FISHERY RESEARCH

DWORSHAK RESERVOIR
NUTRIENT RESTORATION RESEARCH, 2014

DWORSHAK DAM RESIDENT FISH MITIGATION PROJECT

PROGRESS REPORT
March 1, 2014 – February 28, 2015

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ABSTRACT

The Idaho Department of Fish and Game (IDFG) and the U.S. Army Corps of Engineers (USACE) cooperatively conducted a pilot project to assess the effectiveness of nutrient restoration as a means to restore declining reservoir productivity and improve the Dworshak Reservoir fishery. Under this arrangement, the USACE applied nutrients in the form of ammonium nitrate, IDFG monitored the results using a combination of limnological, fish, and angler surveys; and Advanced Eco-Solutions provided the application schedule and limnological analysis. This report summarizes the results from 2014, the third year of a second pilot project. Water quality standards set by the U.S. Environmental Protection Agency and the Idaho Department of Environmental Quality were not violated. The Secchi depth for 2014 (mean = 3.6 m) was the lowest since 2004. The chlorophyll concentration (mean = 1.86 µg/L) was lower than any non-restoration year and phytoplankton biovolume (mean = 0.363 mm^3/L) was below the non-restoration mean (mean = 0.449 mm^3/L). The proportion of edible phytoplankton (58%) was higher than any non-restoration year, and the proportion of *Anabaena* (4%) was lower than any non-restoration year. The length (mean = 0.96 mm) and the density (mean = 3.8 individuals/L) of *Daphnia* was the lowest for restoration years. Together, these resulted in the third lowest biovolume (mean = 54 µg /L) of consumable *Daphnia* from 2005 to 2014. We estimated there were 2.6 million age-1 and older kokanee *Oncorhynchus nerka* in the reservoir, which was tied for the highest abundance on record. The mean length and weight of age-2 kokanee were greater than 2006, a non-restoration year with similar fish abundance. Catch rates for kokanee were estimated to be 1.4 fish/hour, which met the objective of 1.2 fish/hour. However, the mean length (mean = 239 mm TL) was less than the objective of 254 mm TL. Dworshak Reservoir appears to be responding to nutrient restoration as anticipated and greater improvements to the fishery are possible if results are sustained. Our results to date are consistent with those reported for nutrient restoration projects in Kootenay and Arrow lakes in British Columbia.

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INTRODUCTION

Dworshak Reservoir was the most popular fishing destination in Clearwater County and the second most popular destination in the Clearwater region, based on total angler trips in 2011 (Thomas MacArthur, IDFG, unpublished data). It provides a multispecies fishery for naturally-reproducing kokanee *Oncorhynchus nerka*, Smallmouth Bass *Micropterus dolomieu,* and Westslope Cutthroat Trout *O. clarkii lewisi*, as well as hatchery-stocked Rainbow Trout *O. mykiss*. The reservoir also provides important habitat for Bull Trout *Salvelinus confluentus*, which are listed as Threatened under the Endangered Species Act.

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 stock quickly dominated (Horton 1981). Kokanee provide the most popular fishery on the reservoir, with annual effort levels and harvest that have exceeded 140,000 angler hours 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).

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 primarily during the summer and early fall to provide cool water for Chinook salmon *O. tshawytscha* in the Snake River. During this time period, kokanee are distributed farther from the dam and are 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 (2006) conducted a detailed assessment of the reservoir and recommended implementation of a nutrient restoration program. Based on phosphorous (P) loading and mean chlorophyll concentrations, 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 picoplankton, the microbial communities typical of ultraoligotrophic lakes and reservoirs. Dworshak Reservoir becomes nitrogen (N) limited by mid-summer, leading to a dominance of N-fixing cyanobacteria (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. Mid-summer N limitation and the subsequent reduction in zooplankton results in reduced fish production.

The Idaho Department of Fish and Game (IDFG) and the U.S. Army Corps of Engineers (USACE) initiated a five-year pilot project to evaluate nutrient restoration as a management strategy for restoring the Dworshak Reservoir ecosystem and improving the fishing opportunities it provides. The goal of the project was to provide a quality fishery by improving the flow of carbon (C) through all trophic levels to the kokanee. We intend to restore lost productivity by improving the N:P ratios in the reservoir, thereby promoting the growth of desirable phytoplankton (i.e., edible by zooplankton). Increased abundance of edible phytoplankton (including picoplankton) was expected to support increased abundance of zooplankton, and therefore an improved forage base for fish. Stockner and Brandt (2006) anticipated that a moderate N nutrient addition would benefit fish populations without degrading water quality.

The first pilot project began in 2007, for which the USACE applied the nutrients and IDFG monitored the limnological and fishery response. Advanced Eco-Solutions, a private consulting company, was contracted to assist in designing the monitoring program, interpret the results of the limnological data, and adjust the nutrient prescriptions as necessary. However, nutrient applications were suspended prematurely in late July 2010 due to a legal challenge. At that time, the project was being conducted under the legal authority of a Consent Order issued by the Idaho Department of Environmental Quality (DEQ). The U.S. Environmental Protection Agency then made a determination that a National Pollutant Discharge Elimination System (NPDES) permit would be required for nutrient applications to continue. An NPDES permit was not obtained until October 2011, which did not allow for nutrient applications in the final year of the original pilot study. A second pilot project was initiated in 2012 and is intended to run through 2017, at which time a determination will be made as to whether nutrient restoration should be implemented as a management strategy for the reservoir.

The primary purpose of IDFG's monitoring program was to evaluate the effectiveness of the nutrient restoration program at improving the flow of C 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 DEQ, were maintained. Second, limnological data were collected to make comparisons with pretreatment conditions to determine the biological effects of the project, including changes to the plankton communities. In treatment years, data were provided to the consultant to actively manage the nutrient applications. In addition to limnological monitoring, surveys were conducted to monitor the kokanee population. An effective nutrient restoration program is expected to increase the average size of kokanee at any given population density. This could result in larger kokanee at prerestoration levels of abundance, or more kokanee at a similar size to prerestoration. Either scenario is expected to produce higher catch rates in the sport fishery (Rieman and Maiolie 1995).

This report summarizes data collected in 2014, the third year of the second pilot study. These data were used to assess both the limnological and fishery responses to nutrient restoration and determine if the biological communities are responding in a positive manner.

OBJECTIVES

1. Maintain an annual median Secchi depth of ≥3.0 m and an annual median chlorophyll *a* concentration of ≤3.0 µg/L for treated areas of the reservoir.

2. Increase densities of picoplankton by twofold in the first year of nutrient restoration.

3. Increase the mean total length of age-2 kokanee by 20 mm over that observed at a similar pretreatment kokanee density.

4. Maintain a kokanee population that can sustain a catch rate of 1.2 fish per hour with a minimum average size of 254 mm total length.

STUDY SITE

Dworshak Reservoir was impounded after the construction of Dworshak Dam in 1972. The dam is located on the North Fork Clearwater River approximately 2.4 km from its confluence with the mainstem 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. Timber harvest is the primary commercial activity, 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). 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 typical minimum pool elevation reached by the second week of September. The mean hydraulic retention time is 10.2 months (Falter 1982) and the mean daily discharge from 2004-2013 was 152 m^3/s (http://www.cbr.washington.edu/dart/, accessed 1/2/15). Historically, Dworshak Reservoir begins to thermally stratify in April and stratification becomes pronounced from June through September. Destratification begins in the fall and occurs more rapidly at the upper end of the reservoir (Falter 1982).

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 website (http://www.cbr.washington.edu/dart/; accessed 1/2/15).

Limnology

Sample Collection

Limnological sampling was conducted at six stations on the reservoir and one station on the North Fork Clearwater River (NFC) below Dworshak Dam (Figure 1). Four stations on the main reservoir were designated as RK-2, RK-31, RK-56, and RK-72, corresponding 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).

Limnological sampling was conducted twice monthly from April through September and once monthly during March, October, and November. When all seven reservoir stations and the river station could not be sampled in one day, samples were collected over a two-day period.

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

Water depth was measured using a Garmin™ Model GSD22 depth sounder in conjunction with a GPS MAP 4212 chart plotter. Water clarity 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® (YSI) Professional Plus multiparameter meter, polarographic probe, and 70 m cable. 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 recorded.

The level of PAR was measured using a Li-Cor® model LI-250A light meter and a 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 only collected from RK-2 and for the first event each month. They consisted of a single 'grab' from 25 m. 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. Chemical analyses were performed by AM Test Labs of Kirkland, Washington. Analytical methods used for each parameter can be found in Wilson et al. (2010). While collecting the EPI sample at each station, a 'grab' was collected from 1 m and the pH was measured using a pH10A meter from YSI.

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 and 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 Ocean Test Equipment, Inc. 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. All plankton and Chl *a* samples were sent to Advanced Eco-Solutions of Newman Lake, Washington for analysis. Analytical methods used for each parameter can be found in Wilson et al. (2010).

Primary production rates were measured by Advanced Eco-Solutions on June 25, July 23, August 20, and September 24 at RK-31. Briefly, water was drawn from five discrete depths spaced throughout the photic zone. Two clear and one opaque BOD bottles were filled for each depth and inoculated with ^{14}C. Bottles were then incubated for approximately four hours at the same depth from which they were drawn. After retrieval, aliquots from each bottle were filtered through filters of 20, 2, and 0.2-µm pore size. The filters were then sent to the University of Idaho to measure the amount of ^{14}C, from which daily carbon uptake (mgC/m^2/day) could be calculated. For more detail, see Brandt (2015).

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:

$$x = Ln\left[100\left(\frac{l_D}{l_S}\right)\right]$$

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 less than 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 less than the detection limit.

Descriptive statistics were computed using R 3.0.1 (www.r-project.org). 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, 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 increased to match the year with the highest minimum level. That is, values less than the highest minimum level for any year were considered to be equal to that level for the purposes of calculating descriptive statistics.

Phytoplankton densities were recorded both in terms of natural counting units (NCU), which refers to colony numbers for some species and cells for others, and as biovolume (mm^3/L). Prior to 2008, cells/mL was not recorded for colonial species (e.g. *Anabaena sp*.). Therefore, densities are reported as cells/mL whenever possible, 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. Pretreatment data were collected from a depth that was twice the Secchi depth. Since these depths were, on average, similar to the current depth strata, they were compared directly to the data collected from 2008 through 2011 taken from 10 m to the surface. Since data from 2007 were collected from 30 m to the surface, it was first adjusted by calculating the proportion of zooplankton collected in 2008 from 10 – 0 m to the total amount collected in the 10 – 0-m and 30 – 10-m tows (Wilson et al. 2010). The annual mean for this proportion was then applied to the 30 – 0-m data from 2007 to estimate the density of zooplankton in the 10 – 0-m tows. A similar proportion was developed to adjust the estimated biomass of *Daphnia*. These estimates were used when comparing 2007 data to other years.

The forage base for kokanee was evaluated by examining changes in the density and biomass of *Daphnia*, since these are the preferred forage of kokanee and represent the bulk of their diet in most months (Stark and Stockner 2006). The weights of individual *Daphnia* were calculated using the following formula (McCauley 1984):

$$lnw = lna + b \times lnL$$

Where:
lnw = natural log of weight in µg
lna = estimated intercept
b = estimated slope
lnL = natural log of length in mm

For these calculations, we used estimates from McCauley (1984) for *D. galeata* where:

lna = 2.64
b = 2.54

The density and biomass of consumable *Daphnia* were calculated for each tow. Kokanee in Dworshak Reservoir were found to primarily consume *Daphnia* that were 0.80 mm or longer TL (Wilson et al. 2013). The proportion of consumable *Daphnia*, as calculated from a sample of *Daphnia* from that tow, which were measured, was multiplied by the total density of *Daphnia* to determine the density of consumable *Daphnia*. The mean weight of consumable *Daphnia* was multiplied by the density of consumable *Daphnia* to estimate the biomass of available forage for kokanee.

In order to determine the effects of nutrient restoration on the biomass of consumable *Daphnia*, while controlling for top-down effects of grazing by kokanee, we fit the data to a series of linear models. The first set of models compared total kokanee abundance and the abundance of age-1 and older kokanee to determine which was a better predictor of consumable *Daphnia* biomass. The better measure of abundance was then used in a second set of models, which examined the relative importance of nutrient restoration, kokanee abundance, and the interaction between these variable on the biomass of consumable *Daphnia*. The best model was determined by the lowest AIC_c value and the relative plausibility of each model was assessed using both the differences in AIC_c (ΔAIC_c) and Akaike weights (w_i) (Burnham and Anderson 2002). Models with ΔAIC_c <2.0 or $w_i \geq 0.1$ were considered to be relatively important. Individual factors were ranked by summing the w_i of each model with that factor. The higher the sum of w_i for a factor, the higher the importance of that factor (Burnham and Anderson 2002).

