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SNAKE RIVER SOCKEYE SALMON HABITAT AND LIMNOLOGICAL RESEARCH

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EXECUTIVE SUMMARY

Since the late 1980's, Snake River sockeye, *Oncorhynchus nerka*, adults have only returned to Redfish Lake, one of five lakes in the Sawtooth Basin which historically reared sockeye. In 1995 we removed a fish passage barrier at the outlet of Pettit Lake to provide access to more rearing habitat for sockeye. During the same year 8,750 progeny from the captive broodstock program were stocked in Pettit Lake, the only other lake besides Redfish that currently rears Snake River sockeye. In this report, we have summarized activities conducted by Shoshone-Bannock Tribes (SBT) Fisheries Department personnel during the calendar year of 1996.

Our objectives included fertilization of Redfish Lake, characterizing the limnology of Sawtooth Valley lakes, conducting *O. nerka* lake population and escapement surveys, reducing the number of spawning kokanee in Fishhook Creek, evaluating hatchery rainbow trout over-winter survival and potential competition and predation interactions with 0. *nerku* in Pettit Lake, and monitoring smolt outmigration from Pettit Lake.

We applied 994 kg of nitrogen (N) and 5 1 .1 kg of phosphorus (P) to Redfish Lake beginning in August and continuing until mid October. The N:P ratio of 20: 1 was higher than used for fertilization of Great Central Lake, B.C. (Parsons, et al. 1972) to prevent a possible stimulation of N fixing Cyanophyta. Applications were made weekly by traversing twenty parallel transects across the lake at five mph in a boat with the solution directed by hose into the propeller wash.

Whole-lake zooplankton biomass in Redfish Lake was 7.8 μg/l, a 33.9% decrease from 1995. Chlorophyll *a* and mean Secchi depth increased, yet the mean 1% light level decreased. Following a large decline in 1995, zooplankton biomass increased to 9.1 μg/l in 1996 in Pettit Lake. Surface chlorophyll a increased slightly and Secchi depth decreased. Zooplankton, chlorophyll and Secchi depth all increased in Alturas and Stanley lakes compared to 1995.

During 1996 we assessed fish densities using hydroacoustic sampling in Redfish, Pettit, and Alturas lakes. Hydroacoustic estimates of 0. *nerku* densities in 1996 ranged from 6 1 to 480 fish/ha, and biomass ranged from 0.97 kg/ha in Alturas Lake to 36.23 kg/ha in Pettit Lake. Density was greatest in Pettit Lake followed by Redfish and Alturas lakes. Adult 0. *nerka* escapement was 10,622 in Fishhook Creek, 825 in Stanley Lake Creek, and 744 in Alturas Lake Creek.

A picket weir was installed in Fishhook Creek to enumerate spawners and allow only 2,000 females to pass in an attempt to limit recruitment to the lake in 1997. The weir was operated from 8 August through 28 August. We checked the weir one to two times daily depending on the number of fish entering the stream. Unfortunately, the weir did not operate efficiently and we were not able to limit the number of spawners as planned.

Rainbow trout studies in Pettit Lake indicate that the strain of Kamloops rainbow, stocked in 1996, had a higher overwinter survival compared to the Hayspur strain which had been stocked previously. Overwinter survival through February 1997 was 50% compared to 35% for the previous winter. Diet overlap between *O. nerka* and rainbow was 0.004 on the Ivlev Index as chironomids were the only prey item selected by both species of fish during the same sample period. We did not osbserve rainbow trout predation on 0. *nerka* in 1996, but we did observe piscivory of other species by rainbow trout smaller in size than we found in previous years.

We operated a weir to enumerate and PIT tag sockeye smolts in the Pettit Lake outlet stream. This was the first year of operation and construction flaws prevented us from sampling during the peak outmigration. We captured a total of seventy-nine sockeye, four of which had been PIT tagged prior to release in 1995. Sixty-three of the seventy-nine captured were PIT tagged. Based on downstream dam interrogations, the minimum number of outmigrants from Pettit Lake was 2,640.

We also assisted the Idaho Department of Fish and Game in net pen operations and planting egg incubator boxes in Redfish Lake.

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INTRODUCTION

Nineteen ninety six is the fifth year that the Shoshone-Bannock Tribes (SBT) have been actively involved in Snake River sockeye salmon recovery. In March of 1990 the SBT petitioned the National Marine Fisheries Service (NMFS) to list Snake River sockeye salmon under the Endangered Species Act and they were formally listed as endangered in November of 1991 (56 FR 58619). All activities described in this report have been endorsed by the Stanley Basin Technical Oversight Committee (TOC), a committee formed in 1991 with members representing all agencies involved with sockeye recovery. The purpose of this committee is to make recommendations regarding new research, coordinate ongoing research, and actively participate in all elements of Snake River sockeye recovery.

Member agencies include the SBT, the Idaho Department of Fish and Game (IDFG), the National Marine Fisheries Service (NMFS), the USDA Forest Service, the Bonneville Power Administration (BPA), the University of Idaho (UI), and the Idaho Department of Environmental Quality (DEQ).

Historically, thousands of Snake River Sockeye salmon returned to the Sawtooth Valley to spawn. Evermarm (1896) reported that the Sawtooth Valley Lakes "were teeming with red fish." Bjornn (1968) estimated that 4,360 sockeye returned to Redfish Lake in 1955. In the 1980's, less than 50 Snake River sockeye salmon survived to spawn (Bowler 1990). Since 1990, only 15 sockeye have returned to Redfish Lake. We focused our efforts in 1996 on four lakes (Redfish, Pettit, Alturas, and Stanley) designated critical habitat (57 FR 57051) for sockeye salmon.

During 1995 a total of 83,045 and 8,572 sockeye pre-smolts from the captive broodstock program were released into Redfish and Pettit lakes, respectively. We used four release strategies for Redfish Lake; direct lake release in the spring, direct lake release in the fall, summer net pen rearing where the fish were released into the lake in October, and one hundred and twenty adults were also released in October. The fish were released directly into Pettit Lake during July. Much of the work we did in 1996 was directed toward evaluating if those releases, and nutrient additions to Redfish Lake, affected lake environments.

We added nutrients to Redfish Lake to stimulate forage resources for the large release of fish anticipated in 1997. Nutrients were added from August through October, a much shorter period than in 1995.

