

Snake River Sockeye Salmon Habitat and Limnological Research

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Bonneville Power Administration
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**SNAKE RIVER SOCKEYE SALMON HABITAT
AND LIMNOLOGICAL RESEARCH: 2004 ANNUAL PROGRESS REPORT**

Prepared by:

Andre E. Kohler
Doug Taki
Robert G. Griswold¹

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

¹ Biolines
HC-64 Box 9965
Stanley, Idaho 83278

Prepared for:

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

Project Number 91-71

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TABLE OF CONTENTS

LIST OF TABLES	3
LIST OF FIGURES	4
EXECUTIVE SUMMARY	6
INTRODUCTION	10
STUDY AREA	12
MATERIALS AND METHODS	15
Limnology	15
Fertilization	18
Limiting Kokanee salmon Escapement	18
Smolt Monitoring	19
<i>Pettit Lake</i>	19
<i>Alturas Lake</i>	19
Stream Spawning	20
Beach Spawning	20
Gillnet Sampling	21
Diet Analysis	21
Pettit Lake Egg Boxes	22
Sockeye salmon PIT Tagging	22
RESULTS	22
Limnology	22
<i>Profile Data</i>	23
<i>Secchi depth and compensation depth</i>	26
<i>Water Chemistry</i>	28
<i>Chlorophyll a</i>	32
<i>Primary Productivity</i>	34
<i>Heterotrophic bacteria and autotrophic picoplankton</i>	34
<i>Phytoplankton</i>	36
<i>Zooplankton</i>	39
Fertilization	43
Limit Kokanee salmon Escapement	44
Smolt Monitoring	44
<i>Pettit Lake</i>	44
<i>Alturas Lake</i>	46
Growth Rates	47
Stream Spawning	52
Beach Spawning	55
Hydroacoustic Population Estimates	57
Gillnet Sampling	57
Diet Analysis	57
Pettit and Alturas Lake Egg Boxes	57
Sockeye salmon PIT Tagging	57
DISCUSSION	62
Limnology and Fertilization	62
Growth Rates and Survival	64
Diet Analysis	68
Stream Spawning	70
Beach Spawning	71
ACKNOWLEDGEMENTS	72
REFERENCES	73
APPENDIX A. Profile data	76
APPENDIX B. Heterotrophic bacteria and autotrophic picoplankton	80
APPENDIX C. Phytoplankton densities and biovolumes	84

LIST OF TABLES

Table 1. Morphological features of the Sawtooth Valley lakes.....	12
Table 2. Seasonal mean (June-October) surface water temperature (°C), Secchi depth (m), compensation depth (m), epilimnetic chlorophyll <i>a</i> (µg/L), and whole-lake total zooplankton biomass (mg/m ²) for the Sawtooth Valley lakes, 1992-2004.....	25
Table 2. continued.....	26
Table 3. Seasonal mean (June-October) epilimnetic nutrient concentrations (µg/L) and TN:TP ratio in Redfish, Pettit, Alturas, and Stanley lakes during 1992-2004.....	31
Table 3. continued.....	32
Table 4. Heterotrophic bacteria and autotrophic picoplankton (APP) densities (cells/mL) in the epilimnions and compensation depths in four Sawtooth Valley lakes during June-October 2004.....	34
Table 5. Phytoplankton density (cells/mL) and biovolume (mm ³ /L) in the epilimnions and compensation depths in four Sawtooth Valley lakes during June-October 2004.....	37
Table 6. Hatchery sockeye salmon release and migration length, weight, and condition factor data, 1998-2004.....	48
Table 7. Specific growth rate data (fork length) 1999-2004.....	49
Table 8. Specific growth rate data (weight) 1999-2004.....	50
Table 9. Fry recruitment, egg-to-fry survival, and adult escapement in Fishhook, Alturas, and Stanley Lake creeks.....	54
Table 10. Results of Pettit and Alturas lake gillnet samples, 2004.....	58
Table 11. Fish community horizontal gillnet sample and percent diet composition data from Pettit Lake, 2004.....	59
Table 12. Sockeye salmon and <i>O. nerka</i> vertical gillnet and trawl mean length, weight, condition factor, and zooplankton diet percent composition in Redfish, Pettit, and Alturas lakes, 2004.....	60
Table 13. Sockeye salmon and <i>O. nerka</i> gillnet and diet composition data including electivity indices (E), 2004 (* denotes only YOY sample).....	61

LIST OF FIGURES

Figure 1. Map of study area.....	14
Figure 2. Mean annual discharge for the Salmon River at Salmon, Idaho, 1990-2004. Minimum, mean, and maximum are for period of record, 1913 to 2004.....	22
Figure 3. Correlation of mean annual discharge for the Salmon River at Salmon, Idaho, and mean summer surface (0-10 m) temperatures for 1992-2004 in Redfish, Pettit, Alturas, and Stanley lakes. Orange symbols indicate current year.....	23
Figure 4. Secchi depths (m) for Redfish, Pettit, Alturas, and Stanley lakes, January through November 2004.....	27
Figure 5. Compensation depths (m) defined by the 1% light level for Redfish, Pettit, Alturas, and Stanley lakes, May through October 2004.....	27
Figure 6. Concentrations of total nitrogen, total phosphorus, and the TN:TP ratio in the epilimnetic waters of Redfish, Pettit, Alturas, and Stanley lakes during May through October 2004. Grey line denotes method detection level.....	29
Figure 7. Nitrate-nitrite and total dissolved phosphorus concentrations in the epilimnetic waters of Redfish, Pettit, Alturas, and Stanley lakes during May through October 2004. Grey line denotes method detection levels.....	30
Figure 8. Chlorophyll <i>a</i> concentrations ($\mu\text{g/L}$) in the epilimnion, metalimnion, and compensation depths in Redfish, Pettit, Alturas, and Stanley lakes, May-November 2004.....	33
Figure 9. Heterotrophic bacteria densities (cells/mL x 1,000) at eight discrete depths within the euphotic zones of Redfish and Pettit lakes, Idaho, 24 August 2004.....	35
Figure 10. Autotrophic picoplankton densities (cells/mL) at eight discrete depths within the euphotic zones of Redfish and Pettit lakes, Idaho, 24 August 2004.....	35
Figure 11. Phytoplankton density and biovolume at eight discrete depths in Redfish and Pettit lakes, Idaho, 24 August 2004.....	38
Figure 12. Seasonal mean zooplankton biomass (June-October) for the Sawtooth Valley lakes, 1993-2004.....	39
Figure 13. Mean areal zooplankton biomass (June-October) in Redfish Lake, 1998-2004.....	40
Figure 14. Mean areal zooplankton biomass (January-March) in Redfish Lake, 1998-2004.....	40
Figure 15. Mean areal zooplankton biomass (June-October) in Pettit Lake, 1998-2004.....	41
Figure 16. Mean areal zooplankton biomass (January-March) in Pettit Lake, 1998-2004.....	41
Figure 17. Mean areal zooplankton biomass (June-October) in Alturas Lake, 1998-2004.....	42
Figure 18. Mean areal zooplankton biomass (January-March) in Alturas Lake, 1998-2004.....	42
Figure 19. Mean areal zooplankton biomass (June-October) in Stanley Lake, 1998-2004.....	43
Figure 20. Supplemental nutrient applications for Pettit Lake, 9 June to 29 September 2004.....	44
Figure 21. Pettit Lake migrant trapping data and hydrograph 2004.....	45
Figure 22. Pettit Lake migrant length frequency histogram 2004.....	45
Figure 23. Alturas Lake migrant trapping data and hydrograph 2004.....	46
Figure 24. Alturas Lake migrant length frequency histogram 2004.....	47
Figure 26. Stanley Lake Creek, Fishhook Creek, and Alturas Lake Creek kokanee salmon escapement numbers 1991-2004.....	53
Figure 27a. Redfish Lake residual sockeye salmon counts from snorkel surveys (1995 data not available).....	56
Figure 28. <i>Oocystis</i> sp. cells within thick parental wall.....	63
Figure 29. Whole lake <i>Daphnia</i> sp. biomass (mg/m^2) and epilimnetic <i>Oocystis</i> sp. and Chryso-Cryptophacean densities (cells/mL) June through November 2004 in Pettit Lake, Idaho.....	64
Figure 30a. Pettit Lake zooplankton biomass (mg/m^2) June 1, 2003 to June 1, 2004 with overwinter sockeye salmon presmolt specific growth rates in length (SGL), weight (SGW), condition factor (K) and percent outmigration (Out).....	65
Figure 30b. Redfish Lake zooplankton biomass (mg/m^2) June 1, 2003 to June 1, 2004 with overwinter sockeye salmon presmolt specific growth rates in length (SGL), weight (SGW), condition factor (K) and percent outmigration (Out).....	66

Figure 30c. Alturas Lake zooplankton biomass (mg/m^2) June 1, 2003 to June 1, 2004 with overwinter sockeye salmon presmolt specific growth rates in length (SGL), weight (SGW), condition factor (K) and percent outmigration (Out) 67

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. Snake River sockeye salmon were officially listed as endangered in November 1991 under the Endangered Species Act (56 FR 58619). In 1991, the Snake River Sockeye Salmon Habitat and Limnological Research 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 Tribe's 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 their Integrated Fish and Wildlife Program. 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 2004 calendar year.

Project tasks include: 1) monitor limnological parameters of the Sawtooth Valley lakes to assess lake productivity; 2) conduct lake fertilization in Pettit Lake; 3) reduce the number of mature kokanee salmon spawning in Fishhook Creek; 4) monitor and enumerate sockeye salmon smolt migration from Pettit and Alturas lakes; 5) monitor spawning kokanee salmon escapement and estimate fry recruitment in Fishhook, Alturas Lake, and Stanley Lake creeks; 6) conduct sockeye salmon and kokanee salmon population surveys; 7) evaluate potential competition and predation between stocked juvenile sockeye salmon and a variety of fish species in Redfish, Pettit, and Alturas lakes; and 8) assist IDFG with captive broodstock production activities.

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

Task 2. Sixty-one kg of phosphorus and 1,859 kg of nitrogen were introduced to the surface of Pettit Lake from July-September to increase lake productivity.

Task 3. A weir was installed to control the number of kokanee salmon spawning in Fishhook Creek. An escapement goal of 1,200 spawning females was set to reduce kokanee salmon recruitment to Redfish Lake.

Task 4. The number of sockeye salmon that migrated from Pettit Lake was enumerated using catches at the Pettit Lake Creek weir. We evaluated a direct lake fall release of Sawtooth Hatchery parr. Percent migration for this release group was 34.9%. We also enumerated wild/natural fish originating from egg boxes stocked in 2002. Stocked juvenile sockeye salmon migration from Alturas Lake was estimated using catches at the Alturas Lake Creek screw trap. Similar to Pettit Lake, the only presmolt release in Alturas Lake in 2003 was a fall release of fish reared at the Sawtooth Hatchery. The migration estimate for that release strategy was 54.1%. Migration of Redfish Lake sockeye salmon was monitored by IDFG. Survival estimates presented above for Alturas Lake Creek were based on trap efficiency population estimates.

Task 5. Stream spawner counts were used to monitor adult kokanee salmon escapement to inlet streams on Redfish, Alturas, and Stanley lakes in 2004. Fishhook Creek, the primary kokanee salmon spawning tributary to Redfish Lake, had an estimated spawning

escapement of 1,508 adult spawners, Alturas Lake Creek had an estimated 7,101 adult spawners, and Stanley Lake Creek had an estimated 228 kokanee salmon spawners. Fry recruitment, calculated from male-female ratios, fecundity, and egg-to-fry survival rates is estimated at 28,008, 62,080, and 1,197 fry for Fishhook, Alturas Lake, and Stanley Lake creeks, respectively.

Task 6. Three forms of *O. nerka* inhabit Redfish Lake: 1) a resident, stream spawning kokanee salmon population; 2) listed anadromous sockeye salmon; and 3) listed residual sockeye salmon. The residual sockeye salmon component spawns in October in littoral areas, similar to the anadromous form. Since 1993, snorkel surveys have been used to monitor spawning residual sockeye salmon and anadromous sockeye salmon populations in Redfish Lake. In 2004, 921 residual sockeye salmon and 118 sockeye salmon adults were observed during snorkel surveys at the SE Inlet and Sockeye Beach spawning areas in Redfish Lake. Additionally, we conducted a boat survey of Pettit Lake on October 10, and observed 49 residual sockeye salmon spawner redds, 66 clean, circular depressions of unknown origin (redds?), and collected one postspawn residual sockeye salmon carcass. This is the first year residual sockeye salmon spawning was documented in Pettit Lake.

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

salmon and *O. nerka* juveniles were found in the stomach contents of bull char on 20 February 2004.

Task 8. SBT personnel assisted the IDFG in PIT tagging sockeye salmon parr at the Sawtooth Fish Hatchery. We also cooperated with the planting and retrieving of egg boxes from Pettit and Alturas lakes.

Through the spawning matrix design used in the captive broodstock program, we have sustained the genetic integrity of the stock (C.C. Willard, IDFG, personal communication). 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 2-4%, 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. Snake River sockeye salmon were officially listed as endangered in November 1991 under the Endangered Species Act (56 FR 58619). The SBT have been actively involved in the sockeye salmon recovery project (BPA Project Number 91-71) since its inception.

The Bonneville Power Administration (BPA) provides funding for this interagency recovery program through their Integrated Fish and Wildlife Program. Individual collaborators in the recovery program are responsible for different aspects of the program. 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 evaluates spawning and rearing habitat in nursery lakes.

In 1991, only four adult sockeye salmon 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 salmon, residual sockeye salmon, and migrating juveniles. Historically, thousands of sockeye salmon returned to the Sawtooth Valley lakes. Everman (1896) reported that the lakes were 'teeming with redfish.' In 1910, anadromous fish migration was blocked when the Sunbeam Dam was built on the mainstem of the Salmon River approximately 20 miles

downstream from the Sawtooth Valley. In 1934, the dam was breached and upstream anadromous fish populations rebounded. Bjornn (1968) estimated that 4,360 sockeye salmon returned to Redfish Lake in 1955. There has been a steady decline in adult sockeye salmon returns since that time until, in the late 1980's, only a small number of fish were returning to Redfish Lake. A total of 23 adult sockeye salmon returned to the Sawtooth Valley during the 1990's. The recovery program has focused its efforts on restoring anadromous *O. nerka* to Redfish, Pettit, and Alturas lakes, designated as critical spawning and rearing habitat under the ESA listing (56 FR 58619).

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

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

Power and Conservation Council (NWPPC) Independent Scientific Review Panel (ISRP).

STUDY AREA

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

All of the Sawtooth Valley lakes are oligotrophic: mean summer total phosphorus (TP) concentrations in the epilimnion range from 3.1 to 11.6 $\mu\text{g/L}$; surface chlorophyll *a* concentrations range from 0.3 to 2.6 $\mu\text{g/L}$; 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 ($\text{m}^3 \times 10^6$)	Mean Depth (m)	Drainage Area (km^2)
Redfish	6.15	269.9	44	108.1
Alturas	3.38	108.2	32	75.7
Pettit	1.62	45.0	28	27.4
Stanley	0.81	10.4	13	39.4

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

Native fish species found in the nursery lake system include: sockeye salmon/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 williamsoni*; sucker *Catostomus* spp.; redbelt shiner *Richardsonius balteatus*; dace *Rhinichthys* spp.; northern pikeminnow *Ptychocheilus oregonensis*; and sculpin *Cottus* spp.. Nonnative species include brook char *S. fontinalis* and lake trout *S. namaycush*. The only pelagic species besides *O. nerka* are redbelt 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 Redfish Lake. Sport fishing for salmonid fishes is open on all lakes, as well as inlet and outlet streams.

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

Residual sockeye salmon are another form of *O. nerka* previously found only in Redfish Lake and are listed as part of the Snake River sockeye salmon ESU. During 2004 we identified residual sockeye salmon spawning in Pettit Lake from fish released from the captive broodstock. The residual sockeye salmon population remains in freshwater for their entire life cycle, yet are genetically similar to the anadromous *O. nerka* form. The residual sockeye salmon population spawns at the same time as the anadromous form and, similar to the anadromous form, creates redds on lake shoals instead of in tributary creeks.

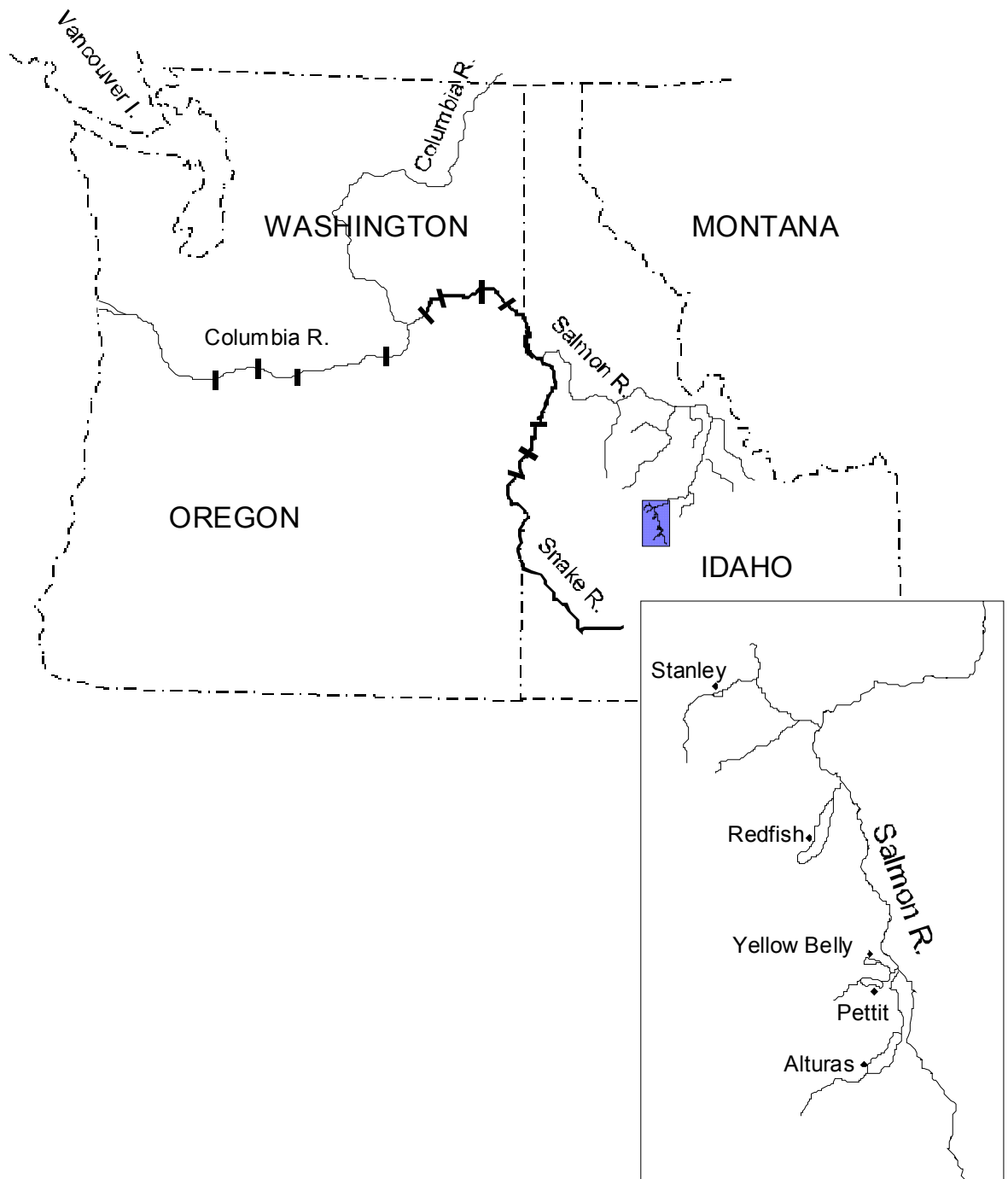


Figure 1. Map of study area.

Sockeye salmon, the anadromous form of *O. nerka*, spend one or two years in fresh water, migrating during spring as one or two year old smolts. Sockeye salmon 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 sockeye salmon return as three year olds, and are referred to as jacks or jills, depending on sex. The anadromous and residual sockeye salmon 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: Pettit Lake was not sampled in February because of poor ice conditions; and Stanley Lake was not sampled in February, March, and November. Redfish, Pettit, and Alturas lakes were stocked with juvenile sockeye salmon from the Redfish Lake captive broodstock in 2004. Stanley Lake was not stocked with sockeye salmon. Water temperature ($^{\circ}\text{C}$), dissolved oxygen (mg/L), conductivity ($\mu\text{S/cm}$), Secchi depth (m), compensation depth (m), nutrient concentrations ($\mu\text{g/L}$), chlorophyll *a* concentrations ($\mu\text{g/L}$), 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 ($\mu\text{g/L}$) 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 2004 in Alturas and Stanley lakes and once per month from May-October in Redfish and Pettit lakes.

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

Temperature ($^{\circ}\text{C}$), dissolved oxygen (mg/L), and conductivity ($\mu\text{S}/\text{cm}$) profiles were collected at the center of each lake using a Hydrolab[®] Surveyor3[™] equipped with a Hydrolab H20[®] submersible data transmitter. The instrument was calibrated each day prior to sampling using barometric pressure and conductivity standards. Temperature, dissolved oxygen, and conductivity were recorded at 1 m intervals from the surface to 10 m, 1-2 m intervals from 10 m to the thermocline, then at 2-10 m intervals to the bottom. Mean water temperatures from 0-10 m were used to calculate seasonal mean (June-October) surface water temperatures. Secchi depth was measured with a 20 cm Secchi disk and a viewing tube, and light attenuation was measured with a Li-Cor[®] Li-1000 data logger equipped with a Li-190SA quantum sensor deck cell and a LI-193SA spherical sea cell. Photosynthetically active radiation (400-700 nm) was measured at 2 m intervals from surface to 2-4 m below the compensation depth (1% light level). Compensation depth was identified using the technique of Wetzel and Likens 1991.

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

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

productivity four times in each of the four study lakes during 2004. The lakes were sampled 16-19 July, 17-20 August, 14-17 September, and 12-15 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 ($\text{mg C}\cdot\text{m}^{-3}\text{ hr}^{-1}$) estimates were plotted and integrated using planimetry to determine hourly rates of primary productivity based on surface area ($\text{mg C}\cdot\text{m}^{-3}\text{ hr}^{-1}$). Hourly productivity estimates were expanded to daily productivity ($\text{mg C}\cdot\text{m}^{-3}\text{ hr}^{-1}$) 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 ($< 2.0\ \mu\text{m}$), nanos ($2.0\text{-}20.0\ \mu\text{m}$), and micros ($>20.0\ \mu\text{m}$). Hauser and Barber (2002) provide a complete description of methods used to determine primary productivity in 2004.

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

Zooplankton was sampled with a 0.35 m diameter, 1.58 m long, 80 μm mesh, conical net with a removable bucket. Vertical hauls were made using a release mechanism that allowed sampling at discrete depth intervals. A General Oceanics flow meter was mounted in the mouth of the net to quantify the volume of water filtered. The net was retrieved by hand at a rate of approximately 1 m/sec. In Redfish, Pettit, and Alturas lakes hauls were made from 10-0 m, 30-10 m, and bottom ($\sim 60\text{ m}$) 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.

Fertilization

In 2004, the SBT, operating under a consent order issued by the IDEQ, added supplemental nutrients (liquid ammonium phosphate (20-5-0) and ammonium nitrate (28-0-0-0)) to Pettit Lake. Nutrients were applied at a ratio of approximately 30:1 N:P by mass to avoid stimulation of nitrogen fixing Cyanophytes. A consent order was issued by DEQ that required measurement of water transparency once per week, estimates of epilimnetic and metalimnetic chlorophyll *a* every two weeks, and measurement of nutrient concentrations once per month. The consent order specified that nutrient enhancement activities may continue as long as water transparencies exceed 6 m, chlorophyll *a* concentrations remain below 3 µg/L in the epilimnion and 6 µg/L in the metalimnion, and total phosphorus concentrations remain below 15 µg/L in the epi- and metalimnions. Nutrient applications were made from a 6.7 m boat equipped with a portable plastic tank and electric pump. Fertilizer was loaded into tanks off-site and sprayed into the boat's wake while traveling over the surface of the lake. Predetermined transect lines were followed using GPS, compass, and local landmarks to evenly disperse the nutrients over the surface of the lake.

Limiting Kokanee Salmon Escapement

A picket weir comprised of vertical aluminum tubes spaced 3/8" and held in place with metal frames was constructed in Fishhook Creek. The weir was operated from 05 August through 8 September 2004. The weir was checked once or twice daily, and all kokanee salmon were enumerated and passed. The goal was to limit the number of females passing upstream to spawn at 1,200.

Smolt Monitoring

Pettit Lake

A weir was operated at the outlet of Pettit Lake, Idaho (Section 31, Township 8 North, Range 14 East) from 21 April through 28 May 2004. The weir was used to evaluate migration of Snake River sockeye salmon smolts. The weir ran continuously at 100% capture efficiency. Discharge ranged from 0.4 m³/s to 2.7 m³/s. 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.

Immediately after removal from the trap, all sockeye salmon were scanned for passive integrated transponder (PIT) tags. Two thousand and fourteen fish planted in October 2003 were tagged before release. All of the fish containing tags were placed in a live box and eight to ten at a time were anesthetized for measuring and weighing using a stock solution of 15 grams of MS222 and 30 grams of sodium bicarbonate per liter of water. All anesthetized fish were weighed to the nearest 0.1 grams and fork length was measured to the nearest millimeter. Fish were held in a live well for 1 to 10 hours after handling and then released. Approximately 50 fish were PIT tagged each day to evaluate downstream survival and SAR's. A condition factor (Fulton's K value, (weight x 10⁵/length³)) for each fish was calculated; mean, minimum, and maximum K values are presented in results. All other fish were counted and immediately released below the weir.