Due to inconsistencies in these data, we chose to make comparisons between years using a graphical analysis of means and confidence intervals rather than attempting more rigorous statistical tests (Johnson 1999). Annual means were weighted by month to account for differences in sampling intensity throughout the year. Likewise, means for the treatment and non-treatment periods were weighted by year to account for interannual differences in sampling intensity. For data that were not normally distributed, we used a bootstrap technique to derive 95% confidence intervals (Chernick 1999; Efron and Tibshirani 1994). For this, the original data were resampled with replacement using R 3.0.1. For each year, 1000 iterations were performed in which a bootstrap mean was calculated. Confidence intervals were derived using the percentile method, where 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 bucket 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:

$$RPD = \frac{|S_1 - S_2|}{(S_1 + S_2)/2} \times 100$$

Where: S_1 = Original sample
S_2 = Duplicate sample

Kokanee Population Monitoring

Abundance

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 RKM 27.0, while Section 2 extended from Dent Bridge to Grandad Bridge at RKM 65.2. Section 3 encompassed the reservoir upstream of Grandad Bridge.

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 2.0 m/s. The echo sounder was set to ping at 0.6 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 proportion 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. This area was determined by first subtracting the mean depth for single targets in each section from the pool elevation at the time of the survey to determine the mean elevation of the kokanee layer. The reservoir area at this elevation was then looked up from a table based on data provided by the USACE (Sam Martin, USACE, personal communication). This table was created using USGS topographic data from pre-impoundment surveys from which the area was calculated at 12.2-m increments between 426.7 and 487.7 m. The areas in the table were then estimated for each 0.3-m increment of elevation using a second order polynomial regression.

During this study, calculations used to produce population estimates have been refined. In order to ensure that estimates were comparable between years, we revised earlier estimates using the newer methodology so that all estimates used the same methods and reservoir area data to the extent possible.

Age and Growth

Trawl surveys were conducted in April and July. A survey was not conducted in October due to mechanical difficulties with the trawler. 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 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 10 fish from every 1-cm length bin from each section. Scales were later examined by two independent readers to determine age (Devries and Frie 1996).

Trawl surveys were based on 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. Due to mechanical problems with the diesel powered trawler, the July survey was conducted with a 7.3-m gasoline powered boat and a 2.4-m by 1.8-m trawl.

The relative weight (W_r) was calculated for all fish greater than119 mm TL. Standard weights (W_s) for kokanee of a given length 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).

We used an age-length key to estimate the age-specific abundance of kokanee in our trawl samples. For this, we first calculated the proportion of each age class represented in each 1-cm bin, as determined from scale analysis. 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.

Descriptive statistics, including mean TL, weight, and W_r for each age class, were calculated in a similar manner. For these, we first calculated a mean 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).

$$s = \sqrt{\frac{\sum X_i^2 - \frac{(\sum X_i)^2}{n}}{n-1}}$$

Where:
s = standard deviation of the population
X_i = ith individual observation
n = sample size

The timing of trawl surveys for previous years varied by up to a month, depending on the timing of the new moon in July. To account for differences in length due to annual differences in the timing of the trawl surveys, we multiplied the mean length of each age class by a correction factor developed for each age class sampled on a given day of the month. This correction factor was developed using the ratio of the theoretical maximum length (L_∞) divided by the predicted length (L_t), as estimated by a von Bertalanffy growth model. The daily ratios of L_∞/L_t were averaged for several years of data to obtain a correction factor for that date.

Annual growth was measured by back-calculating length at age from scales collected from age-1 and older fish captured in the July trawl surveys. These scales were imaged using a microscope and digital camera. The distance from the focus to each annulus and the margin was measured using either FishBC 3.0.1 or ImageJ 1.46r software. Age specific TL (mm) was estimated using the following formula (Carlander 1982):

$$TL_a = \left[\frac{(TL_C - 41)}{(D_M)} \times D_a\right] + 41$$

Where:
TL_a = Total length at age *a*
TL_C = Total length at capture
DM = The distance from the focus to the margin
Da = The distance from the focus to annulus *a*
41 = The mean TL at scale formation

Annual growth was calculated as:

$$G_a = TL_{a+1} - TL_a$$

Where: G_a = Growth for age *a*

Since most fish spawned as age-2, the length at capture was used as $TL_{(a+1)}$ for age-2 fish.

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 years for which a July trawl survey was performed, 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 Surveys

On September 14, 11 days prior to the historical peak of spawning activity (Horton 1980, Stark and Maiolie 2004), prespawn fish were collected from four index streams using a seine and dip nets. These included Isabella (RKM 92), Skull (RKM 105), Quartz (RKM 109), and Dog (tributary to Isabella at RKM 2.6) creeks. 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 oocyte 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:

$$GSI = \frac{GW}{BW - GW} \times 100$$

Where: GW = gonad weight
BW = body weight

Peak spawner counts were conducted on all four index streams on the lower North Fork Clearwater River above the reservoir on September 23-24. Each of the index streams were walked from the mouth to the uppermost extent of kokanee spawning activity. All spawning kokanee were individually counted when possible or estimated in the case of a deep pool with a large group of fish.

Creel Survey

Creel surveys were conducted consistently from April – July 2014. For these surveys, we used an access-access design (Pollock et al. 1994). The survey was stratified by month and day type (weekday or weekend/holiday). Sampling days, locations, and shifts (am or pm) were chosen at random. Each day within a strata and each shift within a day were given equal selection probabilities, with the exception that days were occasionally re-drawn if personnel were not available. Selection probabilities for locations were determined by assessing use from previous years, recent use during the current year, and whether or not a ramp was usable at the time (ramp availability changed with pool elevation).

Creel clerks were instructed to make every effort to interview every party returning to the access site by boat, or departing from the access site by vehicle in the case of shore anglers. In the event that an interview could not be obtained, clerks recorded the party as unknown and noted the time of return.

Daily effort ($\hat{e}_d$), measured in angler hours, was estimated in the following manner:

$$\hat{e}_d = \frac{e_{rsd}}{(\pi_r \times \pi_s \times \pi_b)}$$

Where: $\hat{e}_d$ = Estimated total fishing effort for day *d*.
e_{rsd} = Fishing effort sampled at site *r*, during shift *s*, on day *d*.
π_r = Selection probability of access site *r*.
π_s = Selection probability of shift *s*.
π_b = Probability of sampling a given boat during that shift.

The probability of sampling a given boat during a particular shift was simply calculated as the ratio of the number of boats sampled during that shift (including those that were not fishing) over the number returning (including those that were not sampled). Effort in terms of fishing trips was calculated in a like manner, substituting the number of trips for angler hours in the preceding equations.

Total effort for a given strata was calculated by multiplying the mean daily effort for that strata by the number of days in the strata. Monthly effort was calculated by summing the effort of the strata within each month, and annual effort was calculated by summing the monthly effort.

Total catch and total harvest were estimated in the same manner as effort, substituting each into the above formulas. Formulas used to calculate standard errors for catch and effort can be found on pages 234-236 of Pollock et al. (1994). Catch rates were calculated by dividing total catch for the respective period by total effort. In addition, we calculated these metrics for anglers that specifically targeted kokanee or bass. Confidence intervals for catch rates were calculated using a bootstrap method. For this, mean daily catch and effort were re-sampled with replacement 1,000 times for each strata. Confidence intervals were then calculated in the same manner as described for limnology metrics.

In addition to conducting interviews, self-report cards and drop boxes were placed at every access point. For these, anglers were asked to report the date, number of hours fished, target species, and number of fish harvested or released. From these data, we computed catch rates by summing the total number of fish that were either harvested or released for each period and divided it by the total effort. This was done for all anglers and only those targeting kokanee or bass.

RESULTS

Environmental Conditions

In 2014, inflow to Dworshak Reservoir averaged 178 m^3/s, compared to the 10-year (2004-2013) mean of 152 m^3/s (Figure 2). Inflow peaked on March 10, 2014 at 971 m^3/s and a minimum inflow of 11.3 m^3/s was observed on August 13, 2014. Mean discharge through Dworshak Dam was 173 m^3/s, compared to the 10-year mean of 152 m^3/s. The peak discharge of 569 m^3/s occurred on April 1, 5, and 9. A minimum discharge of 39.6 m^3/s was observed on 25 occasions from January 28 through February 26. Pool elevation was lower than normal from late March through late June of 2014, but was similar to the 10-year mean for the remainder of the year (Figure 2).

Physical and Chemical Limnology

Temperature

The mean water temperature at 1 m for the multiyear sampling frame was 18.9°C for 2014. The mean for 2004-2013 was 17.9°C. The reservoir was completely stratified by June 10, 2014 and remained stratified through August 18, after which a thermocline was only consistently present at RK-2 and RK-31. The mean time of thermal stratification was 144 days, which was similar to the ten-year average (mean = 138 days).

Dissolved Oxygen

Dissolved oxygen concentrations remained near saturation for most of the season. However, DO concentrations less than 5 ppm were observed at all stations except RK-2 and RK-31. Low concentrations were observed beginning in August and continued through November and constituted 3% of the measurements during this time. Most low concentrations occurred at or near the bottom. Additional summaries of DO for this study can be found in Brandt (2015).

Water Clarity

The median Secchi depth for the entire reservoir was 2.9 m, whereas the median for the treated area of the reservoir was 3.1 m. Secchi depths were compared between years using a modified multiyear sampling frame (June – November). Mean Secchi depth for this period was 3.6 m for 2014 (Figure 3) compared with 4.2 m for 2004-2013. Additional summaries of Secchi depths for 2014 can be found in Brandt (2015).

The mean compensation depth for the entire reservoir was 9.2 m. The mean for the modified multiyear sampling frame (June – November) was 10.1 m, which was similar to the mean for 2007-2013 (mean = 9.9 m). Historical summaries of water clarity can be found in Appendix A.

Phosphorus

The median concentration for TP in 2014 was 0.004 mg/L for the epilimnion, 0.006 mg/L for the hypolimnion, and 0.004 mg/L for the river. Mean concentrations for TP were compared between years by first adjusting the MDL to 0.010 mg/L. Mean epilimnetic TP for the multiyear sample frame in 2014 was 0.010 mg/L, compared to the long-term mean of 0.013 mg/L for 2004-2013.

The median concentration for TDP in 2014 was 0.002 mg/L for the epilimnion, 0.005 mg/L for the hypolimnion, and 0.002 mg/L for the river. No adjustments were made when comparing mean concentrations for TDP. Mean epilimnetic TDP for the multiyear sample frame in 2014 was 0.003 mg/L, compared to the long-term mean of 0.004 mg/L for 2005-2013. Additional summaries of phosphorus data for this study can be found in Brandt (2015).

Nitrogen

The median concentration for TN during 2014 was 0.050 mg/L for the epilimnion, 0.060 mg/L for the hypolimnion, and 0.050 mg/L for the river. No adjustments were made when comparing mean concentrations for TN. Mean epilimnetic TN for the multiyear sample frame in 2014 was 0.055 mg/L, compared to 0.109 mg/L for 2011.

The median concentration for TA during 2014 was 0.010 mg/L for the epilimnion, hypolimnion, and river. No adjustments were made when comparing mean concentrations for TA. Mean epilimnetic TA for the multiyear sample frame in 2014 was 0.018 mg/L, compared to 0.019 mg/L for 2011.

The median concentration for N+N during 2014 was 0.001 mg/L for the epilimnion, 0.010 mg/L for the hypolimnion, and 0.024 mg/L for the river. Mean concentrations for N+N were compared between years by first adjusting the MDL to 0.010 mg/L. Mean epilimnetic N+N for the multiyear sample frame in 2014 was 0.010 mg/L, which was lower than the long-term mean of 0.014 mg/L for 2004-2013. Additional summaries of nitrogen for this study can be found in Brandt (2015).

Total Dissolved Solids

The median concentration for TDS during 2014 was 19.0 mg/L for the epilimnion and 17.0 mg/L for the river. The median for EPI during the multiyear sampling frame in 2014 (median = 18.5 mg/L) was the second lowest in recent history (range = 16.0 – 31.0 mg/L). Additional summaries of TDS for this study can be found in Brandt (2015).

