FISHERY RESEARCH

DWORSHAK RESERVOIR NUTRIENT ENHANCEMENT RESEARCH, 2009

DWORSHAK DAM RESIDENT FISH MITIGATION PROJECT

ANNUAL PROGRESS REPORT
March 1, 2009 – February 28, 2010

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ABSTRACT

Nutrient supplementation is being tested as a means to restore declining reservoir productivity and benefit fisheries in Dworshak Reservoir. In 2007, Idaho Department of Fish and Game (IDFG) and the U.S. Army Corps of Engineers (USACE) began a cooperative nutrient supplementation experiment on the reservoir, wherein USACE applied nutrients, IDFG monitored the results using a combination of limnological and fish surveys, and TG Eco-Logic provided the nutrient application schedule and analyzed limnological data. This report summarizes results from 2009, the third year of the project.

In 2009, the snowpack and resulting runoff were about average. A thermocline developed earlier and dissipated later than usual. Dissolved oxygen minima, which are typically observed during late summer and fall, were similar to previous years. None of the water quality standards set forth in the Consent Order issued by the Idaho Department of Environmental Quality (IDEQ) were violated. The median Secchi depth of 3.0 m equaled, but did not exceed, the specified limit. Measurements of total dissolved phosphorus (TDP) and chlorophyll *a* (Chl *a*) in the epilimnion were well below upper limits specified in the Consent Order.

Picoplankton densities in 2009 remained above 2006 levels. Densities of edible phytoplankton, including flagellates, coccoid greens and edible blue-green taxa increased in 2009. With the exception of large, colonial blue-greens, inedible taxa appeared to decrease from previous years. In particular, *Microcystis* densities were of concern, although microcystins were never detected. Increases in edible phytoplankton taxa appear to be sustaining increases in the biomass of large zooplankton, such as *Daphnia*. Mean kokanee lengths decreased from the previous year concurrent with an increased density of age-1 and older fish. However, mean relative weight remained similar to or better than presupplementation years.

Dworshak Reservoir appears to be responding positively to nutrient supplementation through the first three years of the experiment. This is evidenced by a dramatic increase in picoplankton observed during the first year of the experiment, followed by increases in edible phytoplankton and zooplankton in subsequent years. Kokanee size increased initially but appears to be dropping off due to increases in density. These results are similar to those reported for Kootenay and Arrow lakes in British Columbia.

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INTRODUCTION

Dworshak Reservoir is the most popular fishing destination in Clearwater County and the third most popular destination in the Clearwater region, based on total angler trips in 2003 (IDFG 2003a). It provides a multispecies fishery for naturally reproducing kokanee *Oncorhynchus nerka*, smallmouth bass *Micropterus dolomieu,* and cutthroat trout *Oncorhynchus clarkii*, as well as hatchery stocked rainbow trout *Oncorhynchus mykiss*. Furthermore, the reservoir provides important habitat for Endangered Species Act (ESA) listed bull trout *Salvelinus confluentus*.

Kokanee provide the most popular fishery on the reservoir, with annual effort levels that have exceeded 140,000 angler hours and annual harvests of over 200,000 fish (Mauser et al. 1989). The pelagic nature and planktivorous feeding habits of kokanee make them well suited for an oligotrophic reservoir with fluctuating water levels, such as Dworshak Reservoir (Maiolie and Elam 1996). Kokanee were first stocked into Dworshak Reservoir in 1972 (Horton 1981). Although two stocks were originally introduced (early spawners from Anderson Ranch Reservoir, Idaho and late spawners from Lake Whatcom, Washington), the early spawning variety soon dominated (Horton 1981).

Entrainment and oligotrophication have been identified as the primary factors limiting the kokanee population in Dworshak Reservoir (Stark and Stockner 2006). With the exception of high runoff years, entrainment was reduced beginning in the early 1990s when drawdown began occurring during the summer and early autumn to provide cool water for Chinook salmon *Oncorhynchus tshawytscha* in the Snake River. During this time period kokanee are distributed farther from the dam and less vulnerable to entrainment than during winter (Maiolie and Elam 1997). Bennett (1997) found that discharge from January through March had the highest negative correlation with survival compared to other time periods examined. While entrainment remains a limiting factor for kokanee in some years, oligotrophication is more often the primary limiting factor. Bennett (1997) identified declining productivity as a critical factor limiting the kokanee fishery and recommended it be addressed before implementing intensive fisheries management practices.

Following this recommendation, Stockner and Brandt (2005) provided a detailed assessment of the reservoir and recommendations for a nutrient supplementation program. Based on phosphorous loading and mean chlorophyll densities, they classified Dworshak Reservoir as borderline oligo-mesotrophic. However, they found that the phytoplankton communities and associated food web present during the spring were dominated by microbial communities typical of ultraoligotrophic lakes and reservoirs. Dworshak Reservoir becomes nitrogen limited by mid-summer, leading to a dominance of nitrogen fixing blue-green algae. Blue-green algae are typically abundant from mid-summer to early fall and, because they are inedible to zooplankton, represent a considerable carbon sink. These inefficiencies in the food web result in suboptimal fish production.

The Idaho Department of Fish and Game (IDFG) and the U.S. Army Corps of Engineers (USACE) initiated a five-year nutrient supplementation experiment in 2007. This report covers results of the third year of supplementation. The USACE applied ammonium nitrate to the reservoir on a weekly basis from April through September (see Scofield et al. 2010) for spread tables), and IDFG conducted surveys to monitor limnological changes and the kokanee population response. TG Eco-Logic, a private consulting company, was contracted to interpret the results of the limnological data and adjust the nutrient prescriptions as necessary. The goal of the program is to restore the system productivity by improving the nitrogen (N) to phosphorus

(P) ratios in the reservoir, thereby promoting the growth of desirable phytoplankton (i.e. edible by zooplankton). Increased abundance of edible phytoplankton is expected to lead to an increased abundance of zooplankton, therefore providing an improved forage base for fish. Stockner and Brandt (2005) anticipated that a moderate N nutrient supplementation would benefit fish populations without degrading water quality.

The primary task of the monitoring program carried out by IDFG was to evaluate the effectiveness of the nutrient supplementation program at improving the flow of carbon to the kokanee population in Dworshak Reservoir without adversely affecting water quality. Thus, limnological surveys were conducted to meet three major requirements. The first requirement was to ensure that water quality standards, as stipulated in the Consent Order issued by the Idaho Department of Environmental Quality (IDEQ), were maintained. Secondly, limnological data were collected to make comparisons with presupplementation conditions to determine the biological effects of the project, including changes to the plankton communities. Finally, data were provided to TG Eco-Logic to actively manage the nutrient applications. In addition to limnological monitoring, surveys were conducted to monitor the kokanee population. The objectives in the IDFG Fisheries Management Plan for the Dworshak Reservoir kokanee fishery are to maintain a catch rate of 0.7 fish per hour with an average size of 254 mm (IDFG 2003b). An effective nutrient supplementation program is expected to increase the average size of kokanee at any given population density. Kokanee surveys were conducted to determine whether this occurred and if nutrient supplementation will allow for management plan objectives to be achieved.

STUDY SITE

Dworshak Reservoir was impounded after the construction of Dworshak Dam in 1972 on the North Fork Clearwater River approximately 2.4 km from its confluence with the main-stem Clearwater River. The reservoir is narrow, steeply sloped, and primarily surrounded by coniferous forests. The North Fork Clearwater River and its tributaries drain nearly 632,000 ha, which is composed primarily of montane forests in steeply sloped terrain (Falter et al. 1977). The underlying geology is composed of Columbia River basalt and metamorphic sediments with granitic intrusions covered by shallow soils (Falter et al. 1977). Most of the North Fork Clearwater watershed above the reservoir lies within the Clearwater National Forest. The reservoir is immediately surrounded by land managed by the USACE, but much of the lower watershed is privately owned. The primary commercial activity is timber harvest, although there is some agriculture in the lower watershed.

At full pool, Dworshak Reservoir is 86.3 km long with a surface area of 6,916 ha and a volume of 4.3 billion m^3 (Falter 1982). A typical annual drawdown lowers the pool elevation by 24 m and reduces the surface area by 27%. Peak pool elevation is typically reached by late June and drawdown begins after the first week of July, with winter levels reached by the second week of September. The mean hydraulic retention time is 10.2 months (Falter 1982) and the mean daily discharge from 1999-2008 was 151 m^3/s (http://www.cbr.washington.edu/dart/; accessed January 2010).

As part of our sampling design, the reservoir was stratified into three sections (Figure 1). Section 1 extended from the dam to Dent Bridge at river kilometer 27.0, while Section 2 extended from Dent Bridge to Grandad Bridge at river kilometer 65.2. Section 3 encompassed the reservoir above Grandad Bridge. This stratified design was used for the kokanee surveys and for allocating nutrient applications.

Limnological sampling was conducted at seven stations on the reservoir and one station on the North Fork Clearwater River (NFC) below Dworshak Dam (Figure 1). Five stations on the main reservoir were designated as RK-2, RK-31, RK-56, RK-66, and RK-72, where the numerical portion of the station name corresponds with the approximate river kilometer (RKM). Two additional stations were located in untreated areas of the reservoir, RKM six of the Elk Creek arm (EC-6) and RKM three of the Little North Fork arm (LNF-3).

OBJECTIVE

1. Maintain a kokanee population that can sustain a catch rate of 0.7 fish per hour with a minimum average size of 254 mm total length by 2015.

METHODS

Environmental Conditions

Daily mean reservoir inflow, discharge, and pool elevation data provided by the USACE were acquired through the Columbia River Data Access in Real Time (DART) website (http://www.cbr.washington.edu/dart/; accessed January 2010).

Physical and Chemical Limnology

Sample Collection

Limnological sampling was conducted twice monthly from April through September and once monthly during March, October, and November. Because all seven reservoir stations and the river station could not be sampled in one day, samples were collected over a two-day period. Stations RK-66, RK-72 and LNF-3 were not sampled prior to April 20 due to ice.

Physical parameters measured included water depth, Secchi depth, water temperature, dissolved oxygen (DO), and photosynthetically active radiation (PAR). Chemical parameters included total phosphorus (TP), total dissolved phosphorus (TDP), nitrate plus nitrite nitrogen (N+N), total dissolved solids (TDS), and dissolved organic carbon (DOC). Biological parameters included chlorophyll *a* (Chl *a*), picoplankton, phytoplankton, and zooplankton. Sampling for DOC was only conducted at RK-31 and RK-72 during the first event each month. Only TP, TDP, N+N, TDS, and Chl *a* were analyzed for NFC.

Water depth was measured using a Garmin™ Model GSD22 depth sounder in conjunction with a GPS MAP 4212 chart plotter. Secchi depth was measured using a 20 cm Secchi disc, which was lowered from the shaded side of the boat until no longer visible, then raised until it reappeared. Water temperature and dissolved oxygen (DO) measurements were taken concurrently with a Yellow Springs Instruments model 58 meter with a 60 m cable and probe assembly with a high sensitivity membrane. The probe was calibrated at the beginning of each day following the manufacturer's instructions. After recording air temperature, both water temperature and DO measurements were recorded at the surface, 1 m, 2 m, and every 2 m thereafter to 60 m or the reservoir bottom. The depth of the thermocline, defined as a one-degree change in temperature over a one-meter change in depth, was determined and recorded.

Photosynthetically active radiation (PAR) was measured using a Li-Cor® model LI-250A light meter and 400-700 µm quantum sensor (model LI-192SA). The sensor was mounted on a frame and weighted with a lead weight. A 15-second average PAR reading was taken at the water surface and at one meter intervals to 15 m or a reading of zero. A second meter and dry sensor were used to take air readings concurrently with the wet readings.

Water samples were collected from the epilimnion (EPI) and hypolimnion (HYPO) at each station using a 2.2 L Kemmerer bottle. EPI samples consisted of a composite of water from 1, 3, 5, and 7 m, regardless of the presence or depth of a thermocline. One liter of water from each depth was mixed in a splitter bucket. HYPO samples were collected during the first event each month and consisted of a single 'grab' from 25 m. For water depths less than 28 m, HYPO samples were taken 3 m above the bottom and the depth noted on the field datasheet. Two 250 mL polyethylene sample bottles were filled from each sample depth (EPI and HYPO). One bottle (unfiltered sample) was pretreated with sulfuric acid (H_2SO_4) by the contracting lab as a preservative. The other bottle (filtered sample) was filled with water filtered through a 47 mm filtering manifold and a 0.45 µm cellulose acetate filter. A vacuum of up to 38 cm of mercury (Hg) was applied using a hand operated pump. The DOC samples were collected by filling a 40 mL glass vial, leaving no headspace, with the EPI composite water. All bottles were labeled with station, date, time, depth (EPI or HYPO), and filtered or unfiltered. Sample bottles were stored on ice while in the field and transferred to a refrigerator until shipping. Samples were shipped via overnight carrier to the contracting lab within two days of collection.

A Chl *a* sample was collected by filtering 250 mL of the EPI composite water through a 0.45 µm glass fiber filter using a similar filtering manifold and hand pump, also taking care not to exceed a vacuum of 38 cm Hg. The filter was removed from the manifold and folded in half on a 15 by 15 cm piece of aluminum foil. The foil was folded around the filter, placed in a Ziploc™ bag and kept on ice until returning to the field office. After returning to the field office, Chl *a* samples were placed in a freezer until shipping.

Picoplankton samples were collected by filling a 60 mL amber polyethylene bottle with the EPI composite water and preserved with six drops of 50% glutaraldehyde. Phytoplankton samples were collected by filling a 125 mL amber polyethylene bottle with sample water, one each for EPI and HYPO. Samples were preserved with 15 drops of Lugol's solution. All sample bottles were labeled with station, date, time, and depth (EPI or HYPO).

Zooplankton were collected using a 50 cm diameter, 80 µm mesh Wisconsin style net fitted with an OceanTest Equipment flow meter. One vertical tow was performed at each station from 10 m to the surface. Tows were completed by lowering the net to depth and retrieving at a rate of 0.5 m/s. The number of revolutions on the flow meter was recorded on the datasheet and plankton were rinsed from the net into the collection bucket, then rinsed into a collection jar and preserved in 70% ethanol. Collection jars were labeled with station, date, and depth of tow. Prior to the field season, several tows were performed with no net and the number of revolutions recorded to serve as a reference point.

Laboratory Analysis

Water samples for chemical analysis were sent to AM Test Labs of Kirkland, Washington. Analytical methods used for each parameter can be found in Wilson et al. 2010.

Biological samples were sent to TG Eco-Logic of Spokane, Washington for analysis. Analytical methods used for each parameter can be found in Wilson et al. 2010.

