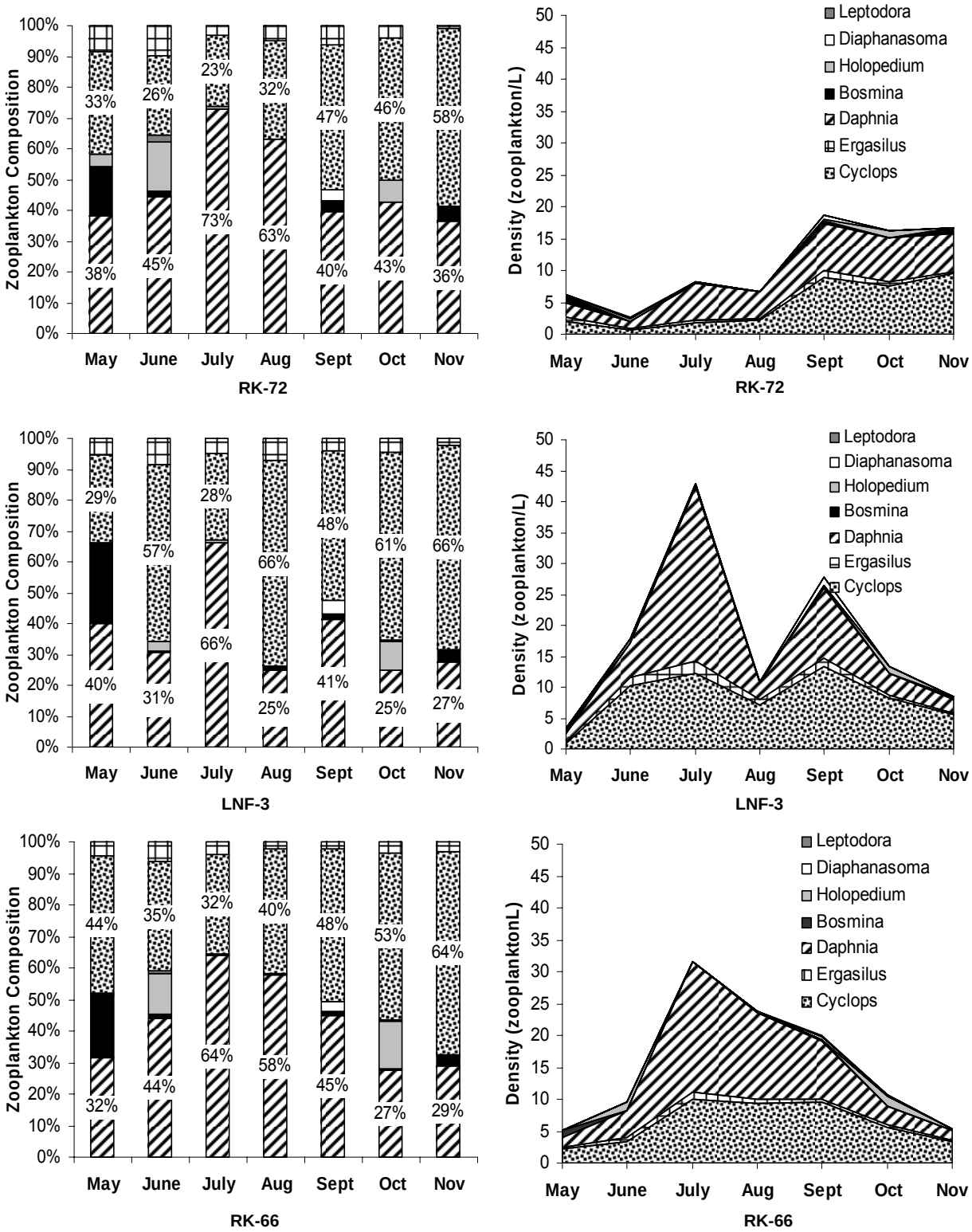
		Zooplankton Densities (number/L)												
		Cladocerans								Copepods				Total
Date	Station	Daphnia	Bosmina	Holop	Lepto	Diaph	Poly	Chydo	Total	Cyclops	Erga	Nauplii	Total	Zoop
5/17/2004	RK-72	2.36	0.98	0.25	0.00	0.00	0.00	0.00	3.59	2.06	0.53	0.00	2.59	6.18
	LNF-3	1.38	0.87	0.01	0.01	0.00	0.00	0.00	2.27	0.98	0.18	0.00	1.16	3.43
	RK-66	1.60	1.00	0.02	0.01	0.00	0.00	0.00	2.63	2.22	0.23	0.00	2.44	5.08
	RK-56	5.37	0.94	0.02	0.02	0.00	0.00	0.00	6.36	5.08	0.43	0.00	5.51	11.87
	RK-42	7.76	0.62	0.00	0.00	0.00	0.00	0.00	8.38	12.86	2.16	0.00	15.02	23.40
	RK-31	11.78	2.00	0.00	0.00	0.00	0.00	0.00	13.78	8.91	1.28	0.00	10.19	23.97
	EC-6	12.25	1.49	0.00	0.00	0.00	0.00	0.00	13.74	14.11	0.50	0.00	14.61	28.34
	RK-11	16.72	2.17	0.00	0.00	0.00	0.00	0.00	18.89	23.91	0.43	0.00	24.35	43.23
	RK-2	8.15	1.36	0.00	0.00	0.00	0.00	0.00	9.51	12.64	0.21	0.00	12.84	22.35
	Mean	7.49	1.27	0.03	0.00	0.00	0.00	0.00	8.79	9.20	0.66	0.00	9.86	18.65
6/21/2004	RK-72	1.15	0.04	0.41	0.06	0.00	0.00	0.07	1.74	0.66	0.25	0.02	0.93	2.67
	LNF-3	5.40	0.13	0.55	0.00	0.00	0.00	0.03	6.12	10.12	1.50	0.11	11.73	17.85
	RK-66	4.23	0.12	1.25	0.07	0.00	0.00	0.01	5.68	3.32	0.60	0.15	4.07	9.74
	RK-56	2.74	0.08	0.84	0.02	0.00	0.00	0.00	3.68	4.37	1.04	0.02	5.42	9.10
	RK-42	4.62	0.07	0.32	0.00	0.00	0.00	0.00	5.01	5.79	0.68	0.02	6.50	11.51
	RK-31	7.21	0.09	0.14	0.03	0.00	0.00	0.00	7.47	10.39	0.99	0.00	11.38	18.85
	EC-6	5.77	0.38	0.19	0.09	0.00	0.00	0.00	6.43	29.05	2.18	0.09	31.32	37.76
	RK-11	5.57	0.00	0.04	0.00	0.00	0.00	0.00	5.61	17.59	1.81	0.00	19.41	25.02
