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SNAKE RIVER SOCKEYE SALMON HABITAT AND LIMNOLOGICAL RESEARCH: 2000 ANNUAL PROGRESS REPORT

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EXECUTIVE SUMMARY

In March 1990, the Shoshone-Bannock Tribes petitioned the National Marine Fisheries Service (NMFS) to list the Snake River sockeye salmon (*Oncorhynchus nerka*) as endangered. As a result of that petition the Snake River sockeye salmon was officially listed as endangered in November 1991 under the Endangered Species Act (56 FR 58619). In 1991 the Snake River Sockeye Salmon Habitat and Limnological Research Program was implemented (Project Number 91-71, Intergovernmental Contract Number DE-BI79-91bp22548). This project is part of an interagency effort to prevent the extinction of the Redfish Lake stock of *O. nerka*.

The Bonneville Power Administration (BPA) provides funding for this inter-agency recovery program through the Northwest Power Planning Council Fish and Wildlife Program (NPPCFWP). Collaborators in the recovery effort include the National Marine Fisheries Service (NMFS), the Idaho Department of Fish and Game (IDFG), the University of Idaho (UI), U.S. Forest Service (USFS), and the Shoshone-Bannock Tribe (SBT). This report summarizes activities conducted by Shoshone-Bannock Tribal Fisheries Department personnel during the 2000 calendar year. Project objectives include: 1) monitor over-winter survival and emigration of juvenile anadromous *O. nerka* stocked from the captive rearing program; 2) fertilize Pettit, and Alturas lakes, fertilization of Redfish Lake was suspended for this year; 3) conduct kokanee (non-anadromous *O. nerka*) population surveys; 4) monitor spawning kokanee escapement and estimate fry recruitment on Fishhook, Alturas Lake, and Stanley Lake creeks; 5) evaluate potential competition and predation interactions between stocked juvenile *O. nerka* and a variety of fish species in Redfish, Pettit, and Alturas lakes; 6) examine diet of emigrating *O. nerka* smolts; 7) monitor limnological parameters of Sawtooth Valley lakes to assess lake productivity.

Objective 1. Stocked juvenile *O. nerka* over-winter survival in Pettit Lake was estimated using tag detections at Lower Granite Dam. 3,430 pre-smolts from the captive rearing program were stocked into Pettit Lake in the fall of 1999. An estimated 1,593 smolts out-migrated from the lake during the spring of 2000. This results in an estimated 46.4% over-winter survival rate as measured at Lower Granite Dam. Stocked juvenile *O. nerka* over-winter survival in Alturas Lake was estimated using catches at the Alturas Lake Creek screw trap. Alturas Lake was stocked with 12,995 pre-smolt *O. nerka* from the captive rearing program in the fall of 1999. An estimated 4,387 smolts out-migrated from the lake in the spring of 2000, resulting in an estimated 33.8% over-winter survival rate. Over-winter survival and out-migration for Redfish Lake was monitored by IDFG.

Objective 2. Pettit, Alturas, and Redfish Lakes received no supplemental fertilization in 2000.

Objective 3. The hydroacoustic estimate of *O. nerka* population in the fall of 2000 for Redfish Lake was 24,481 ± 10,520 with a density of 39.8 ± 17.1. Pettit Lake had an estimated population of 40,435 ± 20,977 and a density of 249.6 ± 129.5. Alturas Lake had an estimated population of 134,867 ± 33,244 and a density of 399.0 ± 98.4. Concurrent trawl sampling and density estimates were conducted by IDGF.

Objective 4. Stream spawner counts were used to monitor adult kokanee escapement to inlet streams on Redfish, Alturas, and Stanley lakes in 2000. Fishhook Creek, the primary kokanee spawning tributary on Redfish Lake, had an estimated spawning escapement of 60 adult spawners. This number is down sharply compared to previous years. Stanley Lake Creek had an estimated 5,665 kokanee spawners, a significant increase compared to previous years. Alturas Lake Creek had an estimated 827 fish, a significant decrease from previous years. Fry recruitment, calculated from male-female ratios, fecundity, and egg to fry survival rates is estimated at 321, 48,181, and 18,223 fry for Fishhook, Stanley Lake, and Alturas Lake creeks respectively.

Objective 5. Potential competition and predation between stocked sockeye salmon (anadromous *O. nerka*), rainbow trout (*O. mykiss*), and other fish species were investigated. In an analysis of rainbow trout diets there were no *O. nerka* found in the guts of any of the fish sampled. Diet overlap was 0.04% for rainbow trout and *O. nerka* consisting of chironomid pupae. Age 0 sockeye salmon, the life stage of primary interest, fed primarily on zooplankton while rainbow trout had a diet dominated by insects. Several potential kokanee/sockeye predators were identified in the lakes including bull trout *Salvelinus confluentus*, northern pikeminnow *Ptychocheilus oregonensis*, and brook trout *S. fontinalis*. No *O. nerka* were identified in the stomachs of any of the northern pikeminnow or brook trout. Piscivory was evident, however, with cyprinids found in the diet of northern pikeminnow and cyprinids and salmonids found in the diet of brook trout. Bull trout diet was composed primarily of salmonids and cyprinids. Due to the progressed state of digestion found in many stomach samples we cannot conclusively rule out predation on *O. nerka* by potential predators.

Objective 6. Limnological parameters including nutrient levels, chlorophyll *a*, secchi depth, primary productivity, phytoplankton, and zooplankton assemblage characteristics (species composition and densities) were monitored concomitant with fertilization activities.

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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 evolutionary significant unit (ESU) is the only extant Snake River stock of *O. nerka*. The spawning and freshwater rearing habitat of this stock is located in the Sawtooth Valley, Idaho, a traditional SBT fishing and hunting area. In March 1990, the SBT petitioned the National Marine Fisheries Service (NMFS) to list the Snake River sockeye salmon as endangered. As a result of that petition the Snake River sockeye salmon was officially listed as endangered in November 1991 under the Endangered Species Act (56 FR 58619). The Upper Snake River Endangered Sockeye Salmon Recovery Program was implemented that same year. The SBT have been actively involved in the sockeye salmon recovery project (BPA Project Number 91-71) since its inception.

The Bonneville Power Administration (BPA) provides funding for this interagency recovery program through the Northwest Power Planning Council's Fish and Wildlife Program. Collaborators in the recovery program include the National Marine Fisheries Service (NMFS), Idaho Department of Fish and Game (IDFG), the University of Idaho (UI), the U.S. Forest Service (USFS), and the SBT. The NMFS 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 hatchery operations in Eagle and Stanley, ID. The UI analyzes genetic samples and participates in designing breeding matrices. The USFS participates in permitting activities and habitat improvements. The SBT monitors a variety of fisheries biology parameters and spawning and rearing habitat in nursery lakes.

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

A variety of activities has been conducted in the effort to conserve and rebuild the Redfish Lake *O. nerka* stock. The captive brood stock has served to preserve the unique genome. Fish barriers on Alturas and Pettit 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 pre-smolt release, and pre-smolt release during spring, summer, and fall, and smolt releases. Lake fertilization has also been implemented in order to increase lake-carrying capacities. Kokanee (non-anadromous form of *O. nerka*) control measures have been implemented in Redfish Lake to reduce intraspecific competition. A variety of fishery and limnological parameters have been monitored in association with these strategies.

The Technical Oversight Committee (TOC) has guided all activities conducted by the SBT in association with the sockeye recovery project. The TOC is composed of representatives of all participating agencies (BPA, NMFS, IDFG, UI, and SBT). The TOC was formed in 1991 to guide new research, coordinate ongoing research, and actively participate in all elements of the Snake River sockeye recovery effort. Scientists with expertise in related fields are often invited to TOC meetings to present their research and discuss activities conducted by TOC agencies. The project as a whole or in part is subject to further review by the Idaho Department of Environmental Quality (DEQ), the USFS, and the NWPPC Independent Scientific Review Panel (ISRP).

STUDY AREA

Four lakes, Redfish, Alturas, Pettit, and Stanley, in the Sawtooth Valley 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 1-1). Specific features of the sockeye rearing lakes are shown in Table 1-1.

All of the Stanley Basin lakes are oligotrophic. Mean summer total phosphorous (TP) concentrations in the epilimnion range from 4.9 to 11.8 *u*g/l. Surface chlorophyll *a* concentrations range from 0.3 to 2.3 *u*g/l. Mean summer secchi disk transparencies range from 9.6 to 15.2 m, excluding Stanley Lake which ranges from 5.0 to 8.2 m.

Table 1-1. Morphological features of the Sawtooth Valley lakes.

Lake	Area (km^2)	Volume (m^3x10^6)	Mean Depth (m)	Drainage Area (km^2)
Redfish	6.15	269.9	44	108.1
Alturas	3.38	108.2	32	75.7
Pettit	1.62	45.0	28	27.4
Stanley	0.81	10.4	13	39.4
Yellow Belly	0.73	10.3	14	30.4

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

Native fish species found in the nursery lake system include sockeye/kokanee salmon *Oncorhynchus nerka*, steelhead/rainbow trout *O. mykiss*, chinook salmon *O. tshawytscha*, cutthroat trout *O. clarki lewisi*, bull trout *Salvelinus confluentus*, mountain whitefish *Prosopium williamsoni,* sucker *Catastomus sp*., redside shiner *Richardsonius balteatus*, dace *Rhinichthys sp*., northern pikeminnow *Ptychocheilus oregonensis*, and sculpin *Cottus sp*.. Non-native species include brook trout *S. fontinalis* and lake trout *S. namaycush*. The only pelagic species besides *O. nerka* are redside shiners. The two species are not sympatric because of differing vertical distributions. Hatchery rainbow trout are stocked by IDFG throughout the summer in all lakes except for Redfish and Yellow Belly lakes. Sport fishing for salmonids is open on all lakes as well as inlet and outlet streams.

The Sawtooth Valley lakes have several different forms of *O. nerka*, the primary pelagic zooplanktivore in the system. There are three distinct life histories in Redfish Lake; anadromous, residuals, and kokanee. Kokanee, a non-anadromous form of *O. nerka*, spends its entire life cycle in the fresh water lakes. Kokanee generally spawn at three to four years of age in the inlet creeks of the lakes during late summer and die afterwards. The Redfish Lake kokanee population is admixed, consisting of several out-of-basin stocks and is genetically dissimilar to the anadromous form. This kokanee population is temporally and spatially separated during spawning from the listed Snake River *O. nerka*. Alturas Lake kokanee are closely related, sharing haplotypes with listed Snake River *O. nerka* (Matt Powell, U of I, personal communication). Pettit and Stanley lakes were treated with rotenone (1950's and 60's) and kokanee were reintroduced from out-of-basin stocks. Data indicate that these fish are genetically different from remaining indigenous *O. nerka*. No Sawtooth Valley kokanee are listed as endangered.

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

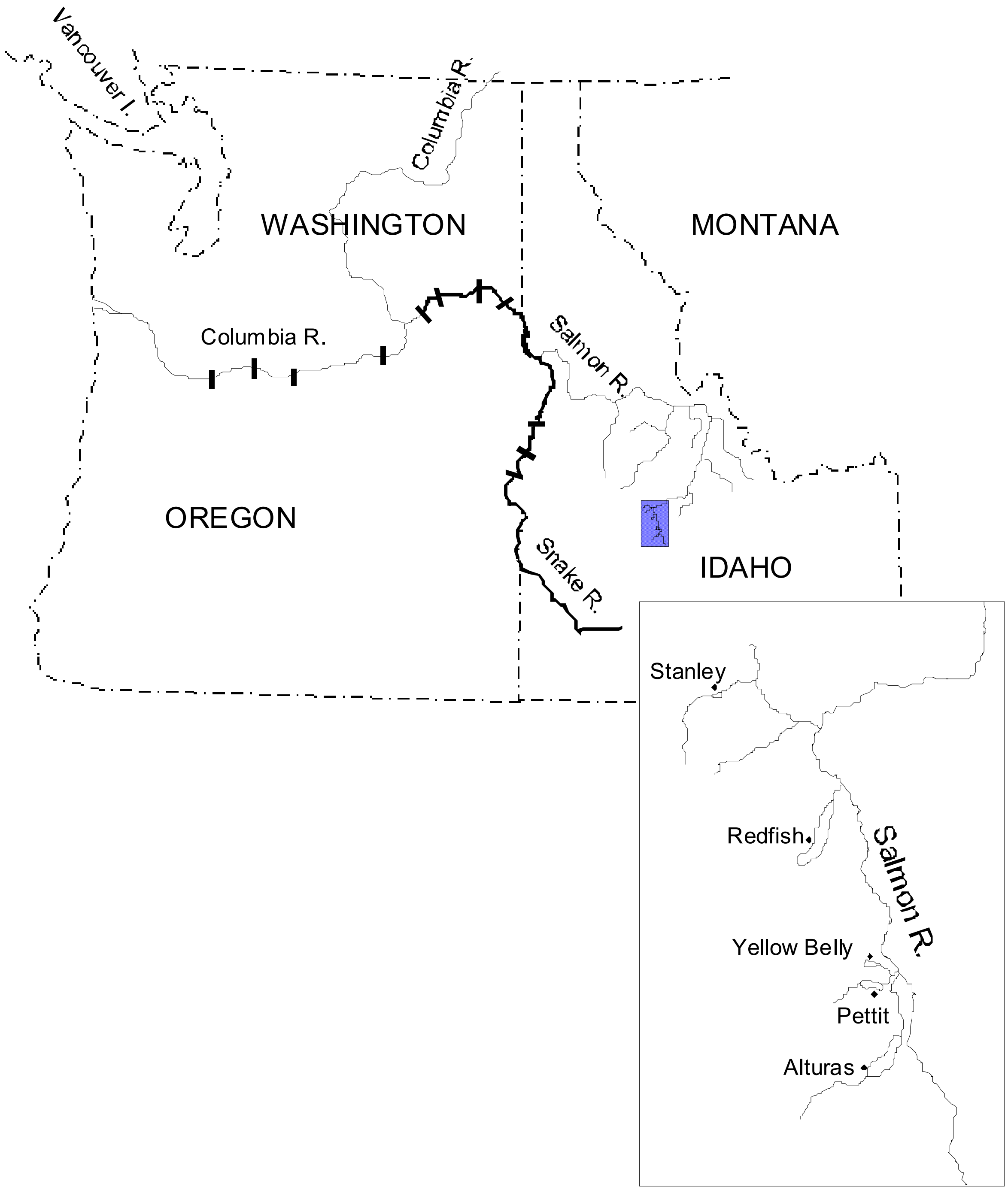

Figure 1-1. Map of study area.

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

MATERIALS AND METHODS

Hydroacoustic Population Estimates

Data Acquisition

Echo sounding data were collected with a Hydroacoustic Technology, Inc. Model 240 split-beam system. Split-beam echosounders have been shown to have less variability for target strength estimates than dual-beam systems (Traynor and Ehrenberg, 1990) and the target tracking capabilities of the split-beam system further reduce variability of individual targets (Ehrenberg and Torkelson, 1996). We used a 15 degree transducer, and the echo-sounder criteria were set to a pulse width of 0.4 milliseconds, a time varied gain of 40 log(R) + 2 r, and five pings per second for Redfish Lake, and six pings per second for Alturas and Pettit Lake. A minimum of six pings per target was necessary to qualify as a fish target. Data were recorded on a Panasonic SV-3700 digital audio tape recorder.

Established transects were followed using a global positioning system (GPS). Waypoints were established in 1994 and set to allow for sampling transects to run zigzag across all lakes except Pettit Lake, where five parallel and one diagonal transects were used (Teuscher and Taki 1995). Twelve and fourteen transects were sampled at Alturas and Redfish lakes, respectively.

Surveys were conducted during two moonless nights in September. We began at approximately 1½ hours after sunset. Boat speed during data collection ranged from 1-1.5 m/s.

Trawling (by IDFG) and vertical gill netting were done concurrently with hydroacoustic sampling. Vertical gill net sampling was used to assist in partitioning targets in Pettit Lake since past trawling efforts have indicated a positive selection for kokanee. Vertical gillnets were used to determine if other fish species were found in the pelagic areas during sampling. Previous gill net sampling conducted in Alturas Lake has not yielded sufficient numbers for partitioning targets and therefore was not used. Due to NMFS Section 10 permit limitations vertical gillnet sampling in Redfish Lake was not conducted.

Data Analysis

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

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

developed by Love (1977) where TS = target strength in decibels, L = fork length in centimeters, and F = frequency of transmitted sound (kHz). Fish density estimates were calculated for different size classes for each lake to approximate cohort densities based on 1999 length frequency distributions and age analyses performed by the IDFG from fish captured in the trawl. Four different size classes were used for all three lakes. Due to overlap in Alturas Lake, we combined the III+ and IV+ kokanee cohorts. Total abundance and vertical distribution were also estimated.

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

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

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

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

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

and variance was estimated by

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

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

FISHPROC software was used to compile acoustic target information for each lake. This allowed us to select targets based on acoustic size, depth or other parameters. We could process single or multiple transects and fish were sorted into one or two decibel bins. Vertical distribution was estimated by

$$\overline{D}_i = \sum_{i=1}^{h} D_{vi} (R_{iu} - R_{il}) \qquad (1\text{-}5)$$

where D_{vi} = number of fish/m^3 in depth stratum *i*, R_{iu} = upper range limit for depth stratum *i*, R_{il} = lower range limit for depth stratum *i*, and *h* = number of depth strata.

These values were then multiplied by the percentage of each depth stratum surveyed within the conical beam.

Correlation analysis was used to compare trawl versus hydroacoustic population estimates. Comparisons were made by combining current and previous year's results for total lake populations and cohort estimates.

Smolt Monitoring

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 25 April through 25 May 2000. *O. nerka* smolts were captured to estimate over-winter survival and smolt emigration and to allow tagging of Snake River sockeye salmon smolts using passive integrated transponders (PIT). There were 12,995 fish introduced as pre-smolts from the captive broodstock program into Alturas Lake in the fall of 1999. 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.

A condition factor (K value, [weight x 10^5]/[length]^3) for each fish was estimated; mean, minimum, and maximum K values are presented in results.

Anesthetized fish were weighed to the nearest 0.1 grams, measured (fork length) to the nearest millimeter, and PIT tagged. Fish were held in a live well for 1/2 to 10 hours after handling and released at dusk. All other fish were counted and immediately released below the screw trap. PIT tags and needles were sterilized in 70% ethanol. PIT-tagged fish used in the mark recapture capture efficiency estimation were held in a live well and released at dusk approximately 300 meters upstream.

Growth Rates

Growth rates of stocked juvenile *O. nerka* were compared in an effort to evaluate fitness associated with differences between lakes, hatchery origin, and stocking strategy. Length data (mm) of stocked *O. nerka* were collected at the time of tagging and smolt emigration. Length and weight data were Log_{10} transformed to normalize and create a linear relationship from an exponential growth curve to facilitate growth rate comparisons. Log_{10} transformed lengths and weights at the time of tagging were compared to Log_{10} transformed length and weight data of *O. nerka* collected during smolt emigration monitoring. An initial pair-wise comparison (t-test) was conducted comparing size at release and size at emigration between lakes and release strategy. A second descriptive comparison was generated using a linear regression between the Log_{10} transformed lengths and weights of pre-smolts and smolts for each release group. The slope of the regression line represents the growth rate of each group of fish and was used to compare growth rates of fish between lakes and release strategies.

Gillnet

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 were composed of graduated mesh sizes (2.54, 3.17, 5.08, and 6.35 cm). Horizontal gillnet sampling was conducted on 24 January and 27 June 2000 in Pettit Lake. Vertical gillnet sampling on Pettit Lake was conducted on 24 January, 7 March, and 27 July 2000. Due to NMFS section 10 permit limitations, there were no gillnets set in Redfish Lake.

Diet Analysis

Fish stomachs collected from gillnet, trawl, and screw trap samples were examined to determine diet composition. Stomach samples from rainbow trout, bull trout, brook trout, northern pikeminnow, and kokanee were collected. 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, and lengths were derived from zooplankton tows collected during the same months. Zooplankton lengths were converted to dry weight using the length-weight relationship reported in McCauley (1984). Aggregate percent of diet by dry weight for all species of fish sampled was calculated (Swanson et al. 1974) and used to determine diet overlap and 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 calculations for prey preferences were used for *O. nerka*.

Stream Spawning

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

Beach Spawning

Sockeye Beach, located near the Redfish Lake boat ramp, and a small section of the southeast corner of Redfish Lake are spawning grounds for residual and adult sockeye. Night snorkel surveys were conducted to estimate the relative abundance of residual spawners and adult sockeye stocked from the captive-rearing program in both locations. Snorkel surveys in Redfish Lake were conducted weekly on four nights from 25

September to 1 November 2000. Three observers equipped with waterproof flashlights snorkeled parallel to shore 10 m apart at depths ranging from 0.5 to 5 m. At Sockeye Beach, estimates of residual spawner abundance were conducted within the boundary (600 m) of Sockeye Beach as delineated by USFS signs. Spawning ground surveys in the south end of the lake were conducted in the 200 m shoal area section near the two southeast inlet streams.

RESULTS

Hydroacoustic Population Estimates

Hydroacoustic population estimates of *O. nerka* during September 2000 were 24,481, 40,435, and 134,867 fish in Redfish, Pettit, and Alturas lakes, respectively (Table 1-2). Redfish Lake *O. nerka* abundance declined the most from 1999 (-65%) and had the lowest density of the three lakes at 39.8 ± 17.1 fish/hectare. Pettit Lake *O. nerka* abundance declined to the lowest level since 1994 yet density remained almost six times as high as Redfish Lake (249.6 ± 129.5 fish/hectare) (Table 1-2).

Redfish Lake- The total *O. nerka* population in Redfish Lake was 35% of the 1999 estimate. The decrease in abundance was seen in every cohort. We are not allowed to set vertical gillnets in Redfish Lake, so we assume every fish tracked in the pelagia is an *O. nerka,* and that no *O. nerka* are in the littoral zone when we sample.

Pettit Lake- The hydroacoustic estimate of *O. nerka* population in Pettit Lake declined by 11,061 (21.5%) fish since 1999. The lowest annual survival occurred from the II+ to III+ cohort (57%). Pettit Lake has experienced a gradual decline in whole lake *O. nerka* abundance during this study, since 1995 and 1996 when it had the highest densities of the three lakes. Zooplankton abundance has increased since a collapse in 1995 but still remains below 1995-1996 abundance (see Chapter 2).

Alturas Lake- Whole lake *O. nerka* population estimates in Alturas Lake are similar to 1999 estimates (Table 1-2). The 1990 trawl estimate in Alturas Lake was 126,644, the highest of the decade. Hydroacoustic sampling did not begin until 1994 when the lowest estimate for both techniques (hydroacoustic and trawl) was recorded: 10,908 for hydroacoustics and 5,785 for trawl (Teuscher and Taki 1996).

Table 1-2. *O. nerka* abundance and density estimates for three Sawtooth Valley lakes from 1994 through 2000.

Lake	Year	***O. nerka* abundance population estimate**	***O. nerka* density (fish/hectare)**
Redfish	2000	24,481 ± 10,520	39.8 ± 17.1
Redfish	1999	69,472 ± 29,887	113.0 ± 48.6
Redfish	1998	107,613 ± 33,615	175.0 ± 54.6
Redfish	1997	131,513 ± 32,319	213.8 ± 52.5
Redfish	1996	66,325 ± 24,000	107.8 ± 39.0
Redfish	1995	103,570 ± 24,500	168.4 ± 39.8
Redfish	1994	133,360	216.80
Pettit	2000	40,435 ± 20,977	249.6 ± 129.5
Pettit	1999	51,496 ± 12,171	317.9 ± 75.1
Pettit	1998	67,206 ± 30,950	414.9 ± 191.1
Pettit	1997	63,195 ± 29,581	390.1 ± 182.6
Pettit	1996	77,680 ± 15,850	479.5 ± 97.8
Pettit	1995	77,765 ± 46,900	480.0 ± 289.5
Pettit	1994	12,265 ± 8.360	75.7 ± 51.6
Alturas	2000	134,867 ± 33,244	399.0 ± 98.4
Alturas	1999	130,133 ± 25,936	385.0 ± 76.7
Alturas	1998	101,519 ± 32,605	300.4 ± 96.4
Alturas	1997	30,795 ± 5,869	91.1 ± 17.4
Alturas	1996	20,620 ± 4,140	61.0 ± 12.3
Alturas	1995	32,260 ± 5,090	95.4 ± 15.1
Alturas	1994	10,980 ± 1,090	32.5 ± 3.2

Table 1-3. Hydroacoustic population estimates by age class for Alturas Lake, 1996– 2000.