Dissolved Organic Carbon

The mean concentration for DOC in the epilimnion during 2014 was 2.6 mg/L. We used a modified multiyear sampling frame (RK-31 only, March – September), for which the mean for 2014 was 3.3 mg/L, which is higher than the long-term mean for 2007-2013 (mean = 3.0 mg/L).

Biological Indicators

Primary Production Rates

In 2014, primary production rates averaged 605 mgC/m^2/day. Mean C uptake at RK-31 in 2014 (48 mgC/m^2/day) was slightly less than 2011 (62 mgC/m^2/day) for the month of June, but higher in every other month for which rates were measured (Figure 4). Primary production peaked in August at 1,140 mgC/m^2/day during 2014. In contrast, productivity at RK-31 peaked in July at 195 mgC/m^2/day and dropped to 91 mgC/m^2/day in August during 2011. Additional summaries and analysis of primary production rates can be found in Brandt (2015).

Chlorophyll *a*

The median value for Chl *a* in the epilimnion was 1.43 µg/L for the entire reservoir. Chl *a* was compared between years using the multiyear sampling frame. The mean for this period in 2014 was 1.86 µg/L, compared to the long term-mean of 2.08 µg/L for 2004-2013. Additional summaries of Chl *a* data can be found in Brandt (2015).

Picoplankton

The mean density of heterotrophic bacteria in 2014 was 864,000 cells/ml. Densities of picoplankton were compared between years using a modified multiyear sampling frame (May – October). The mean density of heterotrophic bacteria for this period during 2014 was 706,000 cells/mL, compared to the long-term mean of 955,000 cells/mL for 2006-2013.

The mean density of picocyanobacteria in 2014 was 90,000 cells/ml. The mean density of picocyanobacteria for the multiyear sampling frame during 2014 was 166,000 cells/mL, compared to the long-term mean of 122,000 cells/mL for 2006-2013. Additional summaries of picoplankton data can be found in Brandt (2015).

Phytoplankton

The mean biovolume of total phytoplankton was 0.353 mm^3/L for 2014. The mean biovolume for the multiyear sampling frame was 0.363 mm^3/L for 2014, as compared to the long-term mean of 0.437 mm^3/L for 2005-2013 (Figure 5). The mean biovolume of total phytoplankton was similar for the restoration (mean = 0.421 mm^3/L) and non-restoration (mean = 0.449 mm^3/L) periods.

The phytoplankton community was composed of five major taxa in 2014. The dominant taxa in 2014 were blue-greens, which represented 34% of the total annual biovolume. The next most common taxa were flagellates (25%) and Coccoid greens (21%). Diatoms (15%) and Dinoflagellates (4%) were less common.

The mean biovolume of edible phytoplankton was 0.226 mm^3/L for 2014. The mean biovolume for the multiyear sampling frame was 0.212 mm^3/L for 2014, as compared to the long-term mean of 0.233 mm^3/L for 2005-2013. The mean biovolume of edible phytoplankton was higher for the restoration period (mean = 0.248 mm^3/L) than the non-restoration period (mean = 0.190 mm^3/L).

The proportion of the phytoplankton community that is known to be edible was 61% for treated areas of the reservoir in 2014. The mean proportion of edible phytoplankton for the multiyear sampling frame for 2014 was 58% (Figure 5), which represents a 28% increase compared to the mean for non-restoration years (40%; 2005-2006, 2011). The increase was no lower than 19% in any bootstrap iteration.

The mean biovolume of *Anabaena sp.* for the multiyear sampling frame in 2014 was 0.018 mm^3/L, which was lower than the mean of non-restoration years (mean = 0.107 mm^3/L). The proportion of the total phytoplankton biovolume that was composed of *Anabaena sp.* for the multiyear sampling frame in 2014 (5%) was 78% lower than the mean of non-restoration years (22%). For 95% of the bootstrap iterations, this decrease was at least 86%. Additional summaries of phytoplankton data can be found in Brandt (2015).

Zooplankton

The mean density of all zooplankters was 36.7 individuals/L for the entire reservoir in 2014 (Figure 6). The mean density for the modified multiyear sampling frame (April – November) was 36.7 individuals/L, compared to a mean of 18.9 for non-restoration years (2005-2006, 2011). Cladocerans accounted for 37% of all zooplankton collected in 2014. This proportion was 35% for the multiyear sampling frame, compared to the mean of 37% for non-restoration years.

The mean density of *Daphnia* for the modified multiyear sampling frame was 3.8 individuals/L in 2014 (Figure 6). This represents an increase of 36% compared to the mean for non-restoration years (mean = 2.8 individuals/L). This increase was positive for 87% of the bootstrap iterations.

The mean biomass of consumable *Daphnia* for the modified multiyear sampling frame was 54 µg /L in 2014 (Figure 6). This represents an increase of 15% compared to the mean for non-restoration years (mean = 47 µg/L). This increase was positive for 67% of the bootstrap iterations.

In 2014, the mean length of *Daphnia* was 0.94 mm for the entire reservoir and 0.96 mm for the multiyear sampling frame. In comparison, the mean for non-restoration years was 0.97 mm. The mean length of *Bosmina* was 0.37 mm for both the entire reservoir and the multiyear sampling frame, compared to 0.36 mm for non-restoration years. Additional summaries of zooplankton data can be found in Brandt (2015).

The abundance of age-1 and older kokanee was found to be the best measure of abundance for predicting the biomass of consumable Daphnia ($\Delta AIC_c = 0$, $w_i = 0.76$, Table 1), and therefore was incorporated into the second set of models. The best competing model for predicting the biomass of consumable *Daphnia* included nutrient restoration and kokanee abundance ($\Delta AIC_c = 0$, $w_i = 0.60$). This model predicts that zooplankton density decreases with increasing kokanee abundance during the non-restoration period, but increases with increasing kokanee abundance when nutrients are added (Figure 7). However, there was also strong evidence for the model including the interaction term (Table 1). Based on the sum of Akaike's weights from models incorporating each factor, nutrient restoration ($\sum w_i = 0.93$) had the most influence on the biomass of consumable *Daphnia*, but the influence of kokanee abundance ($\sum w_i = 0.58$) was similar.

Kokanee Population Monitoring

Abundance and Density

From the hydroacoustic survey conducted from July 14 to 17, we estimated an overall abundance of 4,196,000 kokanee in Dworshak Reservoir (Table 2). Of these, 1,594,000 were age-0, 2,506,000 were age-1, 92,000 were age-2, and 3,500 were age-3. These estimates were based on an overall density of 824 fish/ha (Table 2). When partitioned by age, the densities were 313 fish/ha for age-0, 492 fish/ha for age-1, 18 fish/ha for age-2, and 1 fish/ha for age-3. Of the fish that were captured in the July trawl, 88.5% of the age-2 and 100% of the age-3 fish were beginning to mature sexually. None of the age-1 fish were beginning to mature. Therefore, we estimate 85,000 mature fish in the reservoir during the month of July.

Overall abundance (2,424,000) and density (836 fish/ha) were highest in Section 1 (Table 2). Abundance (466,000) was lowest in section 3, while density (805 fish/ha) was lowest in section 2. Abundances of age-0 and age-1 fish were highest in Section 1, while abundance of age-2 fish was highest in section 2. Age-3 kokanee were only encountered in section 3. Density of age-1 fish was highest in section 1, whereas densities of all other age classes were highest in section3. Revised abundance and density estimates for kokanee are presented in Appendix B.

Size at Age

We sampled 1,061 kokanee from midwater trawls conducted during April 28-29 and July 29-31. Of these, 503 were captured during April trawling and 558 in July. In April, trawl-caught kokanee ranged from 76 to 270 mm TL (Figure 8). Only age-1, age-2, and age-3 fish were sampled in April; no age-0 kokanee were encountered. A total of 172 age-1 kokanee were captured in April, ranging from 76 to 143 mm TL with a mean of 107 mm (Table 3). A total of 62 age-2 kokanee were captured, ranging in size from 197 to 263 mm TL. Age-2 kokanee had a mean TL of 236 mm and a mean W_r of 82. A total of 62 age-2 kokanee were captured, ranging in size from 197 to 263 mm TL. Age-2 kokanee had a mean TL of 236 mm and a mean W_r of 82. A total of 2 age-2 kokanee were captured, with a mean TL of 258 mm and a mean W_r of 80.

In July, trawl-caught kokanee ranged from 28 to 292 mm TL (Figure 8). For the 103 age-0 fish that were sampled, the TL was between 28 and 57 mm, with a mean TL of 41 mm (Table 3). Through scale analysis and length distributions, 421 kokanee were determined to be age-1, and ranged in size from 94 to 170 mm TL. The mean TL of age-1 kokanee was 145 mm. When taking the timing of the survey into account, the corrected TL for age-1 kokanee was 166 mm. The mean W_r for this age class was 79. Another 31 kokanee were determined to be age-2, and ranged in size from 220 to 285 mm TL. Age-2 kokanee had a mean TL of 248 mm. When taking the timing of the survey into account, the corrected TL for age-2 kokanee was 260 mm. The mean W_r for this age class was 80. Another three were determined to be age-3, ranging in size from 259 to 292 mm TL. A correction factor was not available for age-3 fish.

Growth Comparisons

The abundance of age-1 and older kokanee in 2014 (2,601,000) was similar to that of 2006 (2,633,000). The mean TL of age-2 fish was 52 mm longer in 2014 (249 mm TL) than in 2006 (196 mm TL) and the mean lengths of age-1 fish were similar for both years (145 mm TL, Table 4). The mean weight of age-2 fish in 2014 (128.4 g) was more than twice that of 2006 (59.6 g). Mean annual growth, as calculated from back calculated length at age, was 21 mm for age-2 fish in 2014, compared to 14 mm for 2006. The mean weight of age-1 fish in 2014 (26.1 g) was 2.2 g more than that of 2006 (23.9 g).

Biomass and Production

Kokanee production from July of 2013 to July of 2014 was estimated at 100.0 metric tonnes (t). The overall biomass of kokanee was estimated to be 78.3 t during July of 2014, whereas the biomass of mature fish was estimated to be 10.4 t. Mortality by weight was estimated to be 67.1 t. Historical production estimates can be found in Appendix C.

Spawner Counts

On September 8, we collected 74 adult kokanee: 65 from Isabella Creek and 9 from Skull Creek. Of these, 44 were male, 29 were female, and sex could not be determined for one fish. Male kokanee exhibited a multimodal length distribution that ranged from 185 to 322 mm, with a mean of 271 mm TL. Female kokanee exhibited a unimodal length distribution that ranged from 244 to 296 mm, with a mean of 270 mm TL.

Of the females we sampled, two had ovulated but none had finished spawning. Ovaries were obtained from 18 pre-ovulatory females, with a mean fecundity of 377 oocytes per female and a mean oocyte weight of 0.055 g. Fecundity was positively and significantly related to TL (linear regression, $p = 0.03$, $r^2 = 0.25$). Mean oocyte weight was not significantly correlated to TL (linear regression, $p = 0.80$, $r^2 = 0.004$).

Peak kokanee spawner counts were performed on September 23-24, during which 19,277 spawning kokanee were counted in four index streams. This included 10,601 in Isabella Creek, 5,292 in Skull Creek, 1,609 in Quartz Creek, and 1,775 in Dog Creek. Historical spawner count data are shown in Appendix D.

Creel Survey

Thirty-six shifts were completed from April-July of 2014, during which 353 interviews were conducted. Shifts were redrawn on four occasions because personnel were not available on the original randomly selected day. From this, we estimated 6,127 fishing trips (SE = 1,102) and 82,852 angler hours (SE = 12,956, Table 5). Effort increased during this period, from 890 trips and 10,974 angler hours in April to 2,263 trips and 32,581 angler hours in July. The mean party size for fishing trips was 2.2 anglers (range = 1 – 7 anglers). The mean duration of single day fishing trips was 6.1 hours (range = 0.6 – 12.5 hours). We estimated that anglers caught 81,692 kokanee (SE = 13,692) and harvested 79,746 (SE = 12,705). Overall, 97.6% of the kokanee caught were harvested. In addition, we estimated that anglers caught 26,039 Smallmouth Bass (SE = 11,225) and harvested 3,951 (SE = 1,111). Overall, 15.2% of the

Smallmouth Bass caught were harvested. The catch of all other fish was estimated at 1,168 caught and 533 harvested. Other species that were caught included Rainbow Trout, Bluegill *Lepomis macrochirus*, Bull Trout, and Black Crappie *Proximus nigromaculatus*, in order of prevalence.

