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Snake River Sockeye Salmon Habitat and Limnological Research

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SNAKE RIVER SOCKEYE SALMON HABITAT AND LIMNOLOGICAL RESEARCH: 2003 ANNUAL PROGRESS REPORT

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EXECUTIVE SUMMARY

In March 1990, the Shoshone-Bannock Tribes petitioned the National Marine Fisheries Service (NMFS) to list the Snake River sockeye salmon (*Oncorhynchus nerka*) as endangered. As a result of that petition, the Snake River sockeye salmon was 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 Program was implemented (Project Number 1991-071-00). This project is part of an interagency effort to prevent the extinction of the Redfish Lake stock of 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 program through the Northwest Power and Conservation Council Fish and Wildlife Program (NPCCFWP). 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 2003 calendar year.

Project objectives include: 1) monitor limnological parameters of the Sawtooth Valley lakes to assess lake productivity; 2) reduce the number of mature kokanee spawning in Fishhook Creek; 3) monitor sockeye salmon smolt migration from the captive rearing program release of juveniles into Pettit and Alturas lakes; 4) monitor spawning kokanee escapement and estimate fry recruitment in Fishhook, Alturas Lake, and Stanley Lake creeks; 5) conduct sockeye and kokanee salmon population surveys; 6) evaluate potential competition and predation between stocked juvenile sockeye salmon and a variety of fish

species in Redfish, Pettit, and Alturas lakes; and 7) assist IDFG with captive broodstock production activities.

Objective 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 January-March and May-November and twice per month in Redfish and Pettit lakes during summer (June-October) with the following exceptions: Redfish, Alturas, and Stanley lakes were not sampled in January because of unsafe ice conditions. Stanley Lake was not sampled during March because of poor ice conditions; and Alturas Lake was not sampled during May because ice remained on the lake and the road was impassable because of snow-pack. Pettit Lake was not sampled during November because thick ice at the boat ramp precluded launching a boat.

Objective 2. The Fishhook Creek kokanee weir was installed to allow no more than 1,200 spawning females to pass above the weir. We believe kokanee were migrating through a beaver tunnel, with passage circumventing our weir that went unnoticed until the end of the spawning season.

Objective 3. The number of sockeye salmon that migrated from Pettit Lake was estimated using catches at the Pettit Lake Creek weir. Two release strategies were evaluated: 1) a direct lake summer release of Bonneville Hatchery parr (adipose and right ventral fin clip (ADRV)); and 2) a direct lake fall release of Sawtooth Hatchery parr (adipose fin clip (AD)). Migration estimates for Pettit Lake were 20.2% for ADRV hatchery smolts, and 58.8% for AD hatchery smolts.

Stocked juvenile sockeye salmon migration from Alturas Lake was estimated using catches at the Alturas Lake Creek screw trap. The only release in Alturas Lake in 2002 was a summer release of fish reared at the Bonneville Hatchery (ADRV). The migration estimate for that release strategy was 9.0%. Migration for Redfish Lake sockeye salmon was monitored by IDFG. Survival estimates presented above for Alturas Lake Creek were based on trap efficiency population estimates.

Objective 4. Stream spawner counts were used to monitor adult kokanee escapement to inlet streams on Redfish, Alturas, and Stanley lakes in 2003. Fishhook Creek, the primary kokanee spawning tributary on Redfish Lake, had an estimated spawning escapement of 9,679 adult spawners, Alturas Lake Creek had an estimated 48 adult spawners, and Stanley Lake Creek had an estimated 413 kokanee spawners. Fry recruitment, calculated from male-female ratios, fecundity, and egg to fry survival rates is estimated at (117,240), (468), and (3,903) fry for Fishhook, Alturas Lake, and Stanley Lake creeks, respectively.

Objective 5. Three forms of *O.nerka* inhabit Redfish Lake: 1) a resident, stream spawning kokanee population; 2) listed anadromous sockeye salmon; and 3) listed residual sockeye. The residual component spawns in October in littoral areas similar to the anadromous form. Monitoring of spawning residual and anadromous sockeye populations in Redfish Lake has occurred since 1993. Trends in these populations are evaluated with monitoring data collected by weekly snorkel surveys. In 2003, 48 residual sockeye and 112 sockeye adults were observed during snorkel surveys at the SE Inlet and Sockeye Beach spawning areas in Redfish Lake. Hydroacoustic populations for Redfish Lake showed an increase of 68,552 fish from 2002 to a whole lake estimate of 130,087. Pettit and Alturas lakes experienced a modest increase from 2002 (Table 10 and 11).

Objective 6. Potential competition and predation between stocked sockeye salmon, unmarked *O. nerka* (egg box production sockeye or kokanee salmon), rainbow trout (*O. mykiss*), and other fish species was investigated. In an analysis of rainbow trout diets there were no *O. nerka* found in the stomach contents of any of the fish sampled. 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. Several potential kokanee/sockeye predators were identified in the lakes including bull char *Salvelinus confluentus*, northern pikeminnow *Ptychocheilus oregonensis*, and brook char *S. fontinalis*. Piscivory was evident with cyprinids found in the diet of northern pikeminnow, brook char, rainbow trout, and bull char. Bull char diet was composed primarily of cyprinids and salmonids. Due to the progressed state of digestion found in many stomach samples we cannot conclusively rule out predation on *O. nerka* by potential predators. Resident kokanee, primary competitors with lake rearing juvenile sockeye, fed almost entirely on zooplankton prey species. Diet overlap between resident kokanee and rearing sockeye parr was estimated to be 97% in Pettit Lake.

Objective 7. SBT personnel assisted the IDFG in PIT tagging sockeye parr at the Sawtooth Fish Hatchery. We also worked together planting and retrieving egg boxes from Pettit Lake.

In 2003, supplemental nutrients were not applied to any of the Sawtooth Valley lakes. Kokanee salmon densities were expected to be relatively low in 2003 based on hydro-acoustic data collected during September 2002. Kokanee densities were 100.1, 158.3, and 157.8 fish/ha in Redfish, Pettit, and Alturas lakes, respectively. These densities are well below our best estimates of lake carrying capacities (approximately 400-500 fish/ha), and we concluded, with input from the SBSTOC, to forgo lake fertilization in 2003. This decision was supported by hydro-acoustic data collected during September 2003, when kokanee densities ranged from 123 to 212 fish/ha in the three lakes (Table 9).

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 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. As a result of that petition the Snake River sockeye salmon was officially listed as endangered in November 1991 under the Endangered Species Act (56 FR 58619). The Upper Snake River Endangered Sockeye Salmon Recovery Program was implemented the same year. The SBT have been actively involved in the sockeye salmon recovery project (BPA Project Number 91-71) since its inception.

The Bonneville Power Administration (BPA) provides funding for this interagency recovery program through the Northwest Power and Conservation Council's 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 returned to Redfish Lake. These four fish and migrating juveniles captured over the next two years formed the initial captive brood stock. The captive brood stock was supplemented with returning adult sockeye, residuals, and migrating juveniles in subsequent years. Historically, thousands of sockeye 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 returned to Redfish Lake in 1955. There has been a steady decline in adult sockeye 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 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; a variety of stocking strategies have been implemented and evaluated, 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) has guided all activities conducted by the SBT in association with the sockeye recovery project. The SBTOC is composed of representatives of 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 elements of the Snake River sockeye 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 (DEQ), 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 rearing lakes are shown in Table 1.

All of the Stanley Basin lakes are oligotrophic: mean summer total phosphorous (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 8.6 m.

Table 1. Morphological features of the Sawtooth Valley lakes.

Lake	**Area (km^2)**	**Volume ($m^3 x10^6$)**	**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 kilometers from the mouth of the Columbia River. There are 616 kilometers 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.. Non-native 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, residuals, and kokanee. Kokanee, a non-anadromous form of *O. nerka*, spends its entire life cycle in the fresh water lakes. Kokanee generally spawn at three to five years of age in the inlet creeks of the lakes during late summer and die afterwards. The Redfish Lake kokanee population is admixed, consisting of several out-of-basin stocks and is genetically dissimilar to the anadromous form. This kokanee population is temporally and spatially separated during spawning from the listed Snake River *O. nerka*. Alturas Lake kokanee are closely related, sharing haplotypes with listed Snake River sockeye (Matt Powell, U of I, personal communication). Pettit and Stanley lakes were treated with rotenone (1950's and 60's) and kokanee were reintroduced from out-of-basin stocks. Data indicates that these fish are genetically different from remaining indigenous *O. nerka*. No Sawtooth Valley kokanee are listed as endangered.

Residuals are another form of *O. nerka* found only in Redfish Lake and are listed as part of the ESU. The residual population remains in freshwater for their entire life cycle, yet are genetically similar to the anadromous *O. nerka* form. The residual population spawns at the same time as the anadromous form and, similar to the anadromous form, creates redds on the lake shore instead of the inlet creeks.

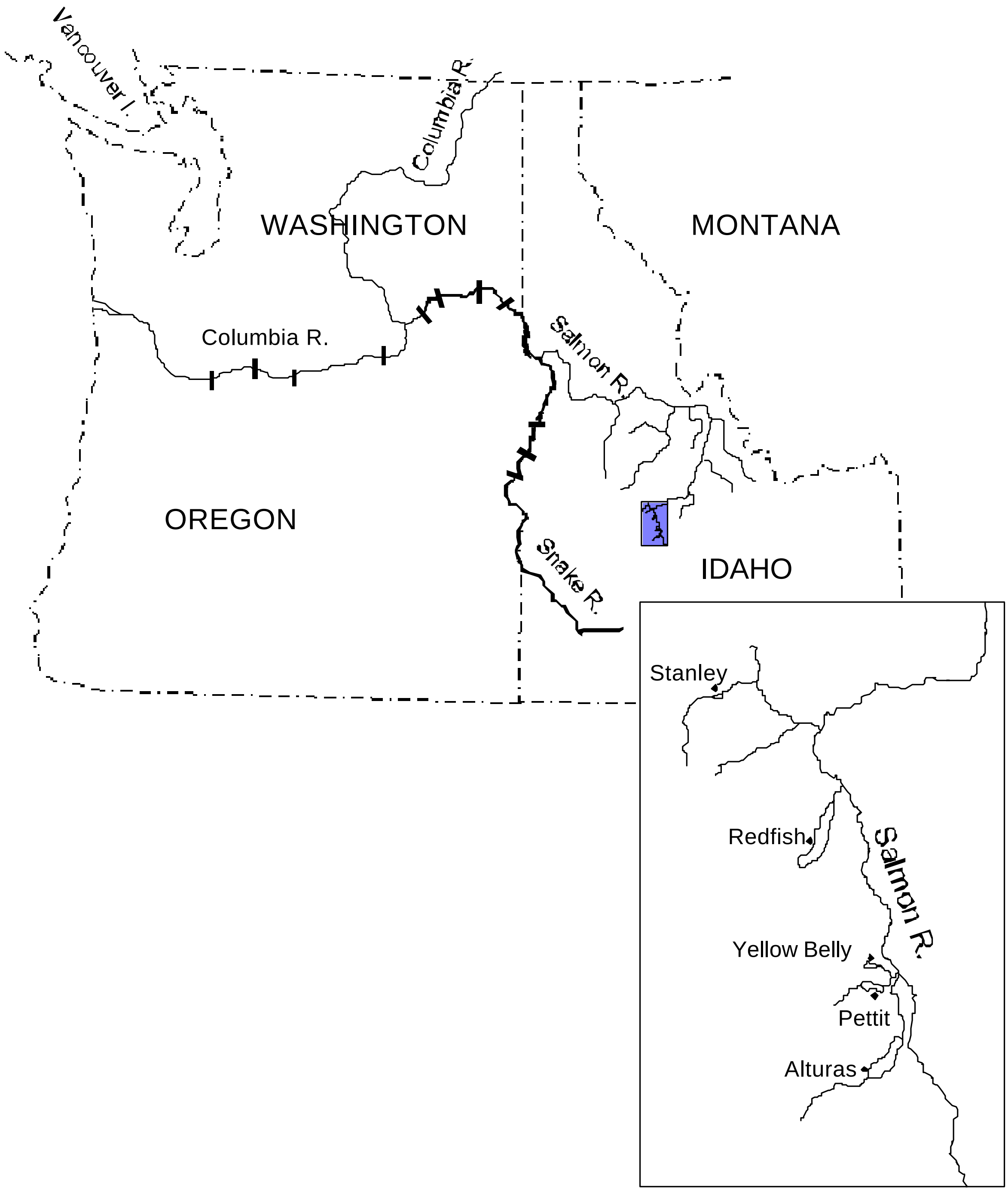

Figure 1. Map of study area.

The anadromous form of *O. nerka* spends one or two years in fresh water, migrating 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.

MATERIALS AND METHODS

Limnology

Limnological monitoring was conducted once per month at each lake during January-March and May-November and twice per month in Redfish and Pettit lakes during summer (June-October) with the following exceptions: Redfish, Alturas, and Stanley lakes were not sampled in January because of unsafe ice conditions. Stanley Lake was not sampled during March because of poor ice conditions; and Alturas Lake was not sampled during May because ice remained on the lake and the road was impassable because of snow-pack. Pettit Lake was not sampled during November because thick ice at the boat ramp precluded launching a boat.

Redfish, Pettit, and Alturas lakes were stocked with juvenile sockeye salmon from the Redfish Lake captive broodstock in 2003. 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) 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 2003 in Stanley Lake 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 three 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 (^{o}C), 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 two-meter 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 that had been rinsed in hydrochloric acid (0.1 N) and 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. Water samples were then frozen and shipped to the University of California at Davis Limnology Laboratory 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). State of Washington Water Research Center personnel estimated primary productivity four times in each of the four study lakes during 2003. The lakes were sampled 15-18 July, 12-15 August, 9-12 September, and 7-10 October. Primary productivity was evaluated within the photic zone, delineated by the depth of the 1% light level. Discrete primary productivity estimates were made at eight depths in Redfish, Pettit, and Alturas lakes and from six depths in Stanley Lake. Discrete primary productivity (mg $C \cdot m^{-3} hr^{-1}$) estimates were plotted and integrated using planimetry to determine hourly rates of primary productivity based on surface area (mg $C \cdot m^{-3} hr^{-1}$). Hourly productivity estimates were expanded to daily productivity (mg $C \cdot m^{-3} hr^{-1}$) using solar irradiance data and the methodology described by Vollenweider (1965) and Britton and Greeson (1987). In addition, size fractionated primary productivity estimates were obtained during August at each depth sampled in Redfish and Pettit lakes. Primary productivity was estimated for picos (< 2.0 µm), nanos (2.0-20.0 µm), and micros (>20.0 µm). Hauser and Barber (2002) provide a complete description of methods used to determine primary productivity in 2003.

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 bio-volume 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 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).

Summer seasonal means were calculated from monthly means for June-October.

Limiting Kokanee Escapement

A picket weir comprised of vertical aluminum tubes spaced 3/8" apart were held in place with metal frames spanning Fishhook Creek. The weir was operated from 19 August through 9 September. The weir was checked once or twice daily, and all kokanee were enumerated and passed. The goal was to limit the number of females passing upstream to spawn at 1,200.

Smolt Monitoring

Pettit Lake

A weir was operated at the outlet of Pettit Lake, Idaho (Section 31, Township 8 North, Range 14 East) from 25 April through 25 May 2003. The weir was used to evaluate migration of Snake River sockeye salmon smolts. The weir ran continuously at 100%

capture efficiency until high water at the end of May. 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. Sampling was discontinued when peak flows associated with spring run-off created logistical problems.

Immediately after removal from the trap, all sockeye salmon were scanned for PIT tags. One thousand five hundred and nineteen fish planted in October 2002 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 measured (fork length) to the nearest millimeter and held in a live well for 1 to 10 hours after handling and then released. A condition factor (Fulton's K value, (weight x 10^5/length^3)) for each fish was calculated; mean, minimum, and maximum K value 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 24 April through 26 May 2003. *Oncorynchus nerka* smolts were captured to evaluate migration and to allow tagging of Snake River sockeye salmon smolts using passive integrated transponder (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 the same as at the Pettit Lake Creek weir. We used the Maximum Likelihood Estimator program developed by the University of Idaho specifically for estimating populations and associated confidence intervals for mark recapture estimates during periods of differing capture efficiencies. We used four separate periods to calculate trap efficiency based on different discharge. Discharge ranged from 4 m^3/s to >25 m^3/s. Trap efficiency estimates were made separately for hatchery and wild fish.

Stream Spawning

Stream surveys were conducted to estimate kokanee escapement in tributaries to Redfish, Alturas, and Stanley lakes. Pettit Lake has no identified stream spawning kokanee 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 03 August, with the final count occurring on 20 September. Total escapement estimates were calculated by summing daily counts of kokanee 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 and adult sockeye. Night snorkel surveys were conducted to estimate numbers of spawning residuals, anadromous sockeye, and adult sockeye stocked from the captive-rearing program in both locations. Snorkel surveys in Redfish Lake were conducted weekly on five nights from 2 to 30 October 2003. 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 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 section 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. Data were recorded on a Panasonic SV-3700 digital audio tape recorder.

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 twelve transects were sampled at Redfish and Alturas lakes, respectively.

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

Trawling (by IDFG) and vertical gill netting were done concurrent to hydroacoustic sampling (alternating lakes). Vertical gill net sampling was used to assist in partitioning targets in Alturas Lake. Vertical gillnets were used to determine if other fish species were found in the pelagic areas during sampling. Trawling the previous night in Pettit Lake did not result in the capture of any other fish species, other than *O. nerka* below five meters so no gill nets were set in that lake. Due to NMFS Section 10 permit limitations vertical gillnet sampling in Redfish Lake was not conducted.

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

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

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 IDFG scale analysis (C. Willard, personal communication) from trawl samples to create size bins for length classes. After entering all the parameters, we queried for fish density by size class and transect. Four different size classes were used for all three lakes. 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

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

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

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

and variance was estimated by

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

where D_i = mean density (number/m^2) in stratum i, D_{ij} = mean density for the jth 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 (5, 6.5, 7.5, 10.0, and 12.0 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, composed of graduated mesh sizes (2.54, 3.17, 5.08, and 6.35

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, and sockeye were collected. Starting in 1997, Pettit and Alturas lakes have received eyed-egg plants from captive broodstock sockeye. Therefore, unmarked juveniles collected for diet analysis are referred to as *O. nerka*, as distinctions between resident kokanee and sockeye cannot be made in the field. Sawtooth Valley lakes 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 determine 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

On 27 May SBT and IDFG personnel retrieved egg boxes that had been placed in the lake the previous fall. Individual boxes were evaluated to determine the number of eyed eggs that hatched, and the number hatched that successfully emerged.

On 25 November, 3 December, and 10 December SBT and IDFG personnel placed a total of fifty egg boxes containing 150,013 eggs in Pettit Lake. On 11 December we stocked seventeen egg boxes containing 49,742 eggs in Alturas Lake.

Sockeye Salmon PIT Tagging

SBT personnel assisted IDFG in PIT tagging sockeye salmon parr at the Sawtooth Fish Hatchery before they were released into the lakes.

RESULTS

Limnology

In 2003, mean annual discharge of the Salmon River at Salmon, Idaho (USGS gage 13302500) was 43.8 m^3/s, 20% less than the 1913-2003 average of 54.8 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.

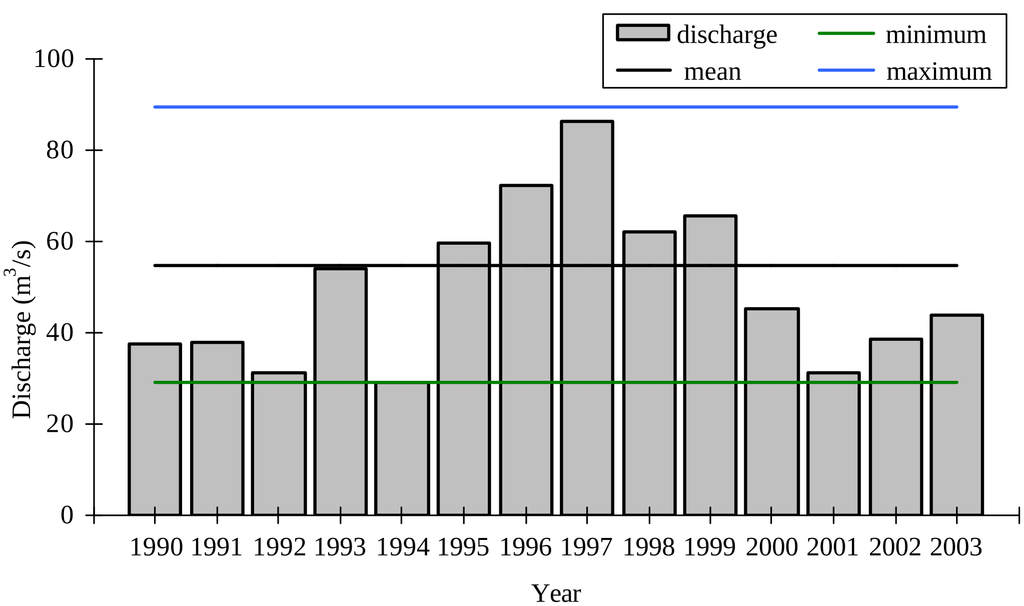

Figure 2. Mean annual discharge for the Salmon River at Salmon, Idaho, 1990 through 2003. Minimum, mean, and maximum are for period of record, 1913 to 2003.

Profile Data

The Sawtooth Valley lakes were inversely stratified and ice covered from early January to May 2003. On 15 May 2003, Redfish Lake was free of ice, Pettit Lake had ice on the main basin but the outlet and boat ramp bays were open, and Alturas and Perkins lakes were covered with ice and the road was impassable above Perkins Lake. Stanley Lake was 25% open water on 14 May and by the following day approximately 90% of the lake surface was ice-free. Redfish, Pettit, and Stanley lakes were all accessible by vehicle on 15 May 2003.

Thermoclines were present from July through October. Maximum surface temperatures were 19-20 °C in each of the four lakes (Appendix A). Seasonal mean surface (0-10 m) water temperatures were 13.9, 13.7, 12.9, and 12.0 °C in Redfish, Pettit, Alturas, and Stanley lakes, respectively (Table 2). Mean temperatures were similar to previous years (1992-2003). 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 1992-2003 ($r = -0.75$, $n=48$) (Figure 3).

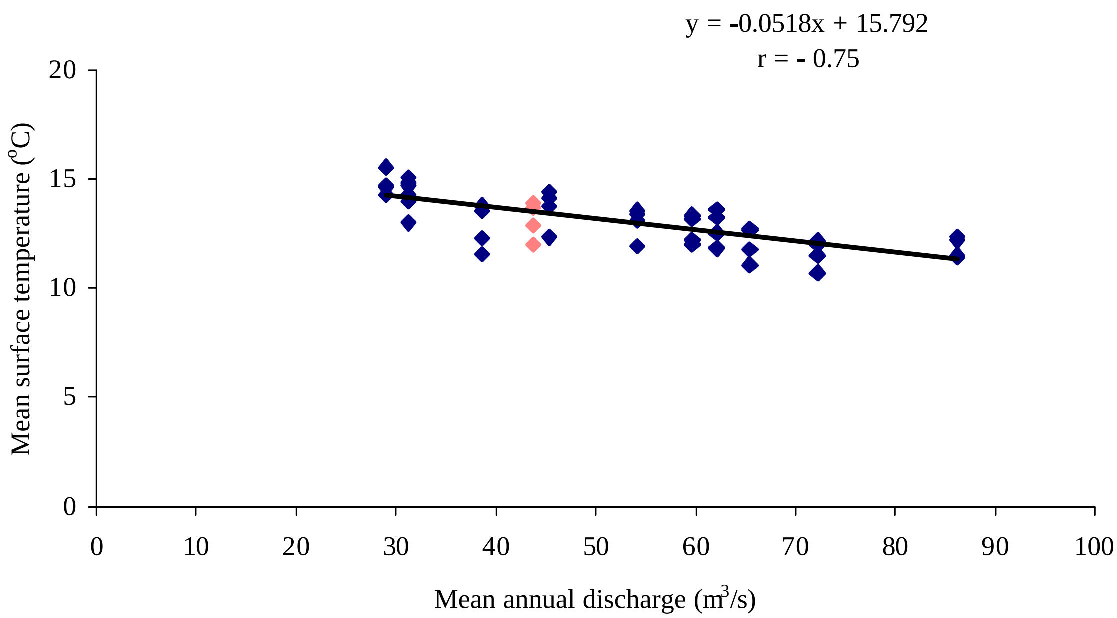

Figure 3. Correlation of mean annual discharge for the Salmon River at Salmon, Idaho, and mean summer surface (0-10 m) temperatures for 1992-2003 in Redfish, Pettit, Alturas, and Stanley lakes. Orange symbols indicate current year.