Alturas Lake

A screw trap was operated in Alturas Lake Creek 8 miles downstream from Alturas Lake, Idaho (Section 32, Township 8 North, Range 14 East) from 20 April through 26 May 2004. *Oncorhynchus nerka* smolts were captured to determine the number of migrants and to allow tagging of Snake River sockeye salmon smolts using PIT tags. Shoshone-Bannock Tribal fisheries personnel checked for fish and cleaned the screw trap at sunrise and sunset. For one week during peak run-off we checked and cleaned the trap at approximately 6 hour intervals during the night to prevent debris accumulation.

All fish captured were handled similar to methods used at the Pettit Lake Creek weir. Discharge ranged from 2.5 m³/s to 17.8 m³/s. Trap efficiency estimates were made separately for hatchery and wild fish.

Stream Spawning

Stream surveys were conducted to estimate kokanee salmon escapement in tributaries to Redfish, Alturas, and Stanley lakes. Pettit Lake has no stream spawning kokanee salmon population. Fish were counted from the bank by one or two observers equipped with polarized sunglasses. On days when counts were missed, the number of fish in the stream was interpolated by dividing the difference between the actual counts by the number of days between the counts. Spawning surveys began 27 July, with the final count occurring on 08 October. Total escapement estimates were calculated by summing daily counts of kokanee salmon and dividing by average stream life as described by English et al. (1992).

Beach Spawning

Sockeye Beach, located near the Redfish Lake boat ramp, and a small section of the southeast corner of Redfish Lake are spawning grounds for residual sockeye salmon and adult sockeye salmon. Night snorkel surveys were conducted at both locations to estimate numbers of spawning residual sockeye salmon, anadromous sockeye salmon, and hatchery sockeye salmon. Snorkel surveys in Redfish Lake were conducted weekly from 5 to 26 October 2004. At least three observers, equipped with waterproof flashlights, snorkeled parallel to shore 10 m apart, at depths ranging from 0.5 to 5 m. At Sockeye Beach, estimates of residual sockeye salmon spawner abundance were conducted within the boundary (600 m) of Sockeye Beach as delineated by USFS signs. Spawning ground surveys in the south end of the lake were conducted in the 200 m shoal area near the two small southeast inlet streams.

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

Pettit Lake Egg Boxes

During May, SBT and IDFG personnel retrieved egg boxes placed in 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.

In November, SBT and IDFG personnel placed a total of 16 egg boxes containing 49,134 eggs in Pettit 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 2004, mean annual discharge of the Salmon River at Salmon, Idaho (USGS gage 13302500) was 34.9 m³/s, 36% less than the 1913-2004 average of 54.8 m³/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.

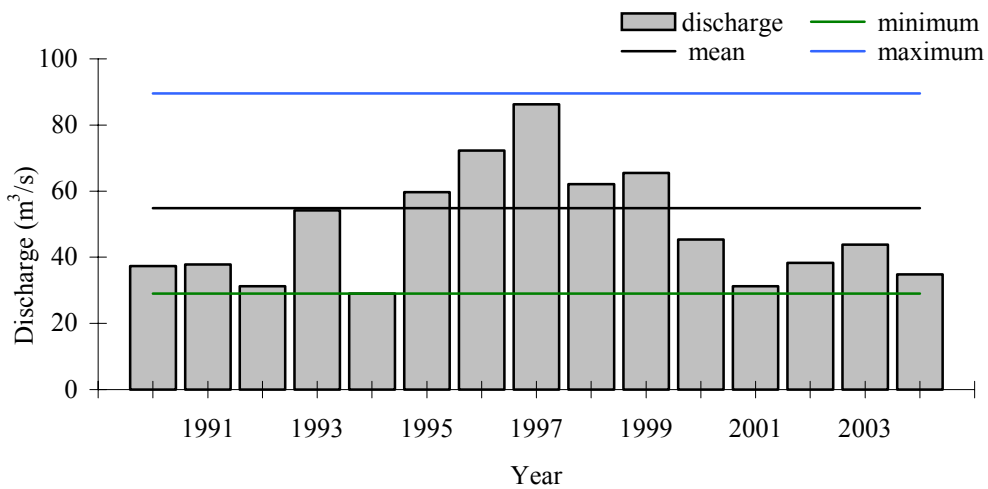


Figure 2. Mean annual discharge for the Salmon River at Salmon, Idaho, 1990-2004. Minimum, mean, and maximum are for period of record, 1913 to 2004.

Profile Data

The Sawtooth Valley lakes were inversely stratified and ice covered from January to April 2004. On 13 April 2004, Redfish Lake was free of ice, Pettit Lake was approximately 80% ice free, and Alturas Lake was covered with ice.

Thermoclines were present from July through October. Maximum surface temperatures were 18-20 °C in each of the four lakes (Appendix A). Seasonal mean surface (0-10 m) water temperatures were 13.5, 14.0, 13.3, and 11.9 °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 1992-2004 ($r = -0.72$, $n=52$) (Figure 3).

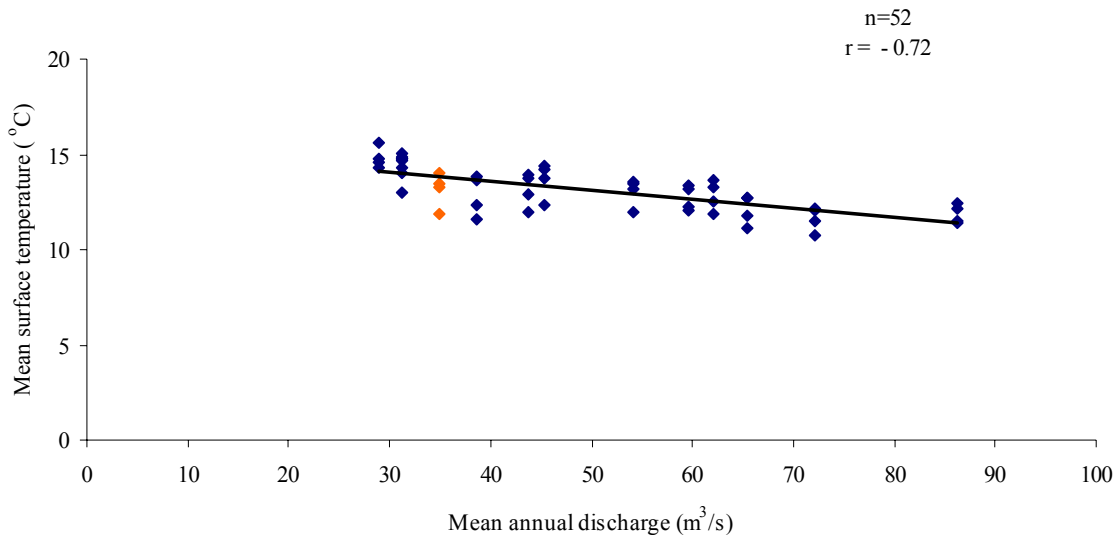


Figure 3. Correlation of mean annual discharge for the Salmon River at Salmon, Idaho, and mean summer surface (0-10 m) temperatures for 1992-2004 in Redfish, Pettit, Alturas, and Stanley lakes. Orange symbols indicate current year.

Redfish Lake mixed completely during May 2004. Hypolimnetic oxygen deficits were minimal; during October and November oxygen concentrations were less than 5 mg/L in the bottom 3-8 m. Pettit Lake mixed to approximately 31 m depth during May or June. During late summer and fall, dissolved oxygen concentrations were less than 5 mg/L below approximately 28 m depth. Oxygen concentrations were less than 5 mg/L in the bottom 5-9 m during September-November in Alturas Lake and in the bottom 3-7 m between July and October in Stanley Lake. During the November sample period the four lakes were approaching isothermy but had not yet mixed.

Table 2. Seasonal mean (June-October) surface water temperature (°C), Secchi depth (m), compensation depth (m), epilimnetic chlorophyll *a* (µg/L), and whole-lake total zooplankton biomass (mg/m²) for the Sawtooth Valley lakes, 1992-2004.

Lake	Year	Surface temperature (°C) 0-10 m	Secchi depth (m)	Compensation depth (m)	Epilimnetic chl <i>a</i> (µg/L)	Whole-lake zooplankton biomass (mg/m ²)
Redfish	2004	13.5	16.5	27.0	0.9	1105.4
	2003	13.9	15.8	25.6	0.7	2005.6
	2002	13.6	13.9	24.5	1.5	1023.4
	2001	14.3	14.5	27.4	1.4	1266.3
	2000	14.2	17.8	26.1	0.8	1166.7
	1999	12.7	14.6	22.5	0.9	430.8
	1998	13.3	12.1	22.1	1.6	617.5
	1997	12.2	11.4	19.7	1.5	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	14.3	25.5	0.9	818.3
Pettit	2004	14.0	10.4	22.3	2.6	3121.4
	2003	13.7	13.2	21.3	1.2	2760.7
	2002	13.8	15.5	24.2	0.7	2869.6
	2001	14.8	15.7	26.2	0.6	1441.7
	2000	14.4	15.0	24.5	1.0	466.7
	1999	12.7	11.2	21.7	1.4	450.5
	1998	13.6	10.6	22.6	1.5	344.0
	1997	12.4	11.3	19.1	1.3	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	13.3	23.4	1.0	1150.6
Alturas	2004	13.3	15.6	22.3	0.7	883.3
	2003	12.9	11.8	17.1	0.7	484.3
	2002	12.3	12.5	20.0	0.7	405.8
	2001	14.0	13.9	22.8	0.8	140.6
	2000	13.8	14.5	19.8	0.9	272.5
	1999	11.8	10.5	16.9	1.2	448.9
	1998	12.6	10.8	17.3	2.0	485.1
	1997	11.4	10.9	15.7	1.0	404.7
	1996	11.5	10.6	13.6	1.0	244.2
	1995	12.2	9.8	16.5	0.4	100.3
	1994	14.3	14.7	24.1	0.4	138.4
	1993	13.1	-	20.6	0.9	15.9
1992	14.7	14.4	27.6	0.6	-	
	mean	12.9	12.5	19.6	0.9	335.3

Table 2. continued

Lake	Year	Surface temperature (°C) 0-10 m	Secchi depth (m)	Compensation depth (m)	Epilimnetic chl <i>a</i> (µg/L)	Whole-lake zooplankton biomass (mg/m ²)
Stanley	2004	11.9	7.5	13.2	1.0	394.5
	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	13.7	1.0	360.2

Secchi depth and compensation depth

Secchi and compensation depths were variable in the Sawtooth Valley Lakes during 2004. Secchi depths consistently deepened through the summer in Alturas and Stanley lakes (Figures 4 and 5). Redfish and Pettit lakes had reductions in Secchi depths in early August that persisted through September. These declines corresponded with several weeks of cool, wet weather. The effect was more pronounced in Pettit Lake, which we attribute to nutrient supplementation. Compensation depths followed similar trends in the four lakes.

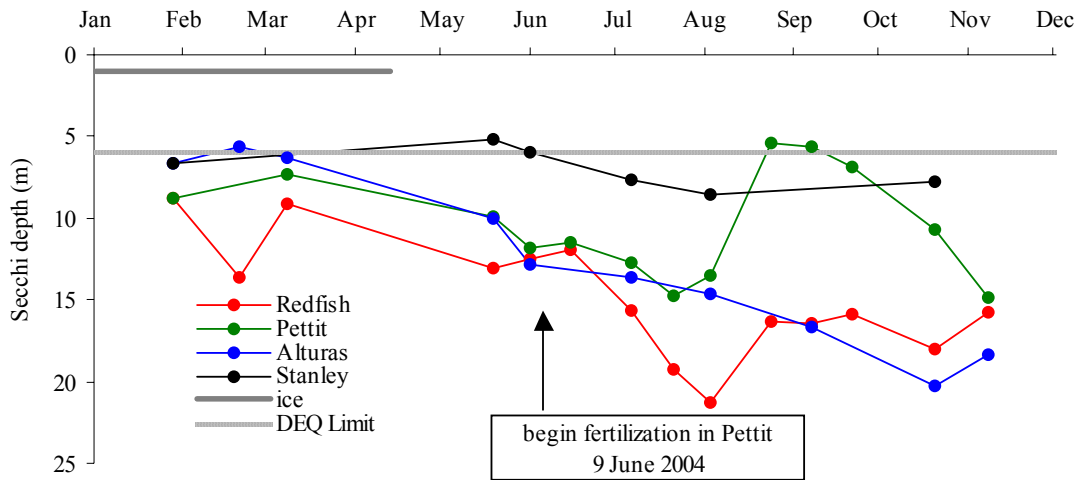


Figure 4. Secchi depths (m) for Redfish, Pettit, Alturas, and Stanley lakes, January through November 2004.

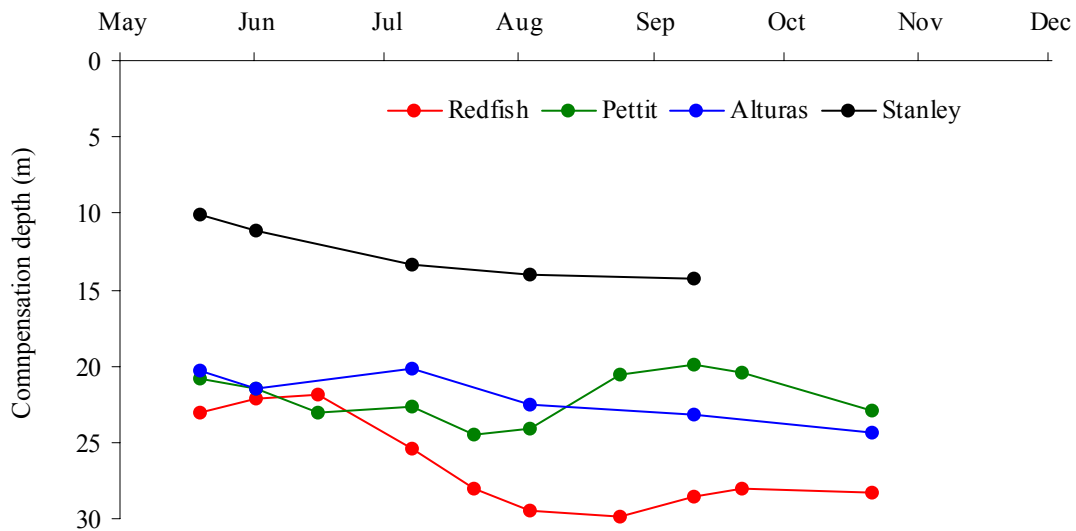


Figure 5. Compensation depths (m) defined by the 1% light level for Redfish, Pettit, Alturas, and Stanley lakes, May through October 2004.

Water Chemistry

During spring turnover (May 2004) depth integrated nutrient concentrations remained extremely low, consistent with the oligotrophic condition of the Sawtooth Valley lakes. TP concentrations were between 5.7 and 9.0 $\mu\text{g/L}$, TDP was $\leq 3.0 \mu\text{g/L}$, and TN concentrations ranged from 68 to 99 $\mu\text{g/L}$. Nitrate-nitrite concentrations were less than 15 $\mu\text{g/L}$ and TN:TP ratios were between 8 and 17.

Nutrient concentrations in the epilimnion of Redfish Lake were low and consistent during summer 2004, with values ranging from 54-64 $\mu\text{g/L}$ total nitrogen, 1-2 $\mu\text{g/L}$ $\text{NO}^3\text{-NO}^2\text{-N}$, 2-5 $\mu\text{g/L}$ dissolved phosphorus, and 5-8 $\mu\text{g/L}$ total phosphorus (Figures 6 and 7). TN:TP ratios were low, ranging from 7.4 to 13.6 (average=10.2). Pettit Lake also had low epilimnetic nutrient concentrations during May and June, prior to nutrient supplementation. During supplementation, nitrogen compounds increased with total nitrogen ranging from 103-189 $\mu\text{g/L}$ and $\text{NO}^3\text{-NO}^2\text{-N}$ between 5-28 $\mu\text{g/L}$. Phosphorus concentrations remained low, similar to Redfish Lake with values ranging between 3-5 $\mu\text{g/L}$ dissolved phosphorus, and 4-7 $\mu\text{g/L}$ total phosphorus. Elevated nitrogen concentrations resulted in higher TN:TP ratios than were observed in Redfish Lake (range 24-31).

Seasonal mean epilimnetic TP concentrations were approximately 6 $\mu\text{g/L}$ and TDP was 3.6 $\mu\text{g/L}$ in Redfish and Pettit lakes. Mean TN concentrations were 61 $\mu\text{g/L}$ in Redfish Lake and 125 $\mu\text{g/L}$ in Pettit Lake, resulting in TN:TP ratios of 10 and 23, respectively. Mean nitrate-nitrite concentrations were 1.4 $\mu\text{g/L}$ in Redfish Lake and 10 $\mu\text{g/L}$ in Pettit Lake (Table 3).

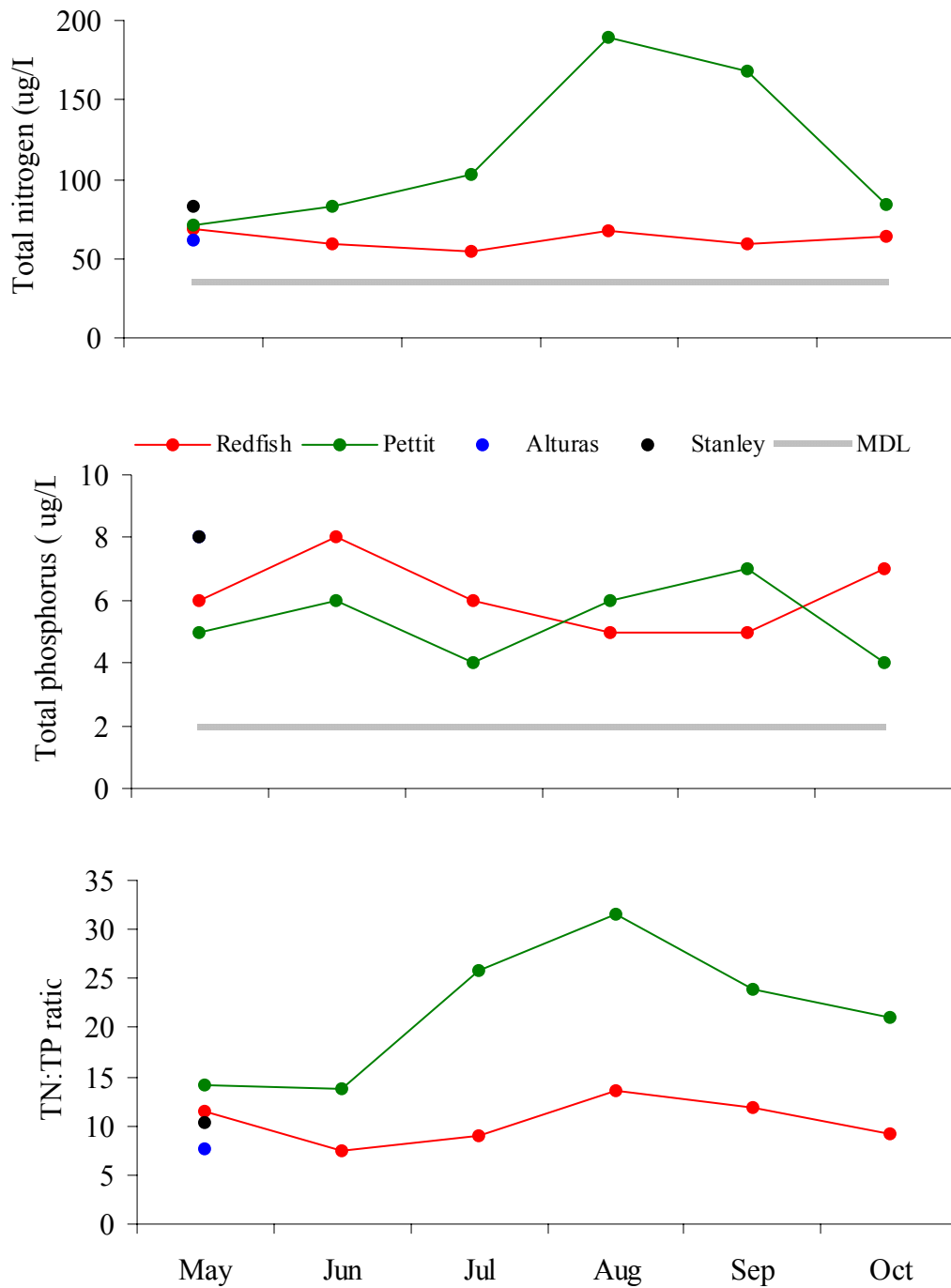


Figure 6. Concentrations of total nitrogen, total phosphorus, and the TN:TP ratio in the epilimnetic waters of Redfish, Pettit, Alturas, and Stanley lakes during May through October 2004. Grey line denotes method detection level.

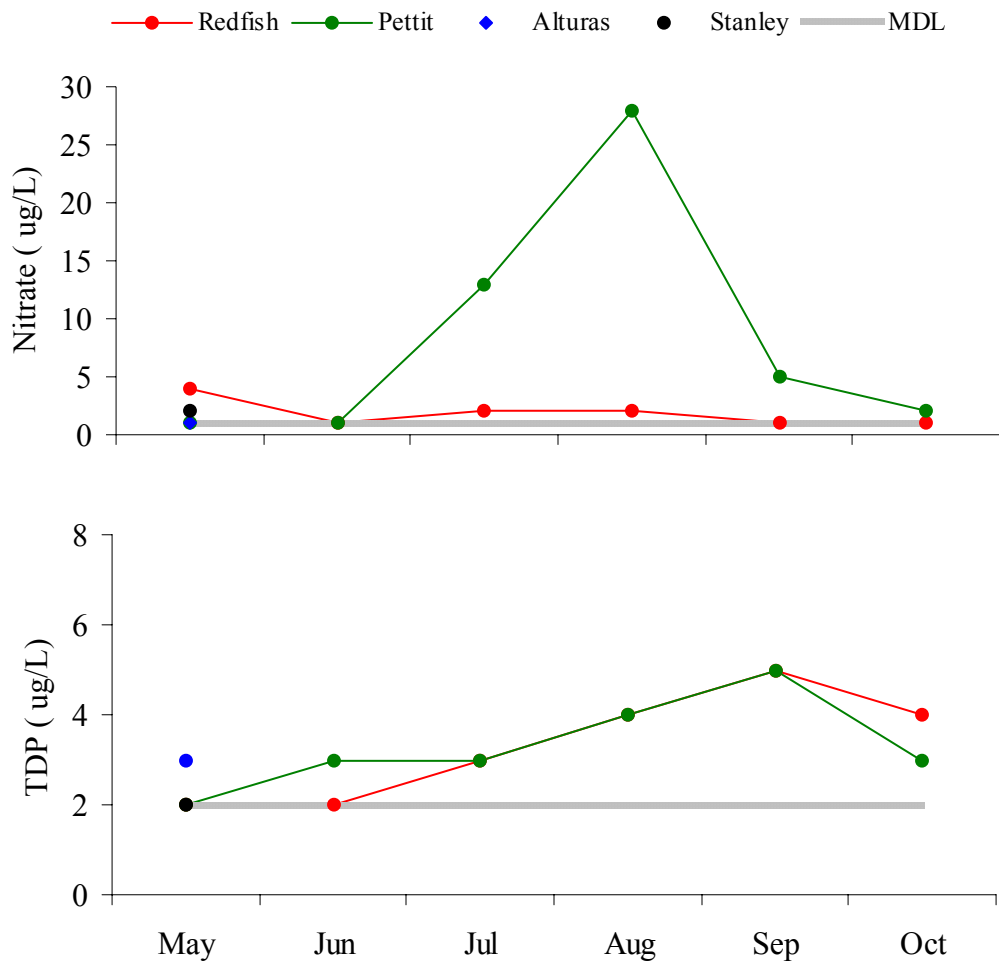


Figure 7. Nitrate-nitrite and total dissolved phosphorus concentrations in the epilimnetic waters of Redfish, Pettit, Alturas, and Stanley lakes during May through October 2004. Grey line denotes method detection levels.

Table 3. Seasonal mean (June-October) epilimnetic nutrient concentrations ($\mu\text{g/L}$) and TN:TP ratio in Redfish, Pettit, Alturas, and Stanley lakes during 1992-2004.

Lake	Year	TP	TDP	SRP	TN	$\text{NO}_3 + \text{NO}_2$	NH_4	TN:TP
Redfish	2004	6.2	3.6	-	60.8	1.4	-	10.2
	2003	4.2	2.9	-	100.1	1.4	-	26.0
	2002	5.0	3.0	-	65.8	4.1	-	14.3
	2001	3.2	2.1	-	108.0	4.6	-	27.2
	2000	4.9	3.0	-	69.5	1.8	3.3	13.2
	1999	5.2	-	-	54.7	3.0	5.1	9.2
	1998	6.2	-	-	61.9	7.2	3.4	10.0
	1997	5.5	-	-0.3	67.0	4.9	3.5	16.0
	1996	5.0	-	0.9	45.7	0.9	1.2	10.3
	1995	7.3	-	1.8	87.1	3.8	6.5	14.8
	1994	8.5	-	2.0	-	-	-	-
	1993	6.4	-	1.6	65.4	1.6	3.2	10.7
	1992	8.6	-	1.8	47.7	6.7	-	6.1
	mean	6.3	2.9	1.5	68.9	3.6	4.0	13.7
Pettit	2004	5.4	3.6	-	125.4	9.8	-	23.2
	2003	4.3	2.7	-	101.0	1.4	-	27.1
	2002	4.8	3.2	-	100.8	1.8	-	24.5
	2001	3.1	2.0	-	117.6	1.2	-	38.3
	2000	5.3	2.7	-	57.5	1.0	2.7	11.2
	1999	6.3	-	-	101.5	2.4	5.0	14.0
	1998	5.4	-	-	86.4	1.3	2.3	15.2
	1997	5.5	-	0.0	71.6	2.0	2.6	17.9
	1996	6.0	-	0.9	42.5	0.5	0.9	8.0
	1995	5.8	-	1.5	86.9	1.0	3.0	16.9
	1994	6.6	-	1.0	-	-	-	-
	1993	6.2	-	1.7	70.1	1.7	3.0	13.6
	1992	5.8	-	2.2	84.6	3.6	-	15.7
	mean	5.5	2.9	1.3	88.5	2.3	2.8	19.2
Alturas	2004	-	-	-	-	-	-	-
	2003	-	-	-	-	-	-	-
	2002	-	-	-	-	-	-	-
	2001	-	-	-	-	-	-	-
	2000	7.1	5.2	-	65.0	1.9	3.9	11.0
	1999	7.9	-	-	93.9	1.7	6.6	9.9
	1998	8.2	-	-	76.6	1.1	2.8	9.3
	1997	8.2	-	0.3	66.6	1.4	1.8	11.6
	1996	8.2	-	1.0	61.1	0.5	1.7	7.9
	1995	8.5	-	1.7	120.5	2.6	6.6	16.4
	1994	11.6	-	2.4	-	-	-	-
	1993	8.0	-	1.2	88.8	3.2	2.6	14.3
	1992	7.5	-	1.0	84.5	4.3	-	10.6
	mean	8.5	5.2	1.3	84.7	2.2	3.8	11.9

Table 3. continued.