For anglers who targeted kokanee, we estimated 4,280 fishing trips (SE = 578) and 56,134 (SE = 8,202) angler hours (Table 5). As with overall effort, effort for kokanee increased from 595 trips and 7,695 angler hours in April to 1,495 trips and 19,588 angler hours in July. Kokanee anglers caught 79,763 (SE = 12,742) kokanee and 723 fish other than kokanee. Kokanee anglers harvested 77,891 (SE = 12,365) kokanee and 293 fish other than kokanee. Harvested kokanee had a mean TL of 239 mm (Figure 9). Since anglers reported releasing only a small percentage of the kokanee they caught, catch and harvest rates were similar. We estimated a catch rate of 1.4 kokanee/hour (95% CI = 1.0 – 2.1 kokanee/hour) for the period of April-July. Catch rates for kokanee were highest in May (1.8 kokanee/hour) and similar for all other months surveyed (1.3 kokanee/hour, table 5).

For 93% of the kokanee trips that we contacted, at least one angler in the group reported catching a kokanee. This proportion ranged from 89% in May to 97% in July. We documented harvest in 92% of the kokanee trips we contacted. This proportion ranged from 89% in May to 97% in June. Overall, 7% of the anglers we interviewed harvested a limit of 25 kokanee. This proportion ranged from 12% in May to none in June.

For anglers who targeted bass, we estimated 17,616 (SE = 3,959) angler hours (Table 5). Bass anglers caught 17,395 (SE = 6,018) bass and 578 fish other than bass, for a catch rate of 1.0 bass/hour (95% CI = 0.4 – 1.8 bass/hour). Catch rates for bass were lowest in April and July (0.4 bass/hour) and highest in June (1.8 bass/hour). Bass anglers harvested 2,115 bass (SE = 750) and 132 fish other than bass. Harvested bass had a mean TL of 300 mm (Figure 10).

For 86% of the bass trips that we contacted, at least one angler in the group reported catching a bass. This proportion ranged from 63% in April to 100% in May and July. We documented harvest in only 22% of the bass trips we contacted. This proportion ranged from 9% in July to 46% in May. Overall, 2% of the anglers we interviewed harvested a limit of 6 bass. May was the only month for which we documented limits of bass. Conversely, 14% of the bass anglers we interviewed reported catching six or more bass, although most did not harvest a limit.

From March-October, anglers submitted 107 self-report cards with useable information. From these, anglers reported catching 1,564 fish of all species and harvesting 1,070 fish during 700 hours of fishing. This results in an overall catch rate of 2.6 fish/hour. Those anglers who targeted kokanee submitted 55 useable cards, 49 of which were submitted for the April-July time period. For these, anglers reported catching 961 kokanee and keeping 763 during 316.75 hours of fishing. This results in a catch rate of 3.0 kokanee/hour and a harvest rate of 2.4 kokanee/hr. 93% of kokanee anglers reported catching on or more kokanee.

DISCUSSION

Water Quality

While the intent of the nutrient restoration project is to restore lost productivity to the reservoir, it is imperative to do so without degrading overall water quality. Three metrics are specified in the NPDES permit as indicators of how the project affects water quality: median Secchi depth, median Chl *a* concentration, and median TP concentration.

The median Secchi depth for the treated portion of the reservoir (median = 3.1 m) was slightly greater than the 3.0 m minimum stipulated by the NPDES permit. Water clarity for the multiyear sampling frame, as measured by Secchi disc, was the lowest recorded since 2004 and very similar to 2006. However, Secchi measurements are inherently prone to observer bias (Larson et al. 2007). Compensation depth, however, has been measured using the same electronic instrument since 2007. The mean CD for the multiyear sampling frame for 2014 (10.1 m) was similar to the long-term mean for 2007-2013 (9.9 m), suggesting that water clarity for 2014 was typical. If Secchi depths for 2014 had followed the same relationship to CD as 2007-2013, we would expect median Secchi for treated portion of the reservoir to be closer to 3.6 m. Because CD, as calculated from PAR measurements, is not biased by the observer, weather, and ambient light, we believe it is a more reliable indicator of trends in water clarity.

The median Chl *a* concentration for the treated portion of the reservoir (median = 1.33 µg/L) was well below the 3.0 µg/L maximum stipulated by the NPDES permit. The mean Chl *a* concentration for 2014 was also below the long-term mean for 2004-2013. Furthermore, our data does not indicate an increase in Chl *a* in response to nutrient restoration.

The median TP concentration for the treated portion of the reservoir (median = 0.004 mg/L) was well below the 0.025 mg/L maximum stipulated by the NPDES permit. Since the project does not involve adding P to the reservoir, we do not anticipate an increase in TP except due to variations in natural input.

Another water quality concern is the prevalence of potentially toxigenic cyanobacteria (blue-green algae). Historically, *Anabaena sp.* has been the dominant taxa of toxigenic cyanobacteria. *Anabaena sp.* typically becomes dominant in late summer after available N becomes exhausted. *Anabaena sp*. are known to fix N and believed to have a competitive advantage when fixed N is no longer available (Darren Brandt, Advanced Eco-Solutions, personal communication). Therefore, it was anticipated that N restoration would reduce the prevalence of *Anabaena sp*. (Stockner and Brandt 2006). In 2014, *Anabaena sp*. accounted for only 5% of the total annual biovolume of phytoplankton, which is a substantial reduction from the proportions observed in non-restoration years (mean = 21%, range = 11-27%). In 2014, no visible concentrations of *Anabaena sp*. were observed while conducting routine sampling. No other toxigenic taxa, including *Microcystis sp.*, were detected at high enough densities to cause public health concerns in 2014. Our data does not indicate an increased prevalence of toxigenic cyanobacteria as a result of N additions, and in the case of *Anabaena sp*., the project has resulted in a decreased prevalence.

Reservoir Productivity

Chl *a* is often used as an indicator of productivity in lakes and reservoirs (Carlson 1977). Mean Chl *a* has not increased in response to nutrient restoration, suggesting that productivity has not increased. However, the relationship between Chl *a* and phytoplankton biovolume is dependent on many variables, including species composition. Furthermore, if the composition of the phytoplankton community has shifted to more edible species, those species may be grazed off by zooplankton at a higher rate, thus masking the increase in productivity (Scofield et al. 2010). Since the intent of this project is to increase the amount of carbon (C) that is passed up to higher trophic levels (i.e., fish), rather than the accumulation of C at lower levels (i.e., algae) an increase in Chl *a* should not be viewed as a prerequisite for success.

Picoplankton are generally the first group to respond to nutrient additions because they are capable of rapid uptake of nutrients and near exponential growth (Stockner and Antia 1986). Densities of heterotrophic bacteria and pico-cyanobacteria were both many times higher than 2006, the only year prior to nutrient restoration for which we have data. However, picoplankton densities did not drop off substantially in 2011, the year that nutrient restoration was suspended. If densities for 2006 and 2011 are averaged to produce a mean for non-restoration years, then the increase in heterotrophic bacteria for 2014 (24%) is more modest. On the other hand, densities of pico-cyanobacteria for 2014 were the highest on record and more than double the mean of non-restoration years. Increases in picoplankton represent a positive response at the lowest trophic level. Picoplankton are a food base for nanoflagellates (Jurgens and DeMott 1995), which in turn are a high-energy food source for zooplankton (Sanders and Porter 1990).

For 2014, the mean biovolume of total phytoplankton for the multiyear sampling frame was below average. The means for restoration and non-restoration years are very similar, indicating no increase in standing crop due to nutrient restoration. The mean biovolume of edible phytoplankton in 2013 was also below average. However, the percentage of the phytoplankton community that was edible in 2013 was higher than all non-restoration years. This suggests that the greatest effect of nutrient restoration on the phytoplankton community is a shift in the community structure.

It may be misleading to elucidate changes in productivity when looking at standing crop alone. Standing crop is affected both by bottom up factors, such as nutrients, and top down factors (i.e. grazing). Estimates of primary production rates are more informative for determining the effects of nutrient restoration on primary productivity. Primary production rates were higher on average in 2014 than in 2011, a year when N was not added to the reservoir. The difference in production rates were highest in August and September, when rates were observed to drop off in 2011. These results suggest that the addition of N is resulting in increased primary productivity within the system.

The mean density of zooplankters in 2014 was the second highest since monitoring began during 2005 and was nearly twice the non-restoration mean. Of greater interest, the mean density of consumable *Daphnia* was only slightly higher than the non-restoration mean. Moreover, the mean length of *Daphnia* in 2014 was the second lowest in recent years and one of only two restoration years with a mean <1 mm TL, both of which occurred in years of high kokanee abundance. This suggests that while zooplankton were more abundant than usual, the availability of preferred prey decreased. However, the biomass of consumable *Daphnia* observed in 2014 was consistent with our best model. The reduction in the size and density of consumable *Daphnia* in 2014 is likely due to heavy grazing pressure by the highly abundant kokanee population. However, consumable *Daphnia* biomass was much higher than what the model predicts without nutrient restoration.

Kokanee Population Monitoring

Abundance estimates are a critical component of evaluating the kokanee response to nutrient additions. Rieman and Myers (1992) found kokanee growth in Idaho lakes and reservoirs was dependent on fish density. Therefore, density should be taken into consideration for any growth analysis. However, the available habitat in Dworshak Reservoir changes in a rapid but predictable manner every summer as pool elevation and surface area decrease due to drawdowns that begin just after July 4. As a result, the timing of the July surveys can have a greater effect on density than abundance. As such, we chose to use abundance instead of density in our comparisons of kokanee growth.

The abundance of age-2 fish for 2014 may have been underestimated. From 1999 to 2014, mean survival from age-0 to age-1, based on abundance estimates, was similar to mean survival from age-1 to age-2. In contrast, survival from age-1 to age-2 for 2013 to 2014 (17%) was almost four times lower than survival from age-0 to age-1 for this period (63%). Furthermore, abundance estimates of mature kokanee, which are composed primarily of age-2 fish, in July of 2014 were lower than expected based on spawner counts, whereas in past years, these metrics have tracked closely (Wilson et al. 2013).

The apparent underestimation of age-2 fish is likely due to partitioning of total abundance into age classes. Estimates of total abundance are based on acoustic data, which has been collected in a consistent manner. While we also partitioned age-0 abundance using acoustic data, we partitioned age-1 and older fish using trawl data. In July of 2014, our trawler was not operational, and surveys were completed using a smaller vessel and net borrowed from another project. Size selectivity of these two vessels and nets is currently unknown. If the larger trawler and net is more efficient at capturing larger kokanee, the proportion of age-2 fish would be underestimated with the smaller net. If this is the case, the estimates of age-1 and age-2 fish were likely biased, but the combined estimate of age-1 and older fish was not, as it is not dependent on trawl data.

Improved kokanee growth is a key indicator of whether nutrient restoration is having desirable effects. To account for the effects of density on fish growth, we compared mean sizes for 2014 with those for 2006, a non-restoration year with similar abundance of age-1 and older fish. Age-2 kokanee were on average both longer and heavier in 2014 than during 2006. Age-1 kokanee were similar in length, but tended to be heavier for a given length. The results for age-1 kokanee are similar to comparisons involving other years of similar abundance, for which fish tend to be somewhat longer and much heavier during restoration years. The greater discrepancy in size of age-2 kokanee in 2014 was due in large part to growth of this cohort the previous year, which occurred in a year of lower age-1 and older abundance. Still, the annual growth of age-2 fish in 2014 was greater than that of 2006, suggesting that there was a growth advantage due to nutrient restoration.

Another way to assess the effect of nutrient restoration on 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. Our methodology provides an estimate of production from July of the first year to July of the second. Unfortunately, we only have one production estimate for this time period from a non-restoration year. While we do not know if this estimate is typical for the non-restoration period, all estimates for the restoration period were higher, including the 2013-2014 estimate, which was nearly double.

Creel Survey

Kokanee have historically been the most popular sport fish in the reservoir, accounting for about 75% of both catch and effort in years for which a creel survey was performed for six months or longer (Horton 1981, Maiolie et al 1993, Cochnauer et al 2001, Hand et al. 2008a, Hand et al. 2008b). This held true for April-July of 2014, with almost 70% of the fishing effort expended targeting kokanee. This estimate is likely an underestimate of effort, as it does not include trips that were split between kokanee and other species. The majority of the kokanee effort has historically occurred from April-July. Kokanee effort is expected to decrease drastically in August, as fish stage in the upper reservoir and eventually enter spawning tributaries. On the other hand, fishing for other species, such as Smallmouth Bass, is likely to continue for several more months. Therefore, the results of this survey do not accurately represent the proportion of effort spent fishing for species other than kokanee on an annual basis, but do indicate that kokanee are still a major component of the fishery.

