B O N N E V I L L E   P O W E R   A D M I N I S T R A T I O N

Snake River Sockeye Salmon Habitat and Limnological Research

Annual Report 2005 | July 2006 | DOE/BP-00026989-1

This Document should be cited as follows:

Taki, Doug, Andre Kohler, Robert Griswold, Kim Gilliland, "Snake River Sockeye Salmon Habitat and Limnological Research", 2005 Annual Report, Project No. 199107100, 97 electronic pages, (BPA Report DOE/BP-00026989-1)

Bonneville Power Administration
P.O. Box 3621
Portland, OR 97208

This report was funded by the Bonneville Power Administration (BPA), U.S. Department of Energy, as part of BPA's program to protect, mitigate, and enhance fish and wildlife affected by the development and operation of hydroelectric facilities on the Columbia River and its tributaries. The views in this report are the author's and do not necessarily represent the views of BPA.

SNAKE RIVER SOCKEYE SALMON HABITAT

AND LIMNOLOGICAL RESEARCH: 2005 ANNUAL PROGRESS REPORT

Prepared by:

Doug Taki
Andre E. Kohler
Robert G. Griswold[1]
Kim Gilliland

Shoshone-Bannock Tribes
P.O. Box 306
Fort Hall, Idaho 83203

[1] Biolines
HC-64 Box 9965
Stanley, Idaho 83278

Prepared for:

U.S. Department of Energy
Bonneville Power Administration
Environment, Fish, and Wildlife
P.O. Box 3621
Portland, Oregon 97208-3621

Project Number 91-71

14 July 2006

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

In March 1990, the Shoshone-Bannock Tribes petitioned the National Marine Fisheries Service (NMFS) to list Snake River sockeye salmon (*Oncorhynchus nerka*) as endangered. Snake River sockeye salmon were officially listed as endangered in November 1991 under the Endangered Species Act (56 FR 58619). In 1991, the Snake River Sockeye Salmon Habitat and Limnological Research Project was implemented. This project is part of an interagency effort to prevent the extinction of the Redfish Lake stock of Snake River sockeye salmon. The Shoshone-Bannock Tribal goal for this project is two tiered: The immediate goal is to increase the population of Snake River sockeye salmon while preserving the unique genetic characteristics of the Evolutionarily Significant Unit (ESU). The Tribes long term goal is to maintain a viable population that warrants delisting and provides Tribal harvest opportunities.

The Bonneville Power Administration (BPA) provides funding for this interagency recovery. Collaborators in the recovery effort include the National Oceanic and Atmospheric Administration (NOAA), the Idaho Department of Fish and Game (IDFG), the University of Idaho (UI), and the Shoshone-Bannock Tribes (SBT). This report summarizes activities conducted by Shoshone-Bannock Tribal Fisheries Department personnel during the 2005 calendar year.

Project tasks include: 1) monitor limnological parameters of the Sawtooth Valley lakes to assess lake productivity; 2) conduct lake fertilization in Pettit and Alturas lakes; 3) reduce the number of mature kokanee spawning in Fishhook and Alturas Lake creeks; 4) monitor and enumerate sockeye salmon smolt migration from Pettit and Alturas lakes; 5) monitor spawning kokanee escapement and estimate fry recruitment in Fishhook, Alturas Lake, and Stanley Lake creeks; 6) conduct sockeye and kokanee salmon population surveys; 7) evaluate potential competition and predation between stocked juvenile

sockeye salmon and a variety of fish species in Redfish, Pettit, and Alturas lakes; and 8) assist IDFG with captive broodstock production activities.

Task 1. Limnological parameters including temperature, dissolved oxygen, conductivity, secchi depth, light compensation depth, water chemistry, chlorophyll *a*, primary productivity, heterotrophic bacteria, autotrophic picoplankton, phytoplankton, and zooplankton assemblage characteristics (species composition and densities) were sampled once per month at each lake during February-March and May-October and twice per month in Redfish and Pettit lakes during summer (June-August) with the following exception: Stanley Lake was not sampled in February.

Task 2. Seven hundred and seventy kg of nitrogen and 28.5 kg of phosphorus were introduced to Pettit Lake. Two thousand three hundred and forty-eight kg of nitrogen and 116.4 kg of phosphorus were introduced to Alturas Lake.

Task 3. A weir was installed to control the number of kokanee salmon spawning in Fishhook Creek. An escapement goal of 1,200 spawning females was set to reduce kokanee salmon recruitment to Redfish Lake. Additionally, a fyke net weir with wings was installed in Alturas Lake Creek to control numbers of spawning kokanee salmon. Both weirs failed to adequately control numbers of kokanee salmon spawners.

Task 4. The number of sockeye salmon that migrated from Pettit Lake was enumerated using catches at the Pettit Lake Creek weir. We evaluated a direct lake fall release of Sawtooth Hatchery parr. Percent migration was 55.5% for this release group. We also estimated 7,518 fish migrated from egg boxes stocked in 2003.

Stocked juvenile sockeye salmon migration from Alturas Lake was estimated using catches at the Alturas Lake Creek screw trap. We estimated 81.6% of the sockeye parr reared at Satooth Fish Hatchery that were released in 2004 migrated in 2005. Migration for Redfish Lake sockeye salmon was monitored by IDFG. Survival estimates presented above for Alturas Lake Creek were based on maximum likelihood population estimates.

Task 5. Stream spawner counts were used to monitor adult kokanee escapement to inlet streams on Redfish, Alturas, and Stanley lakes in 2005. Fishhook Creek, the primary kokanee spawning tributary on Redfish Lake, had an estimated spawning escapement of 4,375 adult spawners, Alturas Lake Creek had an estimated 11,652 adult spawners, and Stanley Lake Creek had an estimated 2,725 kokanee spawners. Fry recruitment, calculated from male-female ratios, fecundity, and egg to fry survival rates is estimated at 65,651, 231,758, and 23,081 fry for Fishhook, Alturas Lake, and Stanley Lake creeks, respectively.

Task 6. Three forms of *O.nerka* inhabit Redfish Lake: 1) a resident, stream spawning kokanee salmon population; 2) listed anadromous sockeye salmon; and 3) listed residual sockeye salmon. The residual component spawns in October in littoral areas similar to the anadromous form. Monitoring of spawning residual and anadromous sockeye salmon populations in Redfish Lake has occurred since 1993. Trends in these populations are evaluated with monitoring data collected by weekly snorkel surveys. In 2005, 58 residual sockeye salmon and 25 sockeye salmon adults were observed during snorkel surveys at the SE Inlet and Sockeye Beach spawning areas in Redfish Lake. During the final boat survey on 8 November we estimated a total of 78 redds. During a survey conducted on 10 October we observed 49 residual sockeye salmon redds and 66 clean circular depressions of unknown origin.

Task 7. Potential competition and predation between stocked sockeye salmon, unmarked *O. nerka* (egg box production sockeye salmon or kokanee salmon), rainbow trout *O. mykiss*, and other fish species was investigated. Diet overlap in Pettit Lake was 0.0% for rainbow trout and *O. nerka* and 0.0% for rainbow trout and sockeye salmon. Age 0 sockeye salmon, the life stage of primary interest, fed almost exclusively on zooplankton while rainbow trout diets were dominated by aquatic insects. Resident kokanee salmon, the primary competitor with lake rearing juvenile sockeye salmon, fed almost entirely on zooplankton prey species. In an analysis of rainbow trout diets there were no *O. nerka* found in the stomach contents of any of the fish sampled; however, several potential kokanee salmon/sockeye salmon predators were identified in the lakes including: bull char *Salvelinus confluentus*; northern pikeminnow *Ptychocheilus oregonensis*; and brook char *S. fontinalis*. Piscivory was evident with *O. nerka* found in the diet of bull char and northern pikeminnow.

Task 8. SBT personnel assisted the IDFG in planting and retrieving egg boxes from Pettit Lake, and retrieving egg boxes from Alturas Lake.

Through the spawning matrix design used in the captive broodstock program, we have sustained the genetic integrity of the stock (Willard et al. 2003). However, to reach our long term goal of a viable population, the adverse effects caused by out of basin activities need to be remedied. For example, adult returns to the Sawtooth Valley in 2000 of two hundred and fifty-seven adults were the largest recorded in several decades. Unfortunately, the smolt-to-adult ratio (SAR) for those fish was only 0.22%. If that ratio increased to between two and four percent, our adult return in 2000 would have been 2,886 to 5,772 returning adults. Adult escapement of that magnitude would move the recovery program toward achieving our long term goal.

INTRODUCTION

Snake River salmon are a valuable cultural resource to the Shoshone-Bannock Tribes. The Shoshone-Bannock Tribes (SBT) traditionally utilized salmon of the Snake River Basin as a subsistence food resource. The Redfish Lake sockeye salmon (*Oncorhynchus nerka*) evolutionarily significant unit (ESU) is the only extant Snake River sockeye salmon stock. The spawning and freshwater rearing habitat of this stock is located in the Sawtooth Valley, Idaho-- a traditional SBT fishing and hunting area. In March 1990, the SBT petitioned the National Marine Fisheries Service (NMFS) to list the Snake River sockeye salmon as endangered. Snake River sockeye salmon was officially listed as endangered in November 1991 under the Endangered Species Act (56 FR 58619). The SBT have been actively involved in the sockeye salmon recovery project since its inception.

The Bonneville Power Administration (BPA) provides funding for this interagency recovery program through their Integrated Fish and Wildlife Program. Collaborators in the recovery program include the National Oceanic and Atmospheric Administration Fisheries (NOAA), Idaho Department of Fish and Game (IDFG), the University of Idaho (UI), and the SBT: the NOAA manages the permitting of activities and the captive rearing program hatchery operations in Manchester, WA; the IDFG monitors a variety of fisheries parameters in the field and is responsible for the captive rearing program with hatchery operations in Eagle and Stanley, ID; the UI analyzes genetic samples and participates in designing breeding matrices; and the SBT monitor a variety of fisheries biology parameters and evaluate of spawning and rearing habitat in nursery lakes.

In 1991, only four adult sockeye salmon returned to Redfish Lake. These four fish and emigrating juveniles captured over the next two years formed the initial captive brood stock. The captive broodstock was supplemented with returning adult sockeye salmon, residuals, and emigrating juveniles in subsequent years. Historically, thousands of sockeye salmon returned to the Sawtooth Valley lakes. Everman (1896) reported that the lakes were 'teeming with redfish.' In 1910, anadromous fish migration was blocked when the Sunbeam Dam was built on the mainstem of the Salmon River approximately 20 miles downstream from the Sawtooth Valley. In 1934, the dam was breached and upstream anadromous fish populations rebounded. Bjornn (1968) estimated that 4,360 sockeye salmon returned to Redfish Lake in 1955. There has been a steady decline in adult sockeye salmon returns since that time until, in the late 1980's, only a small number of fish were returning to Redfish Lake. A total of 23 adult sockeye salmon returned to the Sawtooth Valley during the 1990's. The recovery program has focused its efforts on restoring anadromous *O. nerka* to Redfish, Pettit, and Alturas lakes, designated as critical spawning and rearing habitat under the ESA listing (56 FR 58619).

A variety of activities have been conducted in the effort to conserve and rebuild the Redfish Lake sockeye salmon stock: the captive brood stock has served to preserve this unique genome; fish barriers on Pettit and Alturas lake creeks have been removed to facilitate fish passage; fish from the captive brood stock have been reintroduced into the wild; using a variety of stocking strategies, including adult release for volitional spawning, in-lake egg incubators, net pen rearing with parr release, parr releases (spring, summer, fall), and smolt releases; lake fertilization has been implemented in order to increase lake-carrying capacities; kokanee (non-anadromous form of *O. nerka*) control measures have been implemented in Redfish Lake to reduce intraspecific competition; and a variety of fishery and limnological parameters have been monitored in association with these strategies.

The Stanley Basin Technical Oversight Committee (SBTOC) provided input regarding all activities conducted by the SBT in association with the sockeye salmon recovery project. The SBTOC is composed of representatives from all participating agencies (BPA, NOAA, IDFG, UI, and SBT). The SBTOC was formed in 1991 to guide new research, coordinate ongoing research, and actively participate in all technical elements of the Snake River sockeye salmon recovery effort. Scientists with expertise in related fields are often invited to SBTOC meetings to present their research and discuss activities conducted by SBTOC agencies. The project as a whole or in part is subject to further review by the Idaho Department of Environmental Quality (IDEQ), and the Northwest Power and Conservation Council (NWPCC) Independent Scientific Review Panel (ISRP).

STUDY AREA

Four lakes: Redfish; Pettit; Alturas; and Stanley, in the Sawtooth Valley, Idaho are currently the focus of on going SBT habitat and limnological studies. The lakes were glacially formed, range in elevation from 1,985 m to 2,157 m, and are located in central Idaho (Figure 1). Specific features of the sockeye salmon rearing lakes are shown in Table 1.

All of the Stanley Basin lakes are oligotrophic: mean summer total phosphorus (TP) concentrations in the epilimnion range from 3.1 to 11.6 *u*g/L; surface chlorophyll *a* concentrations range from 0.3 to 2.0 *u*g/L; and mean summer secchi disk transparencies range from 9.8 to 17.8 m, excluding Stanley Lake which ranges from 5.0 to 10 m.

Table 1. Morphological features of the Sawtooth Valley lakes.

Lake	Area (km^2)	Volume (m^3x10^6)	Mean Depth (m)	Drainage Area (km^2)
Redfish	6.15	269.9	44	108.1
Alturas	3.38	108.2	32	75.7
Pettit	1.62	45.0	28	27.4
Stanley	0.81	10.4	13	39.4

Redfish Lake is approximately 1,451 km from the mouth of the Columbia River. There are 616 km of free flowing river from Redfish Lake to the mouth of the Salmon River (Figure 1) and an additional 835 km impacted by eight dams on the Snake and Columbia rivers.

Native fish species found in the nursery lake system include: sockeye/kokanee salmon *Oncorhynchus nerka*; steelhead/rainbow trout *O. mykiss*; chinook salmon *O. tshawytscha*;

cutthroat trout *O. clarki lewisi*; bull char *Salvelinus confluentus*; mountain whitefish *Prosopium Williamson*; sucker *Catastomus* spp.; redside shiner *Richardsonius balteatus*; dace *Rhinichthys* spp.; northern pikeminnow *Ptychocheilus oregonensis*; and sculpin *Cottus* spp.. Nonnative species include brook char *S. fontinalis* and lake trout *S. namaycush*. The only pelagic species besides *O. nerka* are redside shiners. The two species are not sympatric because of differing vertical distributions. Hatchery rainbow trout are stocked by IDFG throughout the summer in all lakes except for Redfish Lake. Sport fishing for salmonid fishes is open on all lakes as well as inlet and outlet streams.

The Sawtooth Valley lakes have several different forms of *O. nerka*, the primary pelagic zooplanktivore in the system. There are three distinct life histories in Redfish Lake: anadromous sockeye salmon; residual sockeye salmon; and kokanee salmon. Kokanee salmon, a non-anadromous form of *O. nerka*, spends its entire life cycle in fresh water lakes. Kokanee salmon generally spawn at three to five years of age in the inlet creeks of the Sawtooth Valley lakes during late summer and die afterwards. The Redfish Lake kokanee salmon population is admixed, consisting of several out-of-basin stocks, and is genetically dissimilar to the anadromous form. This kokanee salmon population is temporally and spatially separated during spawning from the listed Snake River sockeye salmon. Alturas Lake kokanee salmon are closely related to listed Snake River sockeye salmon based on haplotype analysis (M.S. Powell, U of I, personal communication). Pettit and Stanley lakes were treated with rotenone (1950's and 60's) and kokanee salmon were reintroduced from out-of-basin stocks. Genetic data indicates that these fish are not indigenous *O. nerka*. No Sawtooth Valley kokanee salmon are listed as endangered.

The anadromous form of *O. nerka* spends one or two years in fresh water, emigrating during spring as one or two year old smolts. Anadromous forms then spend the majority of their life in the Pacific Ocean, generally returning at four years of age to the Sawtooth Valley lakes. Similar to many species of salmon, some anadromous *O. nerka* return as three year olds, which are referred to as jacks or jills, depending on sex. The anadromous and residual forms have been designated as an ESU.

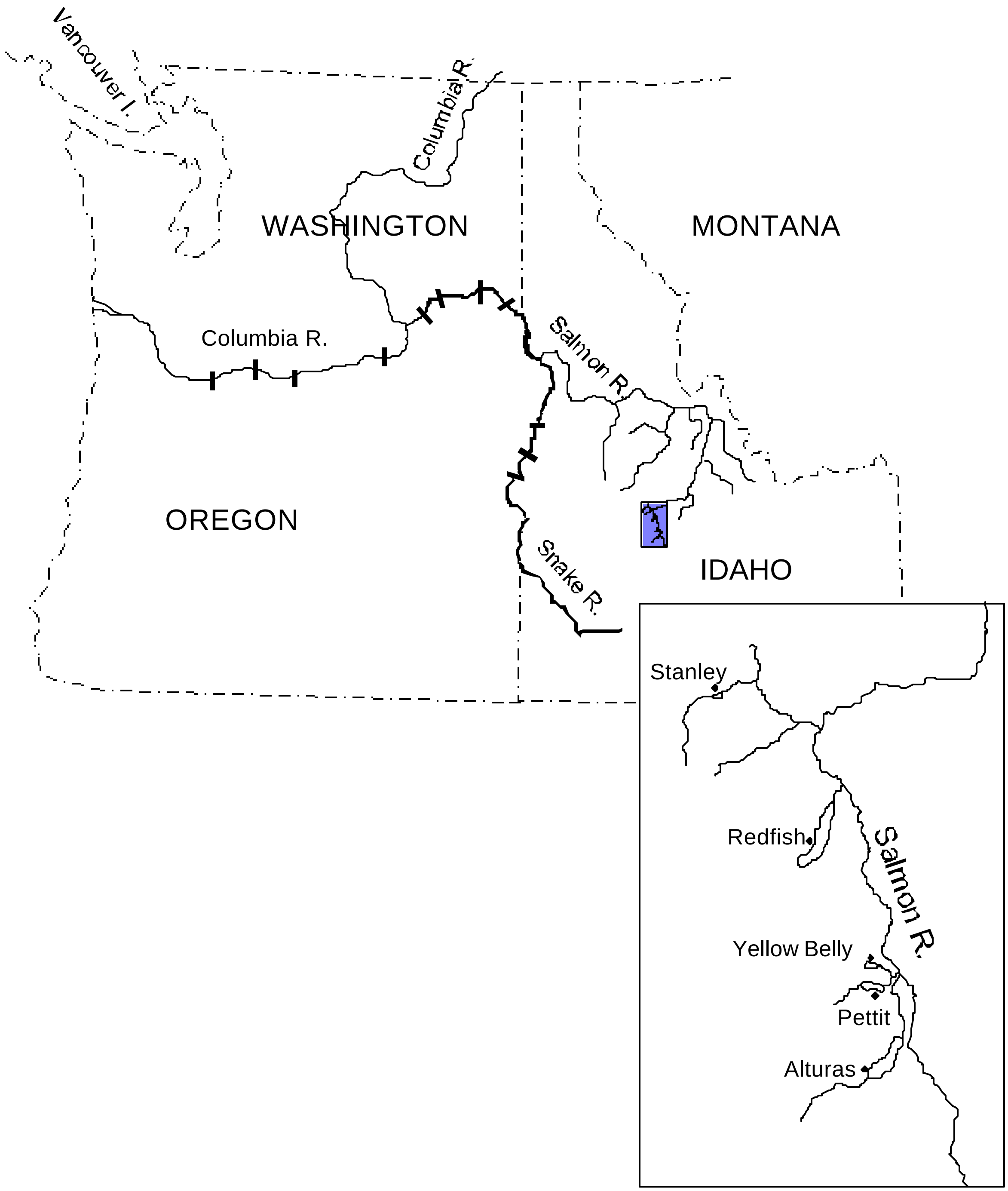


Figure 1. Map of study area.

MATERIALS AND METHODS

Limnology

Limnological monitoring was conducted once per month at each lake during February-March and May-October and twice per month in Redfish, Pettit and Alturas lakes during summer (June-August) with the following exception: Stanley Lake was not sampled in February. Redfish, Pettit, and Alturas lakes were stocked with juvenile sockeye salmon from the Redfish Lake captive broodstock in 2005. Stanley Lake was not stocked with sockeye salmon. Water temperature (^oC), dissolved oxygen (mg/L), conductivity (µS/cm), Secchi depth (m), compensation depth (m), nutrient concentrations (µg/L), chlorophyll *a* concentrations (µg/L), heterotrophic bacteria and autotrophic picoplankton (APP) densities (cells/mL), phytoplankton density (cells/mL) and biovolume (mm^3/L), and zooplankton density (no./L) and biomass (µg/L and mg/m^2) were sampled near the middle of each lake. Additional zooplankton samples were collected from two other stations in each lake. Nutrients were sampled during May 2005 in Alturas and Stanley lakes and once per month from May-October in Redfish and Pettit lakes.

During stratification, water for nutrient analysis was collected from the epilimnion, metalimnion, and hypolimnion. Heterotrophic bacteria, APP, and phytoplankton samples were collected from the epilimnion and compensation depth. Three discrete samples were collected from each stratum with a 3 L Van Dorn bottle and mixed in a churn splitter. When lake strata could not be delineated, surface water was collected from 0-6 m with a 25 mm diameter, 6 m long lexan® tube.

Temperature (^oC), dissolved oxygen (mg/L), and conductivity (µS/cm) profiles were collected at the main station of each lake using a Hydrolab® Surveyor3™ equipped with a Hydrolab H20® submersible data transmitter. The instrument was calibrated each day prior to sampling using barometric pressure and conductivity standards. Temperature, dissolved oxygen, and conductivity were recorded at 1 m intervals from the surface to 10 m, 1-2 m intervals from 10 m to the thermocline, then at 2-10 m intervals to the bottom.

Mean water temperatures from 0-10 m were used to calculate seasonal mean (June-October) surface water temperatures. Secchi depth was measured with a 20 cm Secchi disk and a viewing tube, and light attenuation was measured with a Li-Cor® Li-1000 data logger equipped with a Li-190SA quantum sensor deck cell and a LI-193SA spherical sea cell. Photosynthetically active radiation (400-700 nm) was measured at 2 m intervals from surface to 2-4 m below the compensation depth (1% light level). Compensation depth was identified using the technique of Wetzel and Likens 1991.

Water collected for nutrient analysis was transferred to nalgene bottles rinsed in hydrochloric acid (0.1 N) and then rinsed in sample water and stored on ice while in the field. Water was filtered through 0.45 µm acetate filters at 130 mm Hg for ammonium (NH_4), nitrate-nitrite (NO_3+NO_2), and total dissolved phosphorus (TDP) assays. Both filtered and unfiltered water samples were then frozen and shipped to the High Sierra Water Lab for analysis. NH_4 was assayed with the indophenol method, NO_3+NO_2 with the hydrazine method, organic nitrogen (TKN) using kjeldahl nitrogen, and total phosphorus (TP) and total dissolved phosphorus (TDP) samples were assayed by persulfate digestion (APHA 1995). Total nitrogen (TN) concentrations were estimated by adding TKN and NO_3+NO_2.

Water for chlorophyll *a* analysis was stored on ice in the field and then filtered onto 0.45 µm cellulose acetate membrane filters with 130 mm Hg vacuum pressure. Filters were frozen and then placed in methanol for 12-24 hrs to extract the chlorophyll pigments. Chlorophyll *a* concentrations were measured with a Turner model 10-AU fluorometer calibrated during the spring with commercial chlorophyll standards. Samples were run before and after acidification to correct for phaeophytin (Holm-Hansen and Riemann 1978.

Heterotrophic bacteria and APP samples collected from the epilimnion and compensation depths were fixed in gluteraldehyde and shipped to Eco-Logic Inc. for identification and enumeration. Picoplankton were stained with DAPI fluorochrome stain and were enumerated using a Carl Zeiss Standard Epi-florescence© microscope with mercury lamp following the protocol of MacIsaac and Stockner (1993). Phytoplankton samples were fixed in Lugol's solution and total cell abundance and biovolume determined at 1560x magnification using a Zeiss Inverted Plankton microscope following the protocol of Utermohl (1958).

Zooplankton was sampled with a 0.35 m diameter, 1.58 m long, 80 µm mesh, conical net with a removable bucket. Vertical hauls were made using a release mechanism that allowed sampling at discrete depth intervals. A General Oceanics flow meter was mounted in the mouth of the net to quantify the volume of water filtered. The net was retrieved by hand at a rate of approximately 1 m/sec. In Redfish, Pettit, and Alturas lakes hauls were made from 10-0 m, 30-10 m, and bottom (~ 60 m) to 30 m; at the main station in Redfish Lake an additional haul was made from approximately 85 m to 60 m. Stanley Lake was sampled at 10-0 m and bottom (~26 m) to 10 m. Samples were preserved in 10% buffered sugar formalin. Techniques used to subsample, count, and measure zooplankton were adopted from Utah State University (Steinhart et al. 1994) using techniques and length-weight relationships developed by McCauley (1984) and Koenings et al. (1987).

Fertilization

In 2005, the SBT, operating under a consent order issued by the IDEQ, added supplemental nutrients (liquid ammonium phosphate (20-5-0) and ammonium nitrate (28-0-0-0)) to Pettit and Alturas lakes. Nutrients were applied at a ratio of approximately 20:1 N:P by mass to avoid stimulation of nitrogen fixing Cyanophytes. A consent order was issued by DEQ that required measurement of water transparency once per week, estimates of epilimnetic and metalimnetic chlorophyll *a* every two weeks, and measurement of nutrient concentrations once per month. The consent order stipulates that nutrient enhancement activities may continue as long as water transparencies exceed 6 m in Pettit Lake (4 m prior to 15 July) and 6 m in Alturas lake, chlorophyll *a* concentrations remain below 3 µg/L in the epilimnion and 6 µg/L in the metalimnion, and total phosphorus concentrations remain below 15 µg/L in the epi- and metalimnions. Nutrient applications were made from a 6.7 m boat equipped with a portable plastic tank and electric pump. Fertilizer was loaded into tanks off-site and sprayed into the boat's wake while traveling over the surface of the lake. Predetermined transect lines were followed using GPS, compass, and local landmarks to evenly disperse the nutrients over the surface of the lake.

Limiting Kokanee Salmon Escapement

A picket weir comprised of vertical aluminum tubes spaced 3/8" apart and held in place with metal frames was constructed in Fishhook Creek. The weir was operated from 09 August through 8 September 2005. The weir was checked once or twice daily, and all kokanee salmon were enumerated and passed. The goal was to limit the number of females passing upstream to spawn at 1,200. The picket weir failed to control kokanee salmon escapement. A fyke net weir with wings was installed in Alturas Lake Creek from 10 August to 1 September 2005. The fyke net weir failed to control kokanee salmon escapement.

Smolt Monitoring

Pettit Lake

A weir was operated at the outlet of Pettit Lake, Idaho (Section 31, Township 8 North, Range 14 East) from 20 April through 31 May 2005. The weir was used to evaluate migration of Snake River sockeye salmon smolts. We checked the trap for fish and cleaned the weir at sunrise and sunset. The weir was visited more frequently when high levels of debris were present. The weir ran continuously at 100% capture efficiency, except on 17 May when discharge overwhelmed weir operations. Discharge ranged from 0.11 m^3/s to 2.90 m^3/s.

Immediately after removal from the trap, all sockeye salmon were scanned for passive integrated transponder (PIT) tags. One thousand and thirteen fish planted in October 2004 were tagged before release. All of the fish containing tags were placed in a live box and eight to ten at a time were anesthetized for measuring and weighing using a stock solution of 15 grams of MS222 and 30 grams of sodium bicarbonate per liter of water. All anesthetized fish were weighed to the nearest 0.1 grams and fork length was measured to the nearest millimeter. Fish were held in a live well for 1 to 10 hours after handling and then released. Approximately 50 fish were PIT tagged each day to evaluate downstream survival and SAR's. A condition factor (Fulton's K value, (weight x 10^5/length^3)) for each fish was calculated; mean, minimum, and maximum K values are presented in results. All other fish were counted and immediately released below the weir.

Alturas Lake

A screw trap was operated in Alturas Lake Creek 8 miles downstream from Alturas Lake, Idaho (Section 32, Township 8 North, Range 14 East) from 19 April through 26 May 2005. *Oncorynchus nerka* smolts were captured to determine the number of migrants and to allow tagging of Snake River sockeye salmon smolts using PIT tags. Shoshone-Bannock Tribal fisheries personnel checked for fish and cleaned the screw trap at sunrise and sunset. For one week during peak run-off we checked and cleaned the trap at approximately 6 hour intervals during the night to prevent debris accumulation.

All fish captured were handled similar to methods used at the Pettit Lake Creek weir. Discharge ranged from 0.84 m^3/s to 17.07 m^3/s. Trap efficiency estimates were made separately for hatchery and wild fish.

Growth Rates

Specific growth rates are used to express growth relative to an interval of time and are commonly expressed as a percentage. We calculated instantaneous growth rates using the following formula:

$$Growth\ rate\ (G) = (\log_e Y_2 - \log_e Y_1)/(t_2 - t_1)$$

Y_1= fish size *(length and weight)* at the beginning of a time interval

Y_2= fish size at the end of a time interval

t_1= time at the beginning of an interval

t_2= time at the end of an interval

We then multiplied the resulting values by 100 to report a specific growth rate (percent weight/length gain per day). Data used in growth rate analyses came from individual pit tagged fish released into Redfish, Pettit, and Alturas lakes as presmolts and recaptured the following spring as smolts; therefore, lake specific growth rates represent a mean from samples of individual fish with length and weight data (Y_1 and Y_2) at t_1 and t_2. When the sample size of individually pit tagged fish at t_1 and t_2 was considered too small, group means were used to calculate growth rates.

Stream Spawning

Stream surveys were conducted to estimate kokanee salmon escapement in tributaries to Redfish, Alturas, and Stanley lakes. Pettit Lake has no stream spawning kokanee salmon population. Fish were counted from the bank by one or two observers equipped with polarized sunglasses. On days when counts were missed, the number of fish in the stream was interpolated by dividing the difference between the actual counts by the number of days between the counts. Spawning surveys began 06 August, with the final count occurring on 18 October. Total escapement estimates were calculated by summing daily counts of kokanee salmon and dividing by average stream life as described by English et al. (1992).

Beach Spawning

Sockeye Beach, located near the Redfish Lake boat ramp, and a small section of the southeast corner of Redfish Lake are spawning grounds for residual sockeye salmon and adult sockeye salmon. Night snorkel surveys were conducted at both locations to estimate numbers of spawning residual sockeye salmon, anadromous sockeye salmon, and hatchery sockeye salmon. Snorkel surveys in Redfish Lake were conducted weekly from 5 to 25 October 2005. At least three observers, equipped with waterproof flashlights, snorkeled parallel to shore 10 m apart, at depths ranging from 0.5 to 5 m. At Sockeye Beach, estimates of residual sockeye salmon spawner abundance were conducted within the boundary (600 m) of Sockeye Beach as delineated by USFS signs. Spawning ground surveys in the south end of the lake were conducted in the 200 m shoal area near the two small southeast inlet streams.