Cohort	1995	1996	1997	1998	1999	2000
0+	na	3,255 ± 1,490	4,330 ± 979	73,176 ± 27,411	73,262 ± 19,572	44,346 ± 14,153
I+	na	7,670 ± 3,175	11,859 ± 3,071	20,106 ± 5,372	25,752 ± 5,834	41,334 ± 10,067
II+	na	4,665 ± 635	4,304 ± 1,149	6,399 ± 1,734	21,583 ± 5,951	23,904 ± 8,945
III+	na	3,702 ± 1,300	10,775 ± 2,920	1,838 ± 1,297	10,533 ± 3,303	17,209 ± 8,936
IV+	na	1,260 ± 785	0	0	0	7,054 ± 3,769

Table 1-4. Hydroacoustic population estimates by age class for Redfish Lake, 1994 – 2000.

Cohort	1995	1996	1997	1998	1999	2000
0+	22,360 ± 6,410	12,680 ± 5,030	37,234 ± 14,449	46,747 ± 19,155	41,466 ± 23,578	13,080 ± 8,156
I+	49,120 ± 12,400	34,950 ± 21,040	51,681 ± 14,533	27,767 ± 10,955	28,199 ± 30,829	6,086 ± 2,364
II+	31,070 ± 12,340	18,700 ± 4,570	30,623 ± 6,599	12,450 ± 5,215	11,359 ± 7,389	5,315 ± 2,396
III+	0	0	11,973 ± 3,104	9,926 ± 5,629	2,213 ± 1,639	0

Table 1-5. Hydroacoustic population estimates by age class for Pettit Lake, 1995– 2000.

Cohort	1995	1996	1997	1998	1999	2000
0+	2,880 ± 1,270	4,740 ± 3,020	4,471 ± 2,705	16,593 ± 6,548	9,508 ± 6,576	6,913 ± 2,409
I+	15,600 ± 9,330	17,890 ± 3,020	14,061 ± 6,010	17,027 ± 9,963	13,028 ± 4,942	9,276 ± 4,023
II+	37,270 ± 23,570	31,800 ± 5,820	23,635 ± 11,485	29,974 ± 15,704	16,453 ± 4,493	14,649 ± 8,598
III+	19,667 ± 13,930	23,247 ± 5,100	21,027 ± 11,502	7,895 ± 4,567	8,886 ± 4,402	9,494 ± 7,142

O. nerka abundance in rearing lakes are typically cyclic (Kyle et al. 1988; Hume et al. 1996). Alturas Lake appears to be peaking in *O. nerka* abundance similar to 1990 (based on trawl estimates) and what was observed in Pettit Lake during 1995-96.

Hydroacoustic/trawl Comparisons

Hydroacoustic estimates for Redfish, Pettit, and Alturas lakes were 2.38, 1.00, and 1.08 times the trawl estimate (Figure 1-2). The 7 year mean hydroacoustic/trawl ratios for the lakes are 2.14 for Redfish Lake, 1.73 for Pettit Lake, and 1.85 for Alturas Lake.

Correlation of hydroacoustic and trawl population estimates were variable. Correlating 7 years of total lake *O. nerka* estimates reveals a relationship of R=0.85 (Figure 1-3). Combining individual cohorts from Redfish, Pettit, and Alturas lakes revealed that the YOY was moderately related (R=0.88; Figure 1-4), and that the two year old cohort was strongly related (R=0.96; Figure 1-5).

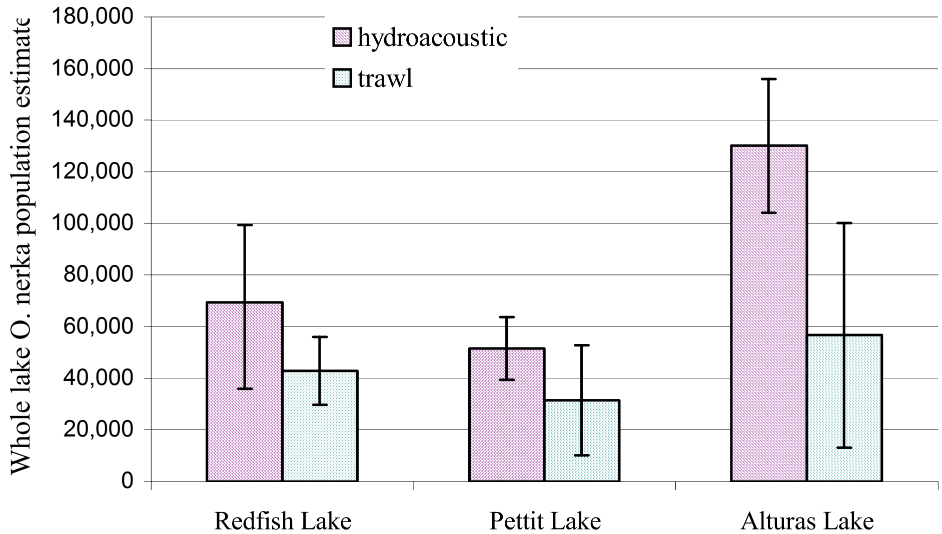

Figure 1-2. Comparison of hydroacoustic versus trawl estimates.

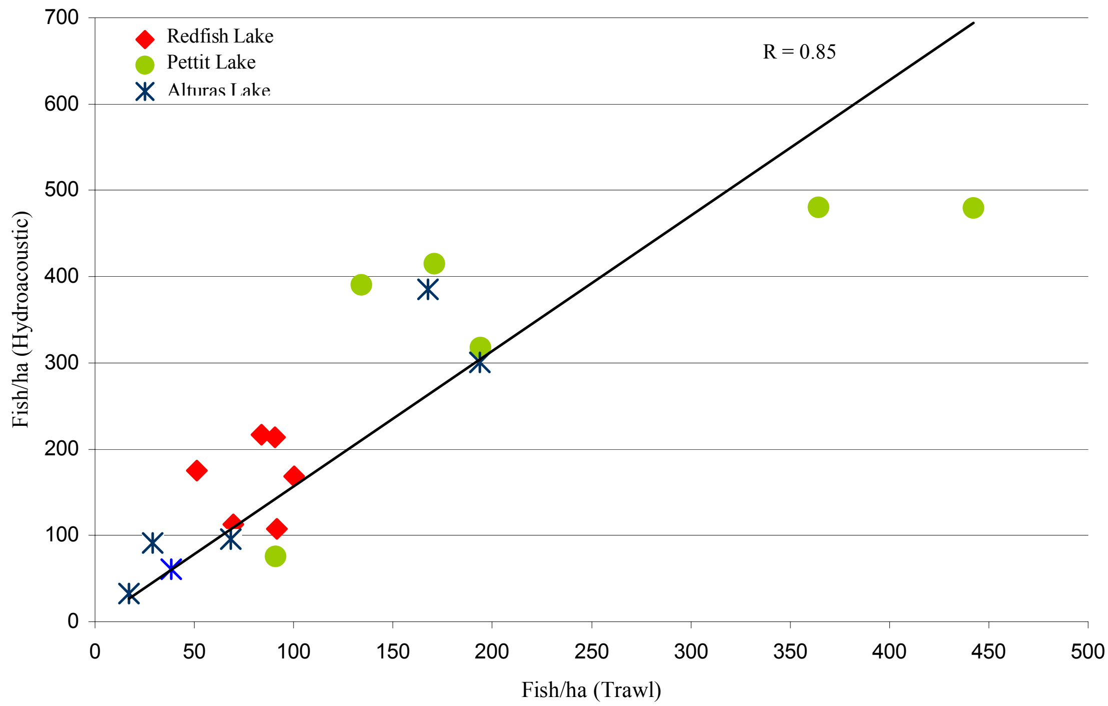

Figure 1-3. Correlation of six years of total lake *O. nerka* hydroacoustic and trawl estimates.

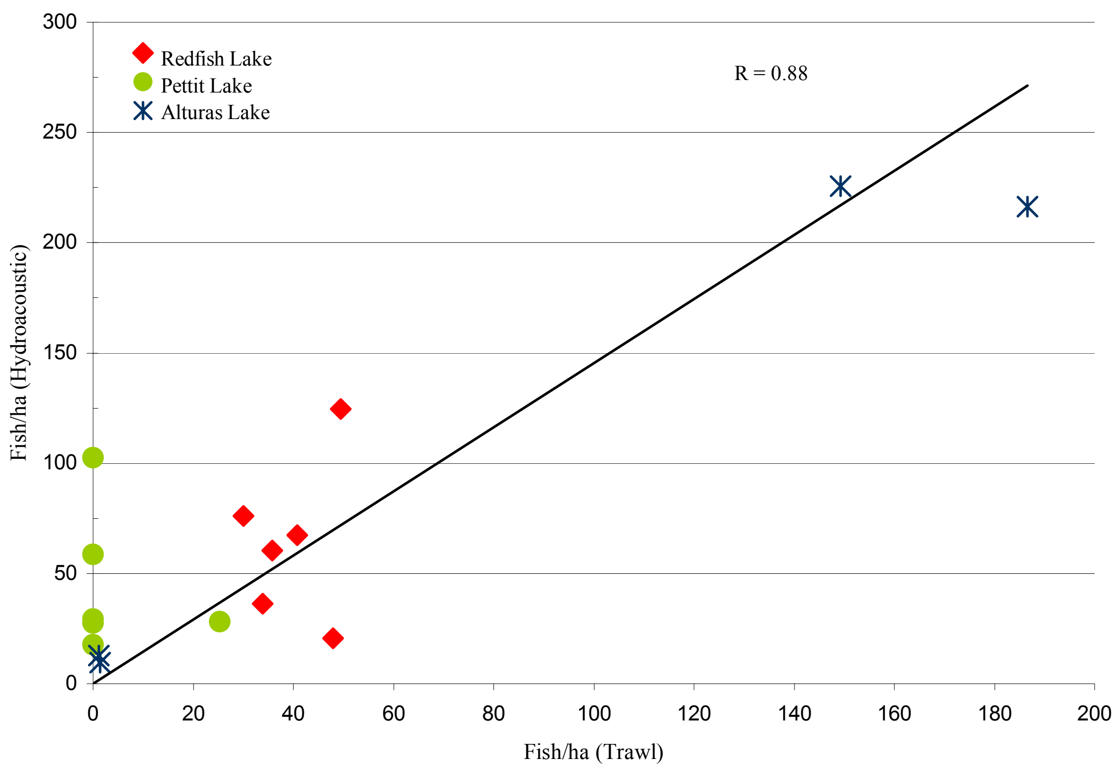

Figure 1-4. Correlation of YOY cohort from Redfish, Pettit, and Alturas lakes.

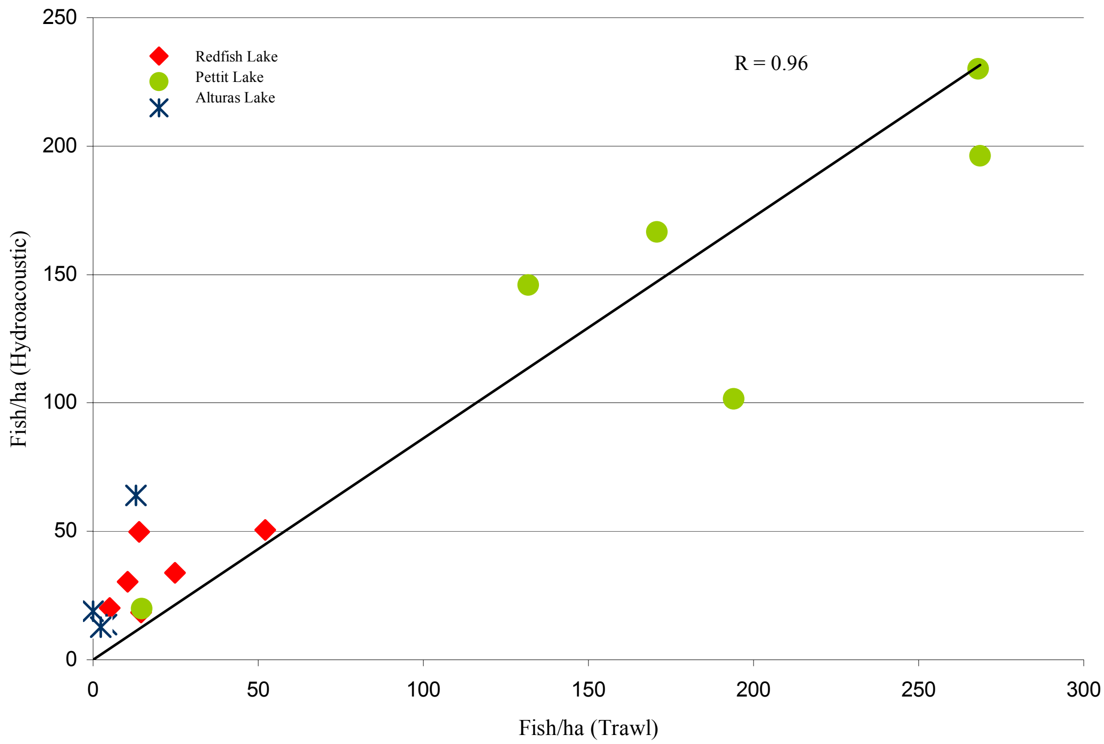

Figure 1-5. Correlation of two year old cohort from Redfish, Pettit, and Alturas lakes.

Smolt Monitoring

Pettit Lake Creek

In the fall of 1999 there were 3,430 Snake River sockeye pre-smolts from the Sawtooth Hatchery stocked into Pettit Lake. This release group included 104 PIT tagged fish. Calculations from tag detections at Lower Granite dam show an estimated over-winter survival of these fish at 1,593 (46.4%) (L. Hebdon, IDFG, personal communication). No smolt monitoring occurred at the Pettit Lake Creek weir during 2000.

Alturas Lake Creek

There were 12,995 pre-smolts from the Sawtooth Hatchery released into Alturas Lake in the fall of 1999. Screw trap monitoring of smolt emigration began on 26 April 2000. The first sockeye was captured on 26 April 2000. Trapping was discontinued on 25 May 2000. Screw trap efficiencies ranged from 10% to 21% for wild and hatchery fish.

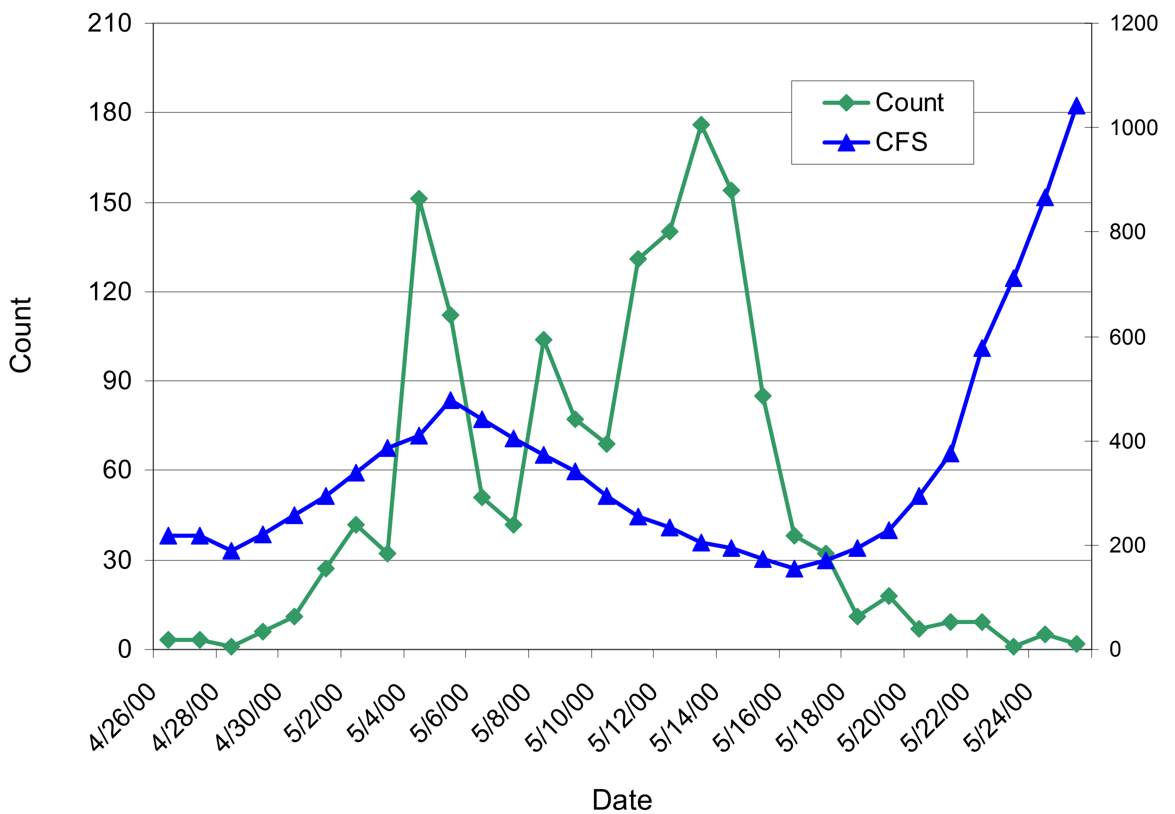

Figure 1-6. Alturas Lake *O. nerka* emigration and spring hydrograph timing.

Using the number of captured hatchery sockeye smolts and a seasonal mean trap efficiency of 8%, it was estimated that 4,416 hatchery sockeye smolts emigrated from Alturas Lake. This results in an estimated 33% over-winter survival rate for the Snake River sockeye pre-smolts introduced from the captive broodstock to Alturas Lake in 1999. Using the number of captured wild smolts and a seasonal mean trap efficiency of 19%, it was estimated that 6,300 wild smolts emigrated from Alturas Lake.
The actual number is potentially higher because additional emigration could have occurred after the trap was pulled. There were 759 sockeye smolts
PIT tagged at the screw trap and released downstream. No clear relationship between discharge and numbers of emigrating fish was found (Figure 1-7).

The mean fork length of captive brood stock *O. nerka* captured at the trap (Figure 1-8) was 110 mm (range 90-125 mm), mean weight was 11.0 g (range 5.7-15.3 g), and a mean K value (condition factor) was 0.79 (range 0.60-1.00). Also captured at the trap were wild *O. nerka* with a mean fork length of 88 mm (range 74-110), mean weight of 5.2 g (range 3.1-10.0) (Figure 1-9), and a mean K value of 0.76 (range 0.61-1.18). Water

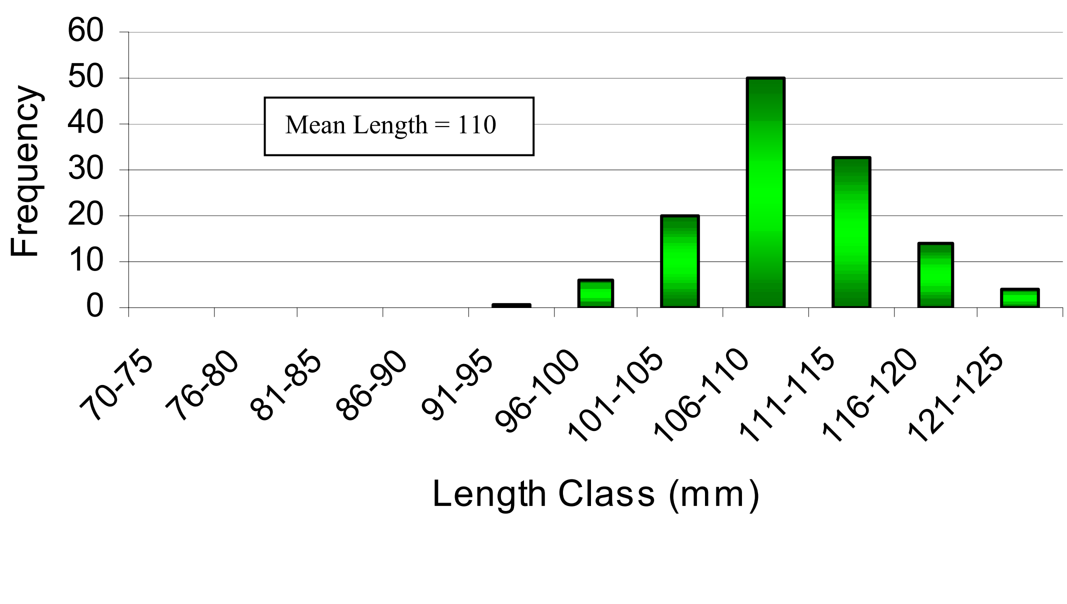

Figure 1-7. The length frequency distribution of *O. nerka* from the captive brood stock captured at the Alturas Lake Creek screw trap.

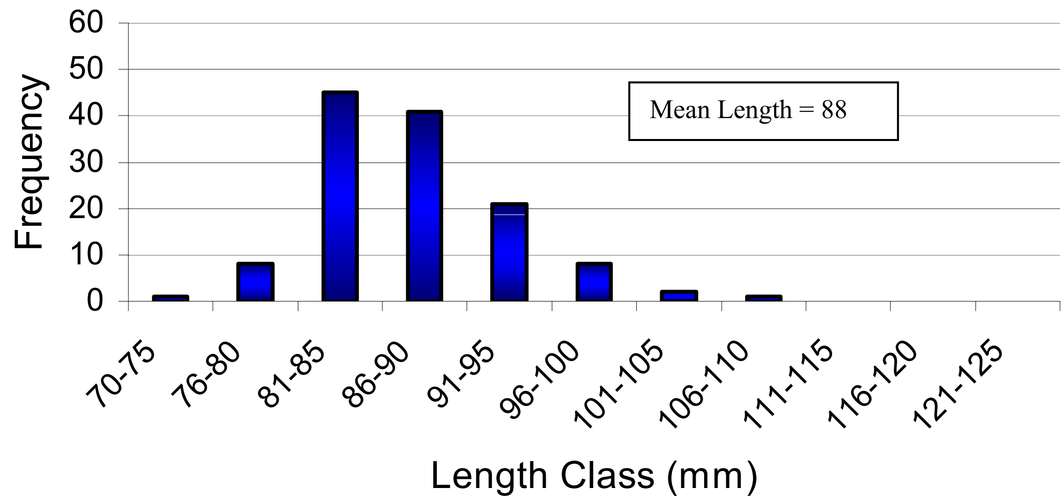

Figure 1-8. The length frequency distribution of wild *O. nerka* captured at the Alturas Lake Creek screw trap.

temperatures at the screw trap ranged from 3.0 to 14.5 ^{o}C. All listed fish captured were handled according to the protocol described in the permit request, and no mortalities were attributed to handling or PIT tagging.

Growth Rates

Captive reared pre-smolts were released into Alturas, Pettit, and Redfish Lakes on 13-Oct-1999. At the time of tagging and release, Alturas Lake pre-smolts were significantly larger (length) ($P<0.000001$) than either group of pre-smolts released into Redfish and Pettit Lakes (Figure 1-10). An analysis of weight data revealed that Alturas and Pettit Lake fish were significantly larger ($p<0.03$) than Redfish Lake pre-smolts at the time of tagging and release (Figure 1-12). At the time of emigration, Alturas Lake smolts were significantly smaller in length ($P<0.00001$) and weight ($P<0.00001$) than fish emigrating from Redfish Lake (Figure 1-10 and 1-12). The weir at Pettit Lake Creek was not operated in the spring of 2000 so no growth comparisons can be made between outmigrating Pettit Lake smolts and those from Alturas or Redfish Lakes.