Redfish Lake mixed completely during May and November, 2003. Hypolimnetic oxygen deficits were minimal; during September and October oxygen concentrations were approximately 4 mg/L on the bottom. Pettit Lake mixed down to approximately 35 m depth during May. During late summer and fall dissolved oxygen concentrations were less than 5 mg/L below 29 m depth. Alturas Lake was not sampled in May because the road was impassible due to snow. In early June the lake had a slight oxygen deficit in the bottom 2 m. By fall the bottom 11 meters had oxygen concentrations less than 5 mg/L. On November 12 the lake was approaching isothermy but had not yet mixed. Stanley Lake was isothermal during the May and November sampling events. In October the bottom 9 m had less than 5 mg/L dissolved oxygen.

Table 2. Seasonal mean (June-October) surface water temperature (^oC), 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, 1992-2003.

Lake	**Year**	**Surface temperature (^oC) 0-10 m**	**Secchi depth (m)**	**Compensation depth (m)**	**Epilimnetic chl *a* (µg/L)**	**Whole-lake zooplankton biomass (mg/m^2)**
Redfish	**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	425.8
	1996	12.0	14.1	18.5	0.7	393.8
	1995	13.4	12.1	26.2	0.5	601.1
	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	**13.5**	**14.2**	**25.3**	**0.9**	**792.2**
Pettit	**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	366.1
	1996	12.2	11.8	17.4	0.8	272.6
	1995	13.2	12.4	22.2	0.5	124.2
	1994	15.6	15.2	30.8	0.3	942.9
	1993	13.6	14.8	23.3	0.6	646.9
	1992	15.1	15.7	29.1	0.4	-
	mean	**13.8**	**13.5**	**23.5**	**0.8**	**971.4**
Alturas	**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**	**12.2**	**19.3**	**0.9**	**285.5**
Stanley	**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	324.4
	1996	10.7	7.5	10.9	1.0	332.6
	1995	12.0	5.8	11.9	0.8	253.2
	1994	14.6	8.3	16.6	0.5	370.1
	1993	11.9	8.3	15.4	1.1	280.0
	1992	14.7	8.6	20.0	0.7	-
	mean	**12.3**	**7.3**	**13.8**	**1.0**	**357.1**

Secchi depth and compensation depth

Secchi and compensation depths decreased between May and June, then gradually deepened as summer progressed (Figures 4 and 5).

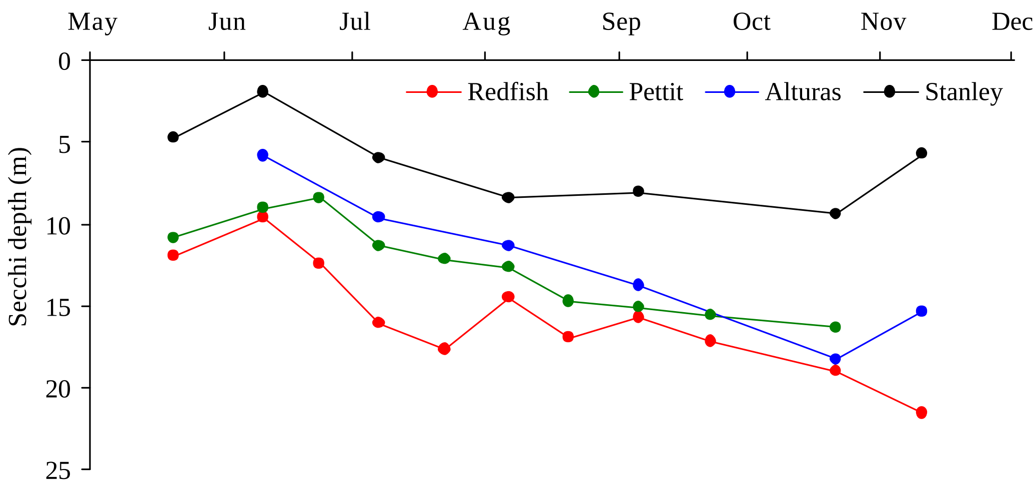

Figure 4. Secchi depths (m) for Redfish, Pettit, Alturas, and Stanley lakes, May through November 2003.

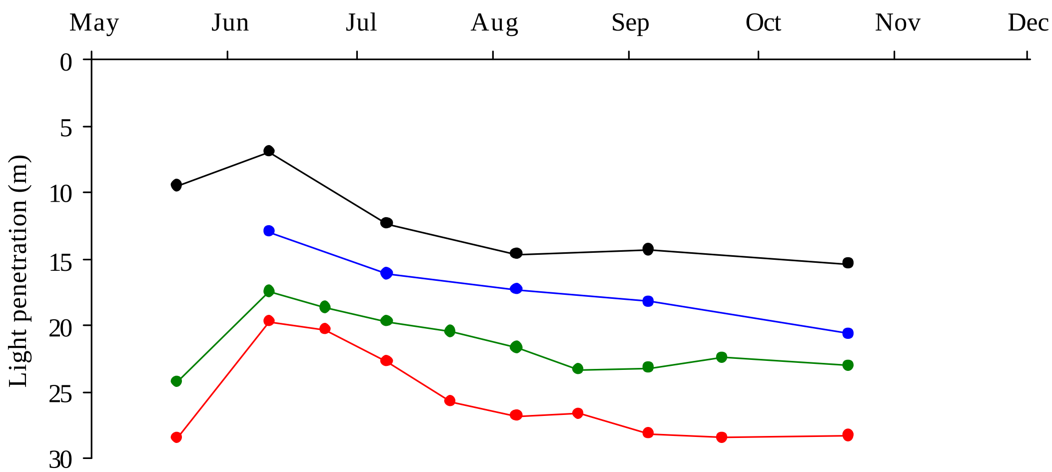

Figure 5. Compensation depths (m) defined by the 1% light level for Redfish, Pettit, Alturas, and Stanley lakes, May through October 2003.

Water Chemistry

During spring turnover (May 2003) depth integrated nutrient concentrations remained extremely low, consistent with the oligotrophic condition of the Sawtooth Valley lakes. TP concentrations were between 5.8 and 8.9 µg/L, TDP was ≤ 5.9 µg/L, and TN concentrations ranged from 110 to 115 µg/L. Nitrate-nitrite concentrations were less than 15 µg/L and TN:TP ratios were between 13 and 19 (Table 3).

Total nitrogen concentrations in the epilimnions of Redfish and Pettit lakes were relatively consistent during summer 2003, ranging from 77-151µg/L (Figure 6). Total phosphorus concentrations were relatively high (6-8 µg/L) during early summer, resulting in TN:TP ratios of 11-17. In July, TP concentrations declined to ≤ 4 µg/L, resulting in TN:TP ratios of >23 for the remainder of the year. Nitrate-nitrite concentrations were near method detection levels except during May in Redfish Lake (Figure 7). Total dissolved phosphorus concentrations were near 4 µg/L until July, then declined to 1-2 µg/L.

Seasonal mean epilimnetic TP concentrations were approximately 4 µg/L and TDP was less than 3 µg/L in Redfish and Pettit lakes. Mean TN concentrations were approximately 100 µg/L in Redfish and Pettit lakes, resulting in TN:TP ratios of 26 and 27, respectively. Mean nitrate-nitrite concentrations were 1.4 µg/L in both lakes (Table 4).

Table 3. Nutrient concentrations (µg/L) and TN:TP ratio during late May (after spring mixing) 1992-2003 in Redfish, Pettit, Alturas, and Stanley lakes, Idaho.

Lake	Year	TP	TDP	SRP	TN	NO^2 - NO^3	NH^4	TN:TP
Redfish	**2003**	5.8	4.1	-	110.3	14.1	-	19.3
	2002	5.9	3.1	-	123.7	11.5	-	21.9
	2001	4.4	2.5	-	52.1	3.4	-	12.3
	2000	4.9	-	-	84.0	19.0	4.1	17.1
	1999	6.8	-	-	78.4	20.4	2.7	11.6
	1998	11.0	-	1.0	82.6	37.0	5.2	7.7
	1997	6.0	-	-	-	17.0	-	-
	1996	4.8	-	-	77.0	12.7	2.3	16.1
	1995	5.0	-	1.0	74.2	3.8	2.0	14.8
	1994	5.6	-	-	-	-	-	-
	1993	8.6	-	-	52.7	6.7	-	6.2
	1992	6.5	-	1.0	61.0	5.5	-	9.5
	mean	**6.2**	**3.2**	**1.0**	**79.7**	**13.0**	**3.1**	**13.9**
Pettit	**2003**	6.2	4.1	-	112.1	3.1	-	18.3
	2002	3.9	2.3	-	125.3	3.7	-	38.3
	2001	5.3	1.8	-	66.7	3.9	-	12.4
	2000	5.2	-	-	37.7	2.0	0.3	7.3
	1999	5.9	-	-	79.5	6.6	1.9	13.5
	1998	10.2	-	0.9	48.0	3.1	0.7	4.8
	1997	5.5	-	-	-	16.5	-	-
	1996	5.3	-	-	64.3	13.0	7.1	11.6
	1995	4.8	-	1.0	88.8	12.0	3.5	18.4
	1994	6.6	-	-	-	-	-	-
	1993	5.8	-	-	94.0	4.0	-	29.2
	1992	6.4	-	1.0	94.5	7.0	-	18.3
	mean	**5.8**	**2.7**	**1.0**	**81.6**	**7.0**	**2.9**	**17.2**
Alturas	**2003**	-	-	-	-	-	-	-
	2002	4.7	3.9	-	115.1	1.8	-	24.8
	2001	7.2	3.5	-	58.6	4.5	-	8.2
	2000	7.5	-	-	56.7	5.4	1.8	7.6
	1999	10.3	-	-	77.4	6.6	1.7	7.4
	1998	18.1	-	1.9	69.6	17.8	3.1	3.8
	1997	10.0	-	-	-	14.7	-	-
	1996	6.0	-	-	74.6	11.6	2.2	12.4
	1995	8.2	-	1.4	66.4	5.8	3.5	7.7
	1994	13.9	-	-	-	-	-	-
	1993	9.4	-	-	72.5	3.3	-	8.2
	1992	10.0	-	2.8	74.0	2.0	-	7.4
	mean	**9.5**	**3.7**	**1.7**	**73.3**	**7.4**	**2.6**	**9.7**
Stanley	**2003**	8.9	5.9	-	114.8	12.7	-	13.2
	2002	8.1	5.1	-	151.9	5.2	-	19.8
	2001	7.0	2.6	-	84.9	3.8	-	11.9
	2000	5.7	-	-	82.3	15.0	4.7	15.4
	1999	14.0	-	-	86.4	14.5	2.5	6.2
	1998	15.1	-	1.2	78.5	19.0	11.6	5.1
	1997	7.2	-	-	-	9.7	-	-
	1996	6.5	-	-	-	-	-	-
	1995	7.0	-	1.2	103.0	9.2	18.0	14.8
	1994	11.3	-	-	-	-	-	-
	1993	11.4	-	-	129.8	8.5	-	12.7
	1992	10.5	-	1.0	93.5	5.0	4.0	8.9
	mean	**9.2**	**4.5**	**1.1**	**104.7**	**10.2**	**10.6**	**12.5**

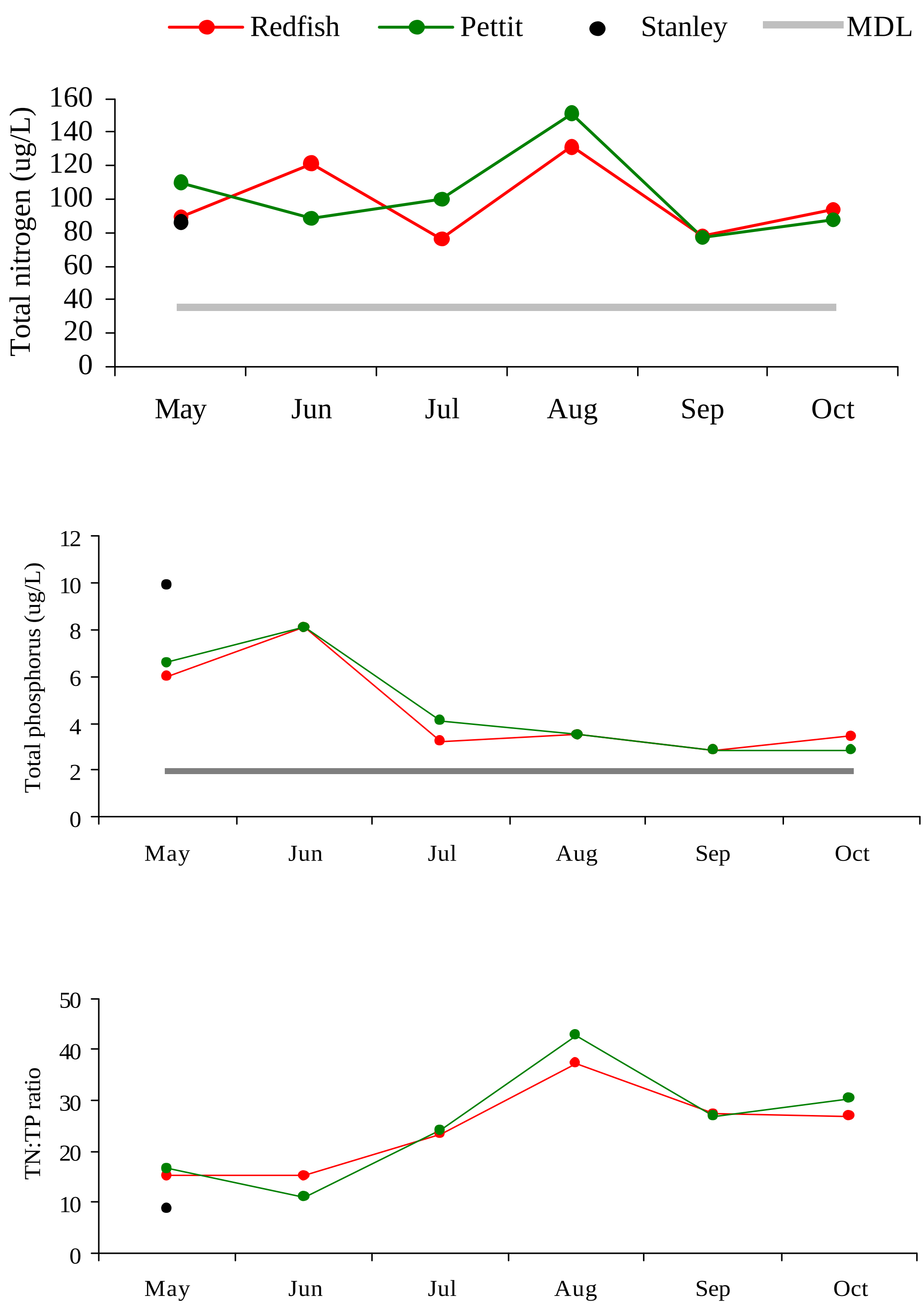

Figure 6. Concentrations of total nitrogen, total phosphorus, and the TN:TP ratio in the epilimnetic waters of Redfish, Pettit, and Stanley lakes during May through October 2003. Grey line denotes method detection level.

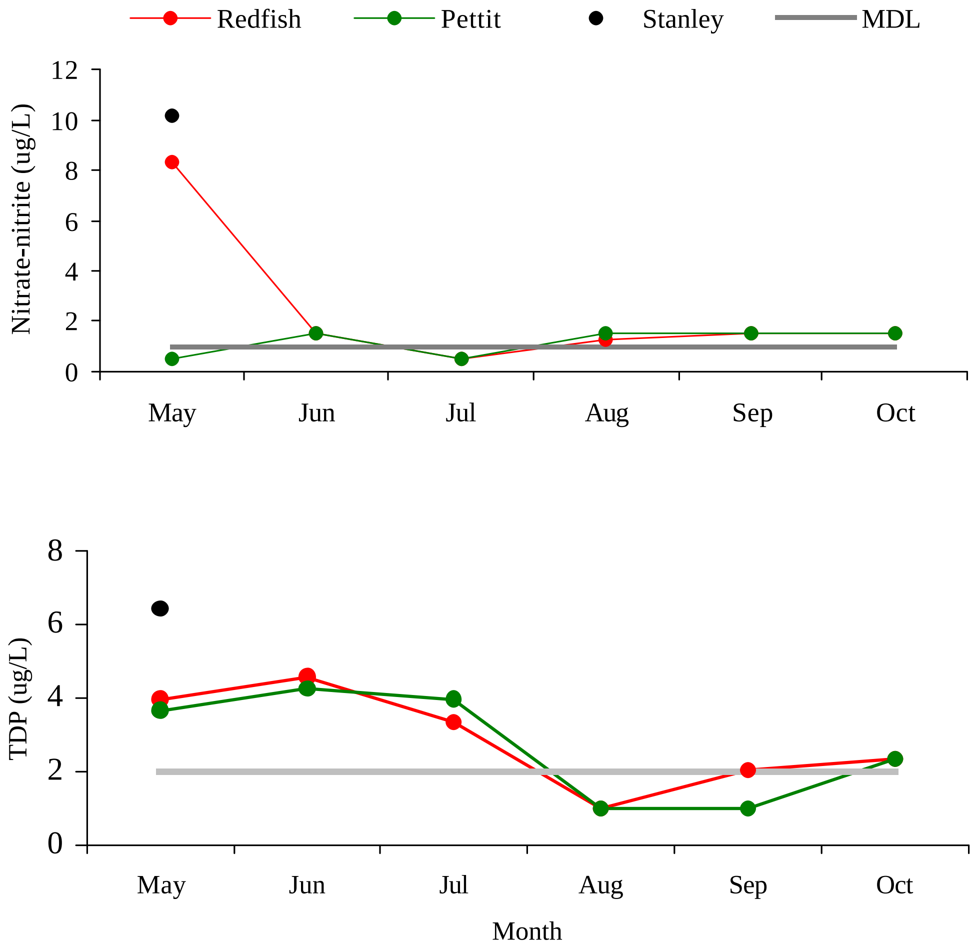

Figure 7. Nitrate-nitrite and total dissolved phosphorus concentrations in the epilimnetic waters of Redfish, Pettit, and Stanley lakes during May through October 2003. Grey line denotes method detection levels.

Table 4. Seasonal mean (June-October) epilimnetic nutrient concentrations (µg/L) and TN:TP ratio in Redfish, Pettit, Alturas, and Stanley lakes during 1992-2003.

Lake	Year	TP	TDP	SRP	TN	N0^3 +NO^2	NH^4	TN:TP
Redfish	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**	**2.7**	**1.5**	**69.6**	**3.8**	**4.0**	**14.0**
Pettit	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**	**2.7**	**1.3**	**84.7**	**1.7**	**2.8**	**18.8**
Alturas	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	**8.5**	**5.2**	**1.3**	**84.7**	**2.2**	**3.8**	**11.9**
Stanley	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 2003, epilimnetic chlorophyll *a* concentrations ranged from 0.2 to 3.6 µg/L in the four Sawtooth Valley lakes (Figure 8). The highest concentrations were observed during spring and fall. During June-October mean epilimnetic chlorophyll *a* concentrations ranged from 0.7 to 1.4 µg/L in the four lakes (Table 2).

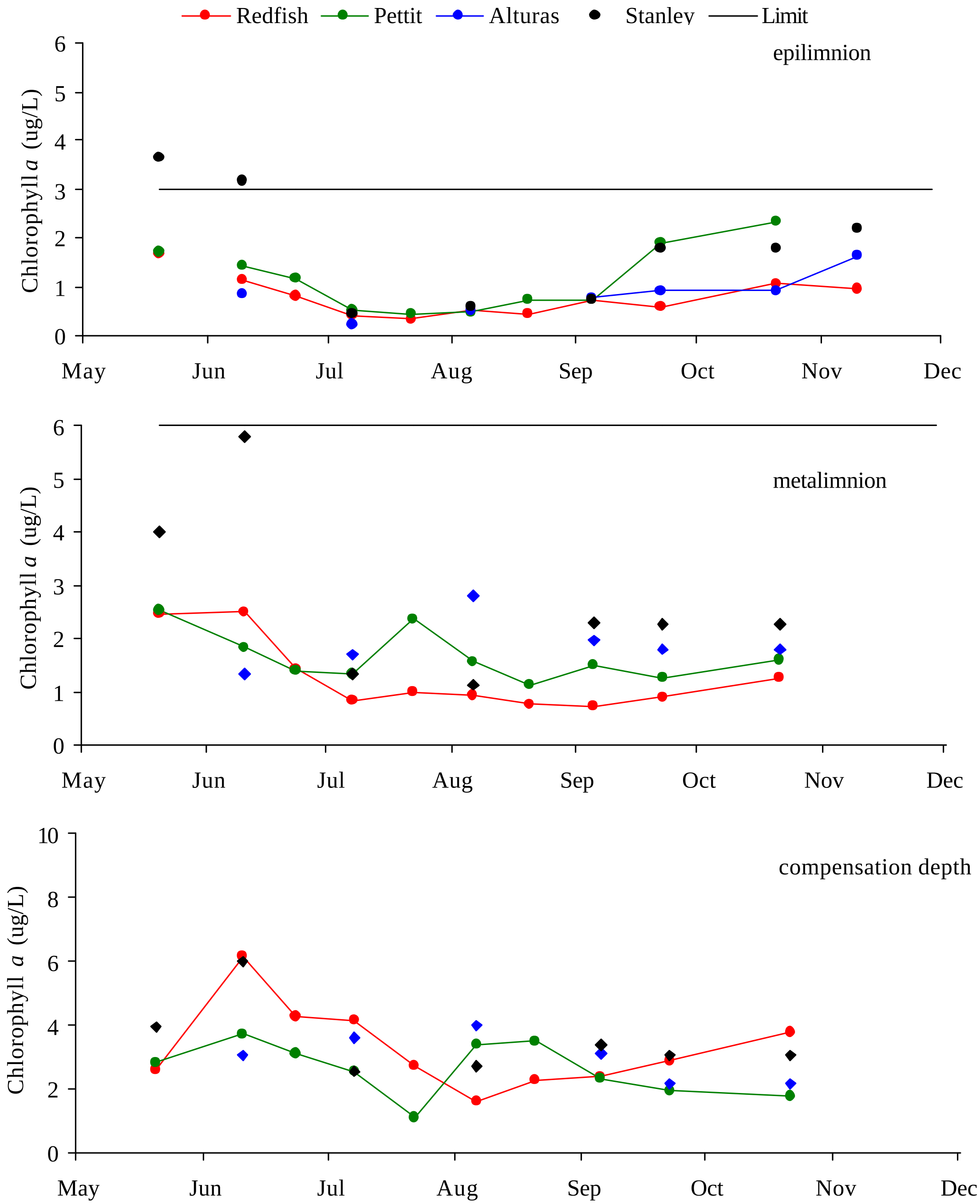

Figure 8. Chlorophyll *a* concentrations (µg/L) in the epilimnion, metalimnion, and compensation depths in Redfish, Pettit, Alturas, and Stanley lakes, May-November 2003.