The objective for catch rates in the kokanee fishery (1.2 fish/h) was surpassed in 2014. This was surprising based on the estimated abundance of age-2 fish, which was well below the ten-year median. This may be another indication that age-2 abundance was higher than estimated. Catch rates estimated from previous surveys averaged 1.2 fish/h and have only exceeded 2014 catch rates in two out of seven years. The mean TL of harvested fish (mean = 239 mm) was less than the objective (254 mm). While we would typically expect to see larger fish in a year with low to average adult abundance, growth was slow due to competition from the record abundance of age-1 fish. Since growth of age-2 fish was better than 2006 (a non-restoration year with similar age-1 and older abundance), fish harvested in 2014 were likely larger than they would have been without nutrient addition.

Until this point in the pilot project periods, research and monitoring have focused on assessing the response of the kokanee population to nutrient restoration. Incorporating creel surveys is a critical next step for understanding the effect that nutrient restoration has on the fishery. Since kokanee populations are highly variable, and the objectives for the kokanee fishery are based on averages, several years of creel data will be needed to assess the effect of nutrient restoration on the fishery.

The number of Smallmouth Bass harvested in 2014 was within the range of estimates from creel surveys performed in 2003 and 2004. Furthermore, the mean size of bass harvested in 2014 was slightly larger than 2004. This suggests that the bass fishery is currently sustainable, but does not indicate whether additional regulation could improve the size structure of the bass population or improve catch rates.

Catch rates calculated from self-report cards were much higher than those calculated from angler interviews. However, the proportion of successful anglers (those who caught at least one target species) was similar between the two methods. This suggests that the self-reporting bias we observed is not due to unsuccessful anglers not filling out cards. Furthermore, anglers self-reported releasing many more kokanee than they reported to creel clerks. This suggests a prestige bias associated with self-report cards. In order for self-report cards to be useful as an index for tracking the fishery, this bias would have to be consistently proportional to actual catch rates across years.

CONCLUSIONS

Nutrient restoration in Dworshak Reservoir showed signs of success and similar responses to those observed in several British Columbia lakes and reservoirs following nutrient additions. Water clarity appeared to decrease slightly during nutrient restoration, but not below the range observed prior to restoration, or to the point where it was detrimental to recreational uses. The effects of nutrient restoration were observed at all trophic levels. We observed increases in picoplankton, which represent the lowest trophic level, beginning in the first year of nutrient additions. Observed increases in the proportion of edible phytoplankton have resulted in increased zooplankton density and biomass. The increased zooplankton availability was likely responsible for increased kokanee length and weight at a given density. If sustained, the responses observed are expected to provide improved recreational fishing in the reservoir. Furthermore, the increased abundance and biomass of spawning kokanee in the North Fork Clearwater subbasin should benefit resident fish and wildlife well beyond the reservoir itself. While it will take additional years of data to confirm that the observed effects are in fact due to restoration and not natural variation, nutrient restoration appears to have had a beneficial effect on the ecology of the reservoir and should be continued.

RECOMMENDATIONS

1. Continue the additional five-year pilot phase to confirm that observed benefits are a result of N restoration and further assess the benefits to the kokanee population and resultant fishery.

2. Conduct creel surveys to monitor changes to the fishery and assess the effects of nutrient restoration on the performance of the fishery.

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Table 1. Comparison of linear models used to determine the effects of several factors on the biomass of consumable *Daphnia*. The first set compares two measures of kokanee abundance, the abundance of age-1 and older fish (≥age-1) and the abundance of all age classes (Total). The second set compares whether nutrients were added to the reservoir in a given year (Nutr), the abundance of age-1 and older kokanee (Kok), and an interaction term. Fit statistics, including the adjusted coefficient of determination (R^2_{adj}), maximized log-likelihood (Log*L*), Akaike's Information Criterion corrected for sample size (AIC_c), simple differences (ΔAIC_c), and Akaike's weight (w_i) are given. Shading indicates models with the strongest support.

Best measure of kokanee abundance

Independent variables	R^2_{adj}	***LokL***	AIC_c	ΔAIC_c	w_i
≥ age-1	0.19	-56.64	113.3	0.0	0.76
Total	0.00	-57.77	115.5	2.3	0.24

Biomass of consumable *Daphnia*

Independent variables			R^2_{adj}	***LokL***	AIC_c	ΔAIC_c	w_i
Nutr	Kok		0.66	-52.19	104.4	0.0	0.60
Nutr	Kok	Nutr:Kok	0.65	-52.68	105.4	1.0	0.36
Nutr			0.38	-55.14	110.3	5.9	0.03
Kok			0.19	-56.64	113.3	8.9	0.01

Table 2. Abundance (thousands of fish) and density (fish per ha) of kokanee in Dworshak Reservoir in July 2014. Estimates were derived from a hydroacoustic survey and age partitions were derived from a fixed-frame trawl survey. Estimates are separated by age class and reservoir section.

	Abundance (thousands of fish)				
Section	**Age-0**	**Age-1**	**Age-2**	**Age-3**	**All Ages**
Section 1	752	1,643	29	0	2,424
Section 2	583	682	40	0	1,305
Section 3	259	180	24	4	466
Whole reservoir	1,594	2,506	92	4	4,196

	Density (fish per ha)					
Section	**Area (ha)**	**Age-0**	**Age-1**	**Age-2**	**Age-3**	**All Ages**
Section 1	2,900	259	567	10	0	836
Section 2	1,622	360	421	24	0	805
Section 3	573	452	314	42	6	814
Whole reservoir	5,094	313	492	18	1	824

Table 3. Descriptive statistics for total lengths of kokanee captured during midwater trawl surveys on Dworshak Reservoir on April 28-29, July 29-31, 2014. Growth is given as the increase in mean length (mm) observed in each age class between surveys. Variance is expressed using standard deviation (SD).

		Total Length (mm)					Growth
Month	**Age**	**N**	**Min**	**Mean**	**Max**	**SD**	**(mm)**
Apr	1	171	76	107	143	12	
	2	62	197	236	263	13	
	3	2	246	258	270	17	
Jul	0	101	28	41	57	4	
	1	421	94	145	170	9	38
	2	31	220	249	285	16	13
	3	3	259	271	292	18	13

Table 4. Length statistics for two age classes of kokanee from Dworshak Reservoir from four years without nutrient additions (2003, 2004, 2006, and 2011) and six years with nutrient additions (2007–2010, 2012-2014, shaded rows). Statistics include the mean total length (TL), the L_∞ estimated from von Bertalanffy growth models fitted independently to each age class for each year that surveys were performed at multiple times throughout the season, a correction factor (CF) developed by taking the mean proportion of L_∞/L_t for each day in July, an estimate of L_∞ obtained by multiplying the CF for the trawl date by the mean TL, and the mean TL of spawning kokanee (age-2) or age-1 kokanee captured in the fall.

Length statistics for age-2 kokanee

Trawl date	Year	Mean TL (mm)	L_∞ from model	CF	L_∞ from CF	Mean TL (spawners)
30-Jul	2003	262		1.05	275	278
13-Jul	2004	295	317	1.06	313	308
24-Jul	2006	196		1.05	206	210
13-Jul	2007	241		1.06	255	264
31-Jul	2008	303	328	1.05	318	306
20-Jul	2009	272	284	1.05	286	287
14-Jul	2010	219	227	1.06	232	249
26-Jul	2011	220	224	1.05	231	250
25-Jul	2012	308	344	1.05	323	321
9-Jul	2013	296	314	1.06	314	316
29-Jul	2014	249		1.05	261	271

Length statistics for age-1 kokanee

Trawl date	Year	Mean TL (mm)	L_∞ from model	CF	L_∞ from CF	Mean TL October
30-Jul	2003	204		1.14	233	
13-Jul	2004	203	235	1.19	242	231
24-Jul	2006	145		1.16	168	
13-Jul	2007	198		1.19	236	
31-Jul	2008	209	252	1.14	238	235
20-Jul	2009	169	200	1.17	198	190
14-Jul	2010	172	193	1.18	203	189[a]
26-Jul	2011	170	235	1.15	196	213
25-Jul	2012	206	255	1.15	237	235
9-Jul	2013	201	230	1.20	241	222
29-Jul	2014	145		1.15	167	

[a] In 2010, the fall survey was conducted in November rather than October due to mechanical difficulties with the trawler.

Table 5. Estimates of angler effort, in terms of trips and angler hours, and catch, in terms of fish caught and harvested (kept). Catch rates (rate) are included for anglers targeting either kokanee or bass. Estimates were derived from access-access creel surveys conducted from April through July.

All anglers

	Angler		Kokanee		Bass		Other	
	Trips	**Hours**	**Caught**	**Kept**	**Caught**	**Kept**	**Caught**	**Kept**
April	890	10,974	10,705	10,463	871	76	178	116
May	1,651	21,014	29,161	29,022	6,776	1,304	143	107
June	1,323	18,283	16,778	16,580	10,103	587	114	63
July	2,263	32,581	25,048	23,681	8,289	1,984	733	247
Total	6,127	82,852	81,692	79,746	26,039	3,951	1,168	533

Anglers targeting kokanee only

	Angler		Kokanee			Other	
	Trips	**Hours**	**Caught**	**Rate**	**Kept**	**Caught**	**Kept**
April	595	7,695	10,268	1.3	10,071	26	24
May	1,235	15,615	27,860	1.8	27,722	250	107
June	955	13,237	16,778	1.3	16,580	246	83
July	1,495	19,588	24,857	1.3	23,518	191	80
Total	4,280	56,134	79,763	1.4	77,891	723	293

Anglers targeting bass only

	Angler		Bass			Other	
	Trips	**Hours**	**Caught**	**Rate**	**Kept**	**Caught**	**Kept**
April	158	2,045	845	0.4	67	128	60
May	294	3,027	4,108	1.4	844	18	18
June	299	5,167	9,513	1.8	517	76	25
July	440	7,377	2,928	0.4	687	355	28
Total	1,192	17,616	17,395	1.0	2,115	578	132

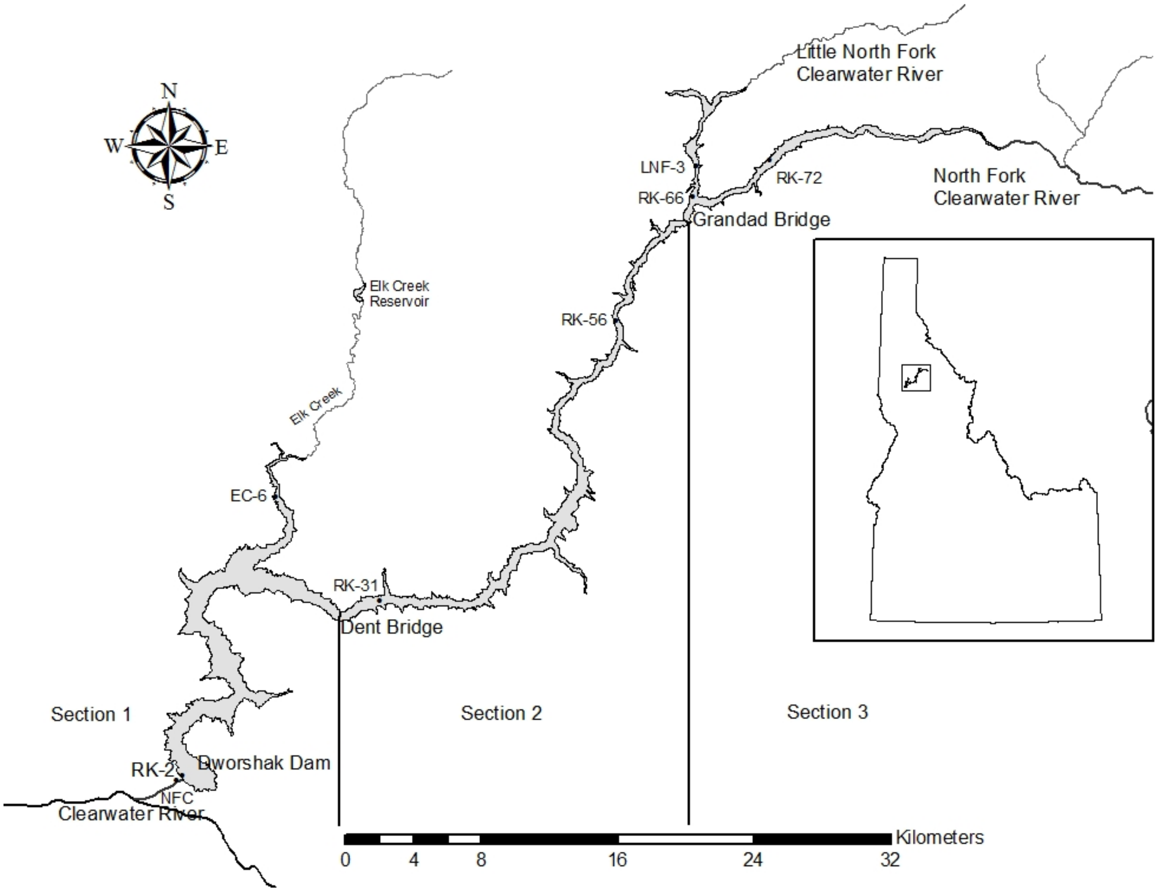

Figure 1. Map of Dworshak Reservoir depicting the locations of seven limnological sampling stations on the reservoir and one on the North Fork Clearwater below Dworshak Dam. Boundaries of reservoir sections used in statistical stratification are also shown.