	RK-2	9.50	0.08	0.08	0.08	0.00	0.00	0.00	9.73	21.08	0.61	0.08	21.77	31.50
	Mean	5.13	0.11	0.42	0.04	0.00	0.00	0.01	5.72	11.38	1.07	0.05	12.50	18.22
7/19/2004	RK-72	5.95	0.02	0.07	0.00	0.00	0.00	0.00	6.04	1.87	0.27	0.00	2.14	8.18
	LNF-3	28.39	0.00	0.35	0.00	0.00	0.00	0.00	28.75	12.14	2.00	0.00	14.14	42.89
	RK-66	20.26	0.00	0.06	0.12	0.00	0.12	0.00	20.56	9.98	1.23	0.06	11.28	31.83
	Rk-56	6.36	0.02	0.22	0.00	0.00	0.00	0.00	6.61	8.50	1.14	0.00	9.64	16.25
	RK-42	3.56	0.08	0.15	0.02	0.00	0.00	0.00	3.81	4.43	0.09	0.00	4.52	8.33
	RK-31	7.71	0.03	0.03	0.03	0.00	0.00	0.00	7.81	11.44	0.14	0.03	11.61	19.43
	EC-6	2.96	0.16	0.00	0.16	0.35	0.00	0.00	3.64	12.92	0.56	0.02	13.50	17.14
	RK-11	2.29	0.11	0.00	0.03	0.00	0.00	0.00	2.43	9.37	0.17	0.00	9.54	11.97
	RK-2	7.61	0.23	0.00	0.06	0.09	0.00	0.00	7.98	10.25	0.17	0.00	10.42	18.40
	Mean	9.46	0.07	0.10	0.05	0.05	0.01	0.00	9.74	8.99	0.64	0.01	9.64	19.38
8/19/2004	RK-72	4.22	0.00	0.00	0.00	0.00	0.00	0.00	4.22	2.13	0.32	0.03	2.48	6.70
	LNF-3	2.70	0.02	0.04	0.02	0.06	0.00	0.00	2.84	7.21	0.79	0.00	8.01	10.85
	RK-66	13.71	0.04	0.00	0.00	0.00	0.00	0.00	13.75	9.36	0.57	0.04	9.97	23.73
	RK-56	8.21	0.03	0.03	0.03	0.00	0.00	0.00	8.31	4.22	1.20	0.00	5.42	13.72
	RK-42	9.06	0.23	0.23	0.00	4.35	0.00	0.00	13.88	3.31	0.44	0.00	3.75	17.63
	RK-31	2.24	0.48	0.02	0.02	5.16	0.00	0.00	7.91	5.72	0.14	0.00	5.86	13.77
	EC-6	1.10	0.26	0.00	0.00	3.88	0.00	0.00	5.24	5.56	0.28	0.00	5.84	11.08
	RK-11	0.31	0.07	0.00	0.07	4.04	0.00	0.00	4.48	8.50	0.33	0.00	8.83	13.32
	RK-2	0.32	0.32	0.00	0.00	12.30	0.00	0.00	12.94	3.19	0.56	0.00	3.74	16.68
	Mean	4.65	0.16	0.04	0.02	3.31	0.00	0.00	8.17	5.47	0.52	0.01	5.99	14.17