Data Analysis

The compensation depth is the depth where light intensity is 1% of the light intensity at 0 m. Before calculating compensation depth, the light intensity at depth was adjusted according to the ratio of the concurrent air measurement divided by the air measurement concurrent with the surface reading. Compensation depths were then calculated from the adjusted light intensity profiles by transforming the data as follows:

$$x = \mathrm{Ln}\,[100\,(I_D/I_S)]$$

Where: Ln = natural logarithm
I_D = light intensity at depth
I_S = light intensity at 0 m

A regression was then developed using the transformed data as the independent variable and the depth (m) at which the measurement was taken as the dependent variable. The resulting equation was solved for x = Ln(1) = 0 to determine the compensation depth.

When summarizing the results of chemical analyses, numerous measurements were below the detection limit of a given assay. In order to calculate descriptive statistics, the detection limit for a given chemical analysis was used whenever the true value was below the detection limit.

Descriptive statistics were computed using JMP 8.0 from Statistical Analysis Software (SAS). Means were reported for data that were normally distributed and medians were reported for data that were not normally distributed. In the case of normally distributed data for which a median value was stipulated in the Consent Order issued by IDEQ, both a mean and median value were reported.

Between year comparisons of limnological data were performed using a multiyear sampling frame, which consisted of months and stations that were sampled consistently for all years compared for the metric in question. This sampling frame included data from stations RK-2, RK-31, RK-56, and RK-72 from May through November, unless noted otherwise. When comparing chemical concentrations, in cases where the minimum detection limit was not consistent for all years compared, the minimum was artificially adjusted upward to match the year with the highest minimum level. That is, values in all years below the minimum level for the year with the highest minimum level were considered to be equal to that level for the purposes of calculating descriptive statistics.

Phytoplankton densities were recorded both in terms of cells and natural counting units (NCU), which refers to colony numbers for some species and cells for others. Prior to 2008, cells/mL was not recorded for colonial species. Therefore, densities will be reported as cells/mL except when making comparisons among years.

Inconsistencies also existed between years in zooplankton collection. To keep comparisons as consistent as possible, only data from collections with an 80 µm mesh net were used. Data collected presupplementation were collected from a depth that was twice the Secchi depth to the surface. Since this depth was, on average, similar to the current depth strata, it was

compared directly to the data collected in 2008 and 2009 from 10 m to the surface. Since data from 2007 was collected from 30 m to the surface, it was first adjusted by calculating the proportion of zooplankton collected in 2008 from 10 to 0 m to the total amount collected in the 10 to 0 m and 30 to 10 m tows (Wilson et al. 2010). The annual mean for this proportion was then applied to the 30 to 0 m data from 2007 to estimate the density of zooplankton from 10 to 0 m. These estimates were used when comparing 2007 data to other years.

Due to inconsistencies in the data, we chose to make comparisons between years using a graphical analysis of means and confidence intervals rather than attempting more rigorous statistical tests. Means were weighted by month to account for differences in sampling intensity throughout the year. For data that was not normally distributed, we used a bootstrap technique to derive 95% confidence intervals (Chernick 1999; Efron and Tibshirani 1994). For this, the original data was resampled with replacement using SYSTAT 11.0. For each year, 1000 iterations were performed in which a bootstrap mean was calculated. Confidence intervals were derived using the percentile method, in which the lower confidence limit was equal to the 2.5 percentile of the bootstrap distribution and the upper confidence interval was equal to the 97.5 percentile (Chernick 1999).

Quality Assurance

All equipment was rinsed in ethanol, followed by a triple rinse with distilled water, prior to each sampling event. The Kemmerer and splitter bucker were rinsed in surface water at each site prior to sample collection. Vacuum manifolds were rinsed in distilled water prior to installation of a new filter. For each sampling event, a station was randomly chosen to collect field duplicates, rinsates, and blanks. Field duplicates for chemical analysis were collected by filling additional sample bottles (one each for filtered and unfiltered) with EPI water. Rinsates were collected by transferring water provided by the analytical lab from the Kemmerer to the splitter bucket and the filtering manifold (filtered sample only) before filling additional sample bottles (one each for filtered and unfiltered). Blanks were obtained by filling additional sample bottles (one each for filtered and unfiltered) with water provided by the analytical lab. Additionally, a duplicate chlorophyll sample was obtained by filtering an additional aliquot of EPI water as previously described.

For each field duplicate that was collected, the relative percent difference (RPD) between the duplicate and original sample was calculated using the following formula:

$$\frac{\qquad}{\qquad}$$

Where: S_1 = Original sample
S_2 = Duplicate sample

Kokanee Population Monitoring

Abundance

A single hydroacoustic survey was conducted in July concurrent with a trawl survey. The survey was conducted using a Simrad model EK-60 echo sounder and a 120 kHz split beam transducer. The unit was calibrated prior to the survey using a -40.4 decibel (dB) calibration sphere. Kokanee abundance was estimated using a stratified systematic sampling design using the previously described strata. Transects of similar length were laid out in a zigzag pattern

across the reservoir, with one transect beginning where the last one ended (Simmonds and MacLennan 2005). Boat speed during the survey averaged 1.6 m/s. The echo sounder was set to ping at 1 s intervals with a pulse width of 0.256 milliseconds.

The pelagic region of each echogram was analyzed using Echoview 4.0 software. For the analysis, a maximum beam compensation of 6.0 dB and a minimum and maximum normalized pulse length of 0.3 and 1.8 were used to distinguish fish from noise. Depths between 10 and 30 m were analyzed using an echo integration technique to calculate the nautical area scattering coefficient (NASC) and mean target strength (TS). Fish densities were calculated as:

$$\text{Density (fish/ha)} = (\text{NASC} / 4\pi 10^{TS/10}) \, 0.00292$$

Frequency distributions were developed by binning the number of single targets in 1 dB intervals (adjusted target strength) for a given transect. Age breaks were then determined using length at age data from the trawl survey. For this, length at age breaks from trawl caught fish were converted into target strengths using Love's (1971) equation. The percentage of age-0 fish in a particular transect was then determined based on these age breaks and the target strength distribution from that transect. Fish above this age break (age-1 and older) were partitioned based on the proportion of each age class captured in the trawl. The mean densities were multiplied by the area of kokanee habitat in each section to arrive at an estimate of age specific abundance for each section.

Age and Growth

Trawl surveys followed the methods described by Rieman (1992). An 8.5 m diesel powered boat was used to tow a fixed-frame midwater trawl. The net was 10.5 m long and attached to a 3.0 m high by 2.2 m wide steel frame. The body of the net consisted of four panels with bar mesh sizes of 32, 25, 19, and 13 mm. The cod end was composed of 6 mm delta mesh held open by a 0.8 m steel hoop.

Three surveys were conducted, one each in April, July, and October. All surveys were conducted within five nights of the new moon to maximize capture efficiency (Bowler et al. 1979). For the July trawling, five randomly preselected transects were surveyed in each section. For the April and October trawling, 3-6 transects were conducted per section in Section 1 and 2. Trawling was not performed in Section 3 due to low reservoir levels. All fish were measured to the nearest mm total length (TL) and a subsample was weighed to the nearest gram. Scales were collected from ten fish from every 1 cm length class from each section. Scales were later examined by two independent readers to determine age (Nielsen and Johnson 1983).

The relative weight (W_r) was calculated for all fish above 119 mm TL. Standard weights (W_s) for kokanee of a given lengths were obtained from Hyatt and Hubert (2000). A W_r for each fish with a known TL and weight (W) was then calculated using the formula from Anderson and Neumann (1996).

In order to estimate the number of fish from each age class caught in the trawl, the proportion of each age class represented in each 1 cm bin was calculated by dividing the number of fish of each age class, as determined from scale analysis, by the total number of fish aged in that bin. These proportions were then applied to the remaining fish in the length bin, which were not aged, in order to estimate the number from each age class within each bin. To calculate the mean TL and W_r for each age class, we first calculated these for each length bin regardless of age. The means for each bin were then multiplied by the estimated number of fish

from each age class in that bin, and the products were totaled for each age class to calculate an arithmetic mean. Standard deviations were calculated in a similar manner using the following formula from Zar (1999).

Where: s = standard deviation of the population
X_i = i^{th} individual observation
n = sample size

Production

Production refers to the overall gain in biomass of a fish stock over a specific period, regardless of the fates of the individual fish that make up the stock (Ricker 1975). To estimate kokanee production between July 2008 and July 2009, we adapted a summation method described by Hayes et al. (2007). For this, we first calculated the mean abundance of each cohort using acoustic estimates for each year. We then calculated the mean weight gain for an individual in each cohort based on data from trawling surveys conducted at the same time. The mean weight gain was multiplied by the mean abundance to obtain an estimate of production, assuming linear rates of growth and mortality.

Spawner Counts

Ten days prior to peak spawning, prespawn fish were collected from each of the index streams using a seine and dip nets. Additional fish were seined from Isabella Creek during peak spawner counts. All fish were measured to the nearest mm TL and weighed to the nearest g. Sex was determined using secondary sexual characteristics or by expressing gametes. Females were euthanized, the ovaries removed and weighed to the nearest g, and preserved in 95% ethanol. Secondary oocytes were later enumerated for each ovary. Mean oocytes weight was calculated by dividing the number of oocytes by the total weight of the ovary (somatic tissue was considered inconsequential). The gonadal somatic index (GSI) was calculated for females using the following formula:

Where: GW = gonad weight
BW = body weight

Peak spawner counts were conducted on four index streams on the lower North Fork Clearwater River above the reservoir on September 26. These included Isabella (RKM 92), Skull (RKM 105), Quartz (RKM 109), and Dog (tributary to Isabella at RKM 2.6) creeks. Each of the index streams were walked from the mouth to the uppermost extent of utilization by spawning kokanee. All spawning kokanee were individually counted when possible or estimated in the case of a deep pool with a large group of fish.

RESULTS

Environmental Conditions

In 2009, inflow to Dworshak Reservoir peaked at 699 m^3/s on May 19 (Figure 2). The mean inflow of 144 m^3/s was similar to the ten-year mean (1999-2008) of 151 m^3/s. Discharge from Dworshak Dam peaked at 479 m^3/s on April 15 (Figure 2). The mean discharge of 153 m^3/s was similar to the ten-year mean (1999-2008) of 152 m^3/s. Full pool (487.7 m above mean sea level) was reached on June 27 and dropped to a low of 461 m on December 23 (Figure 2).

Physical and Chemical Limnology

Temperature

In 2009, water temperatures at 1 m were within the range observed for previous years. The mean temperature for the multiyear sampling frame in 2009 was 18.3°C, which was similar to the long-term mean (2004–2008) of 18.5°C. The minimum temperature observed within this sampling frame in 2009 was 8.0°C, which was warmer than the minimum observed in two of the previous five years. The maximum temperature observed was 24.9°C, which was cool compared to other years (range = 24.0 to 27.2°C). Graphic representations of temperature data are presented in Appendix A.

A thermocline developed by May 18 at all stations except RK-31, which stratified by June 8. Thermal stratification persisted through October 5 at all stations except EC-6, which lasted through September 21. Periodic breaks, or weakening of thermal stratification, occurred at RK-2, RK-56, RK- 72, and LNF-3. Thermocline data are presented in Appendix B.

Dissolved Oxygen

In general, DO concentrations remained near saturation throughout the season. During the first four sampling events, a malfunctioning temperature probe resulted in erroneously low readings at depth; therefore, these results were discarded. As is typical with Dworshak Reservoir, reductions in DO were observed in the metalimnion and hypolimnion late in the year. These reduced DO levels were similar to those observed in past years with similar flow and stratification. DO levels below 5 ppm were observed at EC-6, RK-66, RK-72, and LNF-3. Although they occurred as early as late July, they were typically observed during August and September. Low DO levels were typically observed near the bottom and were most severe at RK-66 in September, at which point most measurements taken below the thermocline were below 5 ppm. At RK-56, DO readings below 5 ppm were observed near the thermocline in October. Additional summaries of DO data can be found in Scofield et al. (2010).

Water Clarity

The median Secchi depth in 2009 was 3.0 m for treated areas of the reservoir, which was equal to the minimum value specified in the Consent Order. The median depth for the reference sites was 2.7 m. In 2009, the median Secchi depth for the multiyear sampling frame was 3.0 m. While this was the lowest median observed during the study period, it was within the range of medians observed prior to supplementation (range = 3.0 to 4.9 m). Because Secchi depths were not normally distributed, they were log transformed prior to statistical testing. Secchi depths from 2004 through 2009 were significantly different (p <0.001; ANOVA). Multiple comparisons testing revealed two groupings of years, 2004, 2005, and 2007 as well as 2006

through 2009, for which mean Secchi depths were not significantly different (α = 0.05; Tukey HSD). Summaries of Secchi depths for 2009 can be found in Scofield et al. (2010).

The mean compensation depth in 2009 was 9.2 m for treated areas of the reservoir and 8.1 m for the reference sites. The mean annual compensation depth for treated areas of the reservoir was not significantly different from 2007 through 2009 (p = 0.37; ANOVA). Compensation depths for 2009 are summarized in Appendix C.

Phosphorus

The annual median value for TP in the epilimnion was 0.007 mg/L. This was well below the limit of 0.025 mg/L set forth in the Consent Order. The annual median for the multiyear sampling frame for 2009 was also 0.007 mg/L, which was the lowest value for the study period (range = 0.007 to 0.019 mg/L). Median values for applications years were all less than median values for presupplementation years (no test for significance). In order to compare TP levels across years, the data were first corrected to a minimum detection level of 0.01 mg/L for all years. Sample means were lower in supplementation years than in presupplementation years; however, bootstrap confidence intervals overlap for most years (Figure 3). The confidence interval for 2009 did not overlap with any presupplementation years.

The annual median for TP in the hypolimnion was 0.007 mg/L, which was equal to that of the epilimnion. As with the epilimnion, sample means for the multiyear sampling frame appear to be trending down. However, bootstrap confidence intervals overlap for most years for the multiyear sampling frame (Figure 3).

The annual median for TP at NFC was 0.006 mg/L, which was similar to both depth strata from the reservoir. There was no apparent trend in sample means since nutrient supplementation began.

In 2009, the annual median value for TDP in the epilimnion was 0.004 mg/L for the whole reservoir and 0.003 mg/L for the multiyear sampling frame. Median values for TDP ranged from 0.006 to 0.012 mg/L prior to nutrient supplementation and from 0.001 to 0.003 mg/L during supplementation. In order to compare TDP levels across years, no adjustment to the minimum detection limit was necessary. Sample means were higher in presupplementation years and bootstrap confidence intervals did not overlap between presupplementation and supplementation years (Figure 3).