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

Chlorophyll a

In 2004, epilimnetic chlorophyll *a* concentrations ranged from 0.3 to 7.2 µg/L in the four Sawtooth Valley lakes (Figure 8). The highest concentrations observed in the three unfertilized lakes were during the spring and fall. In Pettit Lake, chlorophyll *a* peaked during late August (7.2 µg/L) and early September (6.6 µg/L) in response to nutrient supplementation. June-October mean epilimnetic chlorophyll *a* concentrations ranged from 0.7 to 1.0 µg/L in the three untreated lakes and 2.6 µg/L in Pettit Lake (Table 2).

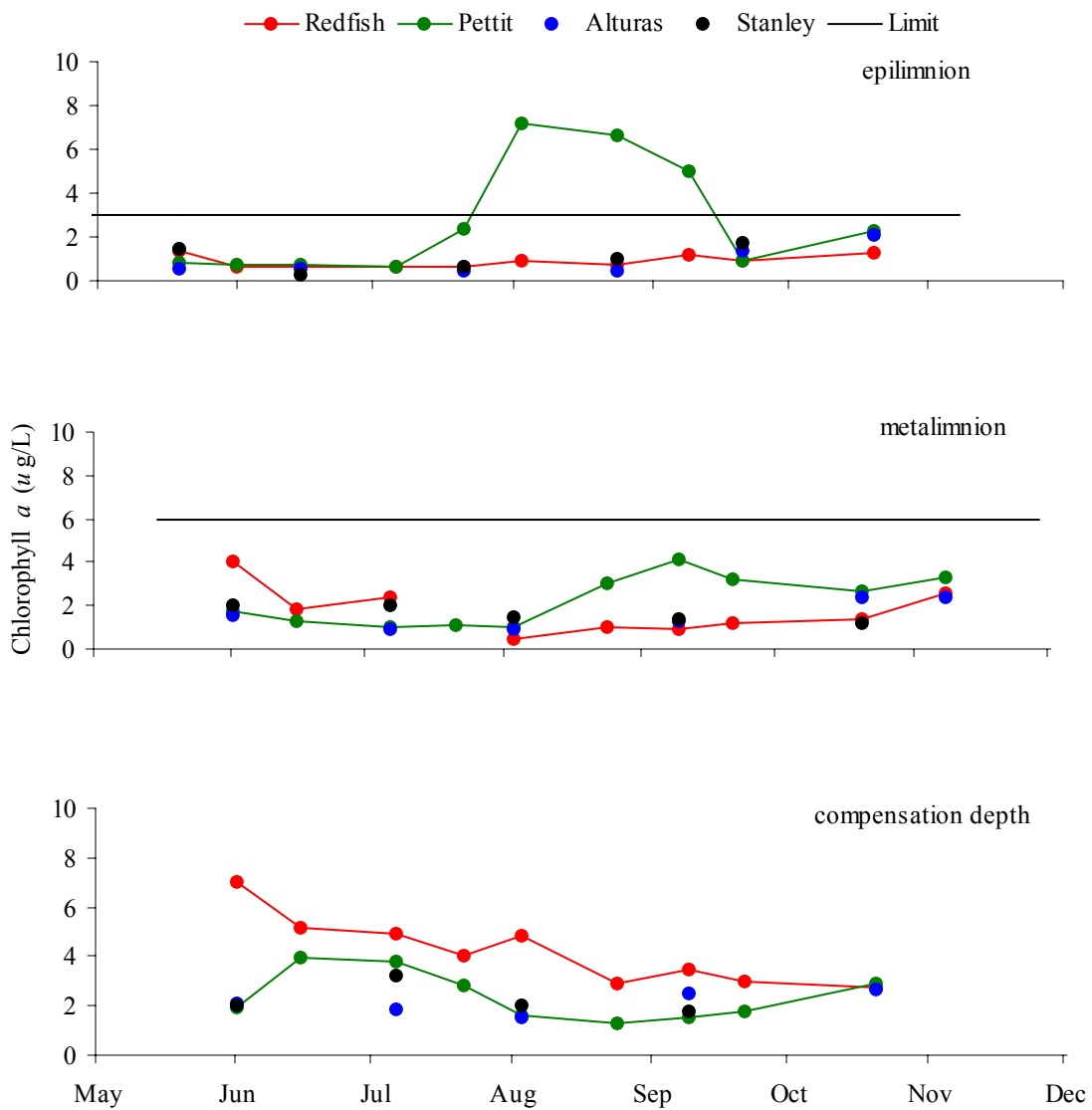


Figure 8. Chlorophyll *a* concentrations ($\mu\text{g/L}$) in the epilimnion, metalimnion, and compensation depths in Redfish, Pettit, Alturas, and Stanley lakes, May-November 2004.

Primary Productivity

Primary productivity data not available at time of writing.

Heterotrophic bacteria and autotrophic picoplankton

Pettit Lake had the highest epilimnetic densities of heterotrophic bacteria; however, densities were relatively consistent between the four lakes. Seasonal mean heterotrophic bacteria densities in the epilimnions of the four Sawtooth Valley lakes ranged from 1,000,000 to 1,480,000 cells/mL (Table 4; Appendix B). Vertical distribution of heterotrophic bacteria was similar in Redfish and Pettit lakes on 24 August 2004 (Figure 9). Pettit Lake had the lowest autotrophic picoplankton (APP) densities with approximately 4,000 cells/mL in the epilimnion and less than 20,000 cells/mL at the compensation depth. The three unfertilized lakes had APP densities ranging from 14,000 and 34,000 cells/mL in their epilimnions and 21,000 and 95,000 cells/mL at the compensation depth. In late August, densities of APP were extremely low in the top 10 m of Pettit Lake, compared to Redfish Lake (Figure 10).

Table 4. Heterotrophic bacteria and autotrophic picoplankton (APP) densities (cells/mL) in the epilimnions and compensation depths in four Sawtooth Valley lakes during June-October 2004.

Lake	Strata	Heterotrophic bacteria			Autotrophic picoplankton		
		min	mean	max	min	mean	max
Redfish	epilimnion	396,599	1,000,706	1,791,644	285	13,655	31,357
	compensation depth	788,922	1,379,010	2,035,376	9,835	21,396	56,443
	mean		1,189,858			17,526	
Pettit	epilimnion	962,100	1,480,351	2,214,968	0	4,176	18,814
	compensation depth	1,128,864	1,679,043	1,988,340	13,113	19,891	39,054
	mean		1,579,697			12,034	
Alturas	epilimnion	712,667	1,329,777	1,941,304	1,568	21,760	52,025
	compensation depth	1,293,490	1,871,605	2,591,256	19,527	94,999	248,436
	mean		1,600,691			58,380	
Stanley	epilimnion	391,254	1,220,038	2,163,656	285	34,080	78,465
	compensation depth	698,057	1,300,706	1,624,880	9,550	54,109	142,177
	mean		1,260,372			44,095	

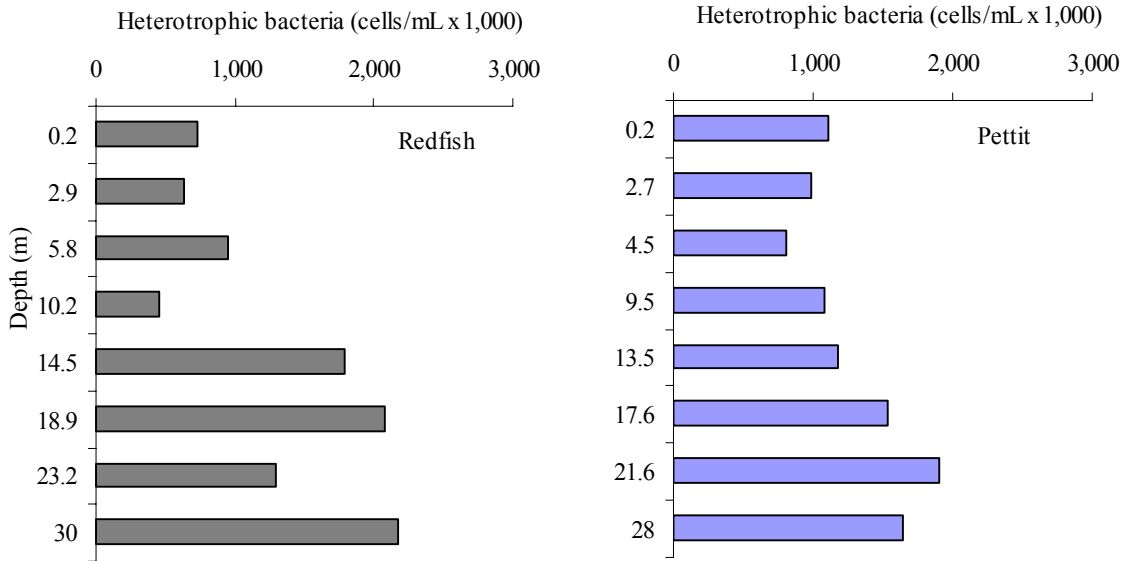


Figure 9. Heterotrophic bacteria densities (cells/mL x 1,000) at eight discrete depths within the euphotic zones of Redfish and Pettit lakes, Idaho, 24 August 2004.

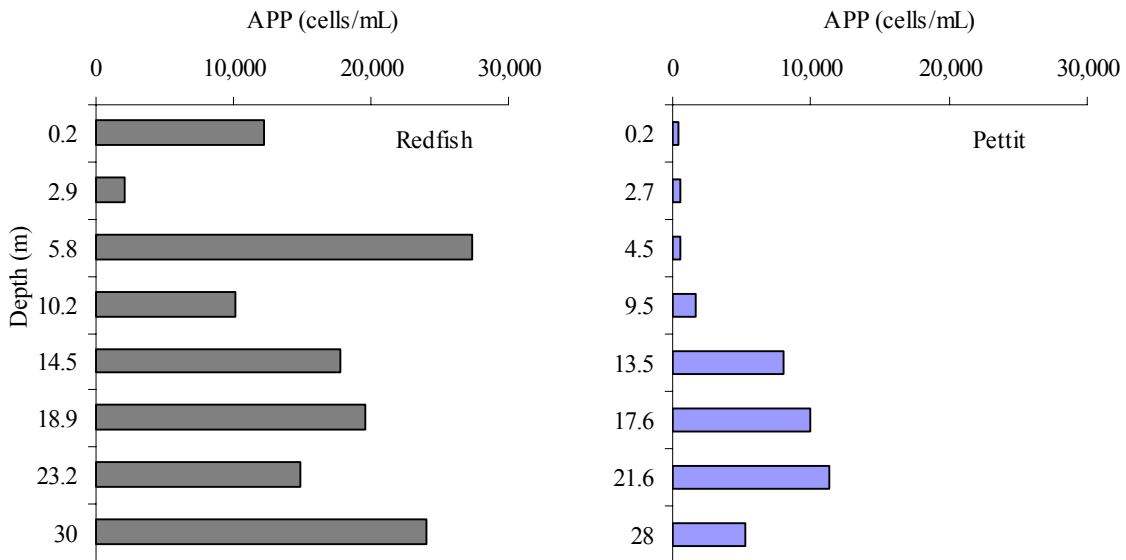


Figure 10. Autotrophic picoplankton densities (cells/mL) at eight discrete depths within the euphotic zones of Redfish and Pettit lakes, Idaho, 24 August 2004.

Phytoplankton

Phytoplankton communities in the three unfertilized Sawtooth Valley lakes were dominated by small grazable taxa during 2004. Total phytoplankton densities ranged from 385-2,960 cells/mL and total phytoplankton biovolume ranged from 0.02 to 0.57 mm³/L in the epilimnions of the three lakes (Table 5; Appendix C). The highest densities and biovolumes were observed in Pettit Lake during fertilization when an *Oocystis* sp. bloom reached 7,998 cells/mL and 3.63 mm³/L.

In the three unfertilized lakes, Chryso- and Cryptophycean nano-flagellates (*Chrysochromulina* sp. and *Rhodomonas* sp.), Cyanophytes (*Synechococcus* sp. and *Oscillatoria* sp.), and Bacillariophytes (*Cyclotella* sp. and *Fragilaria* sp.) were numerically dominant. Dinophycean dinoflagellates (*Gymnodinium* sp. and *Peridinium* sp.), Chryso- and Cryptophycean nano-flagellates (*Chryptomonas* sp. and *Chrysochromulina* sp.), and Bacillariophytes (*Cyclotella* sp., *Fragilaria* sp., and *Asterionella* sp.) had the highest biovolume of any phytoplankton taxa. Chlorophyceans were present in low densities and biovolume and were split between (*Oocystis* sp., *Elakatothrix* sp., *Cosmarium* sp., and *Chlorella* sp.). Biovolume of Cyanophytes was low because of their relatively small size and was comprised of *Synechococcus* sp. and *Oscillatoria* sp..

Pettit Lake had similar species composition with the exception of the large bloom of a Chlorophacean *Oocystis* sp.. This bloom dominated the phytoplankton community in Pettit Lake from July through September with the peak occurring in late August. Phytoplankton samples collected from discrete depths at the peak of the bloom allow comparison of species composition and vertical distribution of phytoplankton taxa (Figure 11). *Oocystis* sp. was also present in Redfish Lake during August; however, in Pettit Lake it appears that fertilization increased this bloom by almost two orders of magnitude in the top 10 m of the water column.

Table 5. Phytoplankton density (cells/mL) and biovolume (mm³/L) in the epilimnions and compensation depths in four Sawtooth Valley lakes during June-October 2004.

Lake	Strata	Density			Biovolume		
		min	mean	max	min	mean	max
Redfish	epilimnion	740	1,456	2,473	0.19	0.28	0.38
	compensation depth	1,744	2,574	4,197	0.35	0.44	0.57
Pettit	epilimnion	466	3,736	7,998	0.06	1.29	3.63
	compensation depth	1,115	2,097	3,791	0.27	0.43	0.80
Alturas	epilimnion	679	1,081	1,439	0.11	0.15	0.19
	compensation depth	649	1,516	2,676	0.09	0.25	0.36
Stanley	epilimnion	1,450	2,074	2,960	0.15	0.26	0.47
	compensation depth	1,581	1,929	2,554	0.16	0.26	0.37

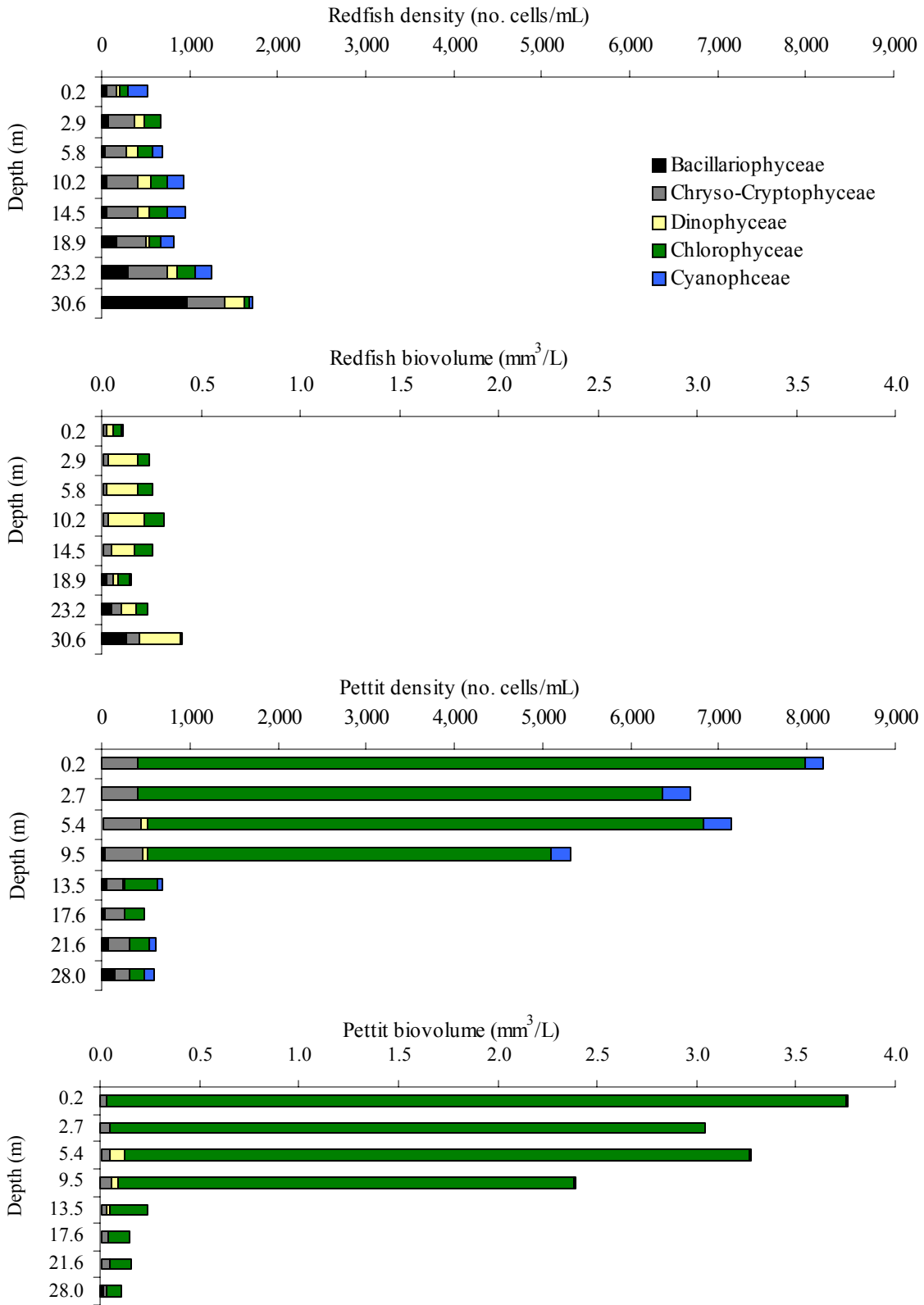


Figure 11. Phytoplankton density and biovolume at eight discrete depths in Redfish and Pettit lakes, Idaho, 24 August 2004.

Zooplankton

In 2004, Pettit Lake had the highest seasonal mean zooplankton biomass followed by Redfish, Alturas, and Stanley lakes, similar to observations in 2003. Zooplankton biomass declined in Redfish Lake and increased in the other three lakes compared to the previous year (Figure 12). Seasonal mean biomass (June-October) was 3,121 mg/m² in Pettit Lake, 1,105 mg/m² in Redfish Lake, 883 mg/m² in Alturas Lake, and 394 mg/m² in Stanley Lake (Table 2).

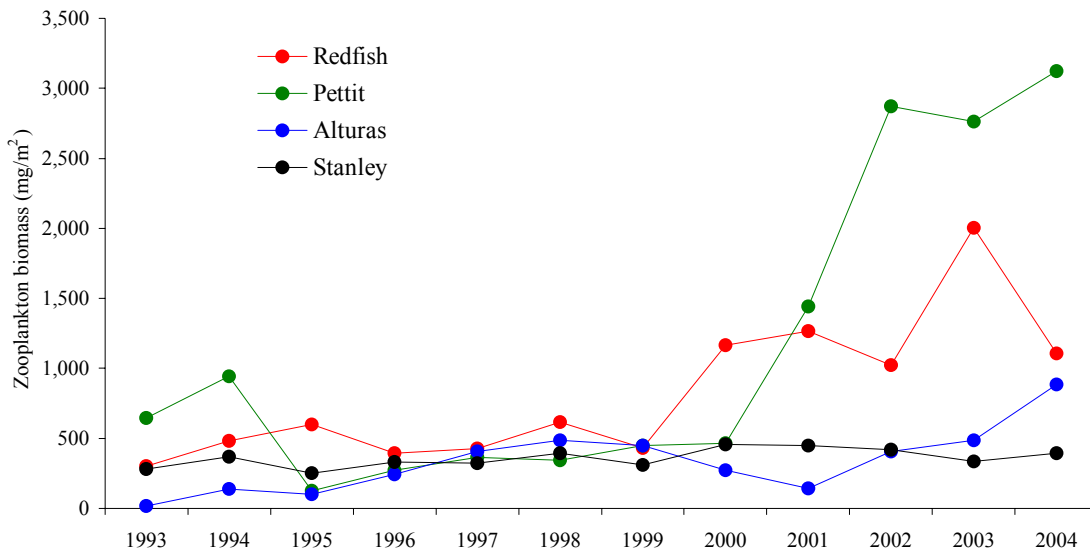


Figure 12. Seasonal mean zooplankton biomass (June-October) for the Sawtooth Valley lakes, 1993-2004.

Redfish Lake zooplankton biomass was similar to 2000-2002 and lower than 2003. *Holopedium* (378 mg/m²), *Daphnia* (353 mg/m²), *Bosmina* (179 mg/m²), and cyclopoid copepods (171 mg/m²) dominated mean summer biomass (Figure 13). During January-March 2004, whole-lake zooplankton biomass averaged 140 mg/m² and was dominated by cyclopoid copepods (104 mg/m²). *Daphnia* biomass was low compared to recent years with 15 mg/m² (Figure 14).

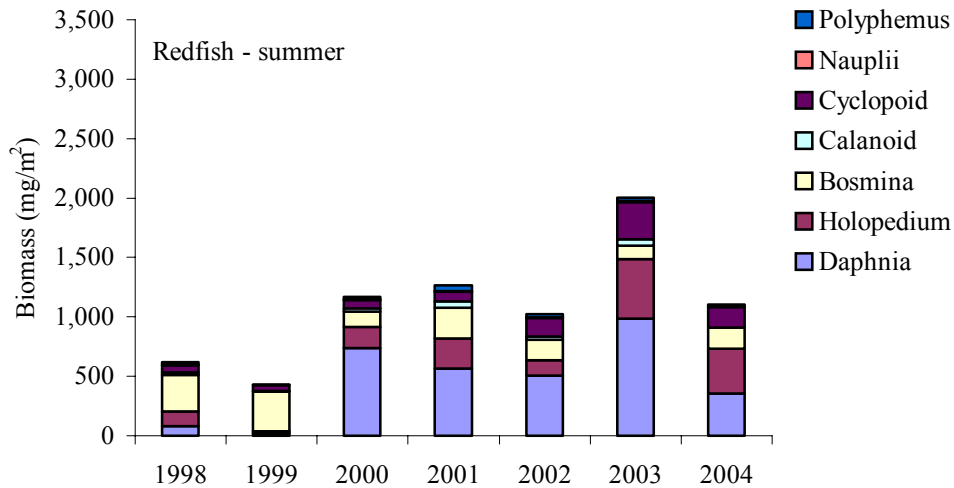


Figure 13. Mean areal zooplankton biomass (June-October) in Redfish Lake, 1998-2004.

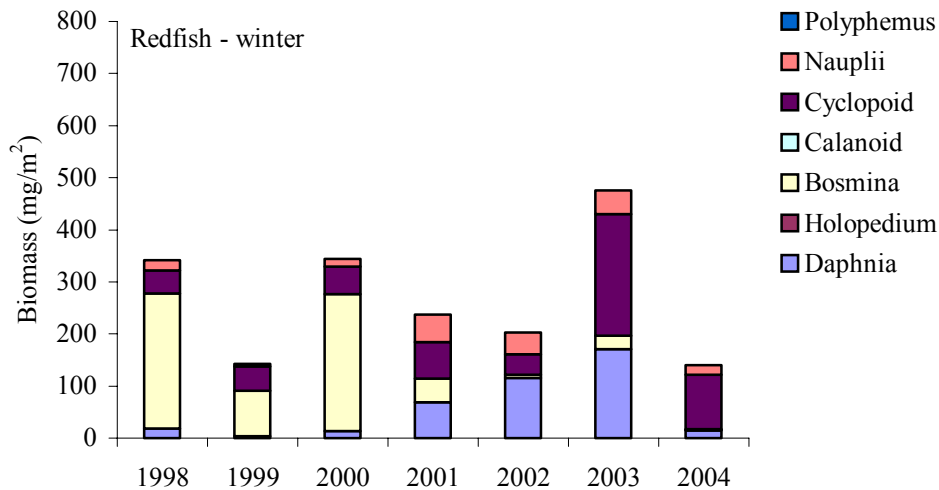


Figure 14. Mean areal zooplankton biomass (January-March) in Redfish Lake, 1998-2004.