Appendix A. Table 14. Continued.

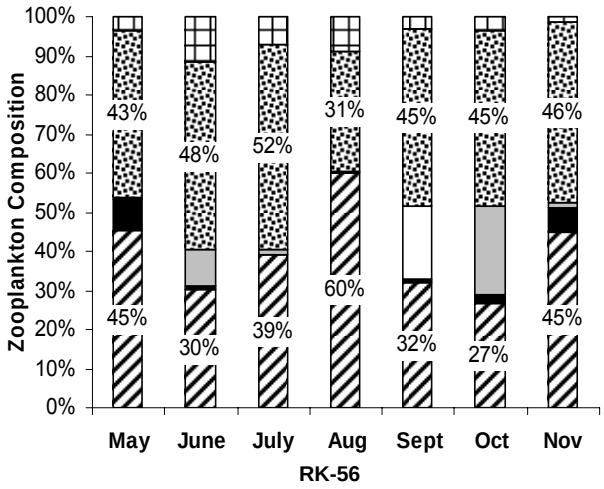
		Zooplankton Densities (number/L)												
		Cladocerans								Copepods				Total
Date	Station	Daphnia	Bosmina	Holop	Lepto	Diaph	Poly	Chydo	Total	Cyclops	Erga	Nauplii	Total	Zoop
9/8/2004	RK-72	7.39	0.57	0.06	0.00	0.72	0.00	0.00	8.73	8.79	1.14	0.24	10.17	18.90
	LNF-3	11.45	0.47	0.00	0.05	1.25	0.00	0.00	13.22	13.43	1.15	0.16	14.73	27.95
	RK-66	8.97	0.18	0.00	0.07	0.61	0.00	0.00	9.83	9.61	0.47	0.11	10.19	20.02
	RK-56	5.24	0.09	0.06	0.00	3.10	0.00	0.00	8.50	7.47	0.48	0.00	7.95	16.45
	RK-42	1.31	0.00	0.00	0.00	18.62	0.00	0.00	19.93	5.59	0.83	0.16	6.58	26.51
	RK-31	1.86	0.04	0.15	0.11	4.22	0.00	0.00	6.38	13.67	1.03	0.04	14.73	21.11
	EC-6	6.31	0.33	0.00	0.17	3.38	0.00	0.00	10.19	13.20	1.46	0.08	14.75	24.94
	RK-11	1.97	0.07	0.00	0.07	0.02	0.00	0.00	2.12	6.28	0.86	0.03	7.17	9.29
	RK-2	3.67	0.12	0.00	0.04	0.02	0.00	0.00	3.85	6.23	0.66	0.02	6.92	10.77
	Mean	5.35	0.21	0.03	0.06	3.55	0.00	0.00	9.19	9.36	0.90	0.09	10.35	19.55
10/6/2004	RK-72	6.90	0.00	1.14	0.00	0.02	0.00	0.00	8.05	7.47	0.66	0.06	8.20	16.25
	LNF-3	3.34	0.02	1.25	0.00	0.05	0.00	0.00	4.66	8.15	0.62	0.02	8.80	13.46
	RK-66	2.90	0.04	1.63	0.00	0.02	0.00	0.00	4.59	5.60	0.38	0.00	5.98	10.57
	RK-56	7.15	0.56	6.12	0.00	0.00	0.00	0.00	13.83	12.00	0.95	0.00	12.96	26.79
	RK-42	2.16	0.10	1.30	0.00	0.00	0.00	0.00	3.56	2.24	0.19	0.00	2.43	5.99
	RK-31	7.90	0.10	3.14	0.00	0.16	0.00	0.00	11.30	10.36	1.05	0.00	11.41	22.71
	EC-6	13.16	0.08	0.21	0.00	0.13	0.00	0.00	13.58	15.55	1.98	0.04	17.57	31.14
	RK-11	9.39	0.56	0.70	0.05	0.14	0.00	0.00	10.84	8.73	1.13	0.09	9.95	20.79
	RK-2	4.01	0.12	0.69	0.10	0.02	0.00	0.00	4.94	4.03	0.76	0.02	4.82	9.76
	Mean	6.32	0.18	1.80	0.02	0.06	0.00	0.00	8.37	8.24	0.86	0.03	9.12	17.50
11/8/2004	RK-72	6.05	0.80	0.03	0.00	0.00	0.00	0.00	6.89	9.58	0.13	0.47	10.18	17.06
	LNF-3	2.29	0.33	0.02	0.00	0.00	0.00	0.00	2.64	5.54	0.18	0.10	5.82	8.46
	RK-66	1.52	0.16	0.01	0.00	0.01	0.00	0.01	1.70	3.38	0.17	0.07	3.62	5.32
	RK-56	2.86	0.42	0.07	0.00	0.01	0.00	0.00	3.37	2.96	0.08	0.11	3.15	6.51
	RK-42	3.27	0.49	0.00	0.02	0.00	0.00	0.00	3.78	4.66	0.19	0.17	5.03	8.81
	RK-31	0.95	0.31	0.01	0.00	0.00	0.00	0.00	1.26	2.39	0.05	0.02	2.47	3.73
	EC-6	4.54	0.56	0.00	0.04	0.00	0.00	0.00	5.14	23.17	0.52	0.04	23.73	28.88
	RK-11	3.58	4.05	0.00	0.00	0.00	0.00	0.00	7.63	11.07	0.72	0.10	11.88	19.51
	RK-2	1.81	0.59	0.01	0.00	0.00	0.00	0.00	2.41	3.07	0.22	0.02	3.32	5.73
	Mean	2.99	0.86	0.02	0.01	0.00	0.00	0.00	3.87	7.31	0.25	0.12	7.69	11.56

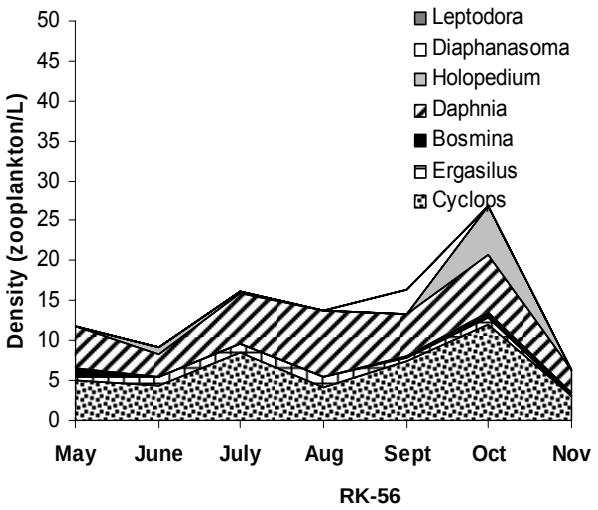
Holop = *Holopedium sp.*
Lepto = *Leptodora sp.*
Diaph = *Diaphanosoma sp.*
Poly = *Polyphemus sp.*
Chydo = *Chydorid spp.*
Erga = Ergasilus sp.