The annual median for TDP in the hypolimnion was 0.004 mg/L, which was equal to that of the epilimnion. Annual means for the multiyear sampling frame exhibited a similar trend to that of the epilimnion. As with TP, mean TDP values for the hypolimnion were higher presupplementation and bootstrap confidence intervals did not overlap (Figure 3).

The annual median for NFC was 0.003 mg/L, which was similar to both strata in the reservoir. There was no apparent trend in sample means for NFC since 2007. Additional summaries of phosphorus data for 2009 can be found in Scofield et al. (2010).

Nitrogen

In 2009, the annual median value for N+N in the epilimnion was 0.005 mg/L for the whole reservoir and 0.003 mg/L for the multiyear sampling frame. Median values for N+N ranged from 0.001 to 0.013 mg/L prior to nutrient supplementation and from 0.001 to 0.003

mg/L during supplementation. In order to compare N+N levels across years, the data were first corrected to a minimum detection level of 0.01 mg/L for all years. Mean nitrogen values were variable from year to year and there were no apparent effects due to nitrogen supplementation. Bootstrap confidence intervals overlapped for 2004, 2005, 2007 and 2009, as well as for 2006 and 2008 (Figure 3).

The annual median for N+N in the hypolimnion was 0.015 mg/L, which was greater than that of the epilimnion. Hypolimnetic N+N has declined since 2006, but means for supplementation years are similar to 2005 (Figure 3).

The annual median for NFC was 0.032 mg/L, which was greater than both strata in the reservoir. There was no apparent trend since 2007 and bootstrap confidence intervals overlap for all three years. Additional summaries of nitrogen for 2009 can be found in Scofield et al. (2010).

Total Dissolved Solids

The annual mean for TDS was 20.3 mg/L for the whole reservoir. Annual means were significantly different (p = 0.03, ANOVA) from 2007 through 2009. Multiple comparisons tests revealed that 2007 was significantly higher than 2009 (α = 0.05; Tukey HSD), but 2008 was not significantly different from the other years.

The annual mean for TDS at NFC was 19.4 mg/L. Annual means were not significantly different (p = 0.80, ANOVA) from 2007 through 2009. Additional summaries of TDS data for 2009 can be found in Scofield et al. (2010).

Dissolved Organic Carbon

The concentration of DOC was measured from the epilimnion at RK-31 and RK-72 during the first sampling event each month. The annual median was 2.1 mg/L. Levels of DOC have trended upward since nutrient applications began in 2007. Bootstrap confidence intervals show that DOC was significantly higher in 2008 and 2009 than in 2007.

Biological Indicators

Chlorophyll *a*

The annual median for Chl *a* in the epilimnion was 1.94 µg/L for the whole reservoir, which was below the maximum stipulated in the Consent Order. The median value for the multiyear sampling frame was 1.99 µg/L, which was slightly less than the range prior to supplementation (2.00-2.10 µg/L). Log transformed means were not significantly different (p = 0.76, ANOVA) between years and bootstrap confidence intervals overlapped for most years (Figure 4).

The annual median for Chl *a* at NFC was 0.45 µg/L, which was less than the epilimnetic median for RK-2. The concentration of Chl *a* at NFC was always 70% or less of the concentration measured at RK-2 during the same sampling event, and in most instances was less than 25% (Figure 4). Additional summaries of Chl *a* data for 2009 can be found in Scofield et al. (2010).

Picoplankton

The median density of picocyanobacteria was 75,000 cells/mL. Differences between annual means for stations, tested using square root transformed data, were not significant (p = 0.53, ANOVA). Reservoir-wide densities were lowest in May (median = 2,000 cells/mL) and peaked in July (median = 277,000 cells/mL). Comparisons were made for the multiyear sampling frame between May and October. Mean densities were substantially higher for supplementation years, and bootstrap confidence intervals overlapped for supplementation years, but no supplementation years overlapped with 2006 (Figure 5).

Unlike picocyanobacteria, heterotrophic bacteria densities were both higher and normally distributed. The annual mean density for the whole reservoir was 1,138,000 cells/mL and the median was 1,165,000 cells/mL. However, differences between stations were not significant (p = 0.5103, ANOVA), including treated and untreated areas of the reservoir. Reservoir-wide densities were lowest in May (mean = 669,000 cells/mL) and highest in September (mean = 1,700,000 million cells/mL). Comparisons were made for the multiyear sampling frame between May and October. As with picocyanobacteria, the mean density of heterotrophic bacteria was substantially higher for all supplementation years than in 2006 (Figure 5). Bootstrap confidence intervals for supplementation years did not overlap with 2006. Confidence intervals for 2009 overlapped with intervals for 2007 and 2008. Additional summaries of picoplankton data can be found in Scofield et al. (2010).

Phytoplankton

In 2009, the mean epilimnetic total phytoplankton density for all stations was 14,596 cells/mL and the median was 11,440 cells/mL. Of the major taxa, blue-green algae exhibited the highest annual density (mean = 8,033 cells/mL; median = 5,878 cells/mL), followed by flagellates (mean = 3,806 cells/mL; median = 3,378 cells/mL) and coccoid greens (mean = 2,360 cells/mL; median = 1,195 cells/mL). Diatoms (mean = 354 cells/mL; median = 146 cells/mL) and dinoflagellates (mean = 17 cells/mL; median = 12 cells/mL) represented a minor portion of the phytoplankton community. Peaks in phytoplankton densities occurred in July and October, driven in large part by increases in blue-greens.

Blue-greens were the dominant species encountered at all stations, accounting for 50% or more of the phytoplankton counted over the entire season. Flagellates accounted for between 22 and 33%, while coccoid greens accounted for between 11 and 20%. Diatoms accounted for less than 6% and dinoflagellates accounted for less than 1%. Reservoir-wide, flagellates were the dominant species from March (86.4%) through May (47.7%), while blue-greens were dominant in all other months.

Microcystis sp. was the dominant taxa of blue-greens in every month except March, accounting for 75% of the blue-greens counted throughout the entire season. *Synechococcus sp.* (8%), *Anabaena sp.* (7%) and *Chroococcus sp.* (6%) were the only other common taxa. *Microcystis sp.* and *Anabaena sp.* are of concern because they are not only inedible to zooplankton, but can produce toxins under certain conditions, making them a potential public health hazard. While *Anabaena sp*. was not observed at high enough densities to cause concern in 2009, *Microcystis sp.* was observed at densities as high as 38,782 cells/mL, and was in excess of 20,000 cells/mL on six occasions. *Microcystis sp.* was found at similar densities throughout the reservoir, with the highest single observation occurring at RK-31 on June 23, and the highest annual median occurring at EC-6.

Phytoplankton edibility was determined from published research and is a key metric for evaluating the effectiveness of the nutrient supplementation program. The mean percentage of phytoplankton in a given sample (measured in cells/mL) for which edibility could be established was 77% for the entire season, while the median was 80.6%. The annual mean density of edible phytoplankton across all stations was 3,419 cells/mL, which represented 38.4% of all phytoplankton for which edibility could be established. The median values were 2,476 cells/mL and 36.1%.

Densities of edible phytoplankton were highest at RK-31 (median = 4,354 cells/mL) and lowest at EC-6 (median = 1,598 cells/mL). The percentage of edible phytoplankton was highest at RK-56 (median = 51.2%) and lowest at EC-6 (median = 26.3%). Densities of edible phytoplankton were lowest in March (median = 152 cells/mL) and peaked in July (median = 6,689 cells/mL). The percentage of edible phytoplankton was highest in March (median = 77.4%) and lowest in June (median = 4.7%).

Comparisons between years were made using NCU/mL, where colonial species were counted in terms of the number of colonies present instead of the number of cells. Total phytoplankton was higher in 2009 than in any year since 2005 (Figure 6). The increase in total phytoplankton was due to increases in blue-greens, flagellates, and coccoid greens. Bootstrap confidence intervals for these three groups do not overlap with confidence intervals for previous years. Densities of diatoms and dinoflagellates were lower in both 2008 and 2009 than previous years. The density of edible phytoplankton was higher in 2009 than in previous years and bootstrap confidence intervals do not overlap (Figure 7). The density of inedible phytoplankton was lowest in 2009 and confidence intervals do not overlap with previous years. Additional summaries of phytoplankton data can be found in Scofield et al. (2010).

Zooplankton

The mean density for total zooplankton across all stations in 2009 was 29.0 individuals/L and the median was 27.0 individuals/L. Total zooplankton densities were lowest in the spring and peaked in early June, late July, and late September. The zooplankton community was composed of two major groups: copepods and cladocerans. The mean density of copepods across all stations was 20.7 individuals/L and the median was 16.2 individuals/L. The mean density of cladocerans across all stations was 8.3 individuals/L and the median was 5.5 individuals/L. Copepods were the dominant class in every month, ranging from 58.3% of the individuals counted in July to 95.9% in March.

Cyclops was the dominant genera of copepod throughout the reservoir, comprising from 40.1% of the mean zooplankton density at RK-72 to 70.0% at EC-6. *Cyclops* was dominant across all stations in every month.

Cladoceran densities are of particular interest, as they are the preferred forage of kokanee. In terms of annual means, *Daphnia* was the dominant genera of cladoceran throughout the reservoir. *Diaphanosoma* was the second most prevalent genera at RK-56, RK-66, RK-72, and LNF-3. *Bosmina* was the second most prevalent genera at RK-2 and EC-6, while *Holopedium* was the second most prevalent genera at RK-31. *Bosmina* was the dominant genera of cladocerans from March through June. *Diaphanosoma* became the dominant cladoceran in July, while *Daphnia* was dominant from August through November.

Zooplankton densities were compared between years using data from stations (RK-2, RK-31, RK-56, and RK-72) and months (June through November) that were consistently

sampled in all years. Data was only used from tows of similar depths or using data that was adjusted for depth strata (2007). The mean density of total zooplankton was highest in 2009, but the bootstrap confidence intervals overlap for all years except 2006 (Figure 8). This pattern also holds true for copepods and cladocerans independently. Mean *Daphnia* densities were highest in 2007 and were higher in all years that fertilizer was applied compared to the two years preceding applications. Bootstrap confidence intervals for *Daphnia* densities overlap for all supplementation years, but those for supplementation years do not overlap with those for the preceding years.

Annual mean lengths of *Daphnia sp.* ranged from 1.04 mm at RK-31 to 1.2 mm at RK-2. The reservoir-wide mean length ranged from 0.80 mm in April to 1.2 mm in June. Annual mean lengths were above 1 mm for all stations and reservoir-wide after May. Mean lengths for RK-2, RK-31, RK-56, and RK-72 from June through November were above 1 mm for all years in which fertilizer was applied, but below 1 mm for two years preceding fertilizer applications (Figure 9). Annual mean total lengths of *Bosmina sp.* ranged from 0.34 mm at RK-72 and RK-56 to 0.38 mm at RK-2 and EC-6. The reservoir-wide mean total length ranged from 0.31 mm in October and November to 0.42 mm in April. Additional summaries of zooplankton data can be found in Scofield et al. (2010).

Kokanee Population Monitoring

Abundance and Density

From the hydroacoustic survey conducted on July 7-10, we estimated an overall abundance of 2,289,000 kokanee in Dworshak Reservoir (Table 1). Of these, 1,250,000 were age-0, 974,000 were age-1, and 65,000 were age-2. No age-3 kokanee were estimated based on ages from the July trawl data. These estimates were based on an overall density of 439 fish/ha (Table 1). When broken out by age, the densities were 239 fish/ha for age-0, 187 fish/ha for age-1, and 12 fish/ha for age-2.

Total abundance (1,334,000; Table 1) and density (460 fish/ha; Table 1) were highest in Section 1. Abundance (265,000) was lowest in section 3 and density (403 fish/ha) was lowest in Section 2. Abundances of all age classes were highest in Section 1. Density of age-0 and age-2 were highest in Section 3, while density of age-1 was highest in Section 2. Historical abundance estimates for kokanee are presented in Appendix E.

Age and Growth

Midwater trawls conducted on April 27, July 19-20, and October 13 sampled a total of 1,164 kokanee. Of these, 454 were captured during April trawling, 412 in July, and 298 in October. In April, trawl caught kokanee ranged from 66 to 290 mm total length (Figure 10). These fish were ages 1-3; no age-0 kokanee were encountered in April (Table 1). A total of 410 age-1 kokanee were captured in April. Individual lengths were recorded for 319 of these and ranged from 66 to 137 mm total length (TL) with a mean of 107 mm. Weights were recorded for 58 of these and the mean relative weight (W_r) was 69 (Table 2). A total of 42 age-2 kokanee were captured, ranging in size from 205 to 283 mm TL. Age-2 kokanee had a mean TL of 247 mm and a mean W_r of 80. Only two age-3 kokanee were captured, with TLs of 274 and 290 mm. Age-3 kokanee had a mean W_r of 74.

In July, trawl caught kokanee ranged from 22 to 289 mm TL (Figure 10). Of these, 140 were age-0 between 22 and 68 mm total length, with a mean TL of 45 mm (Table 2). Through

scale analysis and length distributions, 249 were determined to be age-1, ranging in size from 132 to 209 mm TL. The mean TL of age-1 kokanee was 169 mm and the mean Wr was 86.2 (Table 2). Another 23 were determined to be age-2, ranging in size from 246 to 289 mm TL. Age-2 kokanee had a mean TL of 272 mm and a mean Wr of 84.5. No age-3 kokanee were identified in the July trawl survey.

In October, trawl caught kokanee were between 49 and 222 mm TL (Figure 10). Of these, 156 were age-0 and ranged in size from 49 to 125 mm TL. Age-0 kokanee had a mean TL of 82 mm. Another 142 were determined to be age-1, ranging in size from 155 to 222 mm TL. Age-1 kokanee had a mean TL of 190 mm and a mean Wr of 87.5 (Table 2). None of the kokanee captured in October were determined to be age-2.

When weighted by the estimated abundance for each year class in a given year, the mean TL of age-1 kokanee was 170 mm for the three years prior to supplementation (2003, 2004, and 2006) for which data exist and 181 mm for the first three years of supplementation. The means for age-2 kokanee were 207 mm and 260 mm for these periods. The weighted mean Wr for age-1 fish was 78 presupplementation and 85 post-supplementation. The means for age-2 fish were 77 presupplementation and 86 post-supplementation.

The mean TL of age-0 kokanee increased by 37 mm from July to October (Table 2). The mean TL of age-1 kokanee increased by 61 mm from April to July and by 21 mm from July to October, for a total of 82 mm. The mean TL of age-2 kokanee increased by 25 mm from April to July. Growth, in terms of increases in mean TL, was slower in 2009 than for any recent year for which data exists, including 2004 (presupplementation). Seasonal increases in W_r were second only to 2008 for age-1 kokanee, and only slightly less than 2004 for age-2 kokanee.

