FISHERY RESEARCH

DWORSHAK DAM RESIDENT FISH MITIGATION

PROGRESS REPORT
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Dworshak Dam Resident Fish Mitigation

Project Progress Report

2019-2022 Annual Report

By

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ABSTRACT

Since 2007, the U.S. Army Corps of Engineers (USACE) and Idaho Department of Fish and Game (IDFG) have cooperatively conducted nutrient restoration as a means to restore declining reservoir productivity and improve the Dworshak Reservoir fishery. Under this agreement, the USACE applied nutrients in the form of ammonium nitrate, IDFG monitored the results using a combination of limnological and fish surveys, and Advanced Eco-Solutions provided the application schedule and limnological analysis. This report summarizes the results of the project through 2022. Water quality standards set by the U.S. Environmental Protection Agency and the Idaho Department of Environmental Quality were not violated. We did not observe significant changes in Secchi depth, chlorophyll concentration, or phytoplankton biovolume. However, the biovolume of edible phytoplankton and the proportion of edible phytoplankton were both significantly higher during the restoration period. The proportion of *Dolichospermum* (formerly *Anabaena*) was significantly lower during the restoration period. The density of all zooplankton, as well as the density and biomass of consumable *Daphnia*, were all greater during the restoration period. The abundance and size of kokanee *Oncorhynchus nerka* was also greater for the restoration period. This project previously demonstrated a positive correlation between kokanee abundance and angling effort for kokanee and Smallmouth Bass *Micropterus dolomieu*. Dworshak Reservoir has responded positively to nutrient restoration, resulting in a more efficient food web and more productive fisheries.

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INTRODUCTION

Dworshak Reservoir is 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second most popular destination in the Clearwater region, based on total angler trips in 2011 (Thomas MacArthur, IDFG, unpublished data).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 fisheries 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 (ESA).

Kokanee provide the most popular fishery on the reservoir, with annual effort levels that have exceeded 75,000 angler hours and annual harvest of over 125,000 fish (Hand et al. 2021). 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 1997).

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 autumn to provide cool water for Chinook Salmon *O. tshawytscha* in the Snake River. 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. During this time period, kokanee are distributed farther from the dam and are less vulnerable to entrainment than during winter (Maiolie and Elam 1997). Discharge from January through March had the highest negative correlation with survival compared to other time periods examined (Bennett 1997). Entrainment has the potential to be a limiting factor for kokanee in years with winter drawdown conditions, but oligotrophication is more often the primary limiting factor. Declining productivity was identified as a critical factor limiting the kokanee fishery, and was recommended to be addressed before implementing intensive fisheries management practices (Bennett 1997).

Following this recommendation, a detailed assessment of the reservoir was conducted and recommendations for a nutrient restoration program were provided (Stockner and Brandt 2006). Based on phosphorous (P) loading and mean chlorophyll densities, Dworshak Reservoir was classified as borderline oligo-mesotrophic. However, the phytoplankton communities and associated food web present during the spring were dominated by microbial communities (picoplankton) 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). These cyanobacteria were typically abundant from mid-summer to early fall, and because they are inedible to zooplankton, they 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 in 2007 to evaluate nutrient restoration as a management strategy for restoring the Dworshak Reservoir ecosystem and improving the fishery. The goal of the project was 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 was expected to lead to an increased abundance of zooplankton, therefore providing an improved forage base for fish. A moderate N nutrient restoration was hypothesized to benefit fish populations without degrading water quality (Stockner and Brandt 2006).

The project has been collaborative since its inception with the USACE applying the nutrients and IDFG conducting the monitoring. 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 in late July of 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 determined that a National Pollutant Discharge Elimination System (NPDES) permit would be required for nutrient applications to continue. An NPDES permit was obtained in October of 2011, and the project resumed in 2012.

This report summarizes reservoir data collected through 2022. These data were used to evaluate the action effectiveness of nutrient restoration for both limnological and fishery responses. The primary role of IDFG's monitoring program was to evaluate the effectiveness of the nutrient restoration 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 NPDES permit, were maintained. Secondly, limnological data were collected to make comparisons with pre-treatment conditions to determine the biological effects of the project, including changes to the plankton communities. Furthermore, data were provided to the consultant to actively manage the nutrient applications. Lastly, surveys were conducted to monitor the kokanee population. The nutrient restoration program is expected to increase the average size of kokanee at any given population density.

METHODS

Study Site

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 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 2009-2018 was 164 m^3/s (http://www.cbr.washington.edu/dart/, accessed 4/11/20). 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).

Nutrient Additions

Agricultural grade liquid ammonium nitrate was applied to the reservoir by the USACE on a weekly basis from May through September of 2007-2022, with the exception of 2010. Darren Brandt of Advanced Eco-Solutions provided a weekly nutrient prescription based on epilimnetic volume and historical concentrations of dissolved inorganic nitrogen (DIN) adjusted for precipitation and temperature. Nutrients were applied along the centerline of the reservoir using an 18 m barge, beginning at river km (RKM) 9 and continuing up reservoir as far as the barge could operate. At low pool elevations, a smaller boat outfitted with a tank was used to continue applications as close to slack water as possible to minimize cyanobacterial blooms where the barge was not able to operate. The application schedule and amounts applied can be found in annual reports of nutrient applications (Brandt 2020, 2021, 2022).

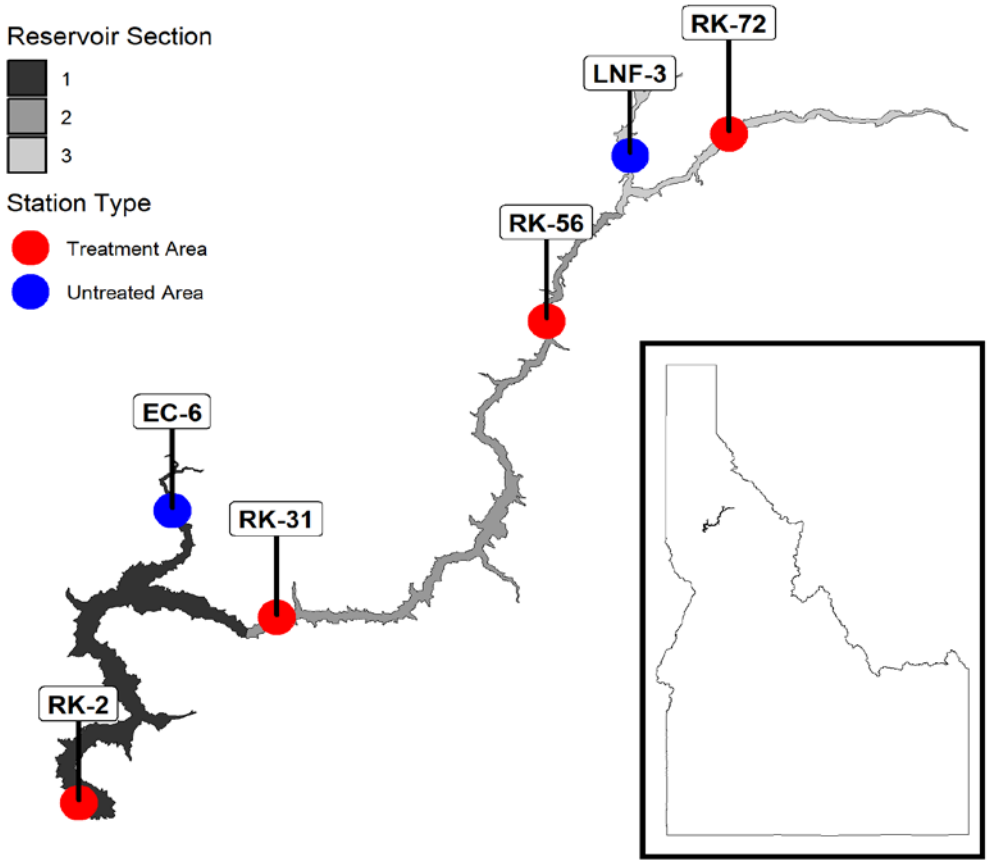

Figure 1. Map of Dworshak Reservoir depicting the locations of four limnological sampling stations on the treated portion of the reservoir (RK-2, RK-31, RK-56, and RK-72) and two on the untreated portion (EC-6 and LNF-3) that were used for trend monitoring. Boundaries of reservoir sections used in statistical stratification are also shown.