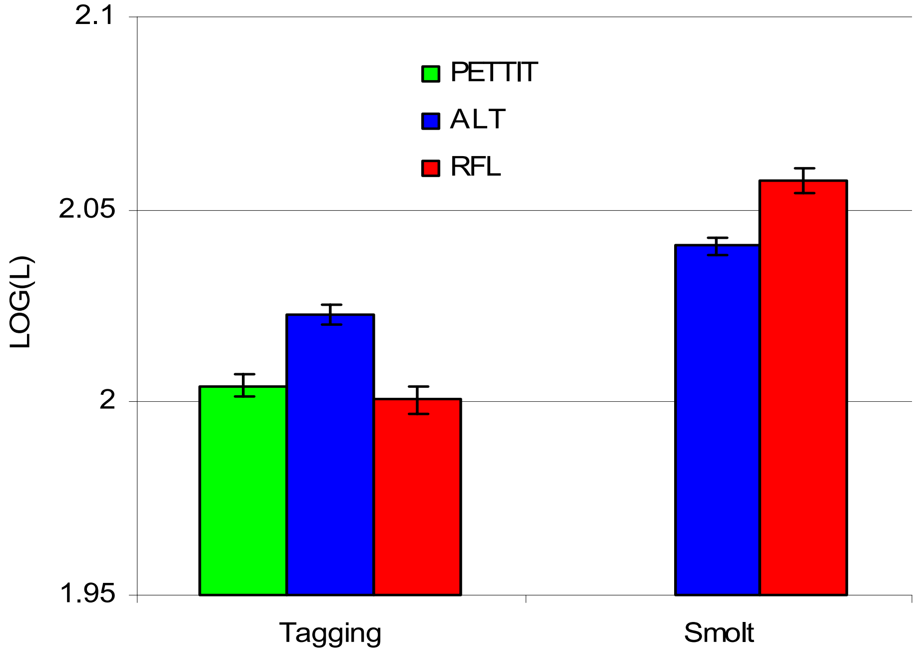

Figure 1-9. *O. nerka* Log (length) comparison between lakes at time of release and emigration. Error bars represent (±) one standard error.

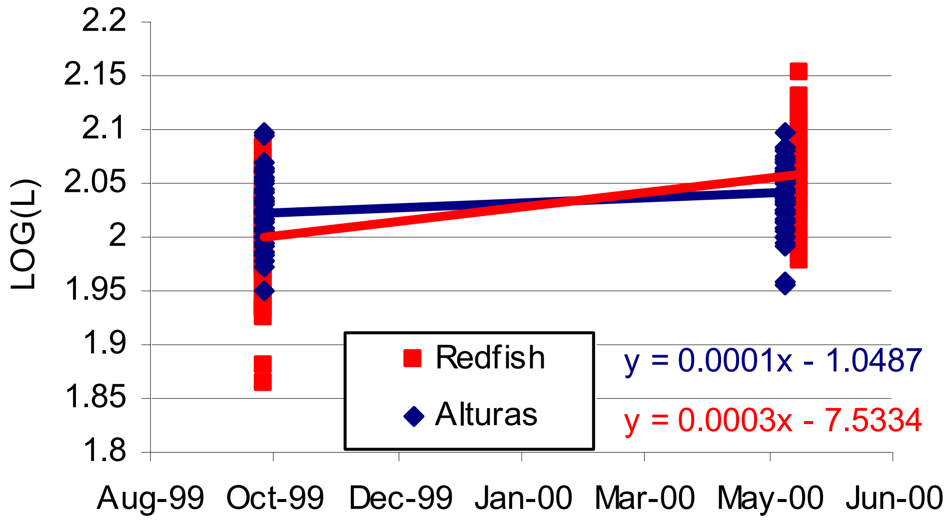

Figure 1-10. Regression of *O. nerka* Log (length) data to generate growth rates for each lake.

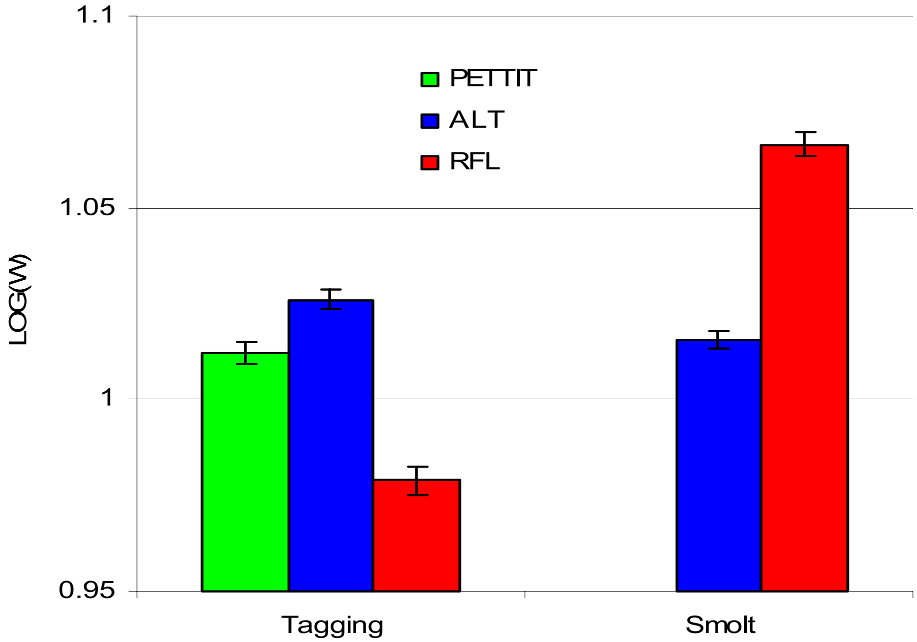

Figure 1-11. *O. nerka* Log (weight) comparison between lakes at time of release (tagging) and emigration (smolt). Error bars represent (±) one standard error.

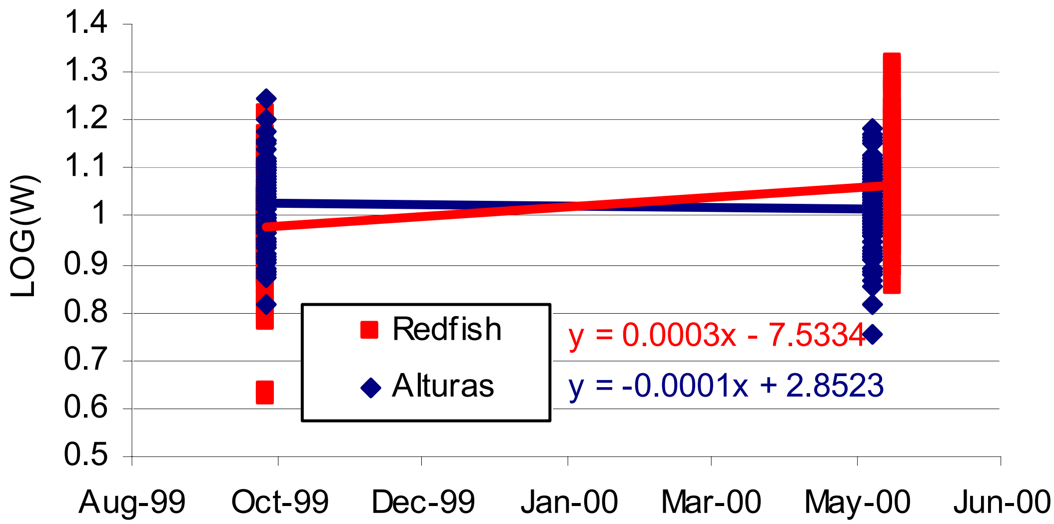

Figure 1-12. Regression of *O. nerka* Log (weight) data to generate growth rates for each lake.

A linear regression of the Log_{10} transformed length and weight data at the time of tagging and smolt emigration for each group of fish by lake produced a slope of 0.0001 (length) and -0.0001 (weight) for Alturas Lake, and 0.0003 (length) and 0.0003 (weight) for Redfish Lake (Figure 1-11and 1-13).

Gillnet

Vertical gillnet efforts yielded very few fish, total catch for all dates consisted of 5 kokanee, 3 sockeye, and 3 redside shiners. Horizontal gillnet mean seasonal catch per unit effort (CPUE) was highest for northern pikeminnows (0.33) followed by bull trout (0.06), stocked rainbow trout (0.05), whitefish (0.04), and brook trout (0.01) (Table 1-6).

Table 1-6. Results of Pettit Lake horizontal gillnet samples 2000.

Date	(n)CPUE	Mean Length (mm)	Mean Weight (g)	Gillnet Hours
Rainbow Trout				
January 24, 2000	(0)	NA	NA	40.35
January 25, 2000	(0)	NA	NA	47.40
January 26, 2000	(2) 0.05	236	144.2	42.45
June 27, 2000	(9) 0.16	263	210	54.55
Bull Trout				
January 24,2000	(3) 0.07	300	381	40.35
January 25,2000	(1) 0.02	NA	NA	47.40
January 26,2000	(0)	NA	NA	42.45
June 27, 2000	(7) 0.13	327	250	54.55
Brook Trout				
January 24, 2000	(0)	NA	NA	40.35
January 25,2000	(1) 0.02	NA	NA	47.40
January 26, 2000	(1) 0.02	NA	NA	42.45
June 27, 2000	(0)	NA	NA	54.55

Table 1-6 (cont.). Results of Pettit Lake horizontal gillnet samples 2000.

Date	(n)CPUE	Mean Length (mm)	Mean Weight (g)	Gillnet Hours
Whitefish				
January 24, 2000	(0)	NA	NA	40.35
January 25, 2000	(1) 0.02	NA	NA	47.40
January 26, 2000	(0)	NA	NA	42.45
June 27, 2000	(8) 0.15	NA	NA	54.55
Northern Pikeminnow				
January 24, 2000	(6) 0.15	206	121	40.35
January 25, 2000	(0)	NA	NA	47.40
January 26, 2000	(1) 0.02	NA	NA	42.45
June 27,2000	(62) 1.14	219	152	54.55

Diet Analysis

The stomachs of 10 rainbow trout (RBT) caught during Pettit Lake gillnet efforts (2 in January, and 8 in June) were analyzed for diet comparison. No *O. nerka* were found in the stomachs of any of the 10 RBT. The diet of the 8 RBT captured in June was composed of 11% plant matter, 23% mollusks, 32% terrestrial insects, 14% coleopterans, 14% odonates, 3% tricopterans, 2% hemipterans, and 1% chironomid pupae (Figure 1-14).

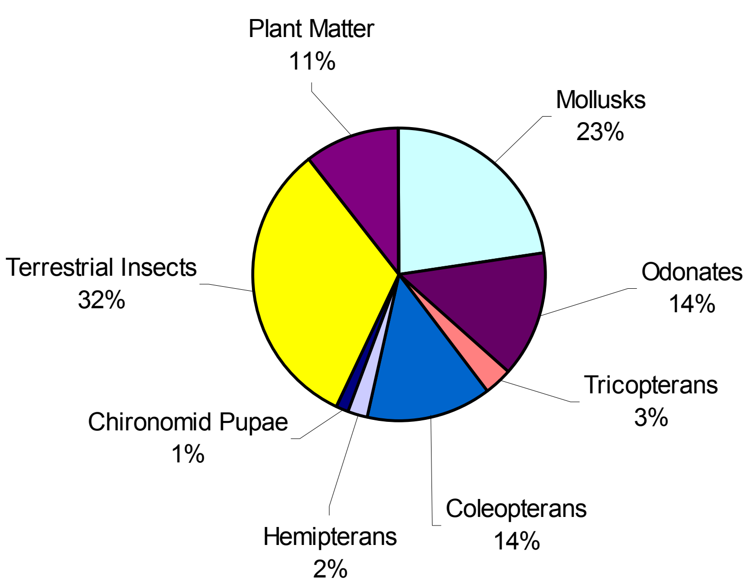

Figure 1-13. Diet of RBT captured on 28 June 2000 (n=8).

Diet analysis was conducted on kokanee that were collected by IDFG trawl sampling in September 2000 (Pettit Lake n=21, Redfish Lake n=5, and Alturas Lake n=32). Kokanee mean size for each lake was as follows: Pettit Lake fork length of 162 mm (range 112-184 mm) and mean weight of 40.7 g (range 13.8-57.3 g); Alturas Lake mean fork length of 92 (range 41-148 mm) and mean weight of 9.3 g (range 0.6-29.9 g); and Redfish Lake mean fork length of 64.2 mm (range 42-91) and mean weight of 3.2 g (range 1.0-7.4). Alturas Lake kokanee were divided into age classes according to size (age 0 <85 mm, age 1+ >85 mm) in order to quantify potential ontogenetic diet shifts (Figure 1-15). Pettit Lake was eliminated from this comparison because only one size class of kokanee was caught in the trawl. Redfish Lake was not included because only 1 kokanee greater than 85mm (age 1+) was caught in the trawl. Zooplankton biomass by species for Alturas Lake is presented here to aid interpretation. A detailed zooplankton analysis is presented in Chapter 2 of this report.

The diet (percent zooplankton by dry weight) of age 0 kokanee in Redfish Lake was dominated by 84% *Daphnia* sp., representing 41% of the in-lake zooplankton biomass (electivity index of 0.34) (Tables 1-7 and 1-8, Figures 1-15 and 1-16). No age 1+ kokanee were caught in September Redfish Lake trawls.

Similar to Redfish Lake, the diet (percent zooplankton by dry weight) of age 1+ Pettit Lake kokanee was dominated by 75% *Daphnia* sp., representing 29% of the in-lake zooplankton biomass (electivity index 0.45) (Tables 1-7 and 1-8, Figures 1-15 and 1-16). No age 0 kokanee were caught in September Pettit Lake trawls.

Differences were found in age 0 and age 1+ kokanee diets (percent zooplankton by dry weight) in Alturas Lake. The diet of age 0 kokanee was dominated by 89% cyclopoid copepod, representing 39% of the in-lake zooplankton biomass (electivity index of 0.38) (Tables 1-7 and 1-8, Figures 1-14 and 1-15). The diet of age 1+ kokanee in Alturas Lake was dominated by 66% *Daphnia* sp., representing 41% of the in-lake zooplankton biomass (electivity index of 0.23) (Tables 1-7 and 1-8, Figures 1-14 and 1-15). Diet overlap between age 1+ and age 0 Alturas Lake kokanee in September was 41%.

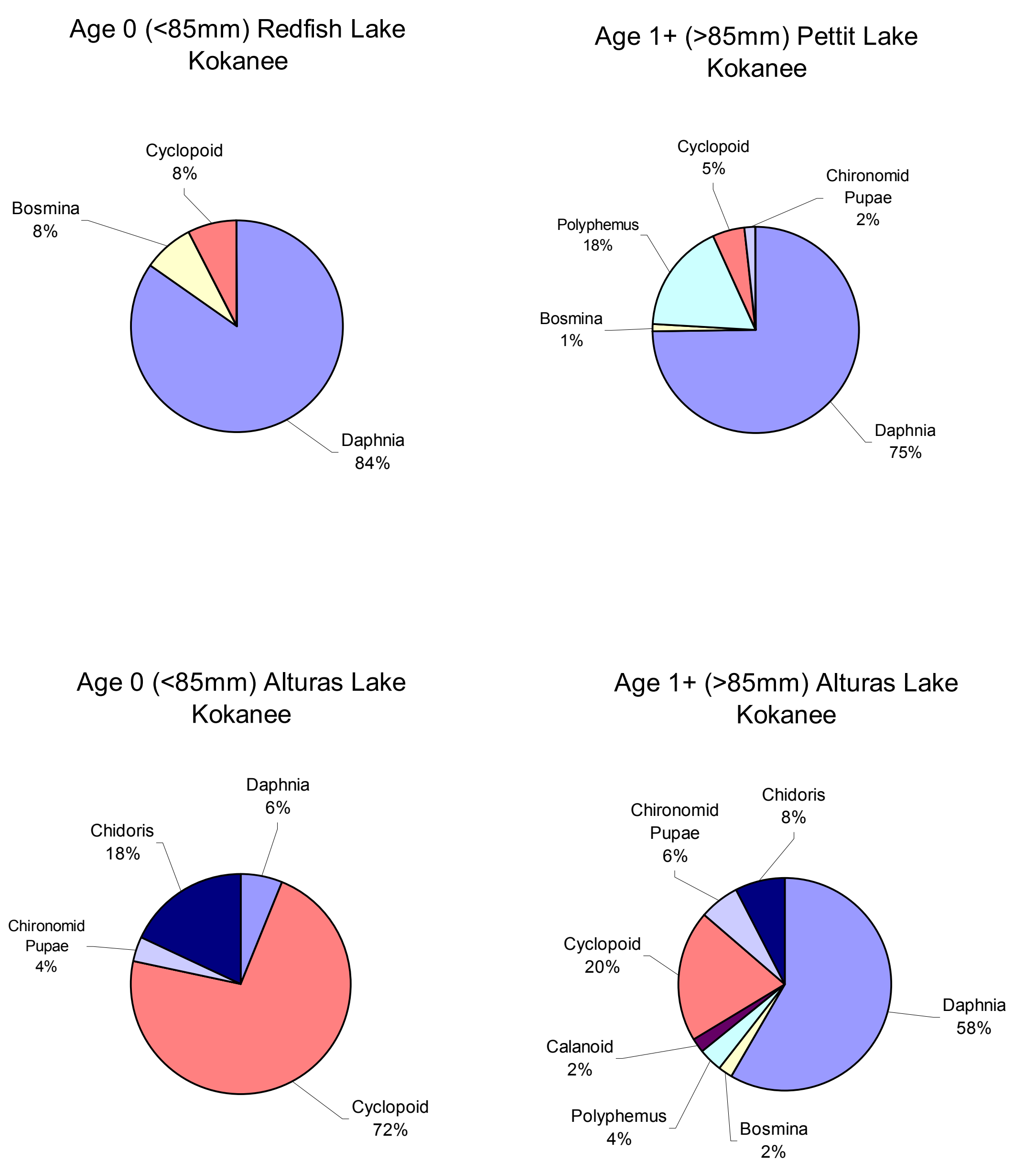

Figure 1-14. Diet of *O. nerka* by age class in September 2000 for Redfish Lake (n=4), Pettit Lake (n=21), and Alturas Lake (age 0, n=14 and age 1+, n=18). Diet is presented as percent composition of prey items.

Table 1-7. Comparison of Alturas Lake kokanee diet by age class (Age 0 and 1+), Redfish Lake (Age 0) diet and Pettit Lake (age 1+) diet from September 2000. Diet is presented as percent dry weight of zooplankton prey species.

	DAPH	HOLO	BOSM	POLY	CYCLOP	CHIRO PUP	CALAN	CHIDORIS
Alturas Lake								
Age 0 (n=14)	6.10	0.00	0.10	0.02	72.08	3.53	0.00	18.17
Age 1+ (n=18)	58.42	0.00	2.00	3.76	19.73	6.15	2.35	7.59
Redfish Lake								
Age 0 (n=4)	84.83	0.00	7.65	0.00	0.00	0.00	0.00	0.00
Pettit Lake								
Age 1+ (n=21)	74.71	0.00	1.12	17.61	4.85	1.70	0.00	0.00

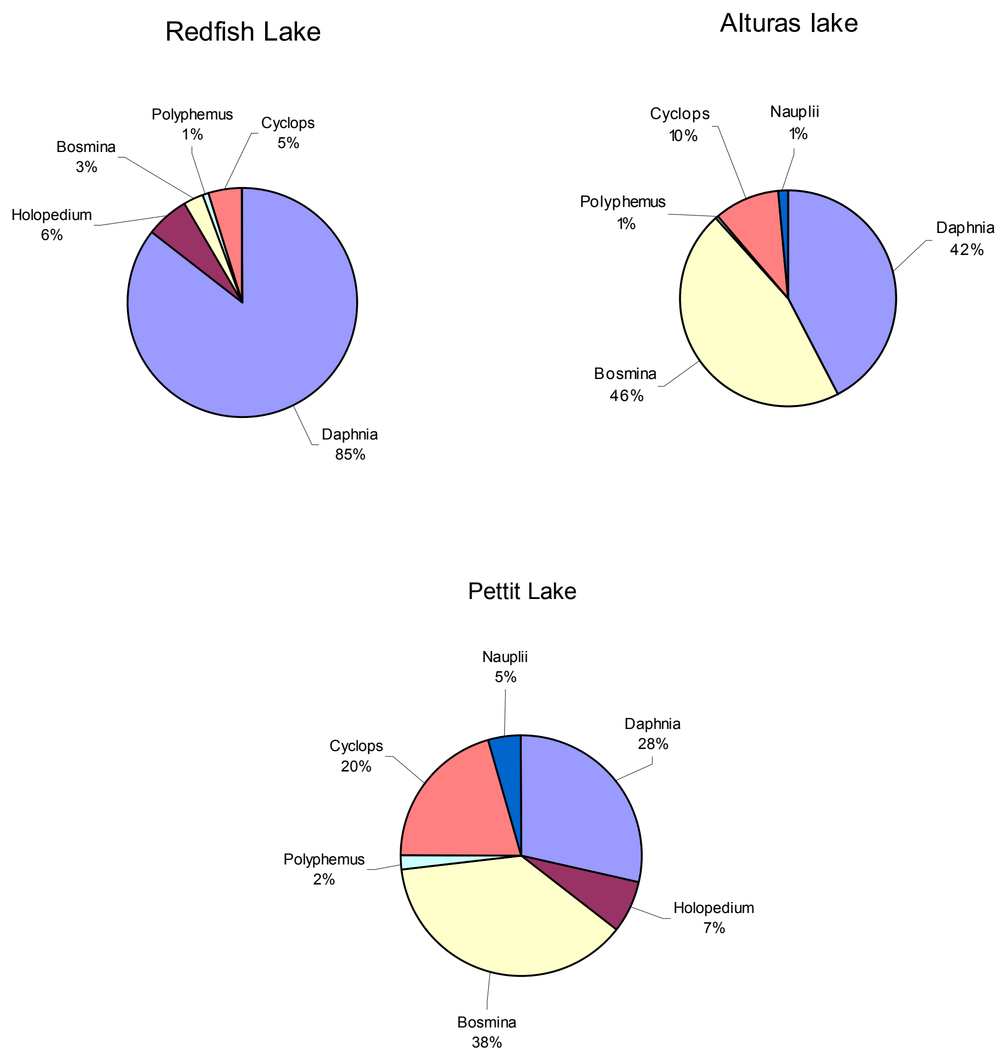

Figure 1-15. Zooplankton species composition by biomass for Redfish, Alturas, and Pettit lakes during September 2000.

Table 1-8. Electivity indices from Redfish, Alturas, and Pettit lakes during September 2000.

	DAPHNIA	HOLOPEDIUM	BOSMINA	POLYPHEMUS	CALANOID	CYCLOPOID	NAUPLII
Redfish Lake							
Age 0	0.34	*	-0.23	*	*	-0.74	-1.00
Alturas Lake							
Age 0	-0.57	*	-0.99	1.00	*	0.38	-1.00
Age 1+	0.23	*	-0.76	1.00	*	-0.18	-1.00
Pettit Lake							
Age 1+	0.45	-1.00	-0.94	0.82	*	-0.61	-1.00

* Prey item not found in fish stomach or lake environment.

There was an average diet overlap of 0.035% for kokanee and rainbow trout in Pettit Lake. This overlap is solely attributed to chironomid pupae. Past diet surveys (Teuscher and Taki 1995) found that chironomid pupae dominated kokanee diets in early summer and shifted to zooplankton domination in late summer

Additional diet analysis was conducted on fish from Pettit Lake that were identified as potential *O. nerka* predators (Table 1-9). An analysis of bull trout diet (n=4 January, n=5 June) found no *O. nerka*. However, their diet did contain some unidentified salmonids (92% in January and 20% in June). Due to the advanced state of digestion these salmonid prey were not identified to species and may have been *O. nerka*. The diet of brook trout (n=7) in January was dominated by 47% salmonids. Again, these may have been *O. nerka* but species level identification was not available. No salmonids were found in stomach samples of brook trout collected in June (n=7). The average diet of northern pikeminnow captured in January (n=3) was composed of 33% cyprinids and 67% Odonates. The average diet of northern pikeminnow captured in June (n=7) was composed of 83% cyprinids, 16% Odonates, and 1% Tricopterans

Table 1-9. Diet by mean percent dry weight of fish caught in Pettit Lake during all of 2000 gillnet sampling.