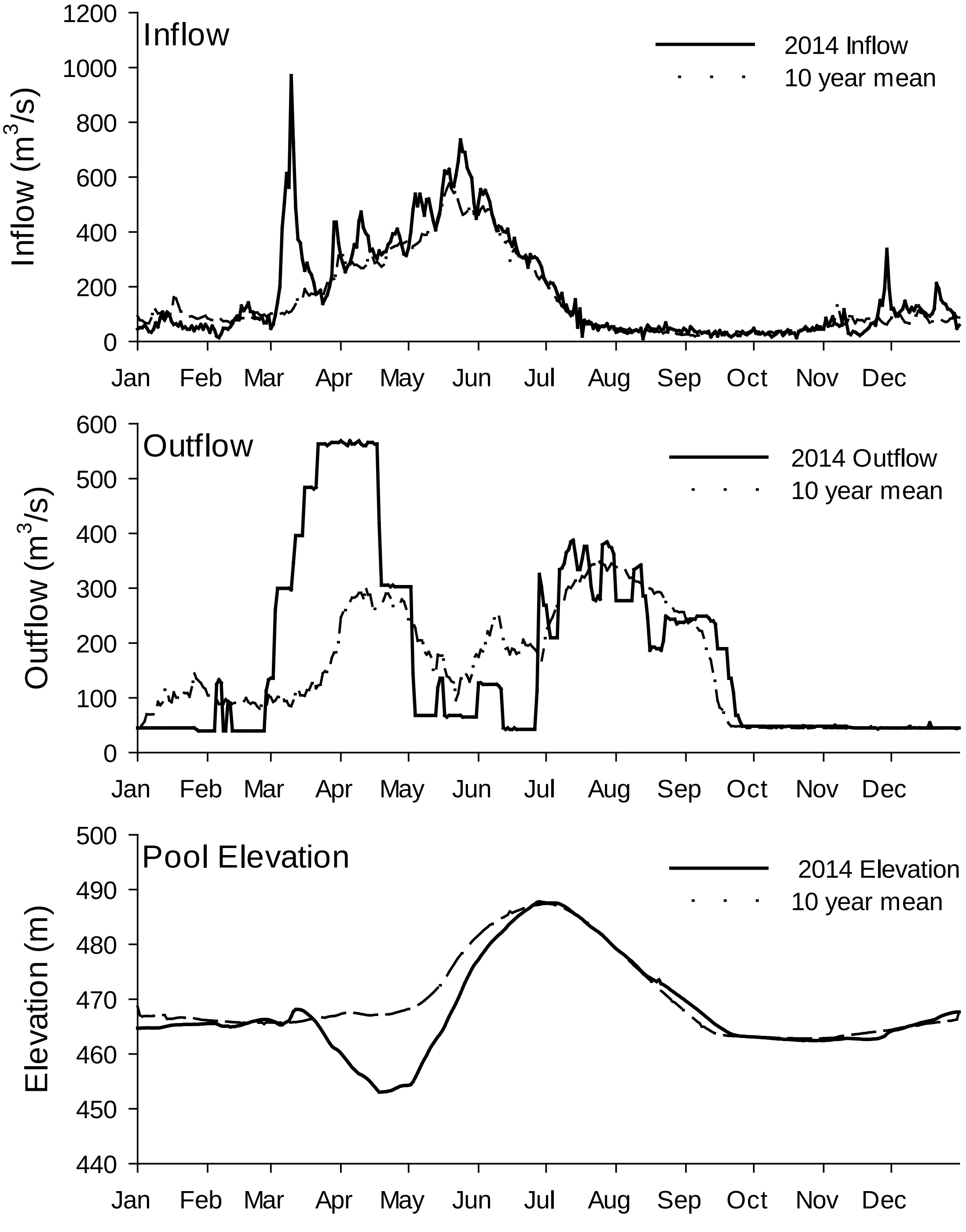

Figure 2. Mean daily inflow, outflow, and pool elevation for Dworshak Reservoir during 2014 along with the 10 year mean (2004-2013). Data provided by the U.S. Army Corps of Engineers through the Columbia River DART website (http://www.cbr.washington.edu/dart/; accessed 1/2/15).

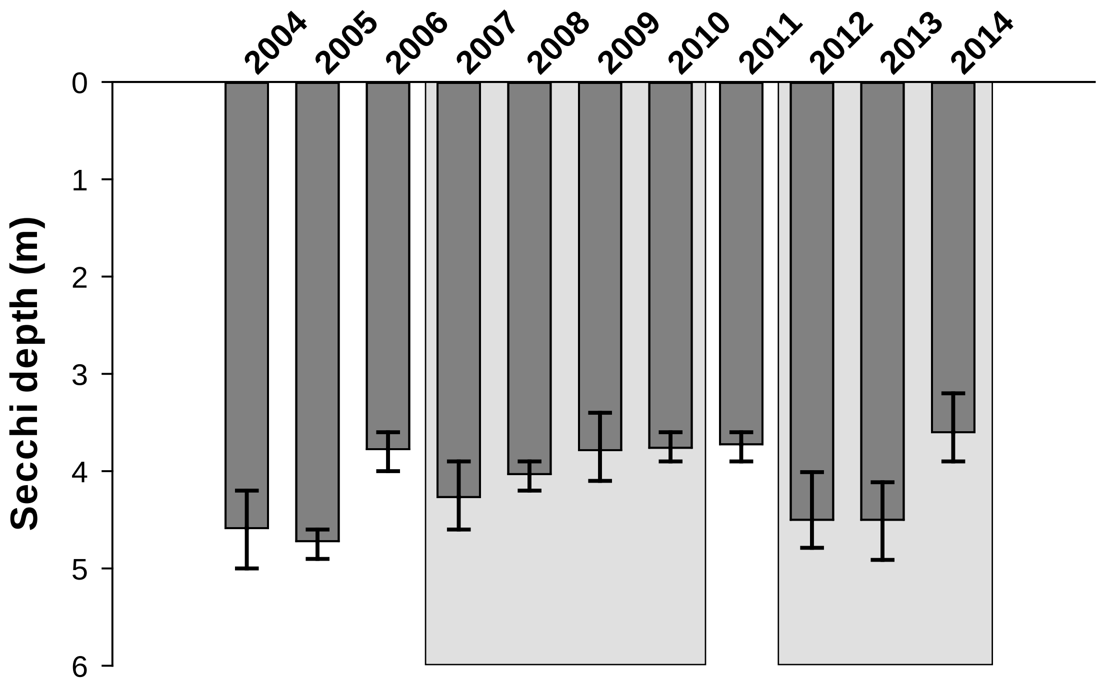

Figure 3. Mean Secchi depth measured at four sampling stations (RK-2, RK-31, RK-56, and RK-72) on Dworshak Reservoir from June through November. Error bars represent 95% confidence intervals derived by classical methods. The box indicates the period that nutrients were added to the reservoir.

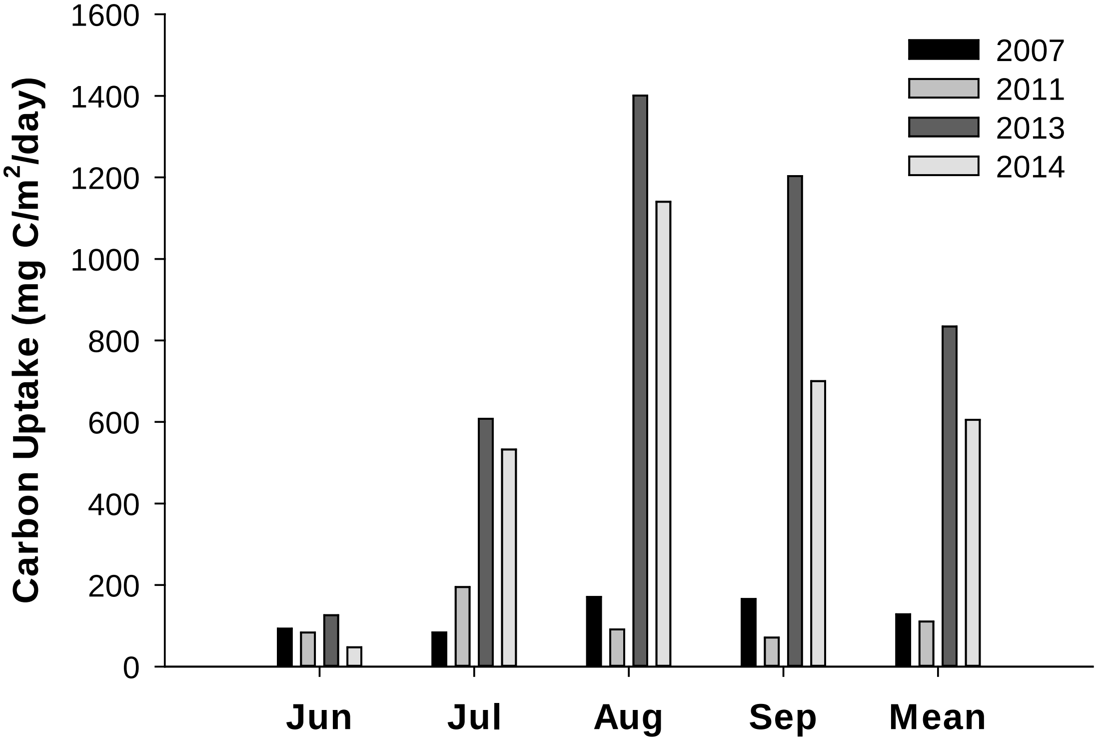

Figure 4. Primary production rates, measured as the uptake of carbon (mg C/m^2/day) into the phytoplankton community, for RK-31. Rates were measured once per month from June through September during three years. Nutrients were added to the reservoir in 2007, 2013, and 2014, but not 2011.