Pettit Lake total summer zooplankton biomass increased slightly from 2003 and remains very high compared to previous years and the other Sawtooth Valley lakes (Figure 15). Zooplankton biomass was predominately *Daphnia* (1,538 mg/m²), and cyclopoid copepods (1,183 mg/m²). During January-March 2004, total zooplankton biomass was 477 mg/m² and was mostly cyclopoid copepods (383 mg/m²; Figure 16).

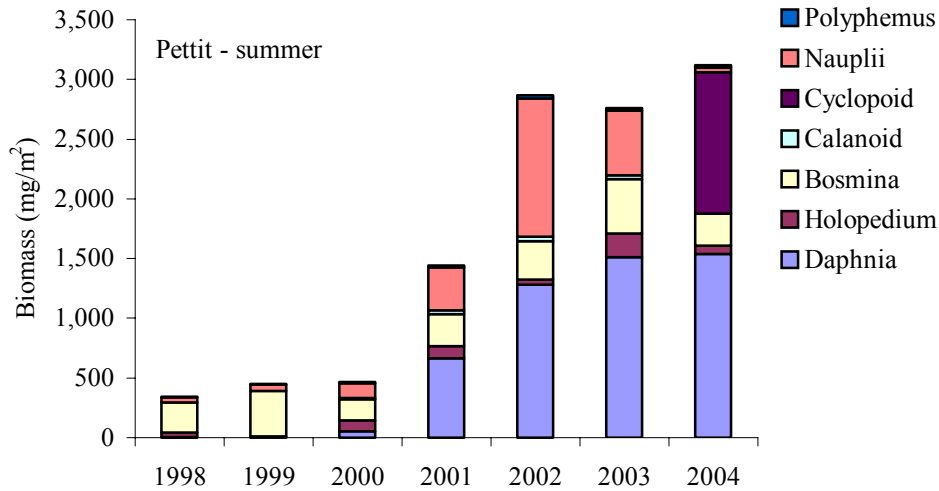


Figure 15. Mean areal zooplankton biomass (June-October) in Pettit Lake, 1998-2004.

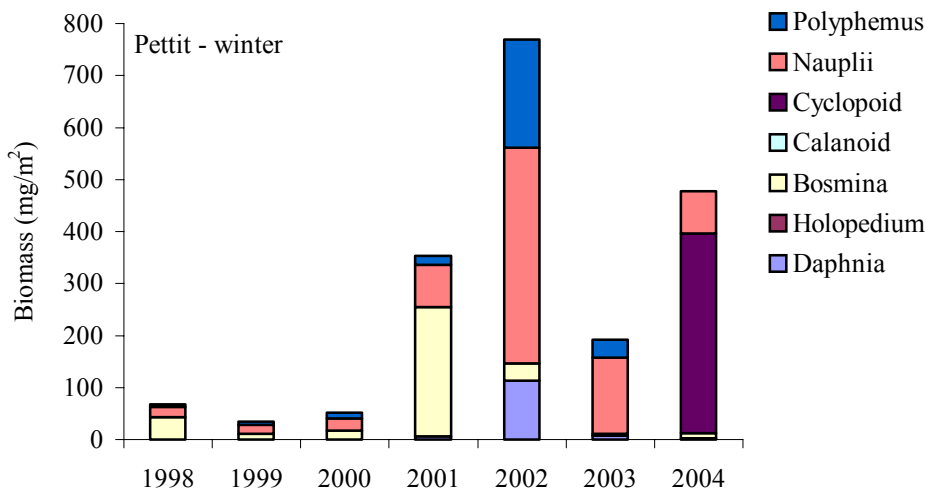


Figure 16. Mean areal zooplankton biomass (January-March) in Pettit Lake, 1998-2004.

In Alturas Lake, mean seasonal total zooplankton biomass was 883 mg/m², an increase from 2003 (Figure 17). During the summer of 2003, zooplankton populations consisted predominantly of *Holopedium* (297 mg/m²) and cyclopoid copepods (257 mg/m²). Mean zooplankton biomass during January-March was low with a total biomass of 104 mg/m² of which 59 mg/m² were cyclopoids and 27 mg/m² were nauplii (Figure 18).

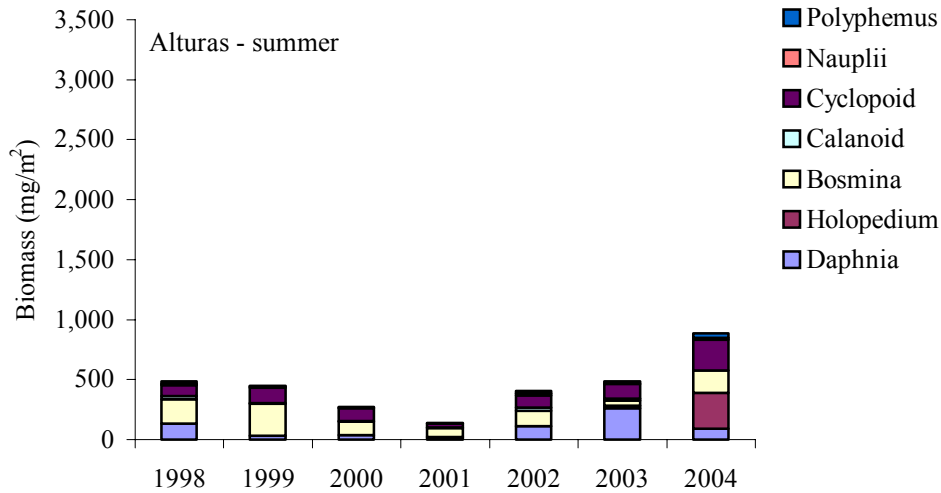


Figure 17. Mean areal zooplankton biomass (June-October) in Alturas Lake, 1998-2004.

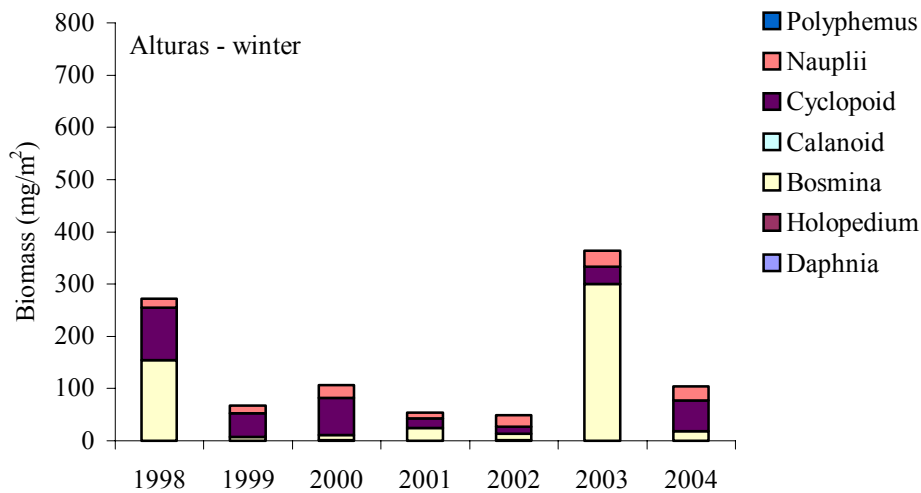


Figure 18. Mean areal zooplankton biomass (January-March) in Alturas Lake, 1998-2004.

Stanley Lake continues to have relatively stable zooplankton assemblages. Seasonal mean zooplankton biomass was (614 mg/m²), slightly higher than previous years (Figure 19). During summer 2004, zooplankton species composition was similar to that observed in 2000 and 2001, with most biomass represented by *Daphnia* and calanoid copepods. In January 2004, total biomass was 103 mg/m² and was predominately *Daphnia* (41 mg/m²) and *Bosmina* (40 mg/m²).

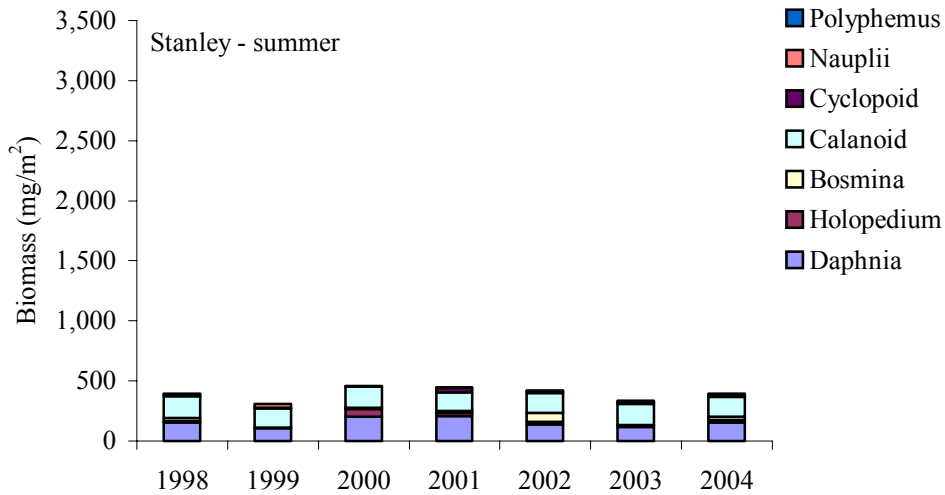


Figure 19. Mean areal zooplankton biomass (June-October) in Stanley Lake, 1998-2004.

Fertilization

Between 9 June and 29 September 2004, 60.8 kg phosphorus (P) and 1,859.3 kg nitrogen (N) were added to Pettit Lake to enhance its productivity. Applications were made once per week during a 16-week period. Applications gradually increased to a peak during weeks 10 and 11 (10-18 August), when Secchi and chlorophyll *a* criteria were exceeded and nutrient applications were suspended (Figure 20). By 29 September chlorophyll *a* and Secchi criteria were within limits and a final nutrient application was made. Areal loading rates were 37.5 mg P/m², or the equivalent of an adult escapement of approximately 7,540 sockeye salmon to Pettit Lake.

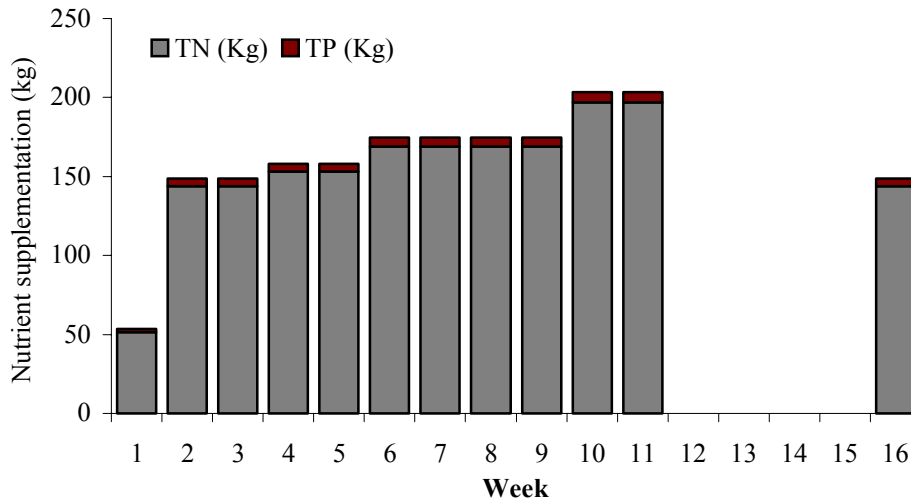


Figure 20. Supplemental nutrient applications for Pettit Lake, 9 June to 29 September 2004.

Limit Kokanee Salmon Escapement

The aluminum picket weir was constructed in Fishhook Creek; however, all fish (1,508) were passed above the weir because total numbers of spawning female kokanee salmon remained below the escapement goal.

Smolt Monitoring

Pettit Lake

We captured a total of 5,294 Snake River sockeye salmon comprised of 61 wild/natural (from the eyed egg release), 5,232 fall release from the Sawtooth Hatchery, and one summer release ADLV from the Eagle Hatchery (2001 release). We recaptured 551 smolts that had been PIT tagged prior to release the previous year. Because of the large numbers of recaptures we only tagged 336 smolts in 2004, resulting in the availability of 887 tagged fish to determine interrogation rates and travel time to the Lower Snake River Dam complex.

Fall release smolts captured at the Pettit Lake Creek weir had a 34.9% migration rate. Migrant numbers and timing, discharge, length frequency histograms, mean fork length, weight, and condition factors of smolt migrations are located in Figures 21 and 22 and Table 6.

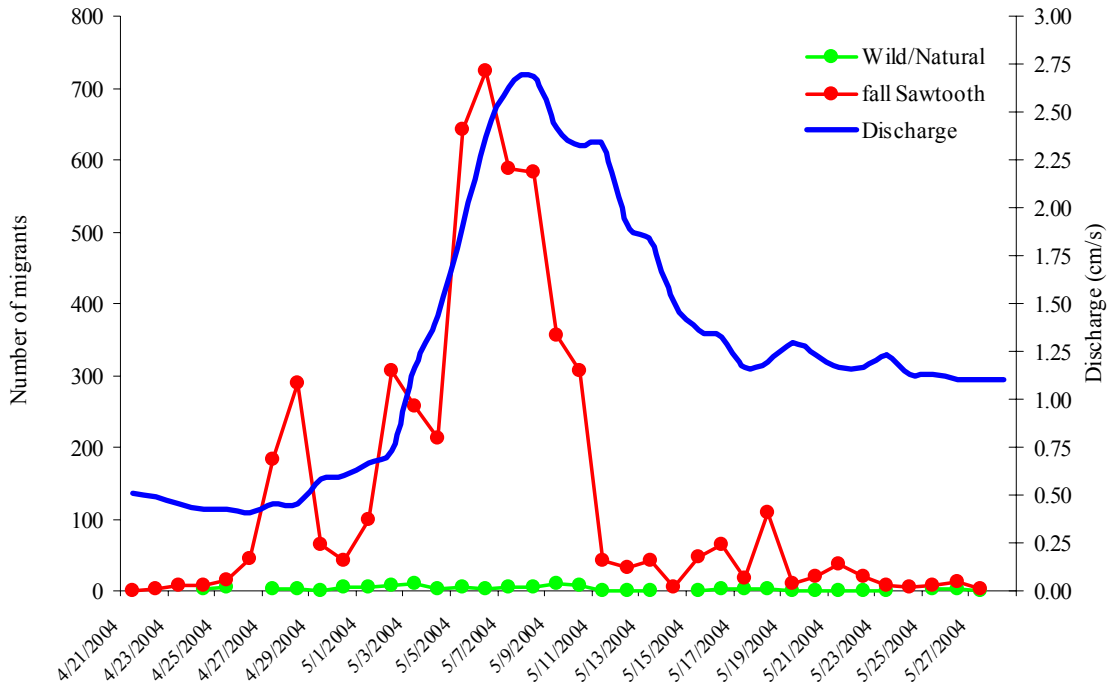


Figure 21. Pettit Lake migrant trapping data and hydrograph 2004.

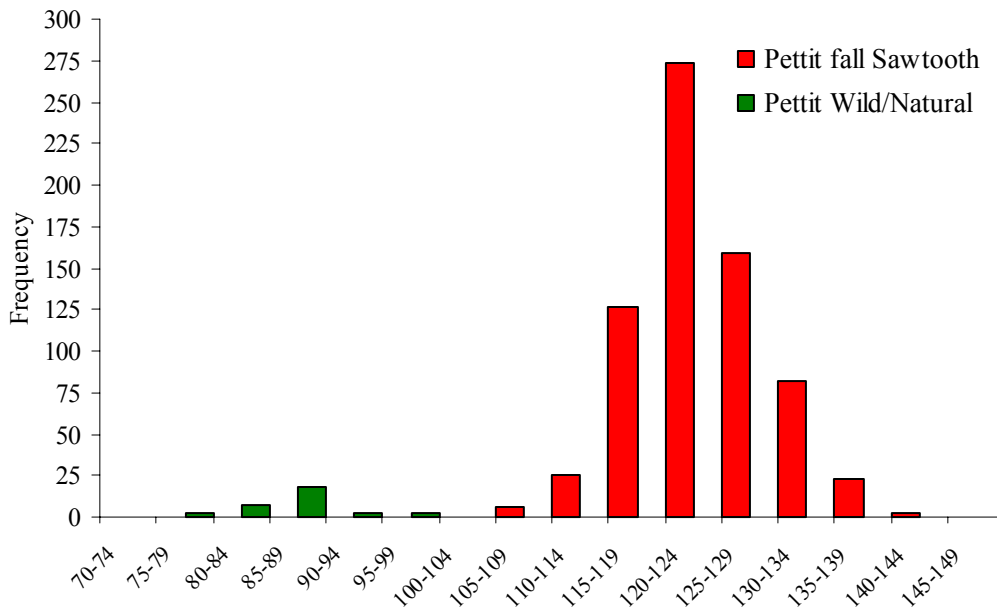


Figure 22. Pettit Lake migrant length frequency histogram 2004.

Alturas Lake

We captured four *O. nerka* without an adipose fin clip (Wild/Natural) with a population estimate of seventy four. We captured 59 hatchery sockeye salmon smolts with a corresponding estimate of 1,091 smolts. All of the hatchery sockeye salmon captured were from the fall 2003 release of 2,017 Sawtooth Hatchery reared fish. We PIT tagged one hatchery fish and recaptured 51 previously tagged sockeye salmon. There were no mortalities during trapping operations. We also captured 1,814 juvenile Snake River Chinook salmon with no mortalities.

Smolts migrating from Alturas Lake had a migration rate of 54.1 %. Migrant timing and discharge, length frequency histograms, mean length, weight, and condition factors of smolt migrations are located in Figures 23 and 24 and Table 6.

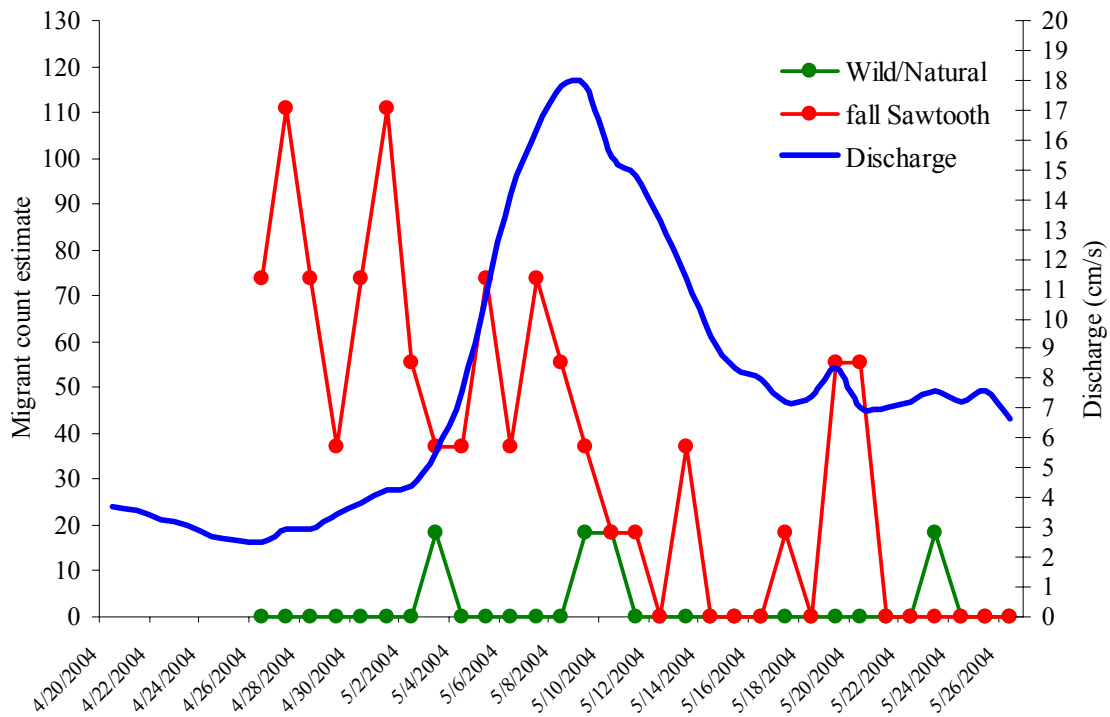


Figure 23. Alturas Lake migrant trapping data and hydrograph 2004.

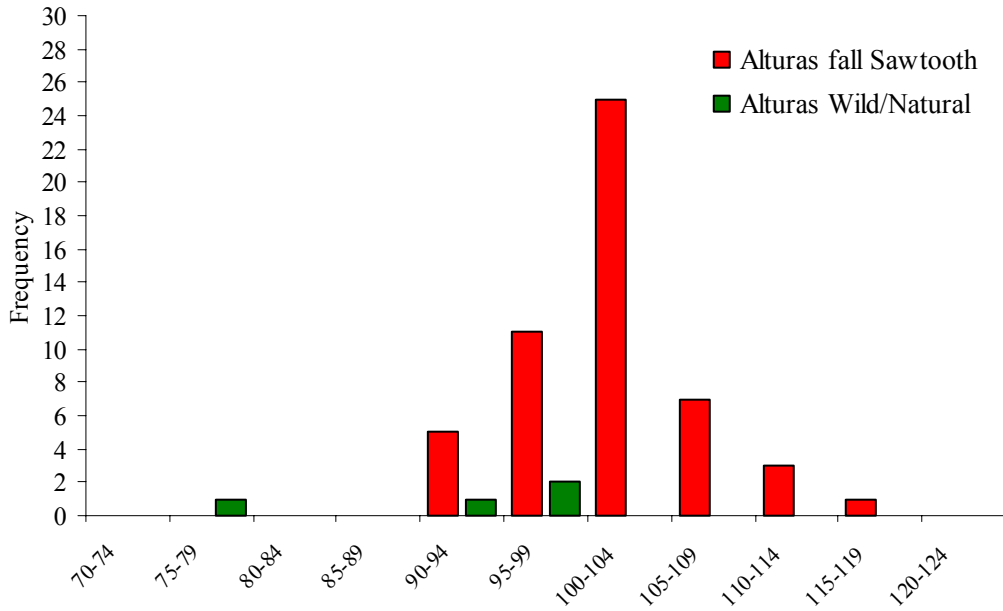


Figure 24. Alturas Lake migrant length frequency histogram 2004.

Growth Rates

Juvenile sockeye salmon from the captive broodstock program were measured and weighed during three different periods: at release into the lakes in 2003; during mid-winter sampling; and at capture as smolts in 2004. Their growth (fork length and weight) increased in Pettit and Alturas lakes; however, condition factor decreased from the time of release to the time of capture as smolts in both lakes. Redfish Lake sockeye salmon decreased in weight and condition factor during the same period (Figures 25a; 25b; 25c; Tables 7 and 8). Fall release fish in Pettit Lake exhibited the greatest increase in both length and weight.

Table 6. Hatchery sockeye salmon 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	10/7/03	AD	Sawtooth	105.67	10.99	0.92	302	2004	108.82	10.55	0.81	61
	10/8/02	AD	Sawtooth	111.87	15.31	1.09	995	2003	124.16	16.84	0.88	741
	8/29/02	ADRV	Bonneville	104.00	9.51	0.85	900	2003	126.50	17.27	0.85	670
	10/8/01	AD	Sawtooth	110.70	13.78	0.99	20	2002	125.42	15.73	0.96	1,204
	10/13/00	AD	Sawtooth	104.70	11.11	0.93	20	2001	115.69	13.49	0.86	1,391
	10/13/99	AD	Sawtooth	100.52	9.76	0.95	104	2000	114.49	11.98	0.79	107
	10/14/98			101.11	10.62	1.03	300	1999	107.97	9.08	0.74	31
PET	10/7/03	AD	Sawtooth	103.14	10.72	0.97	300	2004	123.19	17.78	0.95	696
	10/8/02	AD	Sawtooth	111.90	14.81	1.03	999	2003	126.53	18.16	0.89	617
	8/27/02	ADRV	Bonneville	102.23	8.89	0.83	574	2003	138.30	23.47	0.87	174
	10/8/01	AD	Sawtooth	110.70	13.78	0.99	20	2002	146.88	29.66	0.92	520
	7/30/01	ADRV	Sawtooth	72.75	3.63	0.93	20	2002	161.19	38.73	0.92	114
	7/26/01	ADLV	Eagle	110.35	14.19	1.05	20	2002	168.45	43.71	0.91	87
	10/12/00	AD	Sawtooth	104.70	11.11	0.93	20	2001	128.12	18.61	0.88	137
	7/28/00	ADRV	Eagle	97.42	8.45	0.91	50	2001	121.29	16.99	0.94	7
	7/27/00	ADLV	Sawtooth	66.50	2.95	0.99	50	2001	125.40	17.45	0.87	15
	10/13/99	AD	Sawtooth	101.22	10.45	1.00	104	2000	----	----	----	----
7/14/98	AD	Eagle	93.56	8.69	1.06	1507	1999	120.63	15.23	0.85	79	
ALT	10/7/03	AD	Sawtooth	93.99	7.95	0.95	99	2004	101.21	8.08	0.77	52
	8/27/02	ADRV	Bonneville	101.48	8.71	0.83	694	2003	111.81	12.99	0.83	16
	10/8/01	AD	Sawtooth	110.70	13.78	0.99	20	2002	112.21	10.56	0.73	380
	7/30/01	ADRV	Sawtooth	72.75	3.63	0.93	20	2002	94.83	6.12	0.71	12
	7/26/01	ADLV	Eagle	110.35	14.19	1.05	20	2002	97.60	7.40	0.69	5
	10/11/00	AD	Sawtooth	104.70	11.11	0.93	20	2001	104.41	9.21	0.78	129
	7/28/00	ADRV	Eagle	97.42	8.45	0.91	50	2001	----	----	----	----
	7/27/00	ADLV	Sawtooth	66.50	2.95	0.99	50	2001	90.84	6.27	0.82	19
	10/13/99	AD	Sawtooth	105.59	10.79	0.94	99	2000	109.93	10.52	0.79	127
	10/14/98	AD	Sawtooth	99.39	10.30	1.05	847	1999	107.85	10.02	0.79	75

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

Table 7. Specific growth rate data (fork length) 1999-2004.