	SAL	CYPRIN	MOLUS	ODON	TRICOPT	COLEO	HEMIPT	CHIRO	TEREST	PLANT	OTHER
BRK	10.3	40.4	0.0	40.8	5.5	0.0	0.0	1.9	0.0	0.2	0.9
BULL	51.8	38.9	0.9	4.7	0.0	0.0	0.0	0.0	0.0	0.0	3.7
RBT	0.0	0.0	22.9	13.8	3.0	13.6	2.2	1.4	32.5	10.6	0.0
PIKE	0.0	67.9	0.0	31.1	0.6	0.0	0.0	0.0	0.0	0.4	0.0

(BRK= brook trout, BULL=bull trout, RBT=rainbow trout, PIKE=northern pike minnow, SAL=salmonid, CYPRIN=cyprinid, MOLUS=mollosca, ODON=odonate, TRICOPT=tricoptera, COLEO=coleoptera, HEMIPT=hemiptera, CHIRO=chironomid pupae, TEREST=terestrial insect, PLANT=plant material)

Stream Spawning

Using a modified area under the curve (AUC) method, kokanee escapement for 2000 was estimated for Fishhook Creek (60), Alturas Lake Creek (827), and Stanley Lake Creek (5,665) (Table 1-10, Figure 1-17).

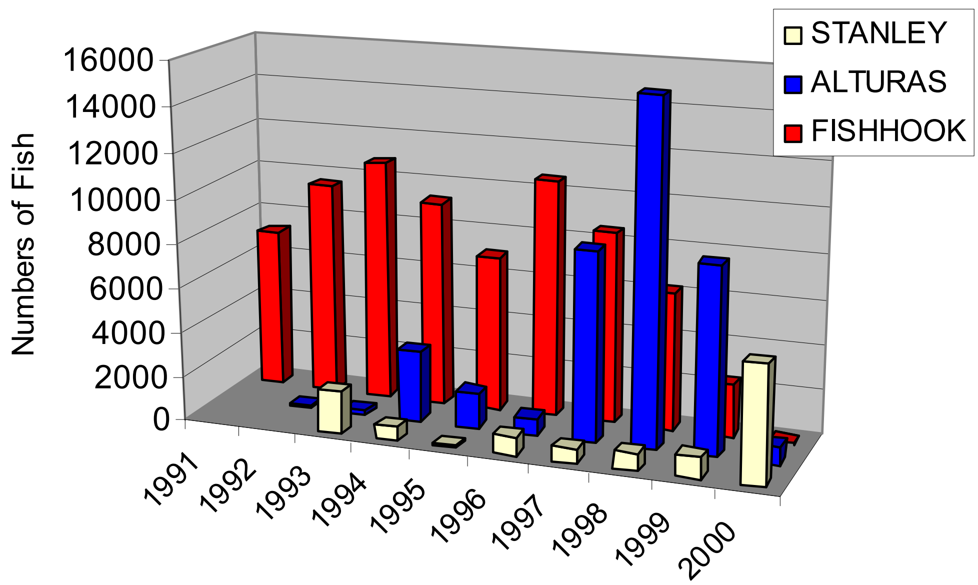

Figure 1-16. Kokanee escapement estimates for Stanley, Alturas, and Fishhook creeks.

Alturas Lake Creek

The 2000 Alturas Lake Creek spawning kokanee population (827 fish) was down approximately 90% from escapement numbers seen in 1999 and down approximately 95% from escapement numbers in 1998. Spawning populations have been variable in Alturas Lake Creek, ranging from a low of 60 in 1992 to a high of 15,237 in 1998. In 2000 the escapement timing for 20, 50, and 80% of kokanee to enter the creek (Table 1-11) was later (5, 3, and 2 days, respectively) than the mean for all years combined. Escapement estimates for Alturas Lake Creek were calculated from field counts between 22 August and 12 September 2000. Assuming equal sex ratios, there was an estimated female escapement of 414 fish in 2000. Mean fecundity was estimated in 2000 at 339 eggs per female (n=12). Female kokanee (n=25) had a mean fork length of 256 mm (range 240-275) and a mean weight of 156 g (range 147-173). Male kokanee (n=27) had a mean fork length of 257 mm (range 239-273) and a mean weight of 179 g (range 134-219 g). At 339 eggs per female, there were an estimated 140,177 eggs deposited in Alturas Lake Creek. Using a 13% egg-to-fry survival rate (Teuscher and Taki 1995) there were an estimated 18,223 fry were produced from the 2000 spawning activities (Table 1-10).

Stanley Lake Creek

The 2000 Stanley Lake Creek spawning kokanee population (5,665) was up 498% from the 1999 escapement estimate (Figure 1-17). Escapement timing for 20, 50, and 80% of kokanee to enter the creek (Table 1-11) was later (approximately 4, 9, and 15 days, respectively) than the 1992-99 mean. Escapement estimates for Stanley Lake Creek were calculated from field counts made every three days from 28 July to 14 September. Female kokanee (n=11) had a mean fork length of 222 mm (range 209-232) and a mean weight of 98 g (range 78-134). Male kokanee (n=10) had a mean fork length of 231 mm (range 215-250) and a mean weight of 126 g (range 89-173 g). Assuming equal sex ratios, the escapement estimate for kokanee females in 2000 was 2,833 fish. Using a mean fecundity of 243 eggs per female approximately 688,239 eggs were deposited in Stanley Lake Creek. An estimated 48,181 fry (7% egg-to-fry survival rate) were produced from the 2000 spawning event (Teuscher and Taki 1995) (Table 1-10).

Fishhook Creek

The Fishhook Creek kokanee escapement estimate for 2000 (60 fish) is the lowest recorded on that creek since monitoring started (Figure 1-17). In 2000 the escapement timing for 20, 50, and 80% of kokanee to enter the creek (Table 1-11) was later than the 1992-95 (approximately 16, 10, and 3 days later) and 1996-99 means (approximately 15, 9, and 3 days later). Fishhook Creek escapement estimates were calculated from counts conducted from 6 September to 12 September 2000. Female kokanee (n=11) had a mean fork length of 212 mm (range 200-230) and a mean weight of 90 g (range 73-108). Male kokanee (n=27) had a mean fork length of 209 mm (range 115-230) and a mean weight of 93 g (range 77-110 g). Using a 2.4:1 sex ratio and estimated escapement there were approximately 18 females spawning in the creek with 2,612 eggs (148 eggs per female) deposited. A 12.3% egg-to-fry survival rate (Teuscher and Taki 1995) will produce an estimated 321 fry in the spring of 2001 (Table 1-10).

Table 1-10. 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	2000	60	148	2.4:1	12.3%	321
Fishhook	1999	2,336	233	1:1	12.3%	33,474
Fishhook	1998	6,149	233	4.6:1	12.3%	35,549
Fishhook	1997	8,572	233	1.4:1	12.3%	102,360
Fishhook	1996	10,662	286	3:1	13.1%	99,866
Fishhook	1995	7,000	230	1:1	12.3%	99,015
Fishhook	1994	9,200	230	1:1	13.6%	143,888
Fishhook	1993	10,800	230	1:1	11.5%	142,830
Fishhook	1992	9,600	300	1:1	11.5%	165,600
Fishhook	1991	7,200	300	1:1	3.3%	35,640
Alturas	2000	827	339	1:1	13.0%	18,223
Alturas	1999	8,334	285	1:1	13.0%	154,387
Alturas	1998	15,273	220	1:1	13.0%	217,889
Alturas	1997	8,492	168	1:1	13.0%	92,733
Alturas	1996	744	150	1:1	13.0%	7,254
Alturas	1995	1,600	150	1:1	13.0%	15,600
Alturas	1994	3,200	150	1:1	13.0%	31,200
Alturas	1993	200	-	1:1	13.0%	2,000
Stanley	2000	5,665	243	1:1	7.0%	48,181
Stanley	1999	948	270	1:1	7.0%	16,637
Stanley	1998	783	270	1:1	7.0%	7,399
Stanley	1997	629	270	1:1	7.0%	5,935
Stanley	1996	825	270	1:1	7.0%	7,796
Stanley	1995	90	270	1:1	7.0%	850
Stanley	1994	600	270	1:1	7.0%	5,670
Stanley	1993	1,900	-	1:1	7.0%	19,000

Table 1-11. Escapement timing for Fishhook, Alturas, and Stanley Lake Creeks. Mean number of days past 1 August that 20, 50, and 80% of the total spawning populations had entered each creek. Presented are 1992-1995 mean (except for Stanley, which starts in 1993), 1996-1999 mean, and 2000.

Creek	Mean 1992-1995			Mean 1996-1999			2000		
	20%	50%	80%	20%	50%	80%	20%	50%	80%
Fishhook	21	29	38	22	30	37	37	39	41
Alturas	18	26	33	23	29	35	28	32	37
Stanley	12	18	27	11	17	23	15	24	36

Beach Spawning

On 25 September 2000, snorkel surveys were conducted by two divers at the southeast shore of Redfish Lake starting at 20:55 and finishing at 21:14. Divers recorded 1 adult sockeye, 1 bull trout, 13 whitefish, and 1 unidentified trout. On the same night divers surveyed sockeye beach on Redfish Lake and recorded a total of 63 suckers, 10 redside shiners, 48 whitefish, and 7 northern pikeminnow. A second snorkel survey at the southeast shore was conducted on the night of 3 October 2000 starting at 20:40 and finishing at 21:00. Fifteen adult sockeye, 3 bull trout, and 13 whitefish were observed. On the same night, a snorkel survey was conducted at sockeye beach starting at 21:20 and finishing at 21:55. Fish observed included 1 residual sockeye, 10 adult sockeye, 16 suckers, 12 redside shiners, and 50 whitefish. A third survey was conducted by three divers on 10 October 2000 starting at 20:55 and finishing at 21:15 at the southeast shore. 35 adult sockeye, 11 bull char, and 6 whitefish were observed while snorkeling. On the same night, snorkel surveys were conducted at sockeye beach starting at 21:40 and finishing at 22:25. Thirty five sockeye, 11 bull trout, and 6 whitefish were observed at the southeast beach and 31adult sockeye, 3 residual sockeye, 4 suckers, 5 bull trout, 15 whitefish, and a northern pikeminnow were observed at sockeye beach. A fourth survey was conducted on 24 October 2000 by 3 divers at the southeast shore starting at 19:58 and finishing at 20:17. Fish observed included 23 adult sockeye, 6 bull trout, 10 whitefish, and a cutthroat trout. On the same evening, 2 divers surveyed sockeye beach starting at 20:36 and finishing at 21:10. One residual sockeye, 15 adult sockeye, 2 suckers, 3 bull trout, and 18 whitefish were observed. A final snorkel survey by 3 divers was conducted on 1 November 2000 at sockeye beach. The survey started at 19:00 and finished at 19:35. Seven adult sockeye, 6 bull trout and 9 whitefish were observed.

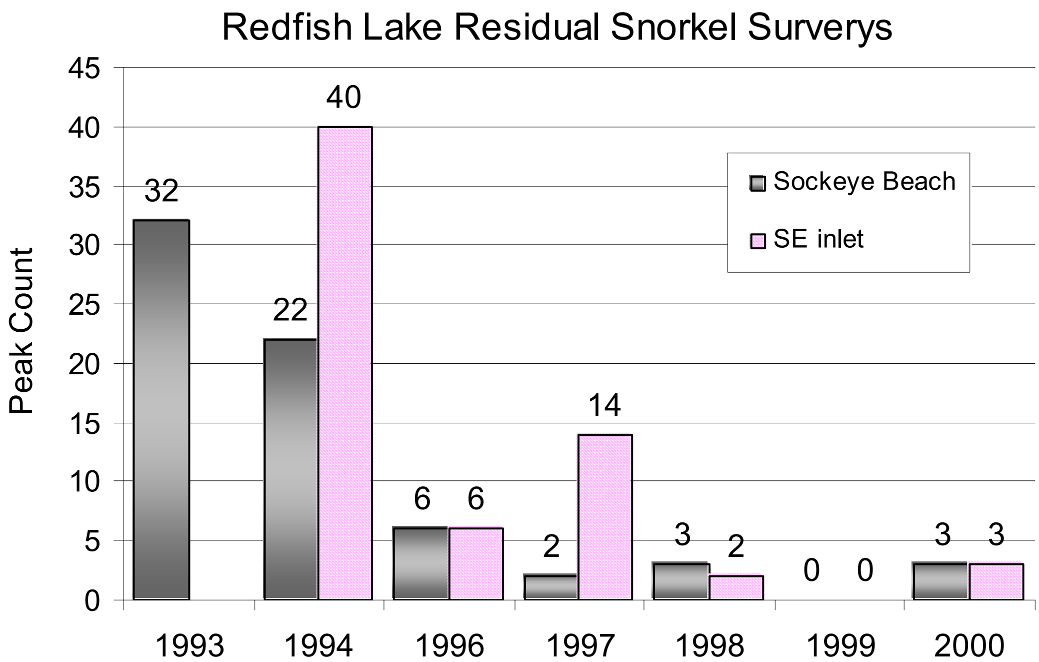

Figure 1-17. Redfish Lake residual *O. nerka* counts from snorkel surveys (1995 data not available).

DISCUSSION

Growth Rates

Growth rates of stocked *O. nerka* from the captive rearing program may provide further insight into potential performance differences associated with hatchery origin and lake rearing conditions. However, these results should be viewed with caution owing to the historic organization of the stocking strategy. Fish grew significantly faster in Redfish Lake compared to fish released into Alturas Lake during 1999-2000. Total estimated zooplankton biomass in Redfish Lake is lower than that of Alturas Lake from October 1999 to May 2000 (55.4 and 33.2 *u*g/l respectively). Yet stocked *O. nerka* have significantly higher growth rates in Redfish Lake compared to Alturas Lake. It is unclear if this is due to hatchery origin or lake differences. Possible explanations include factors such as foraging efficiency, zooplankton community dynamics, and fish community dynamics, which could be affecting growth rates of these fish

Diet Analysis

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

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

The selection by age 1+ kokanee in Pettit and Alturas lakes for *Polyphemus* sp., a poorly represented species, may be the result of several factors. Larger age 1+ kokanee may be less susceptible to predation and have more opportunity to seek *Polyphemus* sp. throughout the water column. *Polyphemus* sp. is a larger bodied organism than cyclopoid copepod or *Bosmina* sp. and may represent a prey item of greater food value. The trade-off of higher food value could make the increased search time metabolically advantageous.

Stocked juvenile sockeye from the captive rearing program were found in the stomachs of stocked rainbow trout (*O. mykiss*) in Pettit Lake during 1995, the first year that sockeye were stocked into that lake (Teuscher and Taki 1996). The sockeye were released at the boat ramp in the littoral zone. After detection of *O. nerka* in *O. mykiss* stomachs, the stocking strategy was modified to a pelagic release using a barge. Since the pelagic release was implemented, annual (1996-00) *O. mykiss* diet analysis has been used to monitor potential predation on stocked *O. nerka*. During that monitoring no subsequent predation of *O. nerka* by *O. mykiss* has been detected in Pettit Lake.

Northern pikeminnow are known to prey on juvenile salmon and are the subject of control efforts in the main stem of the Columbia River. Northern pikeminnow are one of the more abundant species found in the sockeye rearing/nursery lakes of the Sawtooth Valley. There has been concern expressed about their potential predation on stocked juvenile sockeye. Diet analysis has found that while piscivorous (cyprinids composed 68% of prey items in 2000, Table 1-9) there has been no evidence of predation on *O. nerka* by northern pikeminnow. During gillnet sampling, the majority of northern pikeminnow are caught in the littoral zone of the lakes. *O. nerka* are primarily a pelagic species. The low degree of habitat utilization overlap may limit the opportunity for northern pikeminnow to predate on *O. nerka*. Predation by northern pikeminnow is not currently considered a problem. Ongoing monitoring of northern pikeminnow populations and diet is warranted in order to detect any potential changes.

Bull trout are the top piscivorous predator of the fish community in the Sawtooth Valley lakes. Monitoring associated with this program has found that bull trout diet is composed primarily of fish prey (Taki et al. 1999). However, no *O. nerka* have been detected in any of the samples. Salmonids, too digested to be identified, were found in some of the samples and some may have been *O. nerka*. Bull trout 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 take during gillnet sampling is anticipated. This will allow for monitoring of bull trout population dynamics.

Stream Spawning

Kokanee escapement in 2000 showed variation in population densities, timing, and fecundity. The Fishhook Creek kokanee spawning population has been declining since 1996 when escapement was estimated to be 10,662. This years spawning population was estimated at 60 individuals, down from 2,336 in 1999 and approximately 99% below the 1991-1999 mean of 7,947. The Alturas Lake Creek kokanee escapement estimate was down from 8,334 in 1999 to 827 in 2000 and is 83% below the 1991-1999 mean of 4,733. While spawning populations declined in both Fishhook Creek and Alturas Lake Creek, the Stanley Lake Creek kokanee population increased significantly from 948 in 1999 to 5,665 in 2000, 586% above the 1991-1999 mean of 825, Kokanee escapement timing was later in Fishhook, Alturas Lake, and Stanley Lake creeks than previous years. The time at which 20, 50, and 80% of the kokanee had entered Fishhook Creek was 16, 10, and 3 days later than the 1992-1999 mean. The time at which 20, 50, and 80% of the kokanee had entered Alturas Lake Creek was 5, 3, and 2 days later than the 1992-1999 mean and the time at which 20, 50, and 80% of the kokanee had entered Stanley Lake Creek was 4, 9, and 15 days later than the 1992-1999 mean. Alturas Lake Creek female kokanee had higher fecundity compared to previous measurements. The mean number of eggs per female in 2000 was 339, 74% above the 1995-1999 mean. Female kokanee in Fishhook Creek exhibited lower fecundity compared to previous measurements. The mean number of eggs per female in 2000 was 148, 39% below the 1995-1999 mean. Stanley Lake Creek female kokanee fecundity was 243 eggs per female in 2000. Previous estimates used 270 eggs per female. Based on variation in Alturas Lake and Fishhook creek kokanee fecundity all three populations should be measured annually. Length, weight, and condition factor should also be measured in order to quantify changes that could be associated with lake fertilization, meteorological forcing, and changes in population dynamics.

Beach Spawning

Night snorkel surveys along Sockeye Beach and at the south end of Redfish Lake were implemented in 1993 to monitor the densities and spawning activities of residual *O. nerka* and adult sockeye. There has been a steady decline in the number of residual *O. nerka* since the surveys began. Five residuals were observed in 1998 (two during one survey and three on another), no residuals were observed in 1999, and only 6 residuals were observed in 2000. The 2000 residual spawner estimate is 71% below the 1993-1999 mean of 21 spawners.

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Chapter 2: Limnology of the Sawtooth Valley Lakes, 2000

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INTRODUCTION

In December 1991, the National Marine Fisheries Service listed Snake River sockeye salmon (O*ncorhynchus nerka*) as endangered under the Endangered Species Act (Waples et al. 1991). As a result, the Sawtooth Valley Project was initiated to conserve and rebuild sockeye salmon populations in the Sawtooth Valley Lakes (Redfish, Pettit, Alturas, and Stanley lakes). The recovery strategy was to increase the number of juvenile sockeye salmon rearing in the nursery lakes using hatchery broodstocks (Flagg et al. 1998, Kline and Willard 2001), improve growth and survival of juvenile sockeye salmon, and increase lake carrying capacities via lake fertilization (Griswold et al. 2001, Stockner and MacIsaac 1996).

During 1993 and 1994, Utah State University conducted mesocosm studies to determine the efficacy of supplemental nutrient additions to the Sawtooth Lakes (Budy et al. 1998). Based on the results of these studies, supplemental nutrients were added to Redfish Lake during 1995-1998 and to Pettit and Alturas lakes during 1997-1999. In 2000, none of the Sawtooth Valley Lakes received nutrient supplementation, as the natural carrying capacities of the lakes were believed adequate to support the listed sockeye rearing in the lakes.

In 2000, limnological monitoring was conducted to assess productivity and identify changes in physical and chemical characteristics of the Sawtooth Valley Lakes. The information was used to identify inter-annual variation of physical and chemical characteristics, evaluate the effects of past nutrient supplementation efforts, evaluate sockeye rearing conditions, and determine *O. nerka* carrying capacities of the Sawtooth Valley Lakes. These data are used to make decisions about sockeye salmon stocking rates and their allocation between the different Sawtooth Valley Lakes.

STUDY AREA

The Sawtooth Valley Lakes are located in south-central Idaho near the town of Stanley. The watersheds are located in the Sawtooth Mountains, mostly within the Sawtooth Wilderness Area and administered by the United States Department of Agriculture, Forest Service, Sawtooth National Recreation Area. The Sawtooth Mountains are part of the Idaho batholith, comprised of granitelike rock, consisting of granodiorite, quartz diorite and quartz monzonite (Emmett 1975). The lakes are at a relatively high elevation (1985-2157 m), generally ice covered from January to May and classified as oligotrophic. The ratio of drainage area to lake surface area is 48.6 for Stanley Lake, 22.4 for Alturas, 17.6 for Redfish and 16.9 for Pettit Lake (Table 2-1)(Gross et al. 1993). Morphometric maps of the lakes and descriptions of the lakes and their watersheds are reported in Spaulding et al (1993) and Budy et al. (1993), a map of the study area is in Chapter 1 (Figure 1-1) of this report.

Table 2-1. Physical and morphological features of Redfish, Pettit, Alturas, and Stanley lakes, Idaho.

Lake	Area (km^2)	Volume (m^3x106)	Mean Depth (m)	Maximum Depth (m)	Drainage Area (km^2)	Drainage area/ lake surface area	Water residence time in years (Gross, 1993)
Redfish	6.15	269.9	44	91	108.1	17.6	3.0
Pettit	1.62	45.0	28	52	27.4	16.9	2.2
Alturas	3.38	108.2	32	53	75.7	22.4	1.8
Stanley	0.81	10.4	13	26	39.4	48.6	0.3

METHODS

Redfish, Pettit, and Alturas lakes were sampled once per month in January, March, May, October, and November and twice per month from June through September. These three lakes were stocked with juvenile sockeye salmon from the Redfish Lake captive broodstock in 1999. Stanley Lake was not stocked with sockeye salmon. Stanley Lake was used as a reference lake during nutrient enhancement efforts and continues to be sampled. In 2000, Stanley Lake was sampled once per month in January and May-November. Methodologies and sampling designs were developed by Utah State University (USU) during the initial phase of this project (Budy et al. 1995, Luecke et al. 1996) and later modified by Griswold (1997).

Water temperature (^{o}C), dissolved oxygen (mg/L), conductivity (μ S/cm), Secchi depth (m), compensation depth (m), nutrient concentrations (μg/L), chlorophyll *a* concentrations (μg/L), phytoplankton density (cells/ml) and biovolume (mm^3/L), and zooplankton density (No./L) and biomass (μg/L) were sampled near the middle of each lake. Additional zooplankton samples were collected from two other stations in each lake.

During stratification, water for nutrient analysis was collected from the epilimnion, metalimnion, and hypolimnion. Chlorophyll *a* and phytoplankton samples were collected from the epilimnion, metalimnion, and compensation depth (1% light level). Three discrete samples were collected from each stratum with a three L Van Dorn bottle and mixed in a churn splitter. When lake strata could not be delineated, surface water was collected from 0-6 m with a 25 mm diameter, 6 m long lexan® tube and discrete samples were collected from mid-depth (Redfish = 45 m, Pettit and Alturas = 25 m, and Stanley = 12 m) and 1-2 m above the bottom.