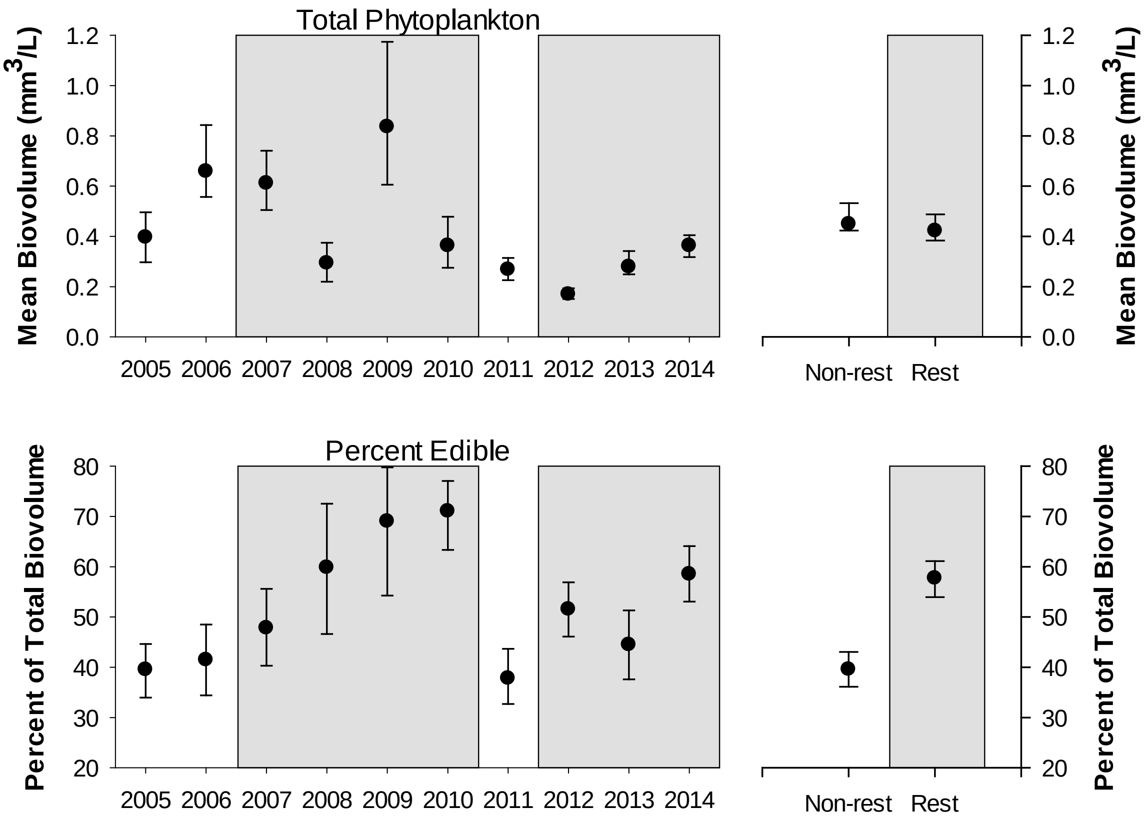

Figure 5. Mean biovolume (mm^3/L) of phytoplankton measured at four sampling stations (RK-2, RK-31, RK-56, and RK-72) on Dworshak Reservoir from May through November. Biovolumes are given for total phytoplankton and edible taxa only. The proportion of the total biovolume that was edible is also shown. Error bars represent 95% confidence intervals obtained by bootstrapping. Treatment periods are indicated by shaded boxes.

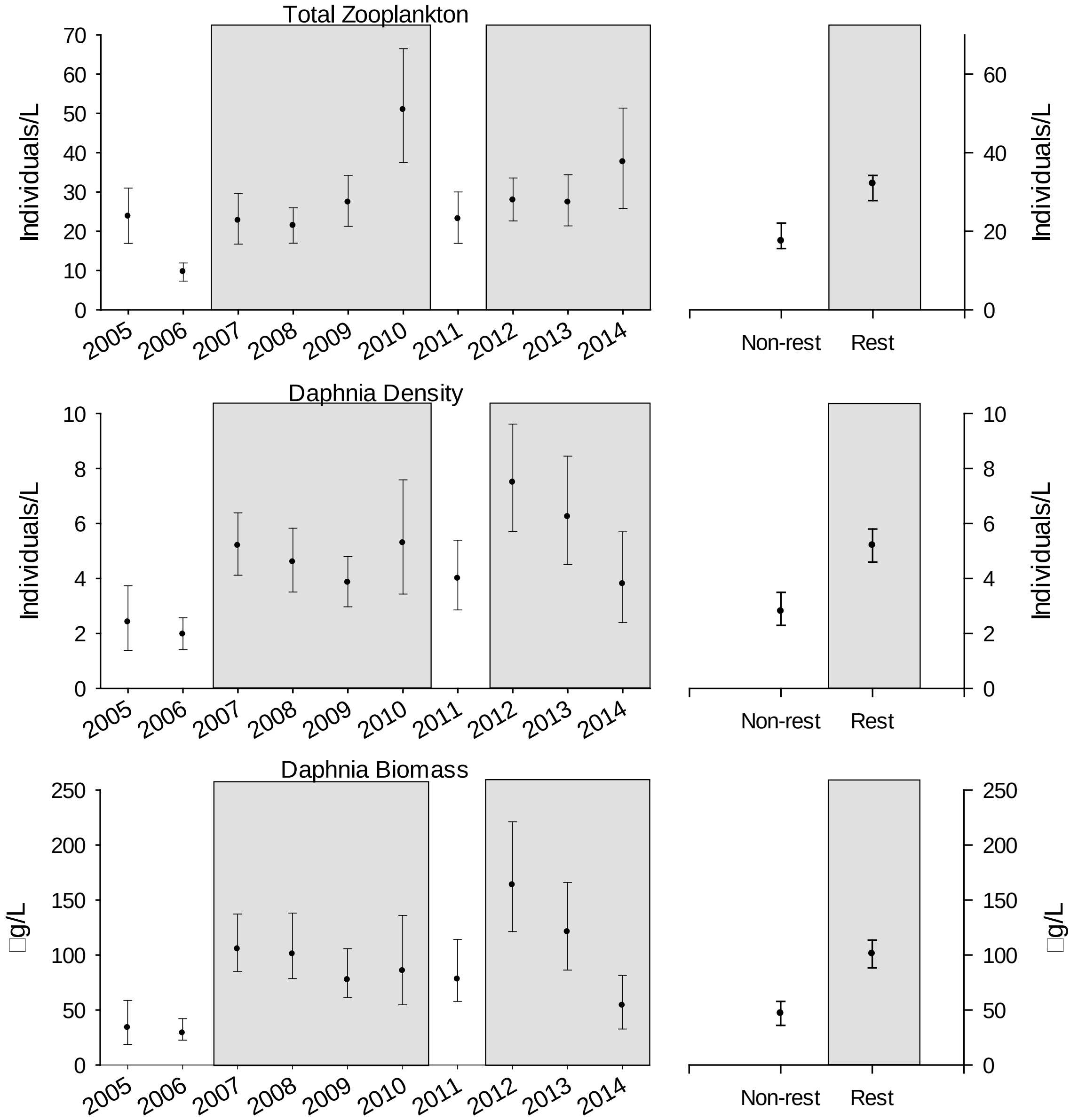

Figure 6. Mean density of zooplankton collected at four sampling stations (RK-2, RK-31, RK-56, and RK-72) on Dworshak Reservoir from April through November. Densities are presented for total zooplankton and *Daphnia*. In addition, the biomass (µg/L) of consumable *Daphnia* (≥0.8 mm TL) is presented. Error bars represent 95% confidence intervals obtained by bootstrapping. Treatment periods are indicated by shaded boxes.

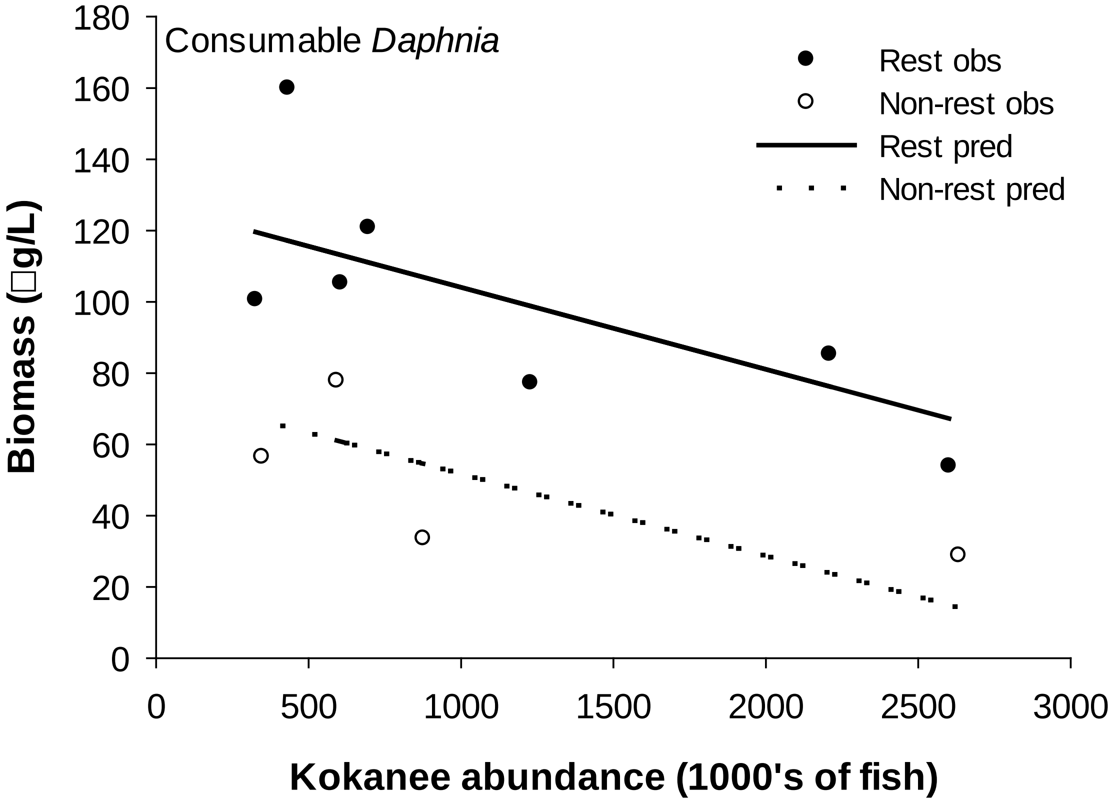

Figure 7. Best competing model explaining the relationship between nutrient restoration, the abundance of age-1 and older kokanee, and consumable *Daphnia* biomass. Restoration years (Rest) are indicated by solid circles and lines, whereas non-restoration years (Non-rest) are indicated by open circles and solid lines. Circles represent observed data (obs) and lines represent model predictions (pred).

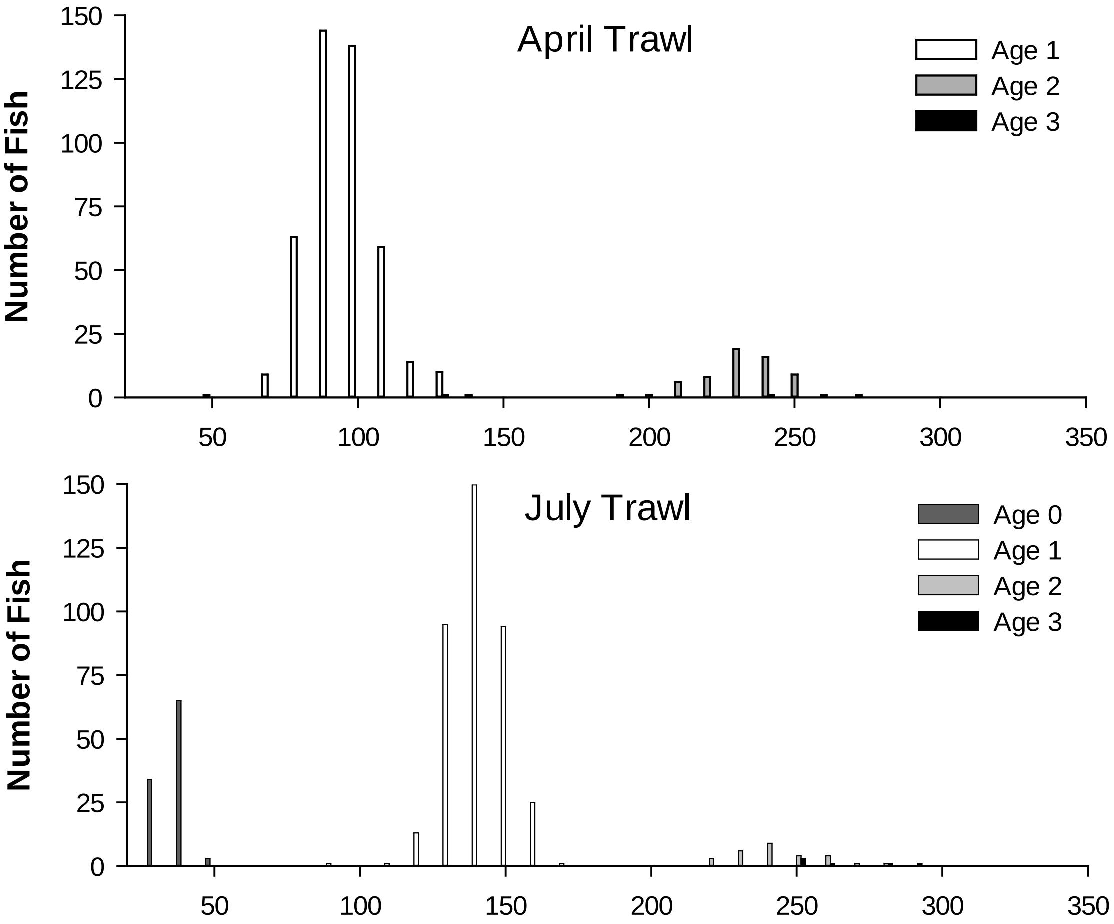

Figure 8. Length frequency of kokanee captured in mid-water trawl surveys on Dworshak Reservoir on April 28-29, July 29-31, 2014.