During 1996 we successfully removed the migration barrier in the Pettit Lake outlet. Removal was intended to be accomplished concurrently with the construction of the weir/trap but was delayed a year due to various problems encountered in 1995.

We also attempted to enumerate kokanee fry entering Redfish Lake as we have done in the past. With limited manpower available, operations were suspended when high run off required operation of the Pettit Lake weir at all times.

STUDY AREA

Four lakes in the Sawtooth Valley are currently the focus of our habitat and limnological studies. The lakes were glacially formed, range in elevation from 1985 to 2 13 8 m, and are located in central Idaho (Figure 1). Specific features of the rearing lakes are shown in Table 1.

All of the Sawtooth Valley lakes are oligotrophic. Mean summer total phosphorous concentrations in the epilimnion range from 5.9 to 8.3 μg/L. Chlorophyll *a* concentrations range from 0.4 to 1.3 μg/L. Mean summer Secchi disk transparencies range from 7 - 16 m.

Table 1. Morphological features of the Sawtooth Valley Lakes.

Lake	Area (km^2)	Volume ($m^3 x 10^6$)	Mean Depth (m)	Drainage Area (km^2)
Redfish	6.15	269.9	44	108.1
Alturas	3.38	108.2	32	75.7
Pettit	1.62	45.0	28	27.4
Stanley	0.81	10.4	13	39.4
Yellow Belly	0.73	10.3	14	30.4

Native fish species found in the nursery lake system include sockeye/kokanee salmon 0. *nerka*, rainbow trout 0. *mykiss*, chinook salmon *0. tshawytscha*, cutthroat trout 0. *clarki*, bull trout *Salvelinus confluentus*, mountain whitefish *Prosopium williamsoni*, sucker *Catastomus sp.*, redside shiner *Richardsonius balteatus*, dace *Rhinichthys sp.*, northern squawfish *Pytchocheilus oregonensis*, and sculpin *Cottus sp.* Non-native species include brook trout *Salvelinus fontinalis*, and lake trout *S. namaycush*. The only pelagic species besides 0. *nerka* are redside shiners. The two species are not sympatric because of differing vertical distributions in the lakes.

Hatchery rainbow trout are stocked throughout the summer in all lakes. Sport fishing for salmonids is open on all lakes as well as inlet and outlet streams.

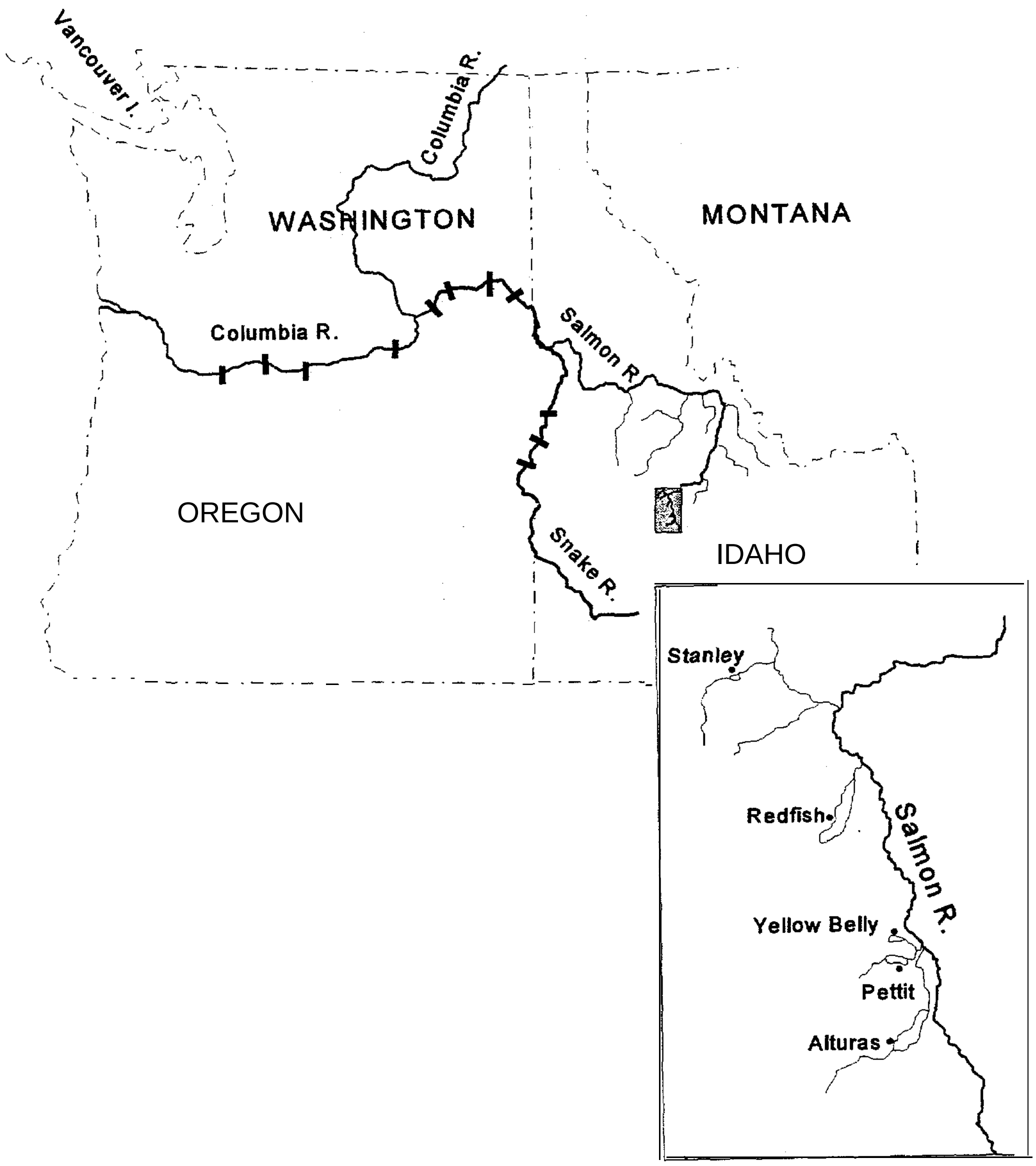

Figure 1. Sockeye rearing lakes in the Sawtooth Valley of central Idaho. Lines across the rivers indicate hydroelectric dams.