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

Water was collected for nutrient analysis once per month in January, March and May-October. Water was transferred to nalgene bottles that had been rinsed in hydrochloric acid (0.1 *N*) and sample water. Samples were stored at 4^o C while in the field. Water was filtered through 0.45 μm acetate filters at 130 mm Hg for ammonia (NH_4), nitrate (NO_3+NO_2), and soluble reactive phosphorus (SRP) assays. Water samples were then frozen and shipped to the University of California at Davis Limnology Laboratory for analysis. NH_4 was assayed with the indophenol method, NO_3+NO_2 with the hydrazine method, organic nitrogen (TKN) using kjeldahl nitrogen, the calorimetric method was used to determine SRP, and total phosphorus (TP) was assayed by persulfate digestion (APHA 1995). Total nitrogen (TN) concentrations were estimated by adding TKN and NO_3+NO_2.

Chlorophyll *a* samples were stored at 4^o C in the field and then filtered onto 0.45 μm cellulose acetate membrane filters with 130 mm Hg vacuum pressure. Filters were placed in centrifuge tubes and frozen (-25^o C). The filters were 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 with chlorophyll standards. Samples were run before and after acidification to correct for phaeophytin (Holm-Hansen and Rieman 1978). Phytoplankton samples were fixed in Lugol's solution and total cell abundance and bio-volume determined at 1560x magnification using a Zeiss Inverted Plankton microscope following the protocol of Utermohl (1958).

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

Lake an additional haul was made from approximately 85 m to 60 m. Stanley Lake was sampled at 10-0 m and bottom (~26 m) to 10 m. Samples were preserved in 10% buffered sugar formalin. Techniques used to subsample, count, and measure zooplankton were adopted from Utah State University (Steinhart et al. 1994) using techniques and length-weight relationships developed by McCauley (1984) and Koenings et al. (1987).

Seasonal means were calculated from monthly means for June-October. This represents a change from previous years. In past years means were calculated for May-October, however, May values were highly variable depending on the number of days after ice-out that the samples were obtained. To minimize this variability we excluded May samples from seasonal means.

RESULTS

In 2000, mean annual discharge of the Salmon River at Salmon, Idaho (USGS gage 13302500) was 45.4 m^3/s, 18% less than the 1913-2000 average of 55.4 m^3/s (Figure 2-1). Mean annual discharge for the Salmon River at Salmon was below average from 1990 to 1994 and above average each year from 1995 to 1999.

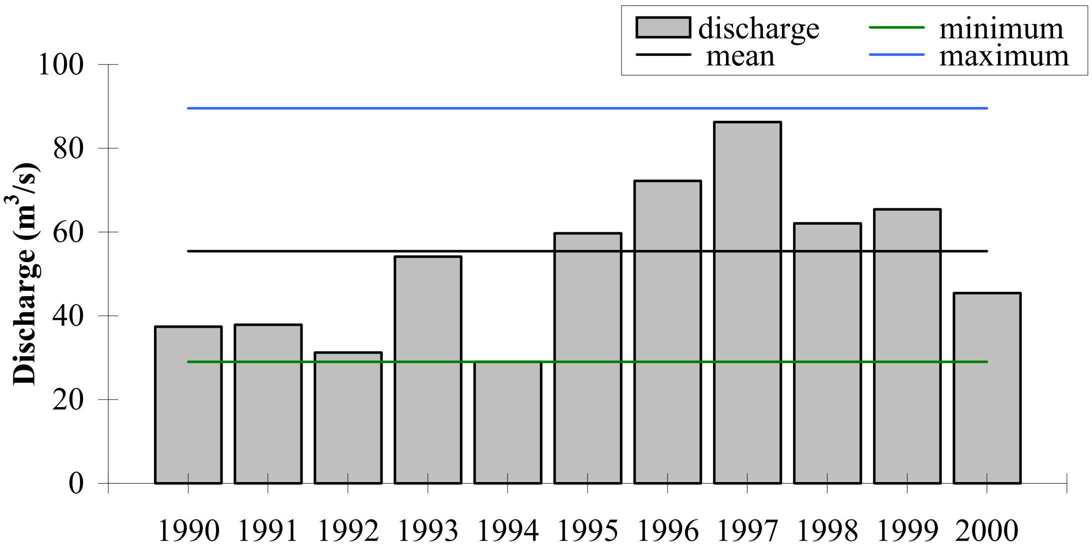

Figure 2-1. Mean annual discharge for the Salmon River at Salmon, Idaho, 1990 through 2000. Minimum, mean and maximum are for period of record, 1913 to 2000.

Profile Data

The Sawtooth Valley Lakes were inversely stratified and ice covered from January to mid May 2000. Thermoclines were well developed from July through October (Figures 2-2a, 2-2b, 2-2c, and 2-2d). The lakes were nearly isothermic by November.

Dissolved oxygen concentrations in the Sawtooth Valley Lakes were generally greater than 5 mg/L, the minimum level that will support growth and survival of salmonids (Lagler 1956). Dissolved oxygen concentrations in Redfish Lake remained above 5 mg/L throughout the entire water column between March and September, then oxygen concentrations fell below 5 mg/L in the bottom 2-3 m during October and November 2000. Pettit Lake, which is meromictic, had dissolved oxygen concentrations less than 5 mg/L below 30 m depth throughout the year. Alturas Lake had low oxygen concentrations in the bottom meter during March. This hypoxic region increased to include the bottom 5 m of the lake by September and the bottom 9 m by November. In Stanley Lake, DO concentrations remained above 5 mg/L throughout the entire water column during spring and early summer. During the summer, dissolved oxygen concentrations declined in the deep waters and by October the bottom 6 m were hypoxic (< 5mg/l). Seasonal declines in dissolved oxygen near the substrates of Redfish, Alturas, and Stanley lakes were less pronounced than in 1998 and similar to those observed in 1999.

Conductivities ranged from approximately 21-25 µS/cm above 30 m depth and 23-45 µS/cm at depths greater than 30 m in Pettit, 25-31 µS/cm in Redfish, 45-55µS/cm in Alturas, and 37-52 µS/cm in Stanley lakes.

Seasonal mean surface (0-10 m) water temperatures were 14.2, 14.4, 13.8 and 12.4 ^{o}C in Redfish, Pettit, Alturas, and Stanley lakes, respectively (Table 2-2). Seasonal mean surface water temperatures were warmer than during the past 4-5 years with above average discharge, but cooler than the extremely low water years of 1992 and 1994.

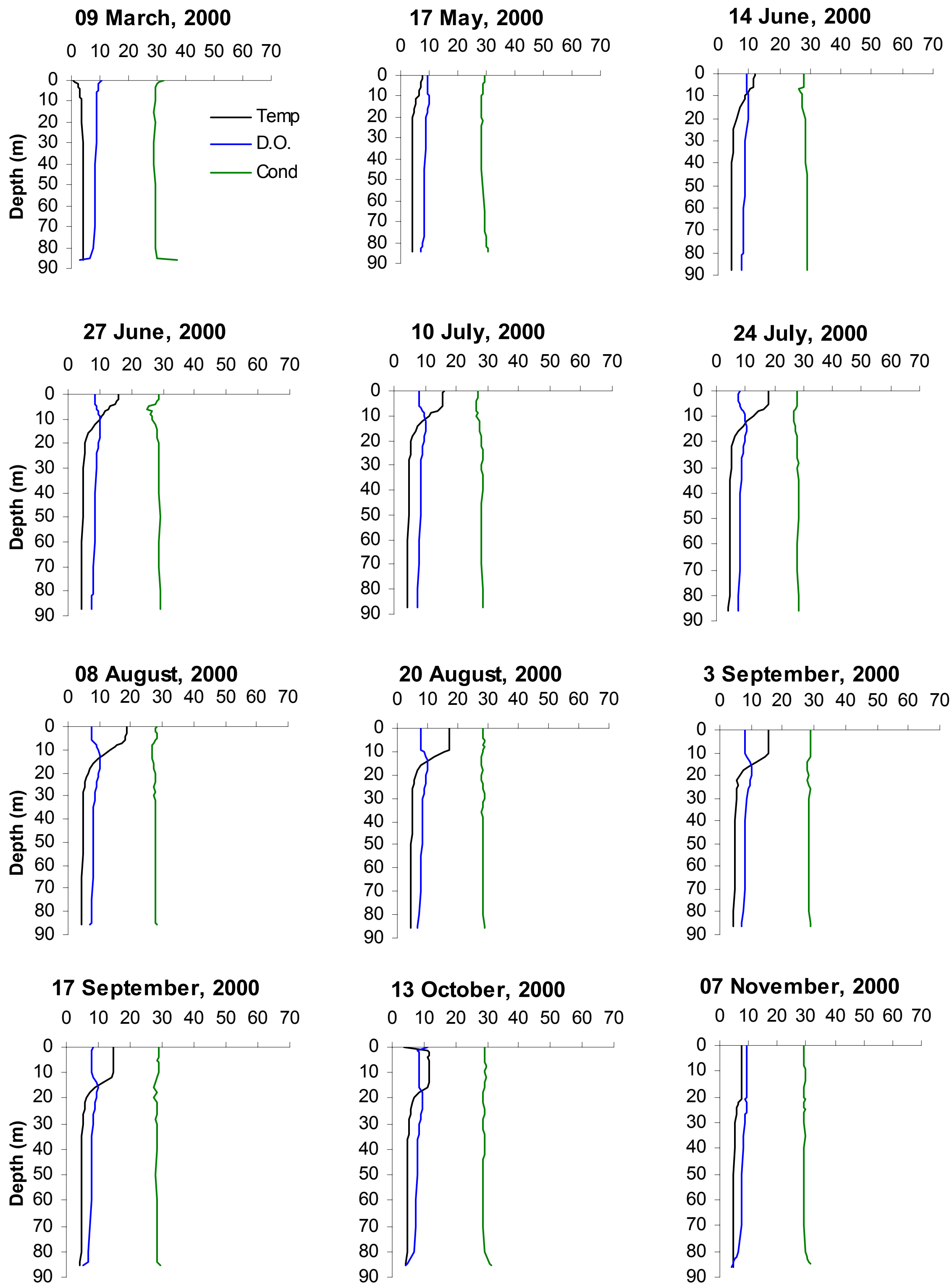

Figure 2-2a. Temperature (°C), dissolved oxygen (mg/L), and conductivity (µS/cm) profiles for Redfish Lake, March through November 2000.

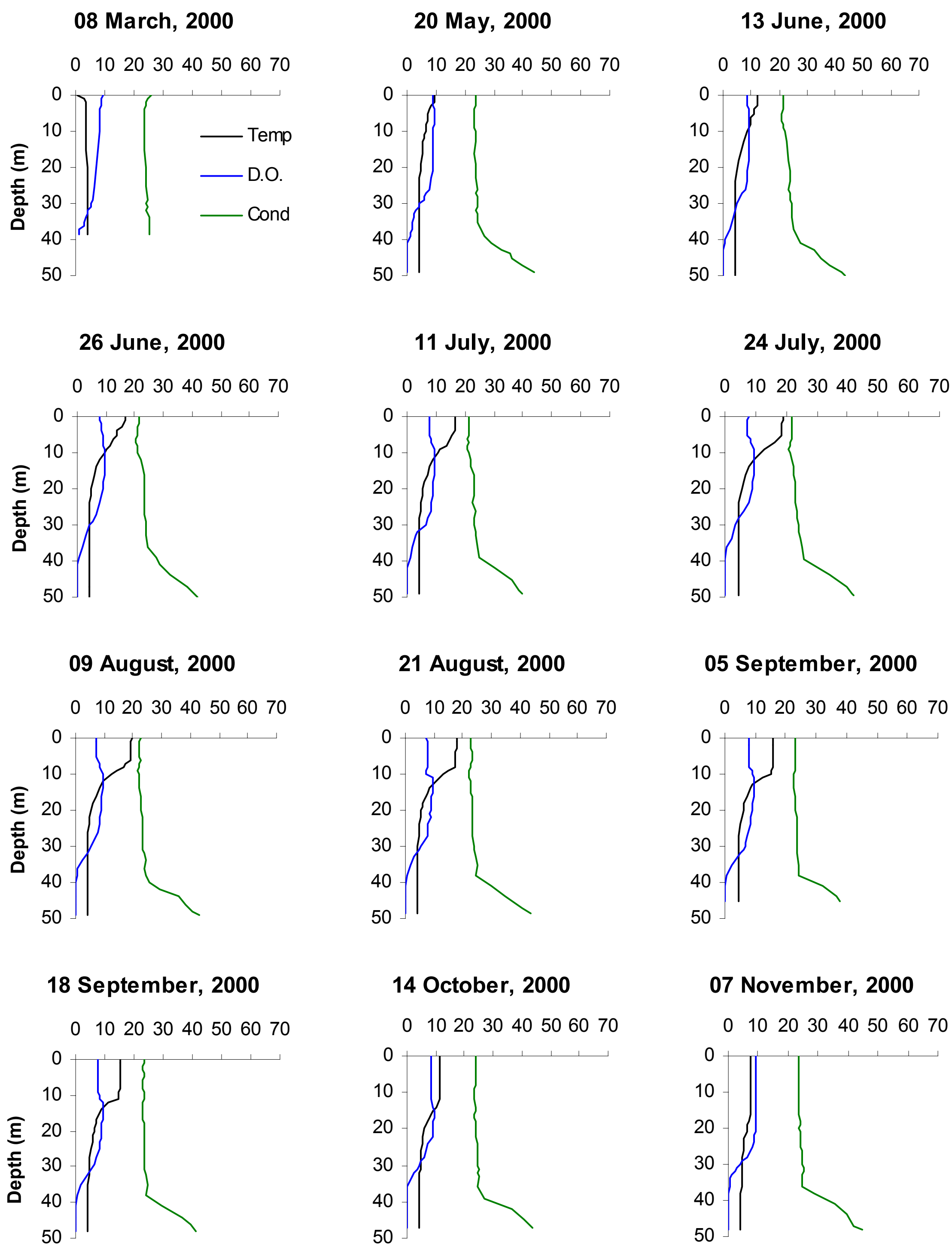

Figure 2-2b. Temperature (^{o}C), dissolved oxygen (mg/L), and conductivity (µS/cm) profiles for Pettit Lake, March through November 2000.

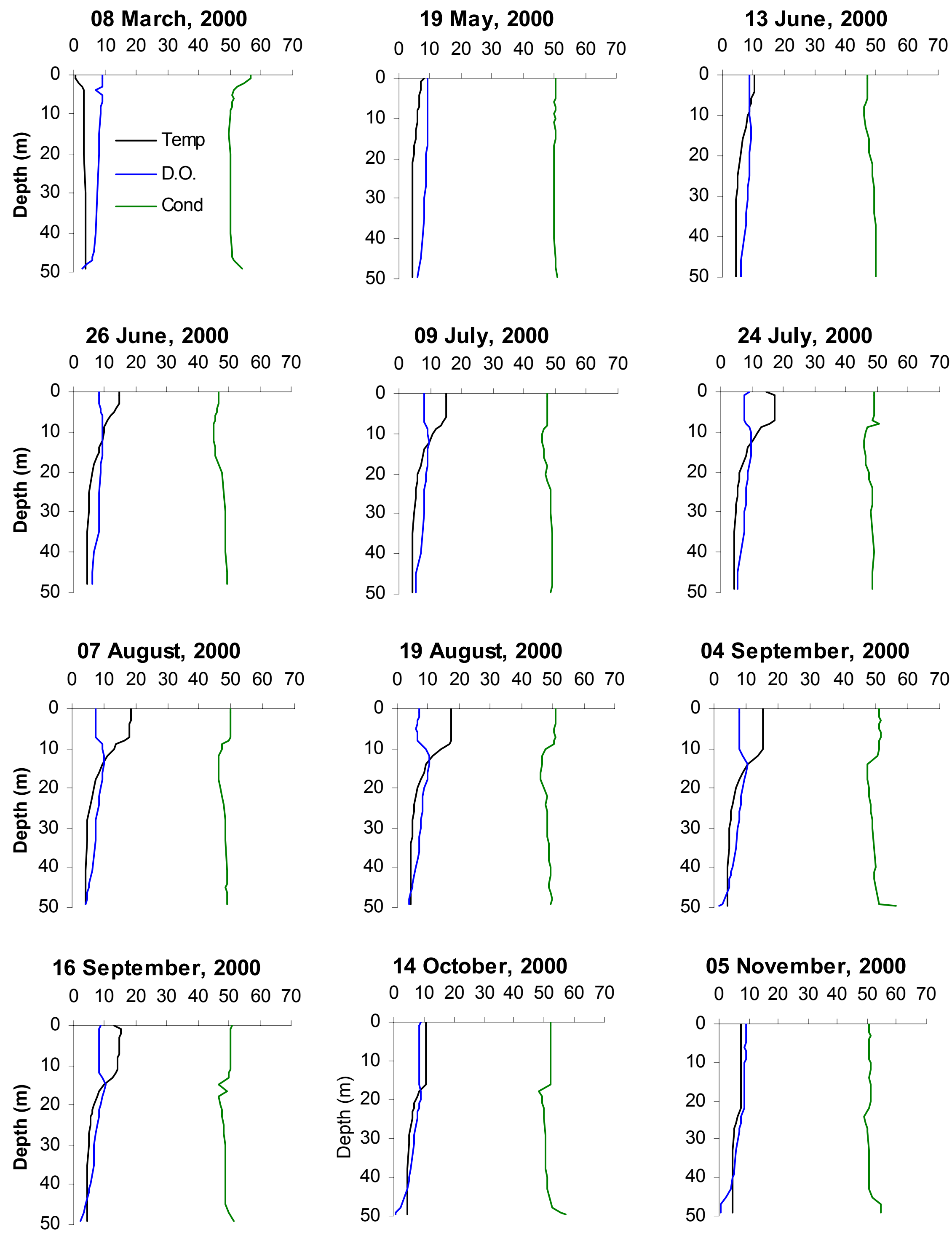

Figure 2-2c. Temperature (°C), dissolved oxygen (mg/L), and conductivity (µS/cm) profiles for Alturas Lake, March through November 2000.

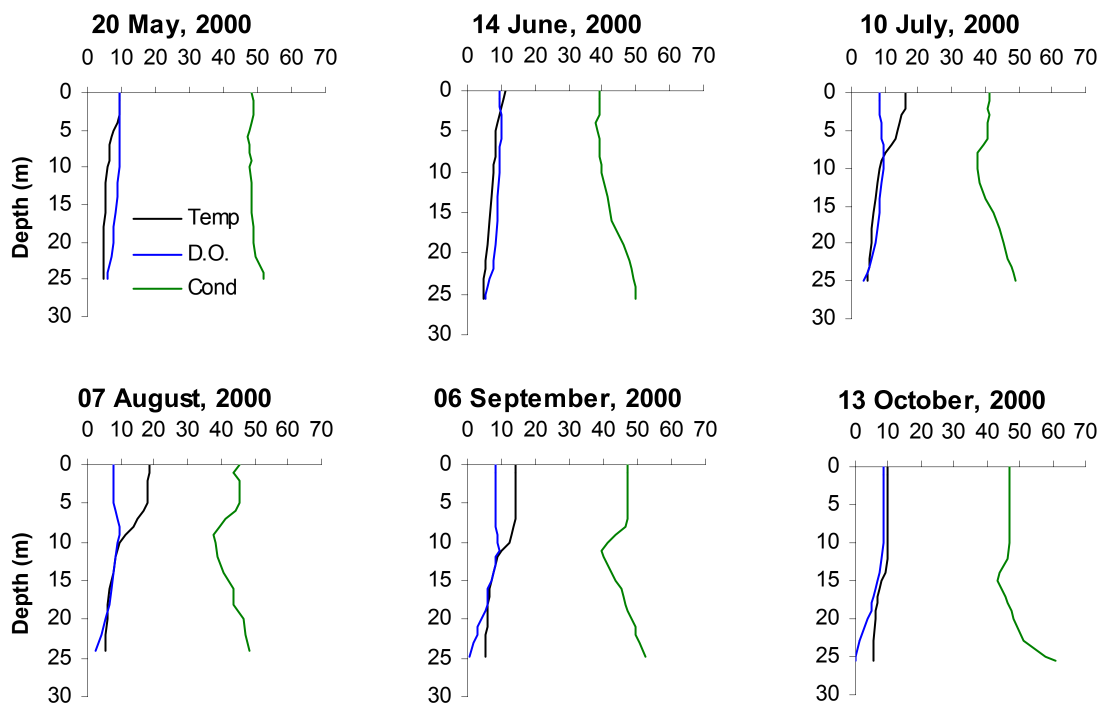

Figure 2-2d. Temperature (°C), dissolved oxygen (mg/L), and conductivity (µS/cm) profiles for Stanley Lake, May through October 2000.

Table 2-2. Seasonal mean (June-October) surface water temperature (^{o}C), Secchi depth (m), compensation depth (m), epilimnetic chlorophyll *a* (µg/L), and whole-lake total zooplankton biomass (µg/L) for the Sawtooth Valley Lakes 1992-2000.

Lake	Year	Surface temperature (^{o}C) 0-10 m	Secchi depth (m)	Compensation depth (m)	Epilimnetic chl *a* (µg/L)	Whole-lake zooplankton biomass (µg/L)
Redfish	**1992**	14.9	13.8	33.3	0.5	-
	1993	13.4	14.0	26.3	0.6	6.9
	1994	14.7	15.8	31.8	0.3	9.9
	1995	13.4	12.1	26.2	0.5	11.3
	1996	12.0	14.1	18.5	0.7	7.5
	1997	12.2	11.4	19.7	1.5	8.1
	1998	13.3	12.1	22.1	1.6	9.9
	1999	12.7	14.6	22.5	0.9	6.8
	2000	14.2	17.8	26.1	0.8	19.1
	mean	**13.4**	**14.0**	**25.2**	**0.8**	**9.9**
Pettit	**1992**	15.1	15.7	29.1	0.4	-
	1993	13.6	14.8	23.3	0.6	23.3
	1994	15.6	15.2	30.8	0.3	28.3
	1995	13.2	12.4	22.2	0.5	3.7
	1996	12.2	11.8	17.4	0.8	9.0
	1997	12.4	11.3	19.1	1.3	11.0
	1998	13.6	10.6	22.6	1.5	9.1
	1999	12.7	11.2	21.7	1.4	13.0
	2000	14.4	15.0	24.5	1.0	12.8
	mean	**13.6**	**13.1**	**23.4**	**0.9**	**13.8**
Alturas	**1992**	14.7	14.4	27.6	0.6	-
	1993	13.1	-	20.6	0.9	0.5
	1994	14.3	14.7	24.1	0.4	3.6
	1995	12.2	9.8	16.5	0.4	3.1
	1996	11.5	10.6	13.6	1.0	6.5
	1997	11.4	10.9	15.7	1.0	12.6
	1998	12.6	10.8	17.3	2.0	12.4
	1999	11.8	10.5	16.9	1.2	12.3
	2000	13.8	14.5	19.8	0.9	5.9
	mean	**12.8**	**12.0**	**19.1**	**0.9**	**7.1**
Stanley	**1992**	14.7	8.6	20.0	0.7	-
	1993	11.9	8.3	15.4	1.1	23.2
	1994	14.6	8.3	16.6	0.5	28.1
	1995	12.0	5.8	11.9	0.8	19.7
	1996	10.7	7.5	10.9	1.0	25.9
	1997	11.5	7.5	13.7	1.2	19.9
	1998	11.8	5.0	11.8	1.0	26.2
	1999	11.1	6.6	11.4	1.6	20.6
	2000	12.4	7.6	13.8	0.8	30.4
	mean	**12.3**	**7.2**	**13.9**	**0.9**	**24.3**

Secchi Depth and Compensation depth

Secchi depths followed seasonal trends similar to previous years with the lowest values observed in May and June. Secchi depths increased as summer progressed with slight reductions during the fall (Figure 2-3). Seasonal mean Secchi depths were deeper than the 9 year average in all four lakes and similar to the low water years of 1992-1994 (Table 2-4). Deeper Secchi depths were likely a result of the low water year combined with the change in methodology (i.e. use of a viewing tube).

Compensation depths in the four Sawtooth Valley Lakes were the shallowest in June after spring turnover and gradually increased throughout the summer and fall (Figure 2-4). Maximum light penetration occurred during summer (July or August) and during November. Seasonal mean light penetration in 2000 was very close to the 9 year average in all four lakes. In general, mean light penetration was less than observed during the dryer, pre-fertilized years (1992-1994) and deeper than mean light penetration in recent years (1995-1999) with higher discharge and nutrient supplementation (Table 2-2).