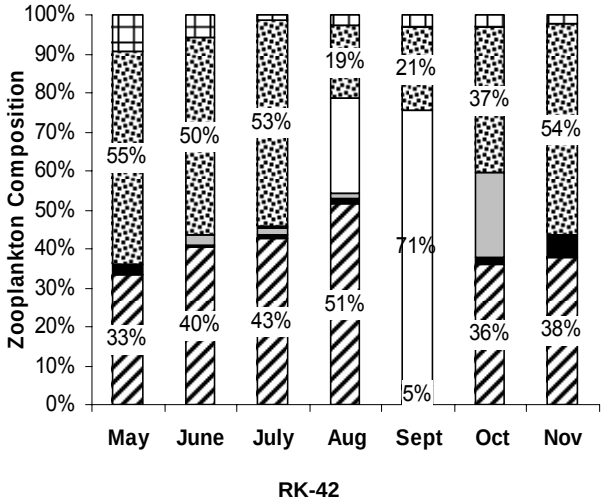
Appendix A. Table 15. Zooplankton composition and densities at each of nine stations collected during Dworshak Reservoir limnological survey, May–November 2004.

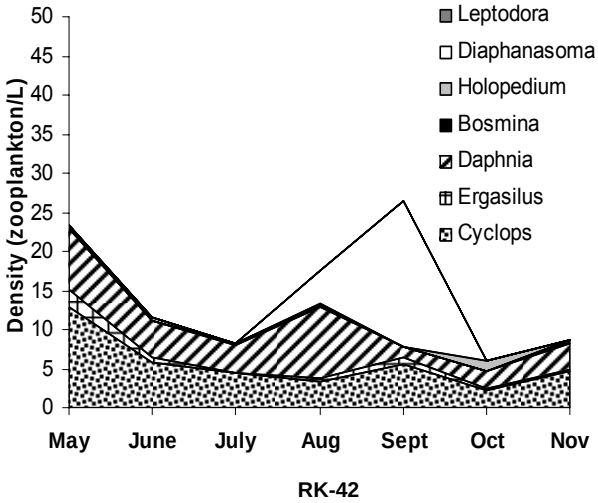


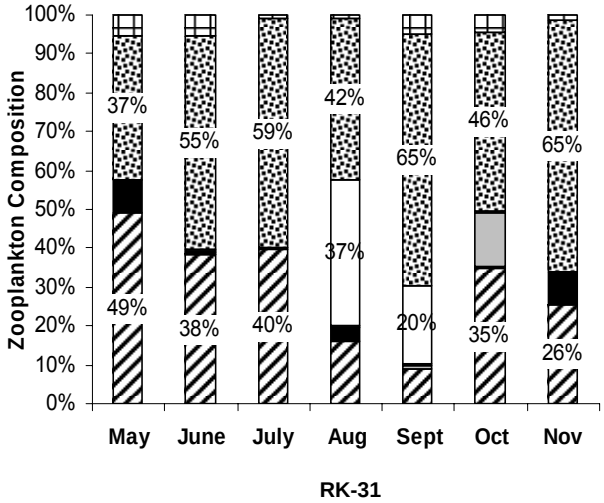
Appendix A. Table 15. Continued.