CHAPTER 1

Fish Population Dynamics in Sawtooth Valley Lakes

METHODS

Tributarv Frv Recruitment

We attempted to estimate kokanee fry recruitment to Redfish Lake. Fry were collected in Fishhook Creek with steel frame drift nets that are 30 cm wide and 60 cm deep. Each frame was fitted with a tapered nylon net. The nylon nets direct fry to live boxes made with plywood and wire-mesh screen with longitudinal partitions used to create backwater refuge for captured fish. The frames, nets, and live boxes were anchored to the substrate with rebar and attached to the Fishhook Creek bridge. In Fishhook Creek, between three and five fry traps were set under the bridge located 50 m above the confluence with the lake. Nets were fished between 1800 and 0800 hrs from 10 through 15 May. After enumeration, all the fry were released.

Smolt Monitoring

We operated a weir at the outlet of Pettit Lake, Idaho (Section 3 1, Township 8 North, Range 14 East) from 24 April through 6 June 1996 to capture, enumerate, and PIT tag Snake River sockeye salmon introduced in July 1995 into Pettit Lake from the captive broodstock program. The weir was designed to operate at 100% capture efficiency. Due to high spring run off we were unable to operate the weir during the peak outmigration period.

During dates we operated the weir, it ran continuously and fisheries personnel checked for fish and cleaned the weir at -six hour intervals during the night and once during the day. Due to defective manufacturing of the weir panels, we were not able to fish the stream with a 100% capture efficiency.

When high runoff flows began we experienced problems with water velocity approaching the screens exceeding the design specifications. This led to impingement and, ultimately, mortality of some sockeye. When we observed the first impinged fish, we modified the stop logs located behind the screen panels and began taking velocity measurements in front of the panels. As more mortalities occurred, we ceased operation and contacted the engineering firm that designed the weir. After closer inspection, more flaws were discovered in the screen panels and were fixed as best as possible to continue sampling. After we resumed, sampling mortalities continued. We removed all screen panels and suspended all sampling until flows abated.

Immediately after removal from the trap, the fish were placed in a stock solution of 15 g of MS222 and 30 g of sodium bicarbonate per liter of water to anesthetize fish prior to measuring, weighing, and PIT tagging. We soaked needles in a 70% alcohol solution at least ten minutes before using them to insert PIT tags.

All fish that were PIT tagged and/or weighed and measured were held in a live well placed below the weir five to ten hours after handling and then released. All other sockeye were counted and released immediately below the weir.

Hydroacoustics

Data acquisition. - Echo sounding data were collected with a Hydroacoustic Technology, Inc. Model 240 split-beam system. We used a 15 degree transducer, and the echosounder criteria were set to a pulse width of 0.4 milliseconds, a time varied gain of 40 log(R) + $2\alpha r$, and four pings per second for Alturas and Redfish lakes, and five pings per second for Pettit Lake. A minimum of four pings per target was necessary to qualify as a fish target. Data were recorded on a Panasonic SV-3700 digital audio tape recorder.

We followed identical transects as were set with a global positioning system (GPS) during 1994 (Teuscher and Taki 1995). Waypoints were set to allow for sampling transects to run zigzag across all lakes except Pettit Lake, where we used five parallel and one diagonal transect (Teuscher and Taki 1995). We sampled twelve and fourteen transects at Alturas and Redfish lakes, respectively.

Surveying was conducted on two nights during the new moon phase in September. We began at approximately one and a half hours after sunset. Boat speed during data collection ranged from 1-1.5 m/s.

Vertical gill netting and trawling (by IDFG) 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 selectivity for *0. nerka*. Therefore, we employed vertical gillnets 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 were not used. Due to permit requirements we were unable to set vertical gillnets in Redfish Lake.

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

$$TS = 19.1 \cdot Log(L) - 0.9 \cdot Log(F) - 62.0 \qquad (1)$$

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 year class densities based on previous years length frequency distributions and age analyses. Five different size classes were used for Pettit and Alturas lakes, and four for Redfish Lake. Total lake abundance and vertical distribution was also estimated.

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

The effective beamwidth equation

$$X\,(ABS \cdot (M^{TS} - F^{TS})^{Y} \qquad (2)$$

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

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

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

and variance was estimated by

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

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

We used *FISHPROC* software 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

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

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.

<u>*0. nerka* Spawning Ground Surveys</u>

Stream Spawning- Stream surveys were conducted to estimate kokanee spawning abundance in Fishhook, Stanley and Alturas Lake tributary streams. Counts were completed from the bank by one or two observers equipped with polarized sunglasses. Surveys were conducted at four day intervals. On days when counts were missed, the number of fish in the stream were estimated by dividing the difference between the actual counts by the number of days between the counts. The average value was added to the actual count day for the following successive non-count days. Total escapement estimates were made by summing daily counts of kokanee and dividing by average stream life as described by English et al. (1992).

On Fishhook Creek, a picket weir was deployed as an alternative method for estimating kokanee escapement and to cull a portion of the female kokanee spawners. Culling was implemented in 1995 to control eventual fry recruitment to Redfish Lake as part of the kokanee management program. The objective of the program is to reduce the kokanee population to reduce competition with introduced juvenile sockeye salmon. Escapement goals for kokanee in Fishhook Creek were set at 1,800 female spawners. Production estimates from egg deposition (287 eggs/female) and subsequent fry emergence (12.3% egg to fry survival) for 1,800 females is 5 16,600 eggs and 63,542 fry.

Beach Spawning -Snorkel surveys in Redfish Lake were conducted on three nights from October to November, 1996. Sockeye Beach and a small section of the south east comer of Redfish Lake are spawning grounds for residual sockeye. Night-time snorkel surveys were conducted to estimate the relative abundance of residual spawners in both locations. At least three observers, equipped with waterproof flashlights, snorkeled parallel to shore 10 m apart, observing at depths ranging from 0.5 to 5 m. For Sockeye Beach, we estimated residual spawner abundance within the boundaries (600 m) of Sockeye Beach as delineated by U.S.D.A. Forest Service signs. Spawning ground surveys in the south end of the lake were conducted in the 200 m shoal area section near the two south-east inlet streams.