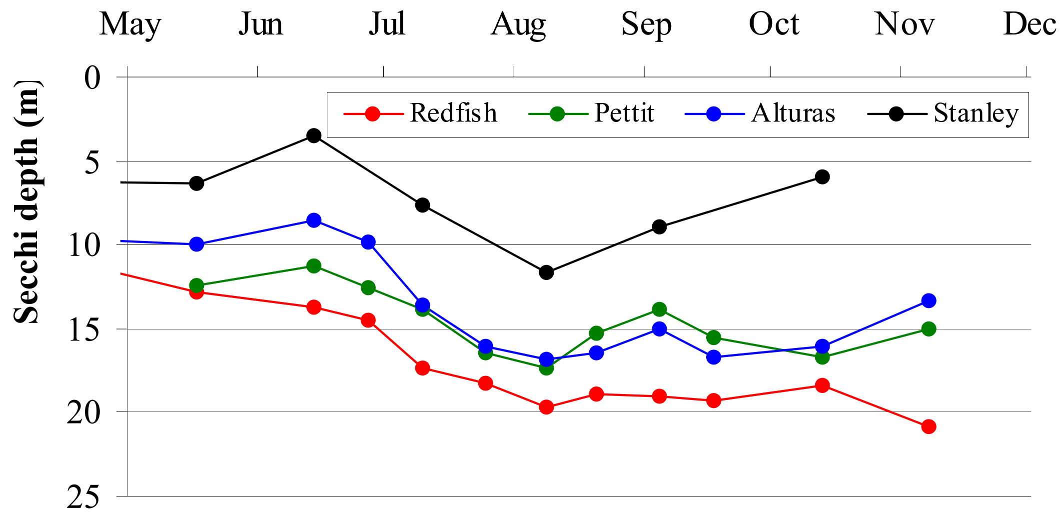

Figure 2-3. Secchi depth (m) for Redfish, Pettit, Alturas and Stanley lakes, May through November 2000.

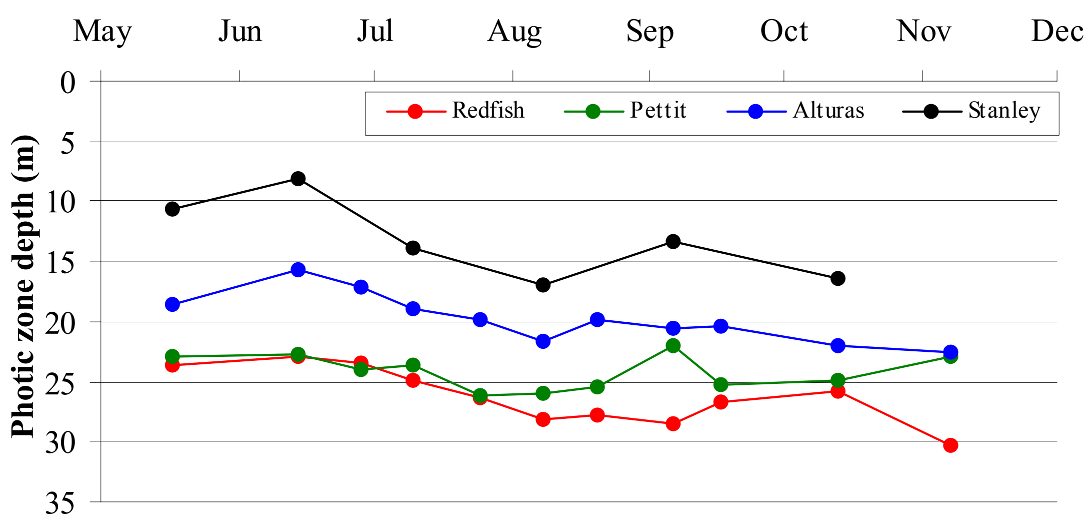

Figure 2-4. Compensation depth (m) defined by the 1% light level for Redfish, Pettit, Alturas, and Stanley lakes, May through November 2000.

Water Chemistry

During spring turnover (May 2000) depth integrated nutrient concentrations remained extremely low, consistent with the oligotrophic condition of the Sawtooth Valley Lakes.

TP concentrations were between 5 and 8 μg/L and TN concentrations were less than 90 μg/L (Table 2-3). Seasonal mean epilimnetic nutrient concentrations were similar to mean values of previous years studied (fertilized and unfertilized). TP ranged from 5-7 μg/L, TN was less than 70 μg/L, nitrate concentrations averaged approximately 2-4 μg/L, and ammonia concentrations were 2-4 μg/L (Table 2-4). Nitrate and ammonia concentrations were near method detections limits during summer stratification (Appendix A). TN/TP ratios were approximately 10-13 in 2000. If we assumed TP bioavailability of 50% the ratios would double to 20-26.

Table 2-3. Nutrient concentrations (µg/L) and TN/TP ratio during late May-early June (after spring mixing) 1992-2000 in Redfish, Pettit, Alturas, and Stanley lakes, Idaho. Concentrations are averages of three discrete depths.

Lake	Year	TP	TN	Nitrate	Ammonia	SRP	TN/TP
Redfish	**1992**	6.5	61.0	5.5	-	1.0	9.5
	1993	8.6	52.7	6.7	-	-	6.2
	1994	5.6	-	-	-	-	-
	1995	5.0	74.2	3.8	2.0	1.0	14.8
	1996	4.8	77.0	12.7	2.3	-	16.1
	1997	6.0	-	17.0	-	-	-
	1998	11.0	82.6	37.0	5.2	1.0	7.7
	1999	6.8	78.4	20.4	2.7	-	11.6
	2000	4.9	84.0	19.0	4.1	-	17.1
	mean	**6.4**	**73.5**	**14.2**	**3.1**	**1.0**	**12.4**
Pettit	**1992**	6.4	94.5	7.0	-	1.0	18.3
	1993	5.8	94.0	4.0	-	-	-
	1994	6.6	-	-	-	-	-
	1995	4.8	88.8	12.0	3.5	1.0	18.4
	1996	5.3	64.3	13.0	7.1	-	11.6
	1997	5.5		16.5	-	-	-
	1998	10.2	48.0	-	0.7	0.9	4.8
	1999	5.9	72.1	6.6	1.9	-	12.3
	2000	5.2	37.7	2.0	0.3	-	7.3
	mean	**6.0**	**72.2**	**8.3**	**2.9**	**1.0**	**14.5**
Alturas	**1992**	10.0	74.0	2.0	-	2.8	7.4
	1993	9.4	72.5	3.3	-	-	8.2
	1994	13.9	-	-	-	-	-
	1995	8.2	66.4	5.8	3.5	1.4	7.7
	1996	6.0	74.6	11.6	2.2	-	12.4
	1997	10.0	-	14.7	-	-	-
	1998	18.1	69.6	17.8	3.1	1.9	3.8
	1999	10.3	77.4	6.6	1.7	-	7.4
	2000	7.5	56.7	5.4	1.8	-	7.6
	mean	**10.2**	**69.6**	**8.5**	**2.6**	**1.7**	**7.8**
Stanley	**1992**	10.5	93.5	5.0	4.0	1.0	8.9
	1993	11.4	129.8	8.5	-	-	12.7
	1994	11.3	-	-	-	-	-
	1995	7.0	103.0	9.2	18.0	1.2	14.8
	1996	6.5	-	-	-	-	-
	1997	7.2	-	9.7	-	-	-
	1998	15.1	78.5	19.0	11.6	1.2	5.1
	1999	14.0	86.4	14.5	2.5	-	6.2
	2000	5.7	82.3	15.0	4.7	-	15.4
	mean	**9.6**	**98.8**	**11.4**	**10.6**	**1.1**	**11.3**

Table 2-4. Seasonal mean (June-October) epilimnetic nutrient concentrations (µg/L) and TN/TP ratio in Redfish, Pettit, Alturas, and Stanley lakes during 1992-2000.

Lake	Year	TP	TN	Nitrate	Ammonia	SRP	TN/TP
Redfish	**1992**	8.6	47.7	6.7		1.8	6.1
	1993	6.4	65.4	1.6	3.2	1.6	10.7
	1994	8.5				2.0	
	1995	7.3	87.1	3.8	6.5	1.8	14.8
	1996	5.0	45.7	0.9	1.2	0.9	10.3
	1997	5.5	67.0	4.9	3.5	-0.3	16.0
	1998	6.2	61.9	7.2	3.4		10.0
	1999	5.2	54.7	3.0	5.1		9.2
	2000	4.9	69.5	1.8	3.3		13.2
	mean	**6.7**	**63.4**	**3.9**	**4.0**	**1.5**	**11.1**
Pettit	**1992**	5.8	84.6	3.6		2.2	15.7
	1993	6.2	70.1	1.7	3.0	1.7	13.6
	1994	6.6				1.0	
	1995	5.8	86.9	1.0	3.0	1.5	16.9
	1996	6.0	42.5	0.5	0.9	0.9	8.0
	1997	5.5	71.6	2.0	2.6	0.0	17.9
	1998	5.4	86.4	1.3	2.3		15.2
	1999	6.3	101.5	2.4	5.0		14.0
	2000	5.3	57.5	1.0	2.7		11.2
	mean	**5.9**	**76.0**	**1.8**	**2.8**	**1.3**	**14.5**
Alturas	**1992**	7.5	84.5	4.3		1.0	10.6
	1993	8.0	88.8	3.2	2.6	1.2	14.3
	1994	11.6				2.4	
	1995	8.5	120.5	2.6	6.6	1.7	16.4
	1996	8.2	61.1	0.5	1.7	1.0	7.9
	1997	8.2	66.6	1.4	1.8	0.3	11.6
	1998	8.2	76.6	1.1	2.8		9.3
	1999	7.9	93.9	1.7	6.6		9.9
	2000	6.3	65.0	2.1	3.9		11.0
	mean	**8.5**	**84.7**	**2.2**	**3.8**	**1.3**	**11.9**
Stanley	**1992**	7.2	89.8	3.4		2.2	12.4
	1993	5.3	76.0	3.0	11.6	1.6	16.1
	1994	9.6				2.7	
	1995	7.9	88.1	2.6	5.4	1.8	11.5
	1996	7.3					
	1997	4.3	57.3	1.3	3.3	-0.5	13.7
	1998	7.6	66.5	1.1	1.8		9.2
	1999	9.9	64.5	5.4	2.6		7.0
	2000	6.8	66.5	1.3	2.0		10.3
	mean	**7.4**	**75.3**	**2.6**	**5.4**	**1.8**	**11.7**

Chlorophyll a and Phytoplankton

In 2000, surface chlorophyll *a* concentrations ranged from 0.2 to 2.4 µg/L in the four Sawtooth Valley Lakes. Chlorophyll *a* concentrations exceeded 1µg/L while the lakes were ice covered. During the ice-free season surface chlorophyll *a* concentrations peaked during May and June, fell to approximately 0.4 µg/L during July and peaked again in October or November (Figure 2-5). Peak chlorophyll *a* concentrations were less than 2 µg/L except in Alturas Lake, which attained a maximum concentration of 2.4 µg/L chlorophyll *a* during November. Seasonal mean surface chlorophyll *a* concentrations ranged from 0.8 to 1.0 µg/L in the four lakes and were similar to the long-term averages but relatively high compared to the low water years of 1992 and 1994 (Table 2-2).

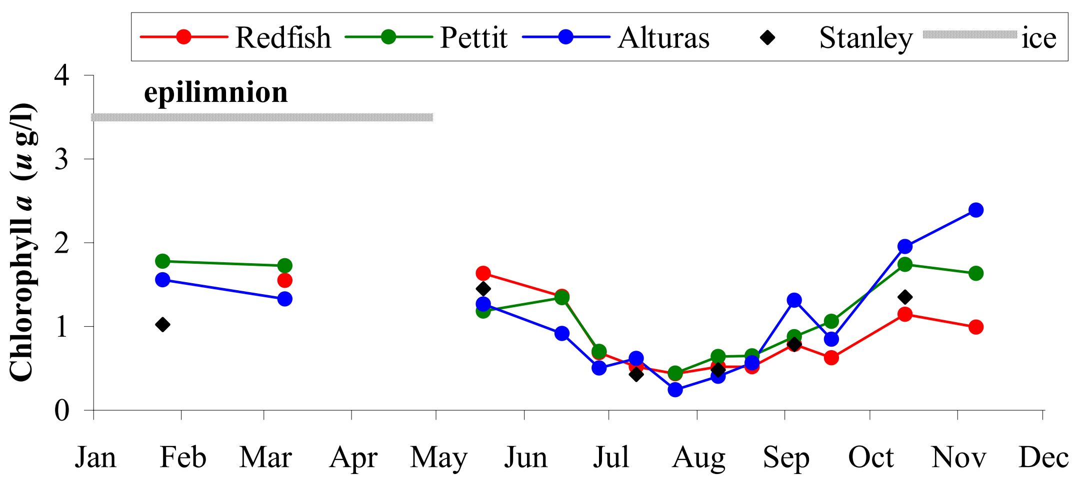

Figure 2-5. Surface chlorophyll *a* concentrations (µg/L) in Redfish, Pettit, Alturas, and Stanley lakes, January-November 2000. Shaded line indicates ice cover.

Phytoplankton communities in the Sawtooth Valley Lakes continued to be dominated by small grazable taxa during 2000. Total phytoplankton densities ranged from 937-23,758 cells/ml and total phytoplankton bio-volume ranged from 0.09 to 1.11 mm^3/L in the four lakes (Table 2-5)(Appendix B). Generally, Chryso- and Cryptophycean nano-flagellates (*Chromulina* sp., *Chrysochromulina* sp., *Rhodomonas* sp., *Dinobryon* sp., *Kephyrion* sp. and *Chryptomonas* sp.) and Cyanophytes (*Synechococcus* sp. and *Oscillatoria* sp.) were numerically dominant. Chryso- and Cryptophycean nano-flagellates (*Chryptomonas* sp., *Dinobryon* sp., *Mallomonas* sp., *Rhodomonas* sp., *Chroomonas* sp. and *Chrysochromulina* sp.), Dinophycean dinoflagellates (*Gymnodinium* sp*. and Peridinium* sp.), and Bacillariophytes (*Cyclotella* sp., *Asterionella* sp., *Fragilaria* sp., and *Ceratoneis* sp.) had the highest bio-volume of any phytoplankton taxa. Chlorophyceans were present in low densities/bio-volume and were split between (*Oocystis* sp., *Cosmarium* sp., *Elakatothrix* sp., *Staurastrum* sp., and *Coelastrum* sp. and *Euglena* sp.). Bio-volume of Cyanophytes was low because of their relatively small size and was comprised of *Synechococcus* sp., *Oscillatoria* sp., *Microcystis* sp. and *Anabena* sp.

Table 2-5. Range of values for phytoplankton density (cells/ml) and bio-volume (mm^3/L) in the epilimnion, metalimnion and at the compensation depth in four Sawtooth Valley Lakes during June-October 2000.

		Density			Biovolume		
Lake	**Strata**	**mean**	**low**	**high**	**mean**	**low**	**high**
Redfish	epilimnion	2,210	1,399	2,950	0.29	0.18	0.37
	metalimnion	2,744	1,784	3,751	0.39	0.24	0.66
	compensation depth	4,083	2,666	8,130	0.80	0.50	1.11
Pettit	epilimnion	2,066	1,308	2,808	0.29	0.17	0.42
	metalimnion	2,065	1,115	3,153	0.28	0.13	0.49
	compensation depth	2,787	1,642	4,369	0.46	0.19	1.01
Alturas	epilimnion	2,238	973	3,832	0.23	0.11	0.46
	metalimnion	2,148	1,368	3,092	0.29	0.14	0.61
	compensation depth	2,652	1,571	5,160	0.40	0.28	0.57
Stanley	epilimnion	5,590	1,561	22,869	0.25	0.09	0.55
	metalimnion	2,800	1,460	4,389	0.24	0.15	0.34
	compensation depth	6,186	1,054	23,758	0.19	0.12	0.29

Zooplankton

In 2000 Stanley Lake had the highest peak and seasonal mean zooplankton biomass followed by Redfish, Pettit and Alturas lakes) (Figure 2.6). Seasonal mean biomass (June-October) was 30.4 µg/L in Stanley Lake, 19.1 µg/L in Redfish Lake, 12.8 µg/L in Pettit Lake and 5.9 µg/L in Alturas Lake. Annual zooplankton biomass peaks occurred during August or September in the four study lakes.

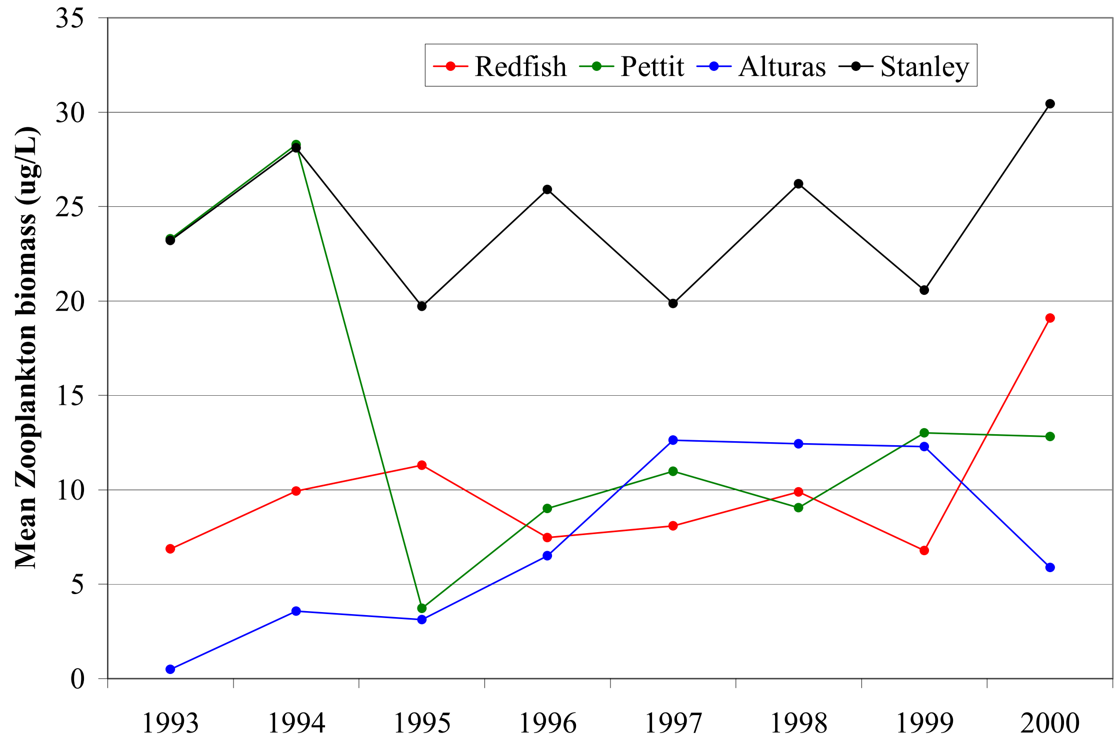

Figure 2-6. Seasonal mean zooplankton biomass (June-October) for the Sawtooth Valley Lakes, 1993-2000.

Redfish Lake zooplankton populations had the highest peak and seasonal mean biomass observed since sampling began in 1992, a result of increased *Daphnia* spp. biomass (Figure 2-7a). Summer biomass was dominated by *Daphnia* spp. (12.2 µg/L) and *Holopedium* spp. (3.1 µg/L). During March, whole-lake zooplankton biomass was 6.9 µg/L and was dominated by *Bosmina* spp. and cyclopoid copepods.

Pettit Lake total zooplankton biomass was similar to biomass observed during 1999 and still depressed compared to 1993 and 1994 (Figure 2-6). Pettit Lake biomass peaked in late August at 26.7µg/L., coinciding with peaks in *Holopedium* spp. and *Bosmina* spp.

biomass (Figure 2-7b). *Daphnia* spp. biomass peaked at 5 μg/L during October. Increased species diversity during the summer of 2000 is a good indicator of a recovery from the 1995 "crash". During January and March 2000, total zooplankton biomass was 1.7μg/L and was predominately cyclopoid copepods and *Bosmina* spp. Winter zooplankton biomass was low in 1999 and 2000 relative to 1992-1998 in Pettit Lake and lower than the other study lakes during winter 2000.

In Alturas Lake mean seasonal total zooplankton biomass declined relative to the past three years (Figure 2-6). Zooplankton populations in Alturas Lake experienced a collapse in the early 1990's, recovered during 1996-1999 and now appear to be declining again (Figure 2-7c). During summer 2000, zooplankton populations consisted predominantly of *Bosmina* spp. and cyclopoid copepods. Total biomass peaked at 13.8 μg/L in late August. *Daphnia* spp. biomass peaked at 4.3μg/L during early September, which was less than the Daphnia peaks observed during the past four years. Total zooplankton biomass during January and March was 3.1μg/L and was mostly composed of cyclopoid copepods and nauplii.

Stanley Lake continues to have relatively stable zooplankton assemblages. Seasonal mean and peak zooplankton biomass was the highest observed to date (Figure 2-6 and Figure 2-7d). During summer 2000, zooplankton species composition was similar to that observed in 1996-1999, with most biomass represented by calanoid copepods and *Daphnia* spp. Seasonal mean *Daphnia* spp. biomass was 13.6 μg/L, higher than previous years studied. Total zooplankton biomass peaked in early August, a result of the seasonal biomass peaks of *Daphnia* spp. and *Holopedium* spp.   In January 2000, total biomass was 3.7 µg/L and was predominately *Daphnia* spp. and calanoid copepods.

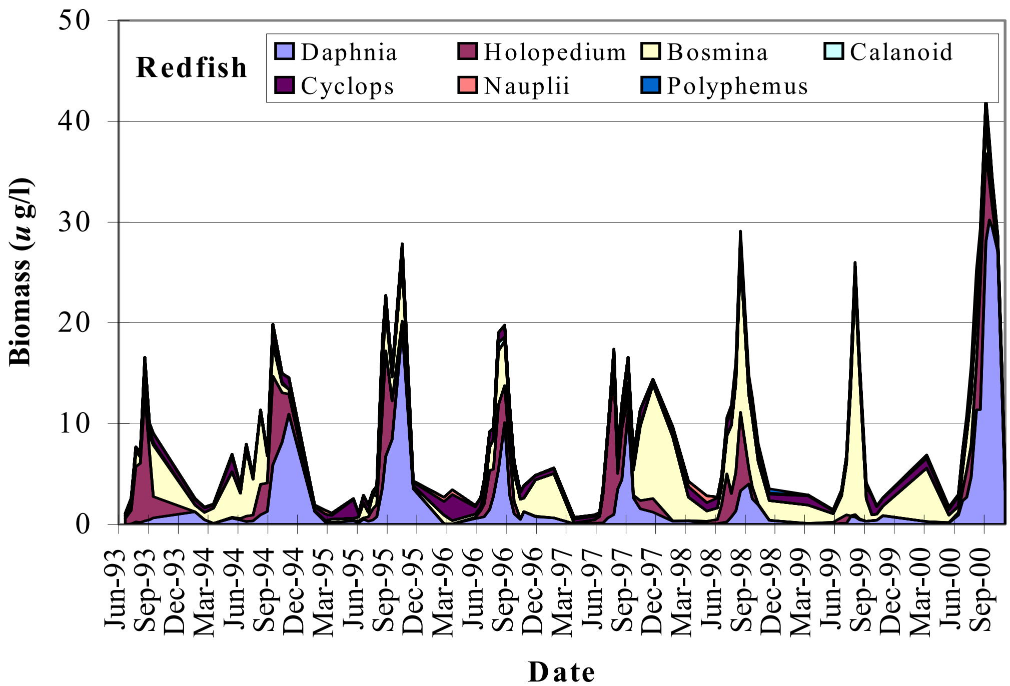

Figure 2-7a. Redfish Lake zooplankton biomass (µg/L) weighted by lake volume, 1993-2000.