Hydroacoustic Population Estimates

Data Acquisition

Echo sounding data were collected with a Hydroacoustic Technology, Inc. Model 240 split-beam system. Split-beam echosounders have been shown to have less variability for target strength estimates than dual-beam systems (Traynor and Ehrenberg, 1990), and the target tracking capabilities of the split-beam system further reduce variability of individual targets (Ehrenberg and Torkelson, 1996). We used a 15 degree transducer, and the echo-sounder criteria were set to a pulse width of 0.4 milliseconds, a time varied gain of 40 log(R) + 2 r, and five pings per second for Redfish Lake, and six pings per second for Pettit and Alturas lakes. A minimum of six pings per target was necessary to qualify as a fish target.

Established transects were followed using a global positioning system (GPS). Waypoints were established in 1994 and set to allow for sampling transects to run zigzag across all lakes except Pettit Lake, where five parallel and one diagonal transects were used (Teuscher and Taki 1996). Fourteen and three transects were sampled at Redfish and

Alturas lakes, respectively. Cold weather caused the equipment to malfunction at Alturas Lake where we usually survey twelve transects.

Surveys were conducted during two moonless nights during the first week of October. We began at approximately 1½ hours after sunset. We tried to maintain a boat speed of 1.5 m/s during data collection.

Data Analysis

Target strengths and fish densities were processed using a Model 340 Digital Echo Processor and plotted with a Model 402 Digital Chart Recorder. Target strengths were used to estimate fish length by the equation

$$TS = 19.1\ Log(L) - 0.9\ Log(F) - 62.0 \qquad (1\text{-}1)$$

developed by Love (1977) where TS = target strength in decibels, L = fork length in centimeters, and F = frequency of transmitted sound (kHz). Using Echoscape (v 2.11) software developed by Hydroacoustic Technology, Inc., an MS Access file was created for each transect surveyed. This software allows inspection of every target and false echoes can be removed. After completing all transects for a given lake, we then made a master file using Excel to compile all transects. Next we created a new MS Access database using data from the Excel file. In this database we entered transect length and size bins to represent each cohort. We used a histogram created by IDFG from trawl samples to create size bins for length classes. Four different size classes were used for all three lakes. After entering all the parameters, we queried for fish density by size class and transect. Total *O. nerka* abundance was also estimated.

Individual fish detections were weighted by the ratio of the designated area width to the diameter of the acoustic beam at the range of the detected targets. An effective beam width was calculated for each tracked target for the fish-weighting algorithm.
The effective beam width equation

$$X[ABS\ (M^{rs} - F^{rs})]^{Y} \quad (1\text{-}2)$$

was used where: X = 8.6; ABS = absolute value of the target strength remainder; M^{rs} = minimum system detection (-60); F^{rs} = mean target strength; and Y = 0.47 (P. Nealson, HTI, personal communication).

Fish densities were computed by using adjacent transects as replicates within a stratum (lake). Population estimates for individual size classes were obtained with the equation

$$\overline{D}_i = \frac{\sum_{j=1}^{Ti} L_j \overline{D}_{ij}}{\sum_{j=1}^{Ti} L_j} \quad (1\text{-}3)$$

and variance was estimated by

$$Var\overline{D}_i = \frac{T_i}{T_i - 1} \sum_{j=1}^{Ti} L_j^2 (\overline{D}_{ij} - \overline{D}_i)^2 \Bigg/ \left(\sum_{j=1}^{Ti} L_i \right)^2 \quad (1\text{-}4)$$

where D_i = mean density (number/m^2) in stratum *i*, D_{ij} = mean density for the *j*th transect in stratum *i*, L_i = length of transect *j*, and T_i = number of transects surveyed in stratum *i* (Gunderson, 1993).

Correlation analysis was used to compare trawl versus hydroacoustic population estimates. Comparisons were made for each size class and total *O. nerka* abundance in each lake for all of the years with available data.

Gillnet Sampling

Horizontal and vertical gillnet sampling was conducted to quantify fish population characteristics including: species composition; habitat utilization (pelagic versus littoral); and diet analysis. Horizontal gillnets (30 m long, 1.8 m high) with lead sinking lines composed of five panels 6 m long of graduated mesh size (2.54, 3.17, 5.08, and 6.35 cm) were set at selected points along the bank, perpendicular to the shore in Pettit Lake. Nets were set with the smallest mesh size panel closest to shore (approximately 10 m from shore) and the largest mesh size panel deeper and further from shore. Vertical gillnets, 3 m wide and 30 m deep, each composed of a different mesh size (1.27, 1.90, 2.54, and 3.81 cm), were set in the pelagic zones of Pettit and Alturas lakes. Due to NMFS section 10 permit limitations, no gillnets were set in Redfish Lake.

Diet Analysis

Fish stomachs collected from gillnet and trawl samples were examined to determine diet composition. Stomach samples from rainbow trout, bull char, brook char, northern pike minnow, kokanee salmon, and sockeye salmon were collected. Starting in 1997, Pettit and Alturas lakes have received eyed-egg plants from captive broodstock sockeye salmon; therefore, unmarked juveniles collected for diet analysis are referred to as *O. nerka*, as distinctions between resident kokanee salmon and sockeye salmon cannot be made in the field. Fish were measured (fork length to the nearest millimeter) and weighed (to the nearest 0.1 gram), after which stomachs were removed and placed in 70% ethanol. Prey were identified, enumerated, blotted dry, and weighed to the nearest 0.01 g. Zooplankton were enumerated from zooplankton tows collected during the same months. Aggregate percent of diet by dry weight for all species of fish sampled was calculated (Swanson et al. 1974). Aggregate percent by dry weight (total diet composition) was used to determine diet overlap and aggregate percent of abundance (zooplankton diet composition) was used to develop electivity indices. Diet overlap indices for *O. nerka* and other species captured were calculated using equations described by Koenings et al. (1987). Electivity indices (Ivlev 1961) describing prey preferences were used for *O. nerka.*

Pettit Lake Egg Boxes

During May, SBT and IDFG personnel retrieved egg boxes placed in Pettit Lake the previous fall. Individual boxes were evaluated to determine the number of eyed eggs that hatched, and the number hatched that successfully emerged.

In November, SBT and IDFG personnel placed a total of 16 egg boxes containing 51,239 eyed eggs in Pettit Lake.

RESULTS

Limnology

In 2005, mean annual discharge of the Salmon River at Salmon, Idaho (USGS gage 13302500) was 34.9 m^3/s, 32% less than the 1913-2005 average of 54.4 m^3/s (Figure 2). The upper Salmon River region experienced drought conditions from 1987 to 1994 and 2000 to the present. Since 1990, the upper Salmon River has experienced the three lowest water years since measurements began in 1913.

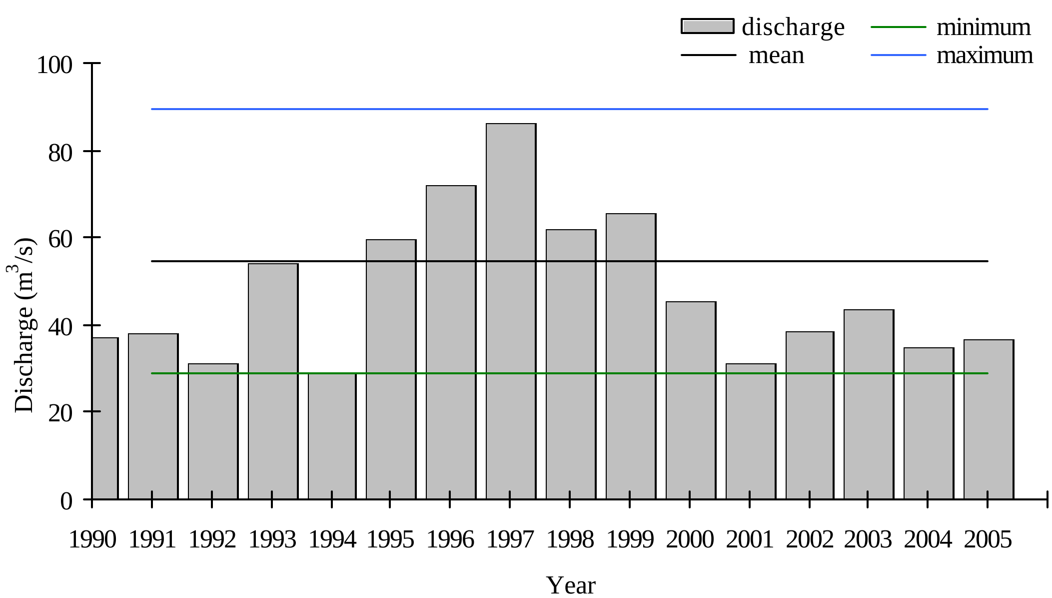


Figure 2. Mean annual discharge for the Salmon River at Salmon, Idaho, 1990-2005. Minimum, mean, and maximum are for period of record, 1913 to 2005.

Profile Data

The Sawtooth Valley lakes were inversely stratified and ice covered from January to May 2005. All four lakes were free of ice by 5 May 2005.

Thermoclines were present from July through October. Maximum surface temperatures were 17-18 ^{o}C in Redfish, Pettit and Alturas lakes: maximum surface temperature was 13.1 in Stanley Lake (Appendix A). Seasonal mean surface (0-10 m) water temperatures were 14.1, 13.7, 13.1, and 10.5 ^{o}C in Redfish, Pettit, Alturas, and Stanley lakes, respectively (Table 2). Mean temperatures were similar to previous years (1992-2004). Seasonal mean surface water temperatures in the Sawtooth Valley lakes were negatively correlated with mean annual discharge in the Salmon River at Salmon, Idaho during 1992-2005 (r = - 0.65, n = 42) (Figure 3).

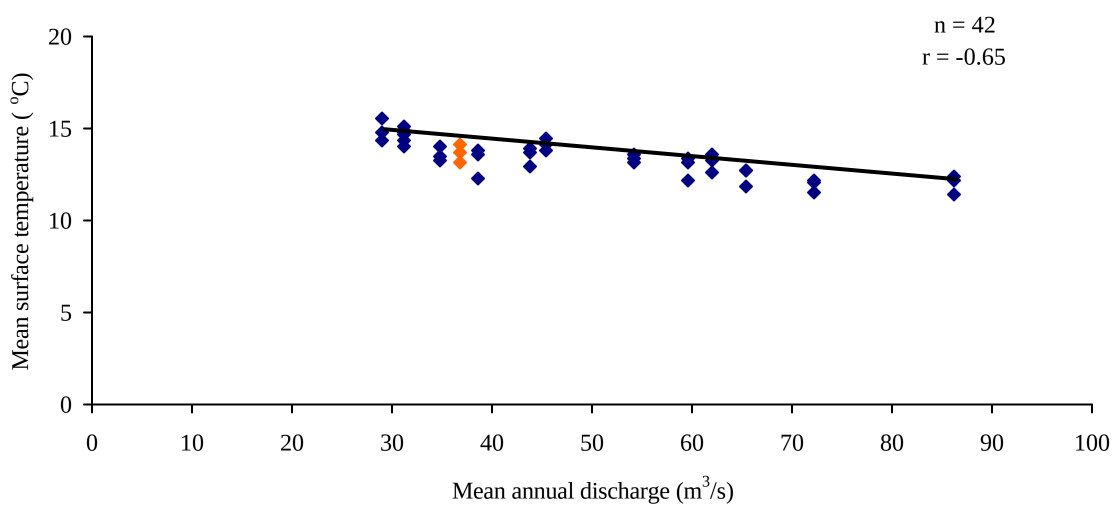


Figure 3. Correlation of mean annual discharge for the Salmon River at Salmon, Idaho, and mean summer surface (0-10 m) temperatures for 1992-2005 in Redfish, Pettit, and Alturas lakes. Orange symbols indicate current year.

Redfish Lake mixed completely during June 2005. Hypolimnetic oxygen deficits were minimal; oxygen concentrations were less than 5 mg/L in the bottom 1 m during October. Pettit Lake mixed to approximately 31 m depth during June. During late summer and fall, dissolved oxygen concentrations were less than 5 mg/L below approximately 30 m depth. Oxygen concentrations were less than 5 mg/L in the bottom 6-8 m during September-October in Alturas Lake and in the bottom 3-7 m between August and October in Stanley Lake. During the October sample period, the four lakes had not yet mixed completely.

Table 2. Seasonal mean (June-October) surface water temperature (°C), Secchi depth (m), compensation depth (m), epilimnetic chlorophyll *a* (µg/L), and whole-lake total zooplankton biomass (mg/m^2) for the Sawtooth Valley lakes, 1992-2005.

Lake	Year	Surface temperature (°C) 0-10 m	Secchi depth (m)	Compensation depth (m)	Epilimnetic chl *a* (µg/L)	Whole-lake zooplankton biomass (mg/m^2)
Redfish	**2005**	14.1	16.3	27.1	0.9	1519.25
	2004	13.5	16.5	27.0	0.9	1105.4
	2003	13.9	15.8	25.6	0.7	2005.6
	2002	13.6	13.9	24.5	1.5	1023.4
	2001	14.3	14.5	27.4	1.4	1266.3
	2000	14.2	17.8	26.1	0.8	1166.7
	1999	12.7	14.6	22.5	0.9	430.8
	1998	13.3	12.1	22.1	1.6	617.5
	1997	12.2	11.4	19.7	1.5	360.1
	1996	12.0	14.1	18.5	0.7	425.1
	1995	13.4	12.1	26.2	0.5	703.8
	1994	14.7	15.8	31.8	0.3	481.0
	1993	13.4	14.0	26.3	0.6	302.0
	1992	14.9	13.8	33.3	0.5	-
	mean	**13.6**	**14.5**	**25.6**	**0.9**	**877.5**
Pettit	**2005**	13.7	14.1	23.4	1.5	2525.5
	2004	14.0	10.4	22.3	2.6	3121.4
	2003	13.7	13.2	21.3	1.2	2760.7
	2002	13.8	15.5	24.2	0.7	2869.6
	2001	14.8	15.7	26.2	0.6	1441.7
	2000	14.4	15.0	24.5	1.0	466.7
	1999	12.7	11.2	21.7	1.4	450.5
	1998	13.6	10.6	22.6	1.5	344.0
	1997	12.4	11.3	19.1	1.3	423.8
	1996	12.2	11.8	17.4	0.8	295.0
	1995	13.2	12.4	22.2	0.5	145.7
	1994	15.6	15.2	30.8	0.3	1061.5
	1993	13.6	14.8	23.3	0.6	738.6
	1992	15.1	15.7	29.1	0.4	-
	mean	**13.8**	**13.3**	**23.4**	**1.0**	**1280.3**

Table 2. continued

Lake	Year	Surface temperature (°C) 0-10 m	Secchi depth (m)	Compensation depth (m)	Epilimnetic chl *a* (µg/L)	Whole-lake zooplankton biomass (mg/m²)
Alturas	**2005**	13.1	13.6	20.3	1.8	1070.8
	2004	13.3	15.6	22.3	0.7	883.3
	2003	12.9	11.8	17.1	0.7	484.3
	2002	12.3	12.5	20.0	0.7	405.8
	2001	14.0	13.9	22.8	0.8	140.6
	2000	13.8	14.5	19.8	0.9	272.5
	1999	11.8	10.5	16.9	1.2	448.9
	1998	12.6	10.8	17.3	2.0	485.1
	1997	11.4	10.9	15.7	1.0	404.7
	1996	11.5	10.6	13.6	1.0	244.2
	1995	12.2	9.8	16.5	0.4	100.3
	1994	14.3	14.7	24.1	0.4	138.4
	1993	13.1	-	20.6	0.9	15.9
	1992	14.7	14.4	27.6	0.6	-
	mean	**12.9**	**12.6**	**19.6**	**0.9**	**391.9**
Stanley	**2005**	10.5	10.0	13.6	1.3	723.2
	2004	11.9	7.5	13.2	1.0	613.9
	2003	12.0	6.8	12.7	1.4	336.2
	2002	11.6	7.4	12.6	1.1	421.2
	2001	13.0	8.1	14.8	0.9	448.6
	2000	12.4	7.6	13.8	0.8	458.1
	1999	11.1	6.6	11.4	1.6	308.4
	1998	11.8	5.0	11.8	1.0	394.8
	1997	11.5	7.5	13.7	1.2	384.5
	1996	10.7	7.5	10.9	1.0	378.5
	1995	12.0	5.8	11.9	0.8	312.8
	1994	14.6	8.3	16.6	0.5	428.4
	1993	11.9	8.3	15.4	1.1	336.7
	1992	14.7	8.6	20.0	0.7	-
	mean	**12.1**	**7.5**	**13.7**	**1.0**	**426.6**

Secchi depth and compensation depth

Secchi depths increased in Redfish, Pettit, and Stanley lakes from May to late July or early August, decreased dramatically during August, particularly in Pettit Lake, then gradually deepened until October (Figure 4). In Alturas Lake, the pattern was similar except that seccgi depths declined between May and late June. Seasonal mean Secchi depths were slightly deeper than average in all four lakes (Table 2).
Compensation depths were relatively consistent in all four lakes (Figure 5).

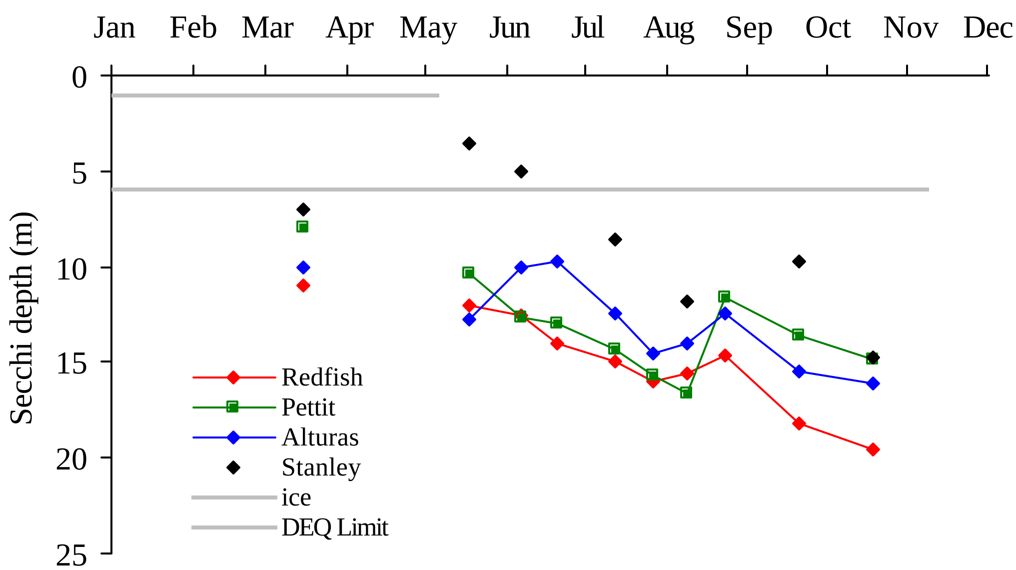


Figure 4. Secchi depths (m) for Redfish, Pettit, Alturas, and Stanley lakes, March through October 2005.

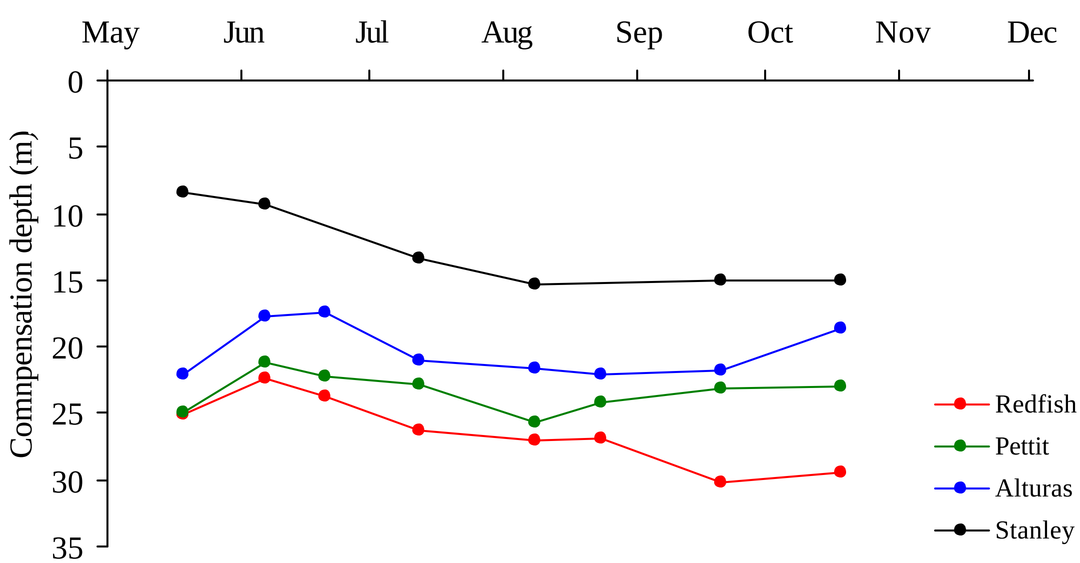


Figure 5. Compensation depths (m) for Redfish, Pettit, Alturas, and Stanley lakes, May through October 2005.

Water Chemistry

During spring turnover (May 2005) depth integrated nutrient concentrations remained low, consistent with the oligotrophic condition of the Sawtooth Valley lakes. TP concentrations were between 6 and 10 μg/L and TN concentrations ranged from 55 to 93 μg/L resulting in TN:TP ratios between 7 and 11. Nitrate-nitrite concentrations were less than 16 μg/L and TDP was 4-5 μg/L in the four Sawtooth Valley lakes.

Nutrient concentrations in the epilimnion of Redfish Lake were low and consistent during summer 2005, with values ranging from 41-70 μg/L total nitrogen, 1-3 μg/L NO^3-NO^2-N, 2-8 μg/L dissolved phosphorus, and 4-10 μg/L total phosphorus (Figures 6 and 7). TN:TP ratios rang from 6 to 15. In Pettit and Alturas lakes, which received supplemental nutrients, we saw little divergence in nutrient concentrations other than slight elevations in total nitrogen and the TN:TP ratio during September and October. Phosphorus concentrations increased during September and October in all three lakes with < 9 μg/L dissolved phosphorus, and < 10 μg/L total phosphorus.

Seasonal mean epilimnetic TP concentrations were 6-7 μg/L and TDP was approximately 5 μg/L in Redfish, Pettit and Alturas lakes. Mean TN concentrations were 59 μg/L in Redfish Lake, 107 μg/L in Pettit Lake, and 77 μg/L in Alturas Lake resulting in TN:TP ratios of 11, 19, and 10, respectively. Mean nitrate-nitrite concentrations were < 2 μg/L in the three lakes (Table 3).

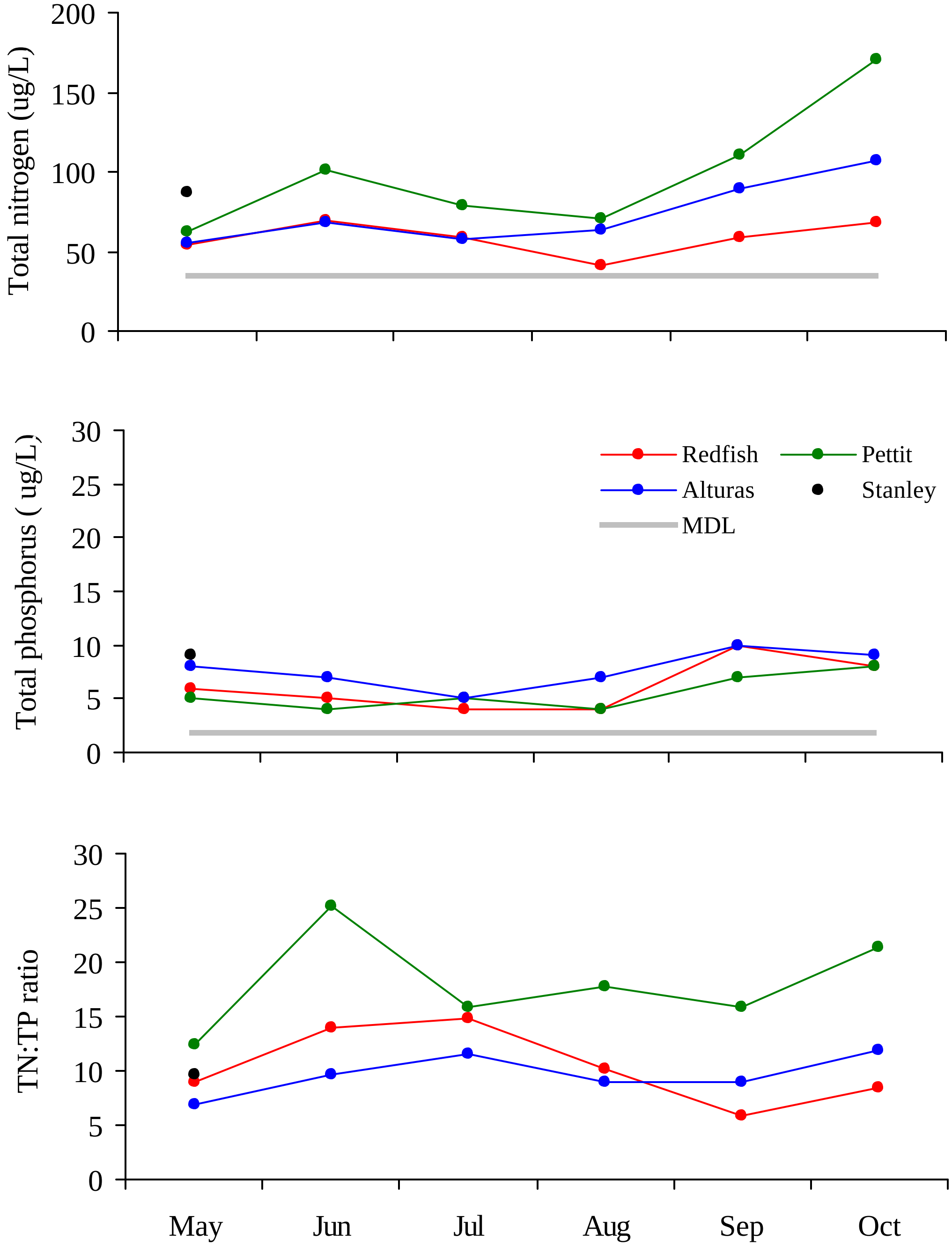


Figure 6. Concentrations of total nitrogen, total phosphorus, and the TN:TP ratio in the epilimnetic waters of Redfish, Pettit, Alturas, and Stanley lakes during May through October 2005. Grey line denotes method detection level.

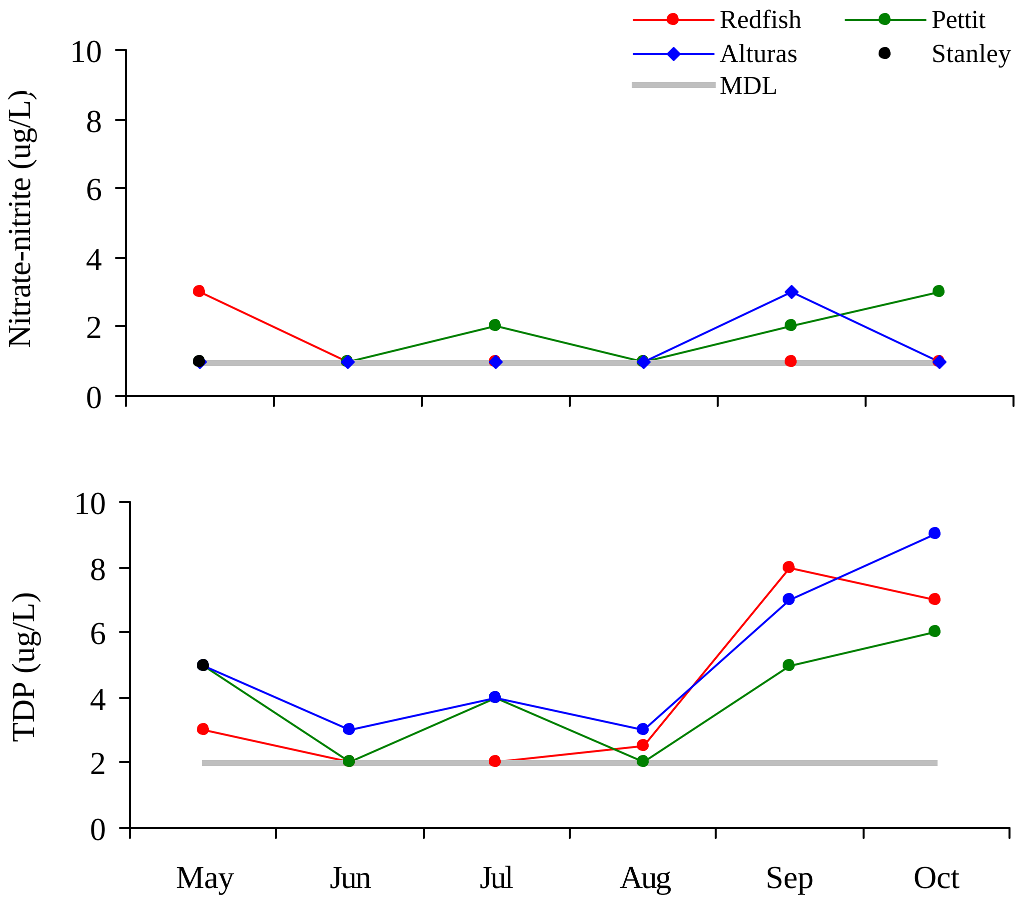


Figure 7. Nitrate-nitrite and total dissolved phosphorus (TDP) concentrations in the epilimnetic waters of Redfish, Pettit, Alturas, and Stanley lakes during May through October 2005. Grey line denotes method detection levels.

Table 3. Seasonal mean (June-October) epilimnetic nutrient concentrations (μg/L) and TN:TP ratio in Redfish, Pettit, Alturas, and Stanley lakes during 1992-2005.