Redd counts were conducted in Redfish Lake by boat to assess relative spawning occurrence of the captive adult broodstock release. The survey area was in the south end of the lake in a 200 m shoal area section near the two southern inlet streams. Three observers equipped with polarized sunglasses estimated redd counts from a boat traveling O-2 mph. The average value of the counts was used as the final estimate. A total of 120 captive brood sockeye were released into Redfish Lake at a 1: 1 male to female ratio.

Boat surveys were conducted on October 16 and 23, 1996. Final estimates for redd counts and test redds were 21 and 23 respectively.

Gillnet Sampling

Pettit Lake was sampled monthly except April, June, October, and December, 1996. Passive horizontal gillnets 30 m in length by 1.8 m in depth with multi panels of square mesh graduating in size from 1.90, 2.54, 3.17, 5.08, and 6.35 cm were used at 4 separate littoral stations on Pettit Lake. The smallest mesh was tied off to eliminate incidental bycatch of non-relevent species (redside shiners). Four single panel vertical gillnets 3 m wide and 30 m deep of square mesh sizes 2.54, 3.17, 5.08, and 6.35 cm were placed at one station in the mid-lake pelagic zone.

Gillnets were set in the morning during ice-cover and the evening otherwise, then checked and pulled the following day. During periods of ice-cover a chainsaw was used to cut blocks of ice for gillnet placement.

Diet Analysis

Pettit and Redfish Lakes were sampled by gill nets and trawl in 1996 to determine gut content prey items. Fish stomachs were removed and placed in 70% ethanol. Prey were then sorted by order, blotted dry and weighed to the nearest 0.01 g. Zooplankton prey were enumerated and lengths were derived from zooplankton tows performed on same sampling months. Zooplankton lengths were converted to weight using the length weight regression equation reported in McCauley (1984). We calculated aggregate percent by weight (Swanson et al. 1974) for all species of fish sampled. Fish collected in trawl surveys were also analyzed for gut content.

Feeding: Experiment

A live prey feeding experiment was implemented to improve foraging efficiency of cultured sockeye. A control group of 30 sockeye were fed only pellets and the live-prey group of 30 sockeye were fed brine shrimp, blood worms, and pellets.

Foraging behavior was observed using a 134 liter aquarium with an opaque background on all but the front side. The sockeye used in the feeding trials underwent a two stage acclimation prior to the feeding trials. After acclimation, 400 large (>1mm) Daphnia were introduced to the aquarium. Only one sockeye was observed for each trial. The number of strikes, the time of first strike, prey type consumed (Daphnia or copepod) and if prey were retained was recorded. The sockeye were then moved to the Redfish Lake netpens where growth was monitored for 3 months.

Table 2. Fry recruitment, egg-to-fry survival and adult escapement in Fishhook, Alturas, and Stanley Lake Creeks.

Location	Brood Year	Fry Recruits	Egg-Fry Survival	Adult Escapement
Fishhook	1996	77,820	12.3%[a]	10,662
Fishhook	1995	99,015	12.3%[a]	7,000
Fishhook	1994	144,000	14%	9,200
Fishhook	1993	142,000	11%	10,800
Fishhook	1992	166,000	12%	9,600
Fishhook	1991	36,000	3%	7,200
Alturas	1996	51,677	13%[b]	744
Alturas	1995	15,600	13%[b]	1,600
Alturas	1994	30,000	13%[b]	3,200
Alturas	1993	2,000	13%	200
Alturas	1992	na	na	60
Stanley	1996	3,431	7%‘“’	825
Stanley	1995	850	7%[c]	90
Stanley	1994	5,000	7%	600
Stanley	1993	19,000	7%	1,900

[a] 1992-94 average [b] survival estimate from 1993
[c] 1993-94 average

RESULTS

Fishhook Creek Tributarv Frv Recruitment

After two successful sampling nights we experienced a freshet that required the traps to be monitored continuously. Debris accumulated constantly during the freshet. Because the Pet-tit weir also required constant attention, and we had limited personnel, we abandoned the Fishhook Creek fry trapping operation. However, based on 3,500 female kokanee spawners in 1995, approximately 805,000 eggs were deposited in Fishhook Creek. An estimated 99,0 15 kokanee fry entered Redfish Lake (12.3% egg to fry survival) from Fishhook Creek. Fry recruitment numbers dropped from estimates made in 1994 and 1995 (Table 2).

The escapement estimate for Stanley Lake Creek kokanee was only 90 fish (Table 2), the lowest of the last three brood years. Assuming equal sex ratios, estimated egg deposition by 1995 adults is 12,150.

The escapement estimate for Alturas Lake Creek kokanee females in 1995 was 800 (.50 * 1,600 adults). The egg production estimate is 120,000 (150 eggs/female). Fry recruitment to Alturas lake is estimated at 15,600 (13% egg to fry survival).

Fry emergence and egg to fry survival percentages have been consistent among systems and between years. Fry emergence begins the first week of April, peaks the end of May and is complete by the first week of July.

Pettit Lake Creek Smolt Monitoring

We captured a total of seventy-nine Snake River sockeye, of which four were PIT tagged before release into Pettit Lake. Idaho Department of Fish and Game (IDFG) personnel PIT tagged eight hundred and sixty-one of the 8,575 fish prior to release into the lake. We PIT tagged sixty-three of the seventy-nine captured. During operation we documented twelve indirect mortalities of listed fish caused by the faulty weir panels. The only other species of fish captured were redside shiners, mountain whitefish, and a single brook trout. All listed fish were captured from 22 May through 29 May 1996. Seven of our PIT tagged fish and one hundred and eight of the 861 PIT tagged fish (before release in the lake) were interrogated at projects in the lower Snake River. The minimum number of fish estimated to have left the lake is 2,640 (P. Kline, IDFG, pers. comm.). Based on that estimation, there was approximately 3 1% survival from lake release until outmigration. This represents twice the outmigration rate of any release strategy at Redfish Lake.

Hydroacoustics

Hydroacoustic estimates of 0. *nerka* densities ranged from 61 to 480 fish/ hectare. Densities were highest in Pettit followed by Redfish (108), Alturas (95) and Stanley Lakes (Figure 2). Volumetric densities were .19, .39, and 1.95 0.