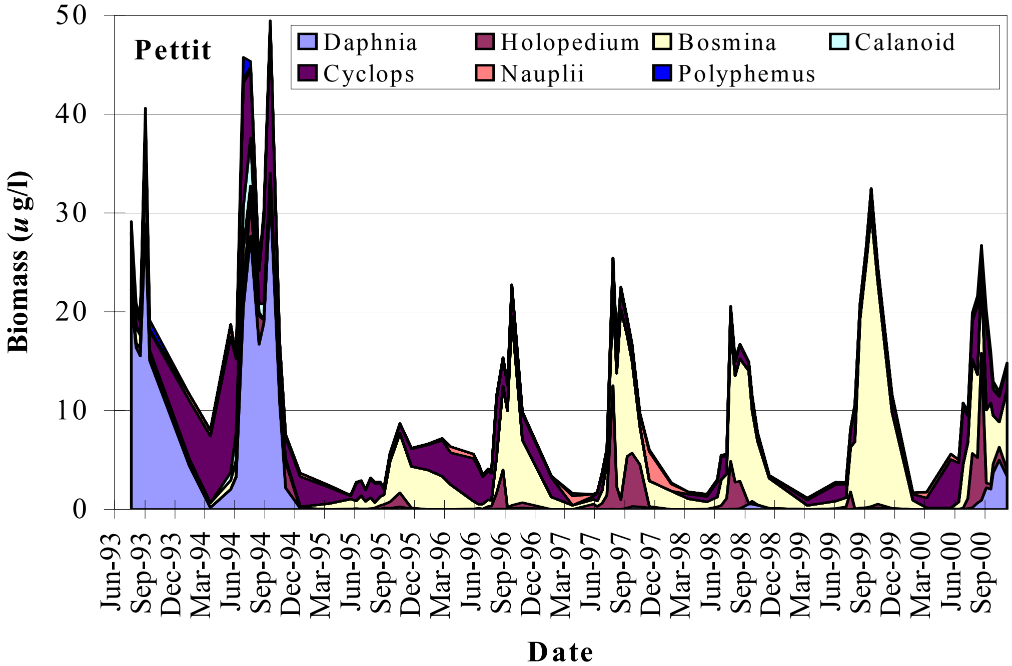

Figure 2-7b. Pettit Lake zooplankton biomass (µg/L) weighted by lake volume, 1993-2000.

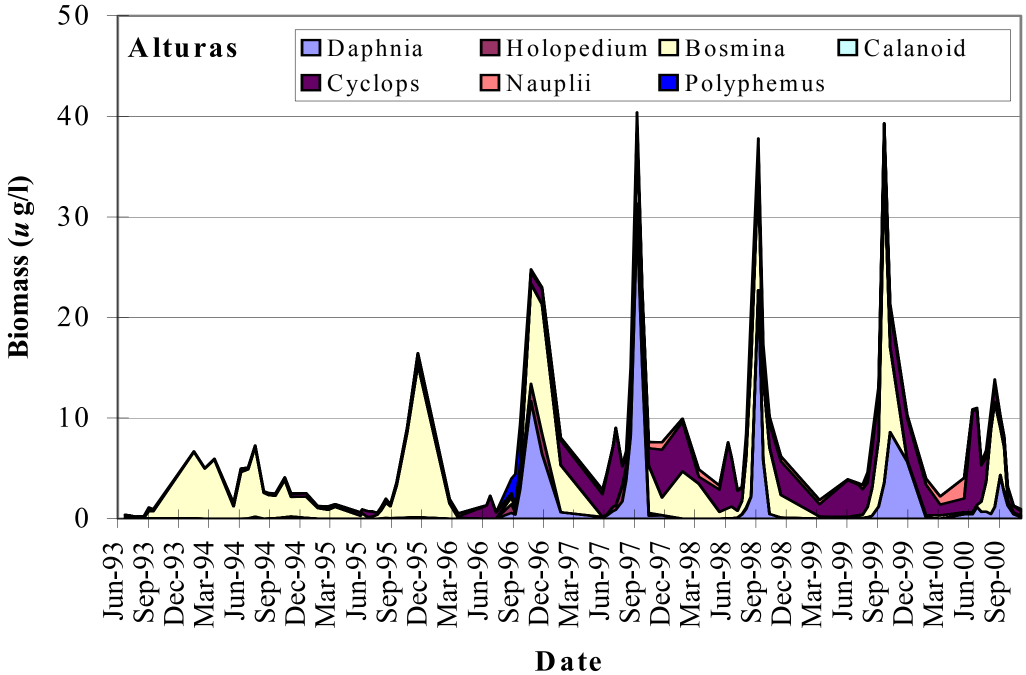

Figure 2-7c. Alturas Lake zooplankton biomass (µg/L) weighted by lake volume, 1993-2000.

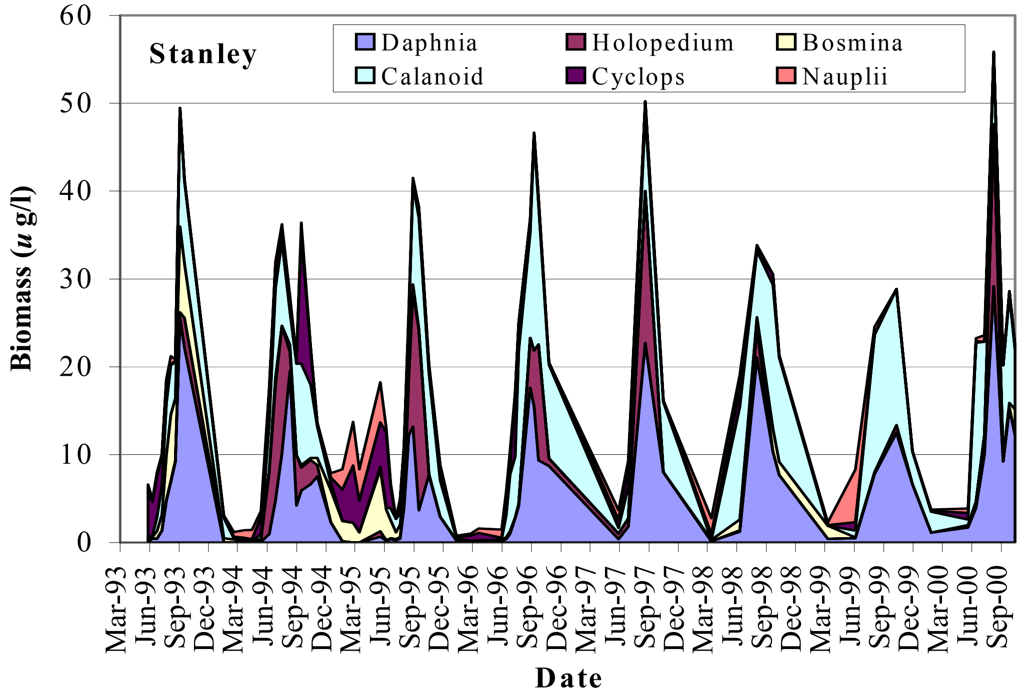

Figure 2-7d. Stanley Lake zooplankton biomass (μg/L) weighted by lake volume, 1993-2000.

DISCUSSION

Hydroacoustic estimates of *O. nerka* populations in the Sawtooth Valley Lakes have shown large fluctuations in kokanee salmon abundance and/or biomass (Chapter 1, Table 1-2). During peaks in kokanee salmon population cycles, intense grazing pressure on macrozooplankton caused striking shifts in species composition and abrupt declines in zooplankton biomass and size, similar to changes observed in Alaskan sockeye lakes under intense sockeye grazing pressure (Koenings and Kyle 1997). In Pettit Lake, kokanee salmon density increased to approximately 480 fish/ha in 1995, zooplankton biomass dramatically declined and species composition shifted from a *Daphnia* dominated system to a *Bosmina* dominated macrozooplankton community (Figure 2-8). Alturas Lake experienced a similar shift during the early 1990's. Zooplankton communities remained depressed for over 5 years following the collapse, recovered during 1996-1999 and in 2000 with *O. nerka* density nearly 400 fish/ha appears to be declining again (Figure 2-7c).

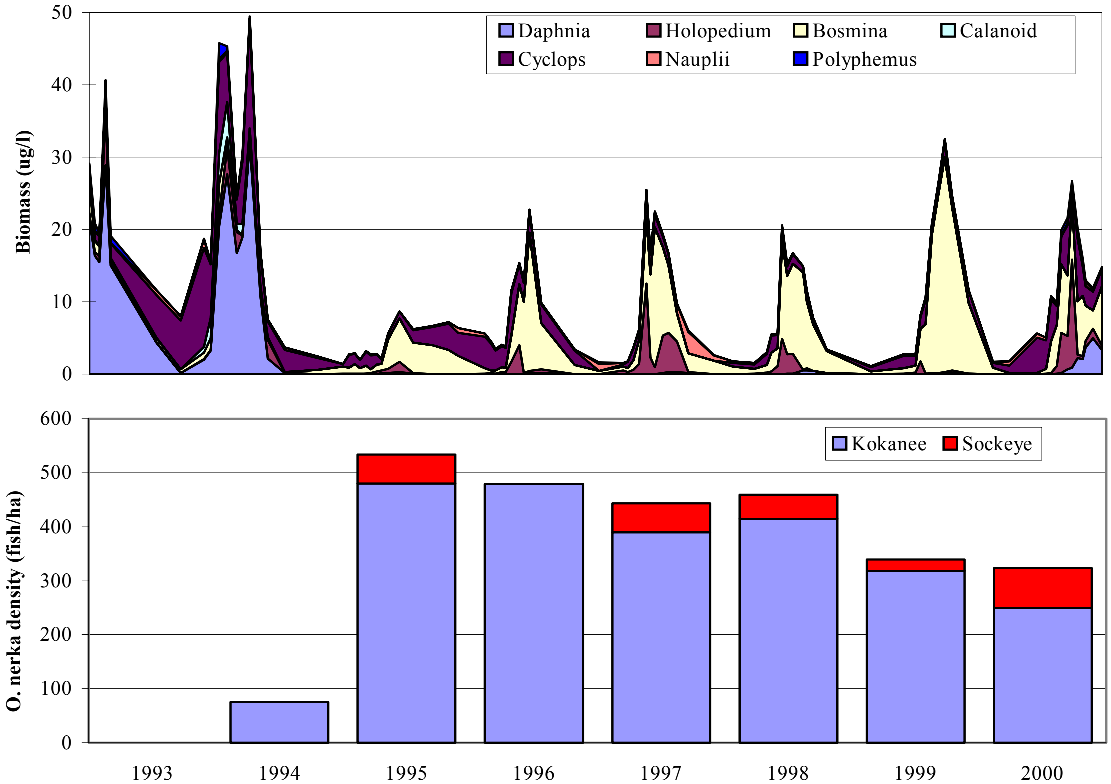

Figure 2-8. Zooplankton biomass (µg/L) and hydroacoustic estimates of *O. nerka* density in Pettit Lake, Idaho, 1993-2000.

Redfish Lake has experienced less dramatic shifts in *O. nerka* abundance (maximum = 214 fish/ha) and consequently the zooplankton assemblages have remained relatively stable. We believe this to be a result of limited spawning habitat relative to lake rearing area, kokanee control and our nutrient supplementation efforts. In order to maintain large bodied cladocerans during summer and fall and cyclopoid copepods during winter for endangered sockeye salmon, kokanee populations should be limited to approximately 200 fish/ha. In Redfish and Alturas lakes, limiting adult escapement to the spawning streams is likely the most efficient and cost effective means to accomplish this goal, however, nutrient supplementation remains a viable alternative, especially when kokanee control efforts fail. In Pettit Lake, kokanee control is not a feasible alternative since spawning occurs during winter at unknown in-lake locations. As a result we will likely continue to experience dramatic shifts in zooplankton species assemblages in Pettit Lake, which may reduce the usefulness of the lake for sockeye recovery. During years with reduced *Daphnia* biomass, recruits from adult volitional spawning or in-lake egg incubators may effectively utilize Bosmina biomass in Pettit Lake.

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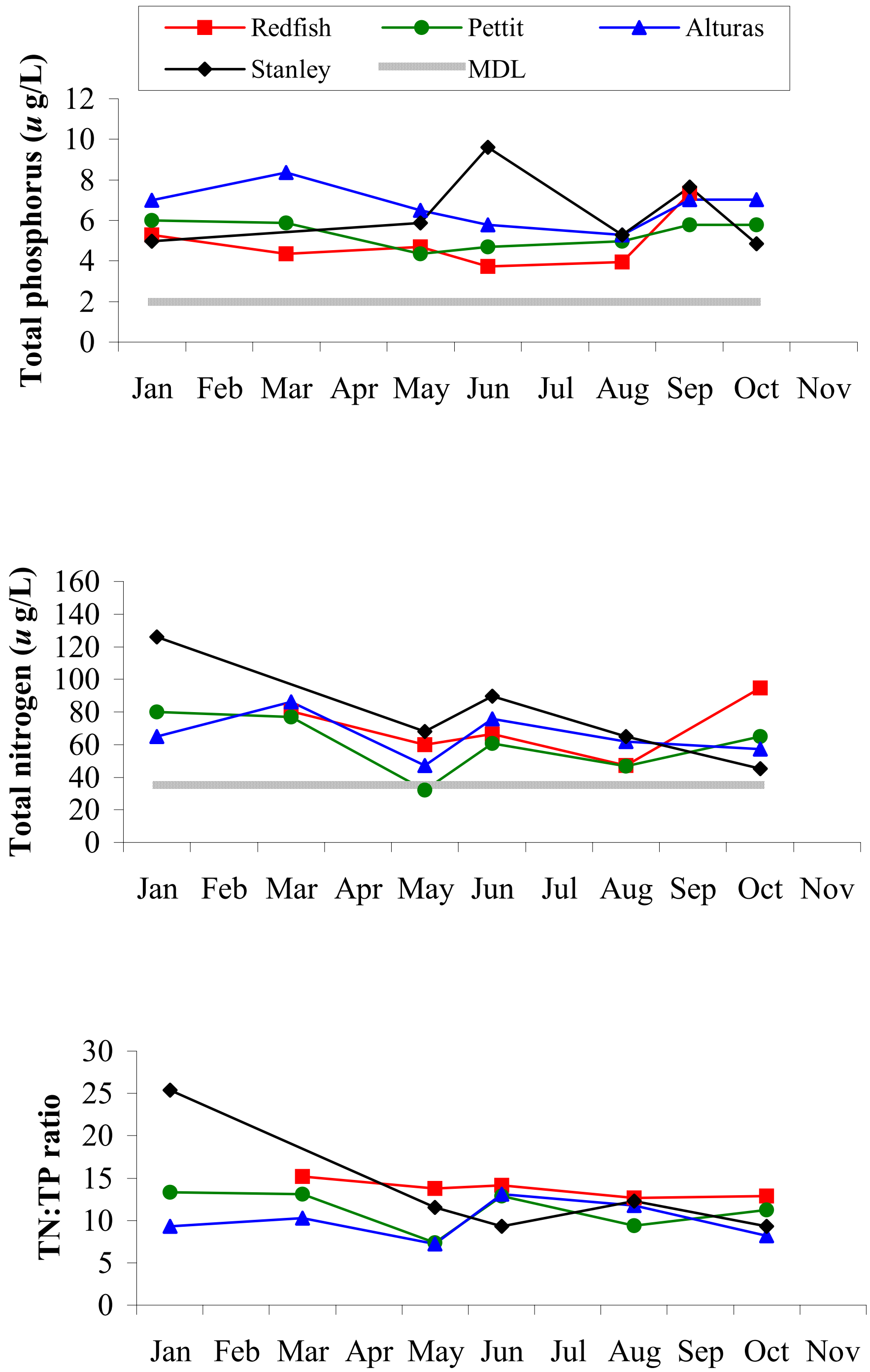
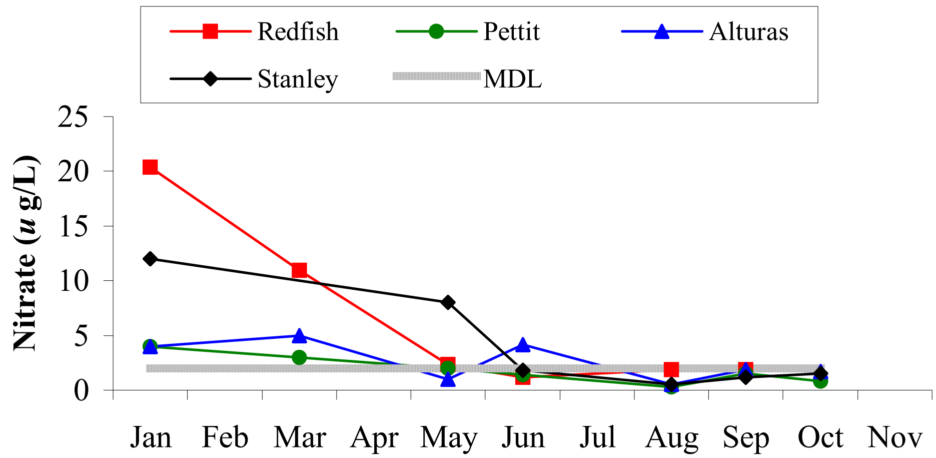
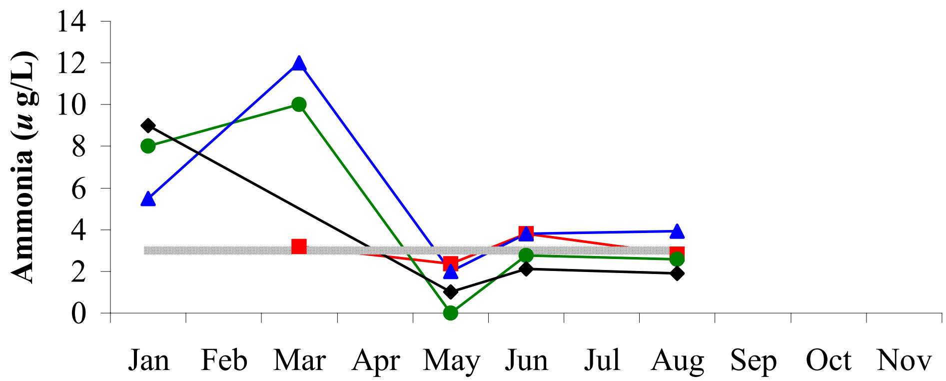
APPENDIX A. Surface nutrient concentrations



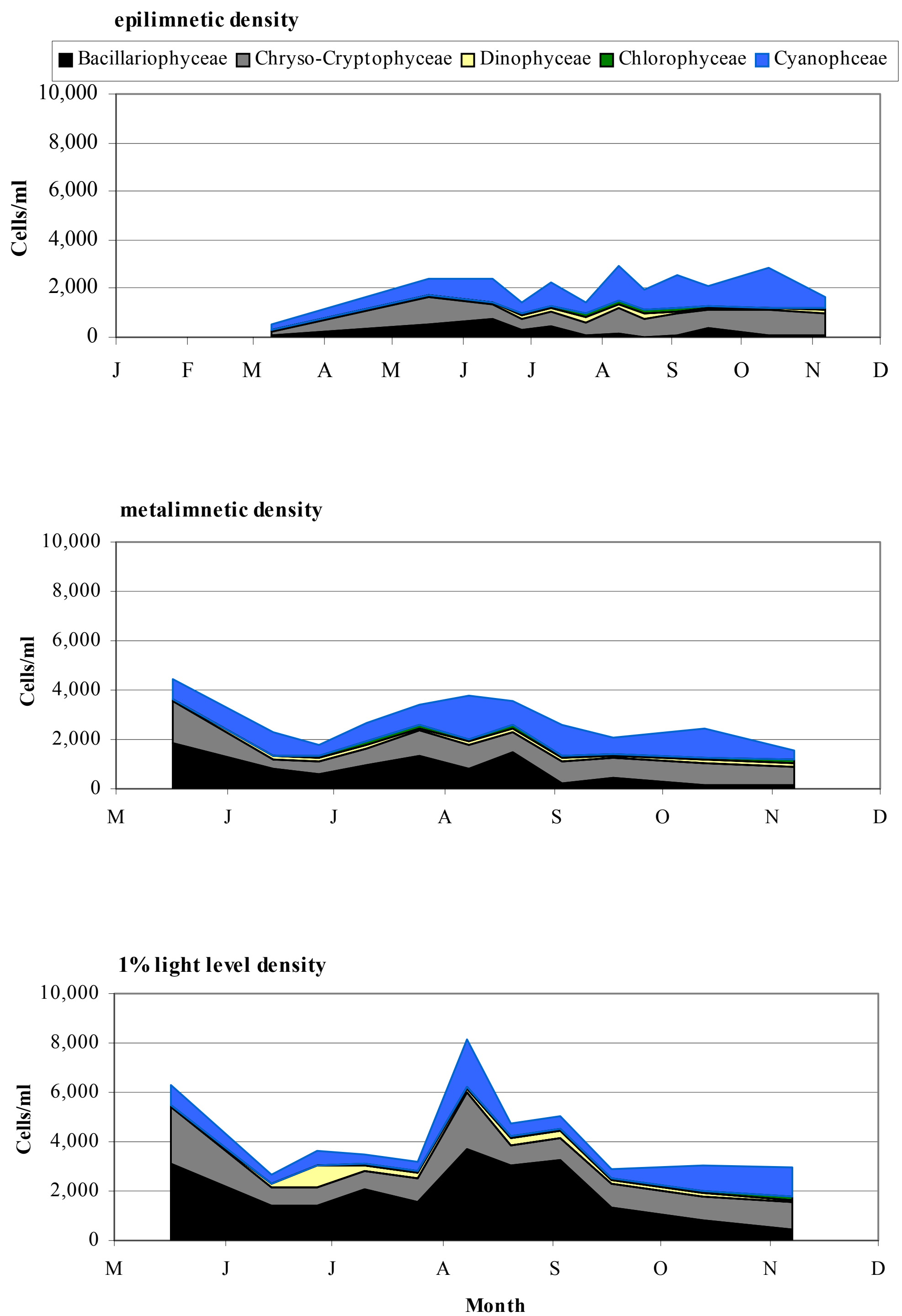
Appendix A. Concentrations of selected nutrients and the TN/TP ratio in the epilimnetic waters of Redfish, Pettit, Alturas, and Stanley lakes during January through October 2000. Grey line denotes method detection levels.



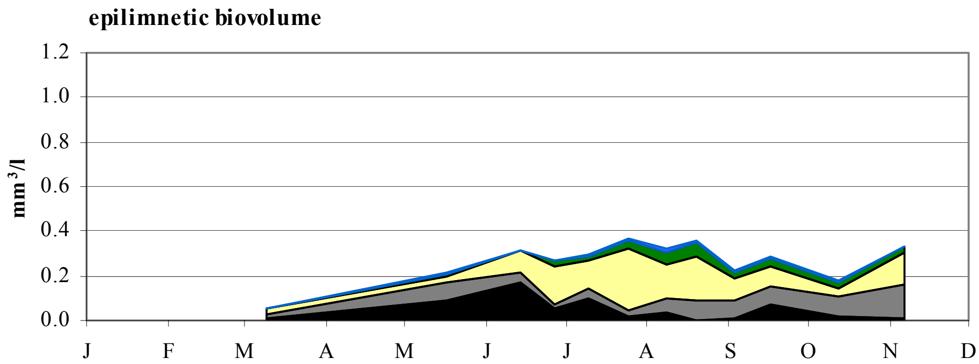


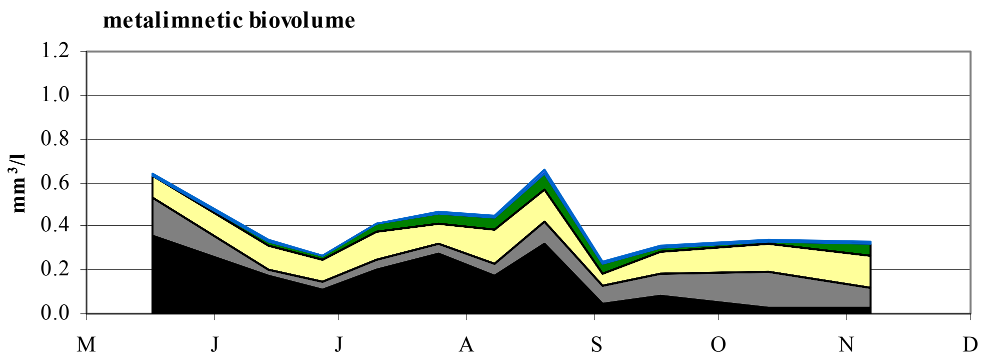
Appendix A cont.