Limnological Sampling

In 2019-2022, limnological sampling was conducted once per month from May through November. 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 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).

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. Secchi measurements were recorded as the reappearance depth. In addition, photosynthetically active radiation (PAR) was measured using a LI-COR® model LI-1500 data logger and a 400-700 µm quantum sensor (model LI-193). The sensor was mounted on a frame and weighted with a lead weight. A 15 s average PAR reading was taken at the water surface and at one-meter intervals

to 15 m or a reading of zero. Air readings were measured concurrently with the wet readings using a dry quantum sensor (model LI-190R) connected to the data logger.

Water samples were collected from the epilimnion (EPI) at each station using a 2.2 L Kemmerer bottle. Epilimnion 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. Two 250 mL polyethylene sample bottles were filled with the composite sample. 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. Sample bottles were stored on ice prior to shipping, and shipped via overnight carrier to the contracting lab within two days of collection. Chemical analyses were performed by AM Test Labs of Kirkland, Washington. Samples were analyzed for total phosphorus (TP), total dissolved phosphorus (TDP), total (Kjeldahl) nitrogen (TN), total ammonia (TA), and nitrite + nitrate (NO_x). Analytical methods used for each parameter can be found in Wilson et al. (2010).

A Chlorophyll *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. The filter was removed from the manifold and folded in half on a 15 cm^2 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, Chlorophyll *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.

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. All plankton and Chlorophyll *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).

Additional details of limnological sampling, including details from previous years, can be found in Wilson and Corsi (2016). Links to published methods can be found in Table 1.

Kokanee Sampling

Kokanee were surveyed each July using a combination of mid-water trawl and hydroacoustic surveys. For these surveys, 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 above Grandad Bridge.

Trawl surveys were based on methods described by Rieman (1992), and were conducted within five days of the new moon to maximize efficiency (Bowler et al. 1979). Tows were conducted at randomly chosen starting points. Step-wise oblique tows were performed through the kokanee layer using a fixed frame net that 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. 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 (Devries and Frie 1996).

Acoustic surveys were conducted within five days of the trawl survey 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. 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). Additional details of kokanee sampling, including details from previous years, can be found in Wilson and Corsi (2016). Links to published methods can be found in Table 1.

Table 1. Links to methods published in www.monitoringresources.org

Physical Limnology Sample Collection and Analyses	https://www.monitoringresources.org/Document/Method/Details/1418 https://www.monitoringresources.org/Document/Method/Details/1420 https://www.monitoringresources.org/Document/Method/Details/1177 https://www.monitoringresources.org/Document/Method/Details/3930 https://www.monitoringresources.org/Document/Method/Details/3933
Biological Limnology Sample Collection and Analyses	https://www.monitoringresources.org/Document/Method/Details/3929 https://www.monitoringresources.org/Document/Method/Details/3928 https://www.monitoringresources.org/Document/Method/Details/3931 https://www.monitoringresources.org/Document/Method/Details/1421
Kokanee Sample Collection and Population Monitoring Analyses	https://www.monitoringresources.org/Document/Method/Details/1001 https://www.monitoringresources.org/Document/Method/Details/1000 https://www.monitoringresources.org/Document/Method/Details/1422

Data Analysis

Secchi depth summaries were calculated using observations collected from June through November at four consistently sampled stations in the treatment area, which included RK-2, RK-31, RK-56, and RK-72. In years where multiple sampling events occurred within a single month, only the first sampling event was used for a given station. The time period of June through November was used to reduce the influence of spring runoff on water clarity.

The compensation depth (CD) is the depth where light intensity is 1% of the light intensity at 0 m. Before calculating CD, 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:

$$x = ln[100(l_D/l_S)]$$

Where x is the ratio of light intensity at a given depth D as related to surface light intensity, l_D is light intensity at depth D, and l_S is light intensity at the surface, or a depth of 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.

Chemical concentrations were often below the detection limit of a given assay. In these cases, the concentration was assumed equal to the detection limit for computing descriptive statistics. Furthermore, detection limits for TP were higher during earlier years of the study. When analyzing trends for TP, all data were artificially adjusted upward to match the highest detection limit.

The analytical lab reported both density and biovolume of phytoplankton. Densities were reported in terms of natural counting units (NCU). Prior to 2008 colonies were used as the NCU for most colony forming taxa. After 2008, cells were used as the NCU for most taxa, including many prevalent colony forming taxa. Furthermore, small taxa may have high densities, yet relatively low biovolume. Therefore, phytoplankton trends were reported as biovolume.

Total length was measured for up to 20 *Daphnia* in a given sample. The weights of individual *Daphnia* were calculated using the following formula (McCauley 1984):

$$ln(w) = ln(a) + b * ln(L)$$

Where w is weight (µg), *a* is the estimated intercept, *b* is the estimated slope, and *L* is the length (mm).

For these calculations, we used estimates from McCauley (1984) for *D. galeata* where ln(a) was 2.64 and *b* was 2.54.

Daphnia biomass was then calculated by multiplying mean weight by density for a given tow. Kokanee in Dworshak Reservoir were found to primarily consume *Daphnia* that were 0.80 mm or longer TL (Wilson et al. 2021). The proportion of consumable *Daphnia* was calculated as the number of consumable *Daphnia* divided by the total number measured in a given tow. This 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 consumable *Daphnia*.

Zooplankton collection was inconsistent during the early years of the study in terms of mesh and tow length. For trend comparisons using earlier data, all data were corrected to 80 µm mesh and 10 m tow length. Specifically, data from 2004 were corrected from 150 µm mesh to 80 µm mesh, and data from 2007 were corrected from 30 to 0 m tows to 10 to 0 m tows. Details of these corrections can be found in Wilson et al. (2021).

Kokanee density was estimated for acoustic transects with Echoview software using echo integration. Only targets from -60 to -30 dB were considered kokanee. Densities were partitioned into age-0 and age-1 and older using corrected target strength. Densities of age-1 and older were further partitioned using proportions from trawl catches in that section of the reservoir. Mean densities were then multiplied by the area of the reservoir at the mean depth of the kokanee layer to estimate abundance. Greater detail for kokanee surveys can be found in Wilson and Corsi (2016) and links to published methods in Table 1.

Trend analyses 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. Comparisons between years were made using a graphical analysis of means and confidence intervals (Johnson 1999). All data wrangling and analysis was performed using the tidyverse family of packages (Wickham et al. 2019) in Program R (R Core Team 2022).

RESULTS

Water Clarity

Median annual Secchi depth across all stations from the June-November timeframe during 2019-2022 ranged from a minimum of 3.1 m in 2022 to a maximum of 4 m in 2019. Mean Secchi depth for this sampling frame ranged from a low of 3.3 m in 2022 to a maximum of 3.9 m in 2019 (Figure 2). Mean Secchi depth was 3.9 m for the restoration period and 4.2 m for the non-restoration period, and 95% confidence intervals overlapped between these two periods (Figure 2). Mean compensation depth has been monitored since 2007 and has ranged from a low of 9.6 m in 2009 to a high of 11.2 m in 2017. Additional summaries of Secchi depths and compensation depths can be found in Brandt 2020 and 2021.