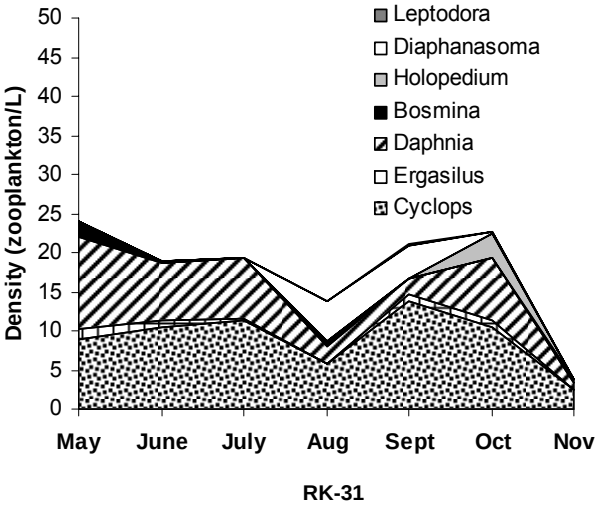




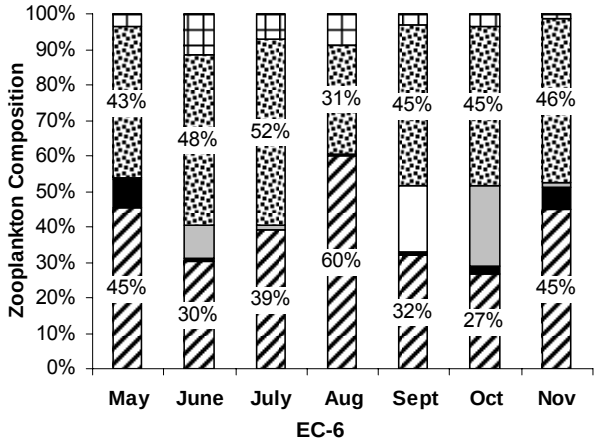


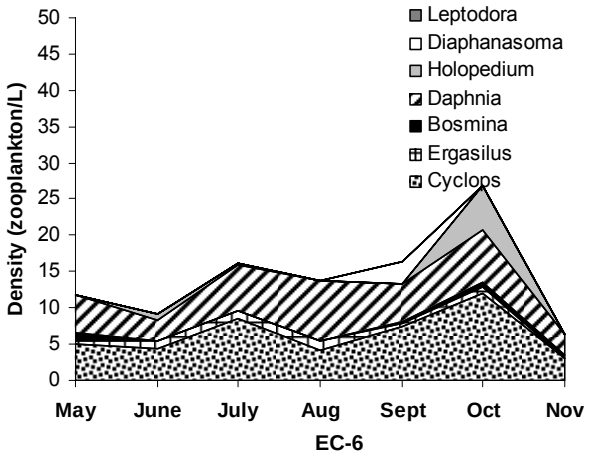


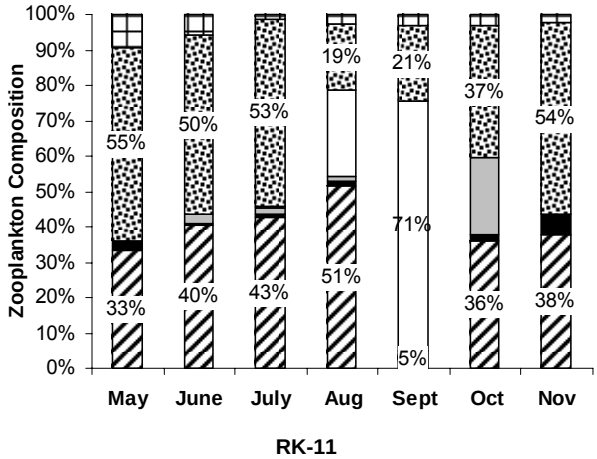


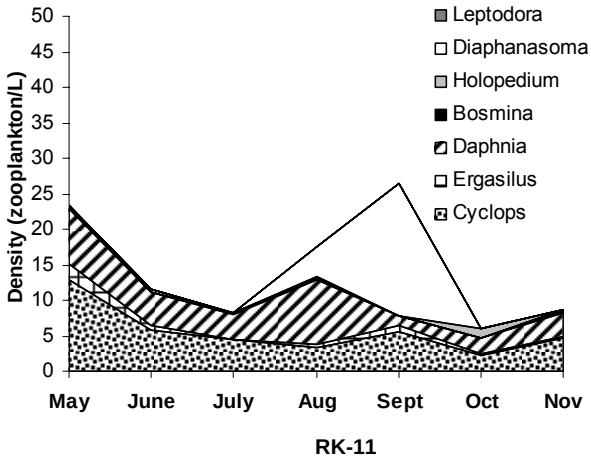


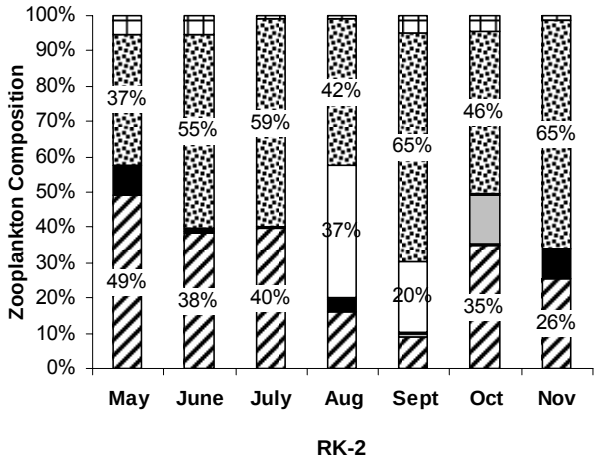
Appendix A. Table 15. Continued.

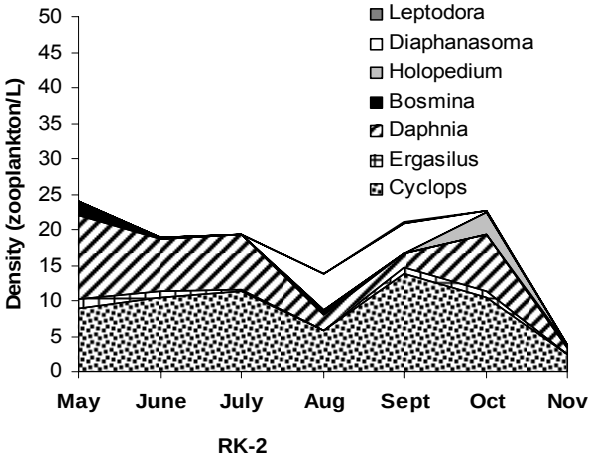












Appendix A. Table 16. Monthly mean zooplankton length statistics collected from nine stations during Dworshak Reservoir limnological survey, May–November 2004.