Primary Productivity

Primary productivity was relatively low in the Sawtooth Valley lakes during July-October 2003. This is consistent with low precipitation and the absence of supplemental nutrients. Daily estimates of depth integrated primary productivity ranged from 50 to 296 mg $C \cdot m^{-2} \cdot day^{-1}$ in the four lakes (Figure 9). Mean primary productivity was highest in Redfish Lake (129 mg $C \cdot m^{-2} \cdot day^{-1}$), a result of the high value observed in July. In Pettit, Alturas, and Stanley lakes average daily primary productivity ranged from 83 to 97 mg $C \cdot m^{-2} \cdot day^{-1}$ (Table 5).

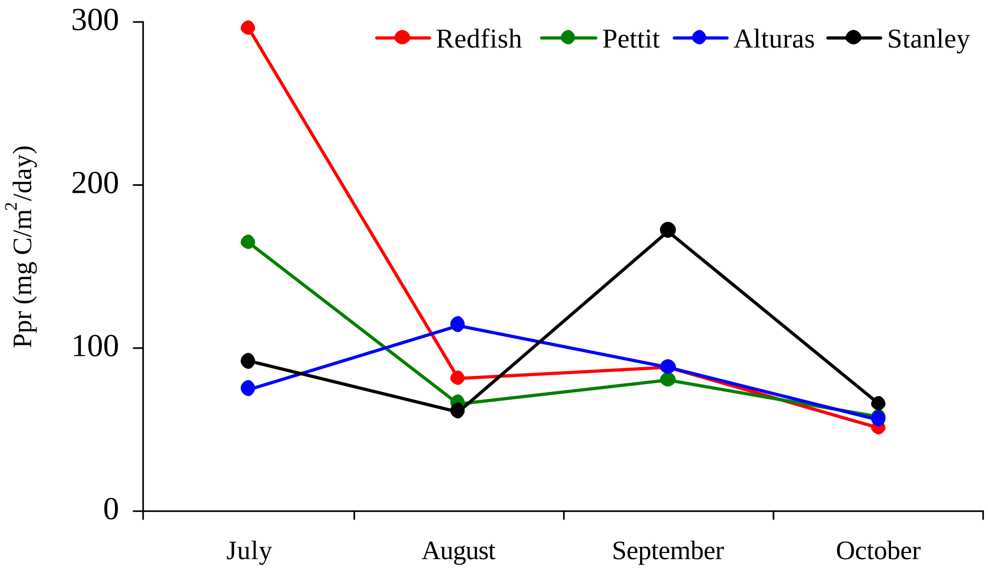

Figure 9. Depth integrated daily primary productivity estimates (mg $C \cdot m^{-2} \cdot day^{-1}$) in Redfish, Pettit, Alturas, and Stanley lakes, Idaho during 2003.

Table 5. Depth integrated daily primary productivity estimates (mg C·m^{-2}·day^{-1}) in Redfish, Pettit, Alturas, and Stanley lakes, Idaho during 1995 to 2003. Shading indicates lake fertilization was occurring at time of sample.

		Daily Primary Productivity (mgC/m^2/day)					
Year	**Lake**	**June**	**July**	**August**	**September**	**October**	**Mean**
2003	**Redfish**	--	295.8	81.3	87.7	50.5	128.8
	Pettit	--	164.8	65.8	80.0	57.5	92.0
	Alturas	--	74.6	113.9	87.7	56.0	83.1
	Stanley	--	91.4	60.8	171.8	65.3	97.3
2002	**Redfish**	--	61.2	76.1	118.5	130.1	96.5
	Pettit	--	46.5	72.1	89.7	93.5	75.4
	Alturas	--	45.9	75.4	111.4	145.7	94.6
	Stanley	--	54.2	52.4	127.1	93.6	81.8
1999	**Redfish**	--	213.0	153.0	208.0	110	171.0
	Pettit	--	274.0	410.0	199.0	187	267.5
	Alturas	--	248.0	258.0	187.0	201	223.5
	Stanley	--	205.0	237.0	111.0	121	168.5
1998	**Redfish N**	276.5	151.0	192.8	232.8	--	213.3
	Redfish S	244.4	205.2	160.0	196.4	--	201.5
	Pettit	240.3	200.0	212.0	150.7	--	200.8
	Alturas	181.8	80.6	208.2	268.3	--	184.7
	Stanley	116.3	131.8	130.8	94.2	--	118.3
1997	**Redfish N**	--	--	--	431.1	184.3	307.7
	Redfish S	--	--	--	469.7	205.8	337.8
	Pettit	--	--	--	318.7	148.9	233.8
	Alturas	--	--	--	227.4	129.5	178.5
	Stanley	--	--	--	218.4	110.9	164.7
1996	**Redfish N**	97.6	130.4	140.1	130.1	146.3	128.9
	Redfish S	206.3	83.6	152.5	122.7	108.4	134.7
	Pettit	117.9	68.7	130.2	148.7	88.0	110.7
	Alturas	105.4	57.0	116.4	113.2	--	98.0
1995	**Redfish**	128.7	360.4	185.6	268.3	--	235.8
	Pettit	83.4	145.3	226.2	198.7	--	163.4
	Alturas	71.2	108.0	147.9	93.5	--	105.2
	Stanley	77.8	119.1	183.1	70.3	--	112.6

Heterotrophic bacteria and autotrophic picoplankton

Heterotrophic bacteria densities in the four Sawtooth Valley lakes ranged from 913,000 to 2,945,000 cells/mL with mean densities between 1,374,000 and 1,903,000 cells/mL (Table 6; Appendix B). Mean phototrophic pico-cyanobacteria densities averaged 3,555 cells/mL in Redfish Lake and ranged from 15,639 to 27,673 cells/mL in Pettit, Alturas, and Stanley lakes.

Table 6. Heterotrophic bacteria and autotrophic picoplankton (APP) densities (cells/mL) in the epilimnions and compensation depths in four Sawtooth Valley lakes during June-October 2003.

		Heterotrophic bacteria			Phototrophic pico-cyanobacteria		
Lake	**Strata**	**min**	**mean**	**max**	**min**	**mean**	**max**
Redfish	epilimnion	938,582	1,295,054	1,795,920	143	1,536	4,133
	compensation depth	1,149,175	1,454,157	1,765,988	570	5,575	15,679
	mean		**1,374,605**			**3,555**	
Pettit	epilimnion	1,414,643	1,955,557	2,945,095	1,425	3,706	7,269
	compensation depth	1,264,474	1,851,095	2,309,040	3,991	27,572	75,970
	mean		**1,903,326**			**15,639**	
Alturas	epilimnion	1,386,137	1,755,868	2,244,900	1,853	9,179	23,375
	compensation depth	803,888	1,581,265	1,988,340	5,274	46,167	137,188
	mean		**1,668,566**			**27,673**	
Stanley	epilimnion	912,926	1,519,584	2,421,285	1,710	14,995	51,027
	compensation depth	1,103,743	1,523,592	2,250,245	5,701	23,689	53,593
	mean		**1,521,588**			**19,342**	

Phytoplankton

Phytoplankton communities in the Sawtooth Valley lakes were dominated by small grazable taxa during 2003. Total phytoplankton densities ranged from 1,115-10,863 cells/mL and total phytoplankton bio-volume ranged from 0.10 to 0.87 mm^3/L in the four lakes (Table 7; Appendix C). Chryso- and Cryptophycean nano-flagellates (*Chrysochromulina* sp. and *Rhodomonas* sp.) and Cyanophytes (*Synechococcus* sp. and *Oscillatoria* sp.) were numerically dominant. Dinophycean dinoflagellates (*Gymnodinium* sp. *and Peridinium* sp.), Chryso- and Cryptophycean nano-flagellates (*Chryptomonas* sp., *Chrysochromulina* sp., *Dinobryon* sp., and *Rhodomonas* sp.), and Bacillariophytes (*Cyclotella* sp., *Fragilaria* sp., *and Asterionella* sp.) had the highest bio-volume of any phytoplankton taxa. Chlorophyceans were present in low densities/bio-volume and were split between (*Planctonema* sp., *Oocystis* sp., *Spondylosium* sp., and *Elakatothrix* sp.). Bio-volume of Cyanophytes was low because of their relatively small size and was comprised of *Synechococcus* sp. and *Oscillatoria* sp..

Table 7. Phytoplankton density (cells/mL) and bio-volume (mm^3/L) in the epilimnion and compensation depths in four Sawtooth Valley lakes during June-October 2003.

		Density			Biovolume		
Lake	**Strata**	**min**	**mean**	**max**	**min**	**mean**	**max**
Redfish	epilimnion	1,115	3,137	12,756	0.10	0.22	0.36
	compensation depth	1,774	4,021	10,863	0.24	0.31	0.46
	mean		**3,579**			**0.27**	
Pettit	epilimnion	1,024	2,888	5,890	0.12	0.18	0.26
	compensation depth	1,135	3,420	6,102	0.21	0.29	0.37
	mean		**3,154**			**0.24**	
Alturas	epilimnion	1,399	2,546	4,562	0.10	0.15	0.20
	compensation depth	1,267	2,735	4,754	0.20	0.26	0.35
	mean		**2,641**			**0.21**	
Stanley	epilimnion	2,950	5,088	9,858	0.15	0.30	0.39
	compensation depth	2,048	4,426	8,262	0.23	0.45	0.87
	mean		**4,757**			**0.37**	

Zooplankton

In 2003, Pettit Lake had the highest seasonal mean zooplankton biomass followed by Redfish, Alturas, and Stanley lakes (Figure 10). Seasonal mean biomass (June-October) was 2,761 mg/m^2 in Pettit Lake, 2,006 mg/m^2 in Redfish Lake, 484 mg/m^2 in Alturas Lake, and 336 mg/m^2 in Stanley Lake (Table 2).

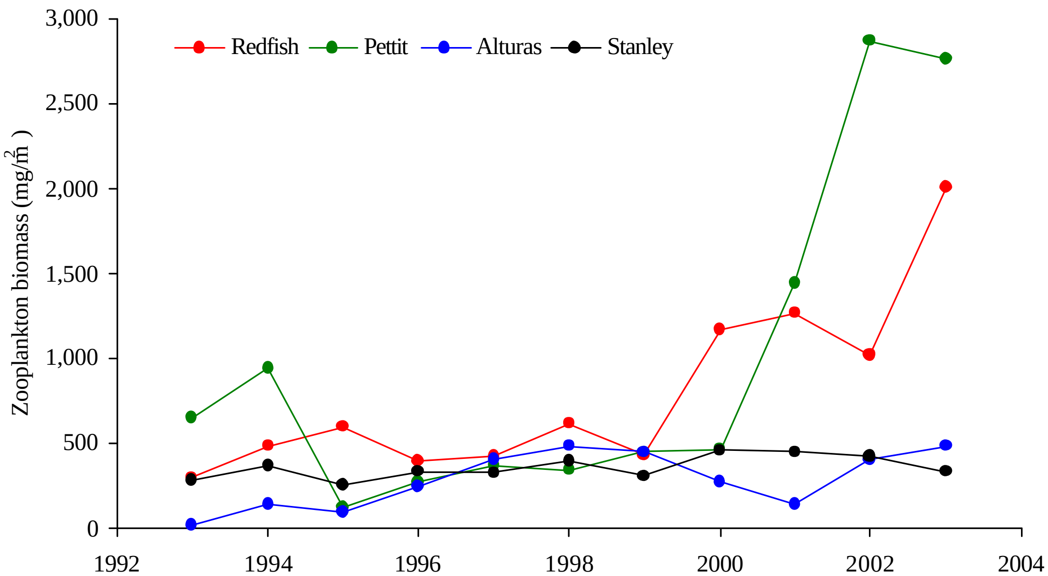

Figure 10. Seasonal mean zooplankton biomass (June-October) for the Sawtooth Valley lakes, 1993-2003.

Redfish Lake zooplankton biomass was the highest observed since monitoring began in 1992. *Daphnia* (984 mg/m^2), *Holopedium* (501 mg/m^2), and Cyclopoid copepods (312 mg/m^2) dominated mean summer biomass (Figure 11). During February-March 2003, whole-lake zooplankton biomass averaged 475 mg/m^2 and was dominated by cyclopoid copepods (234 mg/m^2) and *Daphnia* (171 mg/m^2) (Figure 12).

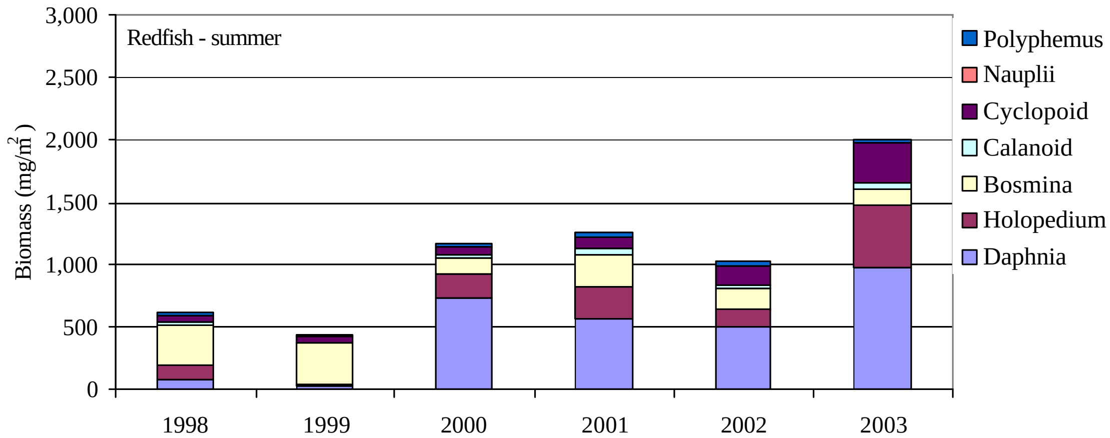

Figure 11. Mean areal zooplankton biomass (June-October) in Redfish Lake, 1998-2003.

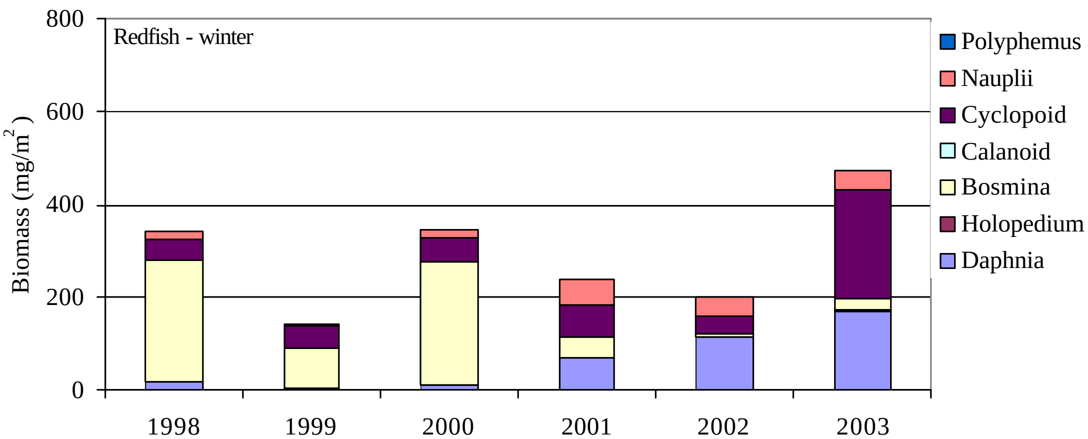

Figure 12. Mean areal zooplankton biomass (January-March) in Redfish Lake, 1998-2003.

Pettit Lake total zooplankton biomass was down slightly from 2002 but still very high compared to previous years and the other Sawtooth Valley lakes (Figure 13). Zooplankton biomass was predominately *Daphnia* (1,510 mg/m^2), nauplii (539 mg/m^2), and *Bosmina* (461 mg/m^2). During January-March 2003, total zooplankton biomass was relatively low (192 mg/m^2) and was mostly nauplii and *Polyphemus* (Figure 14).

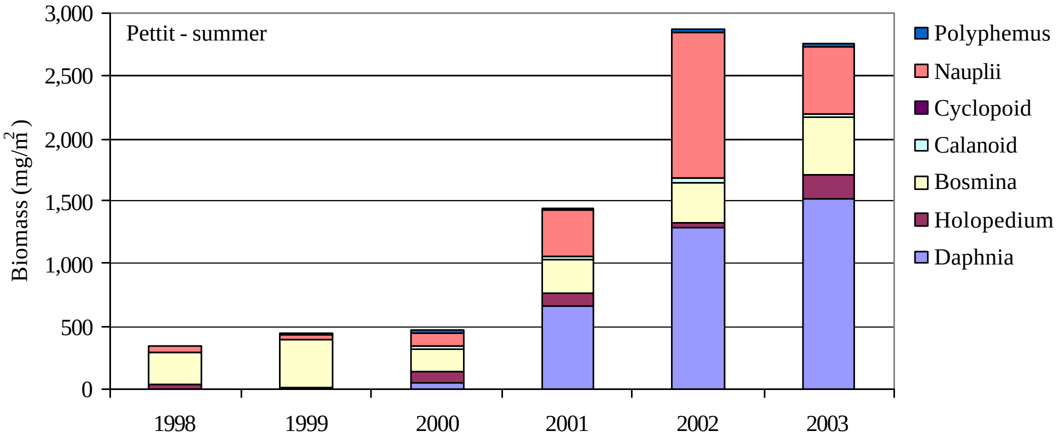

Figure 13. Mean areal zooplankton biomass (June-October) in Pettit Lake, 1998-2003.

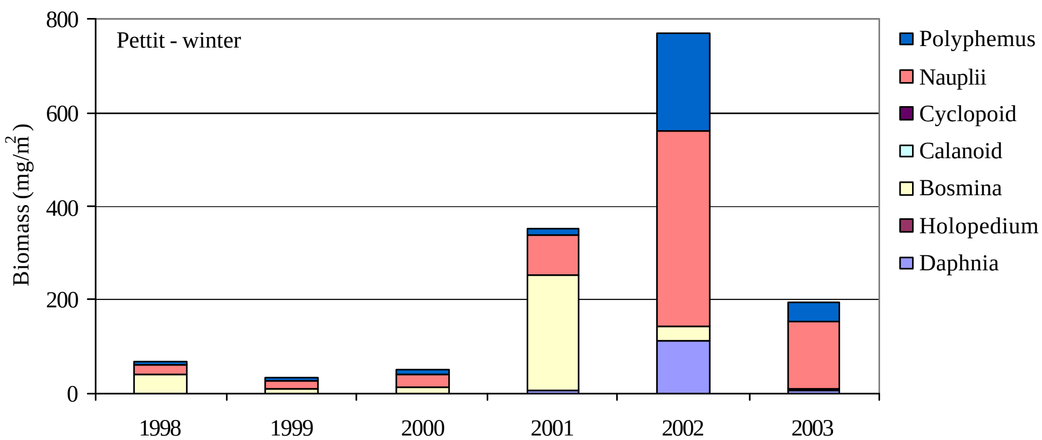

Figure 14. Mean areal zooplankton biomass (January-March) in Pettit Lake, 1998-2003.

In Alturas Lake, mean seasonal total zooplankton biomass was 484 mg/m^2, a slight increase from 2002 (Figure 15). During the summer of 2003, zooplankton populations consisted predominantly of *Daphnia* (261 mg/m^2) and cyclopoid copepods (125 mg/m^2). Mean zooplankton biomass during January-March was higher than past years with a total biomass of 363 mg/m^2 of which 300 mg/m^2 were *Bosmina* (Figure 16).

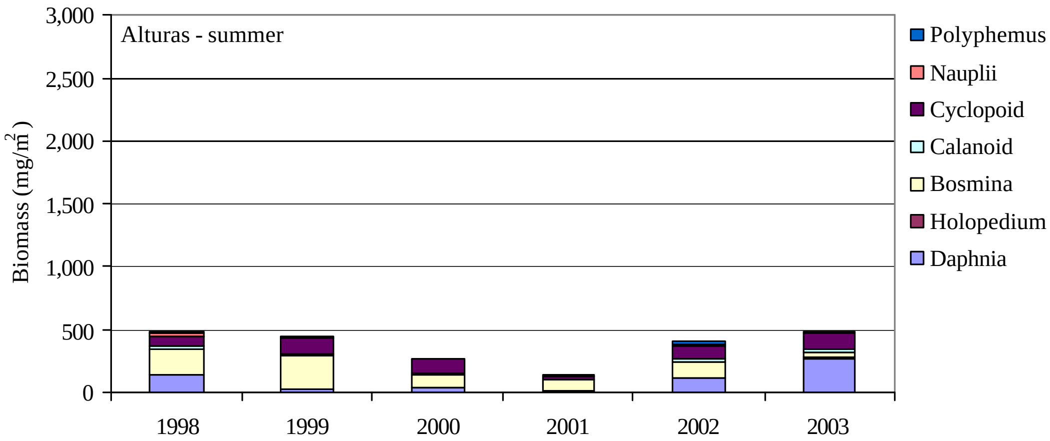

Figure 15. Mean areal zooplankton biomass (June-October) in Alturas Lake, 1998-2003.

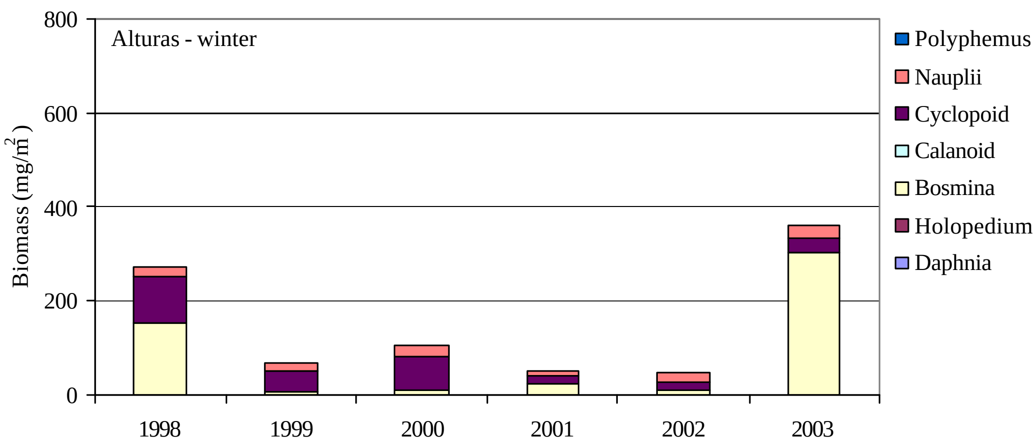

Figure 16. Mean areal zooplankton biomass (January-March) in Alturas Lake, 1998-2003.

Stanley Lake continues to have relatively stable zooplankton assemblages. Seasonal mean zooplankton biomass was (336 mg/m^2), slightly lower than the previous three years (Figure 17). During summer 2003, zooplankton species composition was similar to that observed in 2000 and 2001, with most biomass represented by *Daphnia* and calanoid copepods. In March 2003, total biomass was 720 mg/m^2 and was predominately nauplii (523 mg/m^2) and cyclopoid copepods (191 mg/m^2).