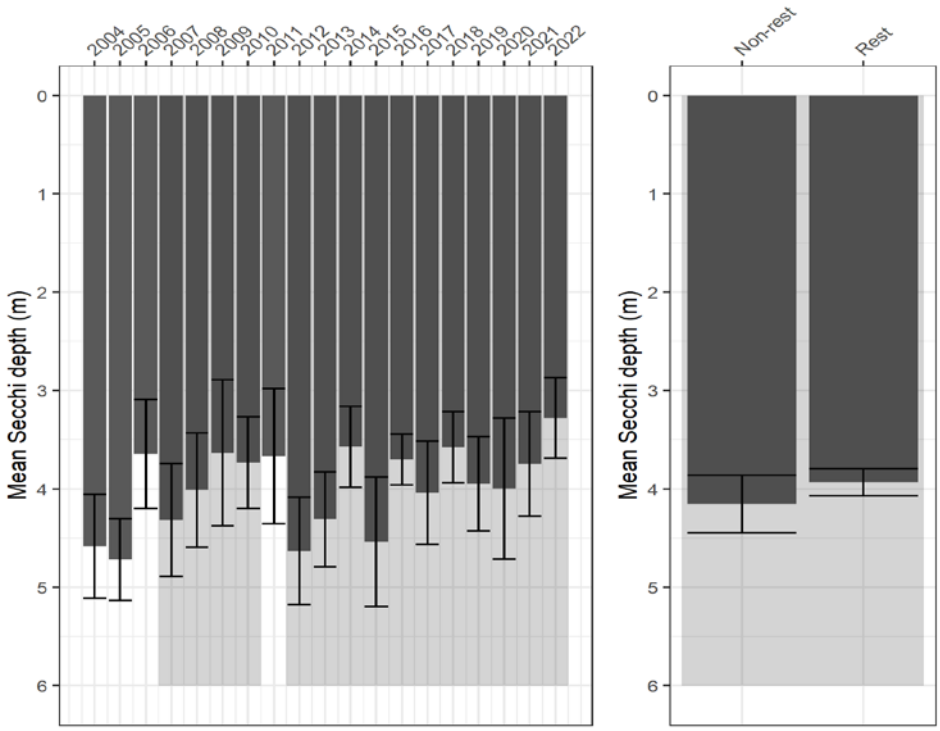

Figure 2. Mean Secchi depth measured at four sampling stations (RK-2, RK-31, RK-56, and RK-72) on Dworshak Reservoir from June through November. Error bars represent 95% confidence intervals derived by classical methods. Treatment periods are indicated by shaded boxes.

Chlorophyll

The mean concentration of Chlorophyll *a* was lower during the restoration period (mean = 1.82 µg /L) than the non-restoration period (mean = 2.36 µg /L). From 2019-2022, median

Chlorophyll *a* concentration ranged from a minimum of 1.02 in 2019 to a maximum of 1.44 in 2020 Additional summaries of Chlorophyll *a* can be found in Brandt 2020 and 2021.

Phytoplankton

The mean biovolume of total phytoplankton decreased from 0.447 mm^3/L during the non-restoration period to 0.325 mm^3/L during the restoration period (Figure 3). The mean biovolume of edible phytoplankton increased from 0.1 mm^3/L during the non-restoration period to 0.144 mm^3/L during the restoration period (Figure 3).

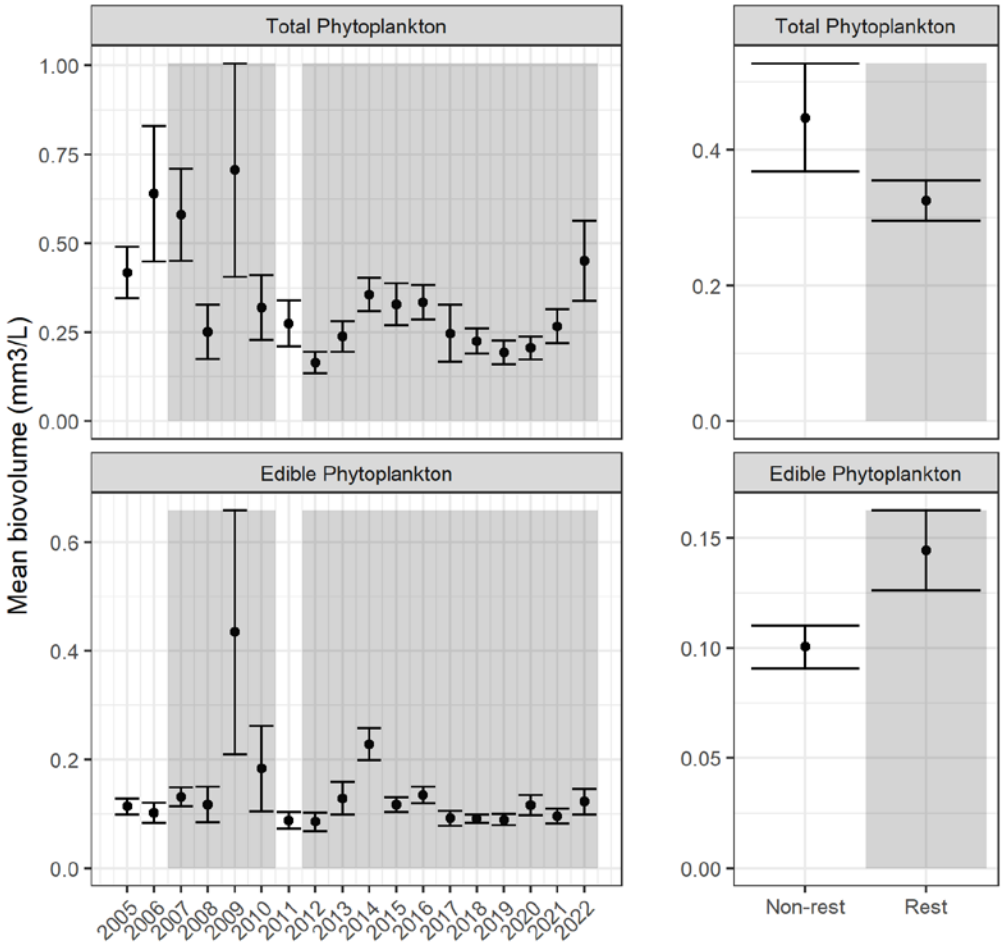

Figure 3. Mean biovolume (mm3/L) of total and edible phytoplankton measured at four sampling stations (RK-2, RK-31, RK-56, and RK-72) on Dworshak Reservoir from May through November, 2005-2022. Error bars represent 95% confidence intervals. Treatment periods are indicated by shaded boxes.

The proportion of the phytoplankton community that was known to be edible increased from 31 percent during the non-restoration period to 50 percent during the restoration period (Figure 4). Additionally, the proportion of the total phytoplankton biovolume that was composed

of *Dolichospermum*, a historically prevalent form of harmful cyanobacteria, decreased from 15 percent during the non-restoration period to 5 percent during the restoration period (Figure 4). Additional summaries of phytoplankton data can be found in (Brandt 2020, 2021).

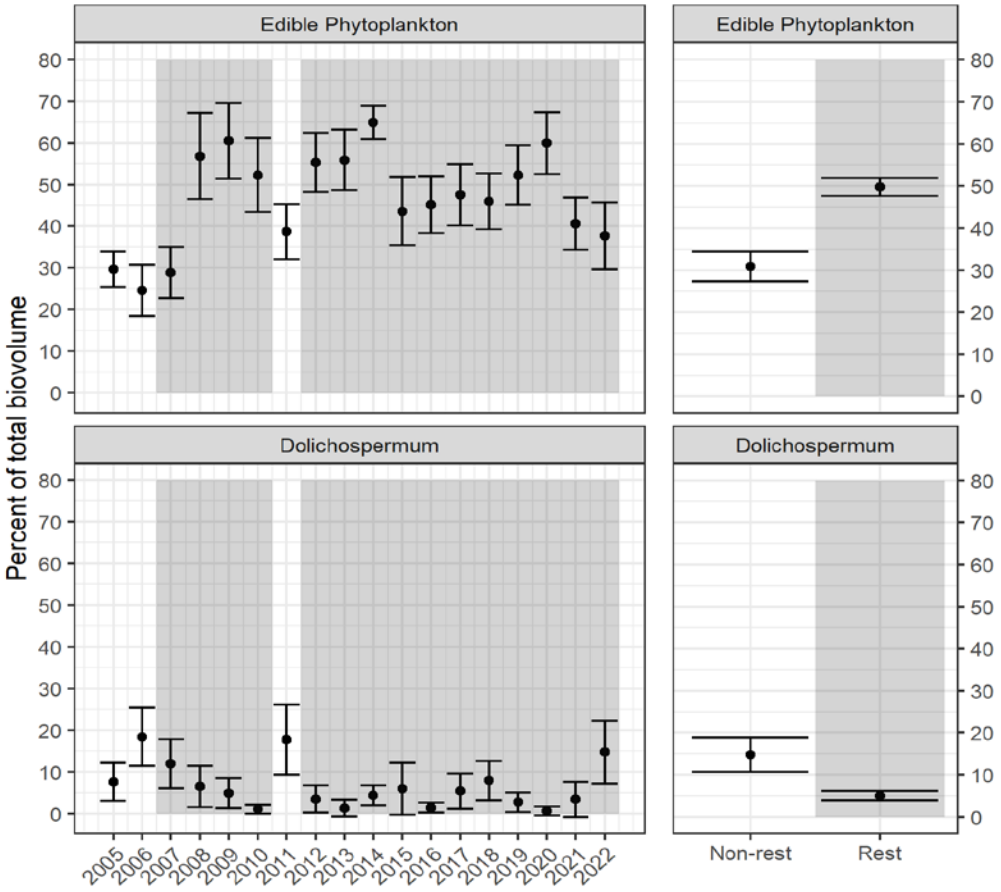

Figure 4. The percent of total phytoplankton biovolume that was comprised of edible taxa, and that which was composed of *Dolichospermum*, the prevalent taxa of harmful cyanobacteria in Dworshak Reservoir, 2005-2022. Treatment periods are indicated by shaded boxes.