Lake	Year	TP	TDP	SRP	TN	$N0^3 + NO^2$	NH^4	TN:TP
Redfish	**2005**	6.2	4.3	-	59.3	1.0	-	10.7
	2004	6.2	3.6	-	60.8	1.4	-	10.2
	2003	4.2	2.9	-	100.1	1.4	-	26.0
	2002	5.0	3.0	-	65.8	4.1	-	14.3
	2001	3.2	2.1	-	108.0	4.6	-	27.2
	2000	4.9	3.0	-	69.5	1.8	3.3	13.2
	1999	5.2	-	-	54.7	3.0	5.1	9.2
	1998	6.2	-	-	61.9	7.2	3.4	10.0
	1997	5.5	-	-0.3	67.0	4.9	3.5	16.0
	1996	5.0	-	0.9	45.7	0.9	1.2	10.3
	1995	7.3	-	1.8	87.1	3.8	6.5	14.8
	1994	8.5	-	2.0	-	-	-	-
	1993	6.4	-	1.6	65.4	1.6	3.2	10.7
	1992	8.6	-	1.8	47.7	6.7	-	6.1
	mean	**6.3**	**3.2**	**1.5**	**68.2**	**3.5**	**4.0**	**13.5**
Pettit	**2005**	5.6	3.8	-	106.6	1.8	-	19.2
	2004	5.4	3.6	-	125.4	9.8	-	23.2
	2003	4.3	2.7	-	101.0	1.4	-	27.1
	2002	4.8	3.2	-	100.8	1.8	-	24.5
	2001	3.1	2.0	-	117.6	1.2	-	38.3
	2000	5.3	2.7	-	57.5	1.0	2.7	11.2
	1999	6.3	-	-	101.5	2.4	5.0	14.0
	1998	5.4	-	-	86.4	1.3	2.3	15.2
	1997	5.5	-	0.0	71.6	2.0	2.6	17.9
	1996	6.0	-	0.9	42.5	0.5	0.9	8.0
	1995	5.8	-	1.5	86.9	1.0	3.0	16.9
	1994	6.6	-	1.0	-	-	-	-
	1993	6.2	-	1.7	70.1	1.7	3.0	13.6
	1992	5.8	-	2.2	84.6	3.6	-	15.7
	mean	**5.5**	**3.1**	**1.3**	**90.1**	**2.3**	**2.8**	**19.2**
Alturas	**2005**	7.6	5.2	-	77.2	1.4	-	10.2
	2004	-	-	-	-	-	-	-
	2003	-	-	-	-	-	-	-
	2002	-	-	-	-	-	-	-
	2001	-	-	-	-	-	-	-
	2000	7.1	5.2	-	65.0	1.9	3.9	11.0
	1999	7.9	-	-	93.9	1.7	6.6	9.9
	1998	8.2	-	-	76.6	1.1	2.8	9.3
	1997	8.2	-	0.3	66.6	1.4	1.8	11.6
	1996	8.2	-	1.0	61.1	0.5	1.7	7.9
	1995	8.5	-	1.7	120.5	2.6	6.6	16.4
	1994	11.6	-	2.4	-	-	-	-
	1993	8.0	-	1.2	88.8	3.2	2.6	14.3
	1992	7.5	-	1.0	84.5	4.3	-	10.6
	mean	**8.4**	**5.2**	**1.3**	**82.9**	**2.1**	**3.8**	**11.6**

Table 3. continued.

Lake	Year	TP	TDP	SRP	TN	$N0^3 + NO^2$	NH^4	TN:TP
Stanley	**2005**	-	-	-	-	-	-	-
	2004	-	-	-	-	-	-	-
	2003	-	-	-	-	-	-	-
	2002	-	-	-	-	-	-	-
	2001	-	-	-	-	-	-	-
	2000	6.8	3.3	-	66.5	1.3	2.0	10.3
	1999	9.9	-	-	64.5	5.4	2.6	7.0
	1998	7.6	-	-	66.5	1.1	1.8	9.2
	1997	4.3	-	-0.5	57.3	1.3	3.3	13.7
	1996	7.3	-	-	-	-	-	-
	1995	7.9	-	1.8	88.1	2.6	5.4	11.5
	1994	9.6	-	2.7	-	-	-	-
	1993	5.3	-	1.6	76.0	3.0	11.6	16.1
	1992	7.2	-	2.2	89.8	3.4	-	12.4
	mean	**7.4**	**3.3**	**1.8**	**75.3**	**2.6**	**5.4**	**11.7**

Chlorophyll a

In 2005, epilimnetic chlorophyll *a* concentrations ranged from 0.7 to 6.4 μg/L in the four Sawtooth Valley lakes (Figure 8). Concentrations were typically low (~1 μg/L) during June through August. Redfish Lake surface chlorophyll *a* concentrations remained low (≤ 1.0 μg/L) during the fall, while the two fertilized lakes had elevated surface chlorophyll *a* concentrations (1.6-3.0 μg/L). June-October mean epilimnetic chlorophyll *a* concentrations were 0.9, 1.5, 1.8, and 1.3 μg/L in Redfish, Pettit, Alturas, and Stanley lakes, respectively (Table 2).

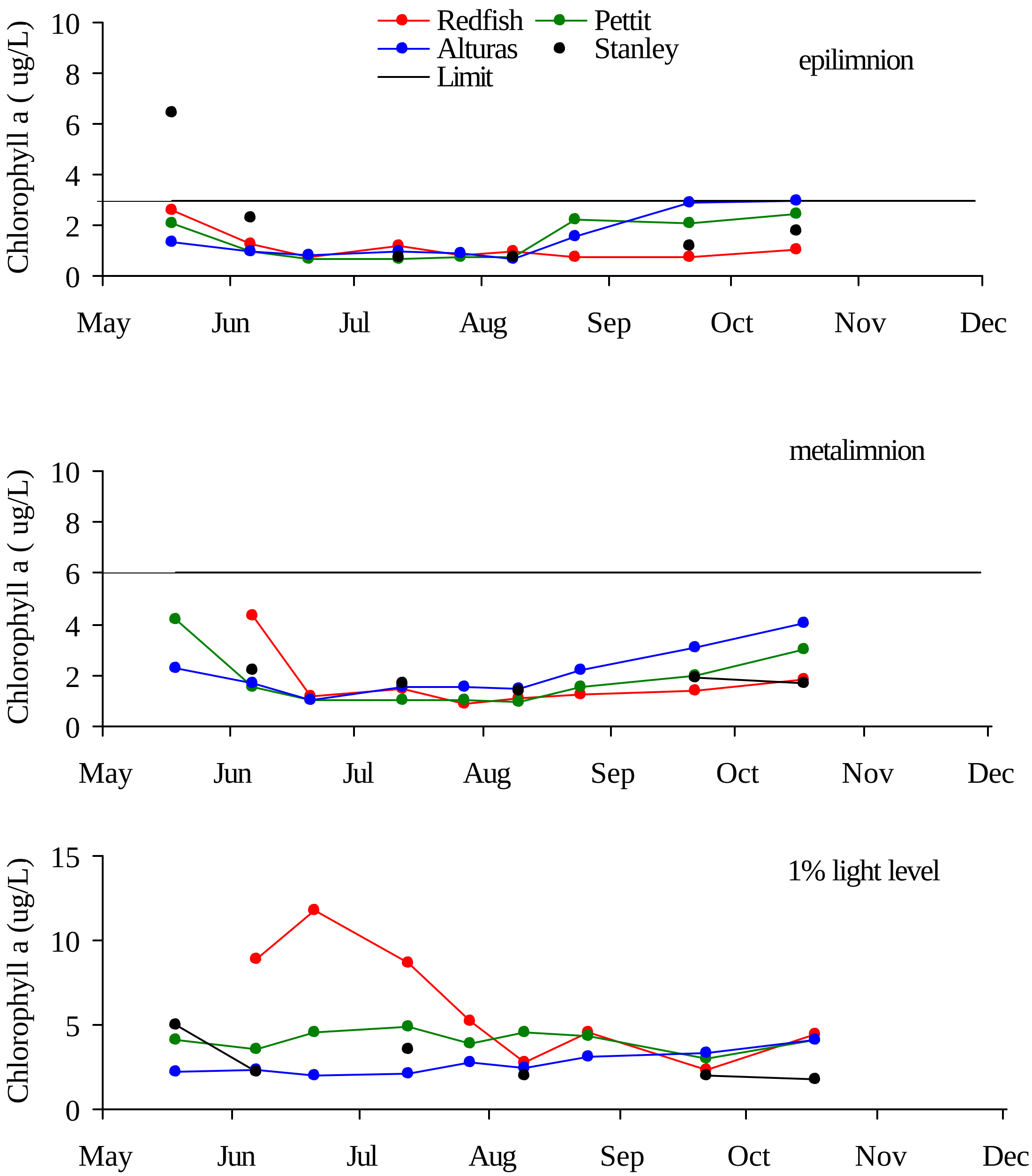


Figure 8. Chlorophyll *a* concentrations (µg/L) in the epilimnion, metalimnion, and compensation depths in Redfish, Pettit, Alturas, and Stanley lakes, May-October 2005.

Heterotrophic bacteria and autotrophic picoplankton

Epilimnetic heterotrophic bacteria densities were relatively consistent between the four lakes. Seasonal mean heterotrophic bacteria densities in the epilimnions of the four Sawtooth Valley lakes ranged from 403,531 to 576,992 cells/mL (Table 4; Appendix B). Stanley Lake had the highest autotrophic picoplankton (APP) densities with approximately 56,000 cells/mL in the epilimnion and 94,000 cells/mL at the compensation depth. The other lakes were relatively consistent with APP densities ranging from 17,00 to 28,000 cells/mL in the epilimnion, and 32,000 to approximately 58,000 cells/mL at the compensation depth.

Table 4. Heterotrophic bacteria and autotrophic picoplankton (APP) densities (cells/mL) in the epilimnions and compensation depths in four Sawtooth Valley lakes during June-October 2005.

		Heterotrophic bacteria			**Autotrophic pico-cyanobacteria**		
Lake	**Strata**	**min**	**mean**	**max**	**min**	**mean**	**max**
Redfish	epilimnion	261,750	403,531	649,181	14,195	17,701	24,582
	compensation depth	162,555	332,251	427,940	23,544	46,135	64,745
	mean		**367,891**			**31,918**	
Pettit	epilimnion	396,779	576,992	783,172	18,177	28,131	37,393
	compensation depth	260,711	344,585	445,598	23,371	32,416	42,932
	mean		**460,789**			**30,273**	
Alturas	epilimnion	326,148	513,632	604,517	15,927	27,871	38,085
	compensation depth	56,089	466,112	652,297	29,083	57,820	100,407
	mean		**489,872**			**42,846**	
Stanley	epilimnion	282,523	403,531	524,538	44,317	56,262	68,207
	compensation depth	217,086	241,236	265,385	75,478	94,348	113,217
	mean		**322,383**			**75,305**	

Phytoplankton

Phytoplankton communities in the Sawtooth Valley lakes were dominated by small grazable taxa during 2005. Total phytoplankton densities ranged from 466 – 5,702 cells/mL and total phytoplankton biovolume ranged from 0.08 – 0.91 mm^3/L in the epilimnions of the four Sawtooth Valley lakes (Table 5).

Redfish Lake phytoplankton densities peaked in early June (4,029 cells/mL), with Chryso- and Cryptophacean nano-flagellates (small microflagellates, *Kephyrion* sp., and *Chromulina* sp. ; 2256 cells/mL) dominating (Appendix C1). Another peak in densities occurred in early August (3,142 cells/mL) due to an increase in Chlorophyceae (mostly *Elakatothrix* sp.; 1,394 cells/mL). Chryso- and Cryptophacean nano-flagellates (10,461 cells/mL), Cyanophytes (mostly *Synechococcus sp*.; 3,725 cells/mL), and Chlorophyceae (mostly *Chlorella*; 3,502 cells/mL) were the most abundant taxanomic groups throughout the season in Redfish Lake. Peak biomass occurred in early August (0.91 mm^3/L), due to Dinoflagellates (mostly *Gymnodinium* sp.; 0.51 mm^3/L) and Chlorophyceae (mostly *Elakatothrix* sp.; 0.55 mm^3/L).

In Pettit Lake, Cyanophytes (mostly *Synochoccus* sp. and *Oscillatoria* sp.; 1,672 cells/mL), Chryso- and Cryptophycean nano-flagellates (mostly small microflagellates; 659 cells/mL), and Bacillariophytes (mostly *Fragilaria capucina*; 634 cells/mL) caused phytoplankton densities to peak in late July (3,218 cells/mL) (Appendix C2). During the season, Chryso- and Cryptophycean nano-flagellates (*Dinobryon* sp.) dominated in Pettit Lake, reaching peak densities in late August (1,682 cells/mL). Peak phytoplankton biomass occurred in October (0.496 mm^3/L), mostly comprised of Dinoflagellates (*Gymnodinium* sp.) and Chryso- and Cryptophycean nano-flagellates (*Dinobryon* sp.).

Alturas Lake supported the highest mean epilimnetic densities of phytoplankton (2,309 cells/mL) and was dominated by Chryso- and Cryptophycean nano-flagellates (mostly *Pseudokephrion* sp.) (Appendix C3). A large bloom of Bacillariophytes (*Asterionella formosa*) resulted in peak phytoplankton densities (5,702 cells/mL) and biovolumes (0.60 mm^3/L) in late August. Another smaller peak in densities (4,105 cells/mL) occurred in early July, comprised of mostly Chryso- and Cryptophycean nano-flagellates *(Pseudokephrion* sp.). Chryso- and Cryptophycean nano-flagellates, Dinoflagellates, and Bacillariophytes accounted for 92% of the total phytoplankton biovolume in Alturas Lake.

Stanley Lake phytoplankton density and biomass peaked in May (1,936 cells/mL; 0.313 mm^3/L), mostly due to Chryso- and Cryptophycean nano-flagellates (Dinobryon sp. and small microflagellates; 1,318 cells/mL, 0.168 mm^3/L) (Appendix C4).

Vertical phytoplankton profiles collected on 24 August 2005 showed the three lakes had similar phytoplankton densities (Redfish Lake = 1,971 cells/mL, Alturas Lake = 1,887 cells/mL, and Pettit Lake = 1,584 cells/mL (Figures 9 and 10). The greatest density of phytoplankton in Redfish Lake occurred at 16.9 m (2,656 cells/mL) and the lowest density at the surface (1,064 cells/mL). The highest phytoplankton densities in Pettit Lake were at 2.4 and 25m with Chryso- and Cryptophycean nano-flagellates and Bacillariophytes most common (Figure 9). Alturas Lake phytoplankton densities were reasonably constant with depth and dominated by Bacillariophytes (6,569 cells/mL) and Cryso-Cryptophytes (2,352 cells/mL) (Figure 9).

Phytoplankton biovolumes followed patterns similar to densities in all three lakes, with the greatest biovolume occurring in Redfish (0.523 mm^3/L), followed by Pettit (0.390 mm^3/L), then Alturas (0.303 mm^3/L). Biovolume in Redfish was mostly Chlorophytes (0.861 mm^3/L), Bacillariophytes (0.744 mm^3/L), and Dinoflagellates (0.739 mm^3/L). Dinoflagellates (1.130 mm^3/L) and Cryso-Cryptophytes (0.815 mm^3/L) accounted for most of the biovolume in Pettit Lake. Dinoflagellates (0.745 mm^3/L) and Bacillariophytes (0.705 mm^3/L) dominated phytoplankton biovolume in Alturas Lake.

Table 5. Phytoplankton density (cells/mL) and biovolume (mm^3/L) in the epilimnions and compensation depths in four Sawtooth Valley lakes during June-October 2005.

			Density			Biovolume	
Lake	**Strata**	**min**	**mean**	**max**	**min**	**mean**	**max**
Redfish	epilimnion	740	2,199	4,029	0.10	0.41	0.91
	compensation depth	2,139	4,232	6,969	0.34	1.04	1.69
	mean		**3,216**			**0.73**	
Pettit	epilimnion	588	1,578	3,218	0.11	0.27	0.50
	compensation depth	1,075	1,898	2,859	0.18	0.33	0.50
	mean		**1,738**			**0.30**	
Alturas	epilimnion	466	2,309	5,702	0.30	0.30	0.31
	compensation depth	760	1,851	3,675	0.13	0.32	0.66
	mean		**2,080**			**0.31**	
Stanley	epilimnion	517	971	1,409	0.08	0.13	0.20
	compensation depth	416	1,150	1,744	0.05	0.18	0.32
			1,060			**0.16**	

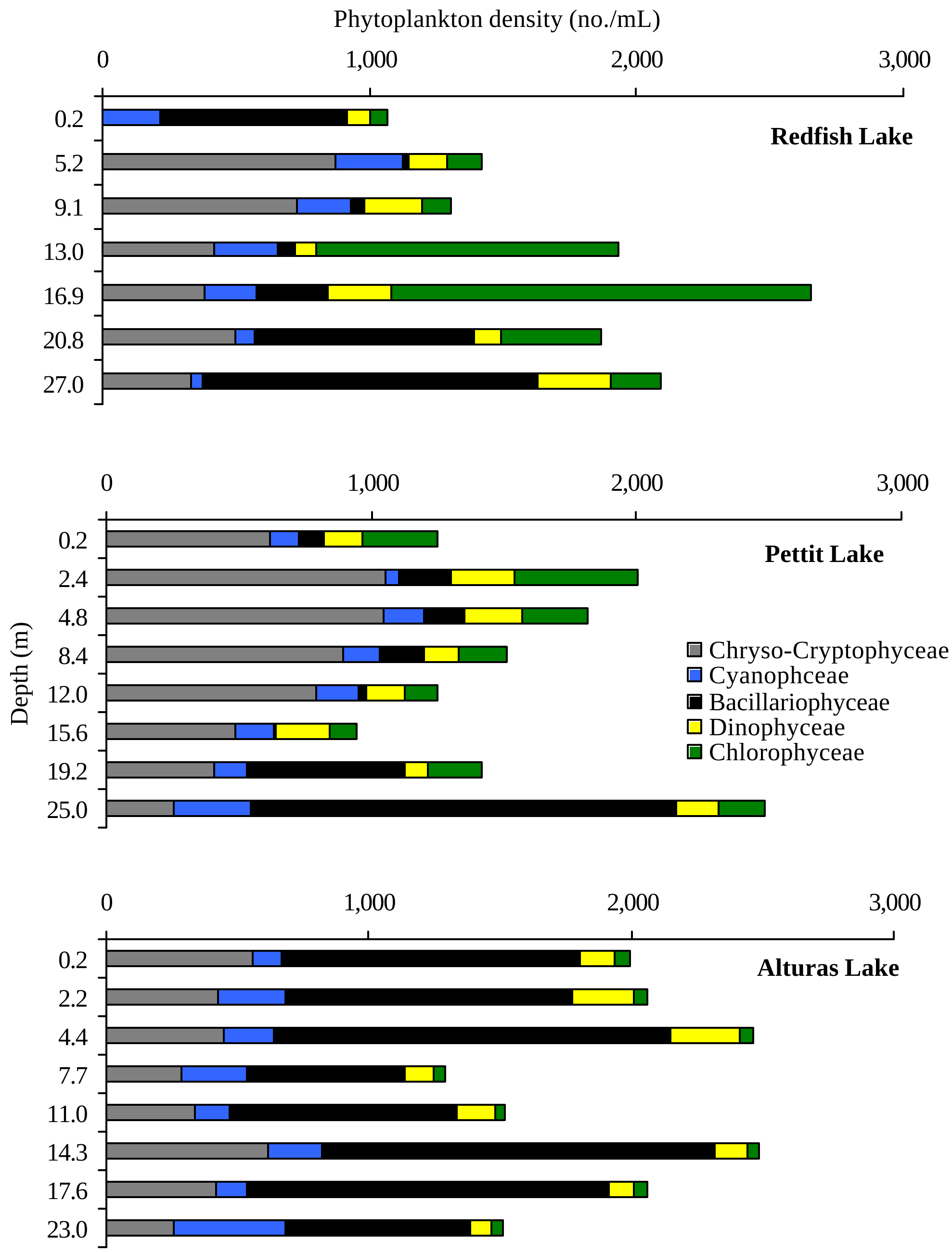


Figure 9. Phytoplankton density at eight discrete depths in Redfish, Pettit, and Alturas lakes, Idaho, 24 August 2005.

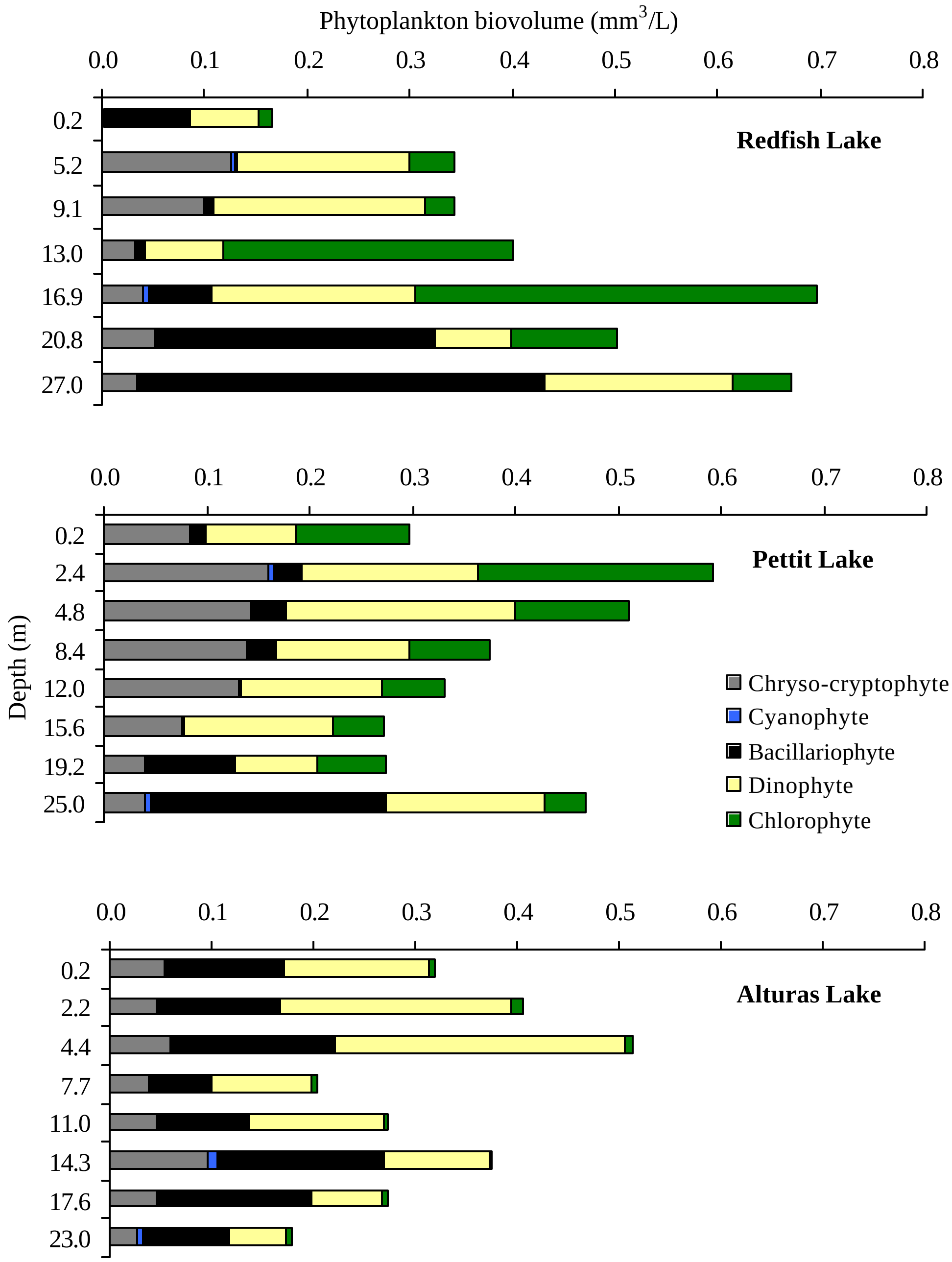


Figure 10. Phytoplankton biovolume at eight discrete depths in Redfish, Pettit, and Alturas lakes, Idaho, 24 August 2005.

Zooplankton

In 2005, Pettit Lake had the highest seasonal mean zooplankton biomass followed by Redfish, Alturas, and Stanley lakes, similar to observations in the previous four years. Zooplankton biomass declined in Pettit Lake and increased in the other three lakes relative to 2004 (Figure 11). Seasonal mean biomass (June-October) was 2,526 mg/m^2 in Pettit Lake, 1,519 mg/m^2 in Redfish Lake, 1,071 mg/m^2 in Alturas Lake, and 723 mg/m^2 in Stanley Lake (Table 2).

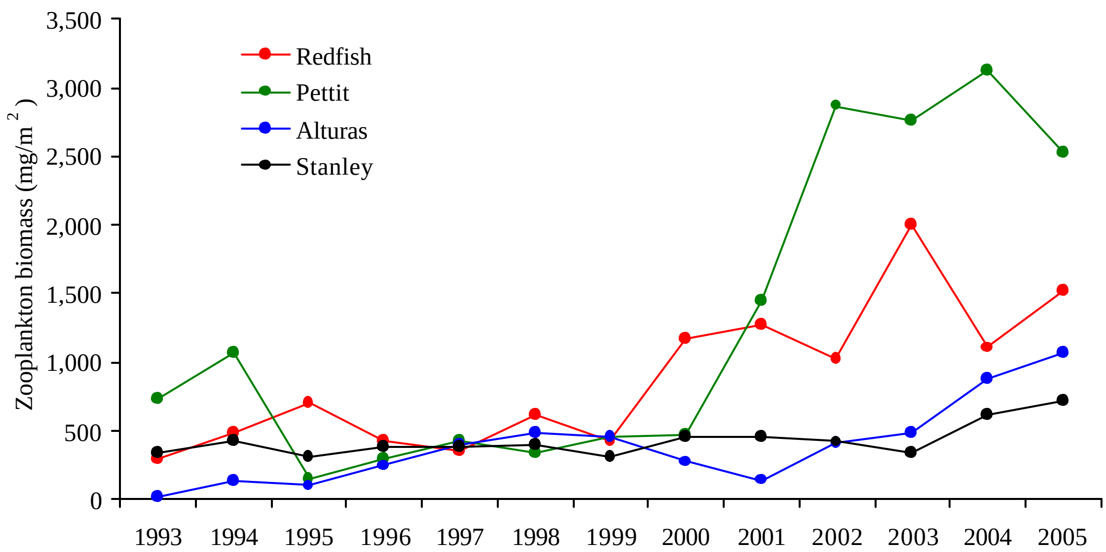


Figure 11. Seasonal mean zooplankton biomass (June-October) for the Sawtooth Valley lakes, 1993-2005.

Redfish Lake zooplankton biomass increased from 2004, and was greater than in previous years with the exception of 2003. *Daphnia* (823 mg/m^2), *Holopedium* (127 mg/m^2), *Bosmina* (295 mg/m^2), and cyclopoid copepods (253 mg/m^2) dominated mean summer biomass (Figure 12). During January-March 2005, whole-lake zooplankton biomass averaged 359.2 mg/m^2 and was dominated by cyclopoid copepods (297 mg/m^2) (Figure 13).

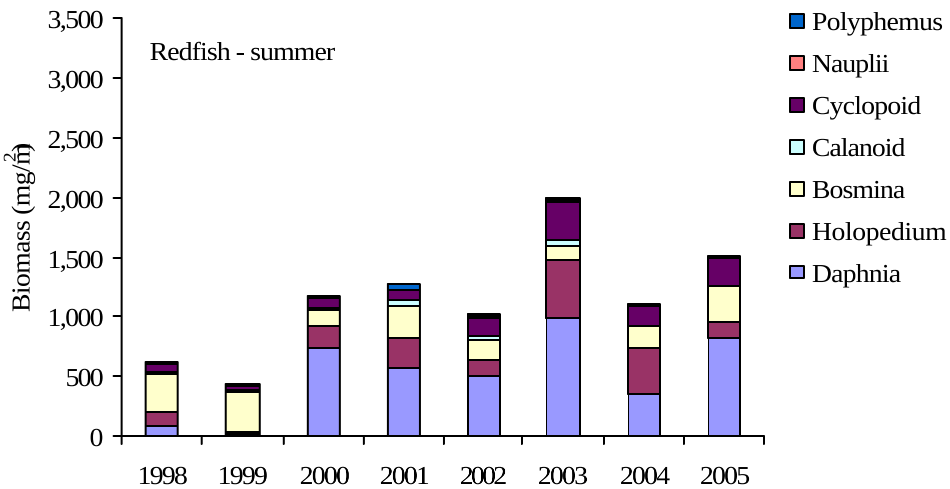


Figure 12. Mean areal zooplankton biomass (June-October) in Redfish Lake, 1998-2005.

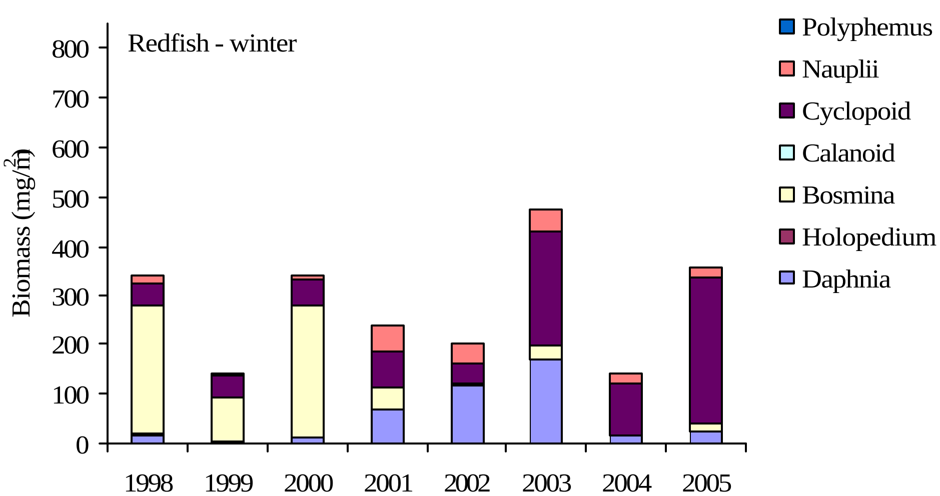


Figure 13. Mean areal zooplankton biomass (January-March) in Redfish Lake, 1998-2005.

Pettit Lake total summer zooplankton biomass decreased from 2004, but remaining high compared to the other Sawtooth Valley lakes (Figures 11 and 14). Zooplankton biomass was predominately *Daphnia* (782 mg/m^2), cyclopoid copepods (769 mg/m^2), and *Nauplii* (581 mg/m^2). During January-March 2005, total zooplankton biomass increased by 74% to 831 mg/m^2 and was mostly *Bosmina* (398 mg/m^2), and cyclopoid copepods (388 mg/m^2; Figure 15).

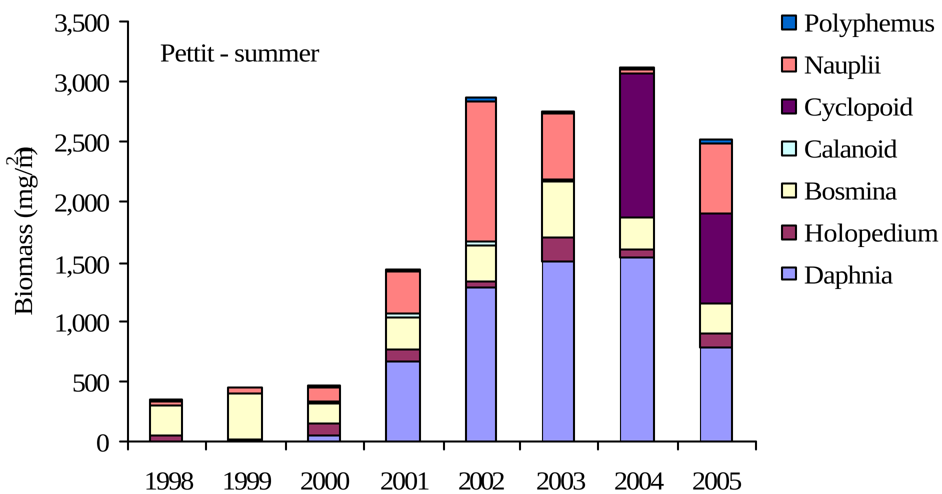


Figure 14. Mean areal zooplankton biomass (June-October) in Pettit Lake, 1998-2005.