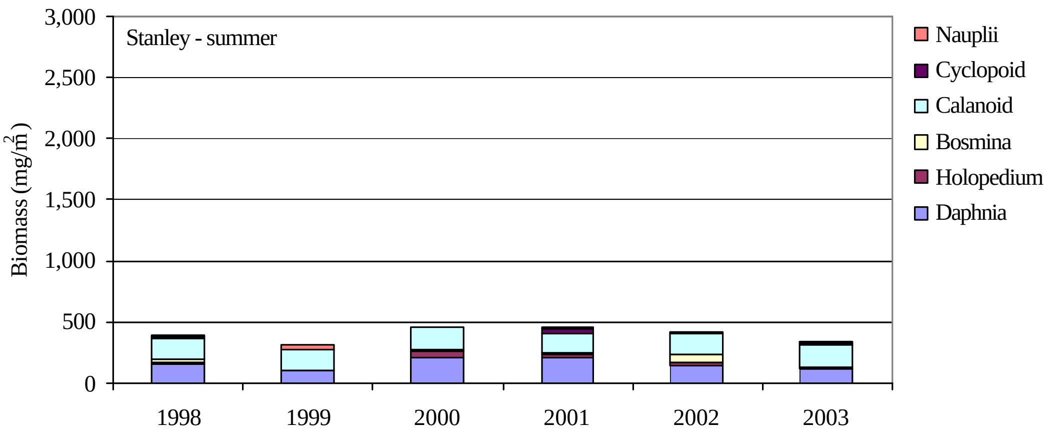

Figure 17. Mean areal zooplankton biomass (June-October) in Stanley Lake, 1998-2003.

Limit Kokanee Escapement

The aluminum picket weir constructed in Fishhook Creek to prevent an over escapement of spawning female kokanee salmon did not function as intended. As a result, an additional 900 female kokanee salmon passed above our weir and potentially contributed to spawning in 2003, surpassing our management objective of 1,200 spawning females.(Table 8). Several theories about the weir failure were postulated: these included loose substrate allowing fish to burrow underneath the pickets; and passage through beaver tunnels that were not located during operation.

Smolt Monitoring

Pettit Lake

We captured a total of 13,343 Snake River sockeye salmon comprised of 28 wild/natural (from the eyed egg release), 11,618 fall release from the Sawtooth Hatchery, eight summer release from the Sawtooth Hatchery (2001 release), and 1,688 summer release fish from the Bonneville Hatchery. We recaptured 1,214 smolts that had been PIT tagged prior to release the previous year. Because of the large numbers of recaptures we only tagged eighty-three smolts in 2003, resulting in the availability of 1,297 tagged fish to determine interrogation rates and travel time to the Lower Snake River Dam complex.

There were a total of three sockeye salmon mortalities. All sockeye salmon mortalities were attributed to weir impingement during high discharge.

All numbers from Pettit Lake Creek are actual counts. On the last day of trapping we captured 227 sockeye salmon smolts, indicating that the migration had not been completed and an unknown number of smolts went unaccounted. Trapping was discontinued when high flows overwhelmed the weir.

Smolts migrating from Pettit Lake had the following migration rates: Sawtooth Hatchery fall release = 58.8%; and Bonneville Hatchery summer release = 20.2%. As mentioned previously, we ceased trapping before the migration season was complete, so values for Pettit are lower than actually occurred. This is especially true for the summer release group as there were more PIT tag detections at downstream projects than we interrogated at the trap.

Alturas Lake

We captured thirteen *O. nerka* without an adipose fin clip ("wild") with a population estimate of two hundred and eighty-six. We captured thirty-eight hatchery sockeye salmon smolts with a corresponding estimate of five hundred and fifty-three smolts. All of the hatchery sockeye salmon captured were from the summer 2002 release of 6,123 Bonneville Hatchery reared fish. We PIT tagged thirteen hatchery fish. There were no mortalities during trapping operations. We also captured seven hundred and fifty juvenile Snake River Chinook salmon with no mortalities.

Smolts migrating from Alturas Lake had a migration rate of 9.0 %. The, mean length, weight, and condition factors of smolt migrations are located in Table 9.

Growth Rates

Juvenile sockeye salmon from the captive broodstock program were measured and weighed during three different periods: at release into the lakes in 2002; during mid-winter sampling; and at capture as smolts in 2003. Their growth (length and weight) increased in all three releases (Alturas Lake summer and Pettit Lake summer and fall releases) from time of release to recapture as smolts (Figure 18a; 18b). The greatest increase in both length and weight occurred for the summer release fish in Pettit Lake-reared at the Bonneville Hatchery prior to release. Summer released fishin the summer in Alturas Lake and fall released fish in Pettit Lake experienced similar growth in length; however, the Alturas group gained more weight (Figure 18a; 18b).

Table 8. Fry recruitment, egg-to-fry survival, and adult escapement in Fishhook, Alturas, and Stanley Lake creeks.

Location	Brood Year	Adult Escapement	Mean # Eggs	Male:femal e Ratio	Egg-Fry Survival	Fry Recruits
Fishhook	2003	9,679	453	3.6:1	12.3%	117,240
Fishhook	2002	8,626	281	1.7:1	12.3%	110,422
Fishhook	2001	5,853	272	1.5:1	12.3%	78,327
Fishhook	2000	60	148	2.4:1	12.3%	321
Fishhook	1999	2,336	233	1:1	12.3%	33,474
Fishhook	1998	6,149	233	4.6:1	12.3%	35,549
Fishhook	1997	8,572	233	1.4:1	12.3%	102,360
Fishhook	1996	10,662	286	3:1	13.1%	99,866
Fishhook	1995	7,000	230	1:1	12.3%	99,015
Fishhook	1994	9,200	230	1:1	13.6%	143,888
Fishhook	1993	10,800	230	1:1	11.5%	142,830
Fishhook	1992	9,600	300	1:1	11.5%	165,600
Fishhook	1991	7,200	300	1:1	3.3%	35,640
Alturas	2003	48	150	1:1	13.0%	468
Alturas	2002	99	150	1:1	13.0%	965
Alturas	2001	145	150	1:1	13.0%	1,414
Alturas	2000	827	339	1:1	13.0%	18,223
Alturas	1999	8,334	285	1:1	13.0%	154,387
Alturas	1998	15,273	220	1:1	13.0%	217,889
Alturas	1997	8,492	168	1:1	13.0%	92,733
Alturas	1996	744	150	1:1	13.0%	7,254
Alturas	1995	1,600	150	1:1	13.0%	15,600
Alturas	1994	3,200	150	1:1	13.0%	31,200
Alturas	1993	200	-	1:1	13.0%	2,000
Stanley	2003	413	270	1:1	7.0%	3,903
Stanley	2002	946	270	1:1	7.0%	8,940
Stanley	2001	6,180	257	1:1	7.0%	55,589
Stanley	2000	5,665	243	1:1	7.0%	48,181
Stanley	1999	948	270	1:1	7.0%	16,637
Stanley	1998	783	270	1:1	7.0%	7,399
Stanley	1997	629	270	1:1	7.0%	5,935
Stanley	1996	825	270	1:1	7.0%	7,796
Stanley	1995	90	270	1:1	7.0%	850
Stanley	1994	600	270	1:1	7.0%	5,670
Stanley	1993	1,900	-	1:1	7.0%	19,000

Release group condition factors (Fulton's K) were variable from time of release to subsequent recaptures. The Alturas Lake group had the same mean value of 0.83 at time of release when compared to capture as smolts (Figure 18c; Table 9c). The Pettit Lake summer release group improved in condition from time of release (K= 0.83) through mid-winter (K=0.97), then experienced a decline when captured as smolts (K= 0.87). Condition of the Pettit Lake fall release group exhibited a constant decline from the time of release (K= 1.03), to mid-winter capture (K=0.99), through capture as smolts (K=0.89) (Figure 18c; Table 9c).

Stream Spawning

Starting in 2000, escapement of adult kokanee salmon to Fishhook Creek increased each year (Table 8). Kokanee salmon adult escapement in Fishhook Creek increased approximately one thousand fish from 2002 to 9,679. Escapement in Alturas Lake Creek reached an all time low of forty-eight fish since counts began in 1993. Unlike Fishhook Creek, Alturas Lake Creek has experienced a decline each year since an all time high in 1998 (Table 8). Stanley Lake Creek escapement was also very low at 413 fish.

Beach Spawning

We snorkeled in Redfish Lake to enumerate beach spawning residual and captive reared adult sockeye salmon. Two areas were snorkeled: Sockeye Beach and the southeast inlet area. The highest peak counts were eighteen and one at Sockeye Beach and the southeast inlet area, respectively. These were the highest peak counts since 1994 (Figure 19a).

Redside shiners represented the largest composition of all the fish species observed during snorkeling. Adult sockeye salmon represented a slightly higher percent of the total species composition than did residual sockeye salmon (Figure 19b).

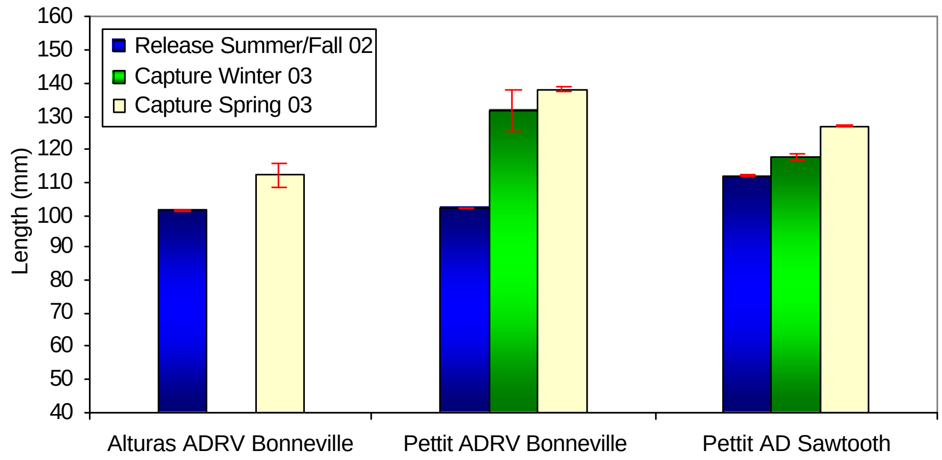

Figure 18a. Alturas and Pettit lakes growth rate evaluation using length data. Error bars are (±) one standard error.

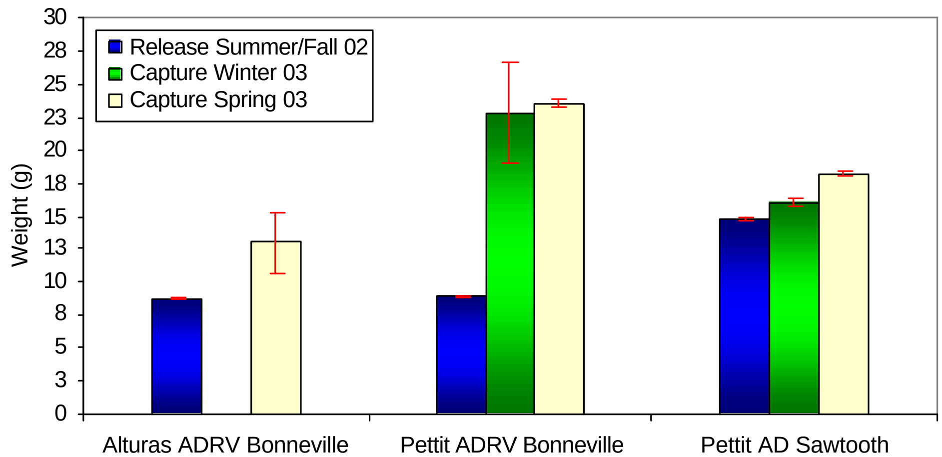

Figure 18b. Alturas and Pettit lakes growth rate evaluation using weight data. Error bars are (±) one standard error.

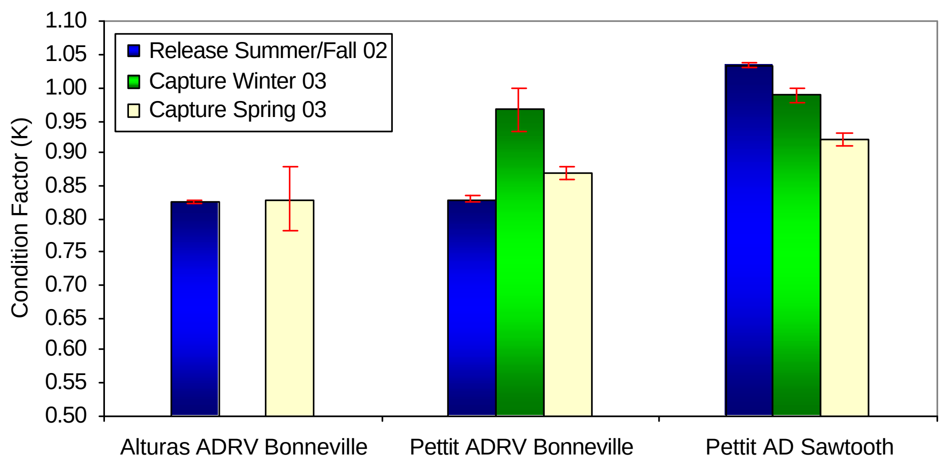

Figure 18c. Alturas and Pettit lakes growth rate evaluation using condition factor data. Error bars are (±) one standard error.

Table 9. Hatchery sockeye release and migration length, weight, and condition factor data, 1998-2004.

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	10/8/02	AD	Sawtooth	111.87	15.31	1.09	995	2003	124.16	16.84	0.88	741
RFL	8/29/02	ADRV	Bonneville	104.00	9.51	0.85	900	2003	126.50	17.27	0.85	670
RFL	10/8/01	AD	Sawtooth	110.70	13.78	0.99	20	2002	125.42	15.73	0.96	1,204
RFL	10/13/00	AD	Sawtooth	104.70	11.11	0.93	20	2001	115.69	13.49	0.86	1,391
RFL	10/13/99	AD	Sawtooth	100.52	9.76	0.95	104	2000	114.49	11.98	0.79	107
RFL	10/14/98			101.11	10.62	1.03	300	1999	107.97	9.08	0.74	31
PET	10/8/02	AD	Sawtooth	111.90	14.81	1.03	999	2003	126.53	18.16	0.89	617
PET	8/27/02	ADRV	Bonneville	102.23	8.89	0.83	574	2003	138.30	23.47	0.87	174
PET	10/8/01	AD	Sawtooth	110.70	13.78	0.99	20	2002	146.88	29.66	0.92	520
PET	7/30/01	ADRV	Sawtooth	72.75	3.63	0.93	20	2002	161.19	38.73	0.92	114
PET	7/26/01	ADLV	Eagle	110.35	14.19	1.05	20	2002	168.45	43.71	0.91	87
PET	10/12/00	AD	Sawtooth	104.70	11.11	0.93	20	2001	128.12	18.61	0.88	137
PET	7/28/00	ADRV	Eagle	97.42	8.45	0.91	50	2001	121.29	16.99	0.94	7
PET	7/27/00	ADLV	Sawtooth	66.50	2.95	0.99	50	2001	125.40	17.45	0.87	15
PET	10/13/99	AD	Sawtooth	101.22	10.45	1.00	104	2000	ND	ND	ND	ND
PET	7/14/98	AD	Eagle	93.56	8.69	1.06	1507	1999	120.63	15.23	0.85	79
ALT	8/27/02	ADRV	Bonneville	101.48	8.71	0.83	694	2003	111.81	12.99	0.83	16
ALT	10/8/01	AD	Sawtooth	110.70	13.78	0.99	20	2002	112.21	10.56	0.73	380
ALT	7/30/01	ADRV	Sawtooth	72.75	3.63	0.93	20	2002	94.83	6.12	0.71	12
ALT	7/26/01	ADLV	Eagle	110.35	14.19	1.05	20	2002	97.60	7.40	0.69	5
ALT	10/11/00	AD	Sawtooth	104.70	11.11	0.93	20	2001	104.41	9.21	0.78	129
ALT	7/28/00	ADRV	Eagle	97.42	8.45	0.91	50	2001	ND	ND	ND	ND
ALT	7/27/00	ADLV	Sawtooth	66.50	2.95	0.99	50	2001	90.84	6.27	0.82	19
ALT	10/13/99	AD	Sawtooth	105.59	10.79	0.94	99	2000	109.93	10.52	0.79	127
ALT	10/14/98	AD	Sawtooth	99.39	10.30	1.05	847	1999	107.85	10.02	0.79	75

ND- No Data

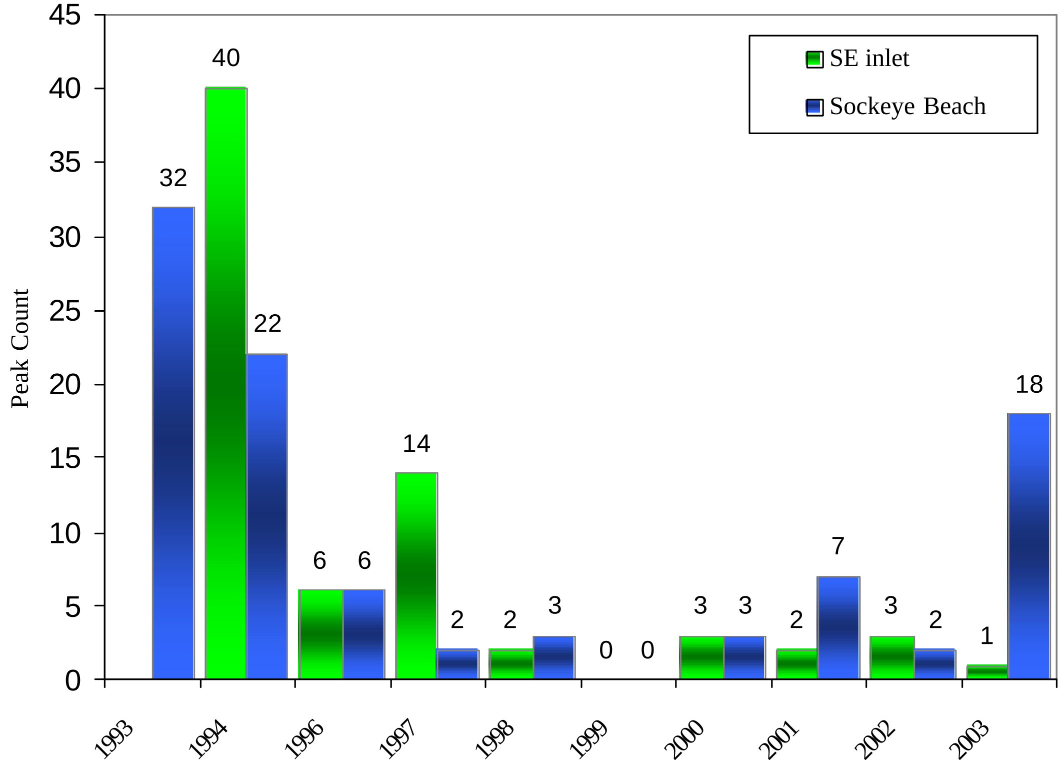

Figure 19a. Redfish Lake residual sockeye salmon counts from snorkel surveys (1995 data not available).

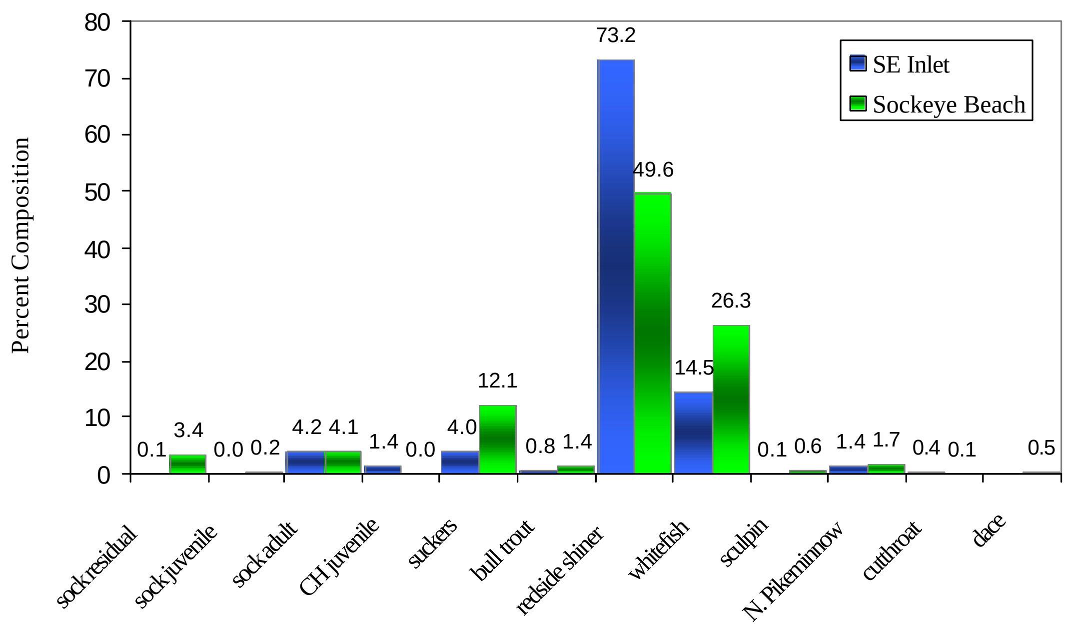

Figure 19b. Redfish Lake residual snorkel survey species composition data at SE Inlet and Sockeye Beach, 2003.

Hydroacoustic Population Estimates

Hydroacoustic population estimates of *O. nerka* in the Sawtooth Valley lakes during September 2003 ranged from 130,087 to 19,805 fish in Redfish and Pettit lakes, respectively (Table 10). Alturas Lake was intermediate with an estimated *O. nerka* population of 48,671.

Table 10. Hydroacoustic and trawl *O. nerka* population estimates for three Sawtooth Valley lakes, 1994-2003.

	Population Estimate (± 95% C.I.)		density(fish/ha)		Biomass Estimate kg/ha	
Lake	Acoustic	Trawl	Acoustic	Trawl	Acoustic	Trawl
REDFISH 2003	130,087 ± 29,979	81,727 ± 25,995	212	133	4.13	1.60
REDFISH 2002	61,535 ± 11,597	50,204 ± 28,485	100	82	2.82	1.00
REDFISH 2001	43,849 ± 16,747	12,980 ± 11,982	71	21	0.71	0.10
REDFISH 2000	24,481 ± 10,520	10,268 ± 5,675	40	17	0.41	0.07
REDFISH 1999	69,472 ± 29,887	42,916 ± 13,097	113	70	1.66	0.93
REDFISH 1998	107,613 ± 33,615	31,485 ± 10,839	175	51	2.50	1.79
REDFISH 1997	131,513 ± 32,319	55,762 ± 13,961	214	91	3.37	2.48
REDFISH 1996	66,325 ± 24,000	56,213 ± 27,306	108	91	2.23	2.83
REDFISH 1995	103,570 ± 24,500	61,646 ± 27,639	168	100	3.41	4.36
REDFISH 1994	133,360	51,529 ± 33,179	217	84	2.39	1.41
PETTIT 2003	19,805 ± 13,234	11,961 ± 3,255	122	74	6.19	5.5
PETTIT 2002	25,642 ± 10,949	18,328 ± 2,351	158	115	8.91	12.00
PETTIT 2001	37,410 ± 24,864	16,931 ± 7,556	231	105	9.08	6.10
PETTIT 2000	40,435 ± 20,977	40,559 ± 11,717	250	250	9.04	10.20
PETTIT 1999	51,496 ± 12,171	31,422 ± 21,280	318	194	9.76	6.33
PETTIT 1998	67,206 ± 30,950	27,654 ± 8,764	415	171	13.47	9.74
PETTIT 1997	63,195 ± 29,581	21,730 ± 11,262	390	134	23.25	5.10
PETTIT 1996	77,680 ± 15,850	71,655 ± 10,631	480	442	36.23	15.19
PETTIT 1995	77,765 ± 46,900	59,002 ± 15,735	480	364	34.16	14.73
PETTIT 1994	12,265 ± 8,360	14,743 ± 3,683	76	91	4.67	3.12
ALTURAS 2003	48,671 ± 14,564	46,234 ± 26,442	144	137	6.37	5.5
ALTURAS 2002	53,339 ± 15,625	24,374 ± 16,968	158	72	4.01	2.20
ALTURAS 2001	130,359 ± 29,446	70,159 ± 18,642	386	208	3.16	2.40
ALTURAS 2000	134,867 ± 33,244	125,462 ± 27,037	399	371	6.12	2.08
ALTURAS 1999	130,133 ± 25,936	56,675 ± 43,536	385	168	4.20	0.40
ALTURAS 1998	101,519 ± 32,605	65,468 ± 33,479	300	194	2.09	1.42
ALTURAS 1997	30,795 ± 5,869	9,761 ± 4,664	91	29	2.34	2.10
ALTURAS 1996	20,620 ± 4,140	13,012 ± 4,668	61	39	0.97	1.34
ALTURAS 1995	32,260 ± 5,090	23,061 ± 9,182	95	68	3.31	1.66
ALTURAS 1994	10,980 ± 1,090	5,785 ± 6,919	33	17	1.07	0.43
ALTURAS 1993		49,037 ± 13,175				2.58
ALTURAS 1992		47,237 ± 61,868				2.42
ALTURAS 1991		125,045 ± 30,708				3.97
ALTURAS 1990		126,644 ± 31,611				3.26

Population estimates in Redfish Lake have increased every year since 2000, the year with the lowest population estimate since we began sampling in 1994. Pettit Lake has experienced a slow decline in *O. nerka* since 1998. Alturas Lake experienced a dramatic decline in 2002 and continued that trend in 2003. Alturas Lake appears to be experiencing a low cycle for the second time since we began sampling.