Specific Growth Rate	Y2(LOG(L))	Y2:n=	Y1(LOG(L))	Y1:n=	T2-T1 (days)	Sp. Growth Rate
Specific Growth_04						
Alturas AD SAW fall	2.00	52	1.97	99	209	0.016
Pettit AD SAW fall	2.09	696	2.01	300	212	0.036
Redfish AD SAW fall	2.04	61	2.02	302	221	0.009
Specific Growth_03						
Alturas ADRV BONN summ	2.05	16	2.01	694	269	0.015
Pettit ADRV BONN summ	2.14	221	2.01	574	262	0.050
Pettit AD SAW fall	2.10	843	2.05	999	224	0.024
Redfish ADRV BONN summ	2.10	670	2.02	1000	257	0.029
Redfish AD SAW fall	2.09	741	2.05		217	0.019
Specific Growth_02						
Alturas ADRV SAW summ	1.98	12	1.86	20	282	0.041
Alturas ADLV EAG summ	2.05	2	2.04	20	284	0.002
Alturas AD SAW fall	2.05	380	2.04	20	214	0.003
Pettit ADRV SAW summ	2.21	114	1.86	20	293	0.118
Pettit ADLV EAG summ	2.23	87	2.04	20	299	0.061
Pettit AD SAW fall	2.17	520	2.04	20	223	0.055
Redfish AD SAW fall	2.10	1200	2.04	20	216	0.026
Specific Growth_01						
Alturas ADLV SAW summ	1.96	19	1.82	50	285	0.048
Alturas AD SAW fall	2.02	129	2.02	20	209	-0.001
Pettit ADRV EAG summ	2.08	7	1.99	50	289	0.033
Pettit ADLV SAW summ	2.10	15	1.82	50	289	0.096
Pettit AD SAW fall	2.11	137	2.02	20	213	0.042
Redfish AD SAW fall	2.06	1391	2.02	20	216	0.021
Specific Growth_00						
Alturas AD SAW fall	2.04	127	2.02	99	210	0.008
Redfish AD SAW fall	2.06	107	2.00	104	215	0.028
Specific Growth_99						
Alturas AD SAW fall	2.03	75	2.00	847	213	0.017
Pettit AD EAG summ	2.08	79	1.97	1507	310	0.036
Redfish AD SAW fall	2.03	31	2.00	300	213	0.011

Table 8. Specific growth rate data (weight) 1999-2004.

Specific Growth Rate	Y2(LOG(W))	Y2:n=	Y1(LOG(W))	Y1:n=	T2-T1 (days)	Sp. Growth Rate
Specific Growth_04						
Alturas AD SAW fall	0.90	52	0.89	99	209	0.004
Pettit AD SAW fall	1.25	696	1.02	300	212	0.107
Redfish AD SAW fall	1.02	61	1.03	302	221	-0.004
Specific Growth_03						
Alturas ADRV BONN summ	1.06	16	0.93	694	269	0.048
Pettit ADRV BONN summ	1.36	174	0.94	574	262	0.162
Pettit AD SAW fall	1.25	617	1.15	999	224	0.045
Redfish ADRV BONN summ	1.24	670	0.98	901	257	0.101
Redfish AD SAW fall	1.23	741	1.18	995	217	0.023
Specific Growth_02						
Alturas ADRV SAW summ	0.78	12	0.55	20	282	0.082
Alturas ADLV EAG summ	1.08	2	1.15	20	284	-0.022
Alturas AD SAW fall	1.01	380	1.12	20	214	-0.054
Pettit ADRV SAW summ	1.58	114	0.55	20	293	0.353
Pettit ADLV EAG summ	1.63	87	1.15	20	299	0.162
Pettit AD SAW fall	1.46	520	1.12	20	223	0.151
Redfish AD SAW fall	1.18	1200	1.12	20	216	0.028
Specific Growth_01						
Alturas ADLV SAW summ	0.78	19	0.46	50	285	0.115
Alturas AD SAW fall	0.94	129	1.02	20	209	-0.037
Pettit ADRV EAG summ	1.22	7	0.92	50	289	0.104
Pettit ADLV SAW summ	1.24	15	0.46	50	289	0.270
Pettit AD SAW fall	1.26	137	1.02	20	213	0.116
Redfish AD SAW fall	1.12	1391	1.02	20	216	0.048
Specific Growth_00						
Alturas AD SAW fall	1.02	127	1.03	99	210	-0.005
Redfish AD SAW fall	1.07	107	0.98	104	215	0.042
Specific Growth_99						
Alturas AD SAW fall	0.99	75	1.01	847	213	-0.007
Pettit AD EAG summ	1.17	79	0.93	1507	310	0.077
Redfish AD SAW fall	0.95	31	1.02	300	213	-0.034

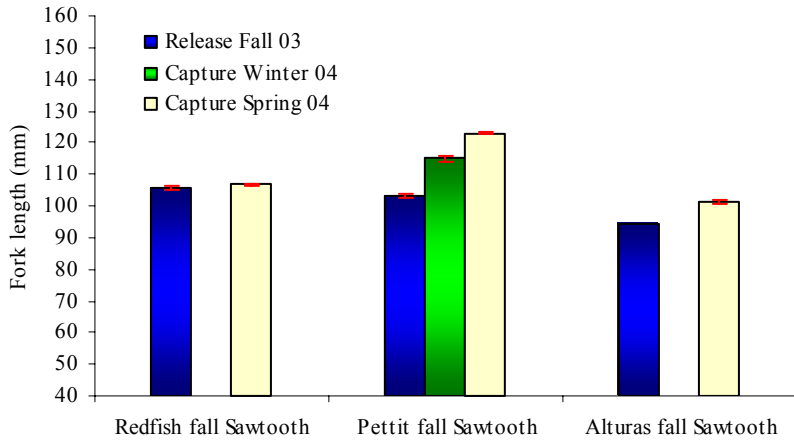


Figure 25a. Redfish, Pettit, and Alturas lakes growth rate evaluation using length data. Error bars are (\pm) one standard error.

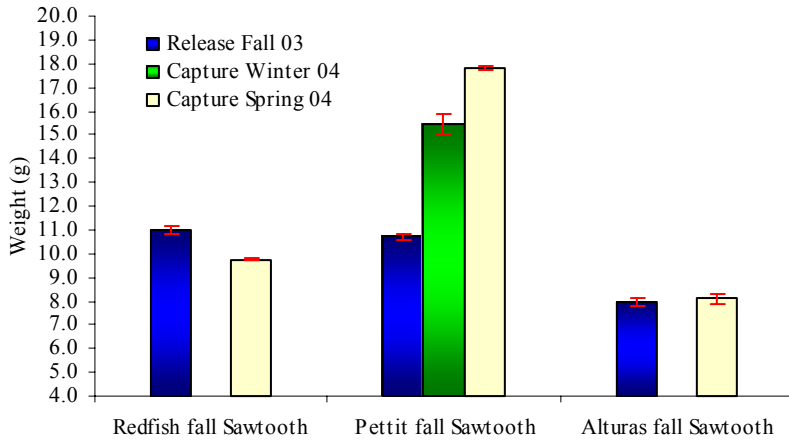


Figure 25b. Redfish, Pettit, and Alturas lakes growth rate evaluation using weight data. Error bars are (\pm) one standard error.

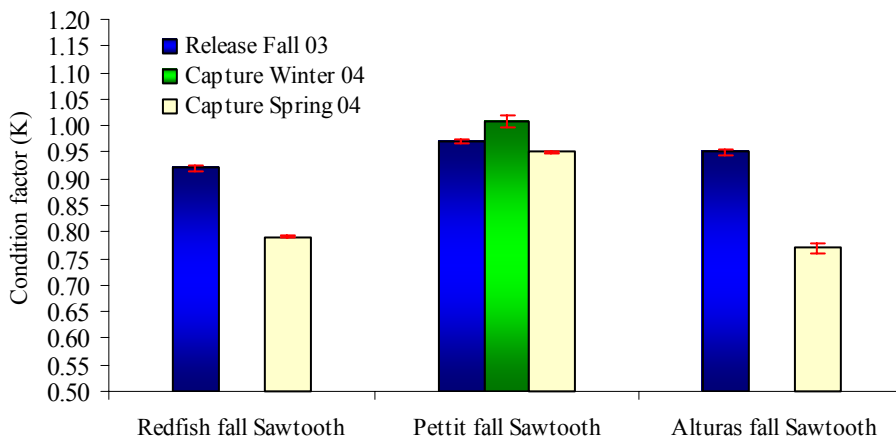


Figure 25c. Redfish, Pettit, and Alturas lakes growth rate evaluation using condition factor data. Error bars are (\pm) one standard error.

Stream Spawning

Starting in 2000, escapement of adult kokanee salmon to Fishhook Creek increased each year until effective Kokanee salmon control efforts were achieved in 2004 (Table 9; Figure 26). Kokanee salmon adult escapement in Fishhook Creek decreased 84% from 9,679 adult spawners in 2003 to 1,508 adult spawners in 2004. Escapement in Alturas Lake Creek reached an all time low of forty-eight in 2003; however, 2004 adult escapement increased dramatically to 7,101 adult spawners. Stanley Lake Creek escapement was very low at 228 fish, a 45% decline from 2003 escapement.

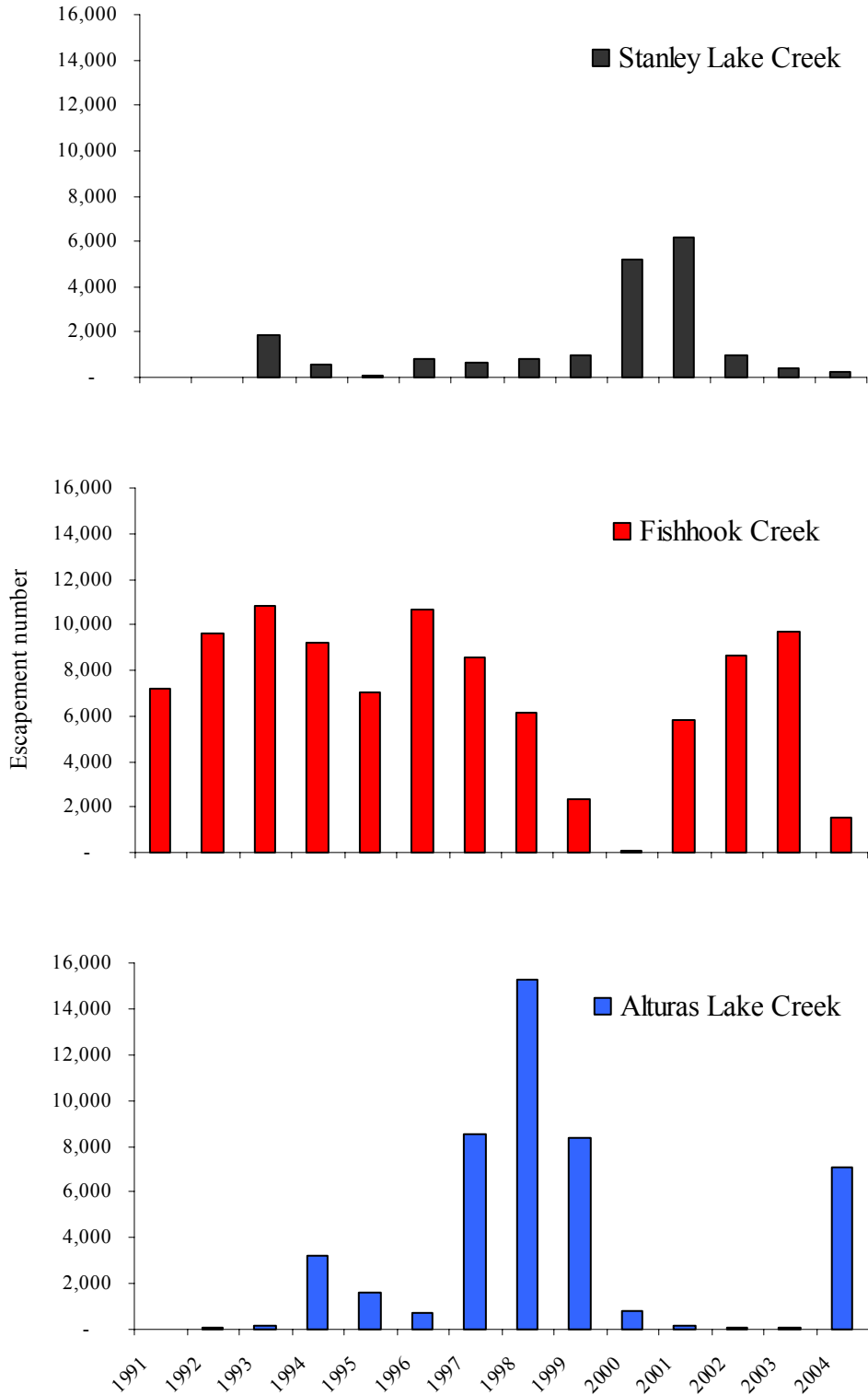


Figure 26. Stanley Lake Creek, Fishhook Creek, and Alturas Lake Creek kokanee salmon escapement numbers 1991-2004.

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

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

Beach Spawning

We snorkeled in Redfish Lake to enumerate beach spawning residual sockeye salmon and captive reared adult sockeye salmon. Two areas were snorkeled, Sockeye Beach and the southeast inlet area. A dramatic increase in the number of residual sockeye salmon spawners observed in Redfish Lake occurred in 2004. The highest peak counts were 345 and 21 at Sockeye Beach and the southeast inlet area, respectively. These were the highest peak counts since 1994 at the southeast inlet and the highest numbers observed to date at Sockeye Beach (Figure 27a). In addition to snorkeling efforts in Redfish Lake, boat surveys for residual sockeye salmon spawners identified 49 redds in Pettit Lake and facilitated the recovery of a residual sockeye salmon spawner carcass, representing the first evidence of residual sockeye salmon spawning in Pettit Lake since the inception of the recovery program.

Redside shiners represented the largest composition of all the fish species observed during snorkeling at the SE Inlet, while residual sockeye salmon dominated the community observed in the Sockeye salmon Beach area (Figure 27b).

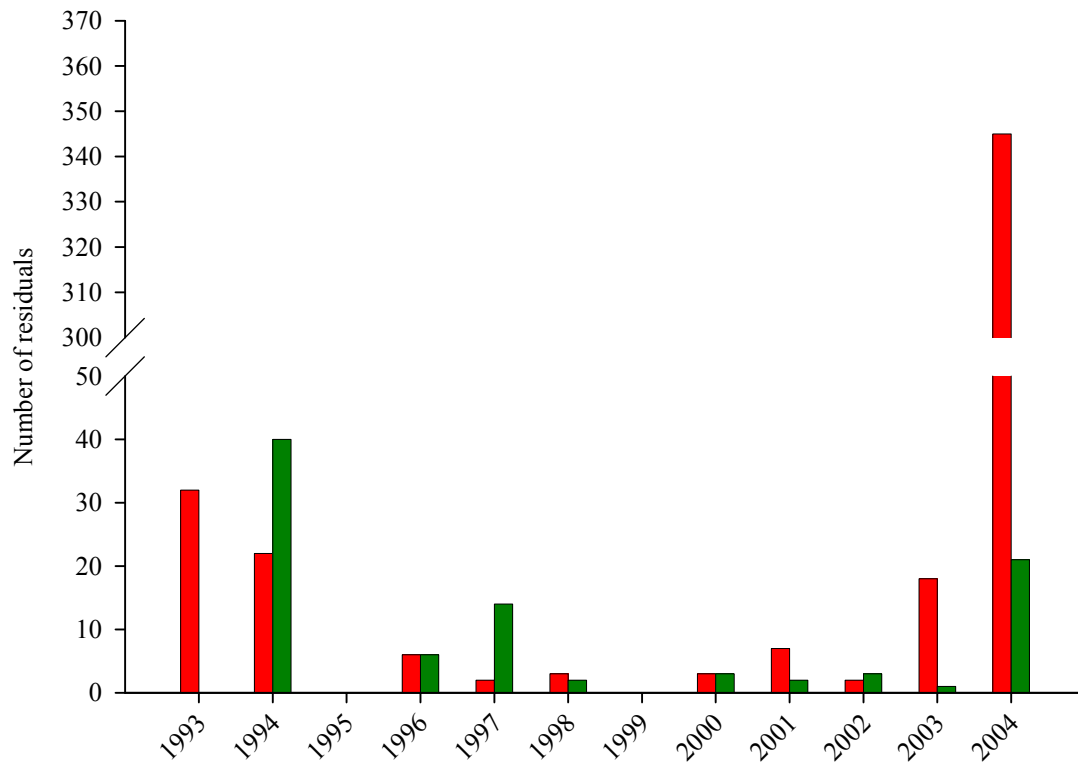


Figure 27a. Redfish Lake residual sockeye salmon counts from snorkel surveys (1995 data not available).

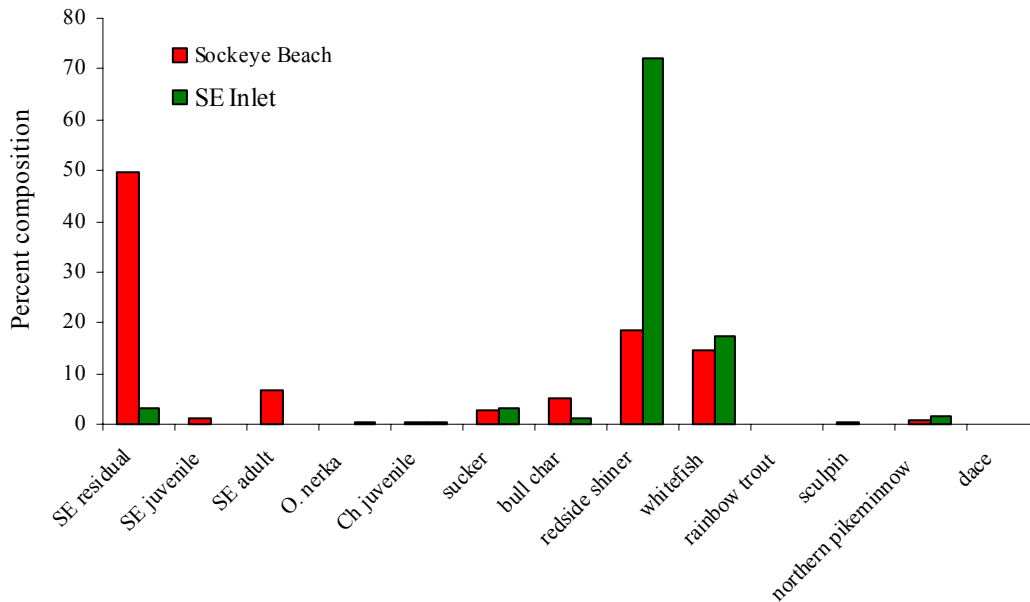


Figure 27b. Redfish Lake residual sockeye salmon snorkel survey species composition data at SE Inlet and Sockeye Beach, 2004.

Hydroacoustic Population Estimates

No hydroacoustic population estimates of *O. nerka* in the Sawtooth Valley lakes are available for 2004 due to equipment failure and theft.

Gillnet Sampling

We conducted vertical and horizontal gillnet sampling in Pettit and Alturas lakes during 2004. Fish species captured during 2004 sampling events included: sockeye salmon/kokanee salmon; steelhead/rainbow trout; bull char; mountain whitefish; northern pikeminnow; redbside shiner; and brook char. Results including location sampled, set type, sample size, catch per unit effort, species sampled, mean fork length, mean weight, and total hours fished are summarized in Table 10.

Diet Analysis

We analyzed stomach contents for diet composition in Redfish, Pettit, and Alturas lake samples collected in 2004. Samples were drawn from gillnet and trawling efforts conducted by the SBT and IDFG, respectively. Summarized data including Pettit Lake fish community prey items as a percent of total stomach contents (Table 11), sockeye salmon and *O. nerka* vertical gillnet and trawl diet composition, fork length, weight, and condition factor (Table 12), and sockeye salmon and *O. nerka* electivity indices (Table 13) are presented.

Pettit and Alturas Lake Egg Boxes

During November of 2004, in conjunction with IDFG personnel, we placed a total of 49,134 eyed sockeye salmon eggs in shoal areas of Pettit Lake.

Sockeye salmon PIT Tagging

During October we assisted IDFG personnel in PIT tagging 3,042 sockeye salmon parr for release into Redfish, Pettit, and Alturas lake

Table 10. Results of Pettit and Alturas lake gillnet samples, 2004.

Date	Station	Set Type	(n) CPUE	Mean Lt (mm)	Mean Wt (g)	Hrs Fished
<u>Pettit Lake</u>						
Rainbow Trout						
January 27, 2004	A	Horizontal	(1) 0.05	260.0	191.2	19.0
February 18, 2004	A	Horizontal	(2) 0.09	261.5	170.2	21.8
March 10, 2004	A	Horizontal	(2) 0.09	249.5	123.0	21.5
July 19, 2004	A	Horizontal	(2) 0.11	231.5	123.0	18.0
Bull Char						
January 27, 2004	A	Horizontal	(1) 0.05	540.0	----	19.0
February 18, 2004	A	Horizontal	(2) 0.09	424.0	----	21.8
February 19, 2004	E	Vertical	(3) ¹ ----	502.7	900.0	----
March 10, 2004	A	Horizontal	(1) 0.05	487.0	1,800.0	21.5
Brook Char						
February 18, 2004	A	Horizontal	(2) 0.09	262.0	155.5	21.8
March 10, 2003	A	Horizontal	(1) 0.05	282.0	----	21.5
Whitefish						
February 18, 2004	A	Horizontal	(1) 0.05	228.0	147.5	21.8
Northern Pikeminnow						
February 18, 2004	A	Horizontal	(2) 0.09	241.5	165.5	21.8
March 10, 2004	A	Horizontal	(8) 0.37	251.1	----	21.5
July 19, 2004	A	Horizontal	(4) 0.22	245.5	208.8	18.0
<i>O. nerka</i>						
January 27, 2004	E	Vertical	(2) 0.11	160.0	48.8	19.0
February 18, 2004	E	Vertical	(1) 0.05	164.0	45.8	22.0
February 19, 2004	E	Vertical	(1) ----	198.0	----	----
March 09, 2004	E	Vertical	(1) 0.05	127.0	20.4	20.5
Kokanee salmon						
January 27, 2004	E	Vertical	(2) 0.11	237.0	147.4	19.0
January 27, 2004	A	Horizontal	(10) 0.53	242.2	187.3	19.0
Sockeye salmon						
January 27, 2004	E	Vertical	(38) 2.00	113.2	15.2	19.0
February 18, 2004	E	Vertical	(4) 0.18	115.7	14.6	22.0
March 09, 2004	E	Vertical	(9) 0.44	130.0	23.5	20.5
Sucker						
January 27, 2004	A	Horizontal	(1) 0.05	----	----	19.0
<u>Alturas Lake</u>						
Bull Char						
January 28, 2004	Boat R	Vertical	(1) 0.05	420.0	----	22.0

Table 11. Fish community horizontal gillnet sample and percent diet composition data from Pettit Lake, 2004.

Date	Species		Sample Size	Percent Diet Composition										
1/28/04	Rainbow Trout		1	<u>SAL</u>	<u>CYP</u>	<u>UN.F.</u>	<u>MOL</u>	<u>ODO</u>	<u>HEM</u>	<u>CH.P.</u>	<u>CH.L.</u>	<u>TER</u>	<u>PLA</u>	<u>OTH</u>
	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.96	93.04
2/18/04			2	<u>SAL</u>	<u>CYP</u>	<u>UN.F.</u>	<u>MOL</u>	<u>ODO</u>	<u>HEM</u>	<u>CH.P.</u>	<u>CH.L.</u>	<u>TER</u>	<u>PLA</u>	<u>OTH</u>
	0.00	0.00		0.00	99.48	0.00	0.00	0.00	0.15	0.00	0.37	0.00		
3/11/04			2	<u>SAL</u>	<u>CYP</u>	<u>UN.F.</u>	<u>MOL</u>	<u>ODO</u>	<u>HEM</u>	<u>CH.P.</u>	<u>CH.L.</u>	<u>TER</u>	<u>PLA</u>	<u>OTH</u>
	3.48	0.00		0.00	46.52	0.00	0.00	0.00	0.00	0.00	50.00	0.00		
7/19/04			2	<u>SAL</u>	<u>CYP</u>	<u>UN.F.</u>	<u>MOL</u>	<u>ODO</u>	<u>HEM</u>	<u>CH.P.</u>	<u>CH.L.</u>	<u>TER</u>	<u>PLA</u>	<u>OTH</u>
	0.00	37.25		0.00	31.65	4.36	0.00	25.67	0.06	0.96	0.00	0.05		
2/18/04	Brook Char		2	<u>SAL</u>	<u>CYP</u>	<u>UN.F.</u>	<u>MOL</u>	<u>ODO</u>	<u>HEM</u>	<u>CH.P.</u>	<u>CH.L.</u>	<u>TER</u>	<u>PLA</u>	<u>OTH</u>
	0.00	11.88		0.00	88.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3/11/04			1	<u>SAL</u>	<u>CYP</u>	<u>UN.F.</u>	<u>MOL</u>	<u>ODO</u>	<u>HEM</u>	<u>CH.P.</u>	<u>CH.L.</u>	<u>TER</u>	<u>PLA</u>	<u>OTH</u>
	0.00	99.94		0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2/19/04	Bull Char		2	<u>SAL</u>	<u>CYP</u>	<u>UN.F.</u>	<u>MOL</u>	<u>ODO</u>	<u>HEM</u>	<u>CH.P.</u>	<u>CH.L.</u>	<u>TER</u>	<u>PLA</u>	<u>OTH</u>
	99.77	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.23
3/11/04	N. Pikeminnow		8	<u>SAL</u>	<u>CYP</u>	<u>UN.F.</u>	<u>MOL</u>	<u>ODO</u>	<u>HEM</u>	<u>CH.P.</u>	<u>CH.L.</u>	<u>TER</u>	<u>PLA</u>	<u>OTH</u>
	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
7/19/04			4	<u>SAL</u>	<u>CYP</u>	<u>UN.F.</u>	<u>MOL</u>	<u>ODO</u>	<u>HEM</u>	<u>CH.P.</u>	<u>CH.L.</u>	<u>TER</u>	<u>PLA</u>	<u>OTH</u>
	0.00	0.00		36.41	0.00	34.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	29.10
2/18/04	M. Whitefish		1	<u>SAL</u>	<u>CYP</u>	<u>UN.F.</u>	<u>MOL</u>	<u>ODO</u>	<u>HEM</u>	<u>CH.P.</u>	<u>CH.L.</u>	<u>TER</u>	<u>PLA</u>	<u>OTH</u>
	0.00	0.00		0.00	14.29	0.00	0.00	0.00	85.71	0.00	0.00	0.00	0.00	0.00

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

Table 12. Sockeye salmon and *O. nerka* vertical gillnet and trawl mean length, weight, condition factor, and zooplankton diet percent composition in Redfish, Pettit, and Alturas lakes, 2004.