	Mean Zooplankton Lengths (µm)														
	Daphnia					Bosmina					Cyclops				
Date	Min	Max	Mean	Sample Size (n)	Standard Deviation (±)	Min	Max	Mean	Sample Size (n)	Standard Deviation (±)	Min	Max	Mean	Sample Size (n)	Standard Deviation (±)
5/17/04	567	1650	986	180	278	267	600	359	180	81	433	1467	812	180	272
6/21/04	633	1933	1331	180	328	267	667	365	38	77	400	1333	801	180	174
7/19/04	633	2300	1326	180	406	233	467	347	26	55	433	1433	848	180	195
8/19/04	567	2233	1300	162	375	200	467	331	61	56	400	1300	895	180	208
9/8/04	600	2133	1195	180	334	200	500	338	55	60	400	1300	842	180	245
10/6/04	633	1800	1158	180	292	200	433	311	47	64	433	1333	922	180	202
11/8/04	533	1567	949	180	263	233	500	358	168	64	367	1333	740	180	211
Overall	533	1567	1167	1242	367	167	667	333	575	67	367	1467	833	1260	233

Appendix A. Table 17. Station mean zooplankton length statistics collected from nine stations during Dworshak Reservoir limnological survey, May–November 2004.

	Mean Zooplankton Lengths (µm)														
	Daphnia					Bosmina					Cyclops				
Station	Min	Max	Mean	Sample Size (n)	Standard Deviation (±)	Min	Max	Mean	Sample Size (n)	Standard Deviation (±)	Min	Max	Mean	Sample Size (n)	Standard Deviation (±)
RK-72	567	2000	1195	140	359	233	533	357	72	65	400	1333	837	140	242
LNF-3	567	2100	1159	140	367	233	467	340	59	62	367	1333	823	140	223
RK-66	533	2233	1195	140	346	233	600	348	51	69	433	1433	854	140	241
RK-56	533	2100	1147	140	362	233	667	345	66	78	433	1433	836	140	247
RK-42	633	1867	1190	140	328	233	600	348	67	70	367	1467	816	140	237
RK-31	600	2000	1171	140	346	233	533	347	69	65	433	1167	811	140	197
EC-6	567	2200	1128	140	397	200	567	343	74	61	400	1433	822	140	223
RK-11	633	2300	1219	134	343	200	500	352	65	82	467	1367	878	140	195
RK-2	633	2133	1180	128	378	200	600	365	70	81	400	1367	858	140	205
Overall	533	1567	1167	1242	367	167	667	333	575	67	367	1467	833	1260	233

Appendix A. Table 18. Number of trawl caught kokanee by 10 mm total length class collected from hauls during Dworshak Reservoir limnological survey, May–November 2004.

Total Length Class (mm)	Number of Trawl Caught Kokanee						
	May	June	July	Aug	Sep	Oct	Nov
20	58	51	1	0	0	0	0
30	37	196	209	6	0	0	0
40	0	9	660	161	26	0	0
50	0	0	169	379	159	3	1
60	0	0	18	206	293	25	5
70	0	0	1	45	229	48	29
80	0	0	2	8	48	61	90
90	0	0	0	1	9	53	154
100	3	0	1	0	0	24	103
110	7	2	6	0	0	3	54
120	6	1	3	0	0	0	16
130	14	4	1	0	0	0	6
140	14	3	3	0	0	0	4
150	23	9	10	1	0	0	0
160	16	10	15	1	1	0	0
170	10	17	8	4	0	1	0
180	3	7	17	6	1	0	0
190	2	7	23	6	3	1	0
200	0	4	32	11	8	1	2
210	0	3	33	13	22	7	12
220	0	3	20	20	39	12	11
230	0	1	7	13	18	7	12
240	0	0	2	2	5	9	16
250	2	0	1	1	1	2	5
260	8	0	1	0	1	0	5
270	4	8	5	0	0	0	0
280	7	10	9	2	1	0	1
290	7	9	13	4	0	0	0
300	0	6	12	1	0	0	1
310	0	1	13	4	0	0	0
320	0	0	1	8	0	0	0
330	0	0	1	3	0	0	0
340	0	0	0	1	0	0	0
350	0	0	0	0	0	0	0
Total:	221	361	1297	907	864	257	527

Appendix A. Table 19. Monthly mean catch, length, and growth of age-0, age-1, and age-2 kokanee captured during trawl sampling in Dworshak Reservoir, May–November 2004.

	Age-0			Age-1			Age-2			Total	
Month	Number Caught	Mean Length (mm)	Mean Growth (mm)	Number Caught	Mean Length (mm)	Mean Growth (mm)	Number Caught	Mean Length (mm)	Mean Growth (mm)	Number Caught	Mean Growth (mm)
May	95	24	^	98	145	^	28	273	^	221	6
June	256	28	4.5	71	169	24.5	34	285	11.5	361	13.5
July	1060	40	11.7	183	190	20.1	54	295	10.1	1297	14.0
Aug	806	52	11.8	78	208	18.9	23	311	16.1	907	15.6
Sept	764	62	10.0	99	218	9.3	1	*	*	864	9.6
Oct	217	80	18.3	40	224	5.7	0	*	*	257	12.0
Nov	462	93	12.8	65	232	8.3	0	*	*	527	10.6
Mean	523		11.5	91		14.5	20		12.6	633	12.5
Total	3660		69	634		87			38	4434	75

^ Statistic not computable, since previous month's data is not existent.
* No age-2 fish captured, therefore statistic not computable.