Redfish Lake- The total *O. nerka* population in Redfish Lake increased for the third year in a row following a three year decline from the 1997 high of 131,513 ± 32,319. The yoy estimate of 65,946 ± 25,854 tracked well with our recruitment estimate of 110,422 from brood year 2002 spawning (Table 11). 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 declined by 5,837 fish from 2002, the fifth consecutive annual decline. The rough fish barrier at the lake outlet was removed in 1996 and coupled with sockeye stocking could be a possible explanation for this trend.

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. This seems to be consistent with four year high low cycles in this lake.

Table 11. Total lake and cohort population estimates from hydroacoustic sampling in 2003.

Redfish Lake 2003

	mean ln (mm)	mean wt(g)	Pop. Est	C.I.	Biomass	Kg/Ha
45-80 mm	60.6	2.4	65,946	25,854	156.3	0.25
81-130 mm	103.7	11.9	34,629	8,234	412.6	0.67
131-180mm	150.8	36.0	16,610	8,348	597.8	0.97
181-270mm	215.4	106.5	12,903	8,012	1,374.4	2.23
		Whole Lake = 130,087 ± 29,979				**4.13**

Pettit Lake 2003

	mean ln (mm)	mean wt	Pop. Est	C.I.	Biomass	Kg/Ha
30-65 mm	53.91	1.64	1,271	1,634	2.1	0.01
66-149 mm	113.49	19.76	9,642	5,858	190.5	1.18
150-190mm	169.30	64.87	5,230	5,051	339.3	2.09
191-23 mm	208.96	128.48	3,662	3,283	470.5	2.90
		Whole Lake = 19,805 ± 13,234				**6.19**

Alturas Lake 2003

	mean ln (mm)	mean wt	Pop. Est	C.I.	Biomass	Kg/Ha
30-80 mm	64.98	3.07	6,091	379	18.7	0.06
81-120mm	102.33	13.03	7,592	2,096	98.9	0.29
121-170 mm	147.58	42.18	21,968	7,494	926.6	2.74
171-200 mm	184.85	85.36	12,984	5,816	1,108.3	3.28
		Whole Lake = 48,671 ± 14,564				**6.37**

Hydroacoustic/trawl comparisons

Hydroacoustic/trawl ratios in 2003 were 1.59, 1.63, and 1.05 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 ten year mean hydroacoustic/trawl ratios are 2.14 for Redfish Lake and 1.98 for Alturas Lake. The eight year mean for Pettit Lake is 1.73.

Correlating hydroacoustic and trawl population estimates varied by comparison. Correlating ten years (n=30) of total lake *O. nerka* estimates reveals a relationship of r=0.85 (Figure 20a). 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 0.84 (n=20) (Figure 20b), the I+ cohort was r=0.57 (n=22) (Figure 20c), and the two year old r value was 0.83 (n=22) (Figure 20d).

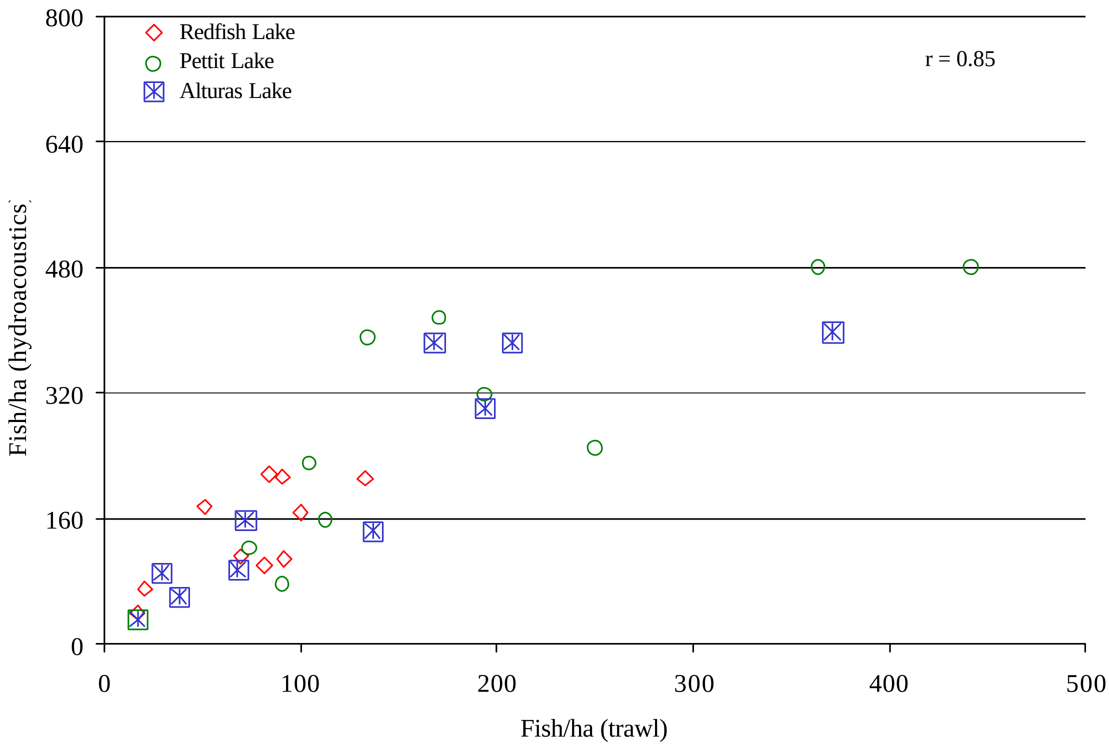

Figure 20a. Correlation of hydroacoustic/trawl whole lake population estimates for 1994-2003.

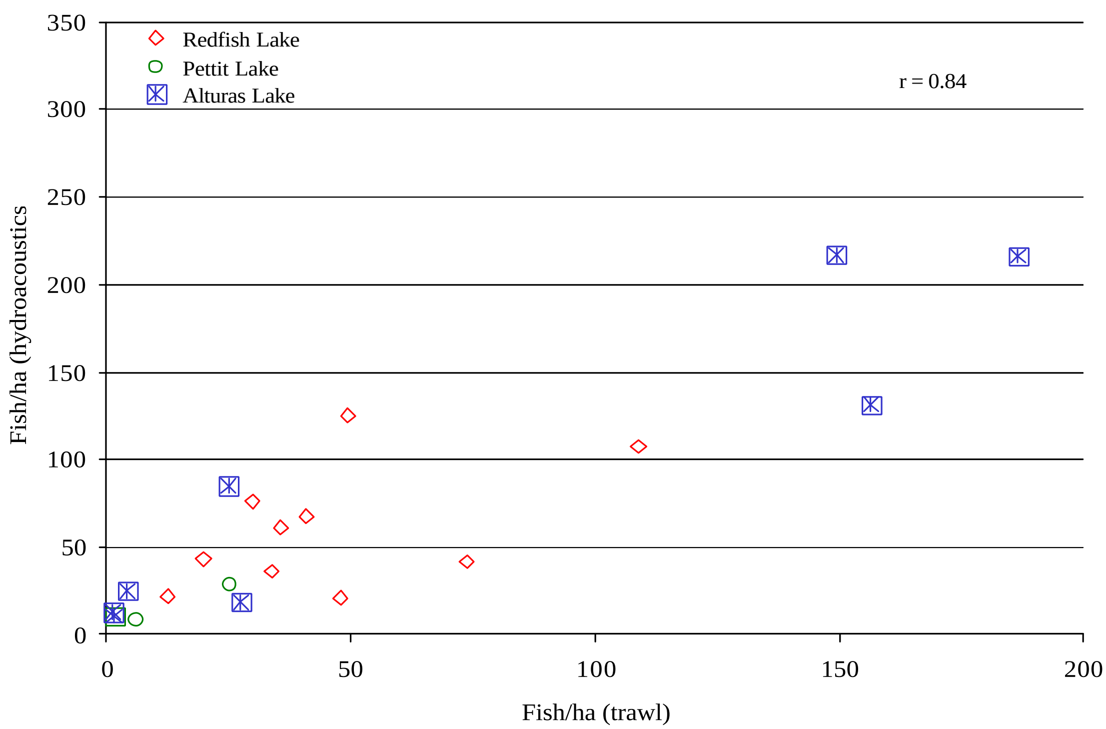

Figure 20b. Correlation of hydroacoustic/trawl yoy population estimates for 1994-2003.

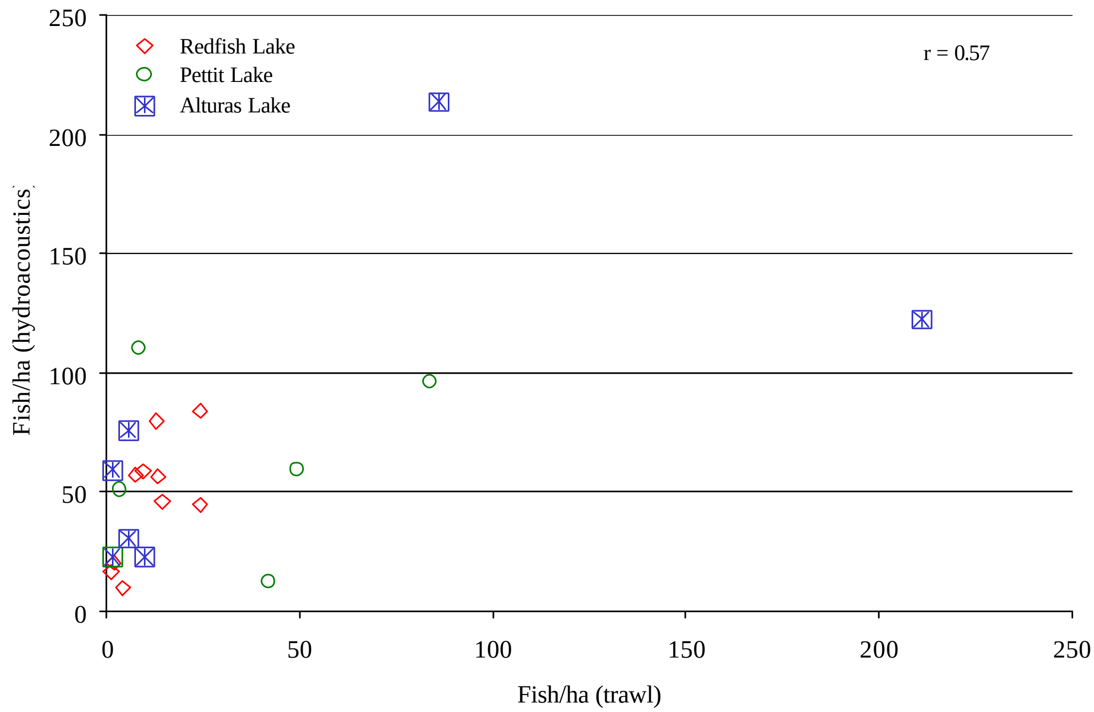

Figure 20c. Correlation of hydroacoustic/trawl 1+ population estimates for 1994-2003.

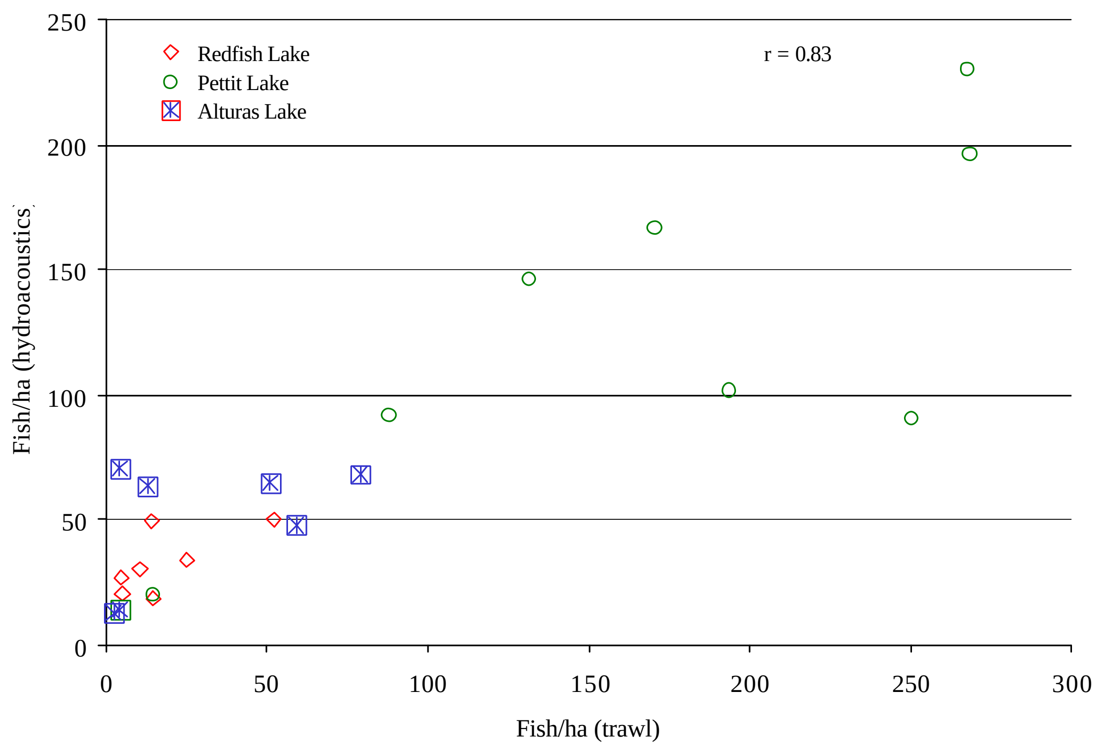

Figure 20d. Correlation of hydroacoustic/trawl 2+ population estimates for 1994-2003.

Gillnet Sampling

We conducted vertical and horizontal gillnet sampling in Pettit and Alturas lakes during 2003. Fish species captured during 2003 sampling events included: sockeye/kokanee salmon *O. nerka*; steelhead/rainbow trout *O. mykiss*; bull char *Salvelinus confluentus*; mountain whitefish *Prosopium williamsoni*; northern pikeminnow *Ptychocheilus oregonensis*; redside shiner *Richardsonius balteatus*; and brook char *S. fontinalis*. Results including location sampled, set type, sample size, catch per unit effort, species sampled, mean fork length, mean weight, mean condition factor, and total hours fished are summarized in Tables 12 and 13.

Diet Analysis

We analyzed stomach contents for diet composition in Redfish, Pettit, and Alturas lake samples collected in 2003. Samples were drawn from gillnet and trawling efforts conducted by the SBT and IDFG, respectively. Summarized data including prey items as a percent of total stomach contents are presented in Tables 14 and 15. Electivity indices are summarized for sockeye and *O. nerka* in Table 15.

Pettit and Alturas Lake Egg Boxes

During November and December of 2003, in conjunction with IDFG personnel, we placed a total of 149,966 eyed sockeye salmon eggs in shoal areas of Pettit Lake. During December we also placed 49,700 eyed sockeye salmon eggs into shoal areas of Alturas Lake.

Sockeye Salmon PIT Tagging

During October we assisted IDFG personnel in PIT tagging 5,550 sockeye salmon parr for release into Redfish, Pettit, and Alturas lakes.

Table 12. Results of Pettit and Alturas lake gillnet samples, 2003.

Date	Station	Set Type	(n) CPUE	Mean Lt (mm)	Mean Wt (g)	Hours Fished
			Pettit Lake			
Rainbow Trout						
January 27, 2003	A	Horizontal	(3) 0.150	301	262.0	20.0
January 27, 2003	A2	Horizontal	(1) 0.048	265	189.0	21.0
January 28, 2003	A	Horizontal	(1) 0.044	239	120.8	22.5
February 18, 2003	A	Horizontal	(2) 0.045	293	281.5	44.0
Bull Char						
February 18, 2003	A	Horizontal	(1) 0.023	ND	ND	44.0
Brook Char						
January 27, 2003	A	Horizontal	(1) 0.050	220	110.0	20.0
February 18,2003	A	Horizontal	(1) 0.023	236	134.0	44.0
Whitefish						
February 18, 2003	A	Horizontal	(1) 0.023	288	247.0	44.0
Northern Pikeminnow						
January 27, 2003	A	Horizontal	(2) 0.100	311	323.0	20.0
January 27, 2003	A2	Horizontal	(8) 0.381	215	128.3	21.0
February 18, 2003	A	Horizontal	(1) 0.023	256	181.0	44.0
O. nerka						
January 27, 2003	A	Horizontal	(4) 0.200	236	128.5	20.0
January 28, 2003	A	Horizontal	(5) 0.222	222	115.0	22.5
January 28, 2003	E	Vertical	(5) 0.217	119	16.6	23.0
February 18, 2003	E	Vertical	(1) 0.045	189	70.4	22.3
March 13, 2003	E	Vertical	(1) 0.021	198	ND	47.0
Sockeye						
January 28, 2003	A2	Horizontal	(2) 0.089	227	119.3	22.5
January 28, 2003	E	Vertical	(22) 0.956	119	16.7	23.0
February 18, 2003	E	Vertical	(44) 1.986	119	16.6	22.3
March 13, 2003	E	Vertical	(4) 0.085	108	11.6	47.0
			Alturas Lake			
Bull Char						
Sept 23, 2003	Boat R	Vertical	(6) 0.462	487	ND	13.0
Northern Pikeminnow						
Sept 23, 2003	Boat R	Vertical	(5) 0.385	286	ND	13.0
O. nerka						
Sept 23, 2003	Boat R	Vertical	(28) 2.154	178	ND	13.0
Redside Shiner						
Sept 23, 2003	Boat R	Vertical	(4) 0.308	90	ND	13.0

ND=no data, NA=not applicable

Table 13. Fish community gillnet sample and percent diet composition data from Pettit and Alturas lakes, 2003.

Date		**Lake**		**Set Type**		**Station**		**Species**		**Sample Size**		**Mean Lt (mm)**		**Mean Wt (g)**	
1/28/03		**Pettit**		**Horizontal**		**A**		**N.Pikemin.**		**7**		**240.57**		**136.90**	
SAL	CYP	UN.F.	MOL	ODO	DIP	TRI	COL	HEM	CH.P.	CH.L.	CHI	TER	ZOO	PLA	OTH
0.00	16.67	0.00	0.00	75.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1/28/03		**Pettit**		**Horizontal**		**A**		**Brook Char**		**1**		**220**		**110**	
SAL	CYP	UN.F.	MOL	ODO	DIP	TRI	COL	HEM	CH.P.	CH.L.	CHI	TER	ZOO	PLA	OTH
0.00	63.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	36.95
1/28/03		**Pettit**		**Horizontal**		**A**		**Rainbow Tr.**		**4**		**291.75**		**243.75**	
SAL	CYP	UN.F.	MOL	ODO	DIP	TRI	COL	HEM	CH.P.	CH.L.	CHI	TER	ZOO	PLA	OTH
0.00	0.00	24.68	31.57	4.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	39.39	0.00
2/19/03		**Pettit**		**Horizontal**		**A**		**N. Pikemin.**		**1**		**256**		**181**	
SAL	CYP	UN.F.	MOL	ODO	DIP	TRI	COL	HEM	CH.P.	CH.L.	CHI	TER	ZOO	PLA	OTH
0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2/19/03		**Pettit**		**Horizontal**		**A**		**Brook Char**		**1**		**236**		**134**	
SAL	CYP	UN.F.	MOL	ODO	DIP	TRI	COL	HEM	CH.P.	CH.L.	CHI	TER	ZOO	PLA	OTH
0.00	98.40	0.00	0.00	1.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2/19/03		**Pettit**		**Horizontal**		**A**		**M. Whitefish**		**1**		**288**		**247**	
SAL	CYP	UN.F.	MOL	ODO	DIP	TRI	COL	HEM	CH.P.	CH.L.	CHI	TER	ZOO	PLA	OTH
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00
2/19/03		**Pettit**		**Horizontal**		**A**		**Rainbow Tr.**		**1**		**320**		**397**	
SAL	CYP	UN.F.	MOL	ODO	DIP	TRI	COL	HEM	CH.P.	CH.L.	CHI	TER	ZOO	PLA	OTH
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.79	95.21
9/24/03		**Alturas**		**Vertical**		**Boat Ramp**		**Bull Char**		**2**		**522.50**		**1500.00**	
SAL	CYP	UN.F.	MOL	ODO	DIP	TRI	COL	HEM	CH.P.	CH.L.	CHI	TER	ZOO	PLA	OTH
36.13	50.00	13.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.71	0.00

SAL=salmonid, CYP=cyprinid, UN.F.=unidentified fish, MOL=mollusk, ODO=odonate, DIP=diptera, TRI=trichoptera, COL=coleopteran, HEM=hemiptera, CH.P.=chironomid pupae, CH.L.=chironomid larvae, CHI=chidorid, TER=terrestrial, ZOO=zooplankton, PLA=plant, OTH=other

Table 14. Sockeye, kokanee, and *O. nerka* gillnet and trawl mean length, weight, condition factor, and zooplankton diet percent composition in Redfish, Pettit, and Alturas lakes, 2003.