Date	Lake	Set Type	Species	Mark	Sample Size	Age	Mean L (mm)	Mean W (g)	Condition Factor (K)	Daph	Hol	Bos	Cal	Cyc	Naup	Poly
9/15/2004	Redfish	Trawl	<i>O. nerka</i>		16	YOY	64.24	2.44	0.88	59.05	0.00	0.29	0.00	39.51	0.00	1.16
9/15/2004	Redfish	Trawl	<i>O. nerka</i>		2	1+	110.00	13.45	1.01	69.61	0.00	19.64	0.00	3.68	0.00	7.07
9/15/2004	Pettit	Trawl	<i>O. nerka</i>		5	YOY	63.80	2.94	1.01	37.91	0.00	0.00	0.00	60.11	0.00	1.98
9/15/2004	Pettit	Trawl	<i>O. nerka</i>		10	1+	156.70	64.08	1.26	91.38	0.00	0.00	0.00	3.95	0.00	4.67
3/09/2004	Pettit	Vertical	Sockeye salmon	AD	9	YOY	123.44	17.61	0.93	0.01	0.00	0.44	0.00	99.53	0.00	0.02
6/16/2004	Pettit	Vertical	<i>O. nerka</i>		2	1+	170.50	----	----	93.27	0.00	1.41	0.00	0.21	0.00	5.11
1/28/2004	Pettit	Vertical	Sockeye salmon	AD	24	YOY	117.29	17.76	1.03	0.57	0.00	0.52	0.00	98.91	0.00	0.00
9/13/2004	Alturas	Trawl	<i>O. nerka</i>		6	YOY	64.17	2.85	0.91	43.06	0.00	0.00	0.00	5.26	0.00	51.68
9/13/2004	Alturas	Trawl	<i>O. nerka</i>		3	1+	196.33	63.37	0.83	66.09	0.00	0.40	0.00	2.37	0.00	31.14

Daph=Daphnia, Hol=Holopedium, Bos=Bosmina, Cal=Calanoid, Cyc=Cyclopid, Naup=Nauplii, Poly=Polyphemus

Table 13. Sockeye salmon and *O. nerka* gillnet and diet composition data including electivity indices (E), 2004 (* denotes only YOY sample).

Date	Lake	Set Type	Species	Mark	N	R _i , P _i	E	Daph	Holo	Bosm	Cala	Cycl	Naup	Poly
9/15/2004	Redfish	Trawl	<i>O. nerka</i> *		17	R _i		59.05	0.00	0.29	0.00	39.51	0.00	1.16
						P _i		17.47	18.90	45.27	0.00	8.14	9.38	0.83
						E		0.54	-1.00	-0.99	----	0.66	-1.00	0.16
9/15/2004	Redfish	Trawl	<i>O. nerka</i>		2	R _i		69.61	0.00	19.64	0.00	3.68	0.00	7.07
						P _i		17.47	18.90	45.27	0.00	8.14	9.38	0.83
						E		0.60	-1.00	-0.39	----	-0.38	-1.00	0.79
9/13/2004	Alturas	Trawl	<i>O. nerka</i> *		6	R _i		43.06	0.00	0.00	0.00	5.26	0.00	51.68
						P _i		2.34	32.18	2.49	0.00	21.01	38.32	3.67
						E		0.90	-1.00	-1.00	----	-0.60	-1.00	0.87
9/13/2004	Alturas	Trawl	<i>O. nerka</i>		3	R _i		66.09	0.00	0.40	0.00	2.37	0.00	31.14
						P _i		2.34	32.18	2.49	0.00	21.01	38.32	3.67
						E		0.93	-1.00	-0.72	----	-0.80	-1.00	0.79
9/15/2004	Pettit	Trawl	<i>O. nerka</i> *		5	R _i		37.91	0.00	0.00	0.00	60.11	0.00	1.98
						P _i		27.15	0.00	16.27	0.00	28.70	27.86	0.03
						E		0.17	----	-1.00	----	0.35	-1.00	0.97
9/15/2004	Pettit	Trawl	<i>O. nerka</i>		10	R _i		91.38	0.00	0.00	0.00	3.95	0.00	4.67
						P _i		27.15	0.00	16.27	0.00	28.70	27.86	0.03
						E		0.54	----	-1.00	----	-0.76	-1.00	0.99
3/09/2004	Pettit	Vertical	Sockeye salmon*	AD	9	R _i		0.01	0.00	0.44	0.00	99.53	0.00	0.02
						P _i		0.00	0.00	2.17	0.00	25.70	72.13	0.00
						E		1.00	----	-0.66	----	0.59	-1.00	1.00
6/16/2004	Pettit	Vertical	<i>O. nerka</i>		2	R _i		93.27	0.00	1.41	0.00	0.21	0.00	5.11
						P _i		6.16	0.63	50.45	0.03	37.15	4.96	0.62
						E		0.88	-1.00	-0.95	-1.00	-0.99	-1.00	0.78
1/28/2004	Pettit	Vertical	Sockeye salmon*	AD	24	R _i		0.88	0.00	0.54	0.00	98.46	0.00	0.12
						P _i		0.12	0.00	1.61	0.00	37.13	61.14	0.00
						E		0.76	----	-0.50	----	0.45	-1.00	1.00

N=sample size, R_i=percent composition of stomach contents, P_i=percent composition of prey items in the environment, E=electivity index
Daph=Daphnia, Holo=Holopedium, Bosm=Bosmina, Cala=Calanoid, Cycl=Cyclopid, Naup=Nauplii, Poly=Polypheumus

DISCUSSION

Limnology and Fertilization

During 2004, the Sawtooth Valley experienced its fifth year of drought, resulting in reduced inflows to the Sawtooth Valley lakes. In Redfish and Alturas lakes, Secchi and compensation depths were slightly deeper than average, epilimnetic chlorophyll was near normal, and Redfish Lake had low nutrient concentrations during stratification. During fertilization, Pettit Lake deviated from the other lakes with reductions in Secchi and compensation depths, elevated epilimnetic nitrogen, phosphorus, and nitrate-nitrite, and chlorophyll concentrations during the later part of the summer. In the metalimnions, chlorophyll concentrations were higher in Pettit Lake compared to Redfish Lake, while the opposite was true at the compensation depth, an indication that nutrient supplementation interrupted development of a deep chlorophyll maxima (DCM).

Heterotrophic bacteria populations were relatively low and stable in the Sawtooth Valley lakes during 2004. Autotrophic picoplankton were low in Pettit Lake compared to the unfertilized lakes, particularly in the epilimnion during late summer. Zooplankton biomass was relatively high in all four lakes compared to previous years but variable when compared between lakes. Pettit Lake had the highest zooplankton biomass observed to date. In Redfish Lake, zooplankton biomass was down from 2003 and similar to the years 2000-2002. Alturas Lake had higher zooplankton biomass than previously observed, but *Daphnia* biomass was lower than the two preceding years. Alturas Lake would be a good candidate for nutrient supplementation in 2005 given the relatively low *O. nerka* abundance and evidence of a recovering zooplankton population.

In Pettit Lake, fertilization appears to have stimulated Chryso-Cryptophcean flagellates during early August, then *Oocystis* sp. bloomed, completely dominating the system until October. *Oocystis* sp. are spherical green algae, common in the Sawtooth Valley lakes, and were reported to be the dominant green algae in nearby Yellowbelly Lake (Pilati and Wurtsbaugh 2003). Wurtsbaugh et al. (2001) reported that fertilization of the epilimnion in Pettit Lake stimulated *Oocystis* sp., while metalimnetic applications favored *Chlorella* sp.. In Pettit Lake, *Oocystis* sp. contained 2-8 cells within the parental wall and ranged in

size from approximately 20-50 μm . At this size they are considered grazable by large bodied cladocerans (Figure 28) (J.G. Stockner, Eco-Logic inc., personal communication); however, they are considered resistant to digestion because of the thick cell wall.



Figure 28. *Oocystis* sp. cells within thick parental wall.

Tessier et al. (2001) found that *Oocystis* spp. abundance increased in response to grazing by small *Daphnia* (*Ceriodaphnia* and *D. ambigua*), but declined when grazed by the large Daphniids (*D. mendotae* and *D. pulicaria*) in treated lake enclosures. They hypothesized that this group, the Chlorococcales, are resistant to digestion because of thick cell walls or gelatinous sheaths, particularly when consumed by the smaller species of *Daphnia*. Schindler (1971) reported low assimilation rates of *Oocystis* sp. when grazed by *D. longispina*. Vanni and Lampert (1992) constructed life tables for *D. galeata* fed various concentrations of *Scenedesmus* sp. and *Oocystis* sp. and found that *Oocystis* sp. was a lower quality food source at low food concentrations. At high concentrations, adult *Daphnia* consumed and assimilated the two species at similar rates while juvenile *Daphnia* assimilated *Oocystis* sp. at lower rates than *Scenedesmus* sp..

During 2004 in Pettit Lake, *Daphnia rosea* peaked during the Chryso-Cryptophcean bloom in early August and declined during the *Oocystis* sp. bloom, an indication that *Oocystis* sp. were not well utilized by *Daphnia* (Figure 29). Future nutrient supplementation efforts should attempt to minimize this bloom. Several adjustments are worth considering, including: application of lighter nutrient loads during late summer when *Oocystis* sp. typically blooms in Sawtooth Valley lakes; rigorous monitoring and

special handling of epilimnetic phytoplankton samples to garner results rapidly; and an adjustment of N:P ratios.

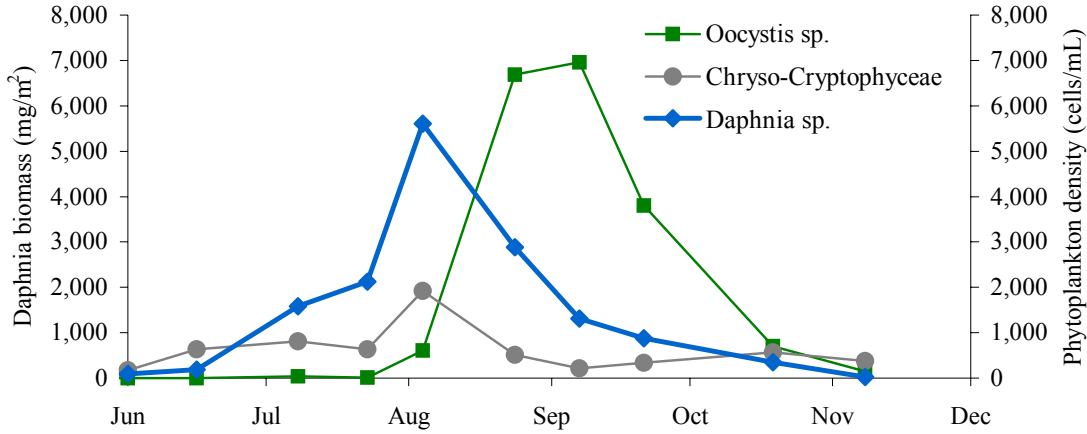


Figure 29. Whole lake *Daphnia* sp. biomass (mg/m^2) and epilimnetic *Oocystis* sp. and Chryso-Cryptophyceae densities (cells/mL) June through November 2004 in Pettit Lake, Idaho.

Growth Rates and Survival

Growth rates of stocked sockeye salmon parr from the captive rearing program provide insight into performance differences associated with lake rearing conditions. We evaluated fall release groups consisting of fish reared at the Sawtooth Fish Hatchery and released into Redfish ($n=59,810$), Pettit ($n=14,961$), and Alturas ($n=2,017$) lakes. These fish typically overwinter in the lake environment and migrate as smolts the following spring. Growth rates were variable: highest in Pettit Lake; much lower in Alturas Lake; and negligible in Redfish Lake migrants. Corresponding percent migration estimates were 25.6, 34.9, and 54.1 in Redfish, Pettit, and Alturas lakes, respectively. Smolt migration estimates assume that stocked sockeye salmon presmolts (fall release) migrate the following spring as 1 year olds. Data suggests that a variable portion of sockeye salmon stocked into Sawtooth Valley lakes migrate as 2 year olds; therefore, we view migration estimates as a conservative measure of overwinter survival.

Consistent with previous trends, Pettit Lake fish exhibited better growth when compared to the same release groups in Redfish and Alturas lakes. Sockeye salmon presmolts

released into Pettit Lake during the fall of 2003 experienced relatively high total zooplankton and *Daphnia* biomass for several months, followed by moderate zooplankton biomass dominated by cyclopoids (Figure 30a). This group had the highest growth rates of any of the release groups in both length and weight. Approximately 35% of the presmolts released during October 2003 outmigrated during spring 2004.

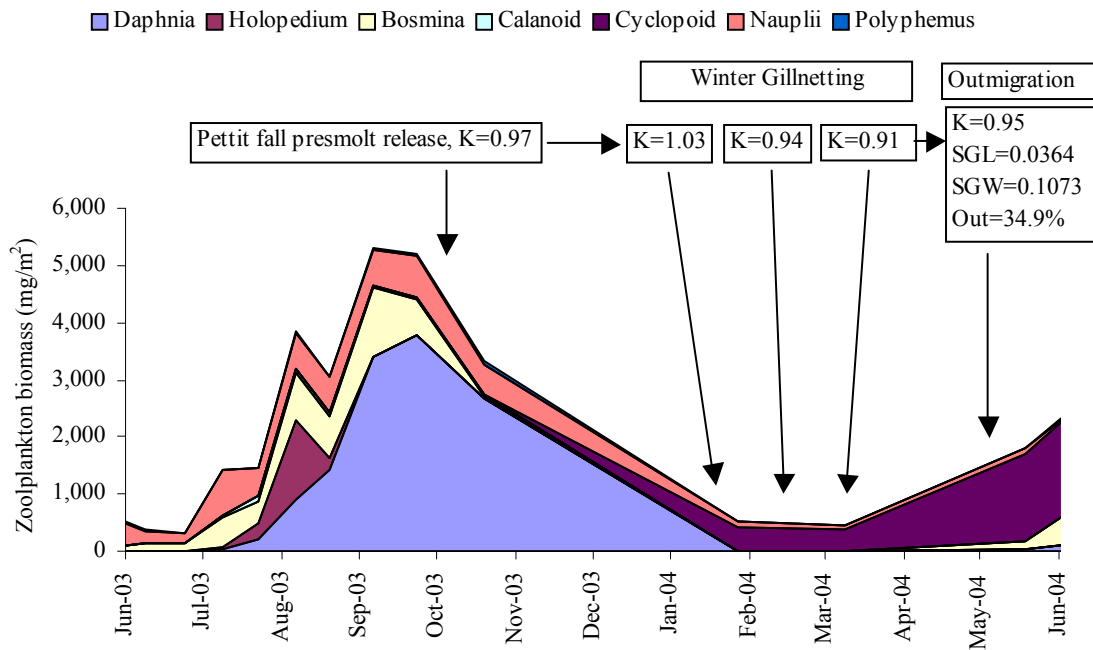


Figure 30a. Pettit Lake zooplankton biomass (mg/m^2) June 1, 2003 to June 1, 2004 with overwinter sockeye salmon presmolt specific growth rates in length (SGL), weight (SGW), condition factor (K) and percent outmigration (Out).

Sockeye salmon presmolts released in Redfish Lake experienced moderate zooplankton biomass during late summer 2003 (Figure 30b). Winter zooplankton biomass in Redfish Lake was intermediate to Pettit and Alturas lakes; yet overwintering presmolts had the lowest growth rates. Presmolts had very slight gains in length and lost weight during the winter. Approximately 26% of the stocked fish left Redfish Lake during spring 2004.

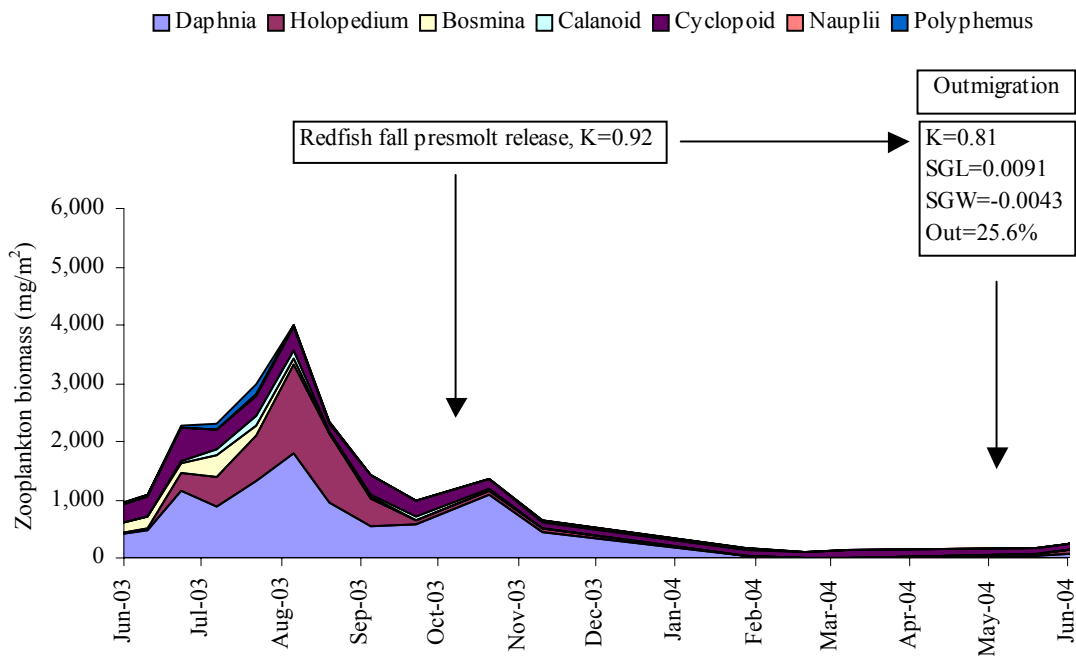


Figure 30b. Redfish Lake zooplankton biomass (mg/m^2) June 1, 2003 to June 1, 2004 with overwinter sockeye salmon presmolt specific growth rates in length (SGL), weight (SGW), condition factor (K) and percent outmigration (Out).

In Alturas Lake, fall release presmolts experienced low zooplankton biomass; growth rates were intermediate to Redfish and Pettit lakes (Figure 30c). It is interesting to note that Alturas Lake presmolts grew faster than those rearing in Redfish Lake, despite experiencing lower total zooplankton biomass. Approximately 54% of these fish migrated during the spring of 2003, a higher rate than was observed in either Redfish or Pettit lakes.

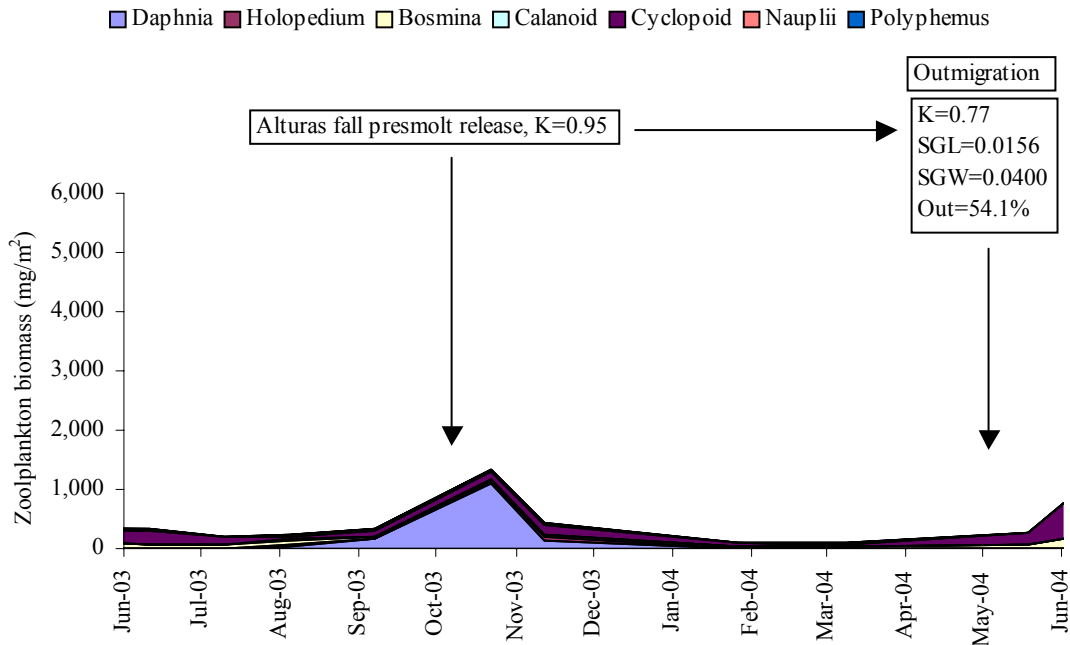


Figure 30c. Alturas Lake zooplankton biomass (mg/m²) June 1, 2003 to June 1, 2004 with overwinter sockeye salmon presmolt specific growth rates in length (SGL), weight (SGW), condition factor (K) and percent outmigration (Out).

Differences in sockeye salmon performance (growth, condition factor, percent migration), kokanee salmon population abundance, and zooplankton abundance, biomass, and species composition are considered each year to determine appropriate numbers of sockeye salmon presmolts to stock into each lake. Hydroacoustic data collected during fall 2003 indicated between 122-212 fish/ha in the three lakes. Biomass was 4.1 kg/ha in Redfish, 6.2 kg/ha in Pettit, and 6.4 kg/ha in Alturas Lake. In addition, sockeye salmon 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 low in Alturas Lake (Figures 13, 15, and 17). In 2003, 76,788 sockeye salmon presmolts 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 salmon presmolts were stocked into Alturas Lake to evaluate growth, condition factor, and percent migration. Continued monitoring and evaluation of migration patterns will continue in 2005.

Diet Analysis

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

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

We found stocked juvenile sockeye salmon from the captive rearing program in the stomachs of stocked rainbow trout (*O. mykiss*) in Pettit Lake during 1995, the first year we stocked sockeye salmon into that lake (Teuscher and Taki 1996). The sockeye

salmon were released at the boat ramp in the littoral zone. After detection of *O. nerka* in *O. mykiss* stomachs, we modified the stocking strategy to a pelagic release using a barge. Since the pelagic release was implemented, annual (1996-03) *O. mykiss* diet analysis is used to monitor potential predation on stocked *O. nerka*. No subsequent predation of *O. nerka* by *O. mykiss* has been conclusively documented in Pettit Lake.

Northern pikeminnow are known to prey on juvenile salmon and are the subject of control efforts in the main stem of the Columbia River. Northern pikeminnow are one of the more abundant species found in the sockeye salmon rearing/nursery lakes of the Sawtooth Valley. Concern has been expressed about their potential predation on stocked juvenile sockeye salmon. Diet analysis has found that while piscivorous, unidentified fish composed 36% of prey items in July 2004 (Table 11), 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 Sawtooth Valley lakes fish community. Monitoring associated with this program has found that bull char diet is composed primarily of fish prey (Taki et al. 1999). Juvenile sockeye salmon and *O. nerka* were found in the stomach contents of bull char from Pettit Lake in February 2004. Bull char were listed as a threatened species in 1998 under the Endangered Species Act and, as the top predator, are an important component of fish community dynamics in the Sawtooth Valley lakes and upper Salmon River. Any predation by this species on *O. nerka* is considered a natural process and no control measures will be implemented. Continued incidental takes during gillnet sampling are anticipated and will allow for monitoring of bull char population dynamics.

Brook char have also been documented in gillnet samples from Pettit Lake. In 2004, no salmonids were found in the stomach contents of brook char.

Stream Spawning

Kokanee salmon escapement in 2004 showed variation in population densities, timing, and fecundity. The Fishhook Creek kokanee salmon spawning population had been declining since 1996, when escapement was estimated to be 10,662, to a low of 60 individual spawners in 2000. The 2001-2003 spawning populations in Fishhook Creek rebounded and were above management objectives aimed at controlling the number of female spawners. The 2004 kokanee salmon escapement was 1,508 spawners, a six-fold decrease from numbers observed in 2003 (9,679) and below the 1991-2003 mean of 7,364; therefore, although the Fishhook Creek weir was installed, no kokanee salmon control measures were necessary. Female kokanee salmon in Fishhook Creek exhibited higher fecundity compared to previous measurements. The mean number of eggs per female in 2004 was 429, significantly higher than the 1991-2003 mean of 270. It was noted that the mean size of adult spawners was larger than previous years, helping to explain an increase in fecundity. Control efforts will continue in the future to reduce intraspecific competition for forage resources in Redfish Lake. The Alturas Lake Creek kokanee salmon escapement estimate was up from 827 adults in 2000, 145 in 2001, 99 in 2002, 48 in 2003, to 7,101 spawners in 2004, well above the 1992-2003 mean of 3,249. Alturas Lake Creek kokanee salmon fecundity was estimated to be 269 eggs per female, higher than the 1994-2003 average of 191. As in Fishhook Creek, control efforts will likely be initiated in Alturas Lake Creek during the 2005 spawning season. The Stanley Lake Creek kokanee salmon spawning population decreased from 5,665 in 2000, 6,180 in 2001, 946 in 2002, 413 in 2003, to 228 in 2004, well below the 1993-2003 mean of 1,686. Stanley Lake Creek kokanee salmon fecundity was estimated to be 150 eggs per female in 2004, less than the 1994-2003 mean estimate of 266. No control efforts are planned for the Stanley Lake Creek kokanee salmon spawning population. Based on variation in Fishhook Creek, Stanley Lake Creek, and Alturas Lake Creek kokanee salmon fecundity, all three populations should be measured annually. Length, weight, and condition factor should also be measured in order to quantify changes that may be

associated with lake fertilization, meteorological forcing, and variable fish population dynamics.