Zooplankton

The mean density of zooplankton increased from 17.4 individuals/L during the non-restoration period to 32.7 individuals/L during the restoration period (Figure 5). The mean density of *Daphnia* increased from 3.4 individuals/L during the non-restoration period to 5.1 individuals/L during the restoration period. Additionally, the mean density of consumable *Daphnia* increased from 2.6 individuals/L during the non-restoration period to 4 individuals/L during the restoration period.

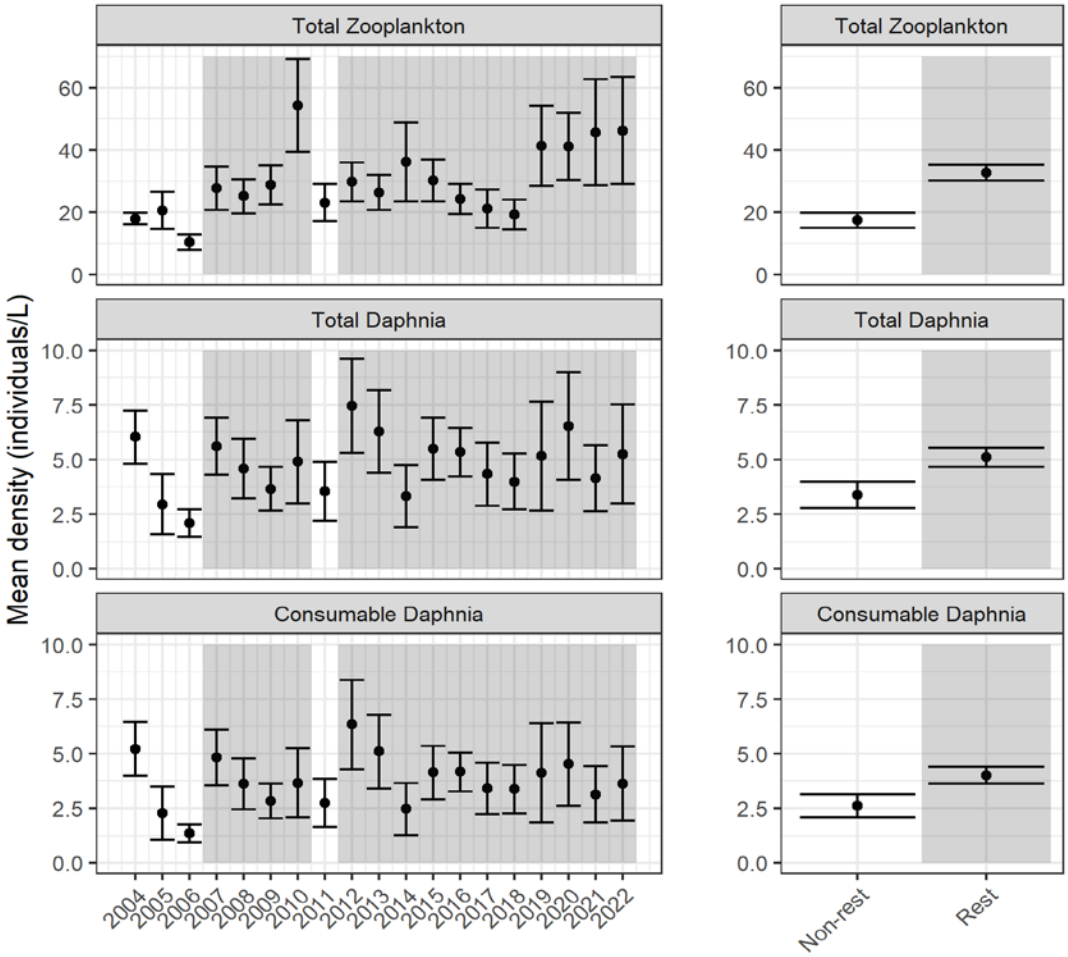

Figure 5. Mean density of total zooplankton, total Daphnia, and consumable Daphnia collected at four sampling stations (RK-2, RK-31, RK-56, and RK-72) on Dworshak Reservoir from April through November, 2004-2022. Error bars represent 95% confidence intervals. Treatment periods are indicated by shaded boxes.

The mean biomass of consumable *Daphnia* increased from 41.1 µg/L during the non-restoration period to 96.4 µg/L during the restoration period (Figure 6).