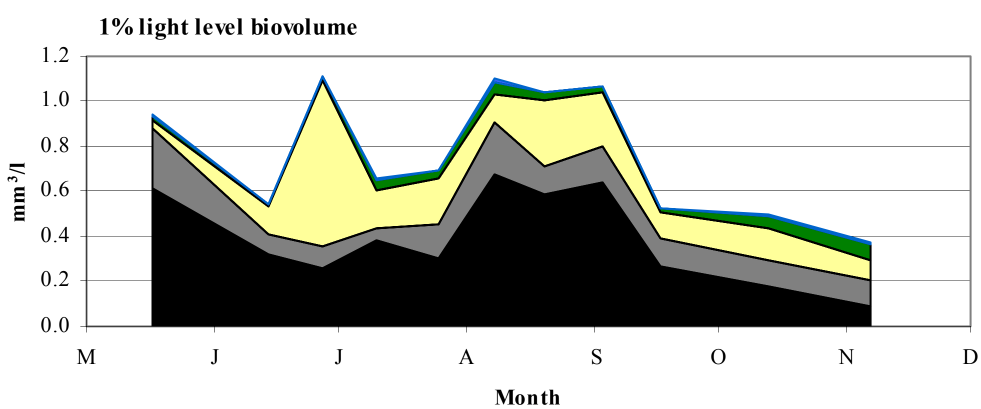
APPENDIX B. Phytoplankton densities and biovolumes



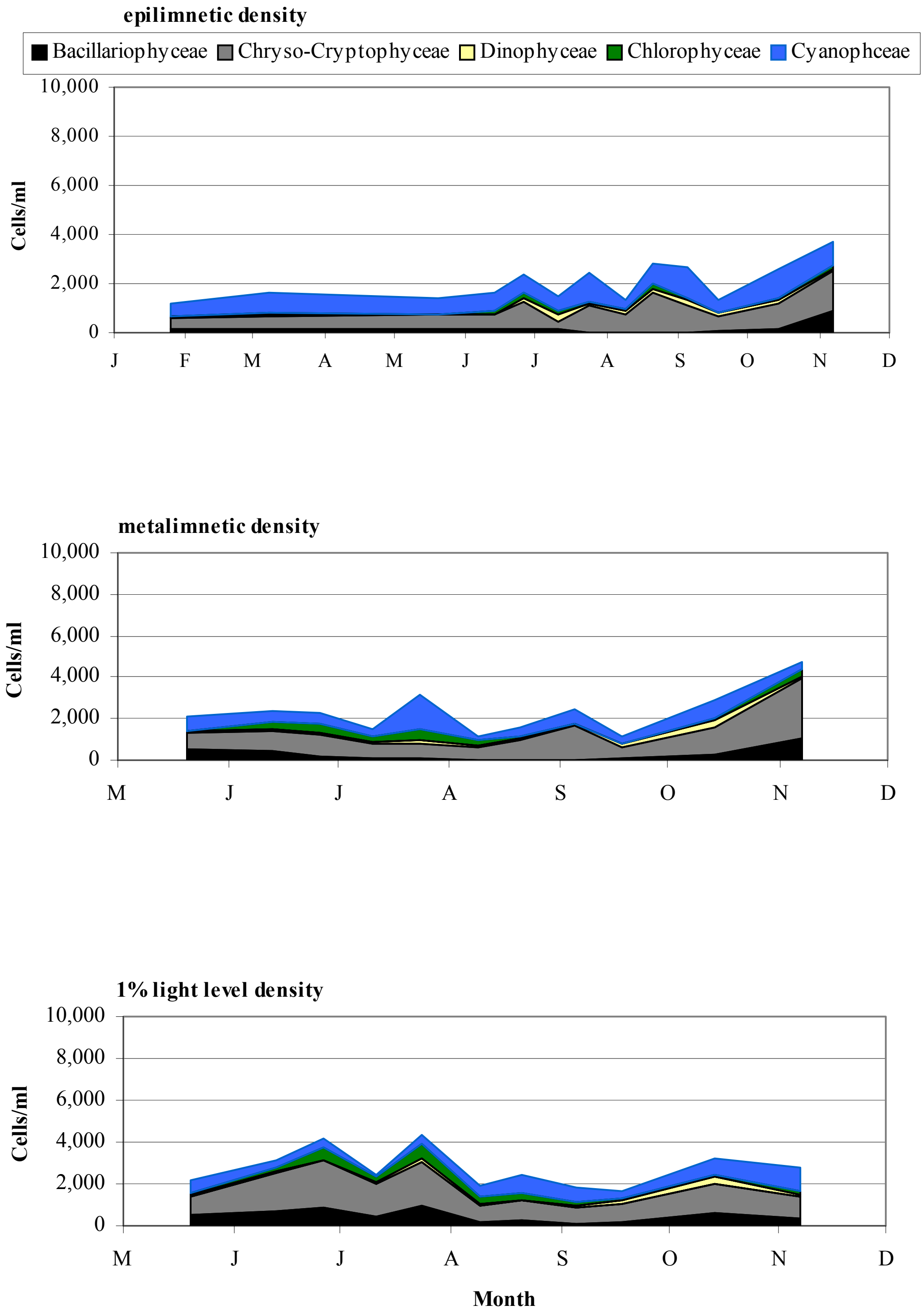
Appendix B-1. Phytoplankton density (cells/ml) and bio-volume (mm^3/l) in the epilimnion, metalimnion and at the compensation depth in Redfish Lake, March through November 2000.



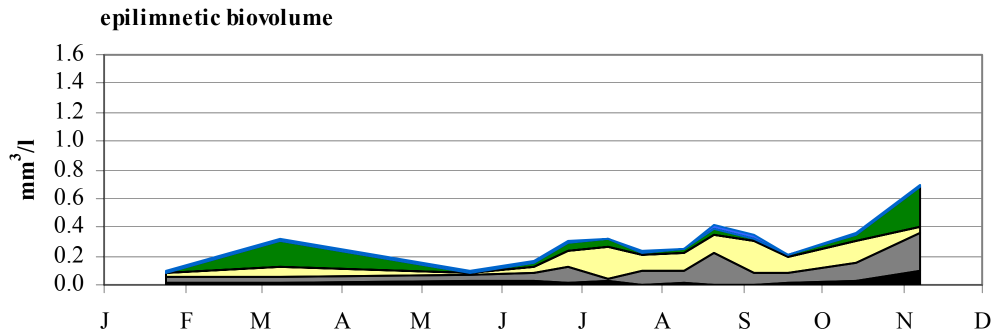


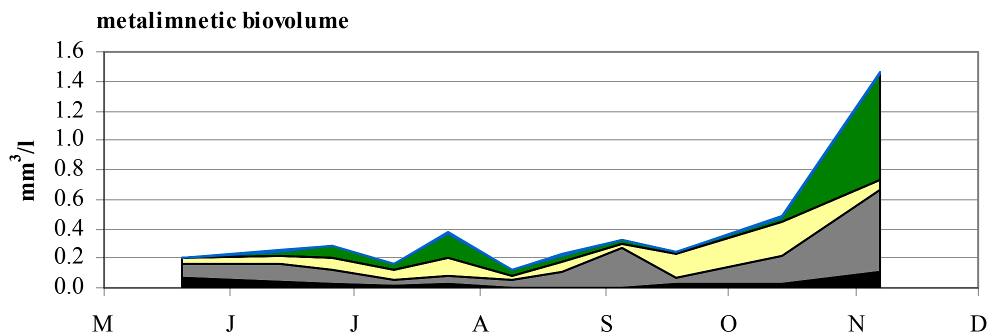


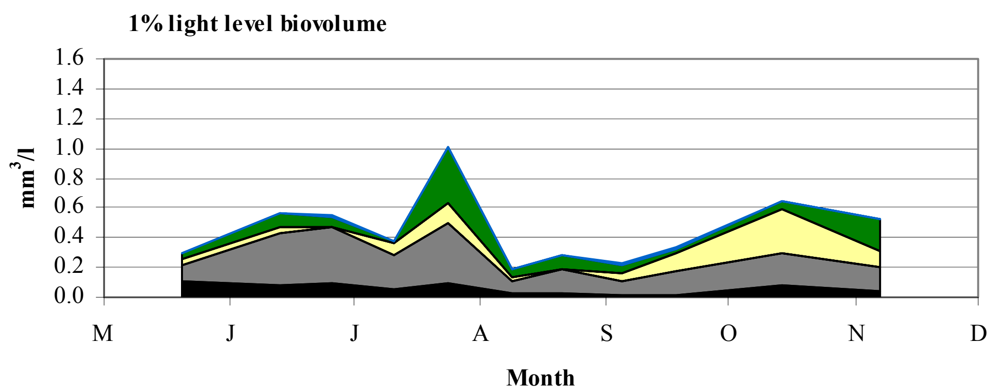
Appendix B-1. Continued.



Appendix B-2. Phytoplankton density (cells/ml) and bio-volume (mm^3/l) in the epilimnion, metalimnion and at the compensation depth in Pettit Lake, March through November 2000.

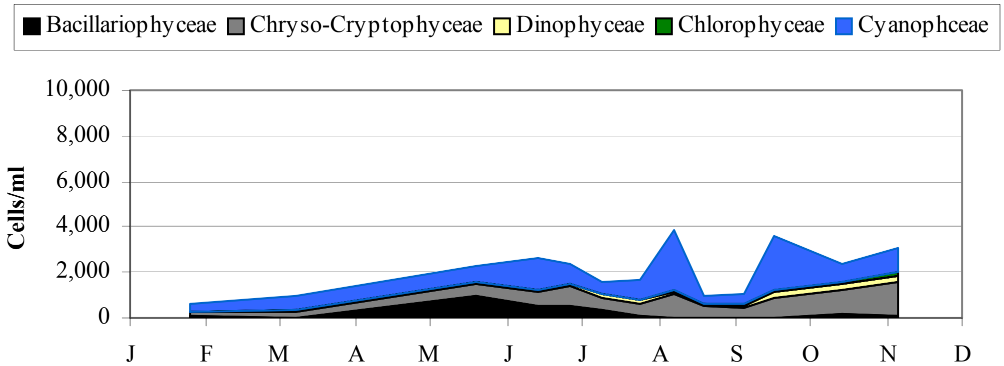




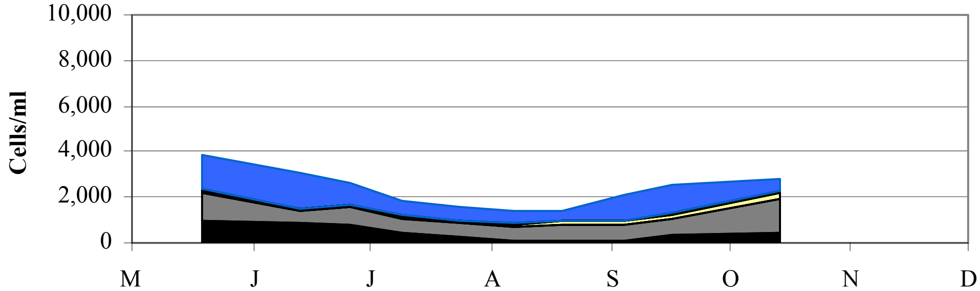


Appendix B-2. Continued.

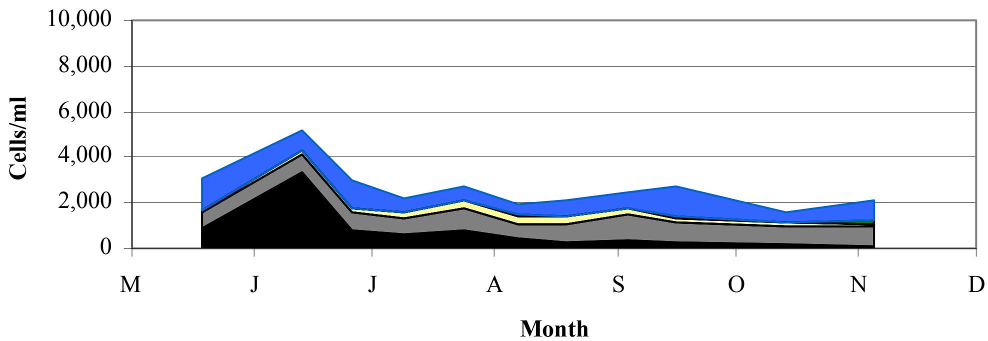
epilimnetic density



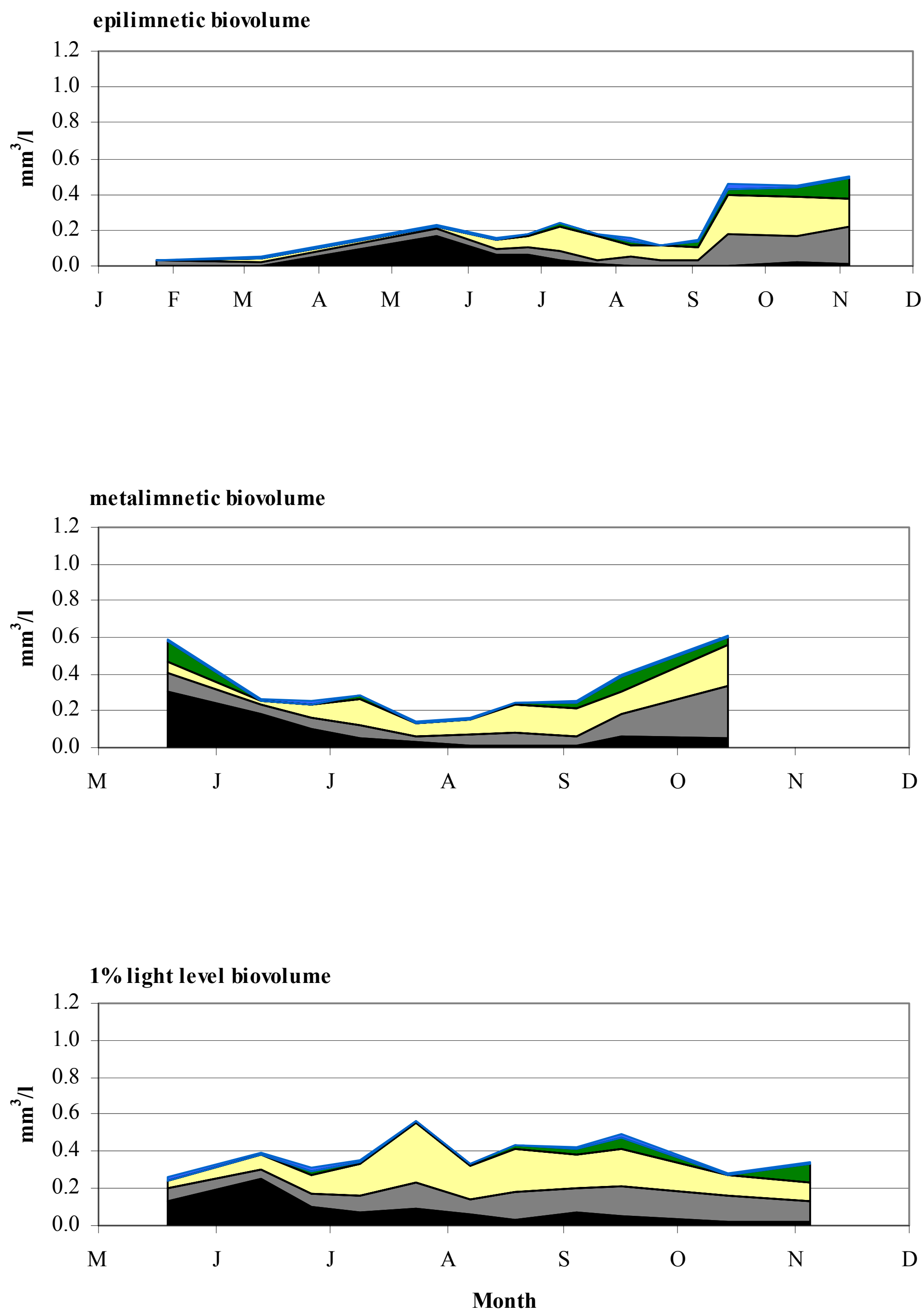
metalimnetic density



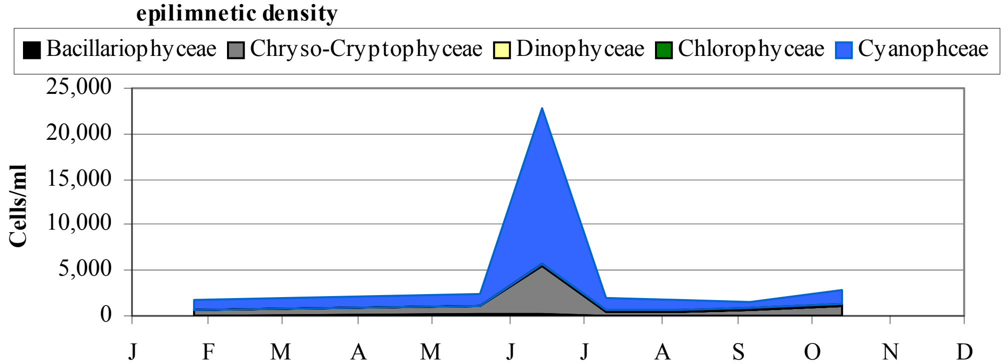
1% light level density

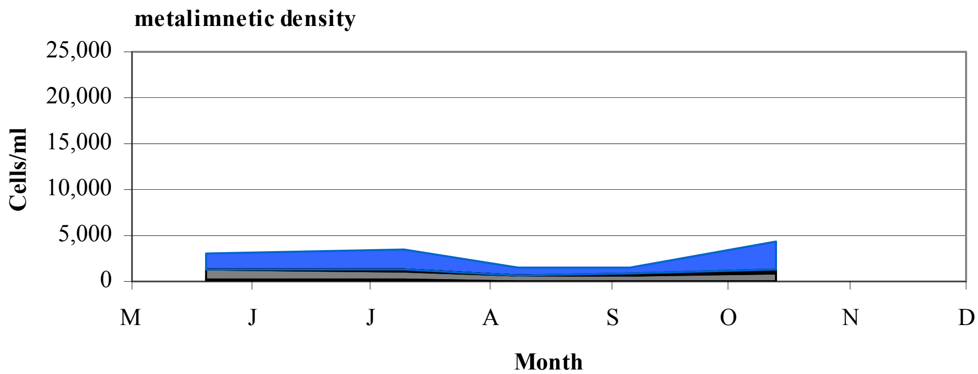


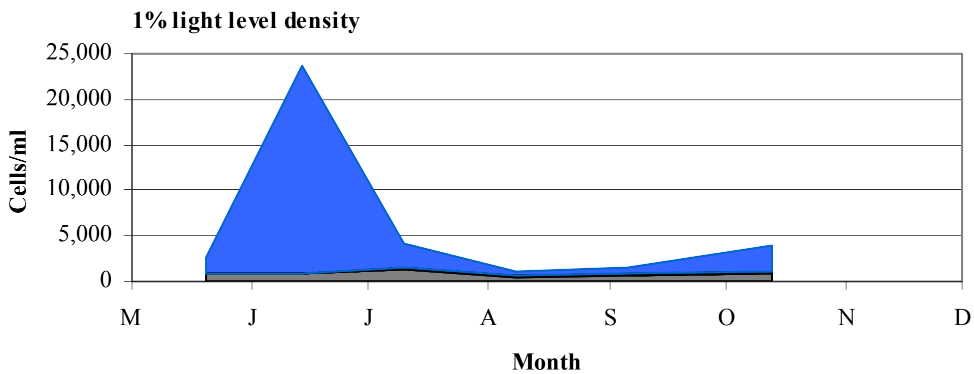
Appendix B-3. Phytoplankton density (cells/ml) and bio-volume (mm^3/l) in the epilimnion, metalimnion and at the compensation depth in Alturas Lake, March through November 2000.



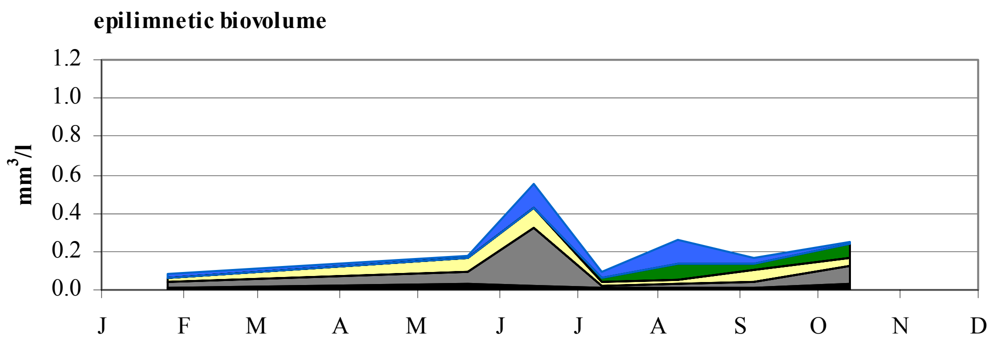
Appendix B-3. Continued.

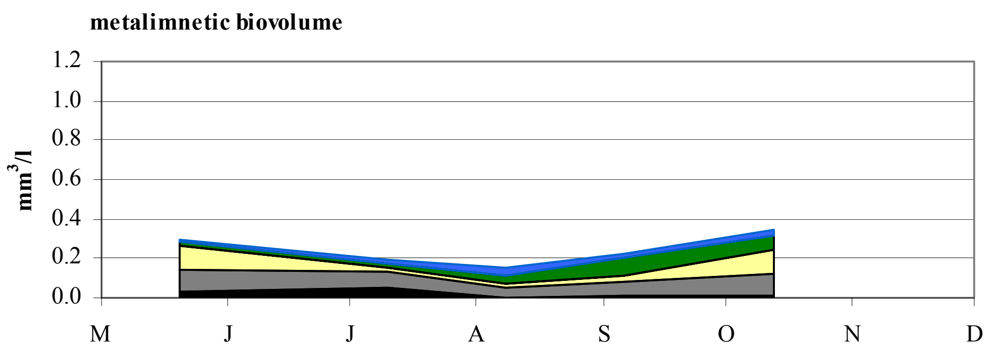


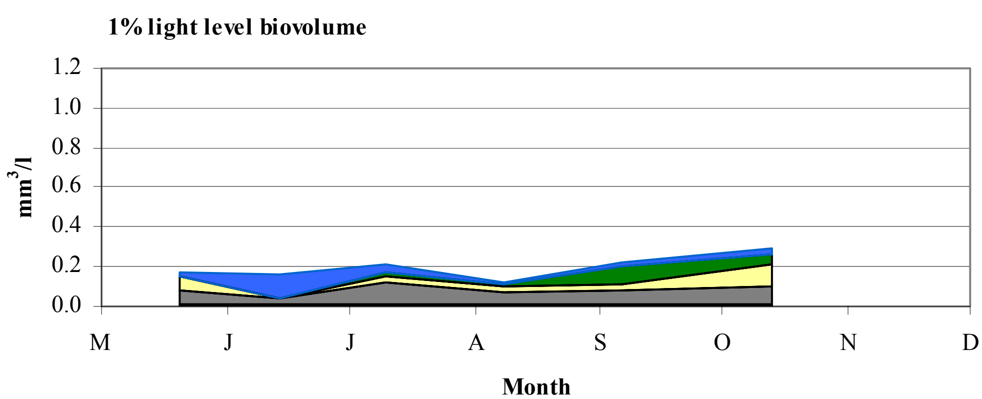




Appendix B-4. Phytoplankton density (cells/ml) and bio-volume (mm^3/l) in the epilimnion, metalimnion and at the compensation depth in Stanley Lake, March through October 2000.







Appendix B-4. Continued