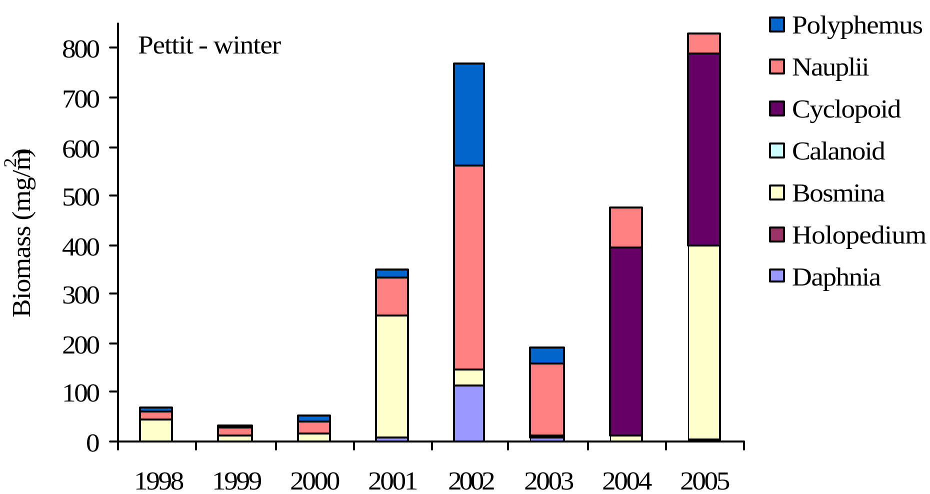


Figure 15. Mean areal zooplankton biomass (January-March) in Pettit Lake, 1998-2005.

In Alturas Lake, mean seasonal total zooplankton biomass was 1071 mg/m^2, continuing a steady increase from 2001 (Figure 16). During the summer of 2005, zooplankton populations consisted predominantly of *Daphnia* (336 mg/m^2), cyclopoid copepods (332 mg/m^2), and *Bosmina* (289 mg/m^2). Mean zooplankton biomass during January-March remained low with a total biomass of 139 mg/m^2 of which 97 mg/m^2 were cyclopoids and 23 mg/m^2 were *nauplii* (Figure 17).

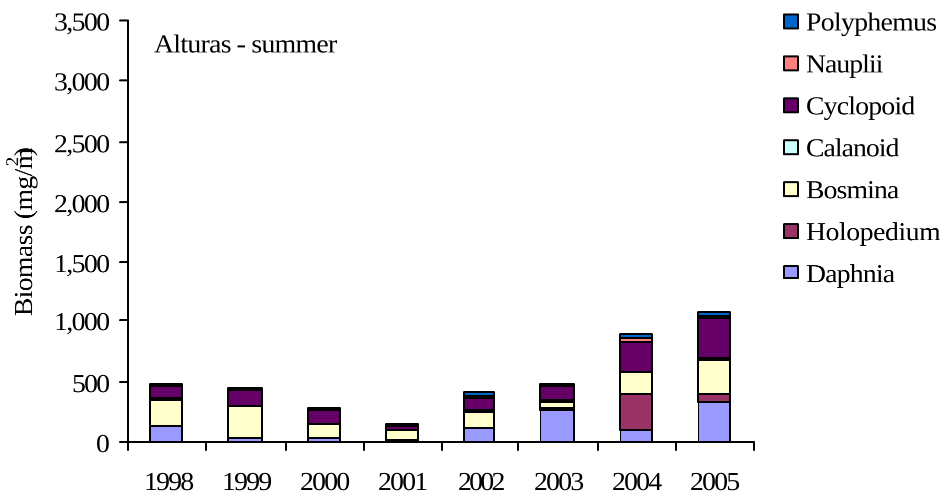


Figure 16. Mean areal zooplankton biomass (June-October) in Alturas Lake, 1998-2005.

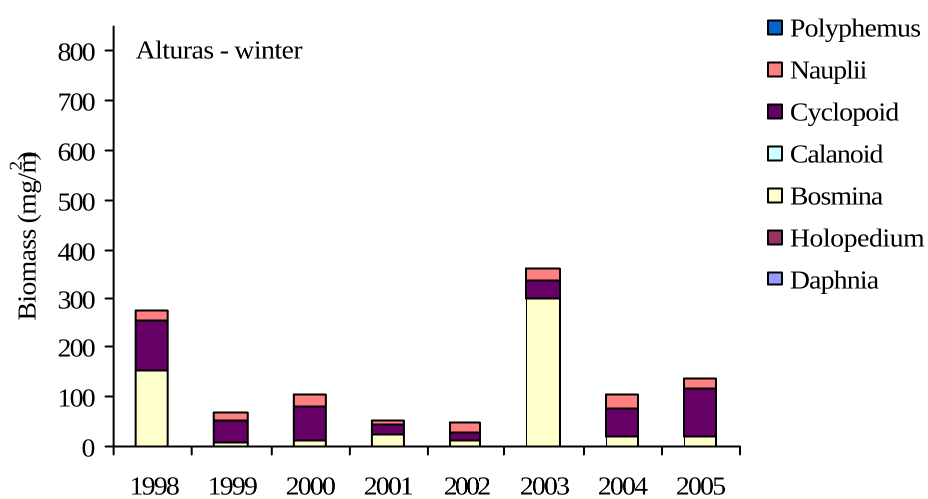


Figure 17. Mean areal zooplankton biomass (January-March) in Alturas Lake, 1998-2005.

Seasonal mean zooplankton biomass in Stanley Lake was (774 mg/m^2), slightly higher than previous years (Figure 18). During summer 2005, zooplankton species composition was dominated by *Daphnia* (309 mg/m^2), cyclopoids (166 mg/m^2), and calanoid copepods (131 mg/m^2). The mean total zooplankton biomass for March and May 2005 was 92 mg/m^2 and was predominately *Daphnia* (72 mg/m^2).

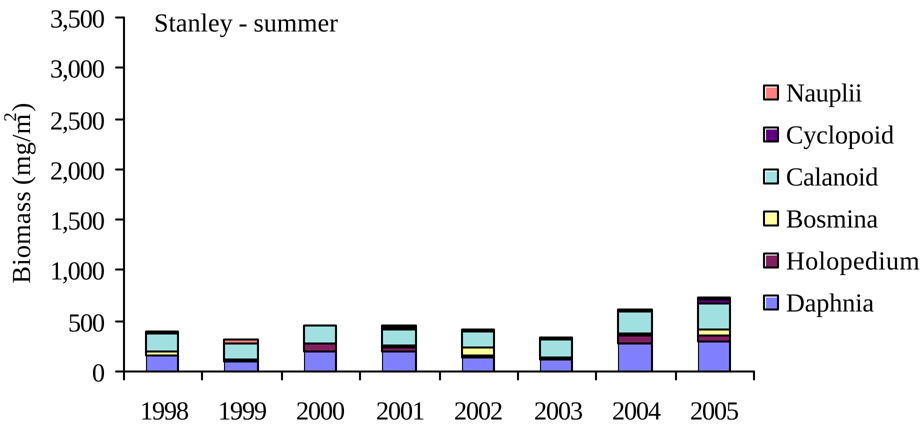


Figure 18. Mean areal zooplankton biomass (June-October) in Stanley Lake, 1998-2005.

Fertilization

Between 29 June and 27 September 2005, 38.5 kg phosphorus (P) and 770.0 kg nitrogen (N) were added to Pettit Lake to enhance its productivity. Fertilization was intermittent and as a result only 38% of the prescribed load was applied to Pettit Lake in 2006. Two applications were made (late June and early July), and then DEQ personnel identified a permitting issue. Applications were suspended while a new consent order was obtained and nutrient supplementation resumed on 10 August. Applications were suspended a second time during the last week of August and the first week of September to avoid stimulating an *Oocystis* sp. bloom, such as the one that occurred in Pettit Lake during August 2004 (Kohler et al. 2005). Fertilization resumed 14 September, did not occur as scheduled on 21 September because of mechanical problems and the last application was made the following week on 27 September. Areal loading rates were 23.8 mg P/m^2, or the equivalent of an adult escapement of approximately 4,774 sockeye salmon to Pettit Lake

Alturas Lake also received less supplemental nutrients than prescribed, a result of the permitting issue that suspended operations during July (Figure 20). The lake received

116.4 kg phosphorus (P) and 2,348.0 kg nitrogen (N). Areal loading rates were 34.4 mg P/m^2, or the equivalent of an adult escapement of approximately 14,435 sockeye salmon to Alturas Lake.

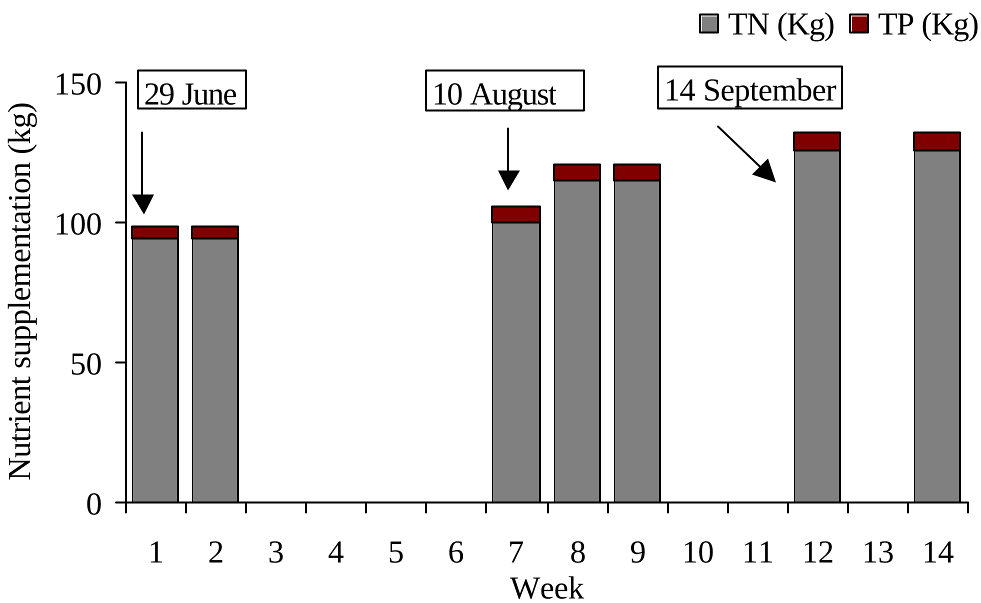


Figure 19. Supplemental nutrient applications for Pettit Lake, 29 June to 27 September 2005.

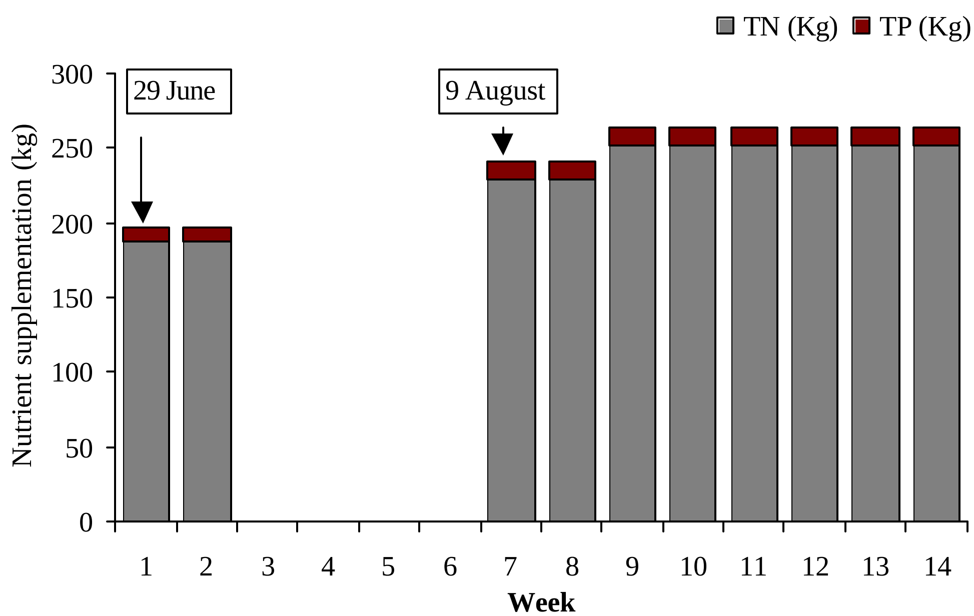


Figure 20. Supplemental nutrient applications for Alturas Lake, 29 June to 27 September 2005.

Limit Kokanee Salmon Escapement

An aluminum picket weir was constructed in Fishhook Creek; however, the weir failed to manage escapement and 4,375 spawning kokanee salmon passed the weir site. Additionally, a fyke net weir with wings was installed in Alturas Lake Creek to manage kokanee salmon spawner numbers. This management technique also failed to control passage and 11, 652 adults entered Alturas Lake Creek.

Smolt Monitoring

Pettit Lake

We captured a total of 24,569 Snake River sockeye salmon comprised of 7,518 fish with adipose fins (presumably from the eyed egg release or residuals) and 17,051 fall release fish from the Sawtooth Hatchery. We recaptured 522 smolts that had been PIT tagged prior to release the previous year. Because of the large numbers of recaptures we only tagged 419 smolts in 2005, resulting in the availability of 941 tagged fish to determine interrogation rates and travel time to the Lower Snake River Dam complex.

Fifty five percent of the smolts released in the fall of 2004 were captured at the Pettit Lake Creek weir in 2005. Migrant numbers and timing, discharge, length frequency histograms, release numbers, numbers of migrants, percent migration, mean fork length, weight, and condition factors of smolt migrants are located in Figures 21 and 22 and Table 6 and 7.

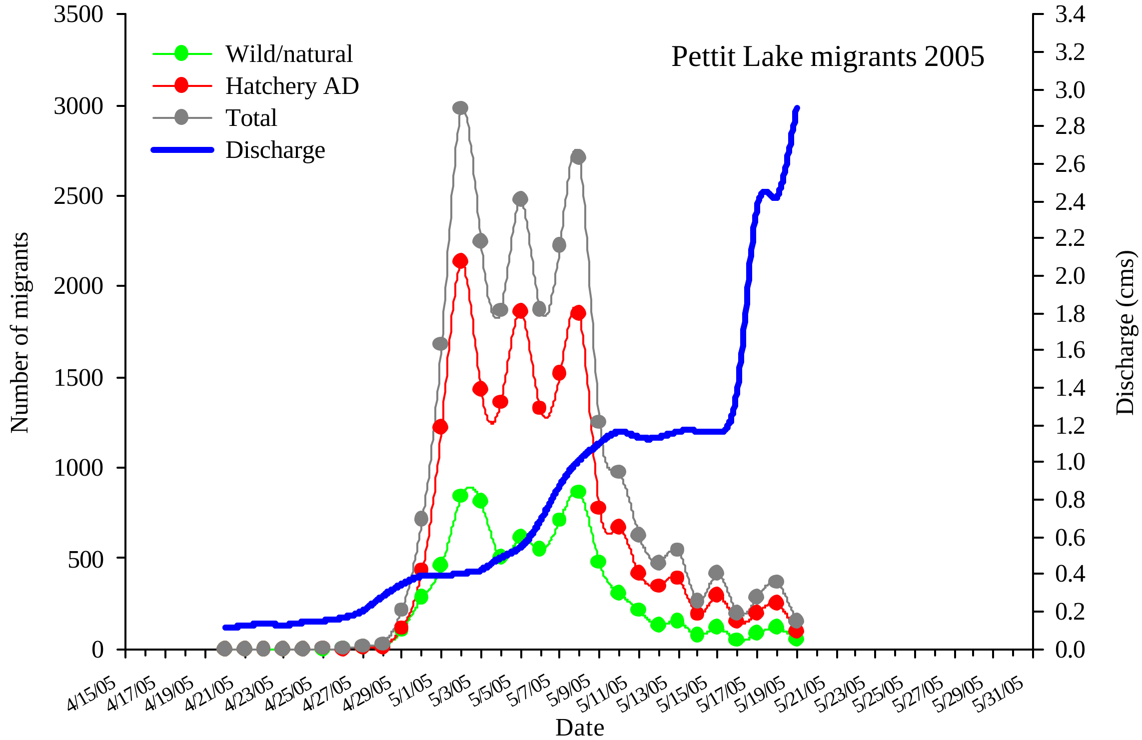


Figure 21. Pettit Lake migrant trapping data and hydrograph, 2005.

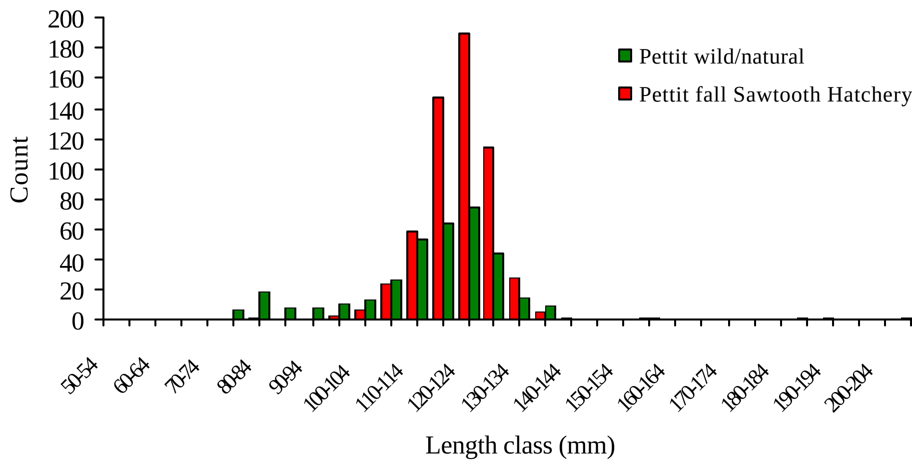


Figure 22. Pettit Lake migrant length frequency histogram, 2005.

Alturas Lake

We captured 381 *O. nerka* without an adipose fin clip (wild/natural) with a population estimate of 6,747 (3,188-14,104). We captured 1,596 hatchery sockeye salmon smolts with a corresponding estimate of 16,422 (10,179-30,492). The hatchery sockeye salmon captured were from the fall 2004 release of 20,129 Sawtooth Hatchery reared fish. We PIT tagged 405 hatchery fish and recaptured 52 previously tagged sockeye salmon. There were no mortalities during trapping operations. We also captured 465 juvenile Snake River Chinook salmon smolts and 84 fry with no mortalities.

Smolts migrating from Alturas Lake had a migration rate of 81.6 %. Migrant timing and discharge, length frequency histograms, release numbers, number of migrants, percent migration, mean length, weight, and condition factors of smolt migrants are located in Figures 23 and 24 and Table 6 and 7.

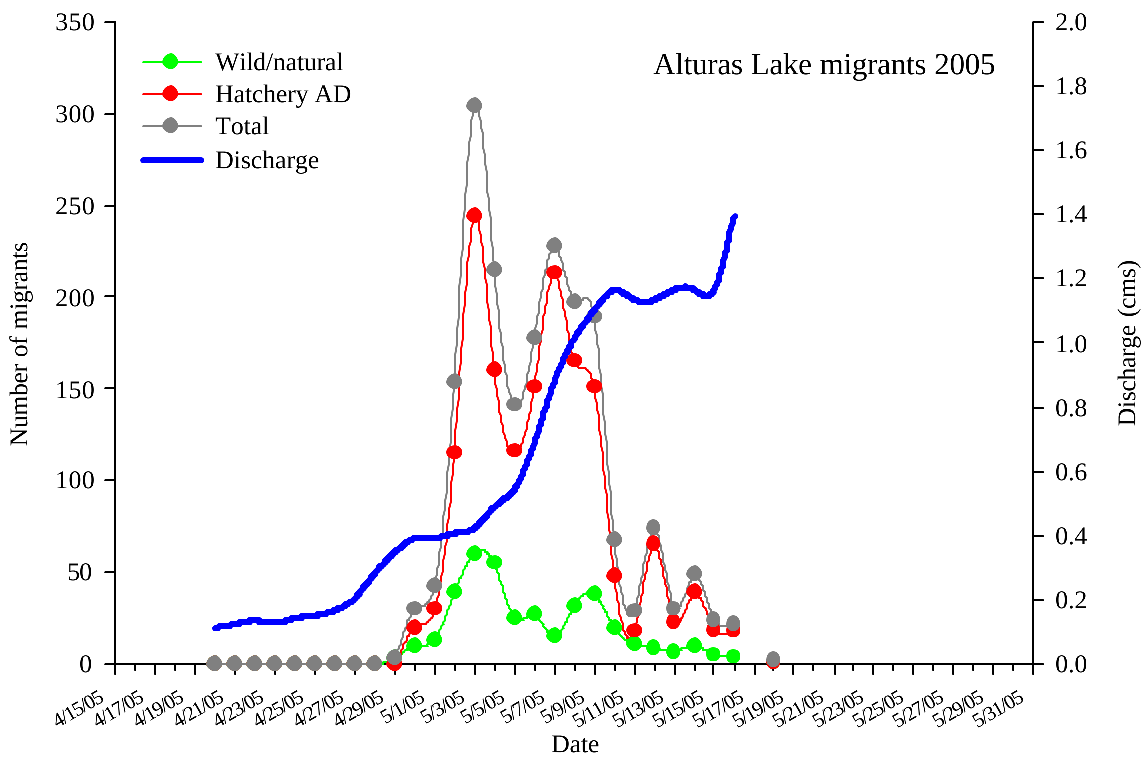


Figure 23. Alturas Lake migrant trapping data and hydrograph, 2005.

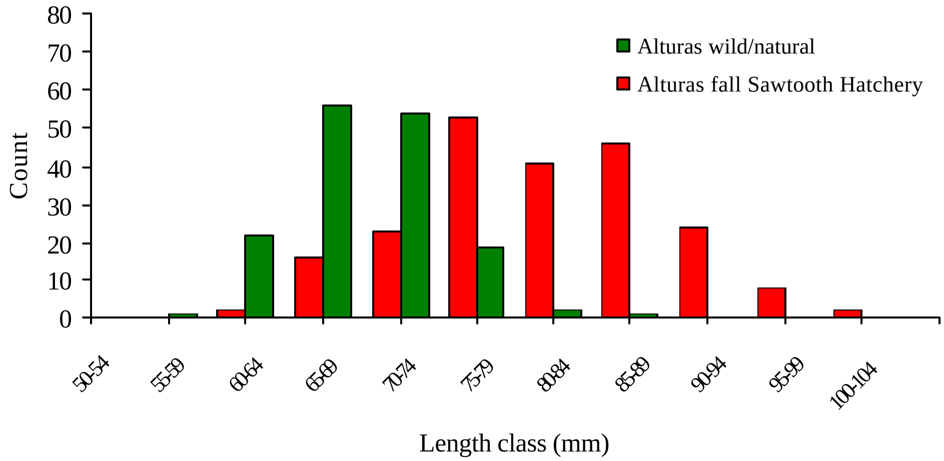


Figure 24. Alturas Lake migrant length frequency histogram, 2005

Table 6. Pettit and Alturas lake sockeye salmon release and percent migration data, 1995-2005.

Lake	Release year	Release season	Hatchery origin	Mark	Number released	migration year	Estimator method	Number of migrants	Percent migration
Pettit	2004	Fall	Sawtooth	AD	30,700	2005	Total count	16,824	55.50
Pettit	2003	Fall	Sawtooth	AD	14,961	2004	Total count	5,227	34.94
Pettit	2002	Fall	Sawtooth	AD	19,981	2003	Total count	11,758	58.85
Pettit	2002	Summer	Bonneville	ADRV	7,805	2003	Total count	1,579	20.23
Pettit	2001	Fall	Sawtooth	AD	4,993	2002	Total count	1,451	29.06
Pettit	2001	Summer	Sawtooth	ADRV	2,998	2002	Total count	200	6.67
Pettit	2001	Summer	Eagle	ADLV	3,059	2002	Total count	152	4.97
Pettit	2000	Fall	Sawtooth	AD	6,067	2001	Total count	1,756	28.94
Pettit	2000	Summer	Eagle	ADRV	2,915	2001	Total count	57	1.96
Pettit	2000	Summer	Sawtooth	ADLV	3,092	2001	Total count	156	5.05
Pettit	1999	Fall	Sawtooth	AD	3,430	2000	Granite[1]	1,593	46.44
Pettit	1998	Summer	Eagle		7,246	1999	Total count	4,478	61.80
Pettit	1997	Summer			8,643	1998	Total count	950	10.99
Pettit	1995	Summer			8,527	1996	Total count	2,640	30.96
Alturas	2004	Fall	Sawtooth	AD	20,129	2005	ML estimate	16,422	81.58
Alturas	2003	Fall	Sawtooth	AD	2,017	2004	TE estimate	1,091	54.09
Alturas	2002	Summer	Bonneville	ADRV	6,123	2003	TE estimate	553	9.03
Alturas	2001	Fall	Sawtooth	AD	5,990	2002	ML estimate	3,505	58.51
Alturas	2001	Summer	Sawtooth	ADRV	3,059	2002	TE estimate	72	2.35
Alturas	2001	Summer	Eagle	ADLV	3,064	2002	TE estimate	51	1.66
Alturas	2000	Fall	Sawtooth	AD	6,003	2001	TE estimate	4,520	75.30
Alturas	2000	Summer	Eagle	ADRV	2,917	2001	TE estimate	14	0.48
Alturas	2000	Summer	Sawtooth	ADLV	3,069	2001	TE estimate	476	15.51
Alturas	1999	Fall	Sawtooth	AD	12,995	2000	TE estimate	4,416	33.98
Alturas	1998	Fall	Sawtooth	AD	39,377	1999	TE estimate	11,847	30.09
Alturas	1997	Fall	Saw/Eag	AD	72,496	1998	TE estimate	28,300	39.04
Alturas	1997	Summer			22,250	1998	TE estimate	4,192	18.84

[1] Number of Pettit Lake migrants was estimated from interrogations at lower granite dam.

Growth Rates

Juvenile sockeye salmon from the captive broodstock program were measured and weighed during three different periods in Pettit and Alturas lakes: at release into the lakes in 2004; during mid-winter sampling; and at capture as smolts in 2005. Redfish Lake fish were measured at release and again at capture as smolt migrants. Their growth (fork length and weight) increased in Redfish and Pettit lakes; however, condition factor decreased from the time of release to the time of capture as smolts in the two lakes. Alturas Lake sockeye salmon decreased in weight and condition factor during the same period (Figures 25a; 25b; 25c; Tables 7 and 8). Fall release fish in Pettit Lake exhibited the greatest increase in weight.

Table 7. Hatchery sockeye salmon release and migration length, weight, and condition factor data, 1998-2005.

Lake	Release date	Mark	Hatchery origin	Release mean length (mm)	Release mean weight (g)	Release Mean condition factor (k)	Release sample size	Migration year	Smolt length (mm)	Smolt mean weight (G)	Smolt Mean condition factor (K)	Smolt sample size
RFL	10/05/04	AD	Sawtooth	91.59	8.12	1.02	211	2005	108.30	9.87	0.77	1,058
	10/7/03	AD	Sawtooth	105.67	10.99	0.92	302	2004	108.82	10.55	0.81	61
	10/8/02	AD	Sawtooth	111.87	15.31	1.09	995	2003	124.16	16.84	0.88	741
	8/29/02	ADRV	Bonneville	104.00	9.51	0.85	900	2003	126.50	17.27	0.85	670
	10/8/01	AD	Sawtooth	110.70	13.78	0.99	20	2002	125.42	15.73	0.96	1,204
	10/13/00	AD	Sawtooth	104.70	11.11	0.93	20	2001	115.69	13.49	0.86	1,391
	10/13/99	AD	Sawtooth	100.52	9.76	0.95	104	2000	114.49	11.98	0.79	107
	10/14/98			101.11	10.62	1.03	300	1999	107.97	9.08	0.74	31
PET	10/04/04	AD	Sawtooth	105.01	11.49	0.98	202	2005	115.53	13.84	0.89	524
	10/7/03	AD	Sawtooth	103.14	10.72	0.97	300	2004	123.19	17.78	0.95	696
	10/8/02	AD	Sawtooth	111.90	14.81	1.03	999	2003	126.53	18.16	0.89	617
	8/27/02	ADRV	Bonneville	102.23	8.89	0.83	574	2003	138.30	23.47	0.87	174
	10/8/01	AD	Sawtooth	110.70	13.78	0.99	20	2002	146.88	29.66	0.92	520
	7/30/01	ADRV	Sawtooth	72.75	3.63	0.93	20	2002	161.19	38.73	0.92	114
	7/26/01	ADLV	Eagle	110.35	14.19	1.05	20	2002	168.45	43.71	0.91	87
	10/12/00	AD	Sawtooth	104.70	11.11	0.93	20	2001	128.12	18.61	0.88	137
	7/28/00	ADRV	Eagle	97.42	8.45	0.91	50	2001	121.29	16.99	0.94	7
	7/27/00	ADLV	Sawtooth	66.50	2.95	0.99	50	2001	125.40	17.45	0.87	15
	10/13/99	AD	Sawtooth	101.22	10.45	1.00	104	2000	----	----	----	----
	7/14/98	AD	Eagle	93.56	8.69	1.06	1507	1999	120.63	15.23	0.85	79
ALT	10/04/04	AD	Sawtooth	105.67	11.68	0.97	211	2005	106.04	10.80	0.90	211
	10/7/03	AD	Sawtooth	93.99	7.95	0.95	99	2004	101.21	8.08	0.77	52
	8/27/02	ADRV	Bonneville	101.48	8.71	0.83	694	2003	111.81	12.99	0.83	16
	10/8/01	AD	Sawtooth	110.70	13.78	0.99	20	2002	112.21	10.56	0.73	380
	7/30/01	ADRV	Sawtooth	72.75	3.63	0.93	20	2002	94.83	6.12	0.71	12
	7/26/01	ADLV	Eagle	110.35	14.19	1.05	20	2002	97.60	7.40	0.69	5
	10/11/00	AD	Sawtooth	104.70	11.11	0.93	20	2001	104.41	9.21	0.78	129
	7/28/00	ADRV	Eagle	97.42	8.45	0.91	50	2001	----	----	----	----
	7/27/00	ADLV	Sawtooth	66.50	2.95	0.99	50	2001	90.84	6.27	0.82	19
	10/13/99	AD	Sawtooth	105.59	10.79	0.94	99	2000	109.93	10.52	0.79	127
	10/14/98	AD	Sawtooth	99.39	10.30	1.05	847	1999	107.85	10.02	0.79	75

RFL= Redfish Lake, PET= Pettit Lake, ALT=Alturas Lake

Table 8. Specific growth rate data 1999-2005.