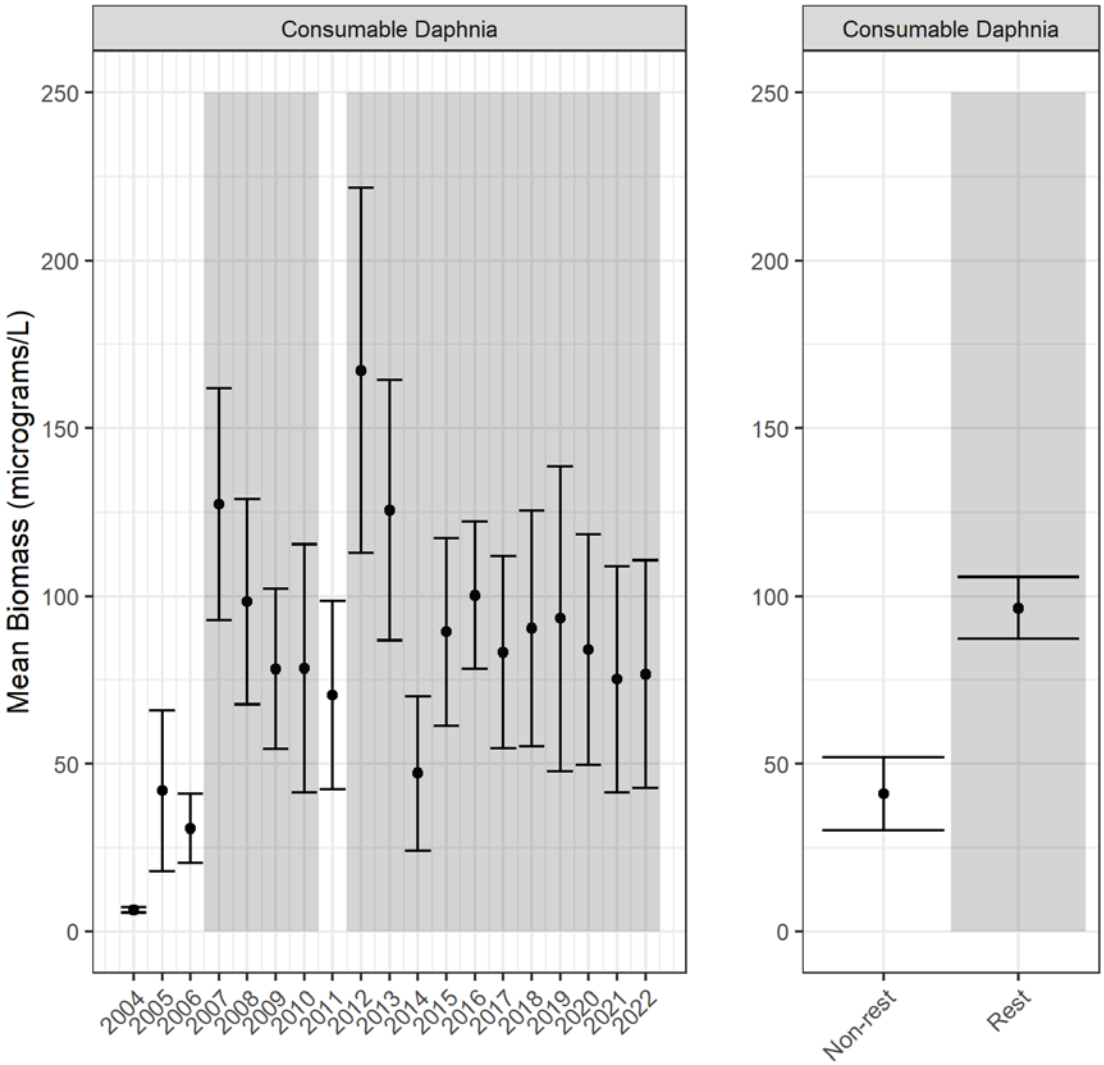

Figure 6. Mean biomass of consumable Daphnia collected at four sampling stations (RK-2, RK-31, RK-56, and RK-72) on Dworshak Reservoir from April through November, 2004-2022. Error bars represent 95% confidence intervals. Treatment periods are indicated by shaded boxes.

Kokanee Population Monitoring

The mean abundance of all age classes from 2004-2022 as estimated using hydroacoustic surveys was 2.4 million kokanee for the non-restoration period and 3.7 million kokanee for the restoration period. The mean abundance of age-1 and older fish was 1.1 million kokanee for the non-restoration period and 1.6 million kokanee for the restoration period. The mean abundance of adult (age-2 and older) fish was 392,000 kokanee for the non-restoration period and 530,000 kokanee for the restoration period. Abundance estimates can be found in Appendix A.

Total length and weight were similar for age-1 kokanee during non-restoration and restoration periods. During the non-restoration period age-1 kokanee averaged 180 mm and 54

g as compared to the restoration period when they averaged 182 mm and 58 g. Total length and weight of age-2 kokanee increased from the non-restoration to restoration periods. During the non-restoration period age-2 kokanee averaged 244 mm and 140 g as compared to the restoration period when they averaged 255 mm and 164 g.

During the non-restoration period average kokanee biomass was 63.7 metric tons as compared to 109.5 metric tons during the restoration period (Figure 7). Biomass was similar to the non-restoration period for the first three years following each start-up period and increased after the third year of restoration in both instances. Since then, biomass has fluctuated with lows similar to that of non-restoration years, but with maxima that are approximately 60% greater than the non-restoration maximum (Figure 7). Historical production estimates can be found in Appendix D.

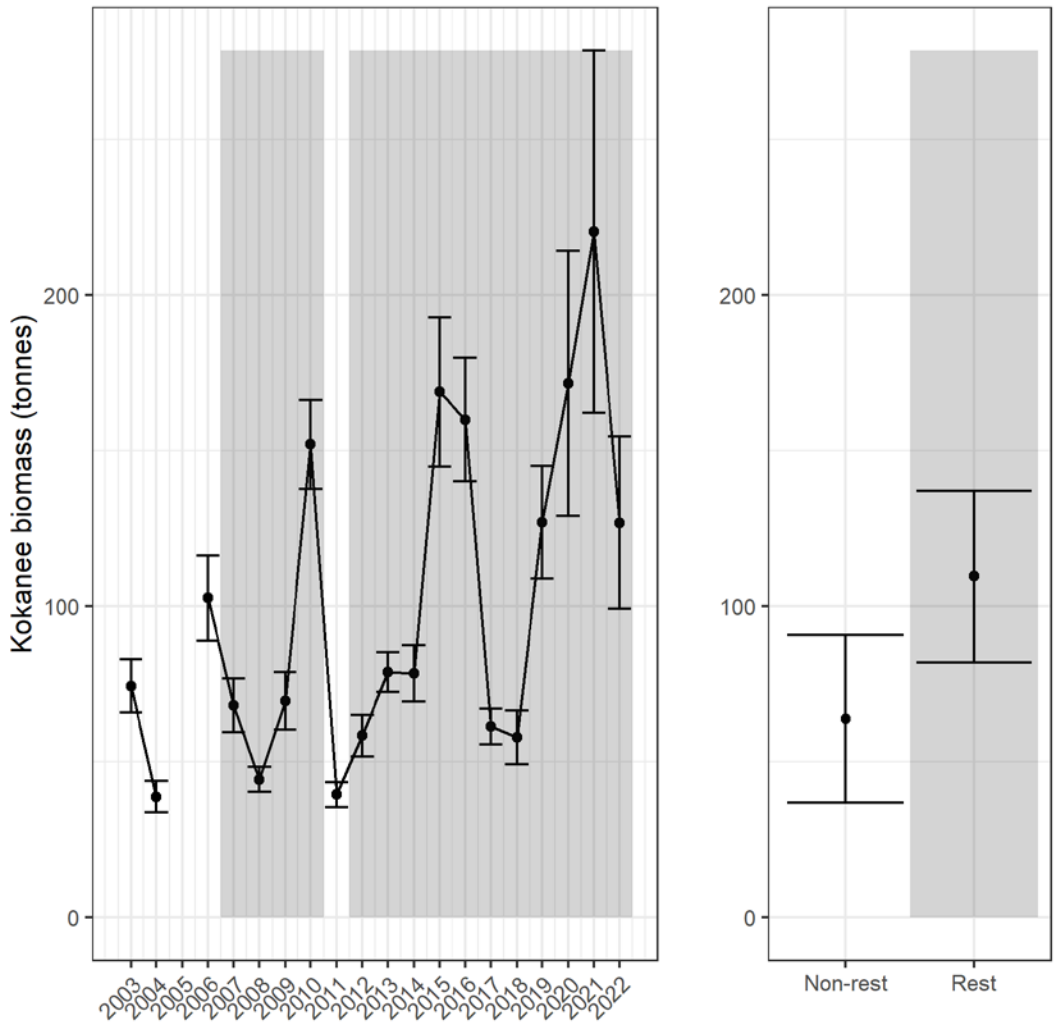

Figure 7. Estimates of kokanee biomass in Dworshak Reservoir during July, 2003-2022. along with means for the non-restoration and restoration periods. Shading represents years that nutrients were added to the reservoir. Treatment periods are indicated by shaded boxes.

DISCUSSION

Water Quality

The nutrient restoration project has increased reservoir productivity, and improved water quality. The NPDES permit specifies that median Secchi depth must be ≥3.0 m, and median Chlorophyll *a* concentration must be ≤3.0 µg/L, and neither of these thresholds were exceeded from 2019-2022.

The nutrient project has not had a significant negative effect on water clarity, as measured by Secchi depth. Secchi depth is influenced by a variety of factors, including suspended solids from spring runoff and Chlorophyll *a* concentration due to summer algal blooms. In order to examine the effects of algal production on water clarity, we concentrated on data from June through November, when the effect of runoff should be minimal. Results of an enclosure experiment designed to study the effect of varying levels of nitrogen addition on the phytoplankton community indicated that N addition will not cause a decline in water clarity unless it favors inedible or indigestible phytoplankton (Wilson and Corsi 2019). Observations from the reservoir revealed no significant difference in Secchi depth when the N-based fertilizer was applied to the reservoir. This suggests that the reservoir is behaving more closely to the enclosures in 2018, when the resulting phytoplankton community was largely edible, grazed off by zooplankton, and did not result in decreased water clarity (Wilson and Corsi 2019).

As with water clarity, N additions have not had a negative effect on Chlorophyll *a* concentration. Instead, the mean Chlorophyll *a* concentration was significantly lower during the restoration period. This response was verified by results from the enclosure experiment in 2018 (Wilson and Corsi 2019). As with Secchi depth, the enclosure experiments demonstrated that N addition can cause increases in Chlorophyll *a*, but only if primary production is channeled into inedible taxa, as was the case in 2017 (Wilson and Corsi 2019). Results from the reservoir indicate that it is behaving as the enclosures did in 2018, during which primary production was shifted to edible taxa and did not result in an increase in Chlorophyll *a* (Wilson and Corsi 2019).