Production

Kokanee production from July of 2008 to July of 2009 was estimated to be 58.1 metric tonnes (t). During this period, biomass was estimated to have increased from 39.4 t in 2008 to 50.7 t in 2009. Mortality by weight was estimated to be 25.3 t. Historical production estimates can be found in Appendix F.

Spawner Counts

On September 15, we seined 59 kokanee: 24 from Isabella Creek, 4 from Quartz Creek and 31 from Skull Creek. On September 23, we seined an additional 30 kokanee from Isabella Creek. In addition, we collected 26 post-spawn kokanee during spawner counts on September 22 and 23. Of these, 11 were collected from Isabella Creek, eight from Quartz Creek, and seven from Skull Creek. Of these, TL was obtained from 91 fish: 25 females and 66 males. Both male and female kokanee exhibited a multimodal length distribution (Figure 11). Based on scale analysis from trawl caught fish in July and October, spawners less than or equal to 225 mm TL were presumed to be age-1. Spawners between 248 and 338 mm TL were presumed to be age-2, and the 380 mm male was presumed to be at least 3 years old. The mean length of age-1 spawners was 210 mm; the mean length of age-2 spawners was 285 mm.

Ovaries were obtained from 17 prespawn females: 11 from Isabella Creek and six from Skull Creek. Of these, seven were presumed age-1 and ten were presumed age-2, based on TL. Linear regressions were performed to test the relationship between TL and GSI, fecundity or mean egg weight. The relationship between TL and GSI was non-significant (linear regression, $p = 0.11$, $r^2 = 0.16$). The relationship between TL and fecundity was nearly significant (linear

regression, $p = 0.07$, $r^2 = 0.21$; Figure 12). The relationship between TL and mean egg weight was significant (linear regression, $p < 0.0001$, $r^2 = 0.90$).

Peak kokanee spawner counts were performed on September 22-23, during which 7,433 spawning kokanee were counted in four index streams. This included 3,738 in Isabella Creek, 2,160 in Skull Creek, 426 in Quartz Creek, and 1,073 in Dog Creek. Historical spawner count data are shown in Appendix G.

DISCUSSION

Water Quality

While the goal of the nutrient supplementation project was to restore lost productivity to the reservoir, it was imperative to do so without degrading overall water quality. In 2009, water quality standards, as set forth in the Consent Order issued by the Idaho Department of Environmental Quality (IDEQ), were not exceeded due to nutrient applications. Although water clarity, as measured by Secchi depth, was the lowest measured during the study period, it was within the range observed during the three years prior to supplementation. Not only was the median chl *a* concentration for 2009 within the limit set by IDEQ, but chl *a* does not appear to be increasing due to nutrient additions. Since phosphorus is no longer applied, we do not expect the project to result in increased TP loading. Moreover, TP and TDP appear to be trending downward since nitrogen supplementation was initiated.

Another water quality parameter of concern is DO. As with previous years, DO minima were observed in the metalimnion and hypolimnion at several stations on the upper end of the reservoir during late summer and early fall. These minima are presumed to be caused by phytoplankton that senesce, settle out of the epilimnion, and collect in the metalimnion where they begin to decay (TG Eco-Logic 2008). Although these metalimnetic dissolved oxygen minima occurred prior to the nutrient enhancement project, it is possible that the addition of nutrients and the increased productivity of the system could intensify this phenomenon. The low DO levels observed in 2009 were more severe than those observed in 2008, but similar to those observed in 2006 and 2007. The degree of DO depletion in the metalimnion and hypolimnion appears to be dependent upon the length of thermal stratification (Scofield et al. 2010). In 2009, the reservoir stratified early and remained stratified later in the year. This increased the time period that the metalimnion and hypolimnion were cut off from surface aeration, resulting in further DO depletion compared to years in which the stratification period was shorter. DO levels have not been a concern in the forebay and are not monitored in the river below the dam as a part of this project, as gas supersaturation is a larger concern in the tailrace.

Water quality downstream of the reservoir in the North Fork Clearwater River was also a concern. In order to evaluate downstream effects of the project, the river below the dam was sampled in addition to the reservoir. Unfortunately, no samples were collected prior to nutrient supplementation, so direct comparisons to previous years are impossible. However, nutrient concentrations at NFC most closely resembled those from the hypolimnion. Comparisons of water temperatures from the epilimnion, hypolimnion, and river indicate that the river temperature closely tracks the temperature of the hypolimnion but not the epilimnion, suggesting that the hypolimnion is the primary water source for the river. Since nutrient levels in the hypolimnion have decreased since nutrient applications were started, it is unlikely that nutrient levels in the river have increased.

Personnel at both Clearwater Fish Hatchery and Dworshak National Fish Hatchery reported increased periphyton growth in raceways over presupplementation years. Because Clearwater Fish Hatchery receives a mixture of epilimnetic and hypolimnetic water directly from the reservoir, it is possible that supplemented nutrients may have reached the hatchery raceways directly. However, nutrient applications were stopped at RKM 21 (18 km above the dam) due to higher nutrient loading from the Elk Creek drainage, making this scenario unlikely. Dworshak National Fish Hatchery receives water directly from the river; therefore, it is less likely than Clearwater Hatchery to receive nutrients directly. Nutrient profiles from the reservoir do not suggest increased nutrient loading to either hatchery. Furthermore, hatchery raceways receive nutrients from other sources (i.e. fish and feed) which confound the effects of nutrients from the source water. Monitoring efforts in 2010 will include nutrient and algae sampling at hatcheries in an attempt to resolve this issue.

Reservoir Productivity

Environmental conditions, such as snowpack and runoff, appear to be the key drivers of the limnological conditions and resultant plankton communities within Dworshak Reservoir. The current intensity of the limnological sampling will be critical in separating the effects of nutrient supplementation from the effects of year-to-year variation in the environment. While the ecology of this system is complex, and there is a great deal of annual variation, we should gain a better understanding of how the reservoir is responding to nutrient supplementation with each year that data is collected.

Chl *a* is often used as an indicator of productivity in lakes and reservoirs. Although phytoplankton densities were higher in 2009 than in the previous four years, chl *a* levels do not appear to have increased. However, the relationship between chl *a* and phytoplankton biomass can vary with species composition, among other variables. Shifts in the composition of the phytoplankton community in 2009, compared to recent years, may explain why chl *a* levels have not increased despite increases in overall phytoplankton densities (Scofield et al. 2010).

For the third consecutive year, densities of picoplankton were substantially higher than in 2006 (presupplementation year). The picoplankton response in Dworshak Reservoir is similar in magnitude to that observed during the first years of nutrient supplementation in BC lakes and reservoirs (Pieters et al. 2003; Stockner and MacIsaac 1996; Stockner and Shortreed 1994). This is not surprising, since these taxa are capable of rapid nutrient uptake and nearly exponential growth (Stockner and Antia 1986), and it is a clear indication that nutrient supplementation is stimulating the lower trophic levels. Since picoplankton are a food source for flagellates (Jurgens and DeMott 1995), it is likely that increases in picoplankton will also result in increased densities in higher trophic levels.

One of the most encouraging results to date is the recent increase in densities of edible phytoplankton. Mean densities of edible phytoplankton were significantly higher during the second and third year of nutrient applications than the previous three years, without an apparent increase in inedible types. This shift is due in large part to increases in flagellates, coccoid greens, and edible species of blue-greens. Flagellates in particular are an excellent source of food for large zooplankton such as *Daphnia* (Sanders and Porter 1990). The apparent decline in inedible phytoplankton was due in large part to substantial decreases in diatoms. In recent years, the dominant diatom species was *Fragilaria crotonensis*, which is inedible. As the species composition shifts to more edible taxa, these taxa are more likely to be grazed down by zooplankton. If this is indeed the case, it indicates that the system is becoming more efficient in transferring energy up the food chain.

Prior to 2008, phytoplankton was counted in terms of natural counting units (NCU). An NCU could be a single cell for many species, or a colony for others. Many colonial species have traditionally been counted using colonies as a counting unit, as individual cells can be difficult to count. However, in 2008, the counting methodology was changed to include cells as a counting unit for all species, as the number of cells in an average colony was found to vary from year to year for some taxa. In these cases, counting cells instead of colonies may provide a much more accurate means of comparing change. While the counting methodology did not affect any of the species known to be edible, the apparent decline in inedible phytoplankton should be viewed with caution, as many of these species exist as colonies.

Microcystis was the dominant species of inedible phytoplankton in 2009. *Microcystis* densities were of further concern due to the potential for *Microcystis* to produce a toxic substance known as microcystin. Densities of *Microcystis* reached as high as 38,000 cells per mL. Densities above 20,000 cells/mL are considered a mild health risk if microcystin is present at a concentration of 0.2 pg/cell and can result in microcystin concentrations in the range of 2-4 µg/L (Falconer et al. 1999). Therefore, the USACE tests for the presence of toxins whenever potentially toxic blue-greens are observed at moderate densities. Fortunately, toxins were never detected in the reservoir during 2009 (Paul Pence, USACE, personal communication).

While the densities of *Microcystis* in 2009 were concerning, it is unlikely that they were a result of nutrient additions. Historically, potentially toxin producing blue-green algae were commonly observed in Dworshak Reservoir, typically in late summer and early fall when available nitrogen was essentially exhausted. In 1972, the first year the reservoir reached full pool, Falter et al. (1977) reported a mean density of 26,200 cells/mL for *Anabaena*, another potentially toxin producing taxa commonly observed in Dworshak Reservoir. In a more recent presupplementation assessment of the reservoir, Stockner and Brandt (2005) noted a prevalence of *Anabaena* and *Microcystis* by late summer, coinciding with the depletion of available N.

Low available N creates a competitive advantage for *Anabaena*, which is capable of fixing atmospheric N, and *Microcystis*, which can absorb available N efficiently at low concentrations. Therefore, N supplementation is expected to reduce this advantage and favor the growth of other taxa. Smith (1983) found that blue-green taxa were prevalent in lakes with a low N:P ratio and were rare in lakes with high N:P ratios. He further suggested N supplementation as a possible means for maintaining desired water quality. Stockner and Shortreed (1988) found that adding fertilizer with a low N:P ratio to Kennedy Lake, BC resulted in blooms of *Anabaena*, whereas addition of a high N:P fertilizer eliminated these blooms. In a survey of midwestern lakes, Graham et al. (2004) found that blue-green densities and the concentration of microcystin was generally high below a threshold value of total nitrogen, and generally low above that value. In Dworshak Reservoir, *Microcystis* was observed at similar densities at fertilized and unfertilized sections of the lake during 2009. This suggests that the current N supplementation has neither caused nor eliminated these blooms.

The recent increases in phytoplankton appear to be translating into increases in zooplankton biomass. Densities of *Daphnia*, the preferred forage of kokanee (Stark and Stockner 2006), were higher in all supplementation years than the two years preceding supplementation. Furthermore, the mean length of *Daphnia* was higher in all supplementation years compared to the two years prior to supplementation. During the first two years of nutrient supplementation, it was not known if this was due to increased productivity or reduced grazing pressure due to a collapse in kokanee numbers following high densities in 2006. However, the

fact that this trend has continued into 2009, despite increasing densities of older kokanee, suggests that the project is beginning to result in increased zooplankton production. If this trend continues, we expect the increased zooplankton production to benefit fish populations within the reservoir.

Kokanee Population Monitoring

A major step toward achieving our project objective is to improve kokanee growth. Since kokanee typically exhibit density dependent growth (i.e. lower densities result in larger fish and vice versa), it is important to consider densities when evaluating growth. Based on the hydroacoustic survey, the combined density of age-1 and older kokanee was higher in 2009 than the previous two years. Therefore, growth should have been slower than in previous years regardless of nutrient supplementation.

Kokanee exhibited higher growth rates during the first two years of nutrient supplementation than that observed during the years preceding nutrient supplementation. However, it is not known if this was primarily a productivity or density effect. In 2009, growth rates (in terms of TL) dropped not only below that seen during the first two years of supplementation, but slightly below that seen in 2004 as well. However, this growth occurred at nearly three times the density of age-1 and older fish than what was observed in 2004. Therefore, the drop in growth is likely density dependent.

When comparing mean TL from the July trawl survey, the mean TL for age-2 fish was larger for the three years of supplementation than for the previous three years for which we have trawl data (2003, 2004, and 2006). While this difference was modest (19 mm), small gains have the potential to result in substantial benefits. For one, kokanee appear to be more susceptible to angling gear as they get larger. A model developed by Rieman and Maiolie (1995) predicts that an increase in TL of 10 mm could result in an increase in relative catchability of 27%. Therefore, large gains in growth are not required to provide substantial benefits to the fishery. However, it is also important to keep in mind that these gains are likely affected by fish densities. Data collected in the coming years will help determine whether and to what extent reservoir productivity is leading to improved growth.

Our data also demonstrates that TL has a strong influence on egg size. Larger eggs produce larger fry (Beacham and Murray 1990; Hutchings 1991). While larger eggs do not necessarily survive better to hatch, larger fry have been found to survive better under certain conditions (Hutchings 1991). If this were the case with kokanee spawned above Dworshak Reservoir, larger females would lead to increased recruitment of fry into the reservoir for a given abundance of spawners. Whether larger kokanee produce larger eggs, more eggs, or both, larger size should lead to increased reproductive potential of the population.

Length is not the only means of comparing fish growth. When more forage is available, fish may put on more weight relative to body length than they otherwise would. Kokanee in Dworshak Reservoir appear to be responding to supplementation with increased body condition more so than increased length. Besides making fish more appealing to anglers, improved body condition and increased fat reserves are likely to translate into increased overwinter survival, and ultimately higher densities of kokanee. Additional years of data will allow us to test whether or not reservoir productivity is leading to apparent increases in relative weight.

Another way to assess benefits to the kokanee population is to assess production. The growth of an individual fish is related to the quantity and quality of forage as well as the number

of fish competing for the available forage. Production, on the other hand, is a measure of how the biomass of the population increased over time, irrespective of the fates of individual fish. Since production should be somewhat density independent, it may be a better indicator of how the population responds to increased forage. Production during two of the first three years of supplementation has been higher than 2004 (the only year for which we can currently calculate production presupplementation), but has been steadily decreasing. This decrease may be linked to low kokanee densities observed during the first two years of the project.

Due to the cyclic nature of this kokanee population, assessments of growth should be conducted using a wide range of fish densities from both presupplementation and supplementation years. Unfortunately, multiple trawl surveys were only conducted during one year (2004) prior to supplementation. While single trawl surveys were not conducted in all years prior to supplementation, scales collected from older fish have the potential to reveal growth rates from previous years. Therefore, back-calculated lengths from scales promise to be a good method for evaluating the kokanee growth response to supplementation. Future efforts will be directed at modeling growth pre- and post-supplementation using back-calculated lengths. The current upswing in kokanee densities should provide additional data points at higher densities, which will benefit this analysis.