Lake	Hatchery	Release type	Year	Specific growth (L)	Specific growth (W)
RED	Sawtooth	AD fall	1999	0.0294	-0.0793
RED	Sawtooth	AD fall	2000	**0.0580**	**0.1031**
RED	Sawtooth	AD fall	2001	**0.0482**	**0.1101**
RED	Sawtooth	AD fall	2002	**0.0564**	**0.124**
RED	Sawtooth	AD fall	2003	0.0475	0.0482
RED	Bonneville	summer	2003	0.0752	0.274
RED	Sawtooth	AD fall	2004	0.0242	0.0018
RED	Sawtooth	AD fall	2005	0.0517	0.0532
PET	Eagle	summer	1999	0.0584	0.1084
PET	Sawtooth	summer	2001	**0.2183**	**0.6103**
PET	Sawtooth	AD fall	2001	**0.1028**	**0.2849**
PET	Eagle	summer	2002	**0.1390**	**0.3686**
PET	Sawtooth	summer	2002	**0.2718**	**0.8131**
PET	Sawtooth	AD fall	2002	**0.1190**	**0.3222**
PET	Sawtooth	AD fall	2003	0.043	0.0573
PET	Bonneville	summer	2003	0.1219	0.3836
PET	Sawtooth	AD fall	2004	0.0782	0.2272
PET	Sawtooth	AD fall	2005	0.0482	0.1132
ALT	Sawtooth	AD fall	1999	**0.0335**	**-0.0275**
ALT	Sawtooth	AD fall	2000	**0.0313**	**0.0315**
ALT	Sawtooth	summer	2001	**0.1096**	**0.2645**
ALT	Sawtooth	AD fall	2001	**0.0002**	**-0.0846**
ALT	Sawtooth	summer	2002	**0.0945**	**0.1893**
ALT	Sawtooth	AD fall	2002	**0.0059**	**-0.1263**
ALT	Bonneville	summer	2003	**0.0342**	**0.1097**
ALT	Sawtooth	AD fall	2004	0.0132	-0.0057
ALT	Sawtooth	AD fall	2005	**0.0187**	**-0.0135**

Bold= group means used to calculate growth instead of individual pit tag data

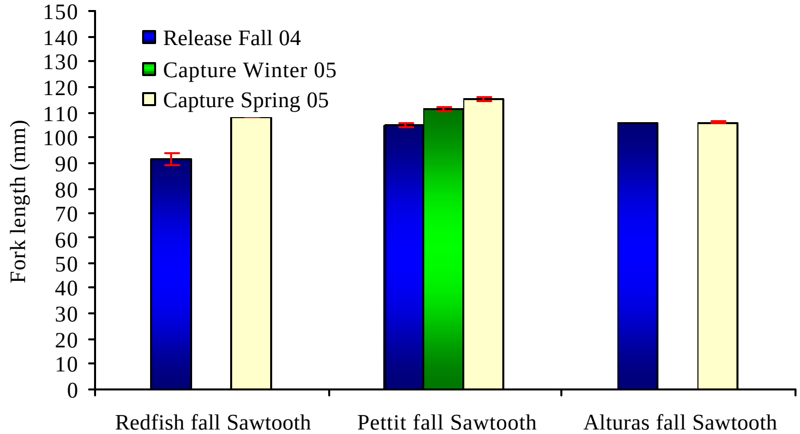


Figure 25a. Redfish, Pettit, and Alturas lakes growth rate evaluation using length data. Error bars are (±) one standard error.

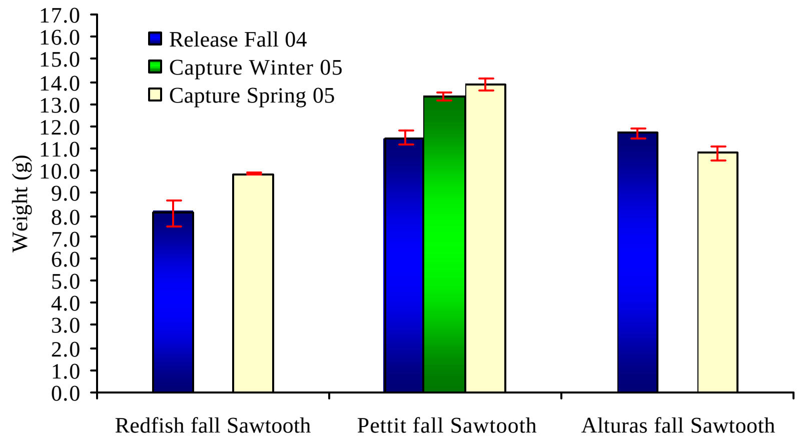


Figure 25b. Redfish, Pettit, and Alturas lakes growth rate evaluation using weight data. Error bars are (±) one standard error.

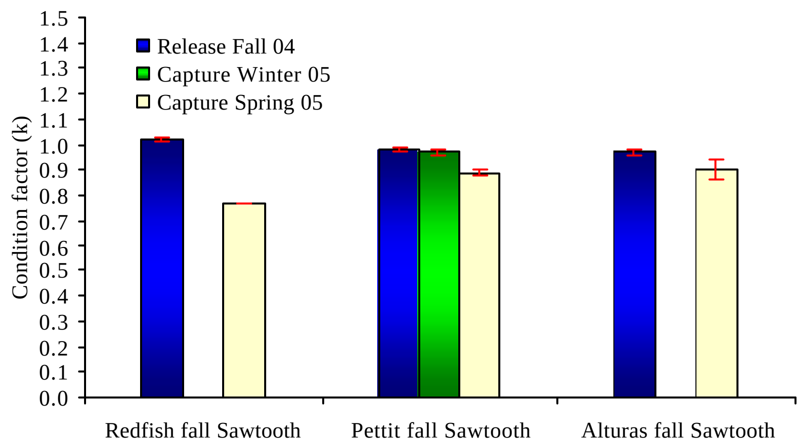


Figure 25c. Redfish, Pettit, and Alturas lakes growth rate evaluation using condition factor data. Error bars are (±) one standard error.

Stream Spawning

Starting in 2000, escapement of adult kokanee salmon to Fishhook Creek increased each year until effective kokanee salmon control efforts were achieved in 2004. Kokanee salmon adult escapement in Fishhook Creek decreased 84% from 9,679 adult spawners in 2003 to 1,508 adult spawners in 2004. Then, in 2005, kokanee escapement increased 190% to 4,375 spawners. Escapement in Alturas Lake Creek reached an all time low of forty-eight spawners in 2003; however, 2004 adult escapement increased dramatically to 7,101 adults. In 2005, esapement increased again to 11,652, a 64% increase from 2004 numbers. Stanley Lake Creek escapement was higher at 2,725 fish, a 1,095% increase from the 2004 escapement of 228 fish. Escapement numbers, run timing, length and fecundity data, and fry recruitment estimates are found in Figures 26-29 and Table 9.

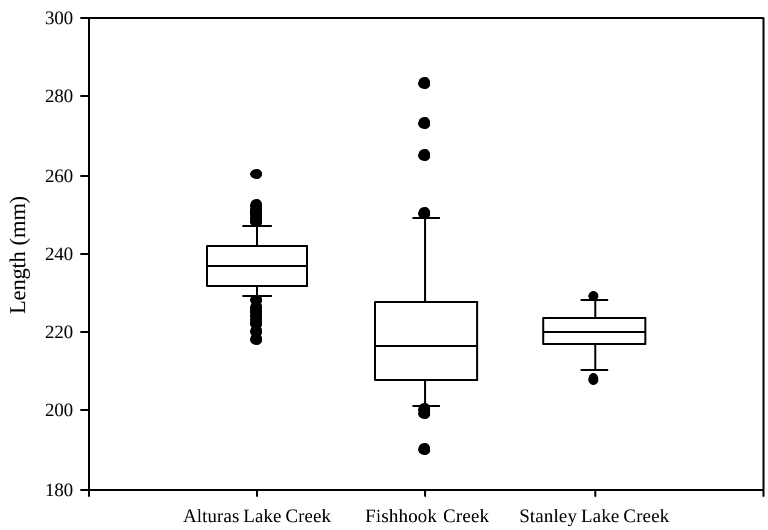


Figure 26. Alturas Lake Creek, Fishhook Creek, and Stanley Lake Creek kokanee salmon length data.

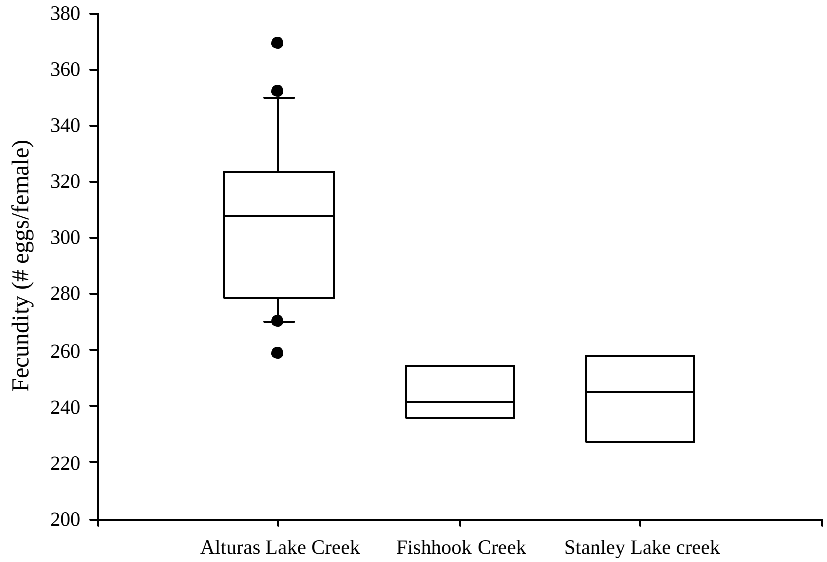


Figure 27. Alturas Lake Creek, Fishhook Creek, and Stanley Lake Creek kokanee salmon fecundity data.

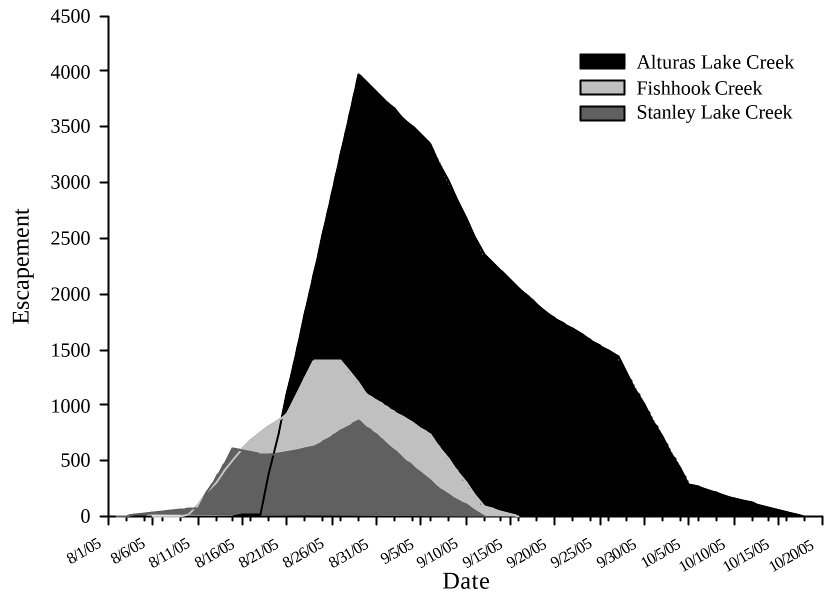


Figure 28. Alturas Lake Creek, Fishhook Creek, and Stanley Lake Creek kokanee salmon run timing.

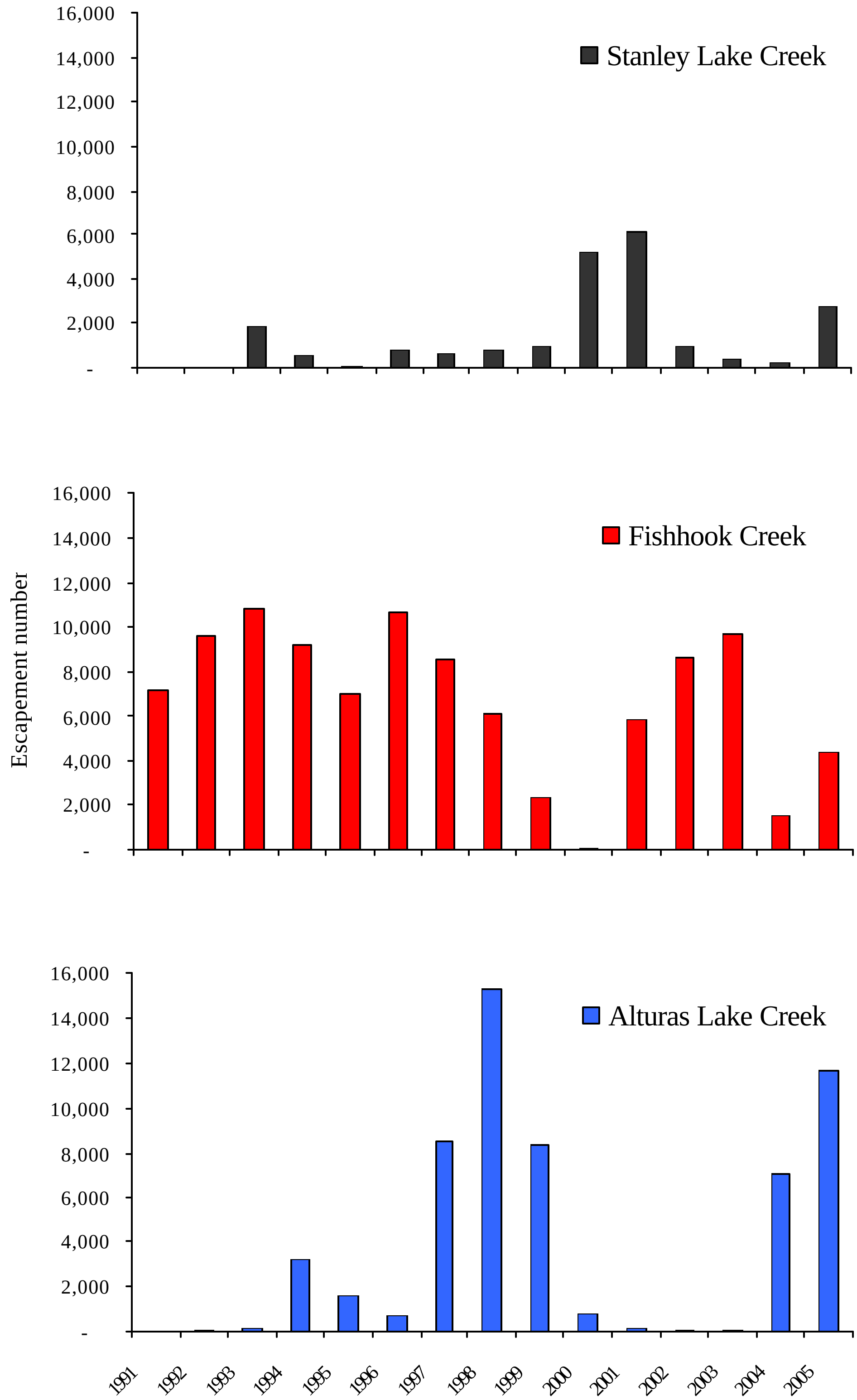


Figure 29. Stanley Lake Creek, Fishhook Creek, and Alturas Lake Creek kokanee salmon escapement numbers 1991-2005.

Table 9. Fry recruitment, egg-to-fry survival, and adult escapement in Fishhook, Alturas, and Stanley Lake creeks.

Location	Brood year	Adult escapement	Mean # eggs	Male:female ratio	Egg-Fry survival	Fry recruits
Fishhook	2005	4,375	244	1:1	12.3%	65,651
	2004	1,508	429	2:1	12.3%	28,008
	2003	9,679	453	3.6:1	12.3%	117,240
	2002	8,626	281	1.7:1	12.3%	110,422
	2001	5,853	272	1.5:1	12.3%	78,327
	2000	60	148	2.4:1	12.3%	321
	1999	2,336	233	1:1	12.3%	33,474
	1998	6,149	233	4.6:1	12.3%	35,549
	1997	8,572	233	1.4:1	12.3%	102,360
	1996	10,662	286	3:1	13.1%	99,866
	1995	7,000	230	1:1	12.3%	99,015
	1994	9,200	230	1:1	13.6%	143,888
	1993	10,800	230	1:1	11.5%	142,830
	1992	9,600	300	1:1	11.5%	165,600
	1991	7,200	300	1:1	3.3%	35,640
Alturas	2005	11,652	305	1:1	13.0%	231,758
	2004	7,101	269	3:1	13.0%	62,080
	2003	48	150	1:1	13.0%	468
	2002	99	150	1:1	13.0%	965
	2001	145	150	1:1	13.0%	1,414
	2000	827	339	1:1	13.0%	18,223
	1999	8,334	285	1:1	13.0%	154,387
	1998	15,273	220	1:1	13.0%	217,889
	1997	8,492	168	1:1	13.0%	92,733
	1996	744	150	1:1	13.0%	7,254
	1995	1,600	150	1:1	13.0%	15,600
	1994	3,200	150	1:1	13.0%	31,200
	1993	200	-	1:1	13.0%	2,000
Stanley	2005	2,725	242	1:1	7.0%	23,081
	2004	228	150	1:1	7.0%	1,197
	2003	413	270	1:1	7.0%	3,903
	2002	946	270	1:1	7.0%	8,940
	2001	6,180	257	1:1	7.0%	55,589
	2000	5,665	243	1:1	7.0%	48,181
	1999	948	270	1:1	7.0%	16,637
	1998	783	270	1:1	7.0%	7,399
	1997	629	270	1:1	7.0%	5,935
	1996	825	270	1:1	7.0%	7,796
	1995	90	270	1:1	7.0%	850
	1994	600	270	1:1	7.0%	5,670
	1993	1,900	-	1:1	7.0%	19,000

Beach Spawning

We snorkeled in Redfish Lake to enumerate beach spawning residual sockeye salmon and captive reared adult sockeye salmon. Two areas were snorkeled: Sockeye Beach and the southeast inlet area. A dramatic increase in the number of residual sockeye salmon spawners observed in Redfish Lake occurred in 2004. The highest peak counts were 345 and 21 at Sockeye Beach and the southeast inlet area, respectively. These were the highest peak counts since 1994 at the southeast inlet and the highest numbers observed to date at Sockeye Beach (Figure 30a). In 2005, peak counts were 28 and 30 at Sockeye Beach and the southeast inlet area, respectively. Trap nets were set on four occasions in the Sockeye Beach area to capture residual sockeye salmon. Two male residual spawners, representing ~7% of the peak count, were trapped using a fyke net and genetic tissue samples were collected.

Redside shiners represented the largest composition of all the fish species observed during snorkeling at Sockeye Beach and the southeast inlet (Figure 30b).

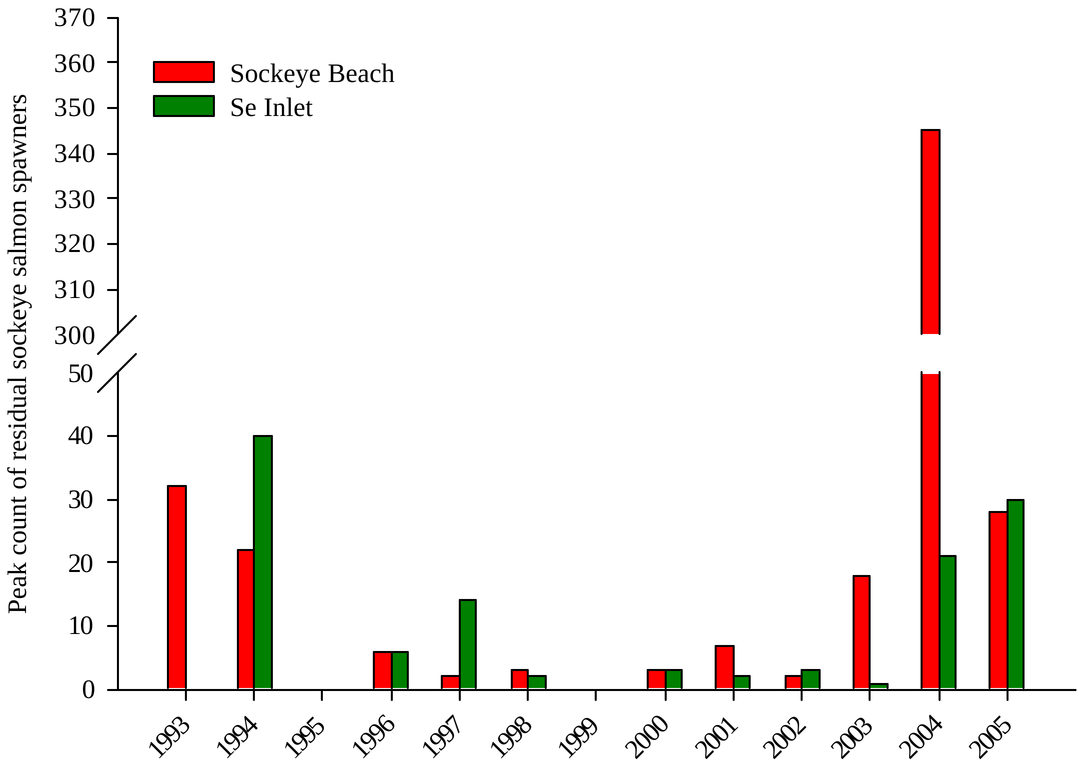


Figure 30a. Redfish Lake residual sockeye salmon counts from snorkel surveys (1995 data not available).

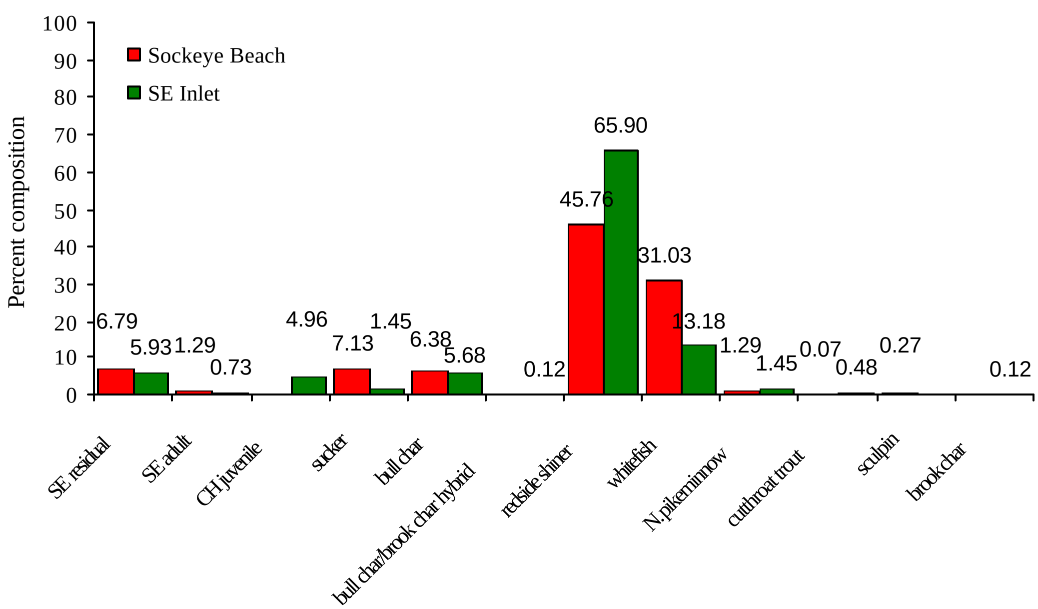


Figure 30b. Redfish Lake residual sockeye salmon snorkel survey species composition data at SE Inlet and Sockeye Beach, 2005.

Hydroacoustic Population Estimates

Hydroacoustic estimates of *O. nerka* in the Sawtooth Valley lakes during October 2005 revealed densities ranging from 303 fish/ha (49,137 total abundance) to 101 fish/ha (34,258 total abundance) in Pettit and Alturas lakes, respectively (Table 10). Redfish Lake was intermediate with an estimated *O. nerka* population of 191 fish/ha (117,327).

Table 10. Hydroacoustic and trawl nerkoid population estimates for three Sawtooth Valley lakes, 1994-2005.

	Population Estimate	(± 95% C.I)	density(fish/ha)		Biomass (kg/ha)	
LAKE	**Acoustic**	**Trawl**	**Acoustic**	**Trawl**	**Acoustic**	**Trawl**
REDFISH 2005	117,327 ± 43,015	56,219 ± 4,192	191	91	2.94	0.3
2004		82,258 ± 35,922		134		0.3
2003	130,087 ± 29,979	81,727 ± 25,995	212	133	4.13	1.60
2002	61,535 ± 11,597	50,204 ± 28,485	100	82	2.82	1.00
2001	43,849 ± 16,747	12,980 ± 11,982	71	21	0.71	0.10
2000	24,481 ± 10,520	10,268 ± 5,675	40	17	0.41	0.07
1999	69,472 ± 29,887	42,916 ± 13,097	113	70	1.66	0.93
1998	107,613 ± 33,615	31,485 ± 10,839	175	51	2.50	1.79
1997	131,513 ± 32,319	55,762 ± 13,961	214	91	3.37	2.48
1996	66,325 ± 24,000	56,213 ± 27,306	108	91	2.23	2.83
1995	103,570 ± 24,500	61,646 ± 27,639	168	100	3.41	4.36
1994	133,360	51,529 ± 33,179	217	84	2.39	1.41
PETTIT 2005	49,138 ± 16,410	23,970 ± 2,136	303	148	8.44	2.2
2004		46,065 ± 22,258		287		9.8
2003	19,805 ± 13,234	11,961 ± 3,255	122	74	6.19	5.5
2002	25,642 ± 10,949	18,328 ± 2,351	158	115	8.91	12.00
2001	37,410 ± 24,864	16,931 ± 7,556	231	105	9.08	6.10
2000	40,435 ± 20,977	40,559 ± 11,717	250	250	9.04	10.20
1999	51,496 ± 12,171	31,422 ± 21,280	318	194	9.76	6.33
1998	67,206 ± 30,950	27,654 ± 8,764	415	171	13.47	9.74
1997	63,195 ± 29,581	21,730 ± 11,262	390	134	23.25	5.10
1996	77,680 ± 15,850	71,655 ± 10,631	480	442	36.23	15.19
1995	77,765 ± 46,900	59,002 ± 15,735	480	364	34.16	14.73
1994	12,265 ± 8,360	14,743 ± 3,683	76	91	4.67	3.12
ALTURAS 2005	34,258 ± 59,226	20,995 ± 2,136	101	62	2.24	0.3
2004		36,206 ±14,170		107		1.9
2003	48,671 ± 14,564	46,234 ± 26,442	144	137	6.37	5.5
2002	53,339 ± 15,625	24,374 ± 16,968	158	72	4.01	2.20
2001	130,359 ± 29,446	70,159 ± 18,642	386	208	3.16	2.40
2000	134,867 ± 33,244	125,462 ± 27,037	399	371	6.12	2.08
1999	130,133 ± 25,936	56,675 ± 43,536	385	168	4.20	0.40
1998	101,519 ± 32,605	65,468 ± 33,479	300	194	2.09	1.42
1997	30,795 ± 5,869	9,761 ± 4,664	91	29	2.34	2.10
1996	20,620 ± 4,140	13,012 ± 4,668	61	39	0.97	1.34
1995	32,260 ± 5,090	23,061 ± 9,182	95	68	3.31	1.66
1994	10,980 ± 1,090	5,785 ± 6,919	33	17	1.07	0.43

Prior to 2005 Redfish Lake had experienced a population decline beginning in 2000. Pettit Lake experienced a slow decline in *O. nerka* since 1998 and then rebounded in 2005. Alturas Lake experienced a dramatic decline in 2002 and continued that trend through 2005. Alturas Lake appears to be experiencing a low cycle for the second time since we began sampling in the early 1990's.

Redfish Lake- In 2005, the total nerkoid population in Redfish Lake decreased since the last hydroacoustic survey in 2003. Both the hydroacoustic and trawl estimates of the YOY cohort were greater than our estimate of fry recruits from 2004 spawning in Fishhook Creek (Table 9). This could be an indicator of production from the 241 captive reared adults that were released in 2004. We are not allowed to set vertical gill nets in Redfish Lake so we assume every fish tracked in the pelagia is an *O. nerka*, and that no *O. nerka* are in the littoral zone when we sample.

Pettit Lake- The total *O. nerka* population in Pettit Lake increased 148% since the 2003 survey. Prior to 2003, Pettit Lake's population had experienced a five year decline. The 71-110 mm cohort, which could possibly represent fish from egg boxes and residual spawning, had the highest estimate compared to the other size class bins.

Alturas Lake- Whole lake *O. nerka* population estimates in Alturas Lake have experienced a continuous decline from the record high of 134,867 in 2000.

Table 11. Total lake and cohort population estimates from hydroacoustic sampling in 2005.

Size class (mm)		mean length (mm)	mean weight (g)	biomass	kg/ha
Redfish Lake					
Whole Lake=	117,327 ± 43,015				
37-90	59,919 ± 21,730	66	3.21	192.3	0.31
91-130	31,425 ± 15,773	106	12.48	392.3	0.64
131-180	19,146 ± 9,557	153	37.72	722.2	1.17
181+	6,828 ± 3,481	193	74.09	505.9	0.82
Pettit Lake					
Whole Lake =	49,138 ± 16,410				
30-70	8,894 ± 12,973	60	2.36	21.0	0.13
71-110	16,686 ± 6,592	88	8.02	133.8	0.83
111-160	13,460 ± 5,432	136	32.59	438.7	2.71
161+	10,090 ± 4,301	178	76.60	773.0	4.77
Alturas Lake					
Whole Lake =	34,258 ± 59,226				
30-70	8,871 ± 15,022	57	1.99	17.7	0.05
71-110	12,159 + 21,074	86	7.46	90.7	0.27
111-160	8,706 ± 14,774	137	33.59	292.4	0.87
171-200	4,522 ± 9,731	179	79.08	357.6	1.06

Hydroacoustic/trawl comparisons

Hydroacoustic/trawl ratios in 2005 were 2.10, 2.05, and 1.63 for Redfish, Pettit, and Alturas lakes, respectively. Parkinson et al. (1994) found ratios ranging from 3.3 to 1.8 in a comparison of these two methods. The eleven year mean hydroacoustic/trawl ratios are 2.14 for Redfish Lake and 1.79 for Alturas Lake. The eight year mean for Pettit Lake is 1.91.

Correlating hydroacoustic and trawl population estimates varied by comparison. Correlating eleven years (n=33) of total lake *O. nerka* estimates reveals a relationship of r=0.85 (Figure 31a). Because of the trawls inability to capture fish from every cohort, incomplete data sets are used for those comparisons. For yearling fish the r value was

0.87 (n=23) (Figure 31b). The r value was 0.58 (n=25) for the age one cohort and 0.85 (n=25) for the two year old cohort.