Another water quality concern is the prevalence of potentially toxigenic cyanobacteria (blue-green algae). Historically, *Dolichospermum* (formerly *Anabaena*) has been the dominant taxa of toxigenic cyanobacteria. *Dolichospermum* typically becomes dominant in late summer after available N becomes exhausted. *Dolichospermum* are known to fix N and believed to have a competitive advantage when fixed N is no longer available (Schindler et al. 2008). Therefore, it was anticipated that N restoration would reduce the prevalence of *Dolichospermum* (Stockner and Brandt 2006). The rapid decline of *Dolichospermum* in response to N additions, followed by its immediate rebound when N additions were suspended, was compelling. Our data do not indicate an increased prevalence of toxigenic cyanobacteria as a result of N additions, and in the case of *Dolichospermum*, the project has resulted in a decreased prevalence. The enclosure experiments confirm the response of *Dolichospermum* to the current N addition program (Wilson and Corsi 2019).

Reservoir Productivity

Changes in primary production were assessed as part of the enclosure experiments by measuring C uptake. While C uptake tended to increase with N addition in the enclosure experiments, this response was also dependent on the phytoplankton community. In 2017, when N-fixing cyanobacteria were not prevalent, C uptake increased as N was added, with most of the increase coming from the lowest dose of N, and relatively little gain from the highest dose. By contrast, when N-fixing cyanobacteria were prevalent, as in 2018, there was essentially no gain

in C uptake with the lowest dose. When looking at C uptake by size fraction, C uptake of nanoplankton more than doubled in the 1x treatment in August, when N-fixers were most prevalent. However, the controls had a similar overall C uptake due to increased uptake in the microplankton, the size fraction that includes N-fixing cyanobacteria. Since these taxa can fix N, it is possible that N fixation (not measured) led to increased C uptake in this fraction (measured), which equalized overall C uptake. Therefore, N addition, at the 1x level, may result in either increasing C uptake, as in 2017, or shifting it to nanoplankton, as in 2018, which tend to be edible by zooplankton, thereby increasing the efficiency of the system (Wilson and Corsi 2019).

Chlorophyll *a* is often used as an indicator of productivity in lakes and reservoirs (Carlson 1977). Mean Chlorophyll *a* has not increased in the reservoir in response to nutrient restoration, suggesting that productivity has not increased. However, if the composition of the phytoplankton community has shifted to edible taxa, which are grazed off by zooplankton at a higher rate, an increase in primary productivity may not be detected in mean Chlorophyll *a* concentration (Scofield and Stockner 2010; Wilson et al. 2018). 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 Chlorophyll *a* should not be viewed as a prerequisite for success. Results from the enclosure studies also suggest that under the right circumstances supplemented N can result in a shift toward edible phytoplankton rather than an increase in primary production (Wilson and Corsi 2019).

As with Chlorophyll *a*, the mean biovolume of total phytoplankton in the reservoir did not increase during years of N addition. However, the mean biovolume of edible phytoplankton was significantly higher during years of N addition. This further indicates a shift in the species composition of the phytoplankton community in the reservoir due to N addition. These observations, along with aforementioned results of the enclosure experiment, confirm that any gains in primary production have been channeled into edible taxa, resulting in a more efficient food web.

The mean density of zooplankton in the reservoir was significantly higher during the restoration period, presumably due to shifts in the edibility of the phytoplankton community. The lack of an increase in the phytoplankton standing stock in the reservoir, concurrent with an observed increase in primary production (Wilson and Corsi 2019), is best explained by an increase in grazing from the zooplankton community. The observed increase in zooplankton densities further supports this conclusion.

Of greater interest, the biomass of consumable *Daphnia* was more than double the non-restoration mean. Daphnia longer than 0.8 mm in length (considered consumable) have been previously found to be the preferred prey of kokanee (Wilson et al. 2021). Furthermore, the biomass of consumable *Daphnia* has been found to be the best predictor of kokanee growth (Wilson and Corsi 2016). This increase in prey availability has essentially increased the carrying capacity of kokanee in the reservoir (Wilson et al. 2021).

Kokanee Population Monitoring

Kokanee abundance and size were higher on average for the restoration period than the non-restoration period. However, kokanee abundance is erratic. Before 2020, the maxima abundances for both periods were similar. However, kokanee growth, especially in years of high abundance, was greater for restoration years, resulting in much higher maximum biomass for the restoration period, and a higher overall mean for this period. The addition of N has resulted in a higher biomass of *Daphnia* at a given kokanee abundance, compared to years without N addition (Wilson et al. 2021). Furthermore, *Daphnia* biomass was found to be the proximate driver of

kokanee growth (Wilson and Corsi 2016). Therefore, N addition has increased the kokanee biomass that the reservoir can support.

The increased abundance of kokanee observed for the restoration period has likely resulted in benefits to the fishery and other fish populations. Wilson and Corsi (2019) found that both catch rates and effort for the kokanee fishery increased as the abundance of age-2 and older kokanee increased, at least at abundances of <1 million. Furthermore, catch rates and effort for the Smallmouth Bass fishery increased as the abundance of age-1 and older kokanee during the previous year increased, presumably due to increased forage available to and improved growth of Smallmouth Bass (Wilson and Corsi 2019). Kokanee were also identified as an important forage species for Bull Trout, and increased kokanee abundance could benefit Bull Trout populations through increased forage. (USFWS 2015).

CONCLUSIONS

The responses observed from more than a decade of nutrient restoration in Dworshak Reservoir, combined with decades of observations from British Columbia lakes, suggest that nutrient restoration is a valuable tool for mitigating declining productivity in lakes and reservoirs. Nutrient restoration in Dworshak Reservoir has decreased the prevalence of harmful algal blooms, resulting in improved value for recreational uses. It has further resulted in a more efficient food web, thereby increasing the productivity of fish stocks and improving fishing opportunities. The success of nutrient restoration in Dworshak Reservoir suggests this tool may be viable in other reservoir environments throughout the Columbia River basin. Whether for mitigation of harmful algal blooms or the restoration of aquatic food webs hampered by reservoir senescence, nutrient restoration programs show great promise for the mitigation of some of the environmental impacts of hydrosystem development.

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REFERENCES

Bennett, D. H. 1997. Evaluation of current environmental conditions and operations at Dworshak Reservoir, Clearwater River, Idaho, and an analysis of fisheries management mitigation alternatives. U.S. Army Corps of Engineers Walla Walla, Washington.

Bowler, B., B. E. Rieman, and V. L. Ellis. 1979. Pend Oreille Lake fisheries investigations. Idaho Department of Fish and Game, Job Performance Report. Idaho Department of Fish and Game, Project F-73-R-1.

Brandt, D. H. 2020. Dworshak Reservoir nutrient enhancement project: 2019 progress report and data summary. Advanced Eco-Solutions Inc., Newman Lake, Washington.

Brandt, D. H. 2021. Dworshak Reservoir nutrient enhancement project: 2020 progress report and data summary. Advanced Eco-Solutions Inc., Newman Lake, Washington.

Brandt, D. H. 2022. Dworshak Reservoir nutrient enhancement project: 2021 progress report and data summary. Advanced Eco-Solutions Inc., Newman Lake, Washington.

Carlson, R. E. 1977. A trophic state index for lakes: trophic state index. Limnology and Oceanography 22(2):361–369.

Devries, D. R., and R. V. Frie. 1996. Determination of age and growth. Pages 483–512 *in* B. R. Murphy and D. W. Willis, editors. Fisheries techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Falter, C. M. 1982. Limnology of Dworshak Reservoir in a low flow year. U.S. Army Corps of Engineers, Walla Walla, Washington.

Hand, G. R., S. M. Wilson, D. Hannasch, J. Renner, and J. DuPont. 2021. Idaho Department of Fish and Game Fishery Management Annual Report, Clearwater Region 2017. Idaho Department of Fish and Game, Report number 21-107, Boise.