Since the effects of nutrient supplementation are expected to work their way up through each trophic level, we do not expect to see the full effects to the kokanee populations immediately. Since the third year of the project marks the first real increase in densities of edible phytoplankton, it could be another year or more before the full effects work their way up to the level of the kokanee population. Furthermore, since most kokanee reside in the reservoir for three summers, next year (2010) will be the first time that most age classes have lived their entire lives under the effects of nutrient supplementation. Kootenay Lake exhibited a similar pattern, where growth and length at age increased initially, followed by increased densities and biomass and a density dependent decline in growth by the third year of the project. Therefore, the effects on Dworshak kokanee to date are encouraging.

CONCLUSIONS

Nutrient supplementation in Dworshak Reservoir continues to show signs of success similar to those of several BC lakes and reservoirs. While water clarity appears to have decreased somewhat during the first three years of nutrient supplementation, it has not declined below the range observed prior to supplementation. Increases in picoplankton, which represent the lowest trophic level, were observed beginning with the first year of nutrient additions. These appear to have translated into increases in edible phytoplankton and zooplankton. The increases in available forage appear to be resulting in improved kokanee body condition. Increases in the TL of spawning kokanee during the first two years of nutrient supplementation have likely lead to larger mean egg size, which is expected to increase recruitment to the reservoir. This, along with the potential for increased survival due to improved body condition, is expected to lead toward increases in kokanee density. The project is just reaching the stage when responses at higher trophic levels should start emerging. Thus, the kokanee responses already observed are encouraging. However, it will take several more years to fully assess the effects of nutrient supplementation, but observations to date are cause for optimism.

RECOMMENDATIONS

1. The five-year experimental phase of the nutrient project should be continued so that the effects of the project can be properly assessed.

2. Continue semimonthly sampling of the epilimnion during the experimental phase of the project to ensure sufficient data to evaluate the project, adequately monitor compliance with the IDEQ Consent Order, and provide data for active management of the nutrient applications.

3. Expand sampling efforts to better understand whether the project is negatively influencing the anadromous fish hatcheries immediately downstream of Dworshak Reservoir.

ACKNOWLEDGMENTS

The Dworshak Reservoir Nutrient Enhancement Project is a cooperative effort involving many people and several organizations. Darren Brandt of TG Eco-Logics was responsible for the fertilizer prescriptions, while Paul Pence and Ben Perkins, with the U.S. Army Corps of Engineers, made sure that fertilizer was accurately applied. John Bailey, Tim Dykstra, Steve Juul, and Ben Tice, also with the USACE, all played important roles in this project. Bill Ament and Bill Harryman assisted with trawl, acoustic, and spawner surveys for this project. We also thank the anonymous IDFG personnel who assisted with fieldwork. This project was funded by the Bonneville Power Administration and we thank Jan Brady and Roy Beaty for administering the BPA contract. Melo Maiolie and Catherine Gidley provided reviews of an earlier draft of this report.

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Table 1. Abundance (thousands of fish) and density (fish per ha) of kokanee in Dworshak Reservoir in July 2009. Estimates were derived from a hydroacoustic survey and age breakdowns were derived from a fixed-frame trawl survey. Estimates are broken down by age class and reservoir section.

Section	Age-0	Age-1	Age-2	All Ages	
Section 1	615	678	41	1334	
Section 2	446	231	13	690	
Section 3	189	65	11	265	
Whole reservoir	1250	974	65	2289	
Section	**Area (ha)**	**Age-0**	**Age-1**	**Age-2**	**All Ages**
Section 1	2904	212	233	14	460
Section 2	1713	260	135	7	403
Section 3	604	313	107	19	439
Whole reservoir	5220	239	187	12	439

Table 2. Summary of total lengths of kokanee captured during midwater trawl surveys on Dworshak Reservoir on April 27, July 19-20, and October 13, 2009. Statistics include number of observations, minimum and maximum observations, mean and standard deviation. Growth is given as the increase in mean length (mm) observed in each age class between surveys.

		Total Length (mm)					Growth
Month	Age	N	Min	Mean	Max	SD	(mm)
	1	319	66	107	137	13.2	
	2	42	205	247	283	16.1	
Apr	3	2	274	282	290	11.3	
	0	140	22	45	68	6.5	
	1	249	132	169	209	11.1	62
Jul	2	23	246	272	289	11.6	25
	0	156	49	83	125	12.2	37
Oct	1	142	155	190	222	11.6	21

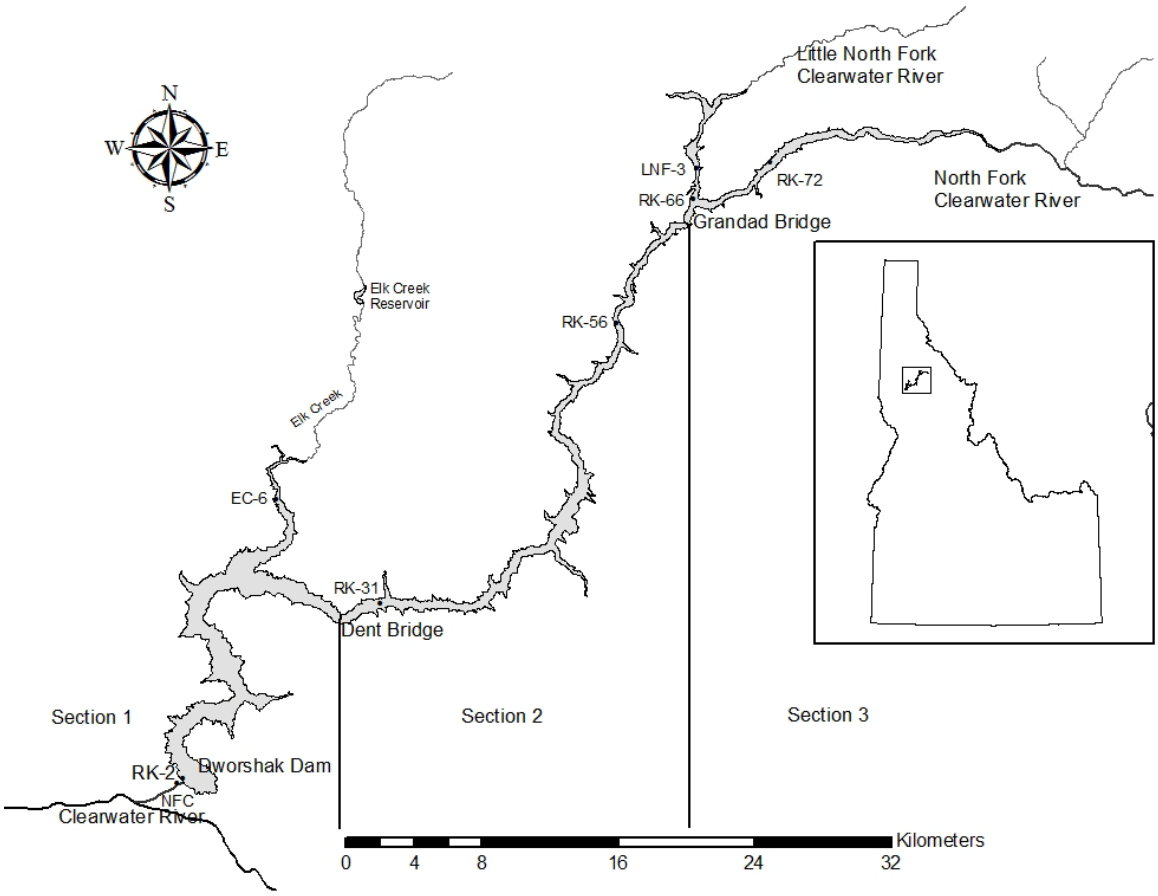


Figure 1. Map of Dworshak Reservoir depicting the locations of seven limnological sampling stations on the reservoir and one on the North Fork Clearwater below Dworshak Dam. Boundaries of reservoir sections used in statistical stratification are also shown.

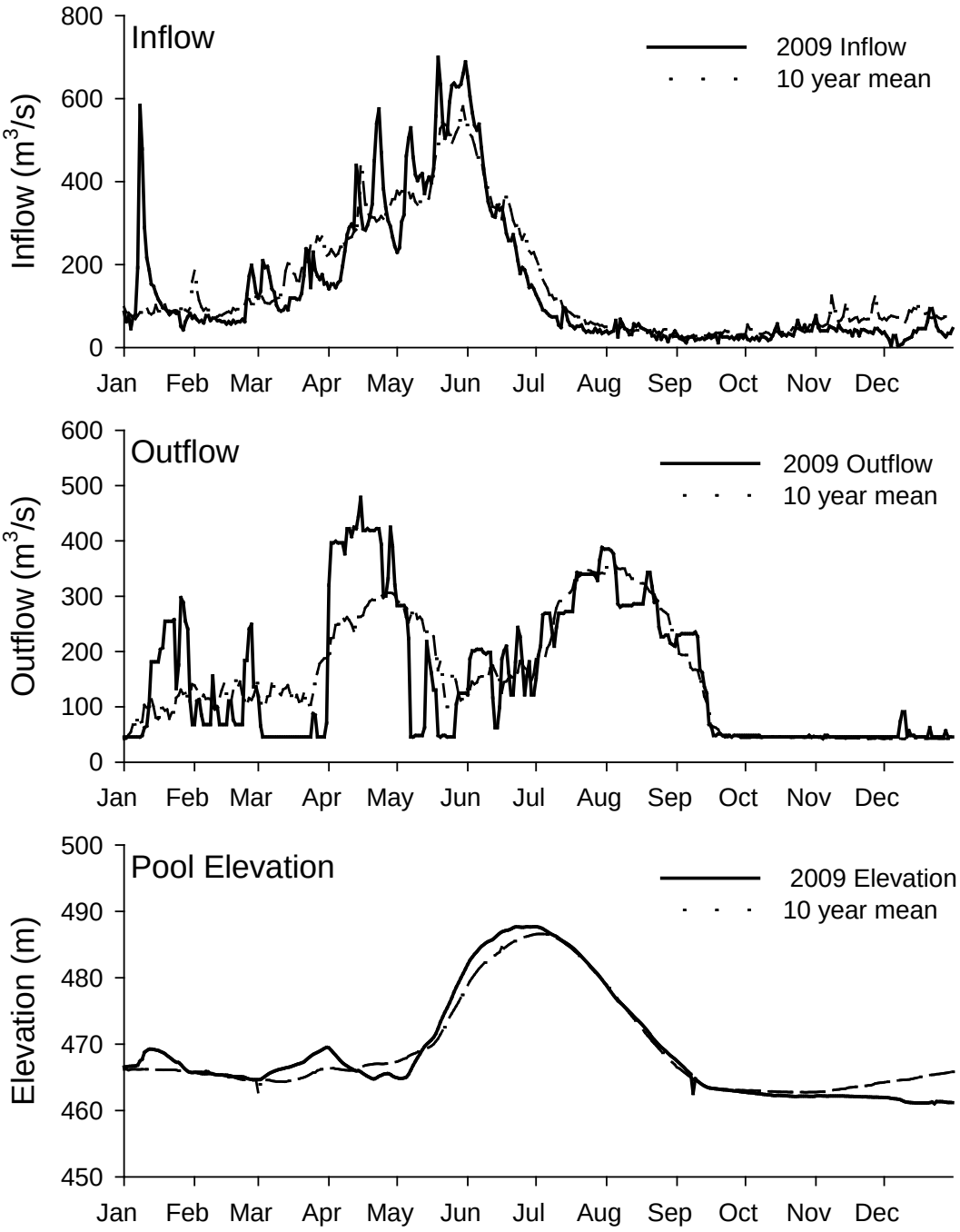


Figure 2. Mean daily inflow, outflow, and pool elevation for Dworshak Reservoir during 2009 along with the 10 year mean (1999-2008). Data provided by the U.S. Army Corps of Engineers through the Columbia River DART website (http://www.cbr.washington.edu/dart/; accessed January 2010).

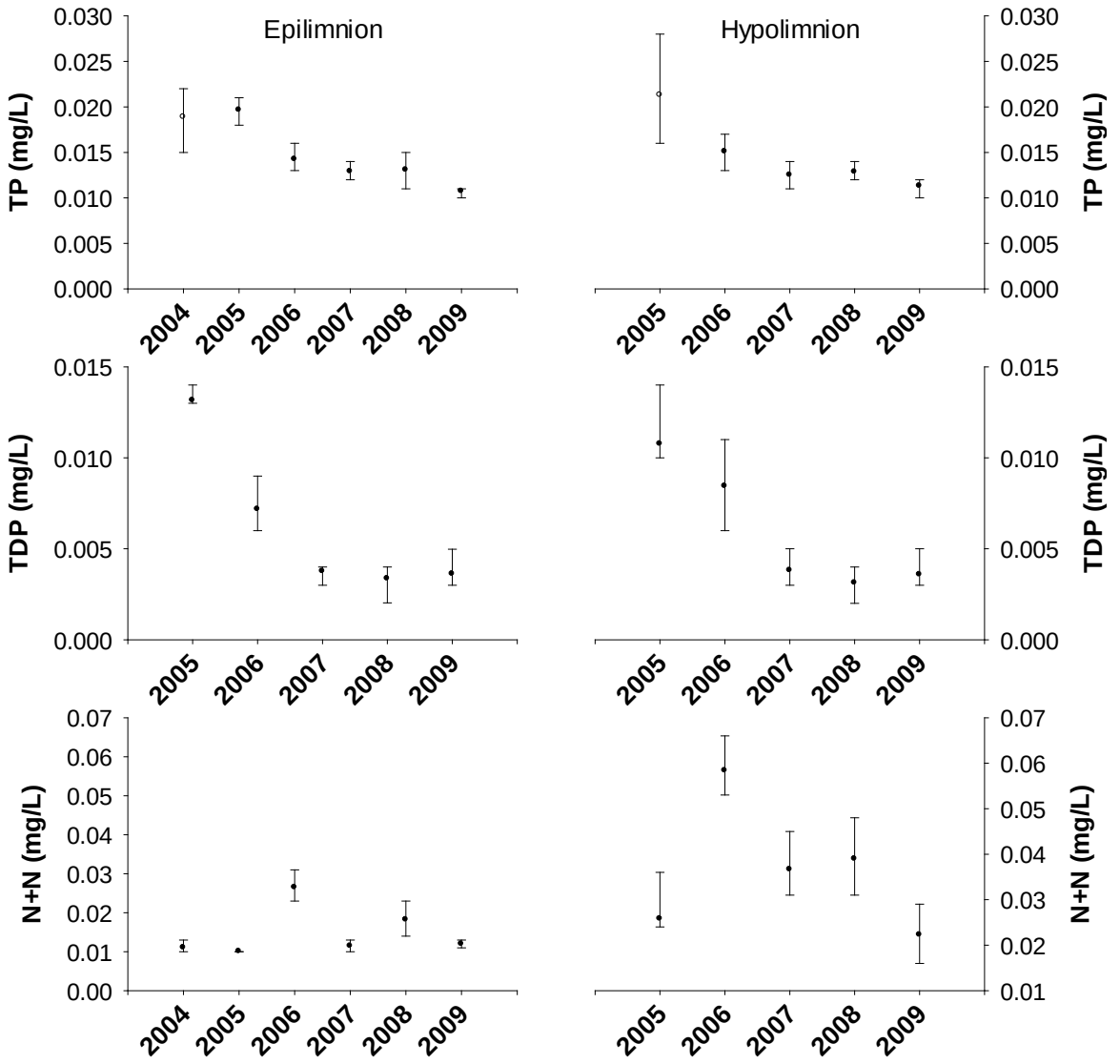


Figure 3. Mean concentration of nutrients measured from two depths at four sampling stations (RK-2, RK-31, RK-56, and RK-72) on Dworshak Reservoir from May through November. Nutrients include total phosphate (TP), total dissolved phosphate (TDP), and nitrite plus nitrate nitrogen (N+N). Because detection limits for TP and N+N differed between years, means were calculated from values that were adjusted to reflect the highest detection limit. Error bars represent 95% confidence intervals derived by bootstrapping.