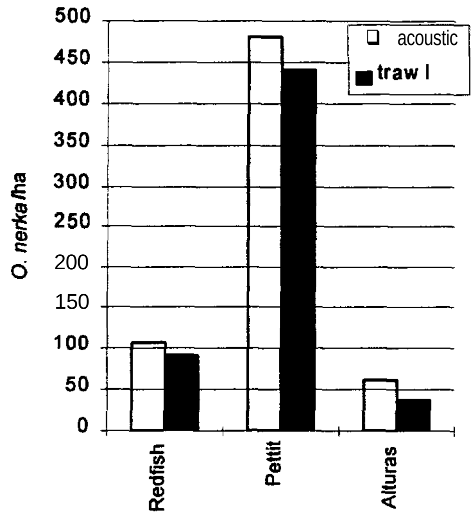

Figure 2. A comparison of hydroacoustic and trawl estimates for September, 1996 (trawl data from Paul Kline,IDFG).

nerka / 1000 m^3 for Alturas, Redfish, and Pettit lakes, respectively. All lakes experienced a decline in 0. *nerka* abundance from 1995 with Alturas and Redfish showing similar decreases at ≈36%. The population estimate change for Pettit Lake was negligible and fell well within the bounds of the confidence intervals (Table 3).

Surprisingly, 0. *nerka* biomass increased 6% from 1995 in Pettit Lake despite overall abundance remaining similar. Biomass declined disproportionate to declines in density in Redfish and Alturas lakes. This may be explained by the relative strength of different cohorts between years.

Table 3. Hydroacoustic and trawl estimates of 0. *nerka* abundance in three Sawtooth Valley lakes.

Lake	Year	Acoustic	Trawl	A/T Ratio
Redfish	1996	66.325	56.213	1.2
Redfish	1995	103.570	61.646	1.7
Redfish	1994	133,360	51,529	2.6
Redfish	1993	203,500	49,628	4.1
Redfish	1992	188,000	39,480	4.8
Pettit	1996	77,680	71,655	1.1
Pettit	1995	77,765	59,004	1.3
Pettit	1994	12,265	14,743	0.8
Pettit	1993	20,400	11,597	1.8
Pettit	1992	19,000	3,009	6.3
Alturas	1996	20,620	13,012	1.6
Alturas	1995	32,260	23,052	1.4
Alturas	1994	10,980	5,785	1.9
Alturas	1993	200,700	49,038	4.1
Alturas	1992	144,000	47,238	3.1

Redfish Lake- In September, total lake 0. *nerka* abundance was 76,987. In lake 0. *nerka* (targets with lengths 30 - 2 10 mm) abundance was 66,325 ± 24,000. That estimate is a 36% decline from the previous year, following a 23% decline from 1994 to 1995. An additional 10,662 age-3 kokanee were spawning in Fishhook Creek during the hydroacoustic survey that were not included in the lake estimate.

Vertical distribution of fish in Redfish Lake was dissimilar to Pettit Lake, with most of the targets located in 15 m to 25 m of water (Figure 3). The 15 to 20 m strata contained the highest proportion of all three size classes. No fish were located above 10 m, and few fish were found below 30 m.

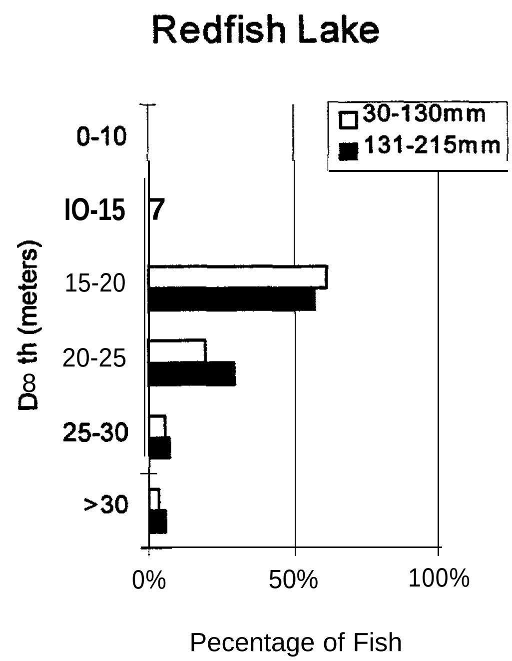

Figure 3. Vertical distribution of 0. ***nerka*** in Redfish lake during September of 1996.

Survival of age-0 kokanee in Redfish Lake in 1996 was poor. Fry survival from May to September was only 13% (12,680 fall fry / 99,015 spring recruits). It is possible that the hydroacoustic survey of Redfish Lake was initiated before full darkness had descended. During the first two transects a large decrease in targets was observed compared to previous years. Robinson and Barraclough (1978) found a direct relationship between trawl effectiveness and ambient light. Since hydroacoustic surveys are also conducted during darkness one could assume a similar relationship.

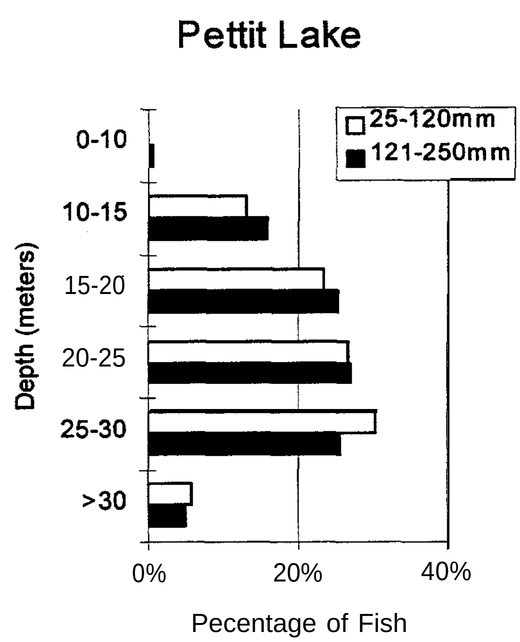

Figure 4. Vertical distribution of 0. ***nerka*** in Pettit Lake during September of 1996.

Table 4. Hydroacoustic and trawl estimates by age class of three Sawtooth Valley Lakes (trawl data from Paul Kline, IDFG).