Johnson, D. H. 1999. The Insignificance of Statistical Significance Testing. The Journal of Wildlife Management 63(3):763.

Maiolie, M. A., and S. Elam. 1997. Kokanee abundance and distribution in Dworshak Reservoir and implications toward minimizing entrainment: Dworshak Dam impact assessment and fisheries investigation project. Idaho Department of Fish and Game, Project 87-99, Report number 97-17, Boise.

McCauley, E. 1984. The estimation of the abundance and biomass of zooplankton in samples. Pages 228-265 *in* J. A. Downing and F. H. Rigler, editors. A manual of methods for the assessment of secondary productivity in fresh waters. Blackwell Scientific Publications, Oxford, England.

R Core Team. 2022. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/.

Rieman, B. E. 1992. Kokanee salmon population dynamics-kokanee salmon monitoring guidelines. Idaho Department of Fish and Game, Job Performance Report, Project F-73-R-14, Subproject II, Study II, Boise.

Schindler, D. W., R. E. Hecky, D. L. Findlay, M. P. Stainton, B. R. Parker, M. J. Paterson, K. G. Beaty, M. Lyng, and S. E. M. Kasian. 2008. Eutrophication of lakes cannot be controlled by reducing nitrogen input: Results of a 37-year whole-ecosystem experiment. Proceedings of the National Academy of Sciences 105(32):11254–11258.

Scofield, B., and J. G. Stockner. 2010. Dworshak Reservoir nutrient enhancement project: 2009 progress report and data summary. Spokane, Washington.

Simmonds, J. E., and D. N. MacLennan. 2005. Fisheries acoustics: Theory and practice, 2nd edition. Blackwell Science, Oxford.

Stark, E. J., and J. G. Stockner. 2006. Dworshak kokanee population and reservoir productivity assessment, 2004 annual report. Idaho Department of Fish and Game Report 06-35. Boise.

Stockner, J. G., and D. Brandt. 2006. Dworshak Reservoir: Rationale for nutrient supplementation for fisheries enhancement. Eco-Logic Ltd. and TerraGraphics Environmental Engineering.

USFWS (U.S. Fish and Wildlife Service). 2015. USFWS Bull Trout (*Salvelinus confluentus*) Recovery Plan. United States Fish and Wildlife Service, Portland, Oregon.

Wickham, H., M. Averick, J. Bryan, W. Chang, L. D. McGowan, R. François, G. Grolemund, A. Hayes, L. Henry, J. Hester, M. Kuhn, T. L. Pedersen, E. Miller, S. M. Bache, K. Müller, J. Ooms, D. Robinson, D. P. Seidel, V. Spinu, K. Takahashi, D. Vaughan, C. Wilke, K. Woo, and H. Yutani. 2019. Welcome to the tidyverse. Journal of Open Source Software 4:1686.

Wilson, S. M., D. H. Brandt, M. P. Corsi, and A. M. Dux. 2018. Early trophic responses to nutrient addition in Dworshak Reservoir, Idaho. Lake and Reservoir Management 34(1):58–73.

Wilson, S. M., and M. P. Corsi. 2016. Dworshak Reservoir nutrient restoration research, 2007-2015. Dworshak Dam resident fish mitigation project. Idaho Department of Fish and Game, 16-22, Boise.

Wilson, S. M., and M. P. Corsi. 2019. Dworshak Dam resident fish mitigation progress report, 2017-2018. Dworshak Dam resident fish mitigation project. Idaho Department of Fish and Game, 19-15, Boise.

Wilson, S. M., M. P. Corsi, D. H. Brandt, and E. J. Stark. 2021. The response of *Daphnia* to nutrient additions and kokanee abundance in Dworshak Reservoir, Idaho. Canadian Journal of Fisheries and Aquatic Sciences 78(11):1677–1688.

Wilson, S. M., A. M. Dux, R. J. Downing, and B. Schofield. 2010. Dworshak Reservoir nutrient enhancement research, 2008. Dworshak Dam resident fish mitigation project. Idaho Department of Fish and Game, 10-05, Boise.

APPENDICES

Appendix A. Estimates of kokanee abundance (1000s of fish) 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 (1,000's of fish)				
		Age-0	Age-1	Age-2	Age-3	Total
2022	Hydroacoustic	2,398	1,408	1,366	9	5,181
2021	Hydroacoustic	4,862	3,990	897	37	9,785
2020	Hydroacoustic	5,747	1,493	525	20	7,786
2019	Hydroacoustic	1,390	1,029	254	1	2,674
2018	Hydroacoustic	1,017	553	58	33	1,660
2017	Hydroacoustic	1,369	280	179	50	1,877
2016	Hydroacoustic	1,341	421	392	314	2,468
2015	Hydroacoustic	1,609	700	1,733	3	4,044
2014	Hydroacoustic	1,594	2,506	92	4	4,196
2013	Hydroacoustic	3,975	553	143	0	4,670
2012	Hydroacoustic	819	341	85	6	1,251
2011	Hydroacoustic	494	361	231	1	1,087
2010	Hydroacoustic	2,331	1,177	1,030	1	4,540
2009	Hydroacoustic	1,022	1,109	119	0	2,250
2008	Hydroacoustic	1,359	233	71	22	1,686
2007	Hydroacoustic	532	148	456	5	1,141
2006	Hydroacoustic	1,997	1,550	1,082	0	4,630
2005	Hydroacoustic	2,340	697	180	0	3,216
2004	Hydroacoustic	449	273	47	27	796
2003	Hydroacoustic	410	269	342	0	1,021
2002	Hydroacoustic	1,247	1,101	128	0	2,476
2001	Hydroacoustic	1,962	781	405	0	3,150
2000	Hydroacoustic	1,895	304	199	0	2,398
1999	Hydroacoustic	1,144	363	38	0	1,545
1998	Hydroacoustic	537	73	39	0	649
1997	Trawling	65	0	0	0	65
1996	Hydroacoustic	231	43	29	0	303
1995	Hydroacoustic	1,630	1,300	595	0	3,539
1994	Hydroacoustic	156	984	304	9	1,457
1993	Trawling	453	556	148	6	1,163
1992	Trawling	1,040	254	98	0	1,043
1991	Trawling	132	208	19	6	365
1990	Trawling	978	161	11	3	1,153
1989	Trawling	148	148	175	0	471
1988	Trawling	553	501	144	12	1,210

Appendix B. Summary statistics for total length (TL), weight, and relative weight (Wr) for two age classes of kokanee captured during July trawl surveys on Dworshak Reservoir. Data are presented for four non-restoration years and eight years of N restoration (shaded), including summary statistics for both periods. Statistics include the mean and standard error (SE).

	Age-1 Kokanee								
	TL (mm)			Weight (g)			W_r		
Year	Mean	LCL	UCL	Mean	LCL	UCL	Mean	LCL	UCL
2003	204	199	208	71.3	65.8	76.6	81	79	83
2004	202	200	206	73.3	69.6	76.5	83	81	84
2006	145	141	148	23.9	21.8	25.7	76	74	77
2007	198	193	202	66.9	66.4	66.8	81	80	82
2008	209	204	213	82.0	75.9	88.7	86	83	88
2009	169	167	170	42.9	43.3	43.4	86	85	86
2010	172	171	172	45.2	45.3	44.8	87	86	87
2011	170	168	172	45.6	45.8	46.2	89	87	91
2012	206	201	211	88.8	89.4	82.0	95	94	97
2013	201	197	204	74.2	77.7	72.7	87	86	88
2014	145	144	146	25.9	26.1	25.9	82	81	83
2015	163	160	166	40.3	40.5	40.8	88	87	90
2016	203	201	206	79.9	80.1	80.1	88	87	89
2017	179	176	181	63.5	60.1	62.2	101	99	103
2018	187	184	190	68.0	67.7	70.3	100	98	103
2019	200	198	202	69.9	70.3	70.4	83	82	84
2020	187	186	189	60.1	61.9	60.6	88	87	89
2021	150	150	151	31.3	30.7	39.6	86	86	87
2022	163	161	165	38.4	37.1	39.6	84	83	85