Appendix A. Table 20. Kokanee length, weight, and stomach contents captured during trawl sampling in Dworshak Reservoir, May–November 2004.

		Kokanee			Kokanee Stomach Contents (number/stomach)					
					Cladocerans			Copepods		
Date	Reservoir Section	Length (mm)	Weight (g)	Age	Daphnia	Bosmina	Leptodora	Cyclops	Ergasilus	Unknown
5/20/2004	2	135	18	1	82	0	0	0	0	351
5/20/2004	2	270	162	2	19	0	0	1	0	88
5/20/2004	2	260	143	2	119	0	0	6	0	283
5/20/2004	2	260	157	2	154	1	0	6	0	242
5/20/2004	2	257	149	2	207	0	0	8	0	251
5/20/2004	2	289	195	2	192	3	0	5	0	206
5/24/2004	1	295	213	2	114	0	0	0	0	71
5/24/2004	1	259	152	2	108	0	0	0	0	140
5/24/2004	1	143	24	1	139	0	0	1	0	40
5/24/2004	1	190	54	1	112	0	0	1	1	95
5/24/2004	2	265	172	2	104	0	0	0	0	87
5/24/2004	2	269	175	2	108	0	0	1	1	101
5/24/2004	2	268	175	2	103	0	0	0	0	56
5/24/2004	2	278	184	2	116	0	0	1	0	27
5/24/2004	2	296	212	2	100	0	0	1	0	31
5/24/2004	2	171	44	1	146	0	0	0	0	267
6/14/2004	3	292	216	2	447	0	0	5	0	121
6/14/2004	2	273	197	2	118	0	0	1	0	167
6/14/2004	2	296	239	2	98	0	0	2	0	141
6/14/2004	2	278	209	2	121	0	0	0	0	36
6/14/2004	2	285	217	2	101	0	1	0	0	27
6/14/2004	2	175	48	1	427	0	3	2	0	53
6/14/2004	2	292	239	2	413	0	19	0	0	22
6/14/2004	2	156	29	1	129	0	9	1	0	30
6/14/2004	2	196	63	1	436	0	0	2	0	13
6/14/2004	2	177	45	1	414	0	2	2	0	69
6/15/2004	1	292	234	2	141	0	0	1	0	99
6/15/2004	1	289	218	2	428	0	0	3	0	123
6/15/2004	1	166	35	1	404	1	0	4	0	161
6/15/2004	2	307	0	2	407	0	0	7	0	173
6/15/2004	2	304	0	2	411	2	0	3	0	201
6/15/2004	2	223	95	1	120	1	0	2	0	123
6/15/2004	2	139	21	1	117	0	0	0	0	148
6/15/2004	2	116	11	1	410	0	0	3	0	135
6/15/2004	2	281	198	2	434	0	0	9	0	130
7/12/2004	3	217	93	1	404	0	2	0	0	76
7/12/2004	3	186	55	1	446	0	5	0	0	84
7/12/2004	3	216	94	1	467	0	4	0	0	115
7/12/2004	3	203	81	1	430	0	0	0	0	103
7/12/2004	3	206	81	1	405	1	0	0	0	31
7/12/2004	3	190	56	1	118	0	0	0	0	67
7/12/2004	3	216	95	1	418	2	1	0	0	147
7/13/2004	2	303	247	2	447	0		0		193
7/13/2004	2	204	75	1	117	0	1	1	0	76
7/13/2004	2	217	88	1	128	0	2	0	0	136
7/13/2004	2	213	83	1	418	0	0	3	0	0
7/13/2004	2	181	48	1	422	0	6	2	0	174
7/13/2004	2	211	76	1	128	0	0	0	0	86
7/13/2004	2	291	215	2	434	0	0	3	0	187
7/14/2004	1	200	70	1	111	0	3	0	0	76
7/14/2004	1	204	68	1	424	0	0	0	0	179
8/23/2004	3	220	88	1	418	0	7	1	0	102
8/24/2004	2	185	46	1	444	0	1	2	0	44
8/24/2004	2	189	58	1	447	0	0	0	0	58
8/24/2004	2	197	66	1	107	0	0	0	0	130
8/24/2004	2	174	44	1	456	0	0	3	0	86
8/24/2004	2	203	67	1	427	0	5	2	0	94
8/24/2004	2	205	80	1	409	0	8	2	0	143
8/24/2004	2	218	84	1	438	0	6	1	0	117
8/24/2004	2	212	68	1	504	0	0	4	0	72
8/24/2004	2	180	48	1	415	0	11	5	0	168

Appendix A. Table 20. Continued.