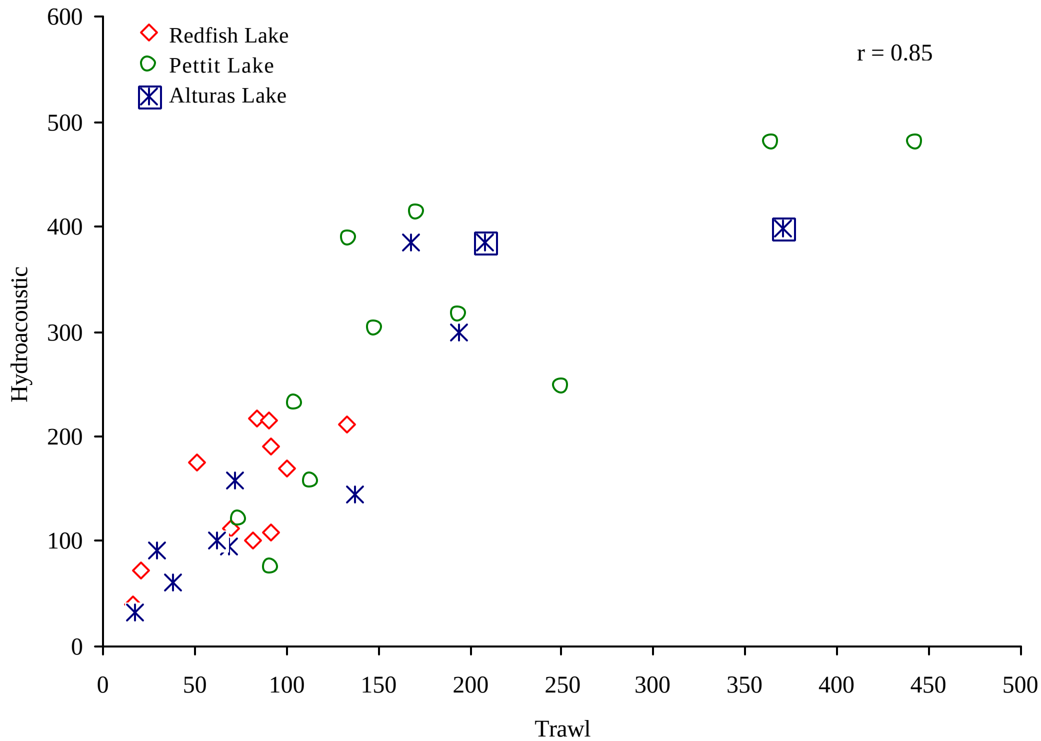


Figure 31a. Correlation of hydroacoustic/trawl whole lake nerkoid population estimates (fish/ha) for 1994-2005.

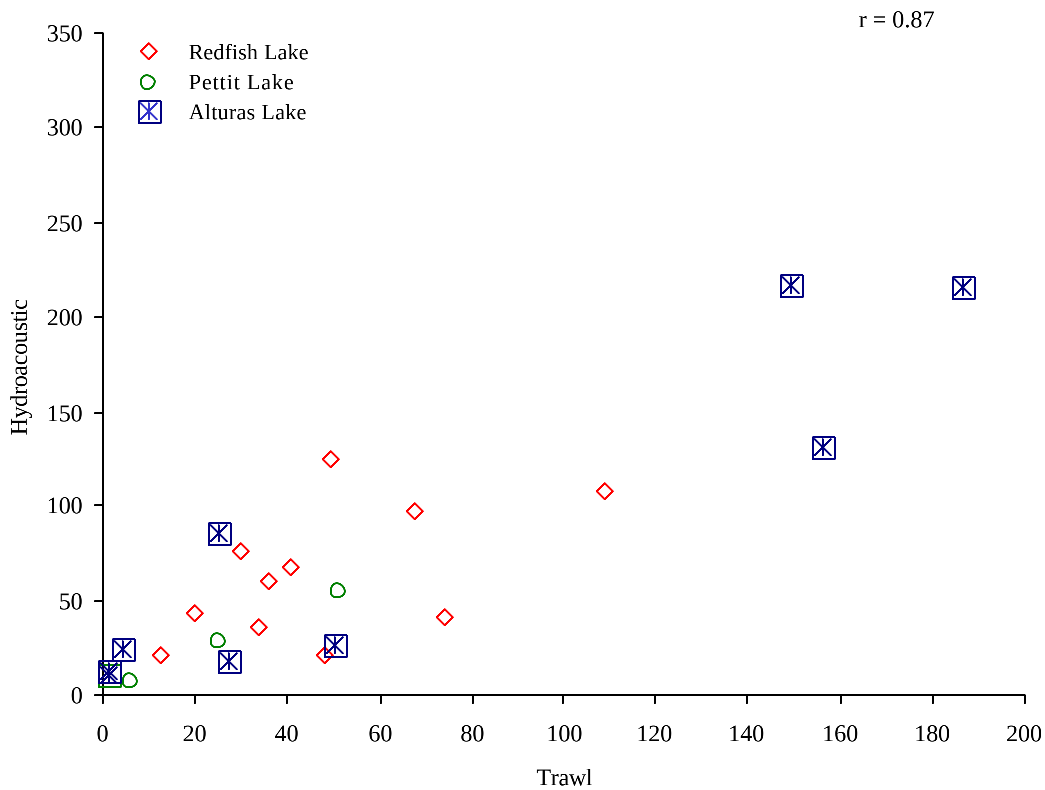


Figure 31b. Correlation of hydroacoustic/trawl YOY nerkoid estimates (fish/ha) for 1994-2005.

Gillnet Sampling

We conducted vertical and horizontal gillnet sampling in Pettit and Alturas lakes during 2005. Fish species captured during 2005 sampling events included: sockeye salmon; kokanee salmon; rainbow trout; bull char; mountain whitefish; northern pikeminnow; sucker, and brook char. Results including location sampled, set type, sample size, catch per unit effort, species sampled, mean fork length, mean weight, and total hours fished are summarized in Table 12.

Diet Analysis

We analyzed stomach contents for diet composition in Redfish, Pettit, and Alturas lake samples collected in 2005. Samples were drawn from gillnet and trawling efforts conducted by the SBT and IDFG, respectively. Summarized data including Pettit Lake fish community prey items as a percent of total stomach contents (Table 13), sockeye salmon and *O. nerka* vertical gillnet and trawl diet composition, fork length, weight, and condition factor (Table 14), and sockeye salmon and *O. nerka* electivity indices (Table 15) are presented.

Pettit Lake Egg Boxes

During November of 2005, in conjunction with IDFG personnel, we placed a total of 51,239 eyed sockeye salmon eggs in shoal areas of Pettit Lake.

Table 12. Results of Pettit and Alturas lake gillnet samples, 2005.

Date	Station	Set type	(n) CPUE	Mean L (mm)	Mean W (g)	Hrs fished
			Pettit Lake			
Rainbow Trout						
March 08, 2005	A	horizontal	(3) 0.13	267.7	153.0	22.9
June 28, 2005	A	horizontal	(6) 0.31	263.2	----	19.5
Bull Char						
March 08, 2005	A	horizontal	(5) 0.22	389.8	745.0	22.9
March 09, 2005	E	vertical	(2) 0.10	400.0	----	20.5
June 28, 2005	A	horizontal	(6) 0.31	419.0	900.0	19.5
Brook Char						
March 08, 2005	A	horizontal	(1) 0.04	287.0	262.7	22.9
Whitefish						
June 28, 2005	A	horizontal	(1) 0.05	210.0	----	19.5
Northern Pikeminnow						
March 08, 2005	A	horizontal	(3) 0.13	230.7	162.4	22.9
June 28, 2005	A	horizontal	(18) 0.92	246.8	----	19.5
O. nerka						
January 26, 2005	E	vertical	(6) 0.28	127.8	28.0	21.8
February 15, 2005	E	vertical	(18) 0.75	149.0	39.3	24.0
March 09, 2005	E	vertical	(5) 0.24	148.0	37.2	20.5
June 28, 2005	E	vertical	(8) 0.47	125.1	15.9	17.0
Sockeye salmon						
January 26, 2005	E	vertical	(2) 0.09	109.0	12.8	21.8
February 15, 2005	E	vertical	(29) 1.21	114.8	15.8	24.0
March 09, 2005	E	vertical	(8) 0.39	132.1	26.4	20.5
Sucker						
June 28, 2005	A	horizontal	(11) 0.56	----	----	19.5
			Alturas Lake			
O. nerka						
March 08, 2005	Boat r.	vertical	(6) 0.27	187.2	66.2	22.2
June 29, 2005	Boat r.	vertical	(4) 0.25	208.0	88.5	16.1
Sockeye salmon						
March 08, 2005	Boat r.	vertical	(1) 0.27	187.2	66.2	22.2
June 29, 2005	Boat r.	vertical	(1) 0.06	96.0	8.6	16.1
Bull Char						
March 08, 2005	Boat R	vertical	(4) 0.18	----	----	22.2
June 29, 2005	Boat r.	vertical	(1) 0.06	----	----	16.1

Table 13. Fish community horizontal gillnet sample and percent diet composition data from Pettit Lake, 2005.

Date	Species	Sample size	Percent diet composition										
3/09/05	**Rainbow Trout**	**2**											
			SAL	CYP	UN.F.	MOL	ODO	HEM	CH.P.	CH.L.	TER	PLA	OTH
			0.00	34.70	0.00	14.21	1.09	0.00	0.00	0.00	0.00	0.00	50.00
6/29/05		**6**											
			SAL	CYP	UN.F.	MOL	ODO	HEM	CH.P.	CH.L.	TER	PLA	OTH
			0.00	0.00	0.00	24.62	9.39	0.00	64.18	0.00	0.00	1.15	0.65
3/09/05	**Brook Char**	**1**											
			SAL	CYP	UN.F.	MOL	ODO	HEM	CH.P.	CH.L.	TER	PLA	OTH
			100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3/09/05	**Bull Char**	**3**							**----**				
			SAL	CYP	UN.F.	MOL	ODO	HEM	CH.P.	CH.L.	TER	PLA	OTH
			100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6/29/05		**2**											
			SAL	CYP	UN.F.	MOL	ODO	HEM	CH.P.	CH.L.	TER	PLA	OTH
			18.99	40.89	0.00	0.00	20.38	0.00	15.28	0.00	0.00	4.47	0.00
3/09/05	**N. Pikeminnow**	**2**							**----**				
			SAL	CYP	UN.F.	MOL	ODO	HEM	CH.P.	CH.L.	TER	PLA	OTH
			0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00
6/29/05		**8**											
			SAL	CYP	UN.F.	MOL	ODO	HEM	CH.P.	CH.L.	TER	PLA	OTH
			12.50	20.30	14.07	0.00	35.80	0.00	0.00	0.00	0.00	0.53	16.80
	M. Whitefish	**1**							**----**				
6/29/05			SAL	CYP	UN.F.	MOL	ODO	HEM	CH.P.	CH.L.	TER	PLA	OTH
			0.00	0.00	0.00	0.47	0.00	0.00	43.35	56.17	0.00	0.00	0.00

SAL=salmonid, CYP=cyprinid, UN.F.=unidentified fish, MOL=mollusk, ODO=odonate, HEM=hemiptera, CH.P.=chironomid pupae, CH.L.=chironomid larvae, TER=terrestrial, , PLA=plant, OTH=other

Table 14. Sockeye salmon and *O. nerka* vertical gillnet and trawl mean length, weight, condition factor, and zooplankton diet percent composition in Redfish, Pettit, and Alturas lakes, 2005.

Date	Lake	Set type	Species	Mark	Sample size	Age	Mean L (mm)	Mean W (g)	Condition factor (K)	Daph	Hol	Bos	Cal	Cyc	Naup	Poly
10/03/05	RED	trawl	*O. nerka*		6	0+	80.50	5.00	0.95	83.68	0.00	0.00	0.00	14.89	0.00	1.43
10/03/05	RED	trawl	*O. nerka*		4	1+	94.00	8.05	0.96	99.23	0.00	0.00	0.00	0.36	0.00	0.41
1/26/05	PET	vertical	SE	AD	2	1+	109.00	12.75	0.98	0.37	0.00	11.63	0.00	88.01	0.00	0.00
2/16/05	PET	vertical	SE	AD	9	1+	111.44	13.21	0.95	0.08	0.00	22.97	0.00	76.95	0.00	0.00
2/16/05	PET	vertical	*O. nerka*		9	1+	138.67	33.32	1.06	0.08	0.00	12.80	0.00	87.13	0.00	0.00
3/10/05	PET	vertical	SE	AD	7	1+	128.14	23.26	0.91	0.00	0.00	21.82	0.00	78.18	0.00	0.00
3/10/05	PET	vertical	*O. nerka*		5	1+	148.00	37.16	0.95	0.00	0.00	17.10	0.00	82.90	0.00	0.00
6/29/05	PET	vertical	*O. nerka*		7	1+	125.71	15.10	1.02	15.56	0.00	64.63	0.00	16.60	0.00	3.20
10/03/05	PET	trawl	*O. nerka*		5	0+	75.80	4.76	1.07	54.09	0.00	0.00	0.00	45.22	0.00	0.68
10/03/05	PET	trawl	*O. nerka*		5	1+	142.20	41.34	1.16	88.89	0.00	0.00	0.00	6.92	0.00	4.18
1/26/05	ALT	vertical	*O. nerka*		6	1+	127.83	28.02	0.99	0.26	0.00	5.71	0.00	94.03	0.00	0.00
3/09/05	ALT	vertical	*O. nerka*		6	1+	186.33	71.07	1.04	0.92	0.00	8.02	0.00	91.05	0.00	0.00
6/30/05	ALT	vertical	SE	AD	1	1+	96.00	8.60	0.97	0.00	0.00	59.53	0.00	40.47	0.00	0.00
6/30/05	ALT	vertical	*O. nerka*		3	1+	208.00	94.60	1.05	0.00	0.00	2.04	0.00	97.96	0.00	0.00
10/04/05	ALT	trawl	*O. nerka*		7	0+	60.43	2.07	0.88	1.02	0.00	0.46	0.00	96.62	0.00	1.90
10/04/05	ALT	trawl	*O. nerka*		3	1+	121.00	20.13	1.06	59.22	0.00	0.11	0.00	32.82	0.00	7.85

SE=Sockeye salmon, Daph=Daphnia, Hol=Holopedium, Bos=Bosmina, Cal=Calanoid, Cyc=Cyclopoid, Naup=Nauplii, Poly=Polyphemus

Table 15. Sockeye salmon and *O. nerka* gillnet and diet composition data including electivity indices (**E**), 2005 (* denotes only YOY sample).

Date	Lake	Set type	Species	n		Daph	Holo	Bosm	Cala	Cycl	Naup	Poly
10/03/2005	Redfish	trawl	*O. nerka* *	6	R_i	83.67	0.00	0.00	0.00	14.91	0.00	1.42
					P_i	82.45	2.45	0.38	1.62	6.84	6.24	0.00
					E	**0.01**	**-1.00**	**-1.00**	**-1.00**	**0.37**	**-1.00**	**1.00**
10/03/2005	Redfish	trawl	*O. nerka*	4	R_i	99.23	0.00	0.00	0.00	0.36	0.00	0.41
					P_i	82.45	2.45	0.38	1.62	6.84	6.24	0.00
					E	**0.09**	**-1.00**	**-1.00**	**-1.00**	**-0.90**	**-1.00**	**1.00**
02/16/2005	Pettit	vertical	SE	9	R_i	0.08	0.00	22.97	0.00	76.95	0.00	0.00
					P_i	0.16	0.00	47.79	0.00	23.72	28.34	0.00
					E	**-0.31**	**----**	**-0.35**	**----**	**0.53**	**-1.00**	**----**
02/16/2005	Pettit	vertical	*O. nerka*	9	R_i	0.08	0.00	12.80	0.00	87.13	0.00	0.00
					P_i	0.16	0.00	47.79	0.00	23.72	28.34	0.00
					E	**-0.35**	**----**	**-0.58**	**----**	**0.57**	**-1.00**	**----**
03/10/2005	Pettit	vertical	SE	7	R_i	0.00	0.00	21.82	0.00	78.18	0.00	0.00
					P_i	0.10	0.00	48.10	0.00	18.34	33.46	0.00
					E	**-1.00**	**----**	**-0.38**	**----**	**0.62**	**-1.00**	**----**
03/10/2005	Pettit	vertical	*O. nerka*	5	R_i	0.00	0.00	17.10	0.00	82.90	0.00	0.00
					P_i	0.10	0.00	48.10	0.00	18.34	33.46	0.00
					E	**-1.00**	**----**	**-0.48**	**----**	**0.64**	**-1.00**	**----**
06/29/2005	Pettit	vertical	*O. nerka*	7	R_i	15.56	0.00	64.63	0.00	16.60	0.00	3.20
					P_i	0.60	0.50	59.62	0.00	35.91	3.25	0.13
					E	**0.93**	**-1.00**	**0.04**	**----**	**-0.37**	**-1.00**	**0.92**
10/03/2005	Pettit	vertical	*O. nerka*	5	R_i	88.89	0.00	0.00	0.00	6.92	0.00	4.18
					P_i	37.24	0.69	3.30	0.48	0.00	35.52	22.77
					E	**0.41**	**-1.00**	**-1.00**	**-1.00**	**1.00**	**-1.00**	**-0.69**
10/03/2005	Pettit	vertical	*O. nerka* *	5	R_i	54.09	0.00	0.00	0.00	45.22	0.00	0.68
					P_i	37.24	0.69	3.30	0.48	0.00	35.52	22.77
					E	**0.18**	**-1.00**	**-1.00**	**-1.00**	**1.00**	**-1.00**	**-0.94**
03/09/2005	Alturas	vertical	*O. nerka*	6	R_i	0.86	0.00	7.97	0.00	91.17	0.00	0.00
					P_i	0.04	0.00	10.71	0.00	5.39	83.87	0.00
					E	**0.92**	**----**	**-0.15**	**----**	**0.89**	**-1.00**	**----**
06/30/2005	Alturas	vertical	*O. nerka*	2	R_i	0.00	0.00	0.33	0.00	99.67	0.00	0.00
					P_i	0.49	0.06	69.89	0.00	28.46	1.04	0.06
					E	**-1.00**	**-1.00**	**-0.99**	**----**	**0.56**	**-1.00**	**-1.00**
10/04/2005	Alturas	vertical	*O. nerka* *	7	R_i	1.02	0.00	0.46	0.00	96.62	0.00	1.90
					P_i	29.52	1.37	1.90	0.27	19.38	47.56	0.00
					E	**-0.93**	**-1.00**	**-0.61**	**-1.00**	**0.67**	**-1.00**	**1.00**
10/04/2005	Alturas	vertical	*O. nerka*	3	R_i	59.22	0.00	0.11	0.00	32.82	0.00	7.85
					P_i	29.52	1.37	1.90	0.27	19.38	47.56	0.00
					E	**0.33**	**-1.00**	**-0.89**	**-1.00**	**0.26**	**-1.00**	**1.00**

SE=sockeye salmon, n=sample size, R_i=percent composition of stomach contents, P_i=percent composition of prey items in the environment, E=electivity index

Daph=Daphnia, Holo=Holopedium, Bosm=Bosmina, Cala=Calanoid, Cycl=Cyclopoid, Naup=Nauplii, Poly=Polyphemus

DISCUSSION

Growth Rates and Survival

Growth rates of stocked sockeye salmon presmolts from the captive rearing program provide insight into performance differences associated with variable lake rearing conditions. We evaluated fall release groups consisting of sockeye salmon reared at the Sawtooth Fish Hatchery and released into Redfish (n=79,887), Pettit (n=30,700), and Alturas (n=20,129) lakes. These fish typically overwinter in the lakes and migrate as smolts the following spring. Growth rates were variable: highest in Pettit Lake; intermediate in Redfish Lake; and negligible in Alturas Lake migrants. Corresponding percent migration estimates were 35.1, 55.5, and 81.6 in Redfish, Pettit, and Alturas lakes, respectively. Smolt migration estimates assume that stocked sockeye salmon presmolts (fall release) migrate the following spring as 1 year olds. However, a variable portion of sockeye salmon stocked into Sawtooth Valley lakes migrate as 2 year olds; therefore, we view migration estimates as a conservative measure of overwinter survival.

Consistent with previous trends, Pettit Lake fish exhibited better growth when compared to the same release groups in Redfish and Alturas lakes. Sockeye salmon presmolts released into Pettit Lake during the fall of 2004 experienced relatively high total zooplankton biomass composed primarily of Cyclopoids and *Daphnia* for the first month after release. During the winter moderate zooplankton biomass was present in the form of Cyclopoids and *Bosmina* (Figure 32a). This group had the highest growth rate of any of the release groups in terms of weight; however, the change in length over time was below that seen in Redfish Lake. Condition factor remained static from release as presmolt to capture in February gillnet sampling, then declined when measured at outmigration. Approximately 56% of the presmolts released during October 2004 outmigrated during spring 2005.

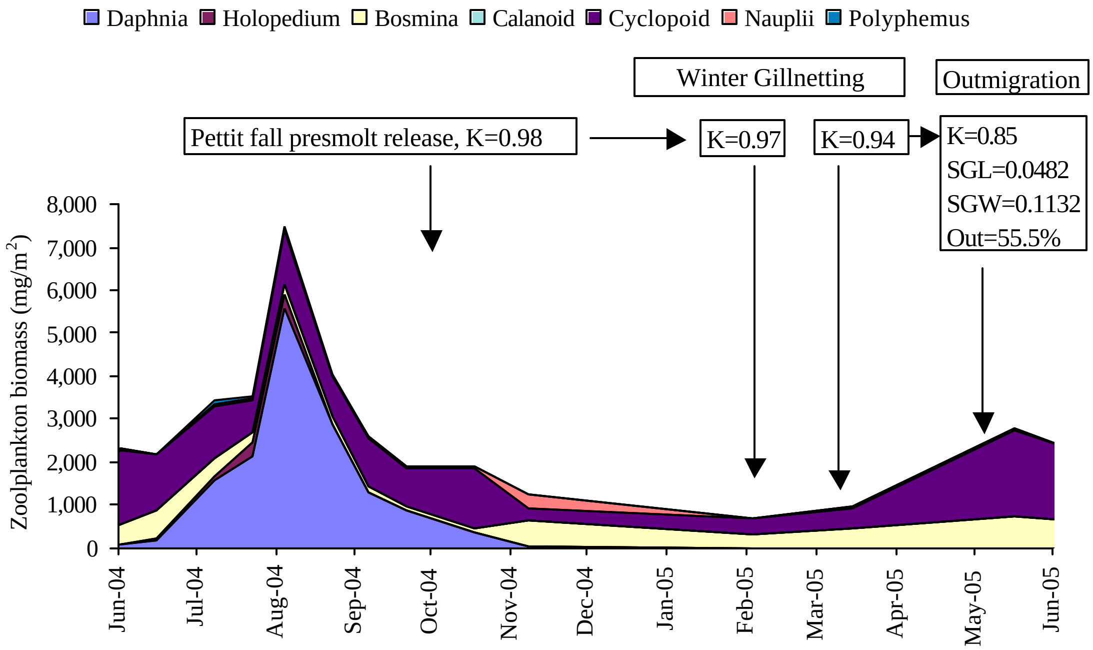


Figure 32a. Pettit Lake zooplankton biomass (mg/m^2) June 1, 2004 to June 1, 2005 with overwinter sockeye salmon presmolt specific growth rates in length (SGL), weight (SGW), condition factor (K) and percent oumigration (Out).

Sockeye salmon presmolts released in Redfish Lake experienced moderate zooplankton biomass during late summer 2004 (Figure 32b). Winter zooplankton biomass in Redfish Lake was intermediate to Pettit and Alturas lakes, as were growth rates. Presmolts grew in length and weight during the winter; however, condition factor declined from 1.02 at release to 0.77 at outmigration. Approximately 35% of the stocked fish left Redfish Lake during spring 2005.

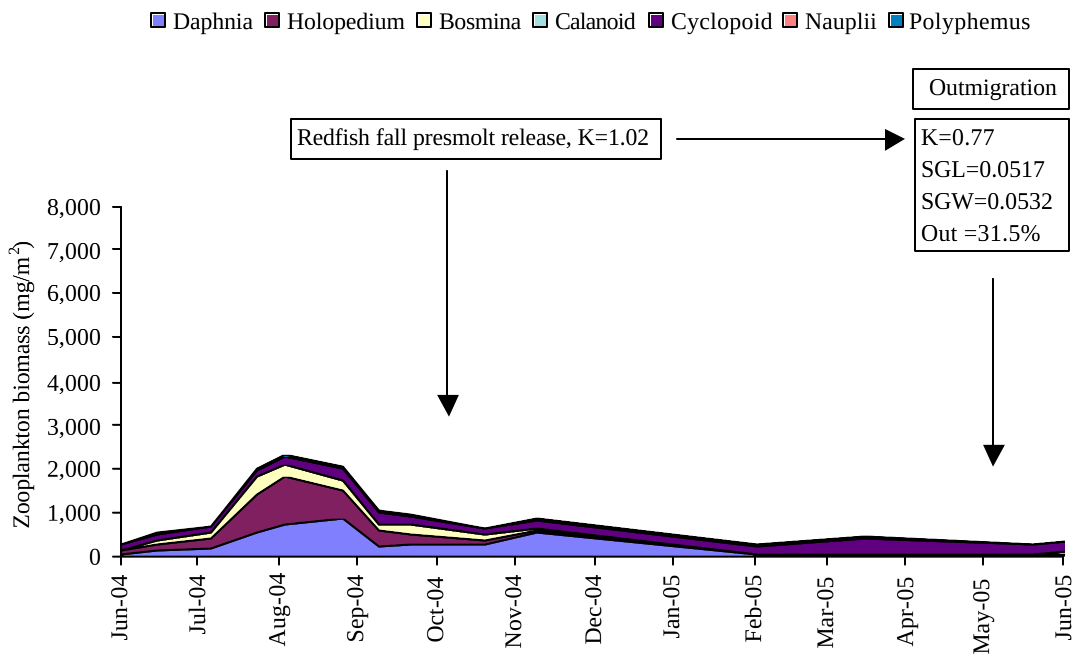


Figure 32b. Redfish Lake zooplankton biomass (mg/m^2) June 1, 2004 to June 1, 2005 with overwinter sockeye salmon presmolt specific growth rates in length (SGL), weight (SGW), condition factor (K) and percent outmigration (Out).

In Alturas Lake, fall release presmolts experienced low zooplankton biomass; growth rates were considerably lower than Redfish and Pettit lakes (Figure 32c). Approximately 82% of fish released in October 2004 migrated during the spring of 2005, a higher rate than was observed in either Redfish or Pettit lakes.

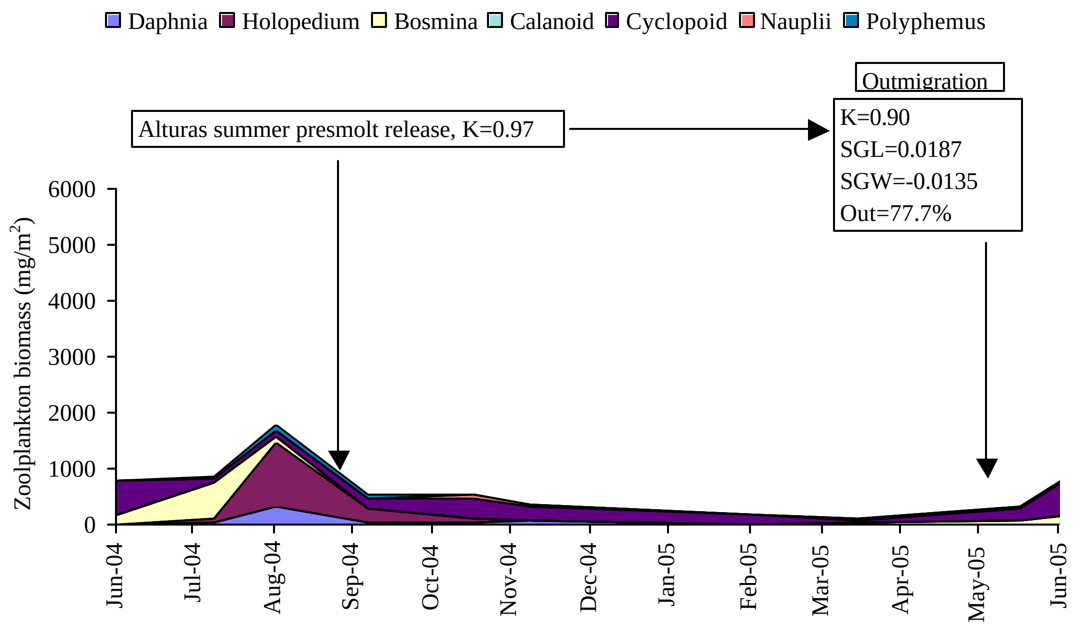


Figure 32c. Alturas Lake zooplankton biomass (mg/m^2) June 1, 2003 to June 1, 2004 with overwinter sockeye salmon presmolt specific growth rates in length (SGL), weight (SGW), condition factor (K) and percent outmigration (Out).

Differences in sockeye salmon performance (growth, condition factor, percent migration), kokanee salmon population abundance, and zooplankton abundance, biomass, and species composition are considered each year to determine appropriate numbers of sockeye salmon presmolts to stock into each lake. Hydroacoustic data collected during fall 2003 indicated between 122-212 fish/ha in the three lakes. Biomass was 4.1 kg/ha in Redfish, 6.2 kg/ha in Pettit, and 6.4 kg/ha in Alturas Lake. In addition, sockeye salmon production from natural release options (241 adults stocked to Redfish Lake and 49,134 eyed eggs in incubators stocked to Pettit Lake during fall 2004) should have occurred during spring 2005. During summer 2005 zooplankton biomass was high in Pettit Lake, intermediate in Redfish Lake, and low in Alturas Lake (Figures 12, 14, and 16). In 2005, 72,108 sockeye salmon presmolts were available for stocking. Equal allocation into each lake based on surface area would have resulted in 39,773 fish into Redfish Lake, 10,477 fish into Pettit Lake, and 21,859 fish into Alturas Lake, resulting in a loading rate of 65 fish/ha in each lake. After discussing allocations at the SBTOC level, the group decided to continue emphasis on rearing in Pettit and Redfish lakes; however, stocking rates were increased in Alturas Lake relative to recent years since kokanee densities and biomass are at or above carrying capacity in Pettit Lake and we anticipated that grazing pressure on that zooplankton assemblage would increase significantly in 2005 and 2006. Stocking rates were adjusted to 39,870 fish (65/ha) into Redfish Lake, 15,289 fish (94/ha) into Pettit Lake, and 16,949 fish (50/ha) into Alturas Lake. Continued monitoring and evaluation of growth, condition factor, and percent outmigration of sockeye salmon will continue in 2006.