	Age-2 Kokanee								
	TL (mm)			Weight (g)			W_r		
Year	Mean	LCL	UCL	Mean	LCL	UCL	Mean	LCL	UCL
2003	261	257	265	160.5	152.6	167.8	85	82	87
2004	296	291	301	232.4	220.1	245.8	85	84	87
2006	196	192	200	59.6	55.2	64.1	76	74	78
2007	241	238	243	125.2	95.2	102.2	86	85	87
2008	303	300	305	261.4	121.2	129.4	89	88	91
2009	272	267	276	178.1	252.3	270.2	85	83	86
2010	219	217	221	94.2	167.9	188.9	86	85	86
2011	220	218	222	98.1	92.0	97.7	89	87	90
2012	308	304	312	297.3	286.3	307.1	97	95	99
2013	296	291	301	242.4	231.0	254.5	89	86	92
2014	248	243	254	131.6	122.1	141.9	82	78	86
2015	202	201	204	80.4	78.5	82.3	93	93	94
2016	258	255	261	167.1	160.5	174.1	93	91	94
2017	255	251	259	178.0	169.7	185.6	102	100	105
2018	277	270	284	204.5	192.3	216.4	92	89	95
2019	287	284	289	211.7	206.7	216.8	86	85	87
2020	247	243	251	140.9	134.8	147.5	89	88	90
2021	226	224	229	98.2	95.4	101.1	81	80	82
2022	180	178	182	51.3	49.7	52.9	83	82	84

Appendix C. Annual growth, given as the change in total length (mm) from April of one year to the next for age-0 and age-1 kokanee. Growth of age-2 kokanee is from April to July of the same year. Growth was independently estimated from back-calculation using scales and as the differences in mean length of trawl caught fish at the beginning of each year. Mean growth is reported for each year that data is available, and means are reported for periods of nutrient restoration (Rest, shaded rows) or no nutrient additions (Non).

		Back-calculation			Trawl		
Year		**Age-0**	**Age-1**	**Age-2**	**Age-0**	**Age-1**	**Age-2**
2001	Non	101					
2002	Non	112	118				
2003	Non	96	136	40			
2004	Non	113		48			
2005	Non	98	71				
2006	Non	120	91	14	113		
2007	Rest	118	132	49	110	133	46
2008	Rest	109	135	46	107	138	57
2009	Rest	119	89	22	117	91	25
2010	Rest	113	82	28	105	83	21
2011	Non	113	130	17	114	128	20
2012	Rest	113	140	67	117	132	75
2013	Rest	101	111	39	107	118	50
2014	Rest	99	69	21	113	66	13
2015	Rest	105	103	29			29
2016	Rest			49			
	Means	109	108	36	111	111	37

Summary statistics for years with trawl data

	Back-calculation			Trawl		
	Age-0	**Age-1**	**Age-2**	**Age-0**	**Age-1**	**Age-2**
Non	118	130	16	113	128	20
Rest	111	108	38	111	109	39

Summary statistics for all years with back-calculation data

	Age-0	**Age-1**	**Age-2**
Non	108	109	29
Rest	110	107	39

Appendix D. 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 tons)			
Period	**Age 0-1**	**Age 1-2**	**Age 2-3**	**Total**
2021-22	119.1	53.4	7.2	179.6
2020-21	149.3	45.6	0.0	194.9
2019-20	85.6	55.4	0.0	141
2018-19	70.9	58.0	1.9	132.1
2017-18	64.5	23.8	6.5	95.3
2016-17	50.9	29.4	9.9	91.8
2015-16	80.5	69.2	112.9	263.7
2014-15	45.7	115.4	1.3	163.5
2013-14	81.5	18.5		100.7
2012-13	50.3	37.1		91.3
2011-12	36.9	56.2	26.4	120.5
2010-11	60.6	37.3	14.9	112.9
2009-10	48.9	54.9		105.5
2008-09	52.1	16.9		69.9
2007-08	31.1	21.3	32.7	86.3
2006-07	71.2	101.6	54.6	227.7
2005-06				NA
2004-05				NA
2003-04	24.7	25.5	20.7	54.1

	Biomass (metric tons)				
Year	**Age-0**	**Age-1**	**Age-2**	**Age-3**	**Total**
2022	1.2	54.0	70.0	1.0	126.2
2021	1.9	125.0	88.1	5.0	220.1
2020	3.8	89.7	74.1	3.9	171.5
2019	1.0	71.9	53.8	0.2	126.9
2018	0.5	37.6	11.8	7.9	57.8
2017	1.2	17.8	31.8	10.6	61.3
2016	0.9	33.6	65.5	59.9	160.0
2015	0.9	28.2	139.3	0.5	168.9
2014	0.7	64.9	12.1	0.6	78.3
2013	3.0	41.0	34.6	0.0	78.7
2012	0.7	30.3	25.3	2.0	58.3
2011	0.2	16.5	22.6	0.1	39.4
2010	1.4	53.2	97.1	0.3	152.0
2009	0.7	47.6	21.1	0.0	69.5
2008	0.9	19.1	18.6	5.8	44.3
2007	0.3	9.9	57.1	0.8	68.1
2006	1.0	37.1	64.5	0.0	102.5
2005					NA
2004	0.3	20.0	11.0	7.4	38.7
2003	0.3	19.2	54.9	0.0	74.3

Appendix E. 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)
2022	39,545	29,520	7,550	2,950	79,295	
2021			No Survey			
2020	13,443	7,922	2,297	3,557	27,219	270
2019	12,177	6,982	1,413	1,014	21,586	
2018	3,332	978	318	395	5,023	275
2017	12,331	3,915	853	1,035	18,134	289
2016	17,546	7,310	2,735	242	27,833	275
2015	19,091	9,204	3,121	1,827	33,243	225
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

Appendix F. Results of creel surveys conducted on Dworshak Reservoir, including angling effort (hours), catch (number of fish), catch rate (fish/hour), harvest (number of fish), and harvest rate (fish/hour). Survey designs included access-access (A-A), Malvesto (Mal), and Idaho Department of Fish and Game (IDFG) computer software.

				All Fish					Kokanee			
Year	Period	Method	Type	Effort	Catch	Catch Rate	Harvest	Harvest Rate	Effort	Catch Rate	Harvest	Harvest Rate
1980	Jun-Sep	A-A	All	104,014			71,541	0.7			44,627	0.43
1988	Jan-Dec	Mal	Kokanee Only	140,416							206,976	1.47
1989	Jan-Dec	Mal	Kokanee Only	128,703							161,175	1.25
1990	Jan-Dec	Mal	All	149,592							94,757	0.63
1995	May-Aug	IDFG	All	95,728	167,830	1.75	158,345	1.7			154,309	1.61
2003	Apr-Sep	R-A	All	188,305	214,631	1.14	167,995	0.9			161,501	0.86
2004	Apr-Aug	R-A	All	273,531	248,069	0.91	206,308	0.8			190,185	0.7
2014	Apr-Jul	A-A	All	82,852	108,899	1.31	84,230	1.0	81,692	0.99	79,746	0.96
2014	Apr-Jul	A-A	Kokanee Only	56,134	80,846	1.43	78,184	1.4	79,763	1.42	77,891	1.39
2015	Mar-Oct	A-A	All	136,033	352,574	2.59	88,485	0.7	54,391	0.4	51,887	0.38
2015	Mar-Oct	A-A	Kokanee Only	41,580	59,172	1.42	52,306	1.3	50,672	1.22	49,765	1.2
2016	Apr-Aug	A-A	All	156,553	267,647	1.71	150,341	1.0	133,828	0.85	133,188	0.85
2016	Apr-Aug	A-A	Kokanee Only	81,216	139,972	1.72	134,690	1.7	133,000	1.63	132,000	1.62
2017	Mar-Jul	A-A	All	110,000	142,000	1.3	81,000	0.7	78,000	0.7	75,000	0.7
2017	Mar-Jul	A-A	Kokanee Only	57,000	80,000	1.3	75,000	1.3	77,000	1.3	74,000	1.3
2018	Apr-Sep	A-A	All	95,969	110,421	1.2	44,574	0.6	54,755	0.6	52,266	0.5
2018	Apr-Sep	A-A	Kokanee Only	37,421	44,036	1.2	40,996	1.1	42,530	1.1	41,130	1.1

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