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, 48 residual sockeye salmon spawners were observed on shoal spawning areas (peak count=21), and in 2004, 1,039 residual sockeye salmon spawners were observed on Sockeye Beach (peak count=345) and the southeast inlet, collectively. 2004 numbers represent a dramatic increase in the numbers of residual sockeye salmon spawners observed in Redfish Lake since monitoring began in 1993. In addition, 2004 was the first year residual sockeye salmon spawning was documented in Pettit Lake; 49 redds, 66 unidentified depressions, and 1 residual sockeye salmon spawner carcass were observed during boat surveys. Annual monitoring will continue to track residual sockeye salmon spawner populations at these locations.

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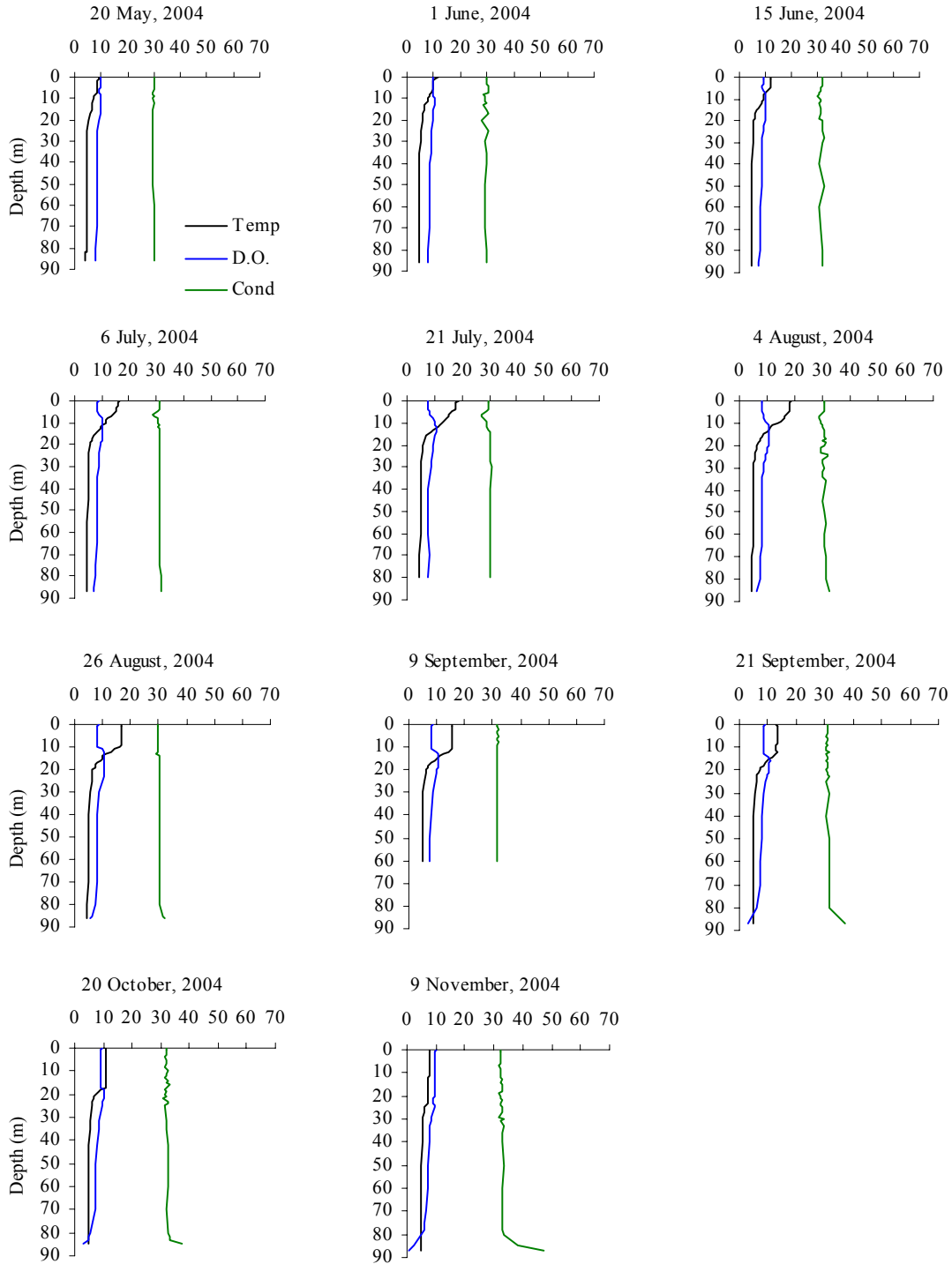
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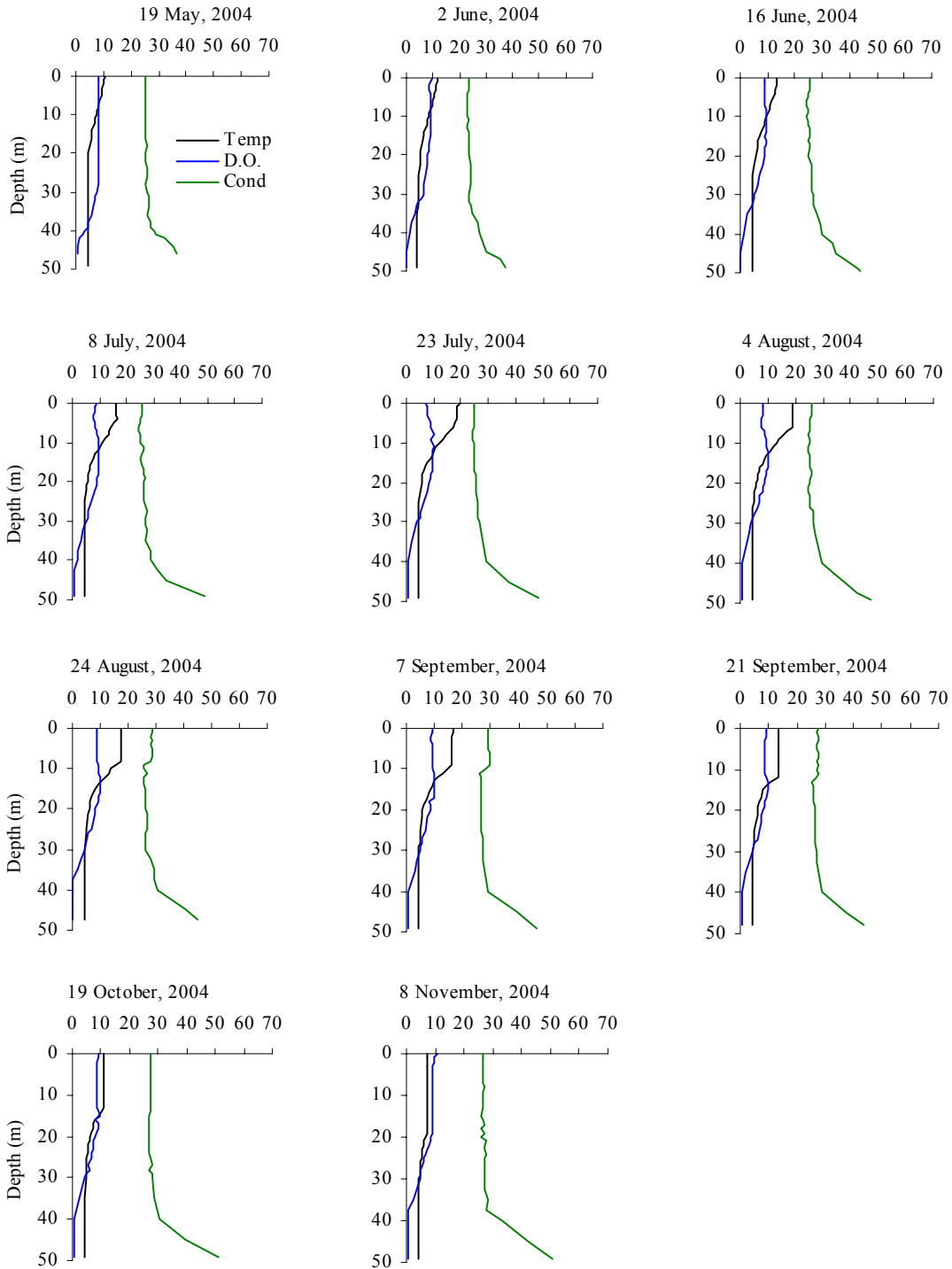
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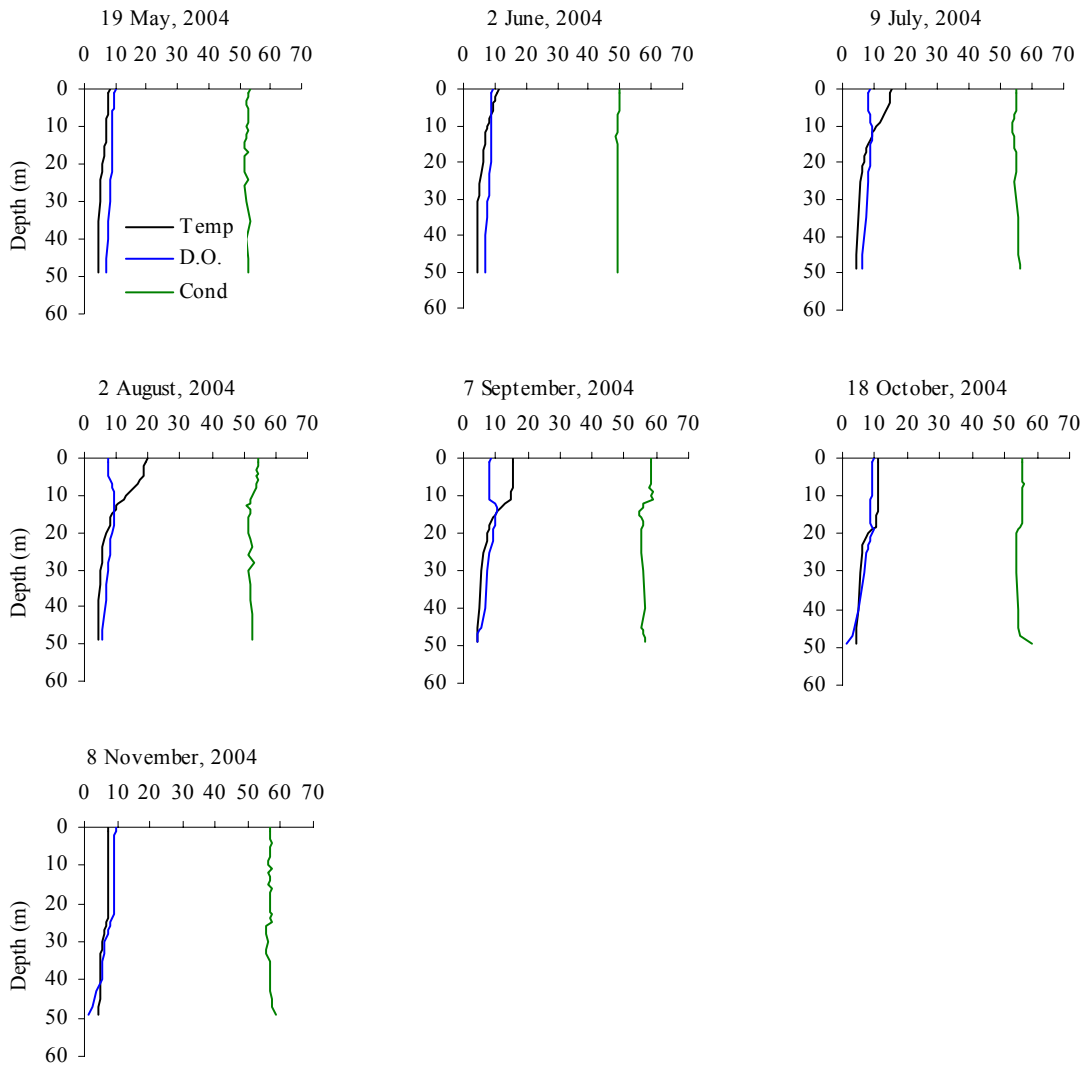
APPENDIX A. Profile data



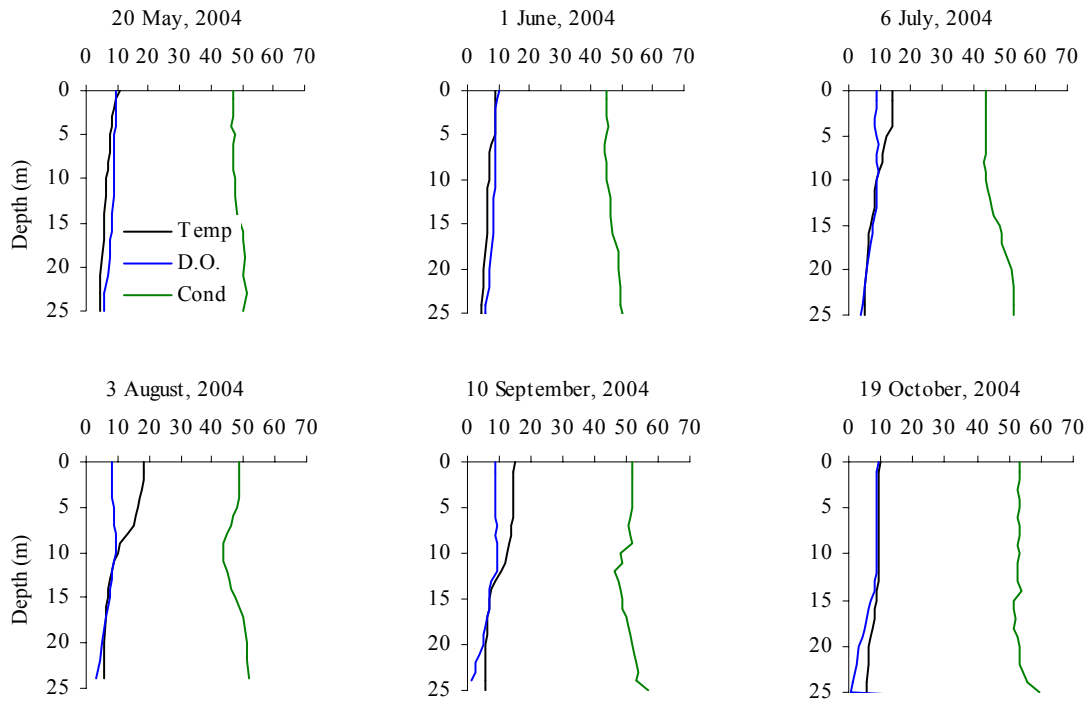
Appendix A1. Temperature ($^{\circ}\text{C}$), dissolved oxygen (mg/L), and conductivity ($\mu\text{S}/\text{cm}$) profiles for Redfish Lake, May through November 2004.



Appendix A2. Temperature ($^{\circ}\text{C}$), dissolved oxygen (mg/L), and conductivity ($\mu\text{S/cm}$) profiles for Pettit Lake, May through November 2004.

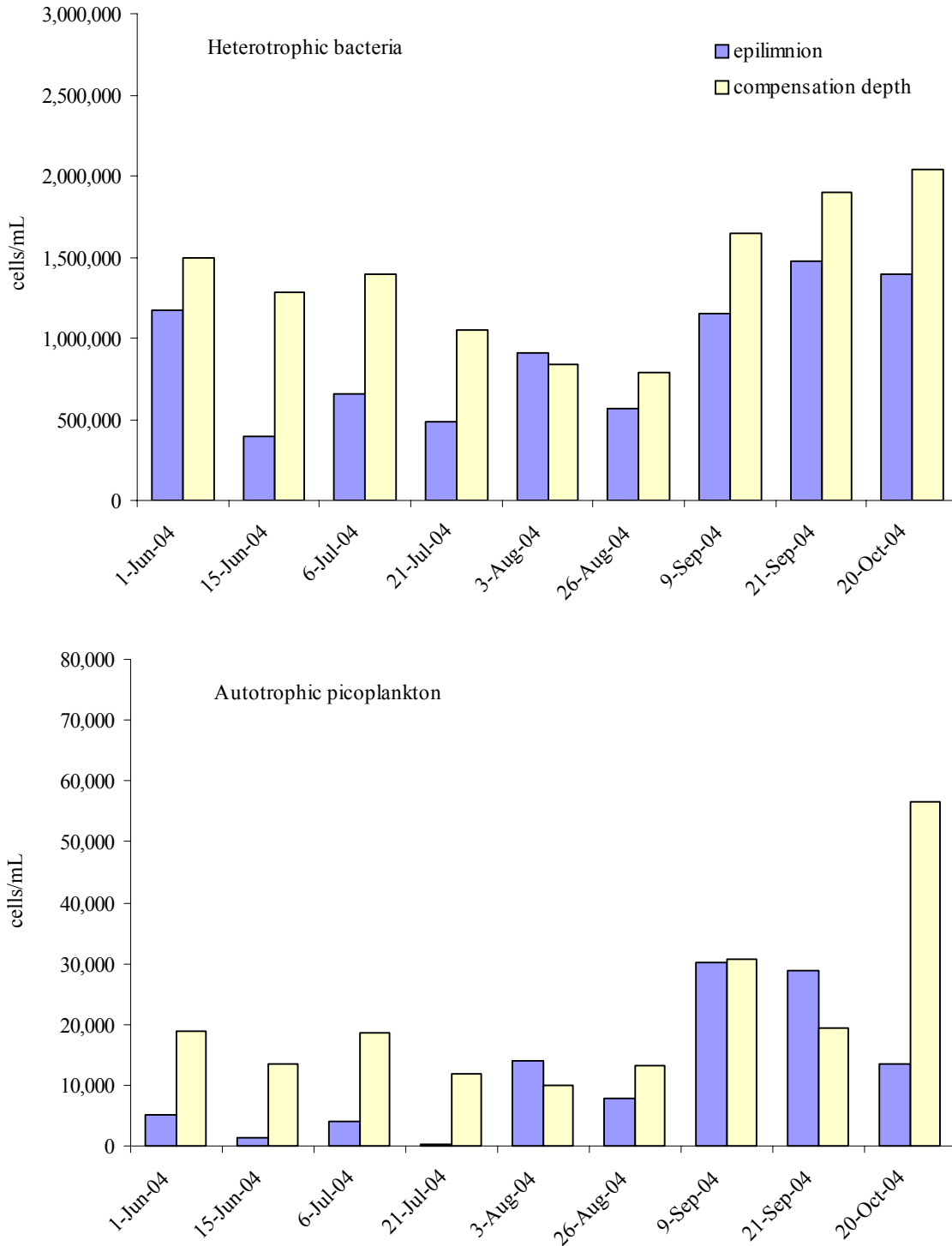


Appendix A3. Temperature ($^{\circ}\text{C}$), dissolved oxygen (mg/L), and conductivity ($\mu\text{S/cm}$) profiles for Alturas Lake, May through November 2004.

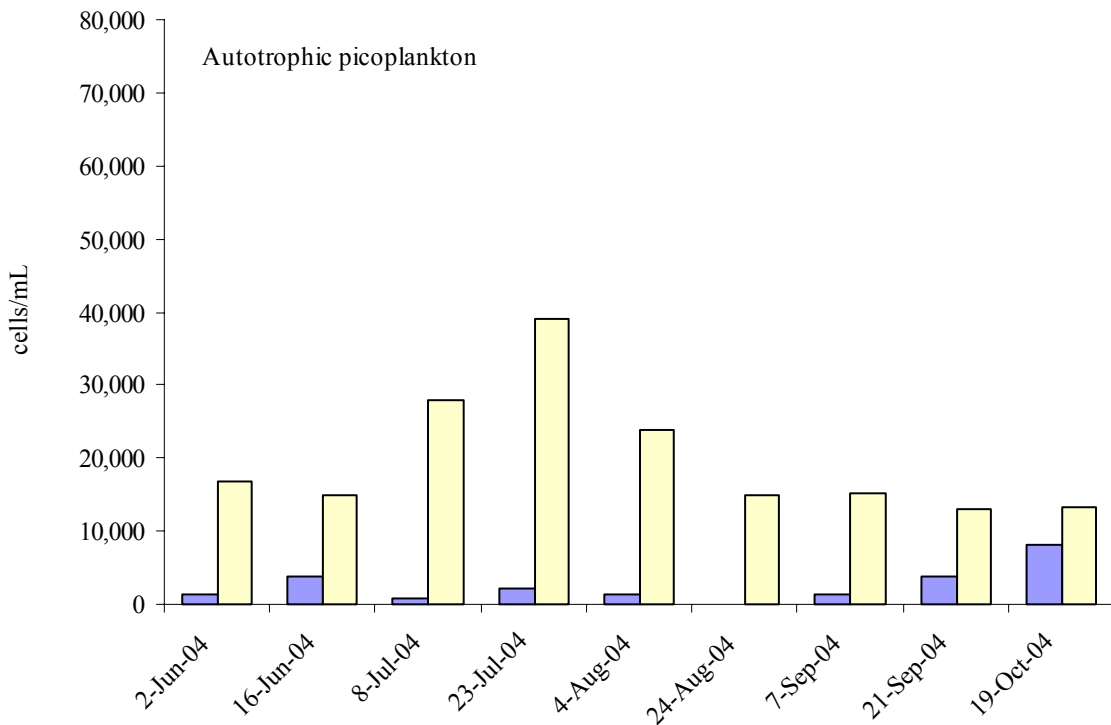
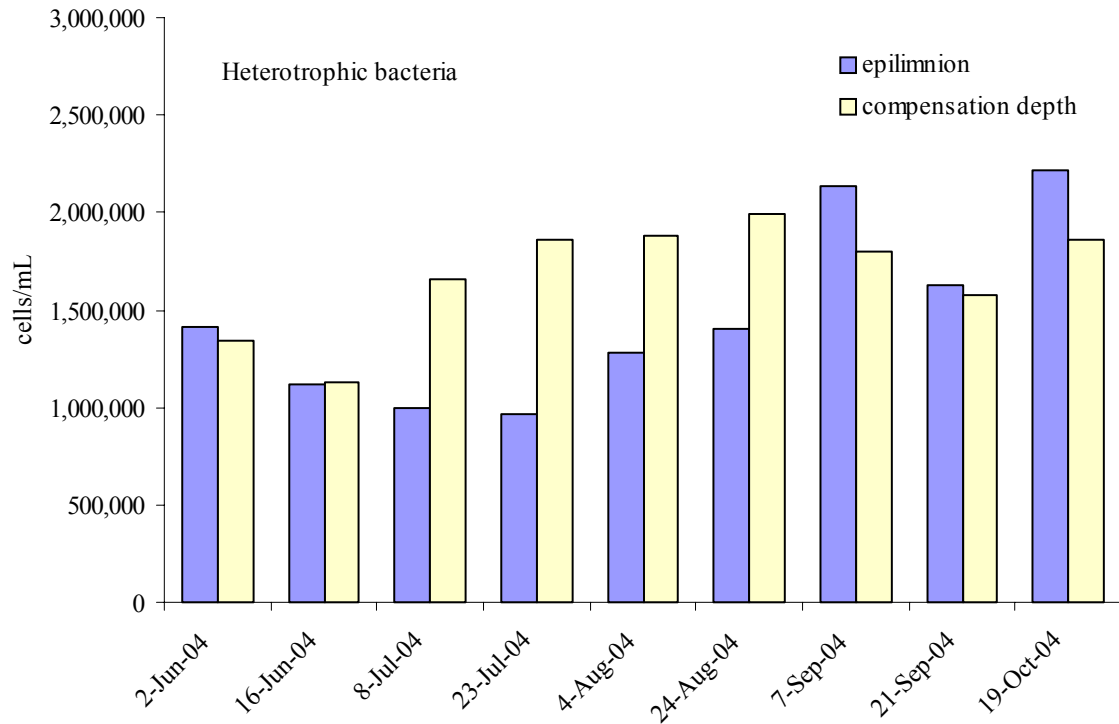


Appendix A4. Temperature ($^{\circ}\text{C}$), dissolved oxygen (mg/L), and conductivity ($\mu\text{S/cm}$) profiles for Stanley Lake, May through October 2004.