Diet Analysis

Intraspecific competition has been identified as one of the potential limiting factors in the sockeye salmon rearing habitat of the Sawtooth Valley lakes. In sockeye salmon systems, intraspecific competition has been demonstrated to be much stronger than the interspecific component (Burgner 1987). An ontogenetic diet shift between age 0+ and age 1+ kokanee salmon has been detected in populations in both Redfish and Alturas lakes. This ontogenetic diet shift may be an evolutionary adaptation to reduce intraspecific competition between age classes and between anadromous sockeye salmon and kokanee salmon.

The vertical distribution of kokanee salmon and zooplankton prey may influence interactions and prey availability. *O. nerka* in the Sawtooth Valley lakes exhibit a diel vertical migration pattern (found higher in the water column at night and deeper during daylight) (Beauchamp et al. 1992) similar to that of sockeye salmon in other systems (Levy 1987, Levy 1990). Budy et al. (1995) documented *Bosmina* sp. movement from a depth of 46 m during the day to 15 m at night; cyclopoid copepods were concentrated in the hypolimnion; and *Polyphemus* sp. and *Daphnia* sp. were found at low densities throughout the water column. Kokanee salmon diet data and zooplankton dispersal patterns seem to indicate that age 0+ kokanee salmon are feeding primarily in deeper waters. Levy (1990) hypothesized that during the day juvenile sockeye salmon in lakes with piscivorous fish populations were concentrated in deeper areas with lower light levels to aid in predator avoidance.

We found stocked juvenile sockeye salmon from the captive rearing program in the stomachs of stocked rainbow trout (*O. mykiss*) in Pettit Lake during 1995, the first year we stocked sockeye salmon into that lake (Teuscher and Taki 1996). The sockeye salmon were released at the boat ramp in the littoral zone. After detection of *O. nerka* in *O. mykiss* stomachs, we modified the stocking strategy to a pelagic release using a barge. Since the pelagic release was implemented, annual (1996-03) *O. mykiss* diet analysis is used to monitor potential predation on stocked *O. nerka.* No subsequent predation of *O. nerka* by *O. mykiss* has been conclusively documented in Pettit Lake.

Northern pikeminnow are known to prey on juvenile salmon and are the subject of control efforts in the main stem of the Columbia and Snake rivers. Northern pikeminnow are one of the more abundant species found in the sockeye salmon rearing/nursery lakes of the Sawtooth Valley. Concern has been expressed about their potential predation on stocked juvenile sockeye salmon. Diet analysis has found that while piscivorous, *O. nerka* have only been positively identified in the stomach of one northern pikeminnow. During gillnet sampling, the majority of northern pikeminnow are caught in the littoral zone of the lakes. *O. nerka* are primarily a pelagic species. The low degree of habitat utilization overlap may limit the opportunity for northern pikeminnow to prey on *O. nerka.* Predation by northern pikeminnow is not currently considered a problem. Ongoing monitoring of the northern pikeminnow populations and diet is warranted in order to detect any potential changes.

Bull char are the top piscivorous predator of the Sawtooth Valley lakes fish community. Monitoring associated with this program has found that bull char diet is composed primarily of fish prey (Taki et al. 1999). Juvenile sockeye salmon and *O. nerka* were found in the stomach contents of bull char from Pettit Lake in February 2004. Bull char were listed as a threatened species in 1998 under the Endangered Species Act and, as the top predator, are an important component of fish community dynamics in the Sawtooth Valley lakes and upper Salmon River. Any predation by this species on *O. nerka* is considered a natural process and no control measures will be implemented.

Continued incidental takes during gillnet sampling are anticipated and will allow for monitoring of bull char population dynamics.

Brook char have also been documented in gillnet samples from Pettit Lake. In 2005, salmonids were found in the stomach contents of one brook char; continued monitoring of brook char diet will take place in 2006.

Stream Spawning

Kokanee salmon escapement in 2005 showed variation in population densities, timing, and fecundity. The Fishhook Creek kokanee salmon spawning population had been declining since 1996, when escapement was estimated to be 10,662, to a low of 60 individual spawners in 2000. The 2001-2003 spawning populations in Fishhook Creek rebounded and were above management objectives aimed at controlling the number of female spawners. The 2004 kokanee salmon escapement was 1,508 spawners, a six-fold decrease from numbers observed in 2003 (9,679). In 2005; kokanee salmon control efforts failed and 4,375 (37% below the 1991-2004 mean) spawners were counted in Fishhook Creek. In 2005 female kokanee salmon fecundity was estimated to be 244, below the 1991-2004 mean of 281. Control efforts will continue in the future to reduce intraspecific competition for forage resources in Redfish Lake. The Alturas Lake Creek kokanee salmon escapement estimate was up from 7,101 in 2004 to 11,652 in 2005, well above (229%) the 1992-2004 mean of 3,545. Alturas Lake Creek kokanee salmon fecundity was estimated to be 305 eggs per female, higher than the 1994-2004 average of 198. Kokanee salmon control efforts failed in Alturas Lake Creek in 2005; renewed efforts and new techniques will be employed to control kokanee salmon spawners in 2006. The Stanley Lake Creek kokanee salmon spawning population increased from 228 in 2004 to 2,725 in 2005, 74% higher than the 1993-2004 mean of 1,565. Stanley Lake Creek kokanee salmon fecundity was estimated to be 242 eggs per female in 2005, slightly less than the 1994-2004 mean estimate of 255. No control efforts are planned for the Stanley Lake Creek kokanee salmon spawning population. Based on variation in Fishhook Creek, Stanley Lake Creek, and Alturas Lake Creek kokanee salmon fecundity, all three populations should be sampled annually. Length, weight, and condition factor should also be measured in order to quantify changes that may be associated with lake fertilization, meteorological forcing, and variable fish population dynamics.

REFERENCES

APHA (American Public Health Association), American Water Works Association, and Water Environment Federation. 1995. Standard Methods for the examination of water and wastewater, 19th edition. APHA, Washington D.C.

Beauchamp, D. A., P. E. Budy, W. A. Wurtsbaugh, H. Gross, C. Luecke, and S. Spaulding. 1992. Fisheries assessment of the abundance and temporal distribution of sockeye and kokanee salmon in lakes of the Sawtooth Valley *in* S. Spaulding, editor. Snake River sockeye salmon habitat and limnological research. U.S. Department of Energy, Bonneville Power Administration, Portland, OR. Project number 91-71.

Bjornn, T. C., D. R. Craddock, and R. Corley. 1968. Migration and survival of Redfish Lake, Idaho, sockeye salmon, *Oncorhynchus nerka.* Trans. Am. Fish. Soc. 97:360-373.

Britton, L.J. and P.E. Greeson. 1987. Methods for collection and analysis of aquatic biological and microbiological samples. Techniques of Water – Resources Investigations of the United States Geological Survey, Book 5, Chapter A4. United States Government Printing Office, Washington, D.C.

Budy, P., C. Luecke, W. A. Wurtsbaugh, H. P. Gross, and C. Gubala. 1995. Limnology of Sawtooth Valley Lakes with respect to the potential growth of juvenile Snake River sockeye salmon. Northwest Science. 69:133-150.

Burgner, R. L. 1987. Factors influencing age and growth of juvenile sockeye salmon (*Oncorhynchus nerka*) in lakes. Pages 129-142 *in* G. D. Smith, L. Margolis, and C. C. Wood, editors. Sockeye salmon (*Oncorhynchus nerka*) population biology and future management. Can. Spec. Publ. Fish. Aquat. Sci. 96.

Ehrenberg, J. C. and T. C. Torkelson. 1996. Application of dual-beam and split-beam target tracking in fisheries acoustics. ICES Journal of Marine Science. 53:329-334.

English, K. K., T. C. Bocking and J. R. Irving. 1992. A robust procedure for estimating salmon escapement based on the area-under-the-curve method. Can. J. Fish. Aquat. Sci. 49:1982-1989.

Everman, B.W. 1896. A report upon salmon investigations in the headwaters of the Columbia River in the State of Idaho, in 1895. Bulletin U.S. Fish Commission 16:151-202.

Gunderson, D. R. 1993. Surveys of fisheries resources. John Wiley and Sons, Inc. New York, New York. 248 pp.

Hauser, T.A., and M.E. Barber. 2002. Primary productivity in four alpine lakes in the Sawtooth Mountains, Idaho during 2002. Project Completion Report prepared for Biolines Environmental Consulting, Stanley, Idaho.

Holm-Hansen, O., and B. Riemann, 1978. Chlorophyll *a* determination: improvements in methodology. Oikos 30:438-447.

Ivlev, V. S. 1961. Experimental ecology of the feeding of fishes. Yale University Press, New Haven, CT.

Koenings, J.P., J.A. Edmundson, G.B. Kyle, and J.M. Edmundson. 1987. Limnology field and laboratory manual: methods for assessing aquatic production. Alaska Department of Fish and Game, Division of Fisheries Rehabilitation, Enhancement and Development. Juneau, Alaska.

Kohler, A.E, D. Taki, and B.G. Griswold. 2005. Salmon River sockeye salmon habitat and limnological research: 1997 annual progress report. U.S. Department of Energy, Bonneville Power Administration, Portland, OR. Project number 91-71.

Levy, D. A. 1987. Review of the ecological significance of diel vertical migrations by juvenile sockeye salmon (*Oncorhynchus nerka*). Pages 44-52 *in* G. D. Smith, L. Margolis, and C. C. Wood, editors. Sockeye salmon (*Oncorhynchus nerka*) population biology and future management. Can. Spec. Publ. Fish. Aquat. Sci. 96.

Levy, D. A. 1990. Sensory mechanism and selective advantage for diel vertical migration behavior in juvenile sockeye salmon. Can. J. Fish and Aquat. Sci. 47: 1796-1802.

Love, R. H. 1977. Measurements of fish target strength: a review. Fisheries Bulletin 69:703-715.

MacIsaac, E.R., and J.G. Stockner. 1993. Enumeration of phototrophic picoplankton by auto-fluorescence microscopy, p. 187-197. B. Sherr and E. Sherr, editors. The handbook of methods in aquatic microbial ecology, CRC Press, Boca Raton, Florida.

McCauley, E. 1984. The estimation of the abundance and biomass of zooplankton in samples. Chapter 7 *in* J. A. Downing and F. Rigler, editors. A manual on methods of secondary productivity in freshwaters, 2nd edition. Blackwell Scientific, Oxford, UK.

Steinhart, G., H.P. Gross, P. Budy, C. Luecke, and W.A. Wurtsbaugh. 1994. Limnological investigations and hydroacoustic surveys of Sawtooth Valley Lakes *in* S. Spaulding, editor. Snake River Sockeye Salmon Habitat and Limnological Research. Annual Report 1993. U.S. Department of Energy, Bonneville Power Administration, Division of Fish and Wildlife, Portland, Oregon. Project number 91-71.

Swanson, G. A., G. L. Krapu, J. C. Bartonek, J. R. Serie, and D. H. Johnson. 1974. Advantages of mathematically weighted waterfowl food habitat data. Journal of wildlife management. 38:302-307.

Taki, D., B. Lewis, and R. Griswold. 1999. Salmon River sockeye salmon habitat and limnological research: 1997 annual progress report. U.S. Department of Energy, Bonneville Power Administration, Portland, OR. Project number 91-71.

Teuscher, D. and D. Taki. 1996. Salmon River sockeye salmon habitat and limnological research. Pages 1-50 *in* Teuscher, D. and D. Taki, editor. Snake River sockeye salmon habitat and limnological research: 1995 annual progress report. U.S. Department of Energy, Bonneville Power Administration, Portland, OR. Project number 91-71.

Traynor, T. C. and J. C. Ehrenberg. 1990. Fish and standard-sphere target-strength measurements obtained with a dual-beam and split-beam echosounding system. Rapp. P.-v. Reun Cons. Int. Explor. Mer. 189:325-335.

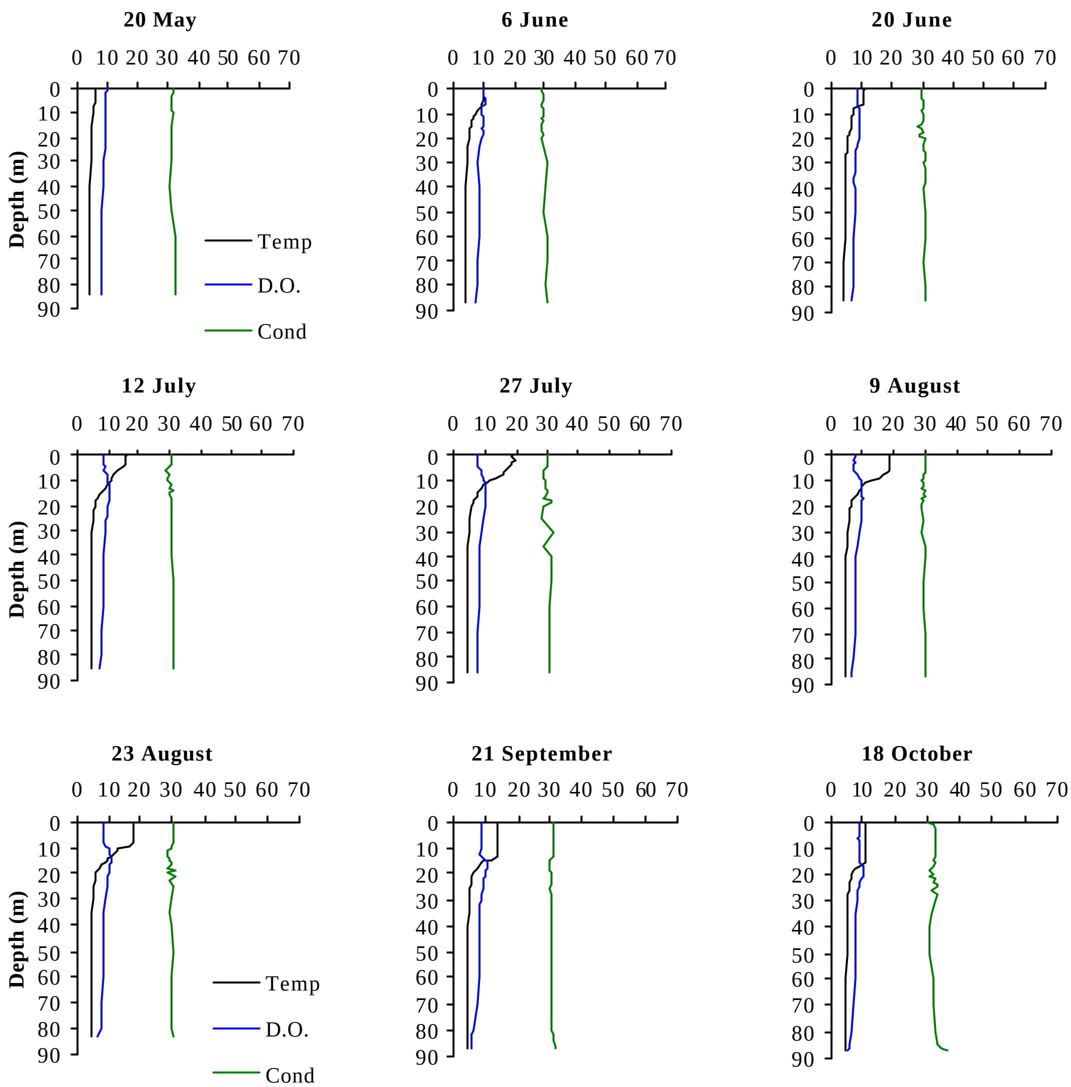
Utermohl, H. 1958. Zur Vervollkommnung der quantitativen phytoplankton methodik. International Vereinigung fuer Theoretische und Angewandte Limnologie und Verhandlugen. Mitteilungen No. 9.

Vollenweider, R.A. 1965. Calculation models of photosynthesis depth curves and some implications regarding day rate estimates in primary productivity measurements. Pages 425-457 *in* C.R. Goldman, editor. Primary Productivity in Aquatic Environments. 1st Italiano Hydrobiologia Memoirs, Supplement 18, University of California Press, Berkeley, CA.

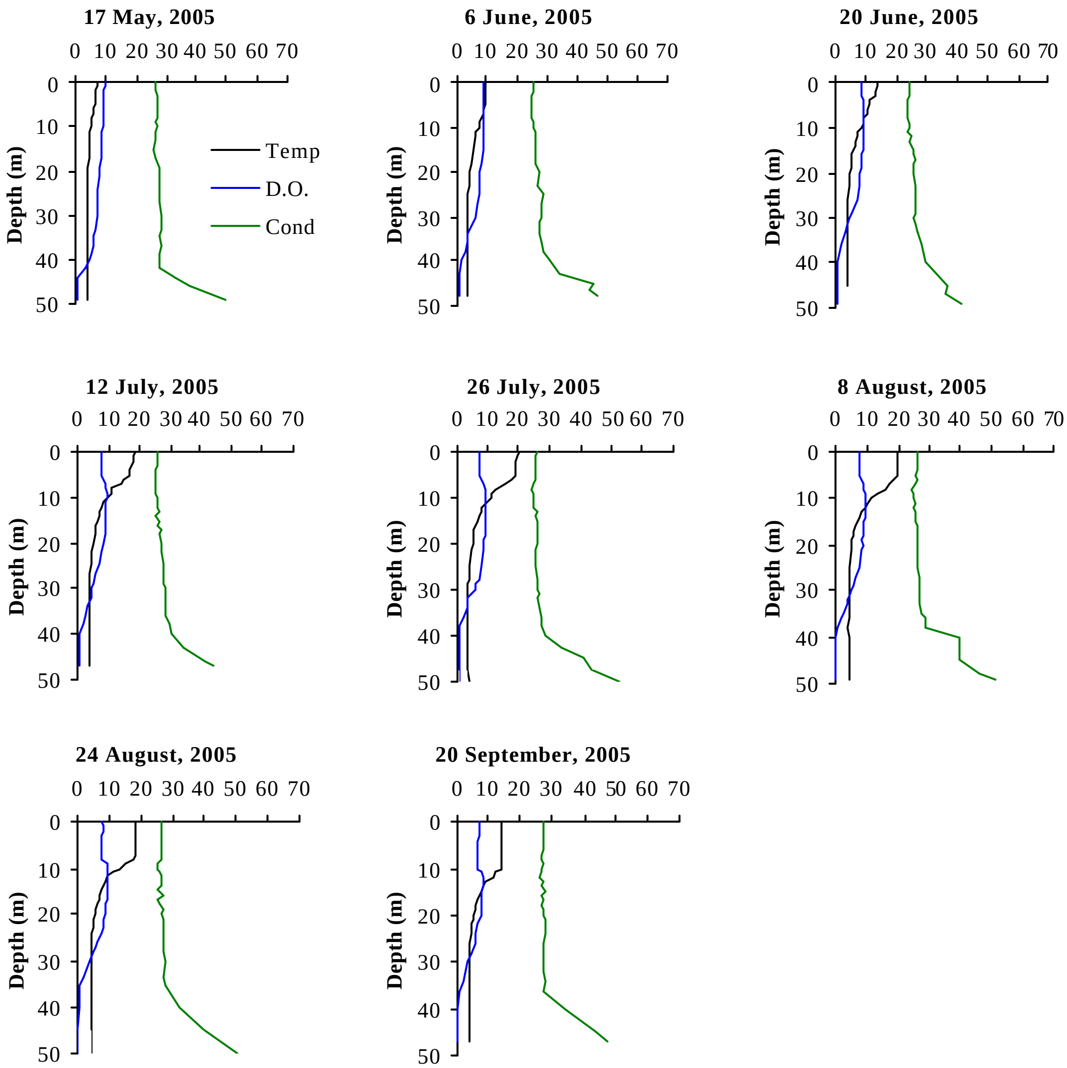
Wetzel, R.G., and G.E. Likens. 1991. Limnological Analyses, 2nd edition. Springer-Verlag. New York.

Willard, C. 2003. Personal Communication. Idaho Department of Fish and Game. Nampa, Idaho.

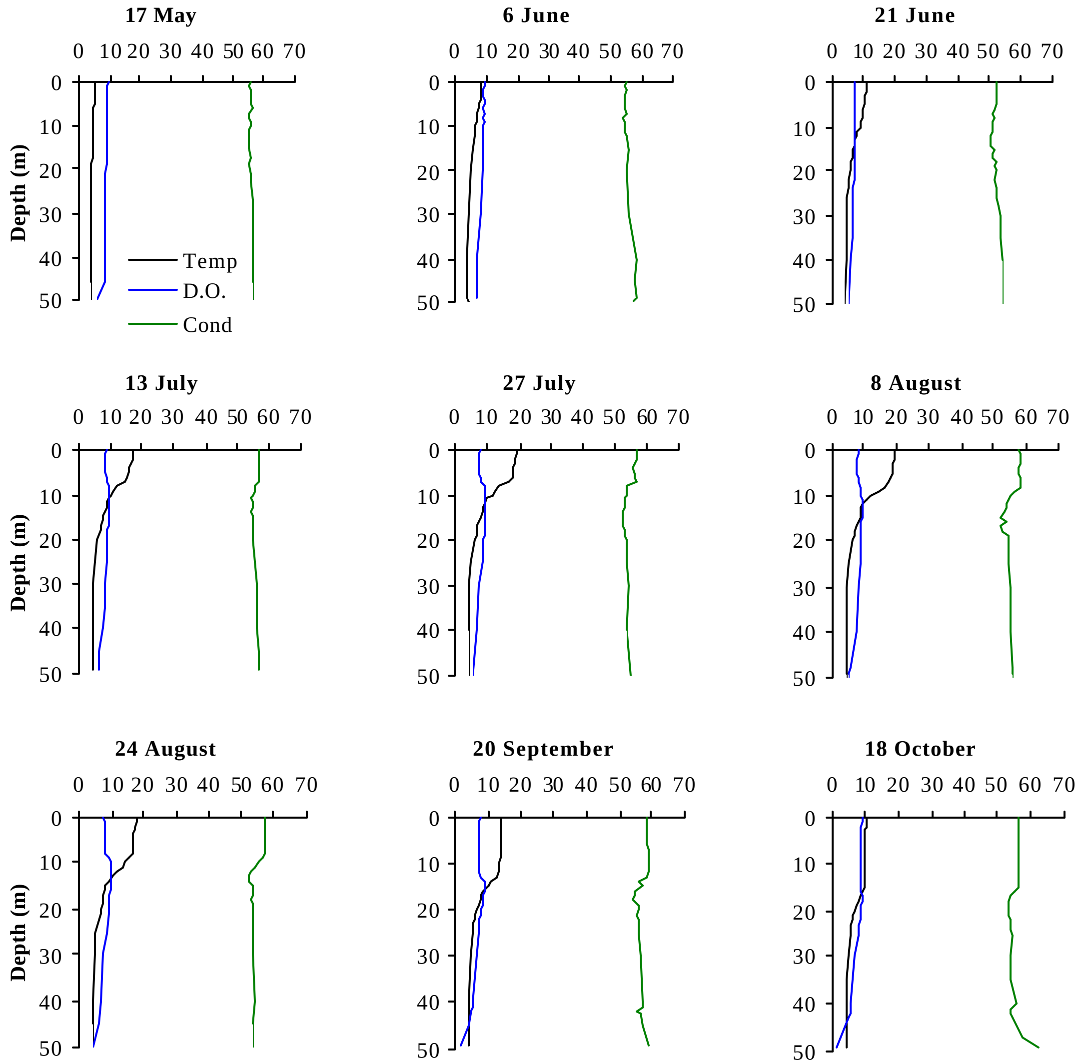
APPENDIX A. Profile data



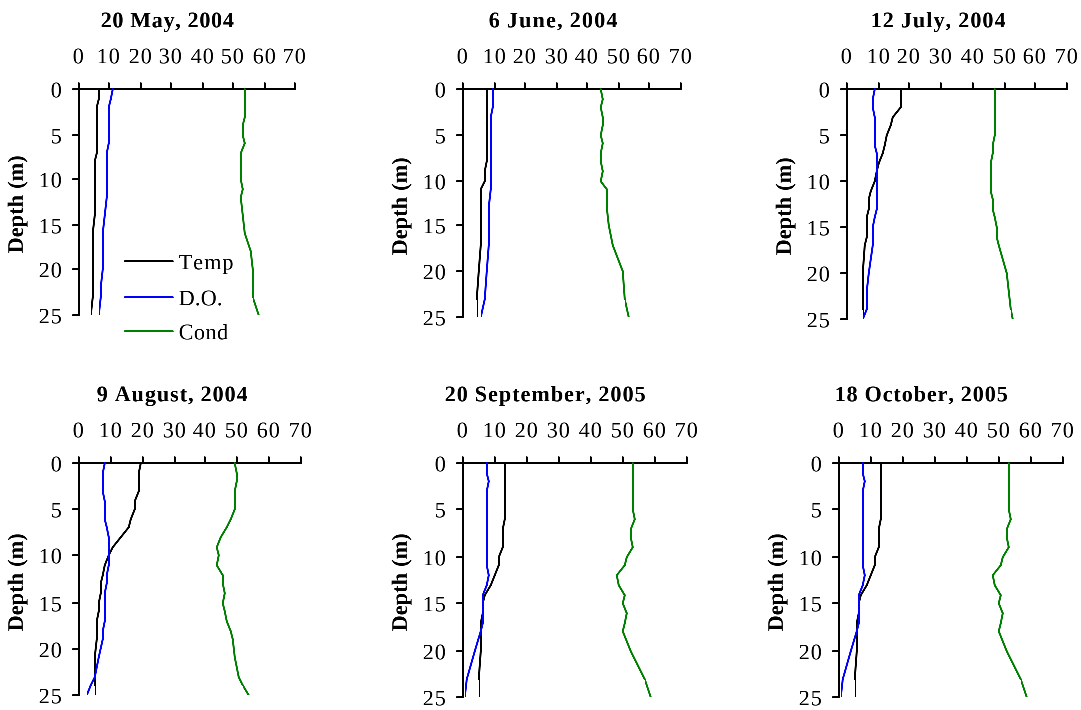
Appendix A1. Temperature (^{o}C), dissolved oxygen (mg/L), and conductivity (μS/cm) profiles for Redfish Lake, May through October 2005.



Appendix A2. Temperature (°C), dissolved oxygen (mg/L), and conductivity (μS/cm) profiles for Pettit Lake, May through October 2005.

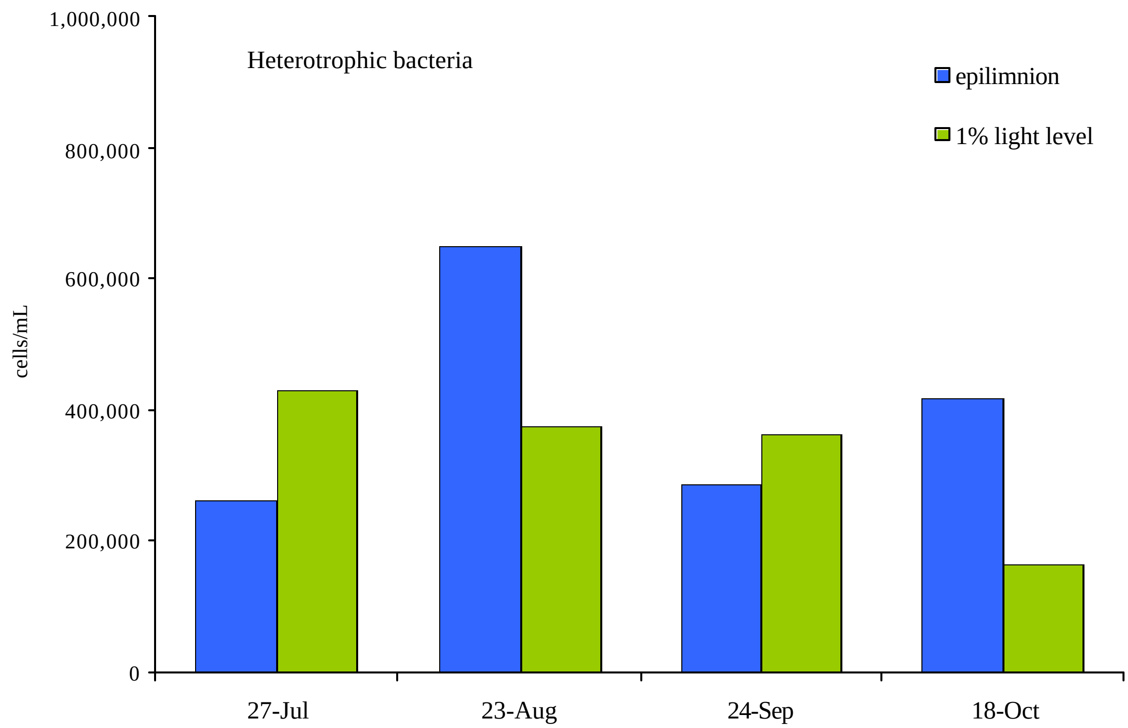


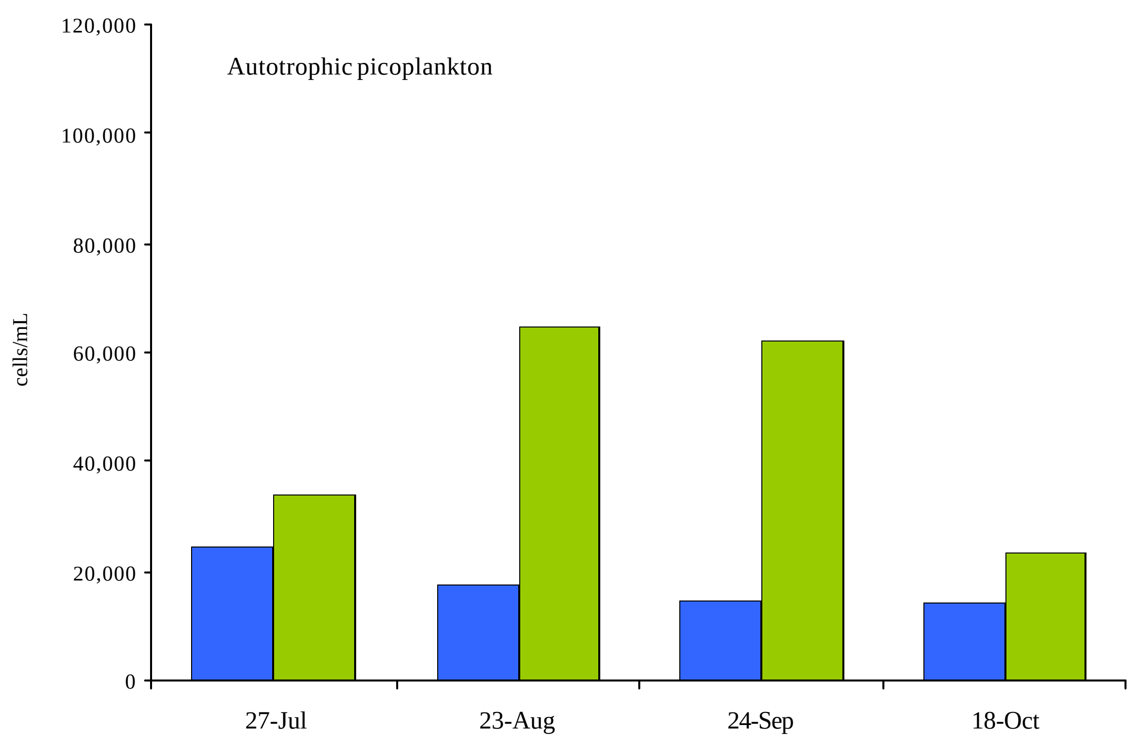
Appendix A3. Temperature (^{o}C), dissolved oxygen (mg/L), and conductivity (μS/cm) profiles for Alturas Lake, May through November 2005.