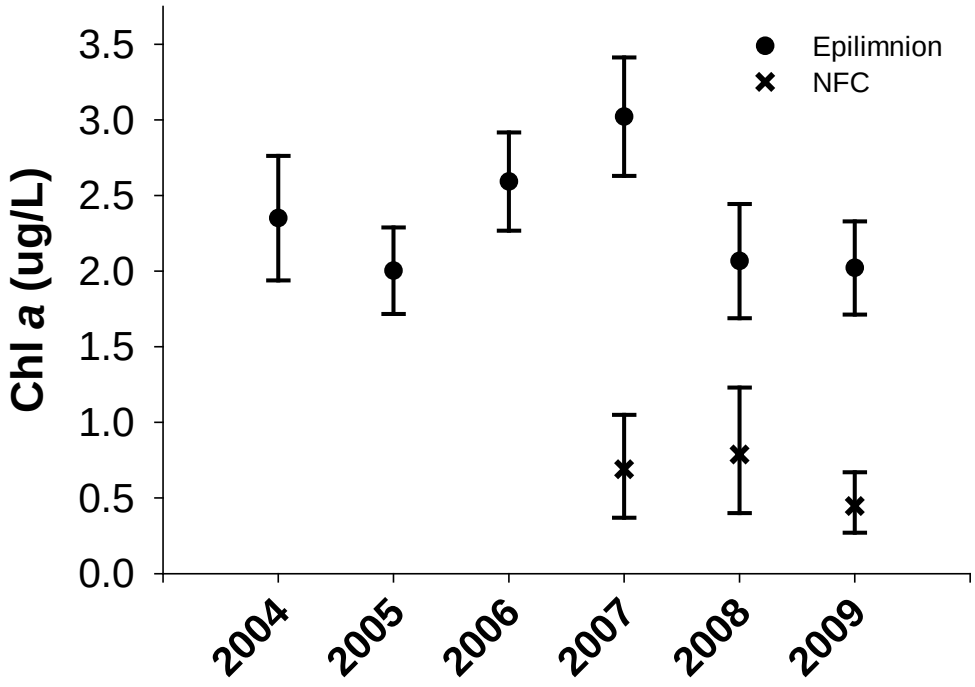


Figure 4. Mean concentration of chlorophyll *a* (Chl *a*) measured at four sampling stations (RK-2, RK-31, RK-56 and RK-72) from May through November for three years prior (2004–2006) to and the first three years (2007–2009) of nutrient supplementation. Also included are means for the North Fork Clearwater River below Dworshak Dam for the first three years of supplementation. Error bars represent 95% confidence intervals derived by bootstrapping.

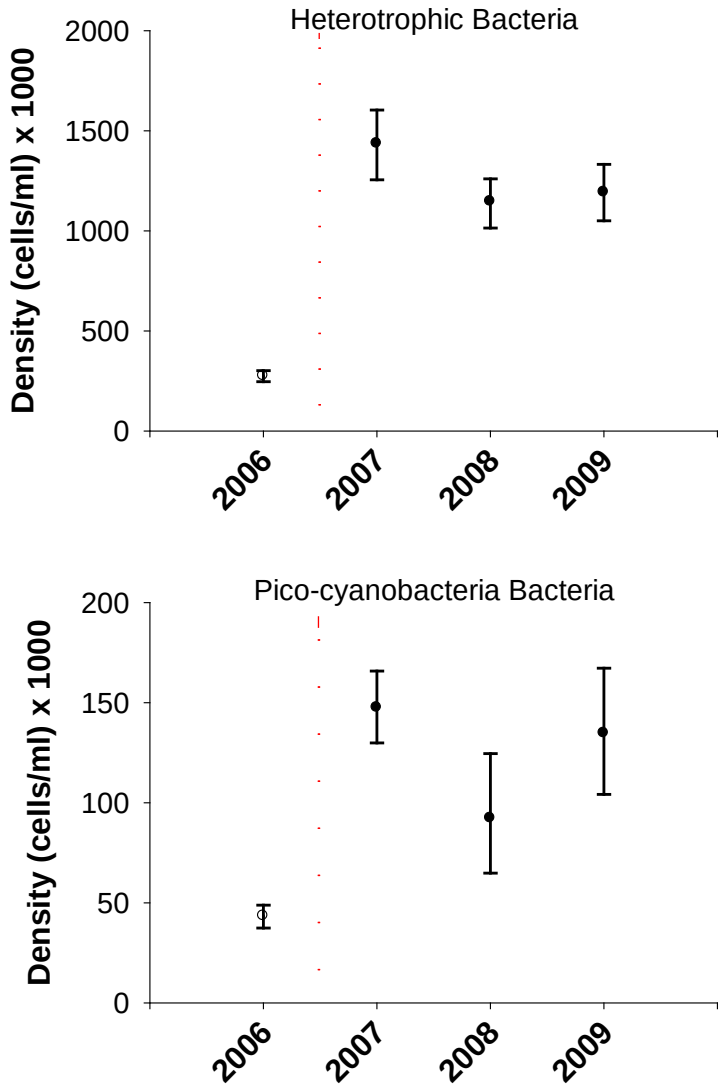


Figure 5. Mean density of picoplankton measured at four sampling stations (RK-2, RK-31, RK-56, and RK-72) on Dworshak Reservoir from May through November. Error bars represent 95% confidence intervals derived by bootstrapping. The vertical red lines indicate the beginning of nutrient supplementation.

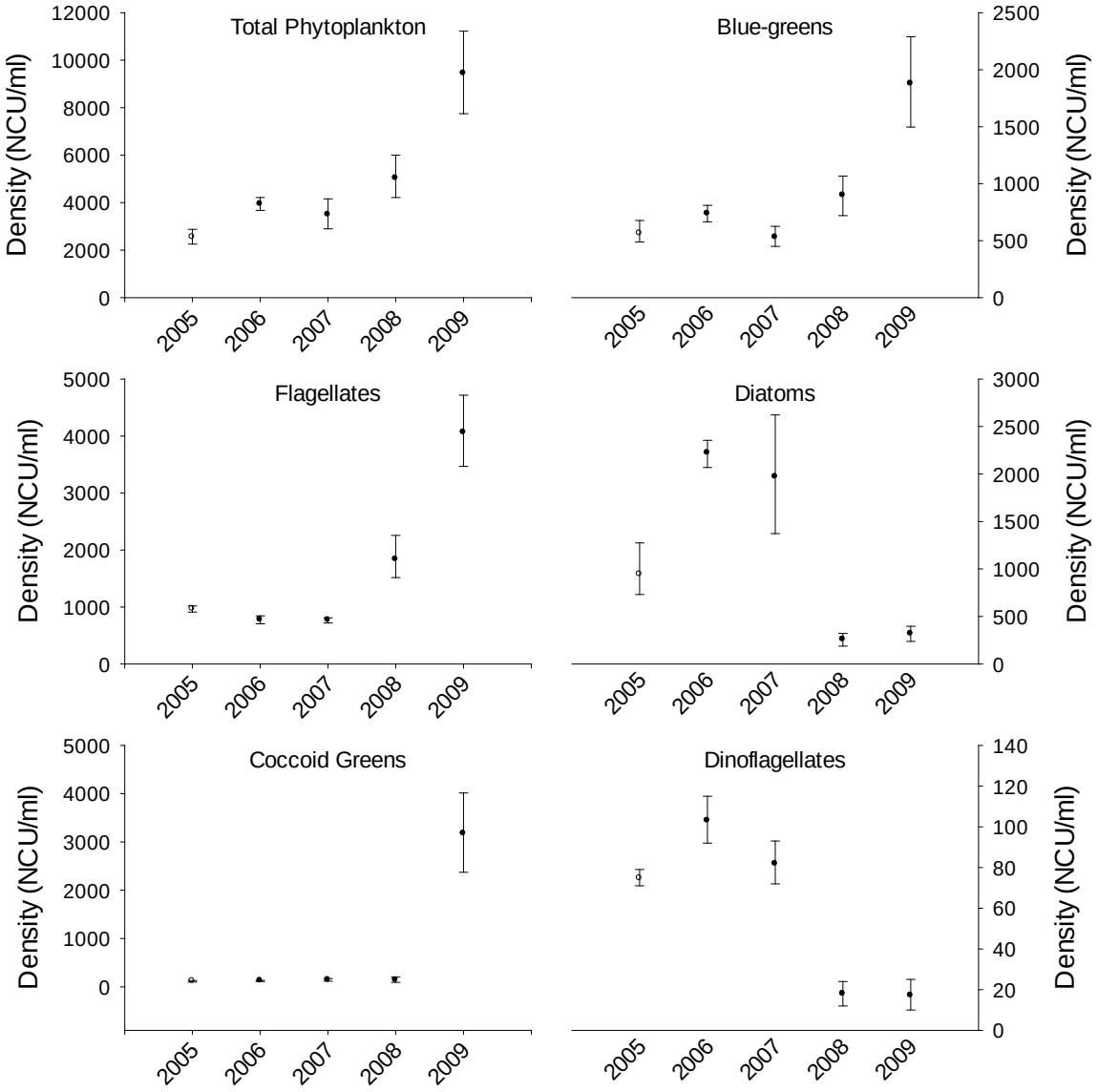


Figure 6. Mean densities of phytoplankton, given in natural counting units (NCU) per mL, measured at four sampling stations (RK-2, RK-31, RK-56, and RK-72) on Dworshak Reservoir from May through November. Densities are given for total phytoplankton and broken out by the five major taxonomic groups present. Error bars represent 95% confidence intervals obtained by bootstrapping.

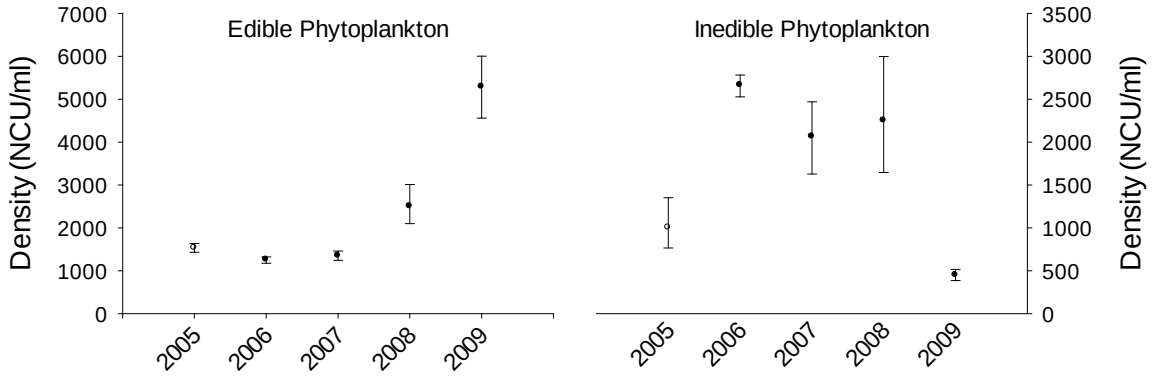


Figure 7. Mean density of phytoplankton, given in natural counting units (NCU) per mL, measured at four sampling stations (RK-2, RK-31, RK-56, and RK-72) on Dworshak Reservoir from May through November. Densities are given for species that are known to be edible to zooplankton during at least part of their life history and those that are known to be inedible. Species for which published information on edibility is not available are not included. Error bars represent 95% confidence intervals obtained by bootstrapping.

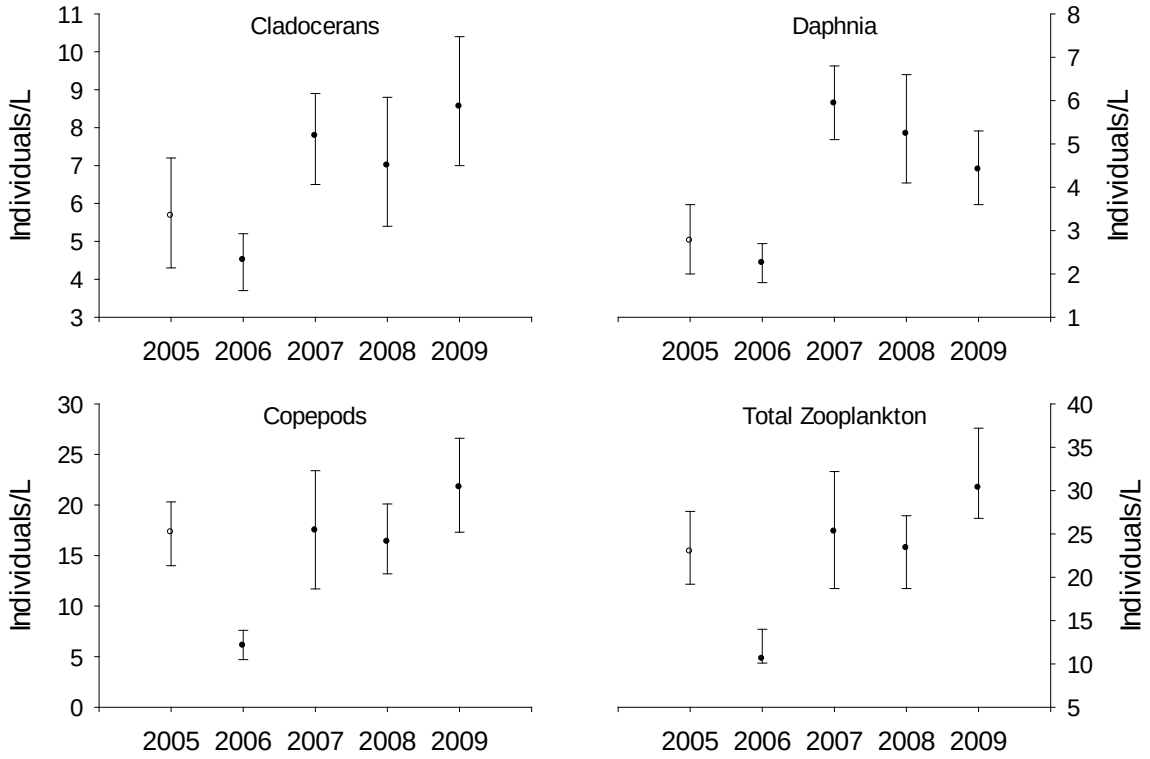


Figure 8. Mean density of zooplankton collected at four sampling stations (RK-2, RK-31, RK-56, and RK-72) on Dworshak Reservoir from June through November. Densities are presented for three taxonomic groups as well as total zooplankton. Error bars represent 95% confidence intervals obtained by bootstrapping.