Date	**Lake**	**Set Type**	**Species**	**Mark**	**Sample Size**	**Mean Lt (mm)**	**Mean Wt (g)**	**Condition Factor (K)**	**Daph**	**Hol**	**Bos**	**Cal**	**Cyc**	**Naup**	**Poly**
1/29/03	PET	Vert	SE	AD	15	118.67	16.42	0.98	5.48	0.00	0.95	0.00	93.57	0.00	0.00
1/29/03	PET	Vert	Kok	None	4	208.50	102.00	1.15	3.80	0.00	0.00	0.00	96.20	0.00	0.00
1/29/03	PET	Hor	Kok	None	1	222	116.60	1.02	16.52	0.00	0.00	0.00	83.48	0.00	0.00
2/19/03	PET	Vert	SE	AD, ADRV	15	117.87	16.10	0.96	8.02	0.00	3.33	0.00	88.66	0.00	0.00
3/13/03	PET	Vert	SE	AD	3	109.67	12.10	1.17	7.15	0.00	0.71	0.00	92.14	0.00	0.00
9/24/03	ALT	Vert	*O. nerka*	None	10	181.10	N/A	N/A	54.06	0.00	0.00	0.82	0.00	0.00	45.12
9/24/03	RFL	Trawl	*O. nerka*	None	9	61.78	1.96	0.82	66.52	0.00	0.12	1.85	30.85	0.00	0.65
9/24/03	RFL	Trawl	*O. nerka*	None	8	151.63	56.99	0.91	82.88	0.00	0.01	2.21	14.05	0.00	0.85
9/25/03	PET	Trawl	SE	AD, ADRV	2	170.50	61.35	1.24	98.58	0.00	0.00	0.00	0.00	0.00	1.42
9/25/03	PET	Trawl	*O. nerka*	None	10	145.80	42.95	1.20	78.97	0.00	0.03	0.04	0.03	0.00	20.93
9/26/03	ALT	Trawl	*O. nerka*	None	10	169.30	51.04	1.05	71.77	0.00	0.07	0.18	0.26	0.00	27.72

Daph=Daphnia, Hol=Holopedium, Bos=Bosmina, Cal=Calanoid, Cyc=Cyclopoid, Naup=Nauphlia, Poly=Polyphemus

Table 15. Sockeye and *O. nerka* gillnet and diet composition data including electivity indices, 2003 (* denotes only YOY sample).

Date	Lake	Set Type	Species	Mark	N	R_i, P_i, E	Daph	Hol	Bos	Cal	Cyc	Naup	Poly
1/29/03	PET	Vert	SE	AD	15	R_i	5.48	0.00	0.95	0.00	93.57	0.00	0.00
						P_i	1.90	0.00	0.79	0.00	32.40	64.91	0.00
						Electivity Index	**0.49**	*	**0.09**	*	**0.49**	**-1.00**	*
1/29/03	PET	Vert	Kok	None	4	R_i	3.80	0.00	0.00	0.00	96.20	0.00	0.00
						P_i	1.90	0.00	0.79	0.00	32.40	64.91	0.00
						Electivity Index	**0.33**	*	**-1.00**	*	**0.50**	**-1.00**	*
1/29/03	PET	Hor	Kok	None	1	R_i	16.52	0.00	0.00	0.00	83.48	0.00	0.00
						P_i	1.90	0.00	0.79	0.00	32.40	64.91	0.00
						Electivity Index	**0.79**	*	**-1.00**	*	**0.44**	**-1.00**	*
2/19/03	PET	Vert	SE	AD, ADRV	15	R_i	8.02	0.00	3.33	0.00	88.66	0.00	0.00
						P_i	1.23	0.10	1.12	0.00	34.12	63.44	0.00
						Electivity Index	**0.73**	**-1.00**	**0.50**	*	**0.44**	**-1.00**	*
3/13/03	PET	Vert	SE	AD	3	R_i	7.15	0.00	0.71	0.00	92.14	0.00	0.00
						P_i	0.28	0.00	1.42	0.00	27.37	70.93	0.00
						Electivity Index	**0.92**	*	**-0.34**	*	**0.54**	**-1.00**	*
9/24/03	ALT	Vert	*O. nerka*	None	10	R_i	54.06	0.00	0.00	0.82	0.00	0.00	45.12
						P_i	31.99	1.47	1.76	0.00	15.55	46.54	2.69
						Electivity Index	**0.26**	**-1.00**	**-1.00**	**1.00**	**-1.00**	**-1.00**	**0.89**
9/24/03	RFL	Trawl	*O. nerka* *	None	9	R_i	78.97	0.00	0.03	0.04	0.03	0.00	20.93
						P_i	58.15	0.05	24.05	0.00	10.17	7.14	0.43
						Electivity Index	**0.15**	**-1.00**	**-1.00**	**1.00**	**-0.99**	**-1.00**	**0.96**
9/24/03	RFL	Trawl	*O. nerka*	None	8	R_i	82.88	0.00	0.01	2.21	14.05	0.00	0.85
						P_i	49.16	7.69	4.74	0.00	17.15	17.58	3.68
						Electivity Index	**0.26**	**-1.00**	**-1.00**	**1.00**	**-0.10**	**-1.00**	**-0.62**
9/25/03	PET	Trawl	SE	AD, ADRV	2	R_i	98.58	0.00	0.00	0.00	0.00	0.00	1.42
						P_i	58.15	0.05	24.05	0.00	10.17	7.14	0.43
						Electivity Index	**0.26**	**-1.00**	**-1.00**	*	**-1.00**	**-1.00**	**0.54**
9/25/03	PET	Trawl	*O. nerka*	None	10	R_i	66.52	0.00	0.12	1.85	30.85	0.00	0.65
						P_i	49.16	7.69	4.74	0.00	17.15	17.58	3.68
						Electivity Index	**0.15**	**-1.00**	**-0.95**	**1.00**	**0.29**	**-1.00**	**-0.70**
9/26/03	ALT	Trawl	*O. nerka*	None	10	R_i	71.77	0.00	0.07	0.18	0.26	0.00	27.72
						P_i	31.99	1.47	1.76	0.00	15.55	46.54	2.69
						Electivity Index	**0.38**	**-1.00**	**-0.93**	**1.00**	**-0.97**	**-1.00**	**0.82**

N=sample size, R_i=percent composition of stomach contents, P_i=percent composition of prey items in the environment, E=electivity index

DISCUSSION

Growth Rates and Survival

Growth rates of stocked sockeye salmon parr from the captive rearing program provide insight into potential performance differences associated with hatchery origin, lake rearing conditions, and stocking strategies. We evaluated two groups with respect to stocking strategies: a summer release group consisting of fish reared at the Bonneville Fish Hatchery; and a fall release group reared at the Sawtooth Fish Hatchery. Summer release fish were stocked into Redfish (n=61,500), Pettit (n=7,805), and Alturas (n=6,123) lakes and fall release groups were released into Redfish (n=45,001) and Pettit (n=19,981) lakes. In both Redfish and Pettit lakes, summer release fish grew faster than fall release fish; however, the percent of smolts detected the following spring during smolt migration was much higher for fall release fish than for summer release fish. Smolt migration estimates assume that stocked sockeye salmon parr migrate the following spring as 1 year olds. Data suggests that a variable portion of sockeye 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 summer release fish exhibited better growth and survival compared to the same release groups from Redfish and Alturas lakes. Redfish Lake summer release fish grew faster than those stocked into Alturas Lake, but percent migration was low in both lakes (9%). Unique lake rearing conditions offer explanations for these differences. Sockeye pre-smolts released into Pettit Lake during the summer of 2002 experienced high total zooplankton and *Daphnia* biomass for several months, followed by extremely low zooplankton biomass dominated by Nauplii (Figure 21). This group had the highest growth rates of any of the release groups in both length and weight; and was the only group that increased in condition factor while rearing in the lake. Sockeye pre-smolts released into Pettit Lake during the fall of 2002, not benefiting from favorable summer rearing conditions, grew in length and weight at a slower rate and experienced a decline in condition factor; however, condition factor was still highest at migration for this group. In addition, the percent of fish stocked that successfully migrated during the spring of 2003 was much higher for this group (58.8%) compared to the summer release group (20.2%). The rapid growth rates of the summer release group may have caused this group to residualize, resulting in the low migration rate.

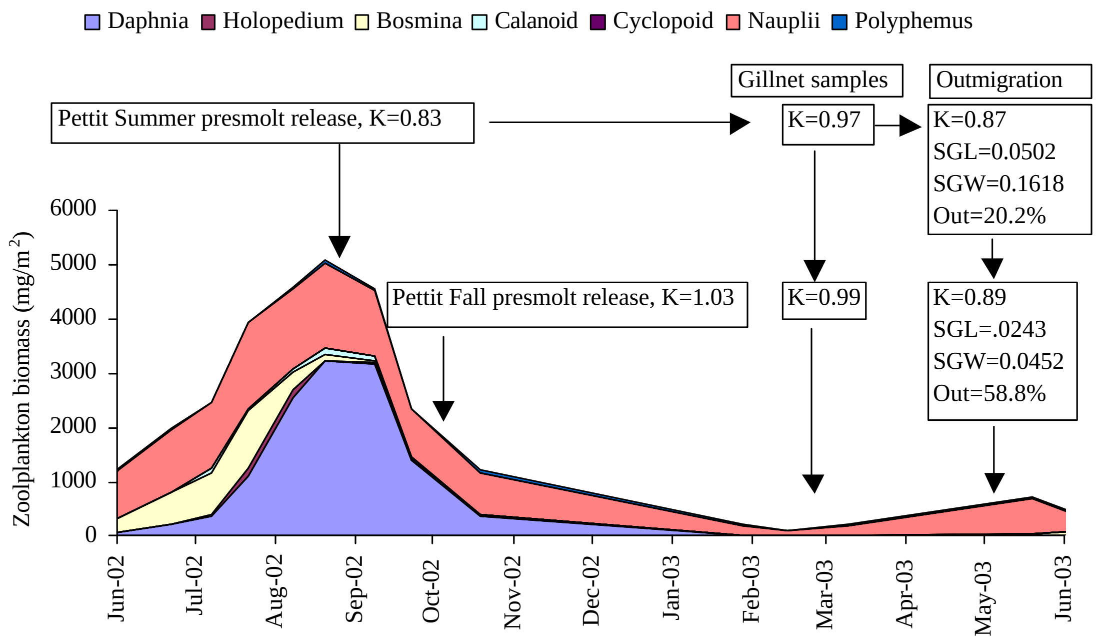

Figure 21. Pettit Lake zooplankton biomass (mg/m^2) June 1, 2002 to June 1, 2003 with summer and fall release times, condition factor (K) at release, during winter gill netting, and at migration. Additional data at migration includes specific growth rates in length (SGL), weight (SGW), and percent outmigration (Out).

Sockeye pre-smolts released in Redfish Lake experienced moderate zooplankton biomass during late summer (Figure 22). Winter zooplankton biomass in Redfish Lake was higher than in Pettit and Alturas lakes and had relatively high *Daphnia* biomass. Growth of pre-smolts was intermediate but percent outmigration was very low (summer=9% and fall=15%).

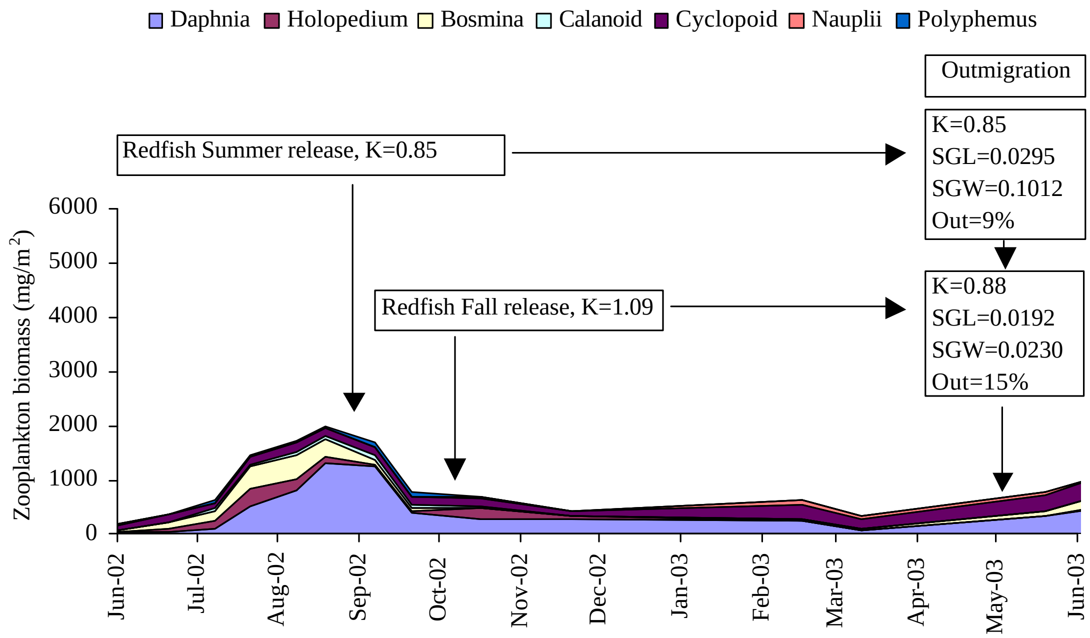

Figure 22. Redfish Lake zooplankton biomass (mg/m^2) June 1, 2002 to June 1, 2003 with summer and fall release times, condition factor (K) at release, during winter gill netting, and at outmigration. Additional data at migration includes specific growth rates in length (SGL), weight (SGW), and percent outmigration (Out).

In Alturas Lake, summer release pre-smolts experienced low zooplankton biomass and grew relatively slowly. Condition factor was low and unchanged (Figure 23). Only 9% of these fish migrated during the spring of 2003, very low compared to Pettit Lake, where 20% of the summer release group outmigrated. It is possible these fish suffered higher mortality, delayed migration for an additional year, or residualized.

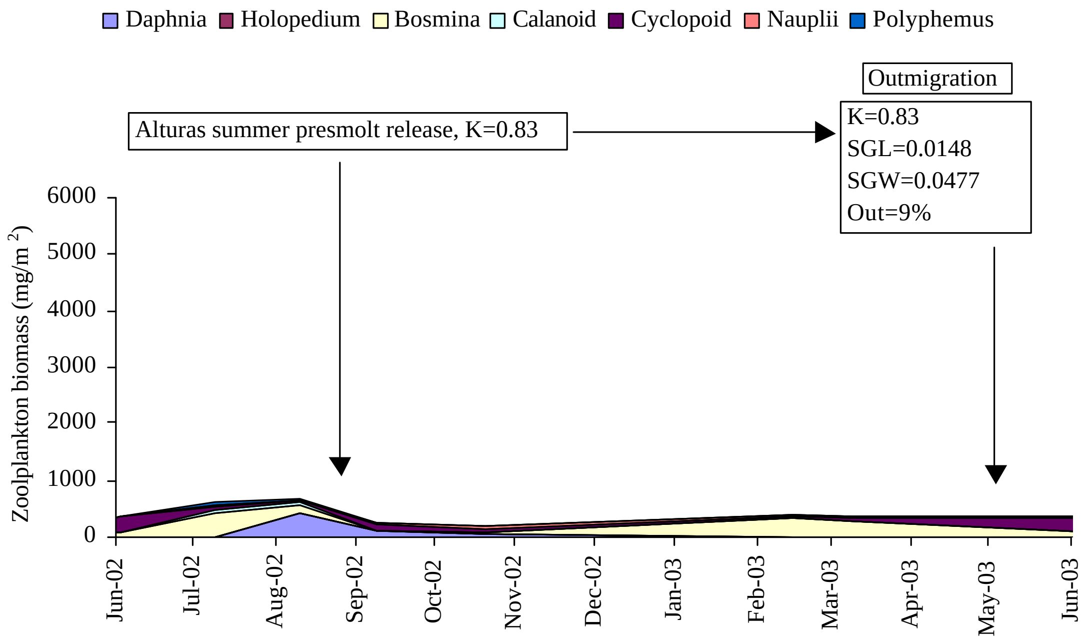

Figure 23. Alturas Lake zooplankton biomass (mg/m^2) June 1, 2002 to June 1, 2003 with summer release time and condition factor (K) at release and migration. Additional data at migration includes specific growth rates in length (SGL), weight (SGW), and percent outmigration (Out).

Differences in sockeye performance (growth, condition factor, percent migration), kokanee population abundance, and zooplankton abundance, biomass, and species composition are considered each year to determine appropriate numbers of sockeye pre-smolts to stock into each lake. Hydroacoustic data collected during fall 2002 indicated between 100-158 fish/ha in the three lakes. Biomass was 2.8 kg/ha in Redfish, 8.9 kg/ha in Pettit, and 4.0 kg/ha in Pettit Lake (Table 10). In addition, sockeye from natural release options (190 adults stocked to Redfish Lake and 30,924 eyed eggs in incubators stocked to Pettit Lake during fall 2002) should have hatched during spring 2003. During summer 2003 zooplankton biomass was high in Pettit Lake, intermediate in Redfish Lake, and very low in Alturas Lake (Figures 11, 13, and 15). In 2003, 76,788 sockeye pre-smolts were available for stocking. Equal allocation into each lake based on surface area would have resulted in 42,354 fish into Redfish Lake, 11,157 fish into Pettit Lake, and 23,277 fish into Alturas Lake, resulting in a loading rate of 69 fish/ha in each lake. After discussing allocations at the SBTOC level, the group decided to emphasize rearing in Pettit and Redfish lakes in 2003. Stocking rates were adjusted to 59,810 fish (97/ha) into Redfish Lake, 14,961 fish (92/ha) into Pettit Lake, and 2,017 fish (6/ha) into Alturas Lake. Minimal numbers of sockeye pre-smolts were stocked into Alturas Lake to evaluate growth, condition factor, and percent outmigration. Continued monitoring and evaluation of migration patterns will continue in 2004.

Diet Analysis

Intraspecific competition has been identified as one of the potential limiting factors in the sockeye rearing habitat of the Sawtooth Valley lakes. In sockeye 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 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 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 in other systems (Levy 1987, Levy 1990). In a Sawtooth Valley sockeye rearing habitat evaluation, 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 diet data and zooplankton dispersal patterns seem to indicate that age 0+ kokanee are feeding primarily in deeper waters. Levy (1990) hypothesized that during the day juvenile sockeye 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 River. Northern pikeminnow are one of the more abundant species found in the sockeye rearing/nursery lakes of the Sawtooth Valley. Concern has been expressed about their potential predation on stocked juvenile sockeye. Diet analysis has found that while piscivorous, cyprinids composed 17% of prey items in January 2003 (Table 13), and no conclusive evidence of predation on *O. nerka* by northern pikeminnow was found. 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 fish community in the Sawtooth Valley lakes. Monitoring associated with this program has found that bull char diet is composed primarily of fish prey (Taki et al. 1999). However, no *O. nerka* have been detected in any of the samples to date. Salmonids, too digested to be identified, were found in some of the samples and may have been *O. nerka*. 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 2003, no salmonids were found in the stomach contents of brook char.

Stream Spawning

Kokanee escapement in 2003 showed variation in population densities, timing, and fecundity. The Fishhook Creek kokanee 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 spawning population rebounded and was estimated at 5,853 individuals. In 2002, the population was even higher with 8,626 adult spawners estimated in Fishhook Creek. No direct control of kokanee escapement occurred in Fishhook Creek in 2002. In 2003, efforts were initiated to control the number of spawning female kokanee in Fishhook Creek, with an escapement goal of 1,200 female spawners. Unfortunately, our control efforts failed due to an unnoticed, subterranean, natural bypass channel that circumvented our weir. Other possible explanations include fish that burrowed under the picket weir through small gravelly substrate. Consequently, 2003 adult kokanee escapement was higher than management objectives had hoped, and was estimated to be 9,679; however, a high male to female ratio (3.6:1) resulted in fewer than expected females on the spawning grounds (approximately 2,104). Total Fishhook Creek escapement in 2003 was higher than the 1991-2002 average of 7,172. The Alturas Lake Creek kokanee escapement estimate was down from 827 adults in 2000, 145 in 2001, 99 in 2002, to only 48 spawners in 2003, well below the 1992-2002 mean of 3,540. The Stanley Lake Creek kokanee spawning population decreased from 5,665 in 2000, 6,180 in 2001, 946 in 2002, to 413 in 2003, well below the 1993-2002 mean of 1,814. Female kokanee in Fishhook Creek exhibited higher fecundity compared to previous measurements. The mean number of eggs per female in 2003 was 453, significantly higher than the 1991-2001 mean of 254. It was noted that the mean size of adult spawners was larger than previous years, helping to explain an increase in fecundity. Stanley Lake Creek kokanee fecundity was estimated to be 270 eggs per female in 2003, similar to the 1994-2002 mean estimate of 266. Alturas Lake Creek kokanee fecundity was estimated to be 150 eggs per female, lower than the 1994-2002 average of 202. Based on variation in Fishhook Creek, Stanley Lake Creek, and Alturas Lake Creek kokanee fecundity, all three populations should be measured annually. Length, weight, and condition factor should also be measured in order to quantify changes that could be associated with lake fertilization, meteorological forcing, and changes in population dynamics.

Beach Spawning

Night snorkel surveys along Sockeye Beach and at the south end of Redfish Lake were implemented in 1993 to monitor the densities and spawning activities of residual sockeye salmon. There had been a downward trend in the number of residual sockeye salmon observed since surveys began; however, in 2003, 18 residual spawners were observed on the Sockeye Beach shoal spawning area. Only one residual spawner was observed near the southeast inlet area. Annual monitoring will continue to track residual spawner populations at these locations.