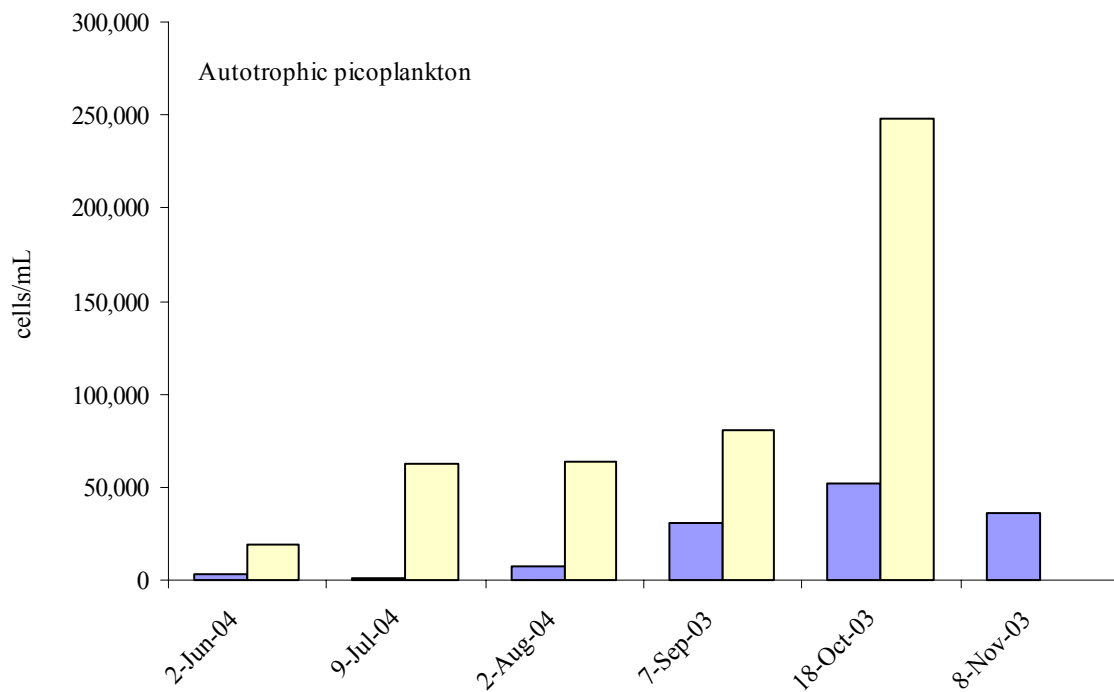
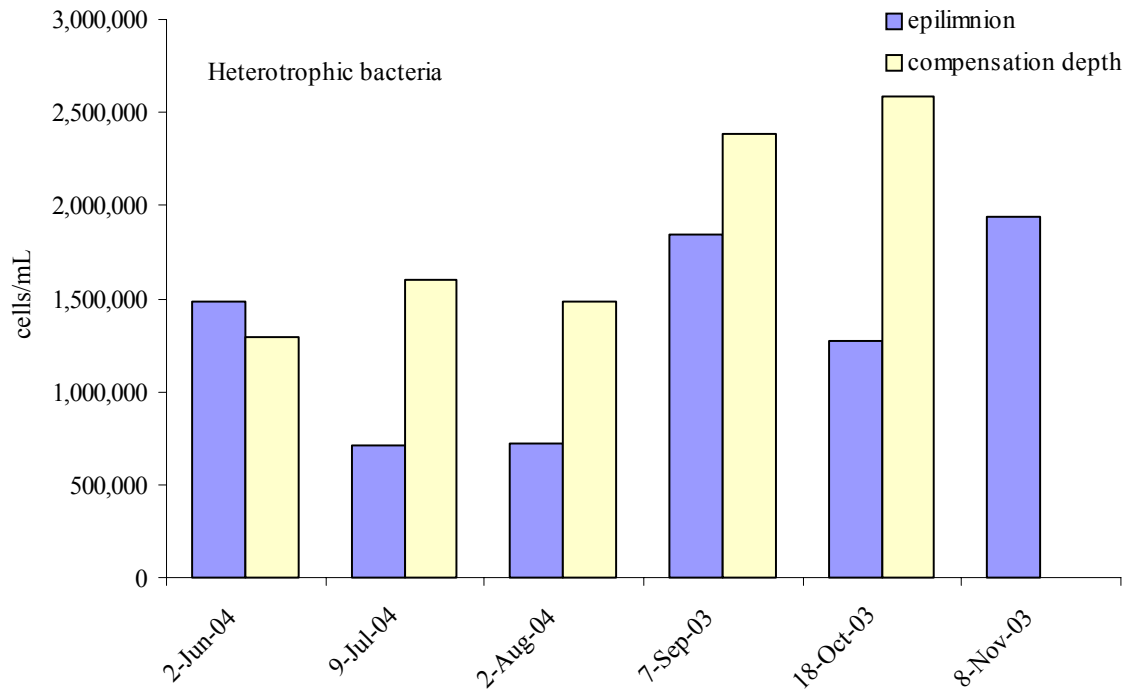
APPENDIX B. Heterotrophic bacteria and autotrophic picoplankton



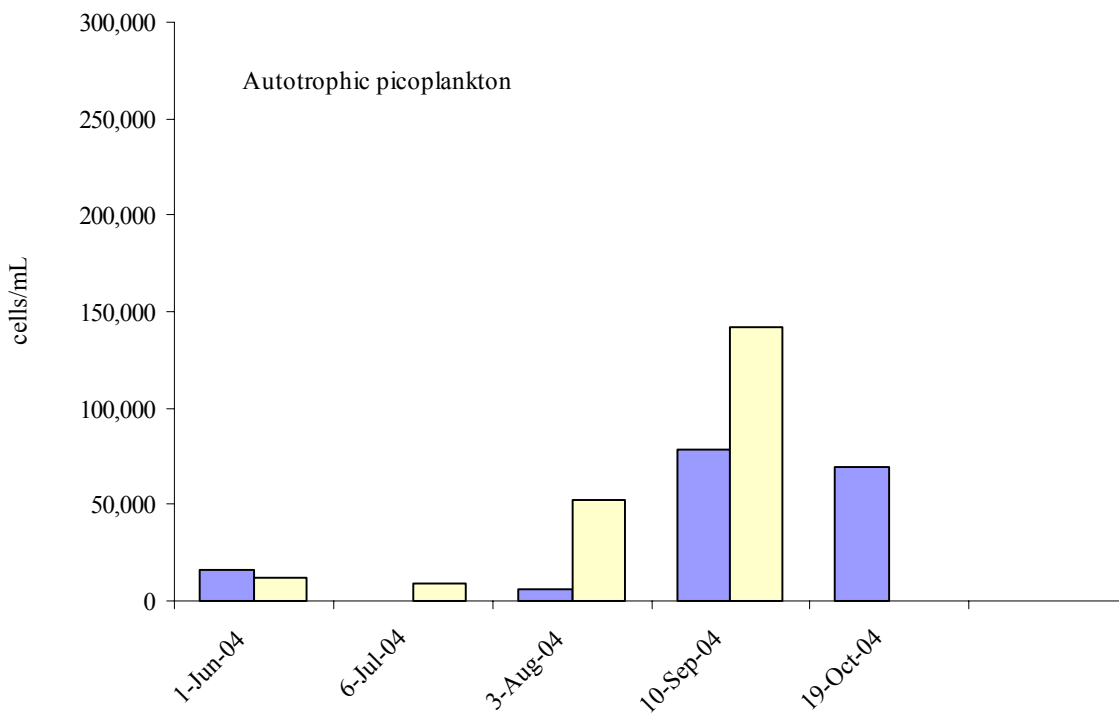
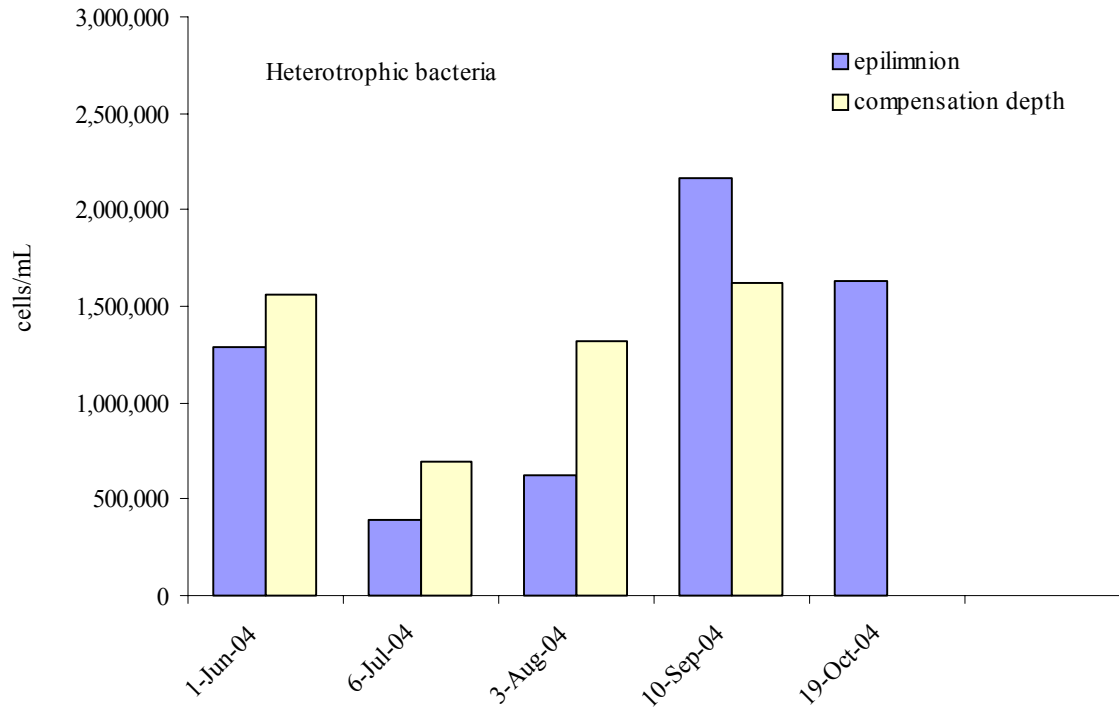
Appendix B1. Heterotrophic bacteria and autotrophic picoplankton (APP) densities (cells/mL) in the epilimnion and compensation depths in Redfish Lake, June through October 2004.



Appendix B2. Heterotrophic bacteria and autotrophic picoplankton (APP) densities (cells/mL) in the epilimnion and compensation depths in Pettit Lake, June through October 2004.

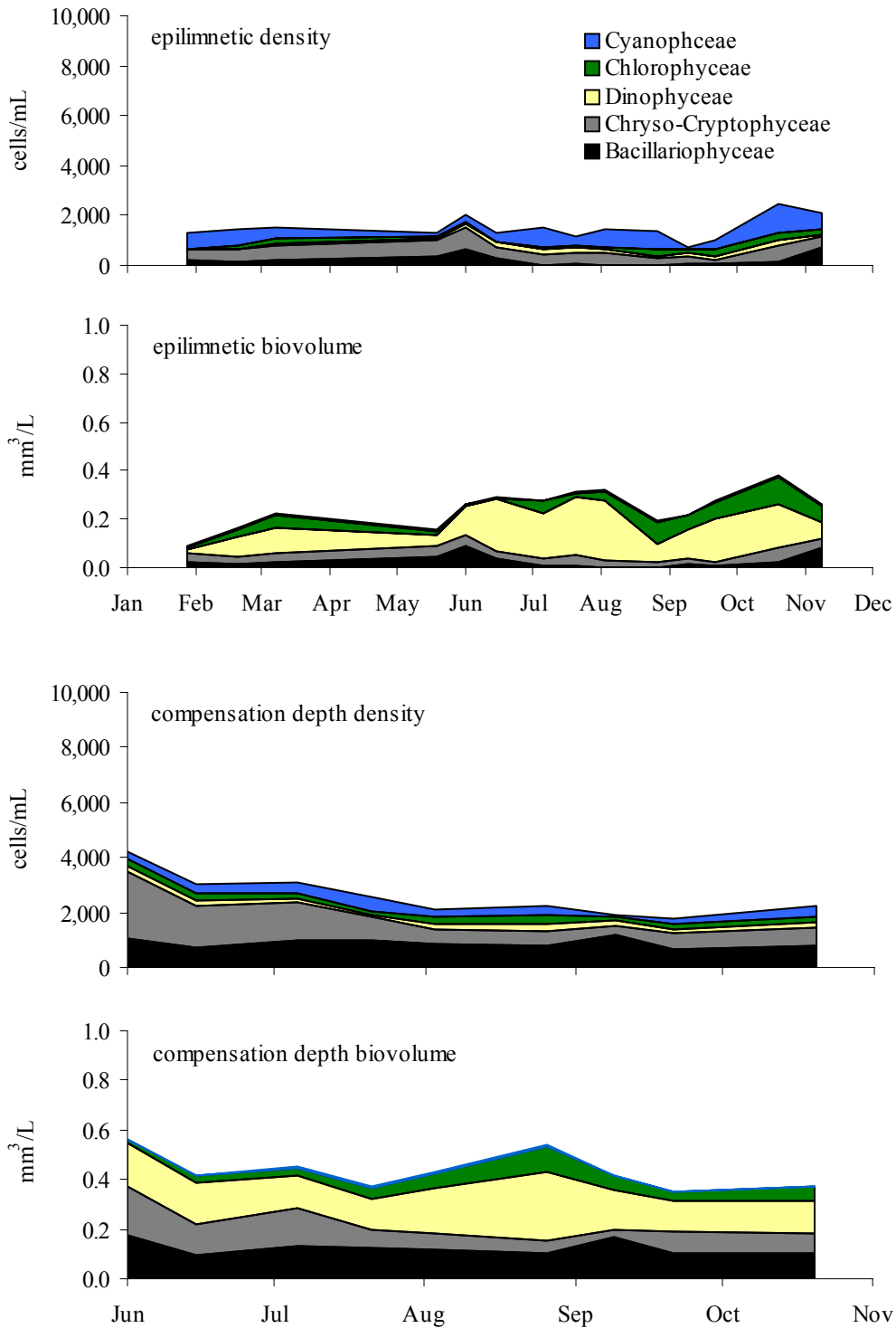


Appendix B3. Heterotrophic bacteria and autotrophic picoplankton (APP) densities (cells/mL) in the epilimnion and compensation depths in Alturas Lake, June through November 2004. Note different scale on y-axis of autotrophic picoplankton figure.

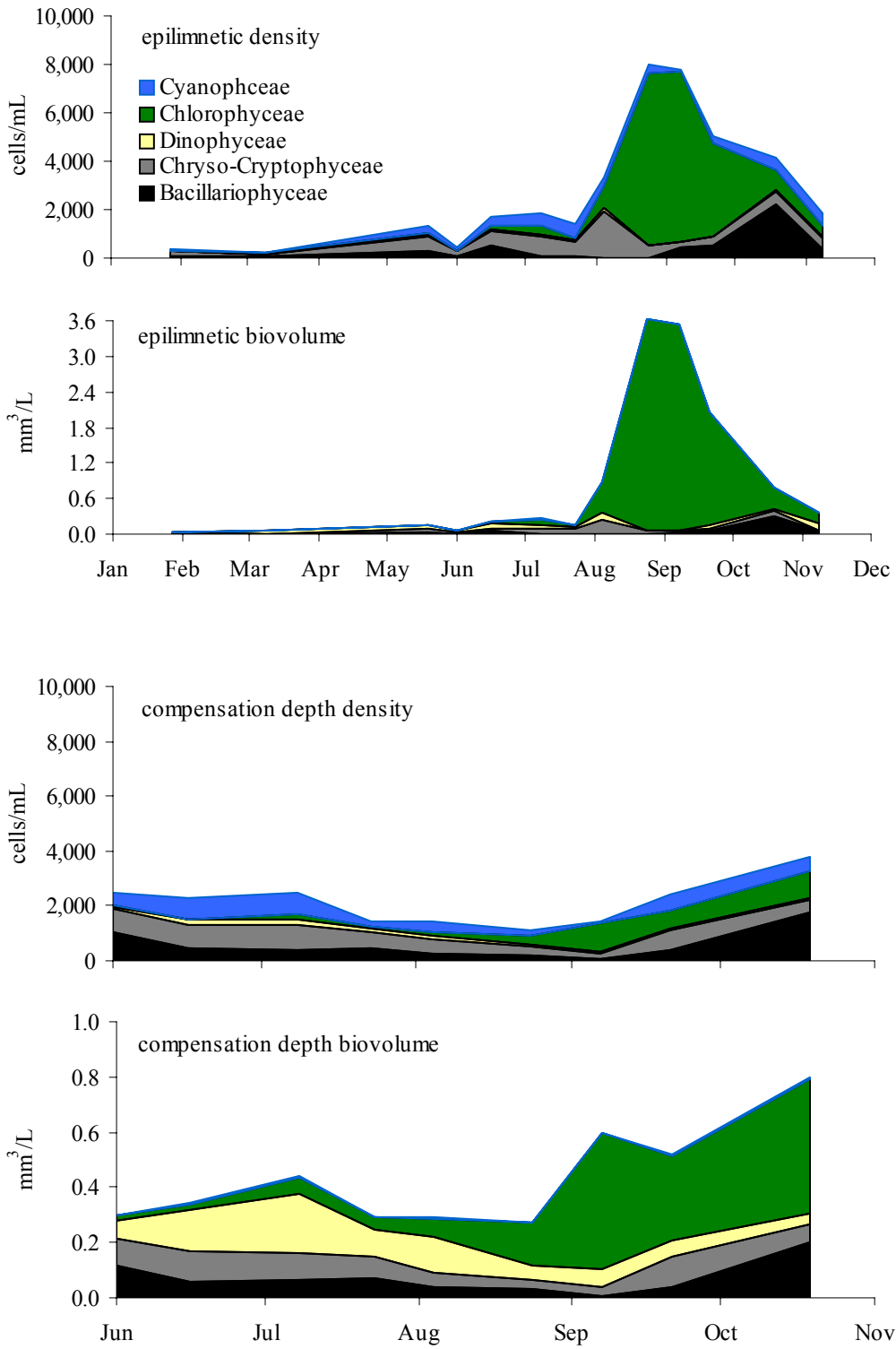


Appendix B4. Heterotrophic bacteria and autotrophic picoplankton (APP) densities (cells/mL) in the epilimnion and compensation depths in Stanley Lake, June through November 2004. Note different scale on y-axis of autotrophic picoplankton figure.

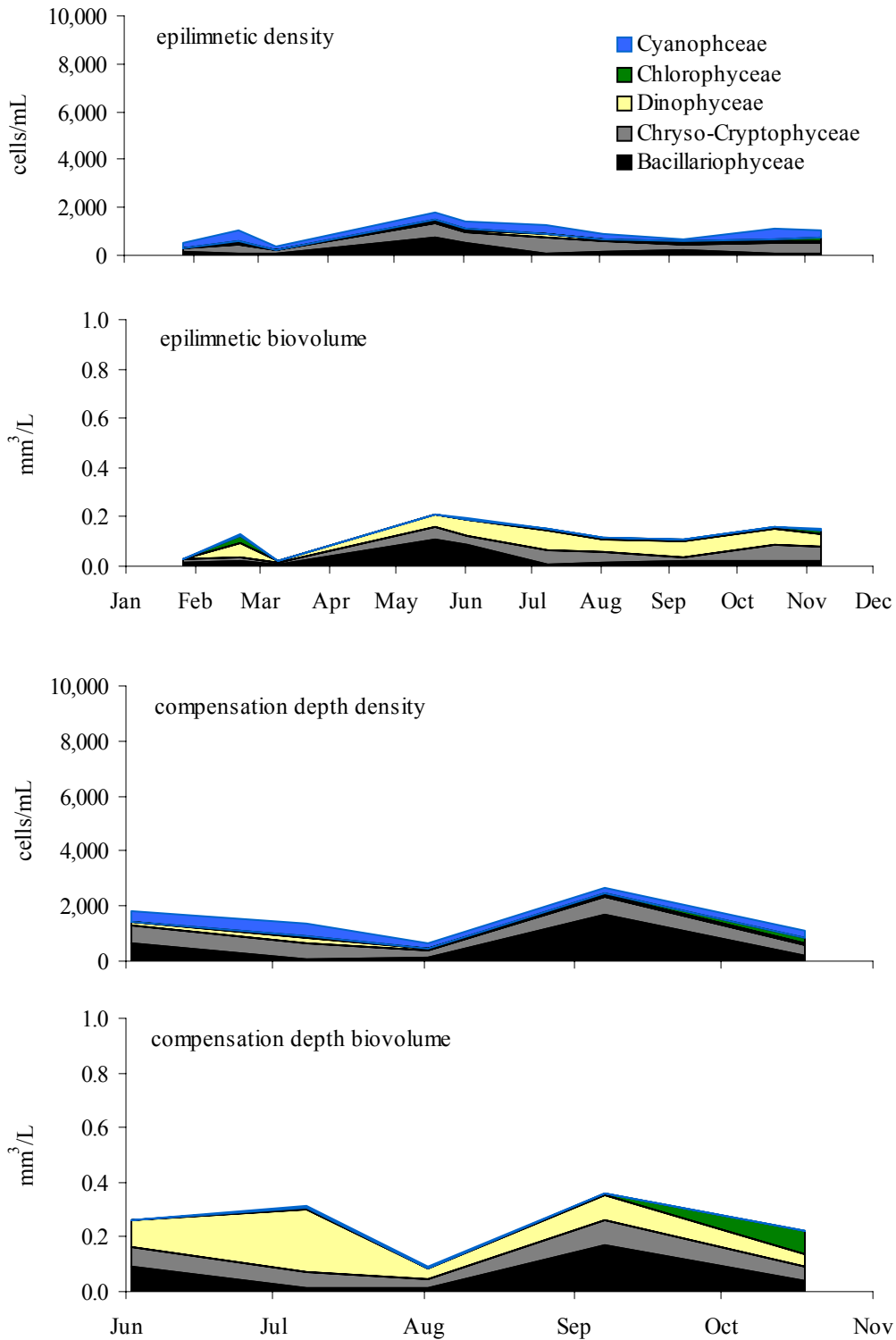
APPENDIX C. Phytoplankton densities and biovolumes



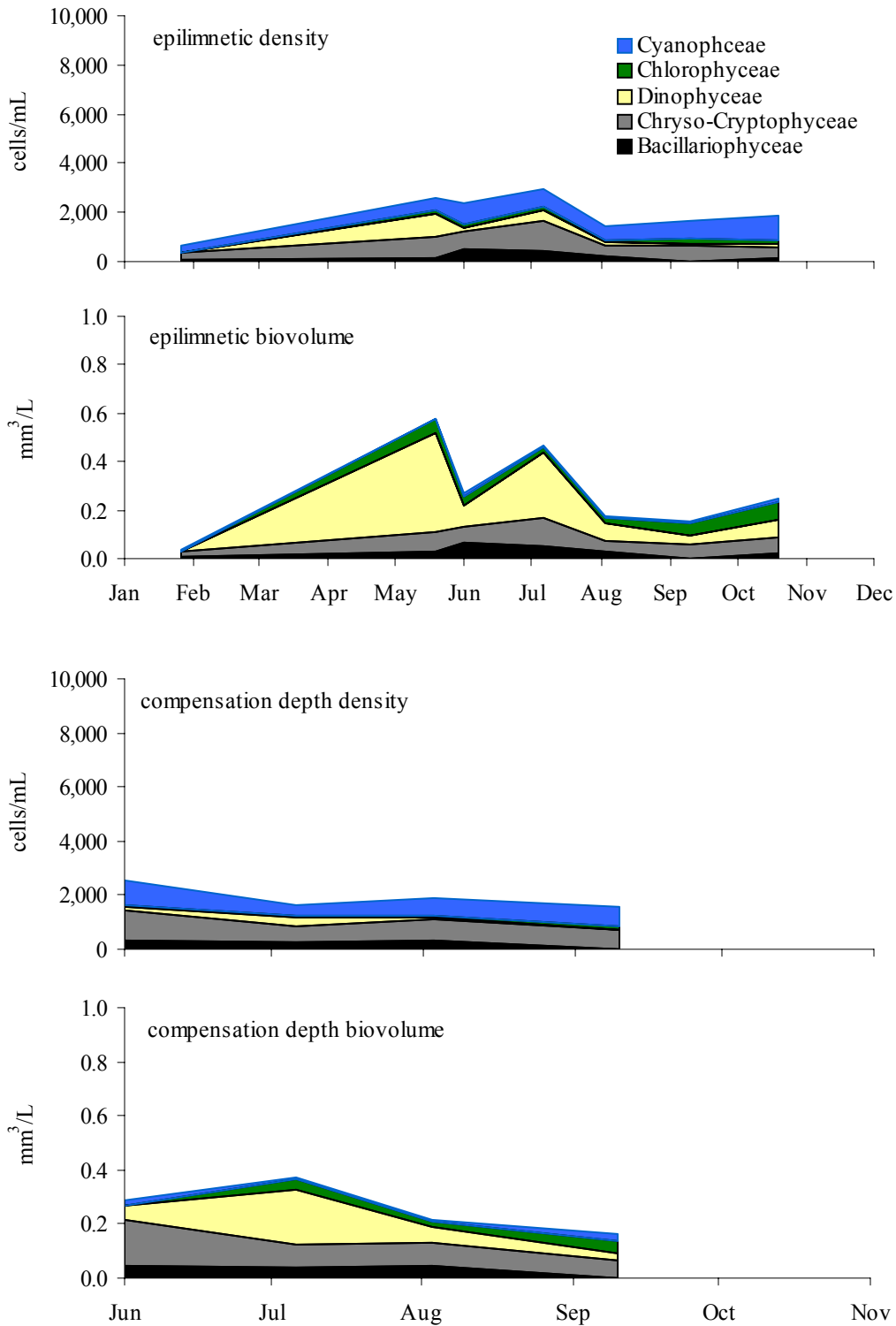
Appendix C1. Phytoplankton density (cells/mL) and biovolume (mm³/L) in the epilimnion and compensation depths in Redfish Lake, January through November 2004.



Appendix C2. Phytoplankton density (cells/mL) and biovolume (mm³/L) in the epilimnion and compensation depths in Pettit Lake, January through November 2004. Note different scale on epilimnetic biovolume figure.



Appendix C3. Phytoplankton density (cells/mL) and biovolume (mm³/L) in the epilimnion and compensation depths in Alturas Lake, January through November 2004.



Appendix C4. Phytoplankton density (cells/mL) and biovolume (mm³/L) in the epilimnion and compensation depths in Stanley Lake, January through October 2004.