Redfish Lake 1994	*Population Estimate*	*(± 95% C.I)*		*Biomass*	*Estimate kg/ha*
size mm (age)*	***Acoustic***	***Trawl***		***Acoustic***	***Trawl***
30-70 (0+)	*76,600 ± 19,560*	*30,449 ± 25,780*		*0.15*	*0.06*
71-130 (I+)	*36,000 ± 8,240*	*5,856 ± 8,867*		*0.6*	*0.08*
131-200 (II+)	*20,760 ± 7,470*	*15,224 ± 18,884*		*1.63*	*1.26*
1995					
30-70 (0+)	*22,360 ± 6,410*	*20,836 ± 11,057*		*0.05*	*0.08*
71-130 (I+)	*49,120 ± 12,400*	*8,000 ± 5,342*		*0.86*	*0.12*
131-200 (II+)	*31,070 ± 12,340*	*32,008 ± 24,761*		*2.5*	*4.02*
III+		*802 ± 1,604*			*0.13*
1996					
30-70 (0+)	*12,680 ± 5,030*	*29,489 ± 26,324*		*0.05*	*0.09*
71-130 (I+)	*34,950 ± 21,040*	*4,608 ± 2,914*		*0.58*	*0.066*
131-200 (II+)	*18.700 ± 4.570*	*6.451 k2.257*		*1.6*	*0.28*
III+		*15,666 ± 6,250*			*2.388*
Pettit* Lake *1994					
25-60 (0+)	*4,580 ± 2,260*	**4,095 ± 7,930**		*0.03*	*0.185*
61-120 (I+)	*1,980 ± 1,310*	*6,286 ± 2,730*		*0.1*	*1.31*
121-200 (II+)	*3,210 ± 1,530*	*3,276 ± 7,329*		*1.77*	*0.96*
201-250 (III+)	*2,600 ± 3,120*	*546 + 668*		*3.37*	*0.83*
1995					
25-60 (0+)	*2,880 ± 1,270*	0		*0.03*	0
61-120 (I+)	*15,600 ± 9,330*	*13,566 ± 3,542*		1.07	0.98
121-200 (II+)	*37,270 ± 23,570*	*43,406 ± 15,151*		*13.6*	*12.45*
201-250 (III+)	19.667 ± 13.930	*2,032 ± 2,346*		*19.52*	*1.3*
1996					
25-60 (0+)	*4.740 ±3.020*	*0*		*0.55*	*0*
61-120 (I+)	*17, 890 ± 3,020 . . .*	*1,339 ± 670*		1.1	*0.15*
121-200 (II+)	*31.800 ± 5.820*	*43.529 ± 2.919*		*11.97*	*6.6*
201-250 (III+)	*23.247 ± 5.100*	*76787 ± 4.391*		*7761*	*8.45*
Alturas* Luke. *1996					
30-60 (0+)	*3,255 ± 1,490*	*465 ± 930*		*0.01*	*0.002*
60-110 (I+)	*7,670 ± 3,175*	*465 ± 930*		*0.13*	*0.006*
111-140 (II+)	*4.665 ± 635*	*1.395 ± 1.781*		*0.26*	*0.1*
141-170 (III+)	*3,702 ± 7,300*	*9,292 ± 4,004*		0.39	*7.05*
171-180 (IV+)	*1760 ± 785*	*1,395 ± 930*		*0.18*	*0.78*

Pettit Lake- We estimated fish abundance in Pettit Lake during September at 77,680 ± 15,850 (Table 3). The estimate is less than one hundred fish different than in 1995. The biggest discrepancy between 1995 and 1996 is the increase in the I+ and II+ age classes (Table 4).

During 1995 we only found 2,880 0+ fish, yet in 1996 the same cohort size was estimated at 17,890. For fish that were I+ in 1995 the estimate was 15,600 fish, yet in 1996 the same cohort was estimated at 3 1,800. IDFG's trawling survey also showed an increase of -30,000 fish for the same cohort (Table 4). It is unclear why these irregularities occurred, but since it happened for both surveying methods, it appears the hydroacoustic survey for Pettit Lake is valid.

Vertical distribution of *O. nerka* in Pettit Lake was spread throughout the water column (Figure 4), unlike the other lakes where they are concentrated in an approximately ten meter stratum. Distribution was similar between different size classes with the exception of a small proportion of large fish above ten meters. Vertical gill nets were used to validate target sizes of 0. *nerka.* A length frequency histogram comparing vertical gill nets and trawl samples shows that relative abundance of different cohorts are dissimilar (Figure 5). This could indicate a size selectivity for trawling as has been postulated in the past. But this comparison is only for one year and more data is required before an inference could be made regarding selectivity for certain sizes by trawling.

Alturas Lake- 0. *nerka* abundance in Alturas Lake was 20,620 ± 4,140 (Table 3) for September of 1996. This is a 36% decrease from 1995. Trawl estimates also showed a decrease of 43%.

Individual age classes were broken down based on otolith readings taken from fish collected in trawl samples by the IDFG (Table 4). Hydroacoustics identified many more 0+ and I+ fish than trawling, yet only one third as many III+. We have not had success in past years using vertical gill nets in Alturas Lake and therefore did not employ them in 1996. However, based on the different proportions of individual size classes between the two methods, future surveys should include a vertical gill net