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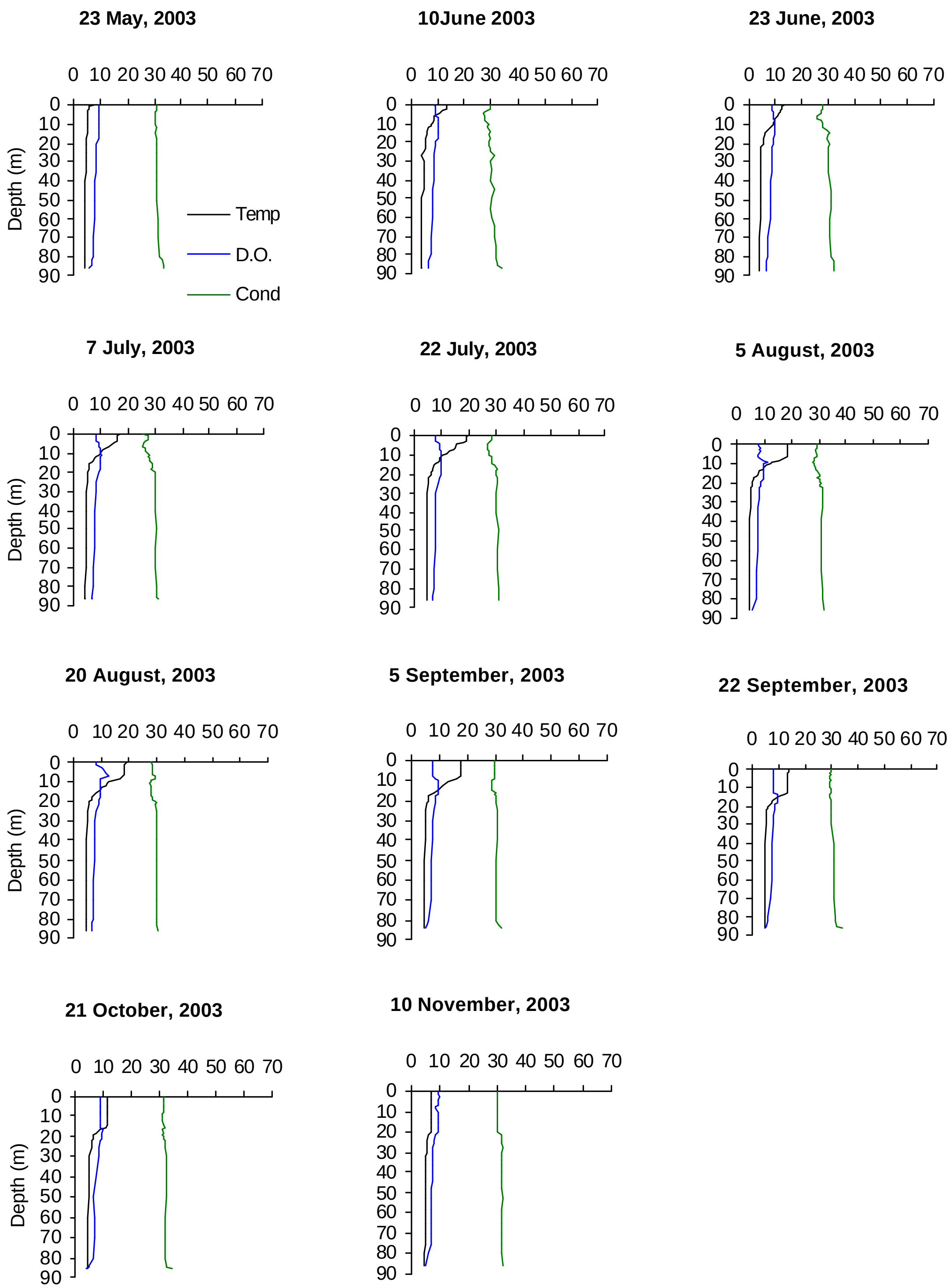
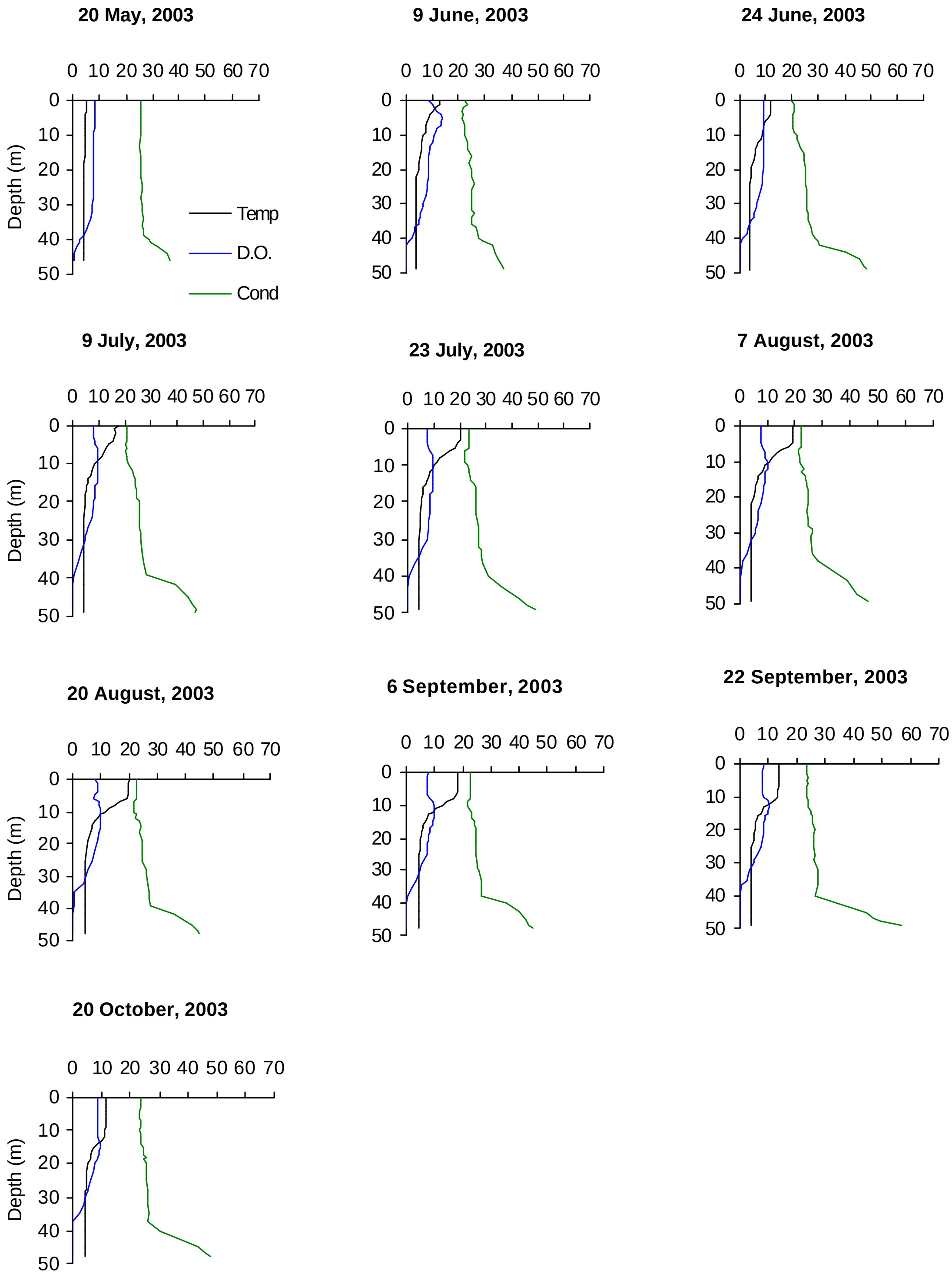
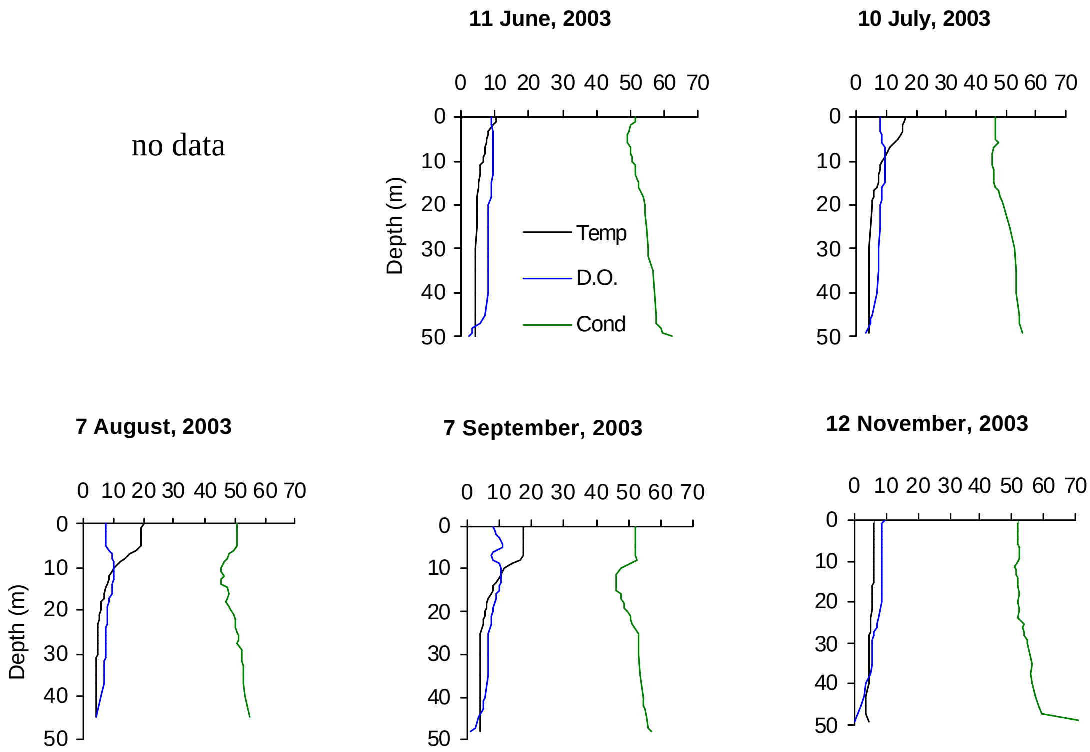
APPENDIX A. Profile data



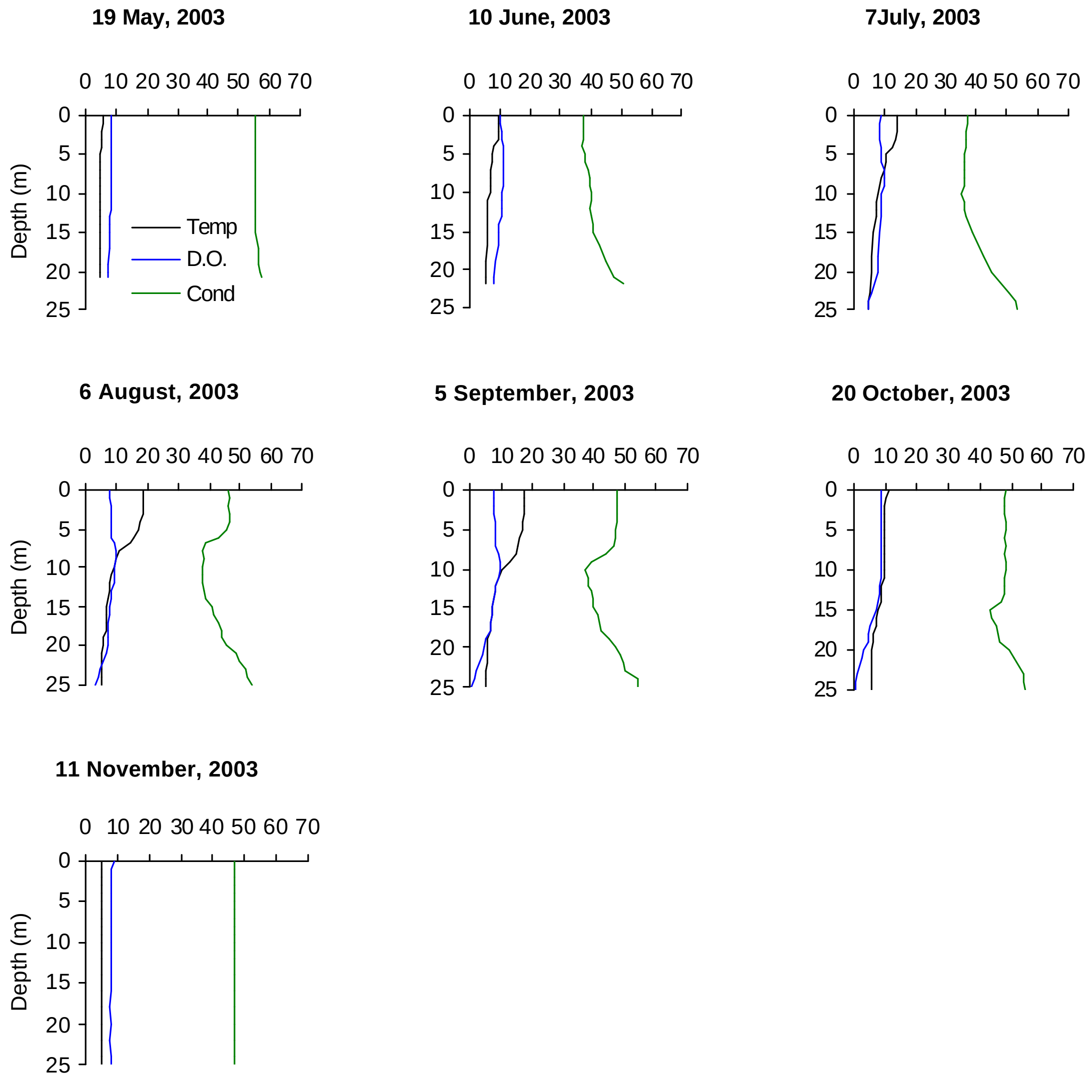
Appendix A1. Temperature (^{o}C), dissolved oxygen (mg/L), and conductivity (µS/cm) profiles for Redfish Lake, May through November 2003.



Appendix A2. Temperature (^{o}C), dissolved oxygen (mg/L), and conductivity (µS/cm) profiles for Pettit Lake, May through October 2003.

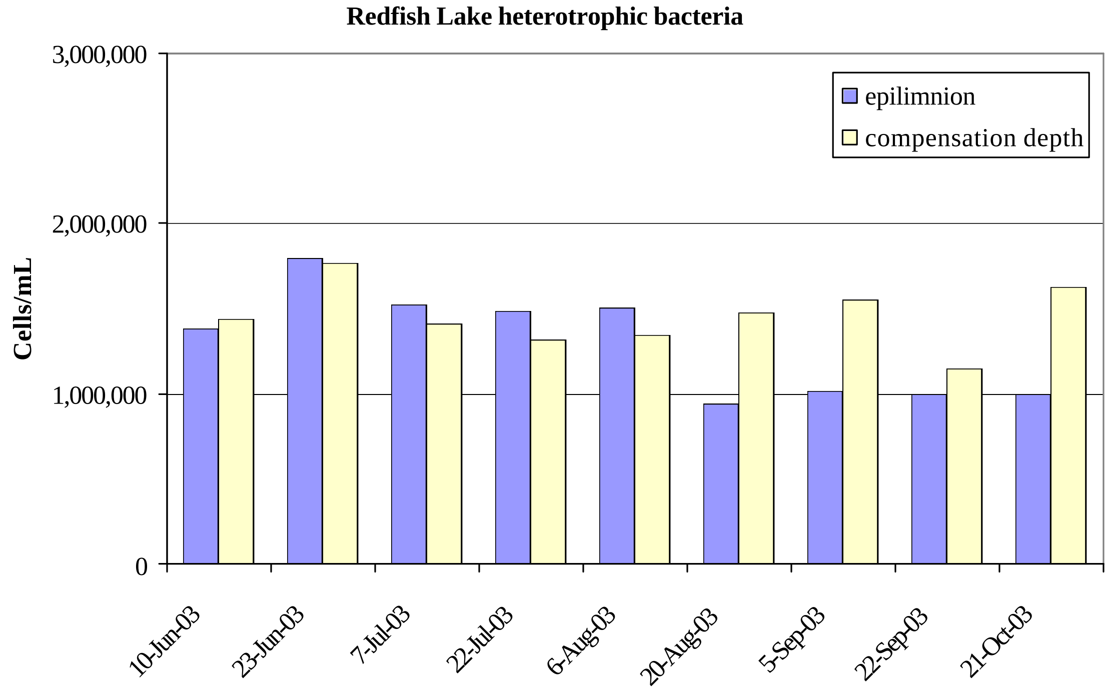


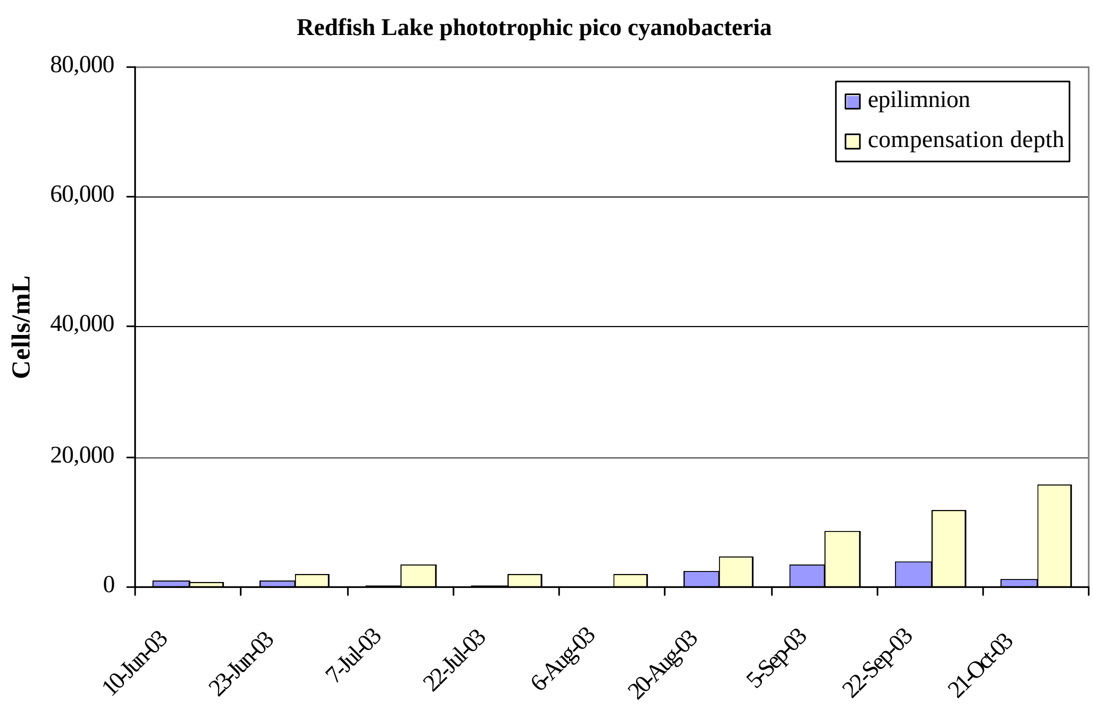
Appendix A3. Temperature (°C), dissolved oxygen (mg/L), and conductivity (µS/cm) profiles for Alturas Lake, June through November 2003.



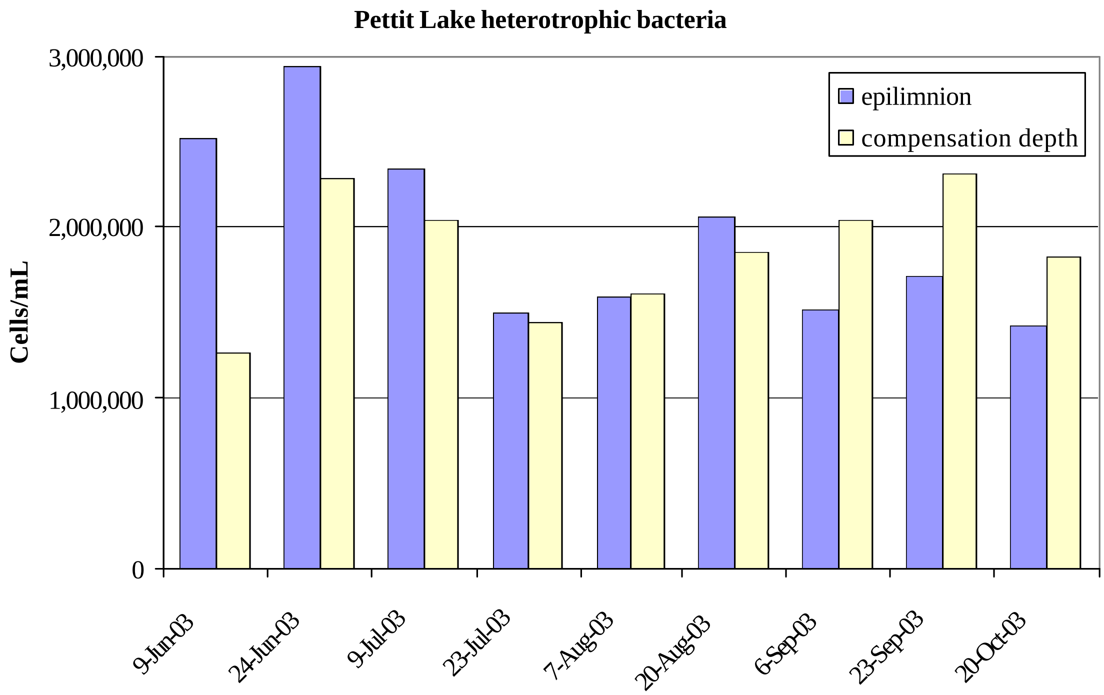
Appendix A4. Temperature (^{o}C), dissolved oxygen (mg/L), and conductivity (μS/cm) profiles for Stanley Lake, May through November 2003.

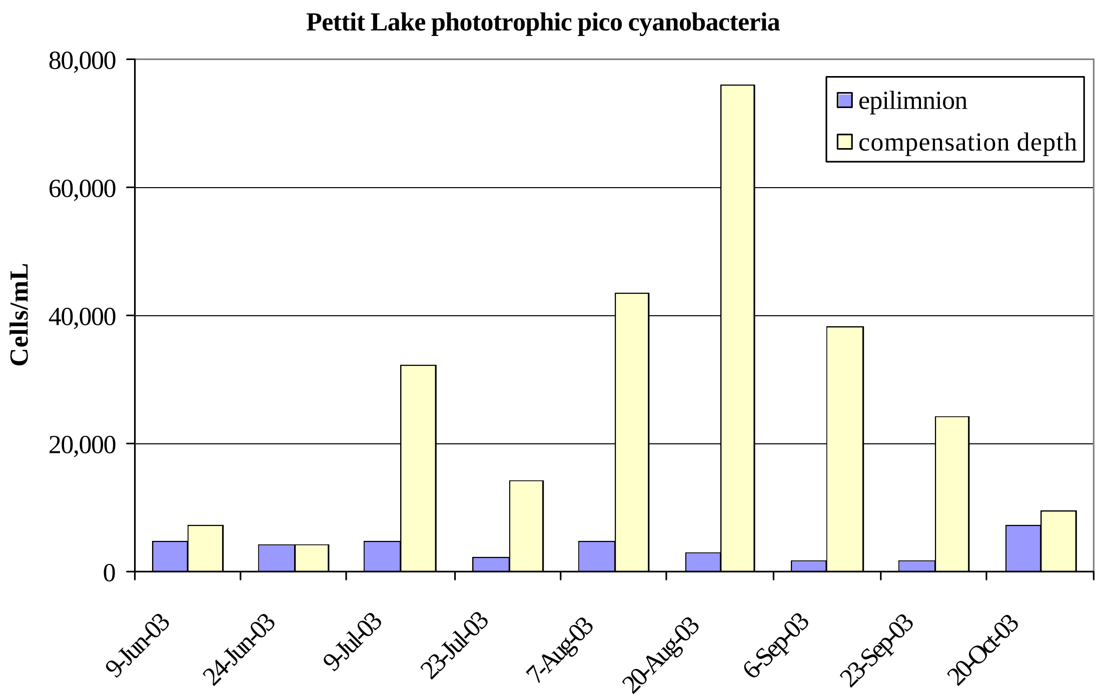
APPENDIX B. Heterotrophic bacteria and autotrophic picoplankton



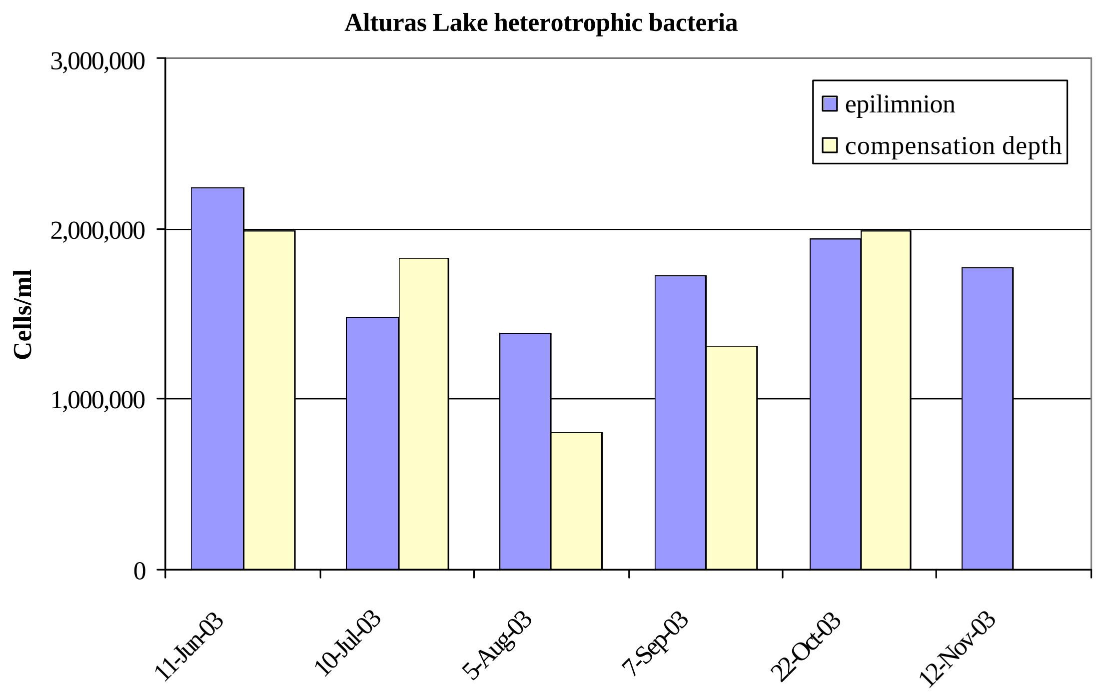


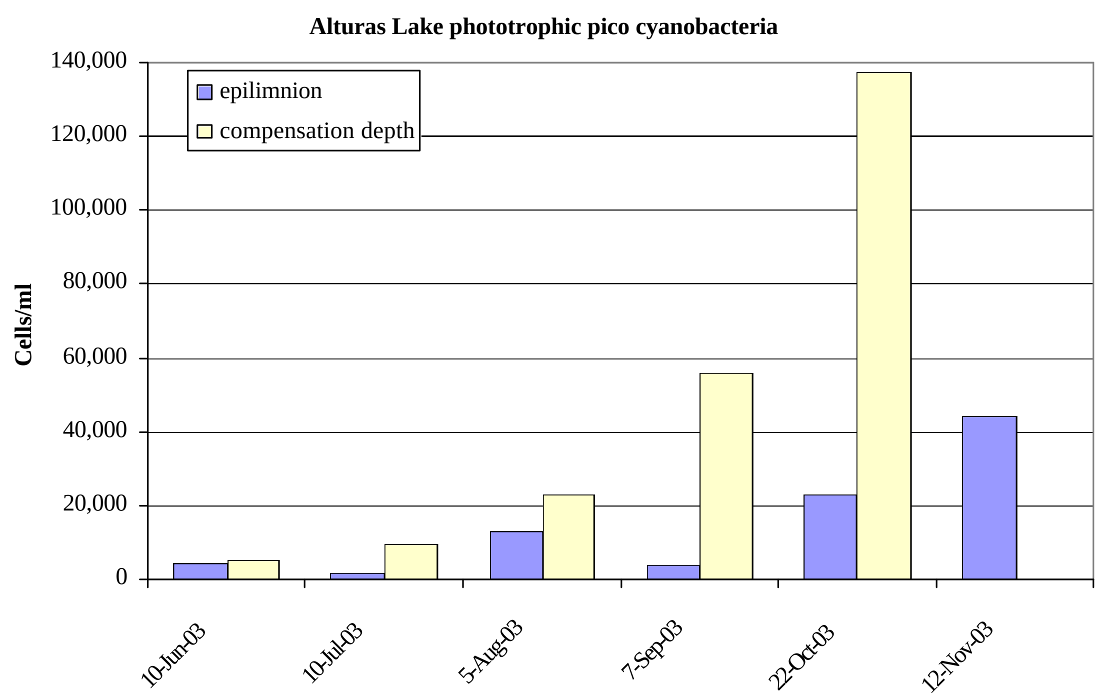
Appendix B1. Heterotrophic bacteria and autotrophic picoplankton (APP) densities (cells/mL) in the epilimnion and compensation depths in Redfish Lake, June through October 2003.