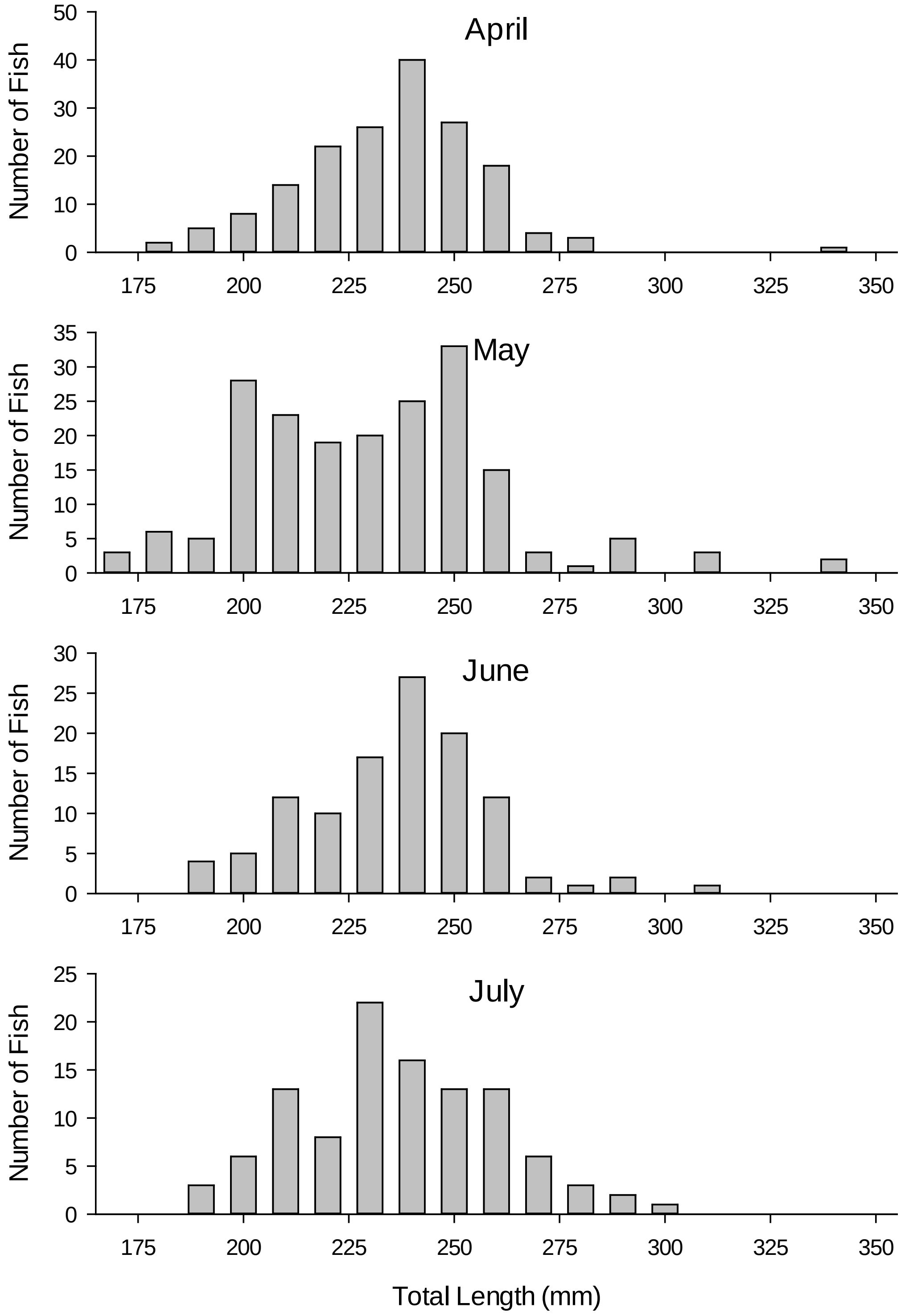

Figure 9. Length frequency distributions of kokanee harvested by anglers on Dworshak Reservoir from April through July of 2014. Fish were binned by 10-mm size groups and separated by month.

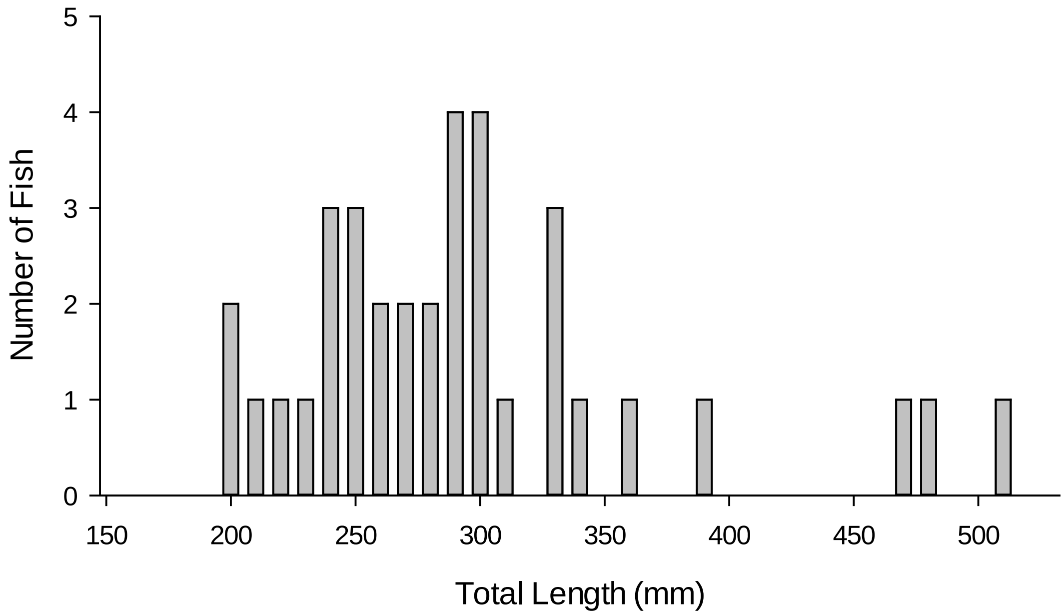

Figure 10. Length frequency of Smallmouth Bass harvested by anglers on Dworshak Reservoir from April through July of 2014. Fish were binned by 10-mm size groups.

APPENDICES

Appendix A. Water clarity statistics, including mean Secchi and compensation depths, for Dworshak Reservoir. Only data from stations RK-2, RK-31, RK-56, and RK-72 from June through November were used. Confidence bounds (LCL = lower confidence limit and UCL = upper confidence limit, 95%) for Secchi depths were obtained by bootstrapping.

	Secchi Depth			**Compensation Depth**	
Year	**mean**	**LCL**	**UCL**	**mean**	**SD**
2004	4.6	4.2	5.0		
2005	4.7	4.6	4.9		
2006	3.8	3.6	4.0		
2007	4.3	3.9	4.6	9.8	1.2
2008	4.0	3.9	4.2	10.2	1.7
2009	3.8	3.4	4.1	9.6	1.5
2010	3.8	3.6	3.9	9.8	1.6
2011	3.7	3.6	3.9	9.7	1.8
2012	4.5	4.0	4.8	10.7	1.5
2013	4.5	4.1	4.9	11.1	1.3
2014	3.6	3.2	3.9	10.3	1.3

Appendix B. Estimates of kokanee abundance and adult (age-2 and older) densities for Dworshak Reservoir. Estimates from 2003 to present have been revised using estimates of available kokanee habitat from data provided by Sam Martin of the USACE.

Year	Sampling Method	Kokanee Abundance (thousands of fish)					Adult Density (fish/ha)
		Age-0	Age-1	Age-2	Age-3	Total	
2014	Acoustic	1,594	2,506	92	4	4,196	19
2013	Acoustic	3,975	553	143	0	4,670	29
2012	Acoustic	819	341	85	0	1,251	18
2011	Acoustic	494	361	231	1	1,087	43
2010	Acoustic	2,331	1,177	1,030	1	4,539	190
2009	Acoustic	1,022	1,109	119	0	2,250	15
2008	Acoustic	1,359	233	71	22	1,686	18
2007	Acoustic	532	147	457	0	1,136	93
2006	Acoustic	1,997	1,550	1,082	0	4,630	242
2005	Acoustic	2,340	697	180	0	3,216	35
2004	Acoustic	449	273	74	0	796	14
2003	Acoustic	373	281	356	0	1,010	69
2002	Acoustic	1,247	1,101	128	0	2,476	24
2001	Acoustic	1,962	781	405	0	3,150	75
2000	Acoustic	1,895	304	199	0	2,398	37
1999	Acoustic	1,144	363	38	0	1,545	7
1998	Acoustic	537	73	39	0	649	7
1997	Trawling	65	0	0	0	65	0
1996	Acoustic	231	43	29	0	303	5
1995[a]	Acoustic	1,630	1,300	595	0	3,539	110
1994	Acoustic	156	984	304	9	1,457	69
1993	Trawling	453	556	148	6	1,163	33
1992	Trawling	1,040	254	98	0	1,043	22
1991	Trawling	132	208	19	6	365	5
1990[a]	Trawling	978	161	11	3	1,153	3
1989[b]	Trawling	148	148	175	0	471	32
1988	Trawling	553	501	144	12	1,210	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 C. Estimates of production and biomass of kokanee in Dworshak Reservoir. Production estimates span the period from July of the first year to July of the second year. Both estimates are based on July acoustic and mid-water trawl surveys. Production estimates could only be obtained when trawl surveys were performed in subsequent years and biomass estimates were obtained for every year that a trawl survey was performed.

	Production (metric tonnes)			
Period	**Age 0-1**	**Age 1-2**	**Age 2-3**	**Total**
2013-14	81.5	18.5		100.0
2012-13	50.3	37.1		87.4
2011-12	36.9	56.2	26.4	119.5
2010-11	60.6	37.6		98.1
2009-10	48.6	54.8		103.7
2008-09	52.3	16.4		68.7
2007-08	32.2	21.3	32.7	86.2
2006-07	71.2	99.6		170.8
2005-06				NA
2004-05				NA
2003-04	23.5	30.5		54.1

	Biomass (metric tonnes)				
Year	**Age-0**	**Age-1**	**Age-2**	**Age-3**	**Total**
2014	0.7	64.9	12.1	0.6	78.3
2013	3.0	41.0	34.6		78.7
2012	0.7	30.3	25.3	2.0	58.3
2011	0.2	16.5	22.8		39.4
2010	1.4	53.2	97.1		151.7
2009	0.7	47.7	21.1		69.6
2008	0.9	19.8	18.6	5.8	45.1
2007	0.3	9.9	57.4		67.5
2006	1.0	40.1	64.5		106.1
2005					NA
2004	0.3	20.1	18.1		38.5
2003	0.3	20.1	56.7		77.1

Appendix D. Number of kokanee spawners counted in index tributaries to the North Fork Clearwater River above Dworshak Reservoir, Idaho during September 1988-2014. Counts were performed on or near September 25, the historical peak of spawning activity.

Year	Isabella Creek	Skull Creek	Quartz Creek	Dog Creek	Total	Mean TL (mm)
2014	10,601	5,292	1,609	1,775	19,277	274
2013	7,535	3,507	758	409	12,209	309
2012	1,447	1,676	574	658	4,355	327
2011	3,598	2,846	773	1,396	8,613	244
2010	26,529	24,212	5,283	3,385	59,409	249
2009	5,366	4,343	918	626	11,253	285
2008	3,738	2,160	462	1,073	7,433	306
2007	11,342	10,913	1,268	1,771	25,294	264
2006	12,604	12,077	2,717	2,345	29,743	210
2005	6,890	3,715	2,137	617	13,359	243
2004	6,922	2,094	450	1,474	10,940	308
2003	12,091	10,225	1,296	1,083	24,695	278
2002	15,933	7,065	2,016	1,367	26,381	267
2001	3,751	1,305	722	301	6,079	305
2000	3,939	402	124	565	5,030	314
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	290
1988	10,960	5,780	5,080	1,720	23,540	280

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