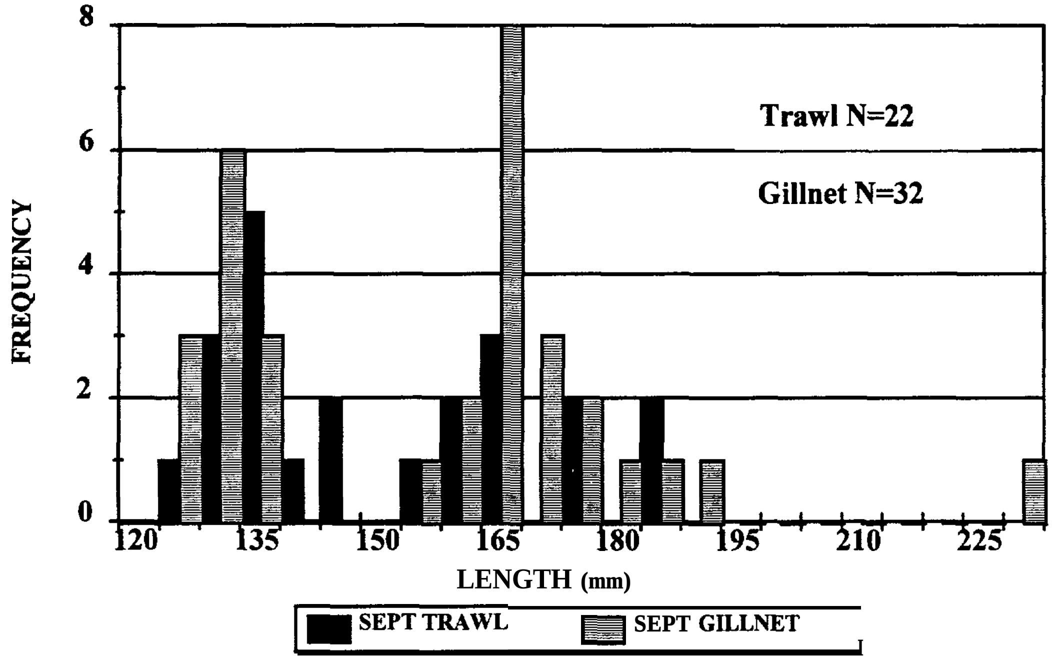

Figure 5. A comparison of trawl versus gill net catch of 0. *nerka* in Pettit Lake during September of 1996.

sample.

Gillnet Sampling

Yearly catch per unit of effort (CPUE) comparisons between the 1995 stocked Hayspur and 1996 Kamloops strains of rainbow trout indicates a higher survival of the Kamloops versus the Hayspur fish (Figure 6). Initial stocking of the Kamloops strain began 19 June 1996 and ended 7 August, 1996. The highest CPUE occurred during the initial release months (Table 4). Catch per unit of effort

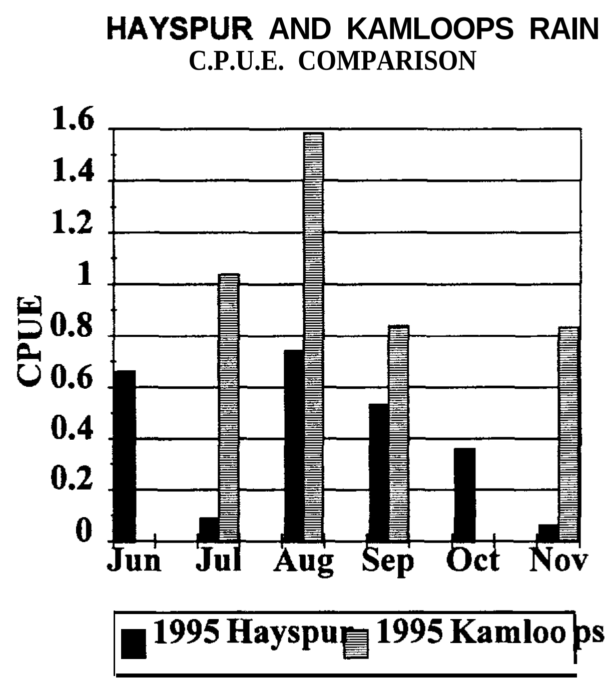

Figure 6. A comparison of gill net efficiencies between 1995 and 1996 in Pettit Lake, ID.

for 0. ***nerka*** *was* during the ice-cover period, due to the littoral zone spawning that occurs during the months of January and early February. The monthly summary of catch per unit of effort for 0. ***nerka***, rainbow and brook trout is presented in Table 5.

A total of 245 rainbow trout were captured in 1996. All were captured in the littoral zone with the exception of three that were captured in the pelagic vertical gill nets on 12 September. A population estimate was made based on gill net captures. However,

Table 5. Results from gill net samples in Pettit Lake, 1996.

		Rainbow		
Date	**N (CPUE)**	**Mean Lt. (mm)**	**Mean Wt. (g)**	**Gillnet Hours**
10 Jan	2 (0.033)	292.5	na	60
22 May	2 (0.038)	305.0	na	52
17 Jul	112 (1.04)	255.4	na	108
27 Aug	57 (1.58)	258.4	189.7	36
25 Sep	39 (0.84)	261.4	na	46.5
7 Nov	30 (0.83)	283.8	na	36
		Brook Trout		
19 Mar	2 (0.26)	238.5	na	76
22 May	9 (0.17)	285.1	na	52
17 **Jul**	22 (0.20)	257.4	na	108
27 **Aug**	1 (0.03)	182.0	56.8	36
25 **Sep**	4 (0.09)	221.2	na	46.5
7 Nov	2 (0.6)	218.0	na	36
		O. nerka		
10 Jan	50 (0.83)	235.0	na	60
22 Feb	5 (0.07)	215.6	na	68
19mar	2 (0.03)	303.5	290	76
22 may	2 (0.39)	302.5	na	52
17 Jul	**4(0.037)**	225.5	na	108
27 Aug	**1** (0.03)	182.0	56.8	36
7 Nov	**5 (0.14)**	**223.5**	**na**	**39**

general assumptions for the Schnabel method such as methodic use of nets for capture and immigration were violated. In 1997 we will incorporate electrofishing and a Peterson mark-recapture method for a more robust estimation. Based on our rainbow population estimates (Tables 6 and 7), the Kamloops strain of rainbows had a 50% overwinter survival rate. That compares to a 39% survival rate over the 1995/1996 winter (Teuscher and Taki 1996). Again, caution should be used when observing these numbers since standard assumptions were violated when making the population estimates. A total of 40 brook trout were gill netted in the littoral zone for 1996.

Table 6. Population estimate for 1996 stocked Kamloops rainbow trout in Pettit Lake.

	Number of Fish Captured			Total # of Marked Fish	
Date	**Marked(R)**	**Unmarked**	**Total ©**	**(M)**	**(CxM)**
17 Jul	113	0	113	1,971	222,723
27 Aug	47	0	47	2,293	107,771
26 Sep	19	0	19	2,293	43,567
07 Nov	27	1	28	2,293	64,204
Total	**206**	**1**			**438,625**
Population					**2,128 (1,991 to 2,283)**

Table 7. Overwinter population estimate for Kamloops rainbow trout in Pettit Lake.