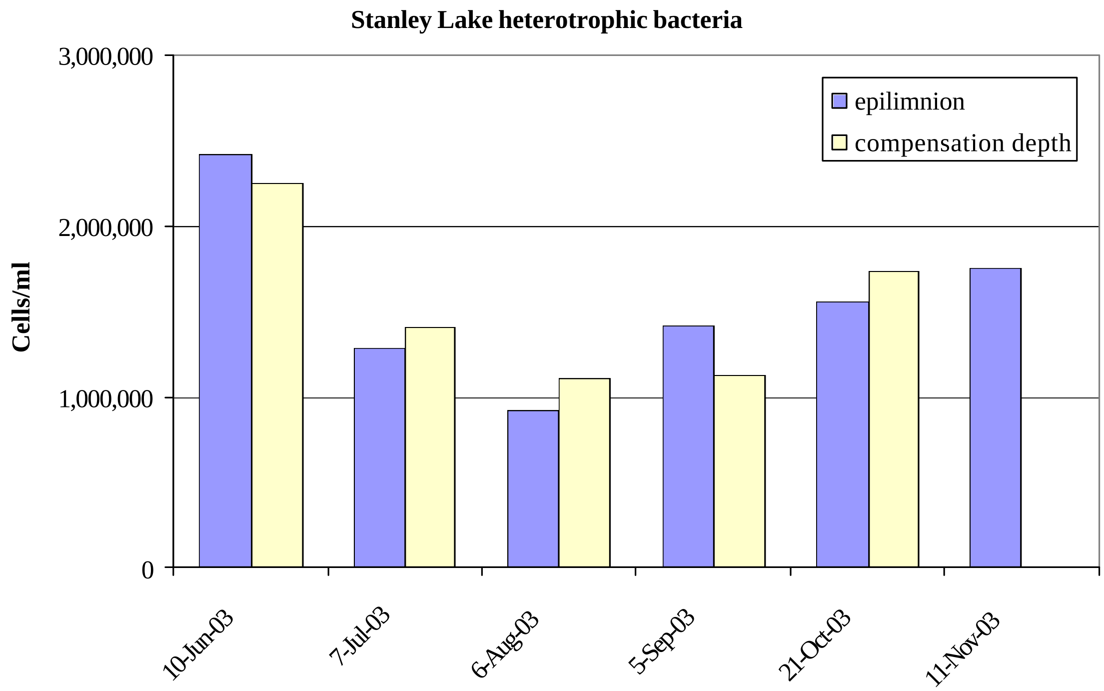


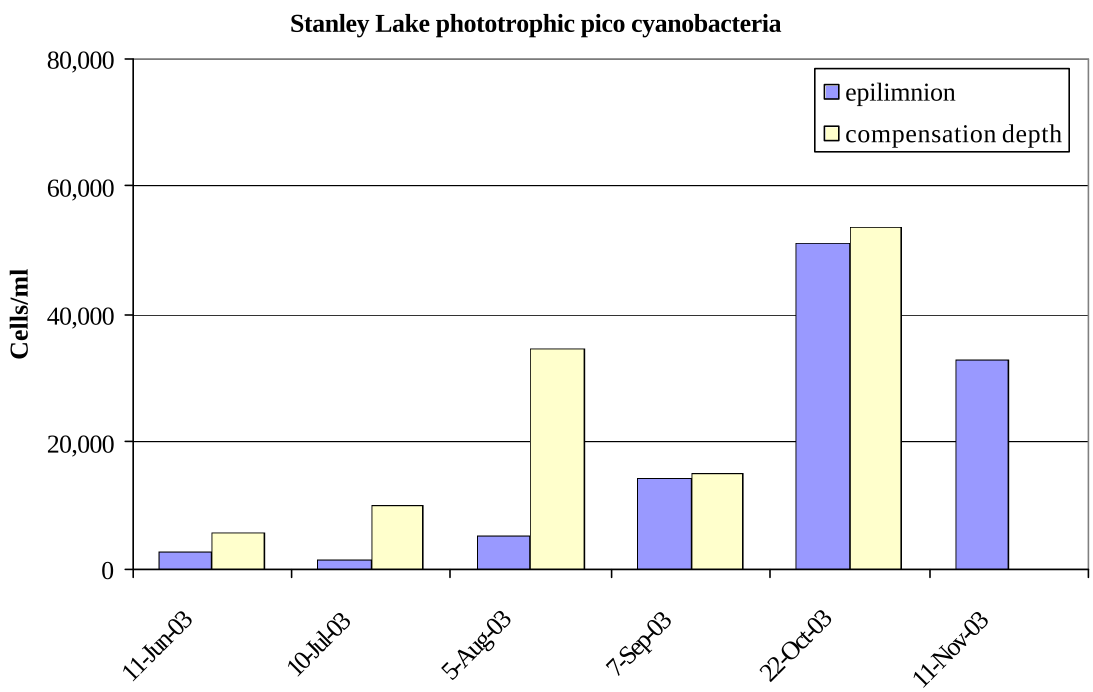
Appendix B2. Heterotrophic bacteria and autotrophic picoplankton (APP) densities (cells/mL) in the epilimnion and compensation depths in Pettit Lake, June through October 2003.





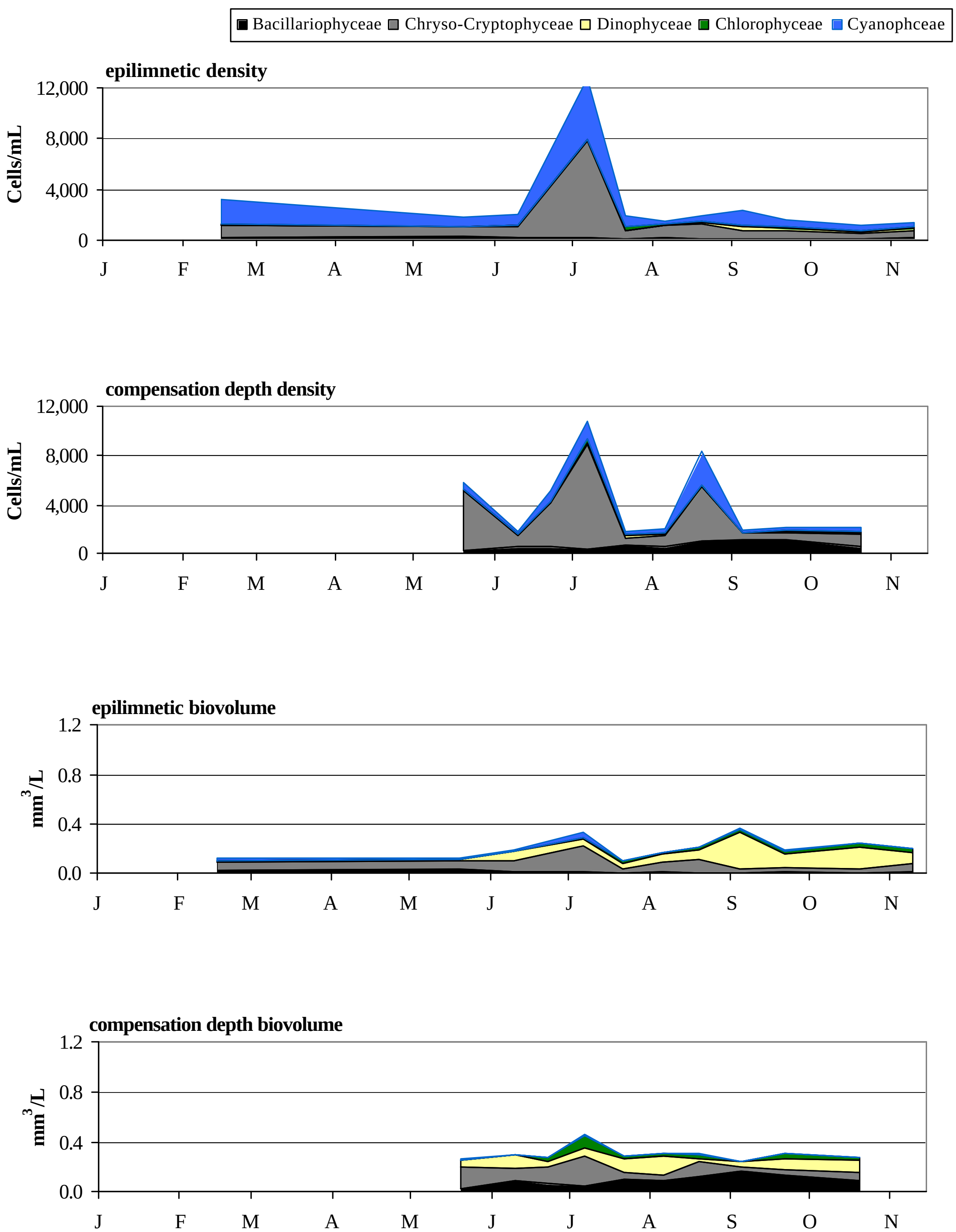
Appendix B3. Heterotrophic bacteria and autotrophic picoplankton (APP) densities (cells/mL) in the epilimnion and compensation depths in Alturas Lake, June through November 2003. Note different scale on y-axis.



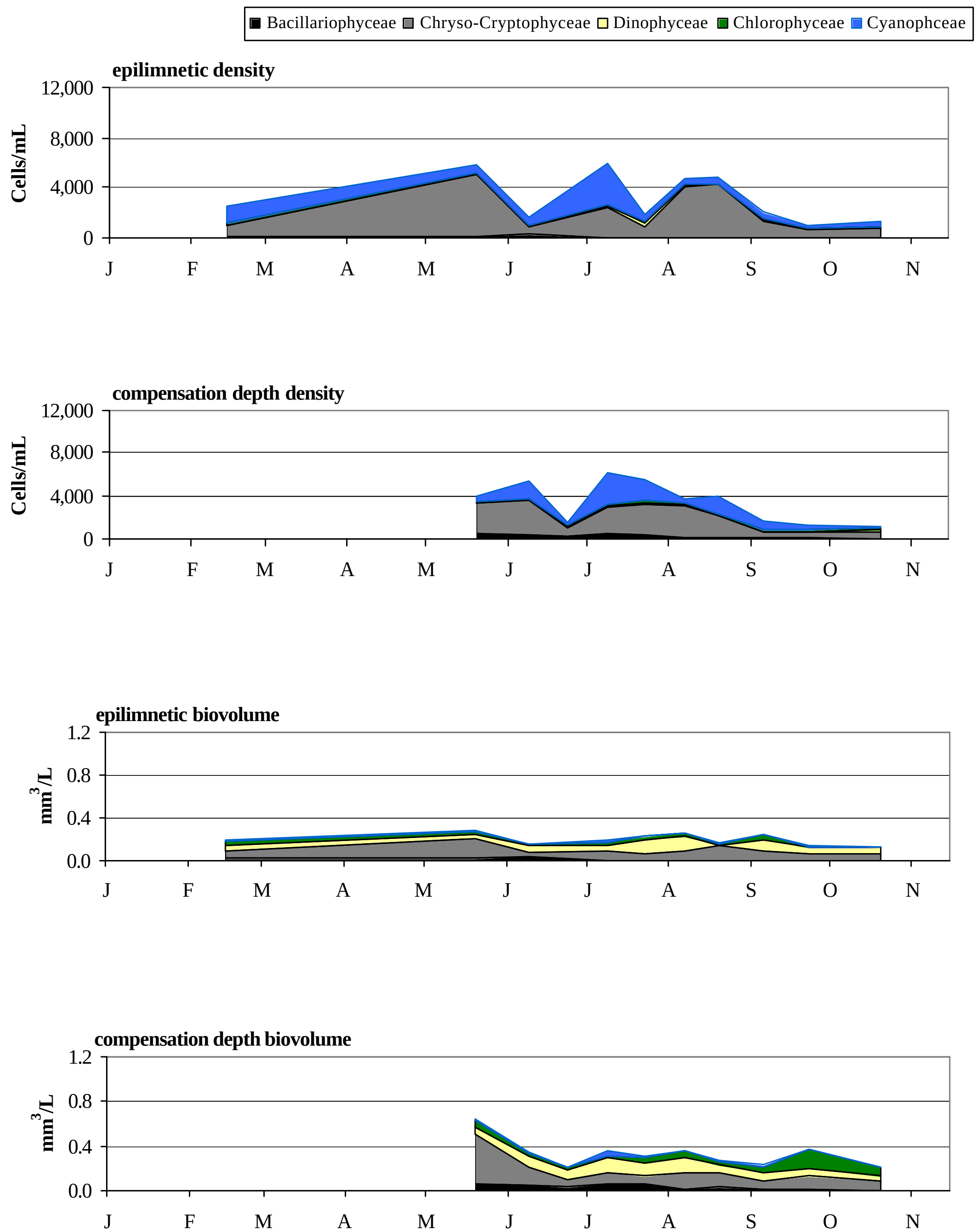


Appendix B4. Heterotrophic bacteria and autotrophic picoplankton (APP) densities (cells/mL) in the epilimnion and compensation depths in Stanley Lake, June through November 2003.

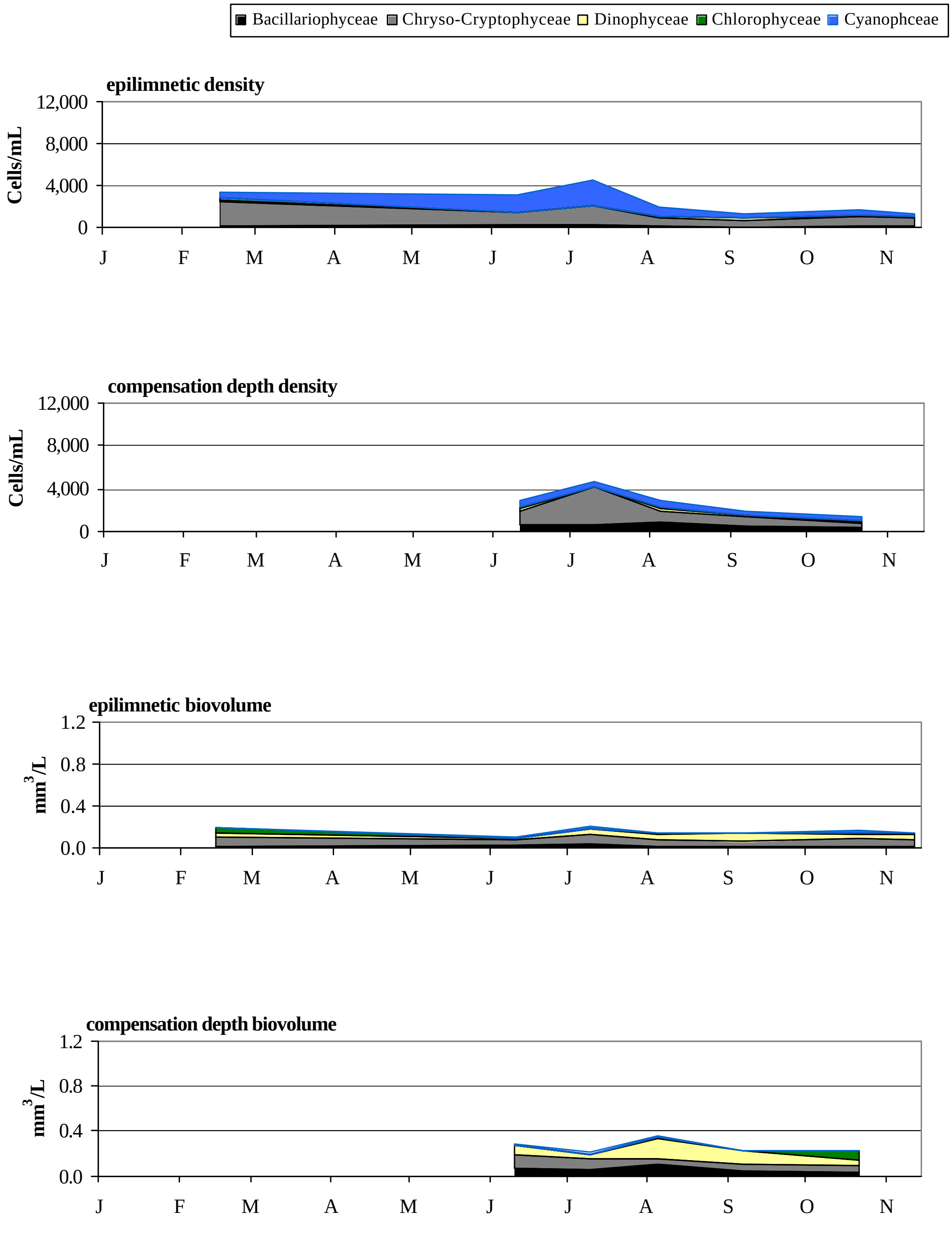
APPENDIX C. Phytoplankton densities and biovolumes



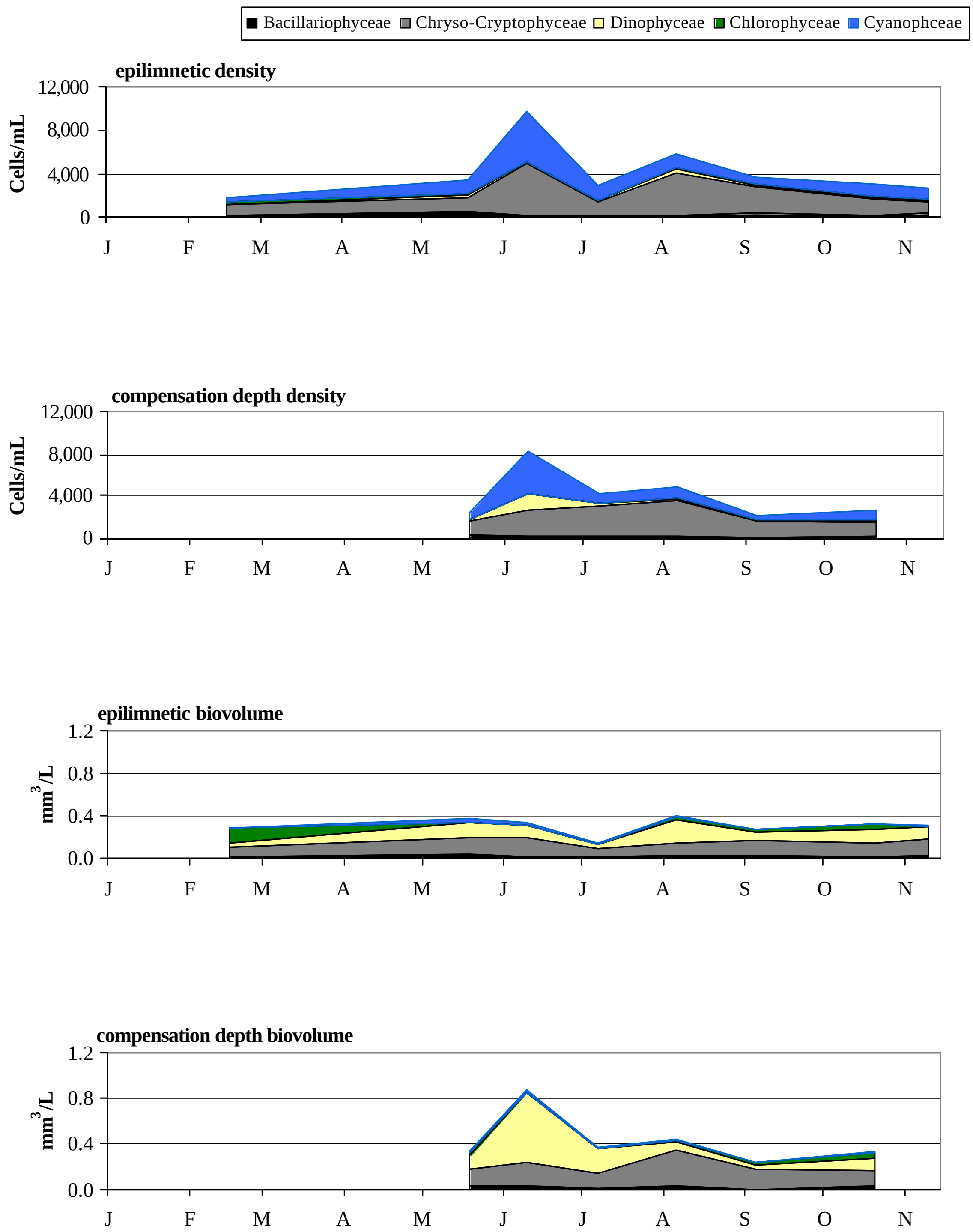
Appendix C1. Phytoplankton density (cells/mL) and bio-volume (mm^3/L) in the epilimnion and compensation depths in Redfish Lake, February through November 2003.



Appendix C2. Phytoplankton density (cells/mL) and bio-volume (mm^3/L) in the epilimnion and compensation depths in Pettit Lake, February through October 2003.



Appendix C3. Phytoplankton density (cells/mL) and bio-volume (mm^3/L) in the epilimnion and compensation depths in Alturas Lake, February through November 2003.



Appendix C4. Phytoplankton density (cells/mL) and bio-volume (mm^3/L) in the epilimnion and compensation depths in Stanley Lake, February through November 2003.