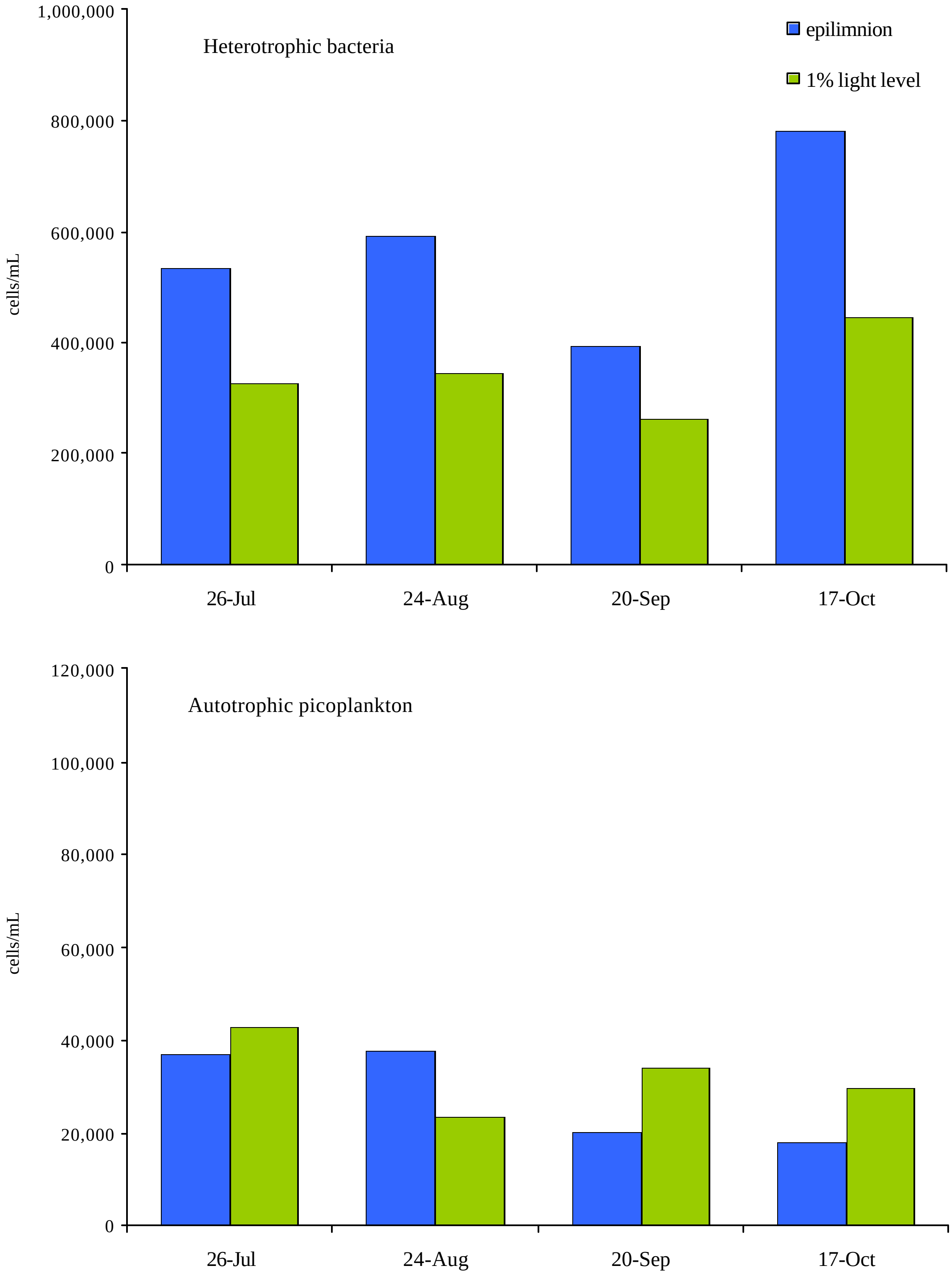
Appendix A4. Temperature (^{o}C), dissolved oxygen (mg/L), and conductivity (μS/cm) profiles for Stanley Lake, May through October 2005.

APPENDIX B. Heterotrophic bacteria and autotrophic picoplankton

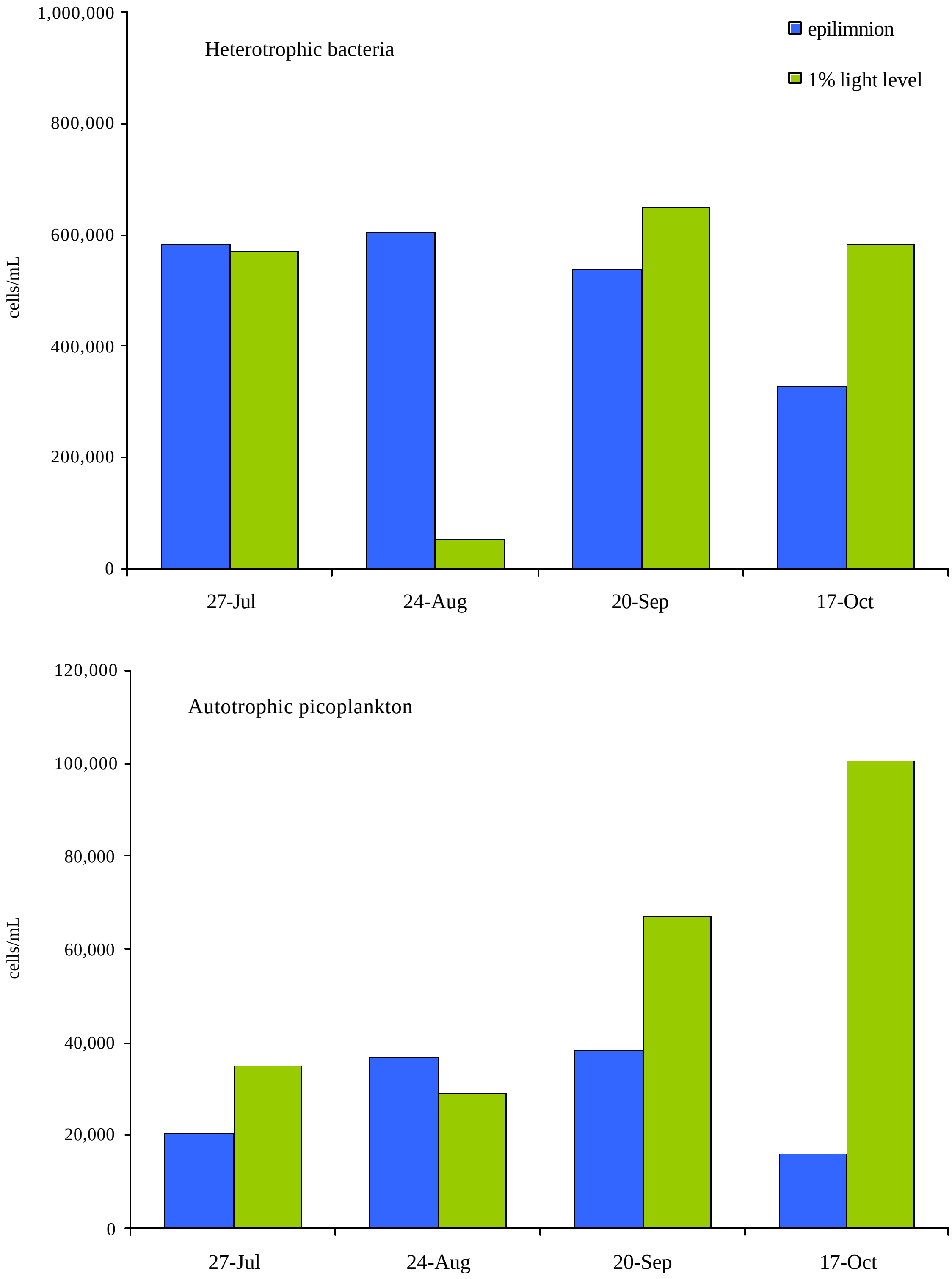




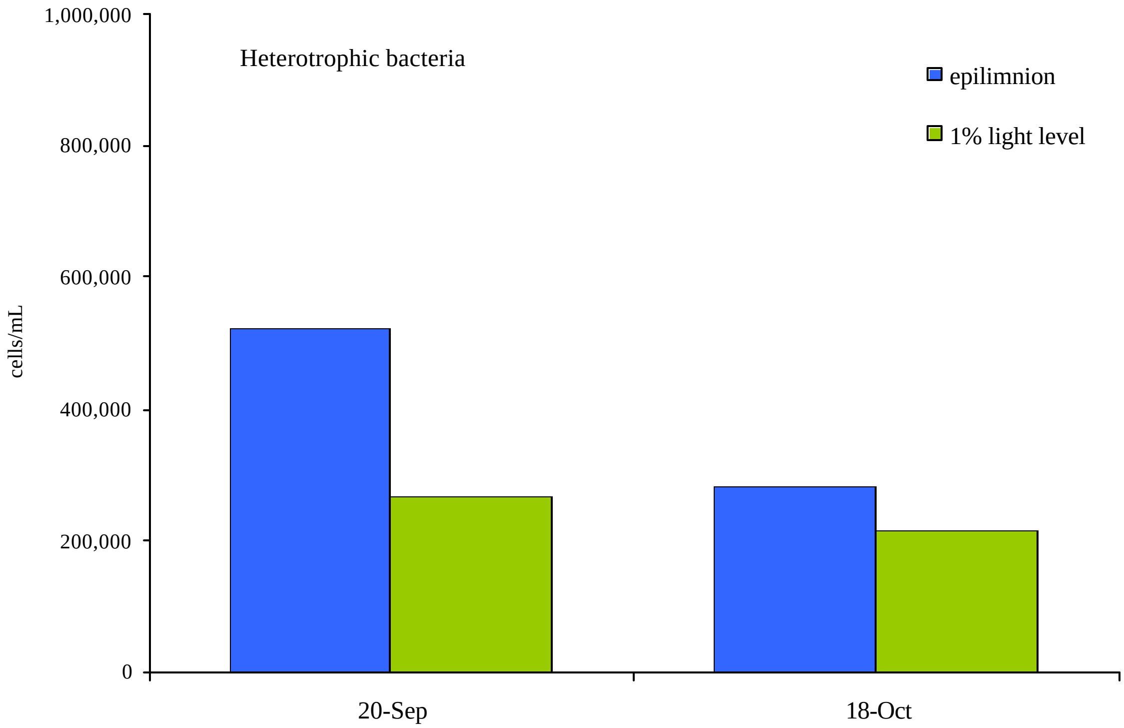
Appendix B1. Heterotrophic bacteria and autotrophic picoplankton (APP) densities (cells/mL) in the epilimnion and compensation depths in Redfish Lake, July through October 2005.

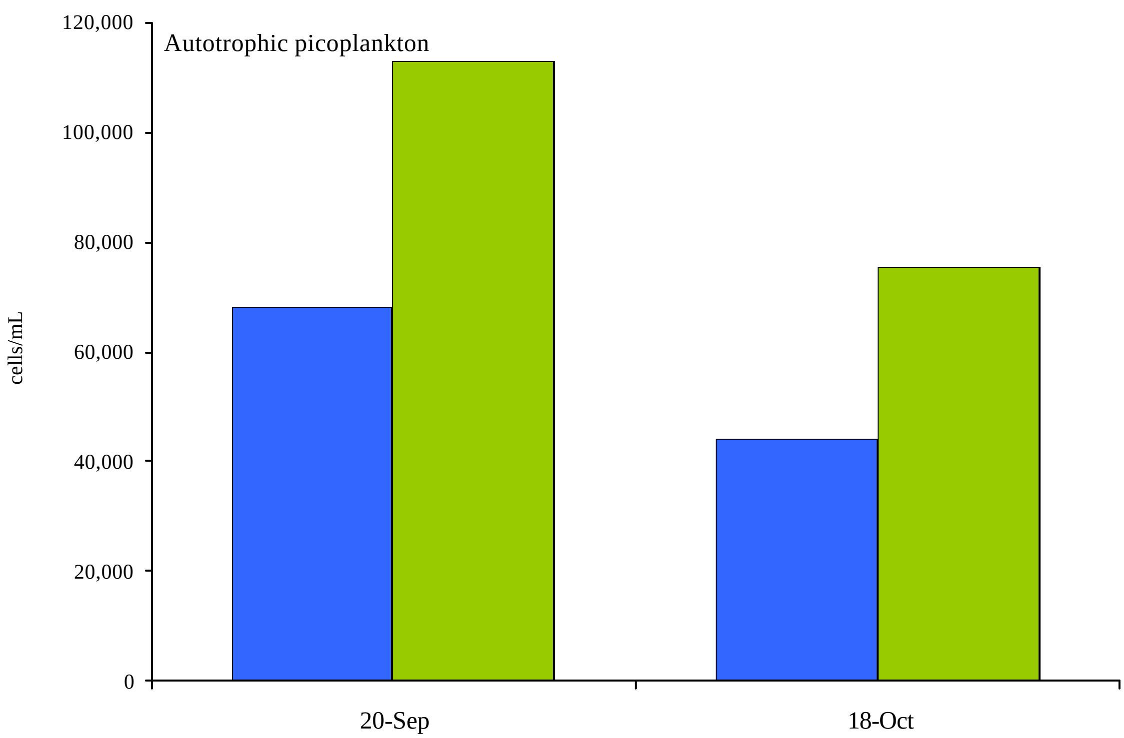


Appendix B2. Heterotrophic bacteria and autotrophic picoplankton (APP) densities (cells/mL) in the epilimnion and compensation depths in Pettit Lake, July through October 2005.



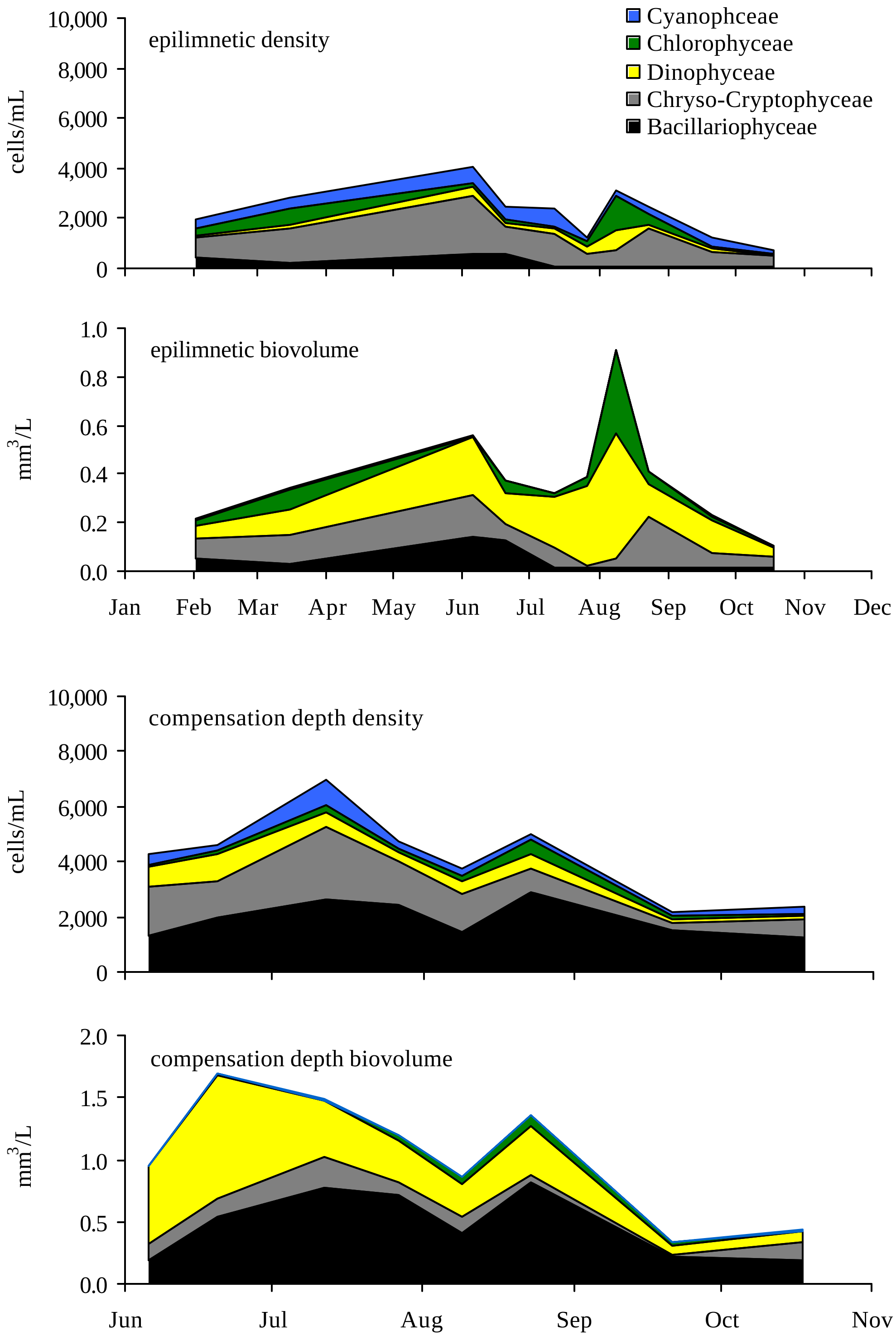
Appendix B3. Heterotrophic bacteria and autotrophic picoplankton (APP) densities (cells/mL) in the epilimnion and compensation depths in Alturas Lake, July through October 2005.



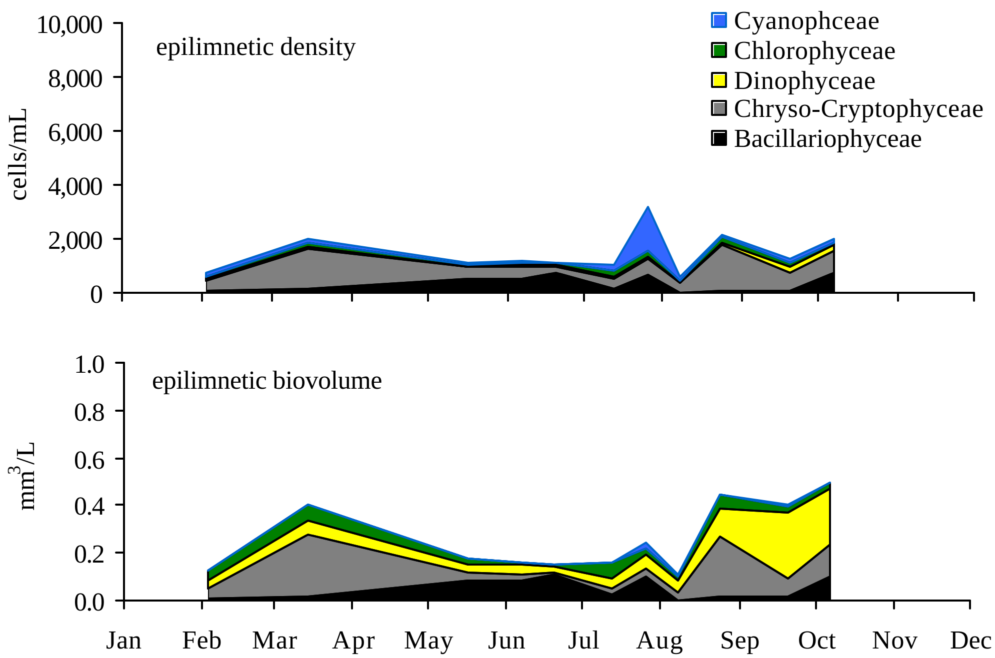


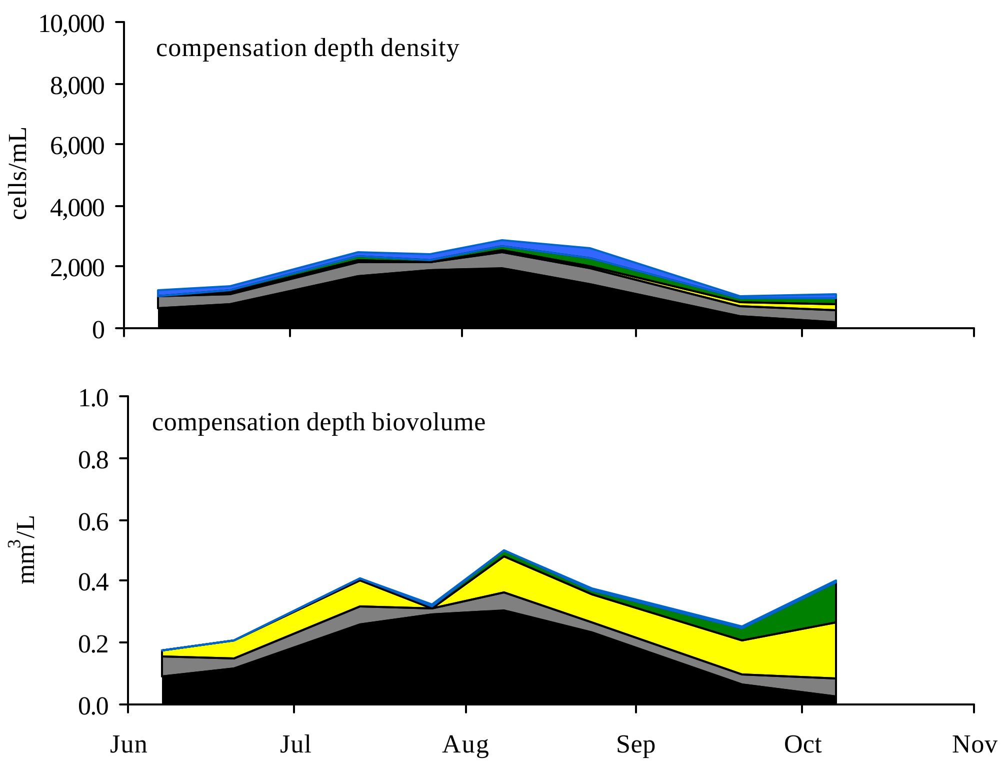
Appendix B4. Heterotrophic bacteria and autotrophic picoplankton (APP) densities (cells/mL) in the epilimnion and compensation depths in Stanley Lake, September and October 2005.

APPENDIX C. Phytoplankton densities and biovolumes

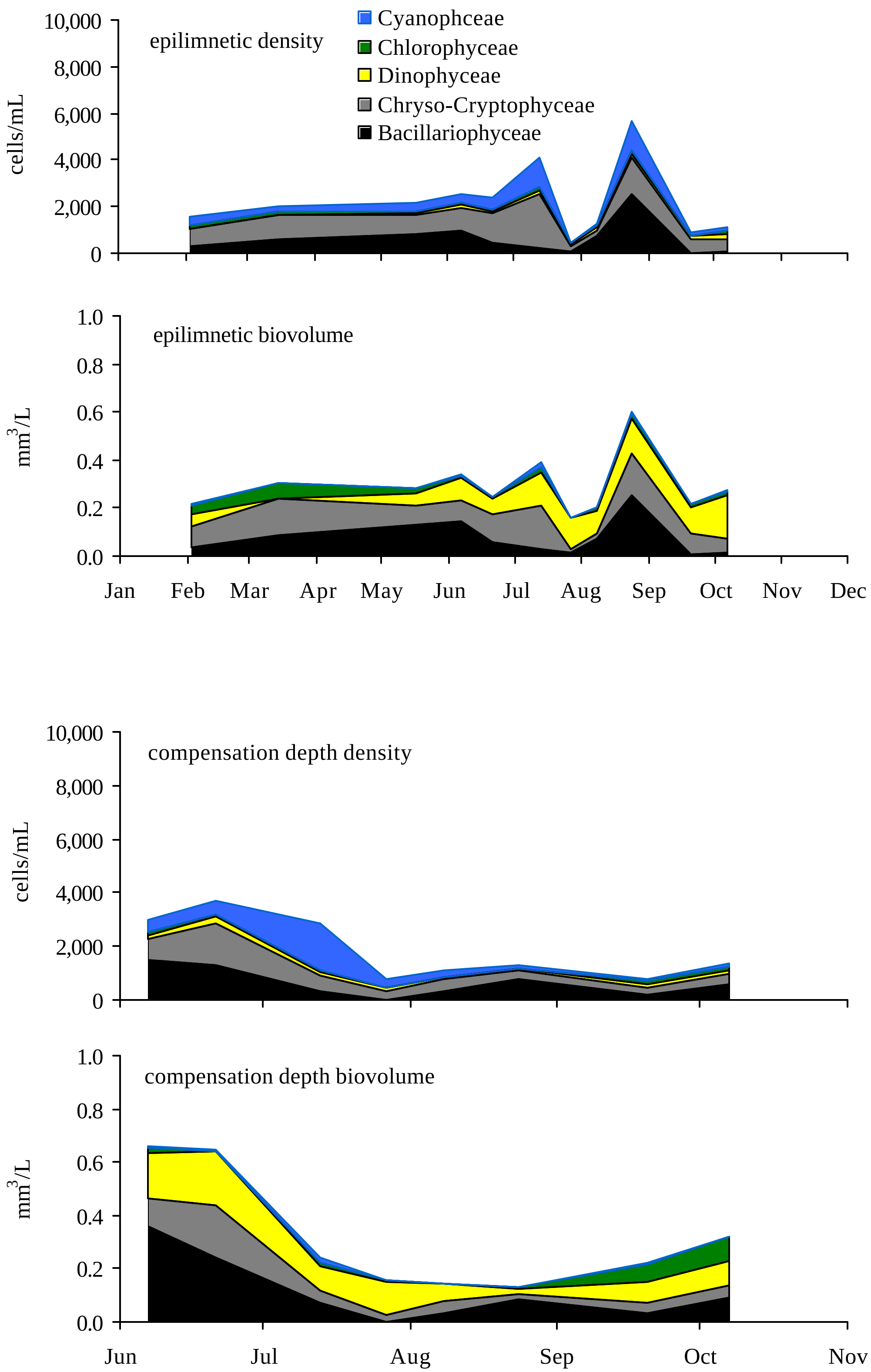


Appendix C1. Phytoplankton density (cells/mL) and biovolume (mm^3/L) in the epilimnion and at the compensation depth in Redfish Lake, February through October 2005.

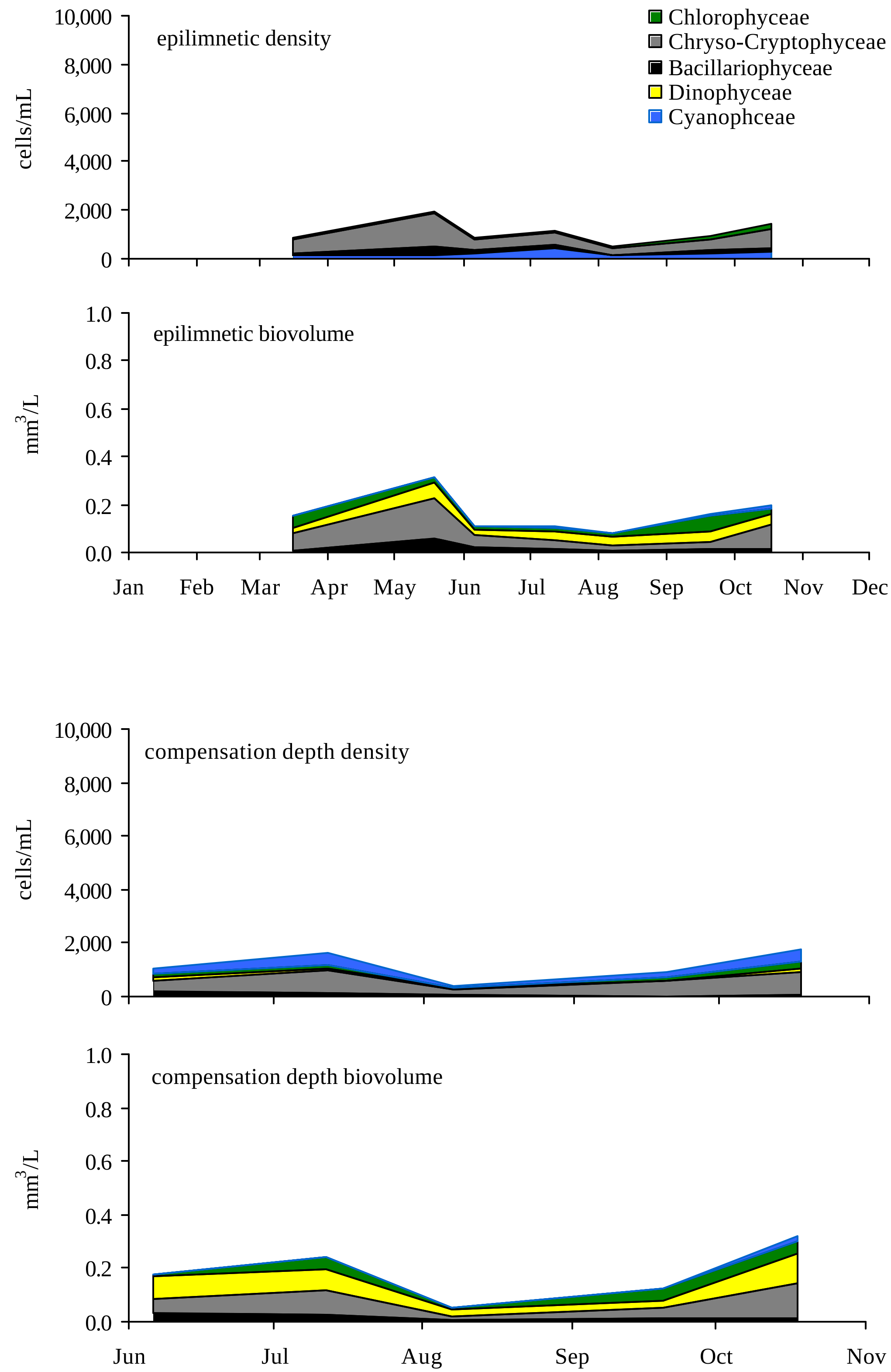




Appendix C2. Phytoplankton density (cells/mL) and biovolume (mm^3/L) in the epilimnion and at the compensation depth in Pettit Lake, February through October 2005.



Appendix C3. Phytoplankton density (cells /mL) and biovolume (mm^3/L) in the epilimnion and at the compensation depth in Alturas Lake, February through October 2005.



Appendix C4. Phytoplankton density (cells/mL) and biovolume (mm3/L) in the epilimnion and compensation depths in Stanley Lake, March through October 2005.