		Kokanee			Kokanee Stomach Contents (number/stomach)					
					Cladocerans			Copepods		
Date	Reservoir Section	Length (mm)	Weight (g)	Age	Daphnia	Bosmina	Leptodora	Cyclops	Ergasilus	Unknown
8/24/2004	2	203	73	1	424	0	0	0	0	53
8/24/2004	2	206	72	1	429	0	0	0	0	23
8/26/2004	1	229	104	1	400	0	6	0	0	37
9/13/2004	2	215	91	1	480	0	3	1	0	96
9/13/2004	2	233	121	2	416	0	3	0	0	173
9/13/2004	3	211	80	1	410	1	7	0	0	62
9/13/2004	3	224	100	1	118	0	0	2	0	78
9/13/2004	3	236	127	2	437	0	12	0	0	28
9/14/2004	1	190	56	1	391	0	6	18	0	74
9/14/2004	1	242	128	2	393	0	16	8	0	97
9/14/2004	1	215	87	1	428	0	5	4	0	43
9/14/2004	1	225	101	1	418	0	9	1	0	76
9/14/2004	1	230	113	1	407	0	11	2	0	56
9/14/2004	1	266	166	2	466	0	4	6	0	36
9/14/2004	1	227	101	1	397	8	14	0	0	14
9/14/2004	1	224	97	1	466	1	10	3	0	128
9/14/2004	1	229	101	1	425	0	12	6	0	15
9/14/2004	1	160	36	1	387	0	8	7	0	45
10/12/2004	3	230	112	1	409	0	0	0	0	38
10/12/2004	3	240	131	2	503	0	0	3	0	81
10/12/2004	3	248	146	2	544	0	7	0	0	32
10/12/2004	3	252	167	2	523	1	4	1	0	14
10/13/2004	1	225	112	1	498	0	0	0	0	186
10/13/2004	1	243	129	2	428	0	0	2	0	149
10/13/2004	1	250	144	2	433	0	0	0	0	138
10/13/2004	1	242	134	2	414	0	0	2	0	78
10/13/2004	1	221	98	1	449	0	0	0	0	40
10/13/2004	1	216	97	1	426	0	0	0	0	110
10/13/2004	1	237	129	2	520	0	0	6	0	206
10/13/2004	1	241	124	2	430	0	1	5	0	0
10/13/2004	1	240	128	2	417	0	2	2	0	77
11/15/2004	2	233	109	2	406	0	0	4	0	144
11/15/2004	2	212	81	1	462	0	0	0	0	157
11/15/2004	2	214	84	1	419	0	0	0	0	98
11/15/2004	3	230	100	1	452	0	0	4	0	136
11/15/2004	3	242	154	2	538	0	0	3	0	179
11/16/2004	1	260	155	2	13	0	0	1	0	395
11/16/2004	1	236	112	2	445	0	0	5	0	129
Mean					338.15	0.23	2.46	2.08	0.02	104.47
Percent Composition					75.579%	0.051%	0.549%	0.465%	0.005%	23.351%

Appendix A. Table 21. Chlorophyll *a* maximum, mean, and minimum concentrations for select stations collected during limnological sampling on Dworshak Reservoir, 1992-995 and 2004.

	Chlorophyll *a* Concentration (µg/L)									
	RK-2		EC-6		RK-31		RK-56		LNF-3	
Measure	1992-1995	2004	1992-1995	2004	1992-1995	2004	1992-1995	2004	1992-1995	2004
Maximum	5.1	5.0	10.5	7.0	6.7	5.0	4.1	2.0	5.6	6.0
Mean	2.4	2.8	3.6	3.7	2.4	2.7	2.3	1.6	2.9	2.9
Minimum	0.5	0.5	0.5	1.0	0.3	2.0	0.4	1.0	0.3	2.0
Number of Cases (n)	40	7	21	7	22	7	13	7	13	7
Standard Deviation (±)	1.1	1.5	2.7	2.3	1.6	1.1	1.2	0.5	1.5	1.5

Appendix A. Table 22. Epilimnetic maximum, mean, and minimum nitrite + nitrate concentrations for select stations collected during limnological sampling on Dworshak Reservoir 1972–1975, 1992–1995, and 2004.

	Nitrate Concentrations (ug/L)														
	RK-2			EC-6			RK-31			RK-56			LNF-3		
Measure	**1972-1975**	**1992-1995***	**2004**	**1972-1975**	**1992-1995***	**2004**	**1972-1975**	**1992-1995***	**2004**	**1972-1975**	**1992-1995***	**2004**	**1972-1975**	**1992-1995***	**2004**
Maximum	52	20	3	45	20	8	41	37	14	45	57	24	45	80	30
Mean	38	8	2	33	10	3	31	13	5	31	15	8	31	22	8
Minimum	15	5	1	17	5	1	19	5	1	18	5	1	17	6	1
Number of Cases (n)	3	20	5	3	14	5	3	12	5	3	13	5	3	13	5
Standard Deviation (±)	20	4	1	14	6	3	11	9	5	14	14	9	14	23	12

* Nitrate values listed for 1992 – 1995 data are Nitrite + Nitrate values (Juul and Funk 1996).

Appendix A. Table 23. Epilimnetic maximum, mean, and minimum orthophosphate concentrations for select stations collected during limnological sampling on Dworshak Reservoir, 1972–1975, 1992–1995, and 2004.

	Orthophosphorus Concentrations (ug/L)														
	RK-2			EC-6			RK-31			RK-56			LNF-3		
Measure	**1972-1975**	**1992-1995**	**2004**	**1972-1975**	**1992-1995**	**2004**	**1972-1975**	**1992-1995**	**2004**	**1972-1975**	**1992-1995**	**2004**	**1972-1975**	**1992-1995**	**2004**
Maximum	19	1	13	22	3	7	17	2	10	16	6	5	27	4	7
Mean	16	1	6	18	1	4	13	1	4	13	1	3	18	1	3
Minimum	11	1	3	12	1	3	10	1	3	10	1	3	11	1	3
Number of Cases (n)	3	20	5	3	14	5	3	12	5	3	13	5	3	13	5
Standard Deviation (±)	4	0	5	5	1	2	4	0	3	3	2	1	8	1	2

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