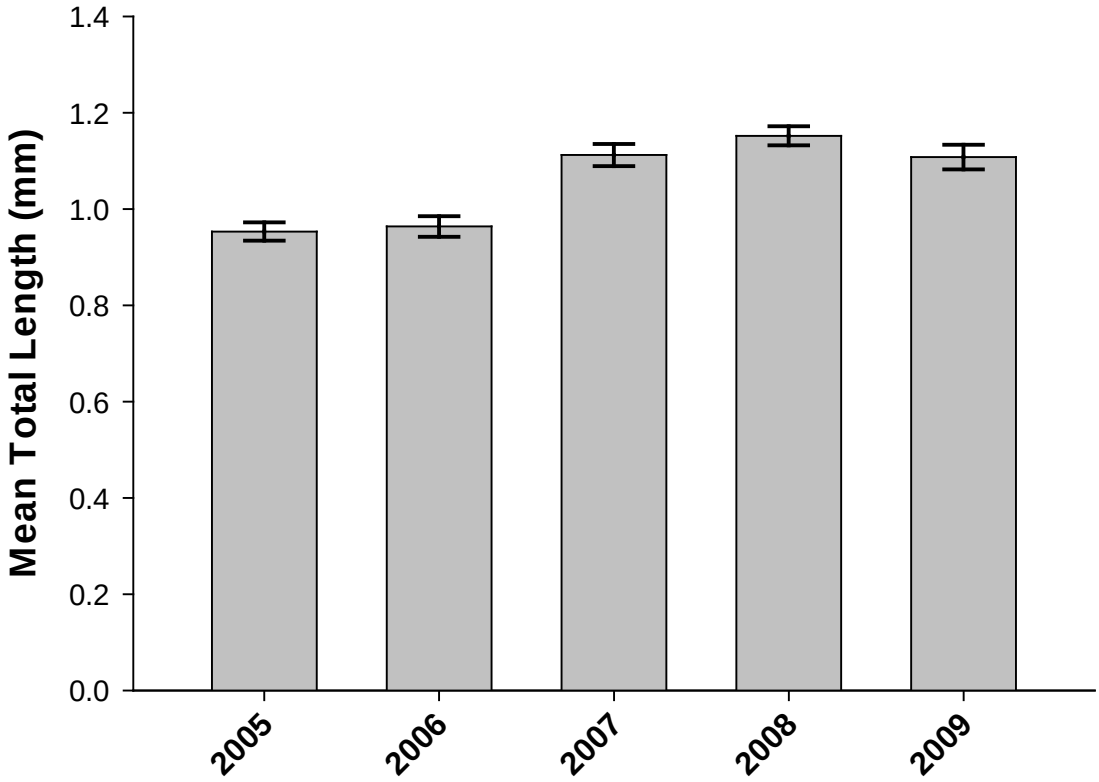


Figure 9. Mean length of Daphnia collected at four sampling stations (RK-2, RK-31, RK-56, and RK-72) on Dworshak Reservoir from June through November. Error bars represent 95% confidence intervals obtained by classical methods.

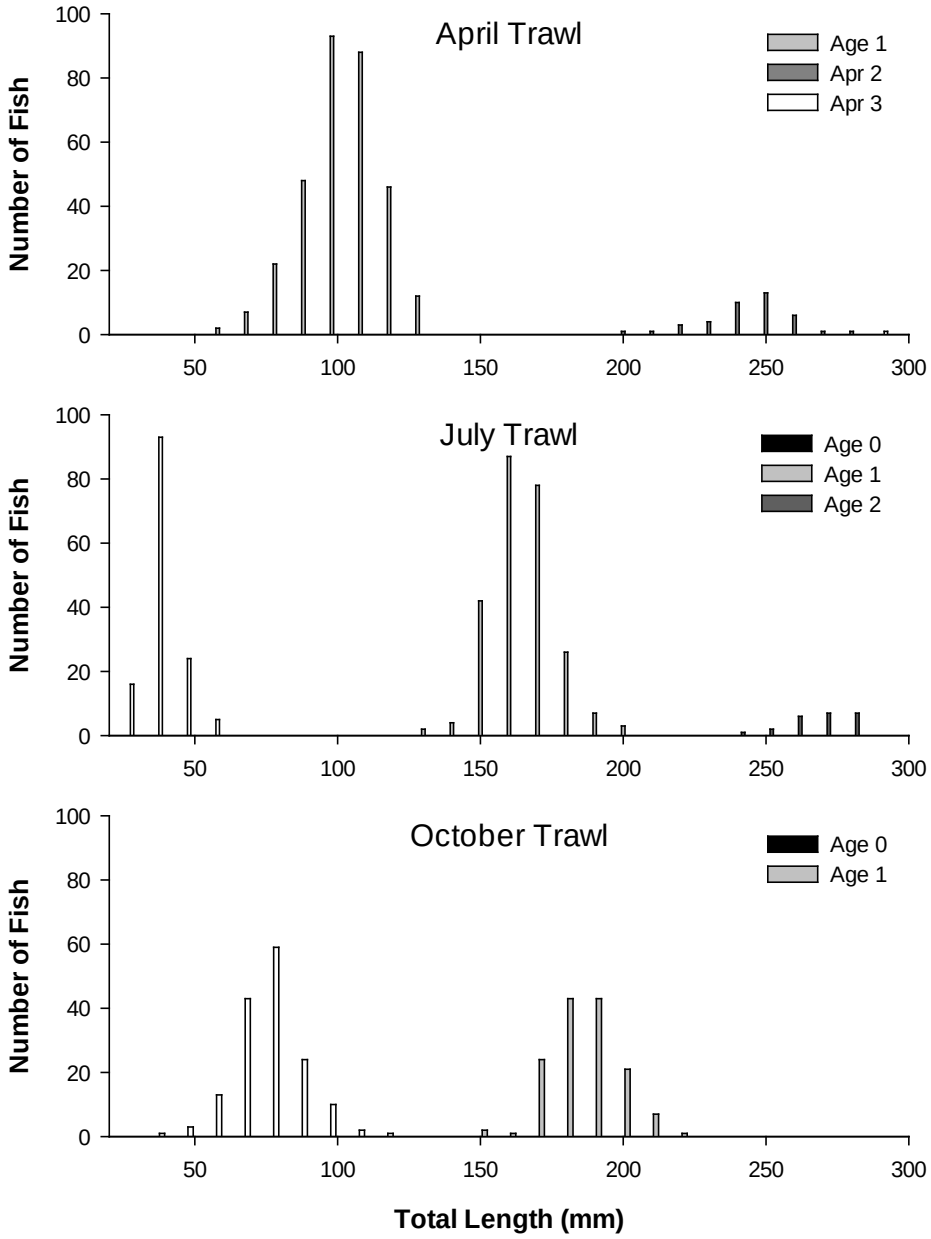


Figure 10. Length frequency of kokanee captured in mid-water trawl surveys on Dworshak Reservoir on April 27, July 19-20, and October 13.

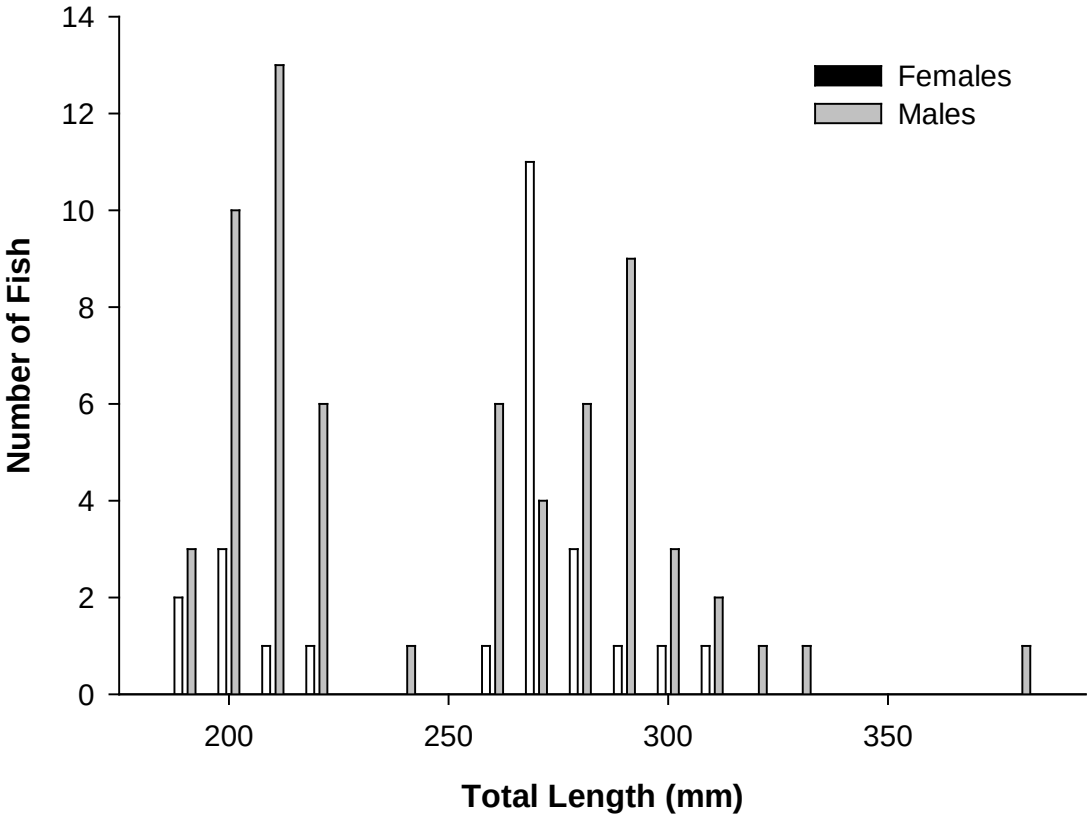


Figure 11. Length frequency of kokanee spawning in four tributaries to the North Fork Clearwater River collected on September 14 and 22-23, 2009. The tributaries surveyed include Isabella, Skull, and Quartz creeks.

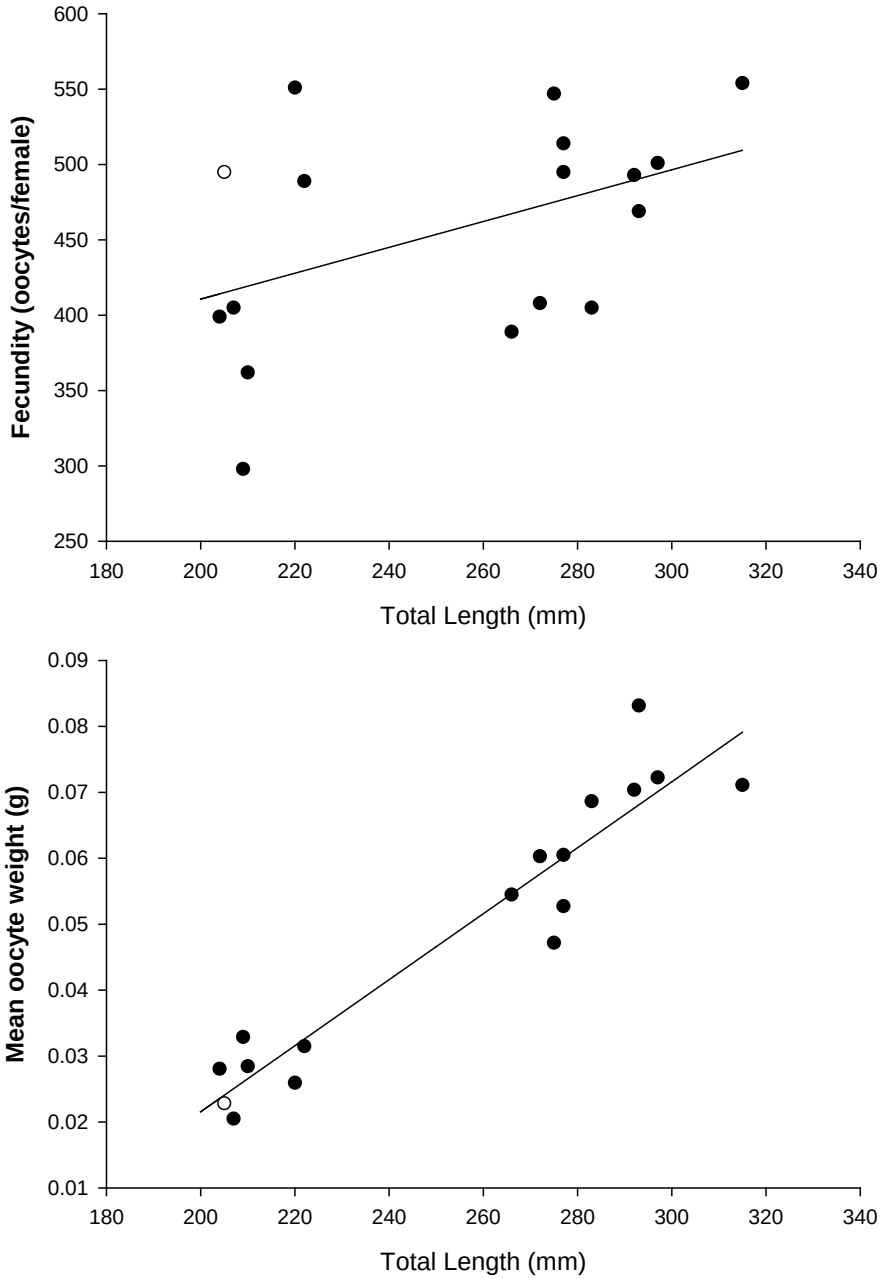
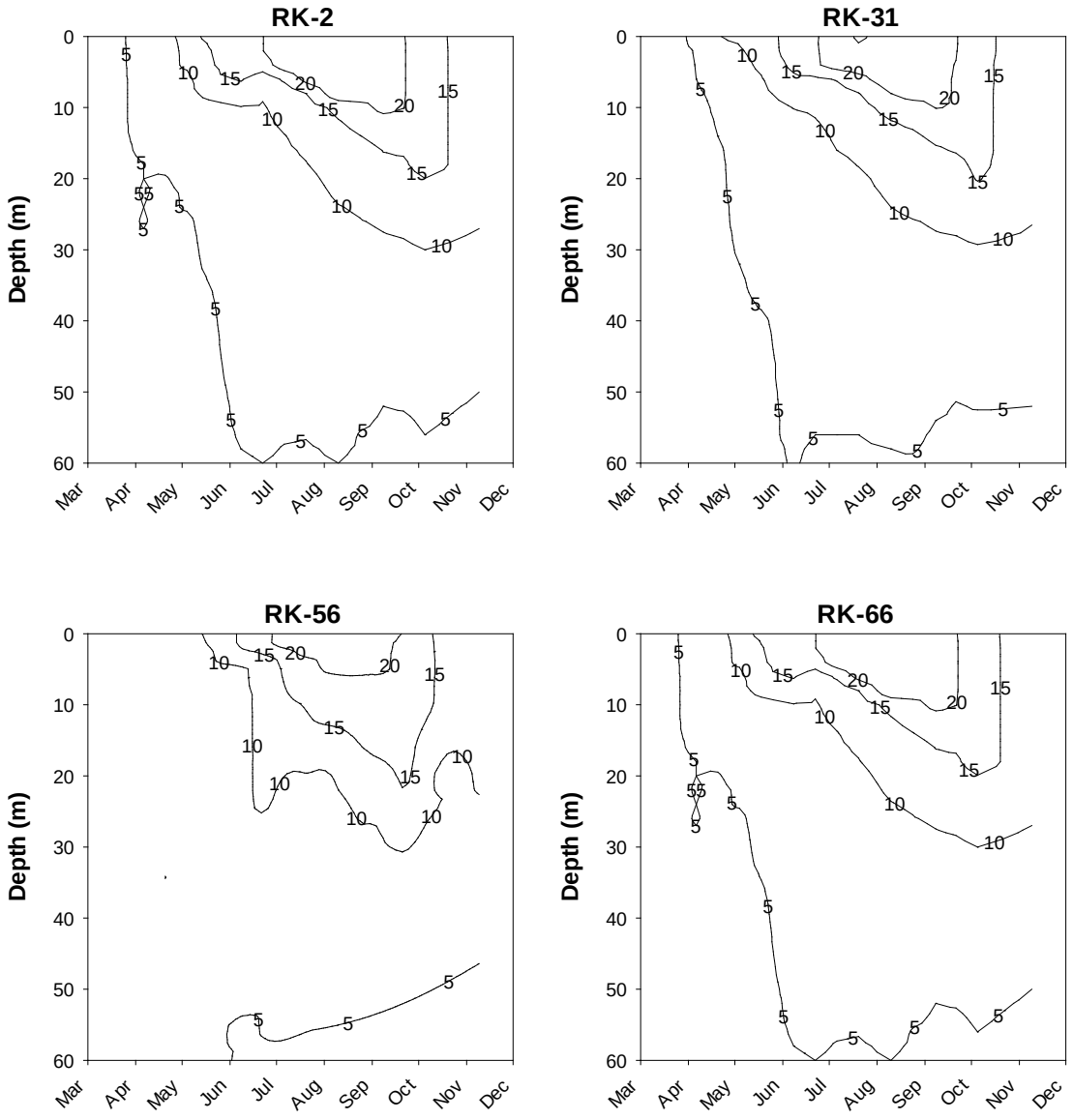


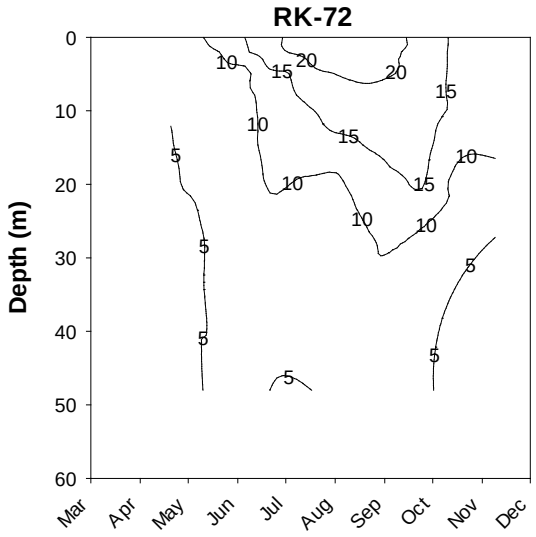
Figure 12. Relationship between fecundity and total length (linear regression, p = 0.07, r^2 = 0.21, n = 17) and oocytes weight and total length (linear regression, p < 0.0001, r^2 = 0.90, n = 17) for female kokanee seined from four tributaries of the North Fork Clearwater on September 14 and 23, 2009. The tributaries surveyed include Isabella, Skull, and Quartz creeks.

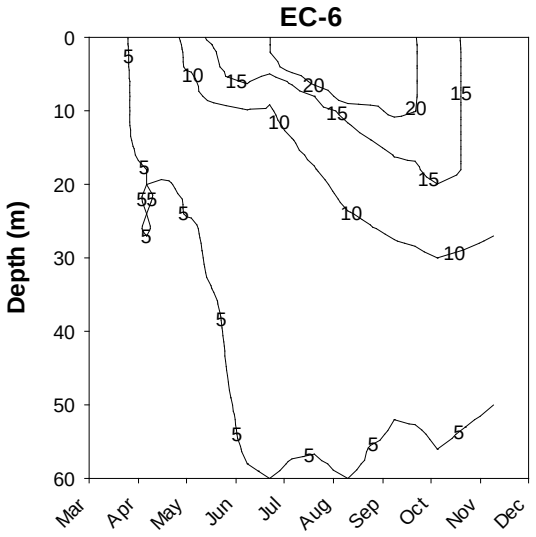
APPENDICES

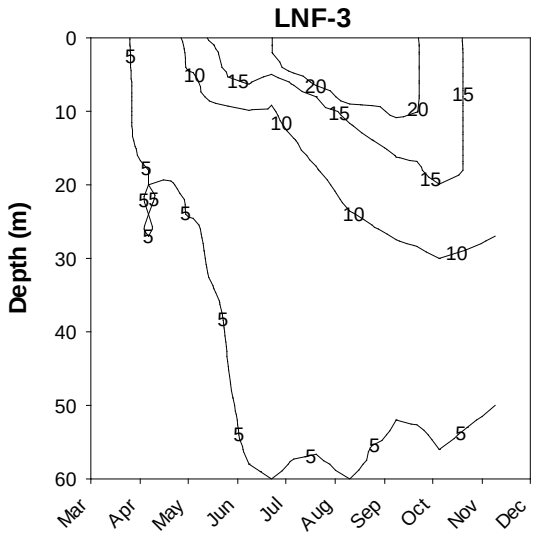
Appendix A. Depth and temperature profiles for seven sampling stations on Dworshak Reservoir from March through November 2009. Isopleths indicate water temperature in degrees Celsius at 5 degree intervals.



Appendix A. Continued.







Appendix B. Depth of the thermocline measured at each of seven sampling stations on Dworshak Reservoir from March through November 2009. The thermocline was defined as a change in temperature of one degree Celsius over a depth of one meter. NS denotes times and locations where stratification was weak or absent.

	Depth of Thermocline (m)						
Date	RK-2	RK-31	RK-56	RK-66	RK-72	EC-6	LNF-3
23-Mar	NS	NS	NS	NS	NS	NS	NS
6-Apr	NS	NS	NS	NS	NS	1.0	NS
20-Apr	NS	NS	NS	NS	NS	5.0	NS
4-May	5.0	NS	NS	NS	NS	5.0	NS
18-May	7.0	NS	3.0	2.0	2.0	2.0	2.0
8-Jun	NS	3.0	5.0	3.0	NS	5.0	3.0
22-Jun	3.0	5.0	5.0	3.0	3.0	3.0	3.0
6-Jul	5.0	5.0	3.0	1.0	2.0	3.0	2.0
20-Jul	5.0	2.0	5.0	3.0	5.0	3.0	3.0
10-Aug	9.0	7.0	5.0	13.0	5.0	7.0	13.0
24-Aug	9.0	7.0	15.0	5.0	5.0	9.0	5.0
7-Sep	11.0	11.0	9.0	19.0	21.0	9.0	19.0
21-Sep	11.0	11.0	NS	23.0	NS	9.0	NS
5-Oct	19.0	21.0	13.0	13.0	17.0	NS	11.0
9-Nov	23.0	NS	NS	NS	13.0	NS	17.0
23-Mar	NS	NS	NS	NS	NS	NS	NS

Appendix C. Number of observations (n), minimum, mean, median, maximum, and standard deviation (SD) for compensation depth at seven sampling stations on Dworshak Reservoir from March through November 2009. Compensation depths were calculated as the depth at which 1% of the photosynthetically active radiation measured at the surface was still present. Statistics are presented by month (all stations combined) and by station (entire year).

	Compensation Depth (m)					
Month	**n**	**Min**	**Mean**	**Median**	**Max**	**SD**
May	4	5.7	8.4	9.2	9.4	1.8
Jun	11	4.9	8.2	8.3	9.8	1.4
Jul	14	5.5	8.3	8.2	10.7	1.4
Aug	14	6.5	9.0	9.2	11.0	1.2
Sep	14	6.2	8.9	8.7	13.5	1.9
Oct	14	6.5	8.5	8.6	11.0	1.3
Nov	14	7.7	8.9	8.9	10.1	0.7
Station	**n**	**Min**	**Mean**	**Median**	**Max**	**SD**
RK-2	15	6.5	8.9	8.6	12.9	1.5
RK-31	15	7.2	8.9	8.5	12.7	1.4
RK-56	15	7.6	9.5	8.9	13.5	1.6
RK-66	13	8.1	9.4	9.3	11.2	1.0
RK-72	13	7.9	9.2	9.0	11.0	1.1
EC-6	15	4.9	7.2	6.7	11.8	1.7
LNF- 3	13	8.1	9.3	9.4	11.0	1.0

Appendix D. Summary of the relative percent difference and difference between original and duplicate samples for six water quality parameters measured at seven sampling stations on Dworshak Reservoir from March through November 2009.

	Relative Percent Difference				Difference			
Parameter	**mean**	**median**	**min**	**max**	**mean**	**median**	**min**	**max**
TDP (mg/L)	62.1%	44.4%	0.0%	200.0%	0.002	0.002	0.000	0.005
TP (mg/L)	33.9%	15.4%	0.0%	200.0%	0.002	0.001	0.000	0.007
N+N (mg/L)	68.2%	40.0%	0.0%	200.0%	0.004	0.003	0.000	0.010
TDS (mg/L)	9.3%	5.4%	0.0%	22.2%	1.1	0.0	0.0	5.0
Chl *a* (µg/L)	33.8%	30.5%	5.4%	69.9%	0.49	0.31	0.04	1.06

Appendix E. Estimates of kokanee abundance and adult (age-2 and older) densities for Dworshak Reservoir.

		Kokanee Abundance					Adult Density
Year	**Sampling Method**	**Age-0**	**Age-1**	**Age-2**	**Age-3**	**Total**	**(fish/ha)**
2009	Hydroacoustic	1,249,964	974,068	65,191	0	2,289,223	21
2008	Hydroacoustic	1,401,809	242,095	63,347	34,308	1,741,559	18
2007	Hydroacoustic	584,547	332,017	235,346	0	1,151,910	48
2006	Hydroacoustic	2,182,983	1,508,780	2,123,631	0	5,815,394	484
2005	Hydroacoustic	2,134,986	769,663	107,466	0	3,011,626	21
2004	Trawling	2,136,892	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[a]	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] June sampling likely resulted in an underestimate of age-0 kokanee.
[b] September sampling likely resulted in an underestimate of mature kokanee.

Appendix F. Production and biomass estimates for kokanee in Dworshak Reservoir, Idaho for 2004 through 2009. Production was calculated from July of the previous year to July of the year listed when weight data from trawl surveys was available in both years. Biomass was calculated for July in all years where weight data was available.

Production (metric tonnes)				
Year	**Age 0-1**	**Age 1-2**	**Age 2-3**	**Total**
2009	50.3	14.3		64.6
2008	34.8	38.7	18.4	91.8
2007	71.3	68.4		139.8
2006				
2005				
2004	40.8	45.1		85.9
2003				

Biomass (metric tonnes)					
Year	**Age-0**	**Age-1**	**Age-2**	**Age-3**	**Total**
2009	0.9	41.9	11.6		54.4
2008	0.9	20.5	16.6	9.0	47.1
2007	0.3	22.2	29.5		52.0
2006	0.8	30.0	51.7		82.5
2005					
2004	1.4	51.0	22.1		74.4
2003	0.7	31.0	43.9		75.6

Appendix G. Number of kokanee spawners counted in index tributaries to the North Fork Clearwater River above Dworshak Reservoir, Idaho during September 1988-2009. Counts were performed on or near September 25, the historical peak of spawning activity.

Year	Isabella Creek	Skull Creek	Quartz Creek	Dog Creek	Total
2009	5,366	4,343	918	626	11,253
2008	3,738	2,160	462	1,073	7,433
2007	11,342	10,913	1,268	1,771	25,294
2006	12,604	12,077	2,717	2,345	29,743
2005	6,890	3,715	2,137	617	13,359
2004	6,922	2,094	450	1,474	10,940
2003	12,091	10,225	1,296	1,083	24,695
2002	15,933	7,065	2,016	1,367	26,381
2001	3,751	1,305	722	301	6,079
2000	3,939	402	124	565	5,030
1999	10,132	361	827	2,207	13,527
1998	627	20	13	18	678
1997	144	0	0	0	144
1996	2,552	4	13	82	2,651
1995	12,850		2,780	1,160	16,790
1994	14,613	12,310	4,501	1,878	33,302
1993	29,171	7,574	2,476	6,780	46,001
1992	7,085	4,299	1,808	1,120	14,312
1991	4,053	1,249	693	590	6,585
1990	10,535	3,219	1,702	1,875	17,331
1989	11,830	5,185	2,970	1,720	21,705
1988	10,960	5,780	5,080	1,720	23,540

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