	Number of Fish Captured			Total # of Marked Fish	
Date	**Marked(R)**	**Unmarked**	**Total ©**	**(M)**	**(CxM)**
22 Jan	2	0	2	1,064	2,128
10 Feb	6	0	6	1,064	6,384
Total	**4**		**4**		**8,512**
Population					**1,064 (714 to 2,086)**

A total of 110 0. ***nerka*** were gill netted in both the pelagic and littoral zones. Vertical gill net captures in the pelagic zone constituted 43% of total 0. ***nerka*** captures. Predominant vertical mesh size captures were 2.54 cm and 3.17 cm.

Spawning Surveys

Stream Spawners- Using a modified area under the curve (AUC) method, kokanee escapement for 1996 in Fishhook, Alturas, and Stanley Lake Creeks was 10,662, 744, and 825, respectively (Figure 7; Table 2).

Since 1992, spawning populations have been variable in Alturas Lake Creek, ranging from 60 to 3,200. The Stanley Lake Creek population rebounded in

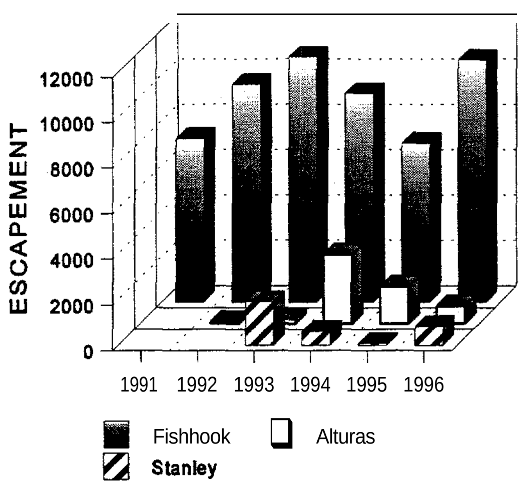

Figure 7. Escapement estimates for Fishhook, Alturas, and Stanley creeks.

escapement numbers for 1996. Fishhook Creek adult returns continue to remain constant.

The male-to-female ratio of kokanee spawners collected at Fishhook weir was 3.3: 1. Males dominated the entire run from 8 August to 27 August, 1996 (Table 8). Female kokanee not passed were culled for fecundity estimates and mean egg weight (g). Kokanee were also culled as part of the management control plan. Males and females released above the weir to spawn were 79% and 86% of the their respective totals. A total of 50 females and 251 males were removed from the Fishhook Creek weir. Fecundity estimates (286), mean fork length (240 mm) and mean total egg weight (*23.5* g) were higher than 1995 (n = 26; Table 9). Females passed over the weir deposited an estimated at 805,000 eggs (3,500 females * 258 eggs / female). Resulting fry recruitment estimates are 99,015 (805,000 eggs * 0.123 egg/try survival).

In 1996, the adults returned one week later than in 1995. Kokanee entered the creek the second week of August with peak counts in mid-August. Weir Counts

Table 8. 1996 adult kokauee passage counts at Fishhook Creek weir.

Date	♂ Counted	♂ Passed	♀ Counted	♀ Passed	% Female	Fecundity
10 Aug	9	9	2	0	18%	
11 Aug	30	30	4	0	12%	
12 Aug	41	41	6	0	13%	
12 Aug						
13 Aug	54	50	14	13	21%	20
14 Aug	49	48	9	7	16%	
14 Aug	1	1			0%	1
15 Aug	86	86	21	21	20%	5
16 Aug	276	276	64	64	19%	
17 Aug	184	65	31	21	14%	
18 Aug	120	45	37	37	24%	
19 Aug	121	90	32	29	21%	
20 Aug	69	69	28	26	29%	
21 Aug	27	27	17	17	39%	
22 Aug	15	15	8	8	35%	
23 Aug	33	30	36	33	52%	
24 Aug	78	75	32	29	29%	
25 Aug	25	14	26	14	51%	
26 Aug						
27 Aug						
27 Aug	4	0	2	0		
Total	**1,222**	**971**	**369**	**319**	**x̄23%**	**26**

for Fishhook Creek adult returns are reported in Table 8.

O. nerka Diet Analysis

Gut content analysis was performed on 95 kokanee captured by trawl and gill nets. Mean percent dry weight values were derived from 68 kokanee containing varying numberss of prey items. Twenty-seven kokanee were void of prey items or prey were highly digested and unidentifiable. Dominant prey items during *the* ice-cover period were *Bosmina spp.,* Cyclopoids and Chironomids (Appendix A).

Electivity indices (Ivlev, 1961) were

Table 9. 1996 fecundity estimation analysis of adult kokanee collected at Fishhook weir.

Date	Lt.(mm)	Wt.(g)	Egg Count	Egg Wt.(g)	%Egg to body weight
10 Aug	236	na	262	na	na
	250	na	239	na	na
11 Aug	235	na	253	na	na
	239	na	288	na	na
12 Aug	238	151.2	317	24.9	16%
	230	135.6	296	21.1	16%
13 Aug	239	na	263	23.3	na
14 Aug	244	150.7	252	23.9	16%
	240	143.9	321	24.8	17%
17 Aug	239	148.0	na	24.0	16%
	240	153.7	na	28.6	19%
	235	141.8	na	25.3	18%
18 Aug	238	na	321	23.7	na
	241	153.7	194	22.8	15%
	238	136.2	352	22.3	16%
19 Aug	233	140.7	314	25.4	18%
	240	140.0	266	21.2	15%
	243	146.5	339	25.1	17%
20 Aug	246	158.3	346	24.7	16%
	246	142.0	316	24.9	18%
23 Aug	240	148.6	326	22.0	15%
	250	151.9	295	21.5	14%
	235	138.0	320	22.1	16%
24 Aug	243	134.7	182	17.3	13%
	236	142.0	304	24.6	17%
27 Aug	238	138.0	213	23.6	17%
Average	**240**	**143.8**	**286**	**23.5**	**16%**

performed for prey items found in gut content analysis (mean percent dry weight) in proportion to zooplankton biomass (**μg/l**) found in Pettit Lake on concurrent sampling days (Figure 8).

0. *nerka* selection index was the highest for Daphnia during periods of high prey availability. The selective ability of 0. ***nerka*** is the sum total of two factors: preference for particular prey and the

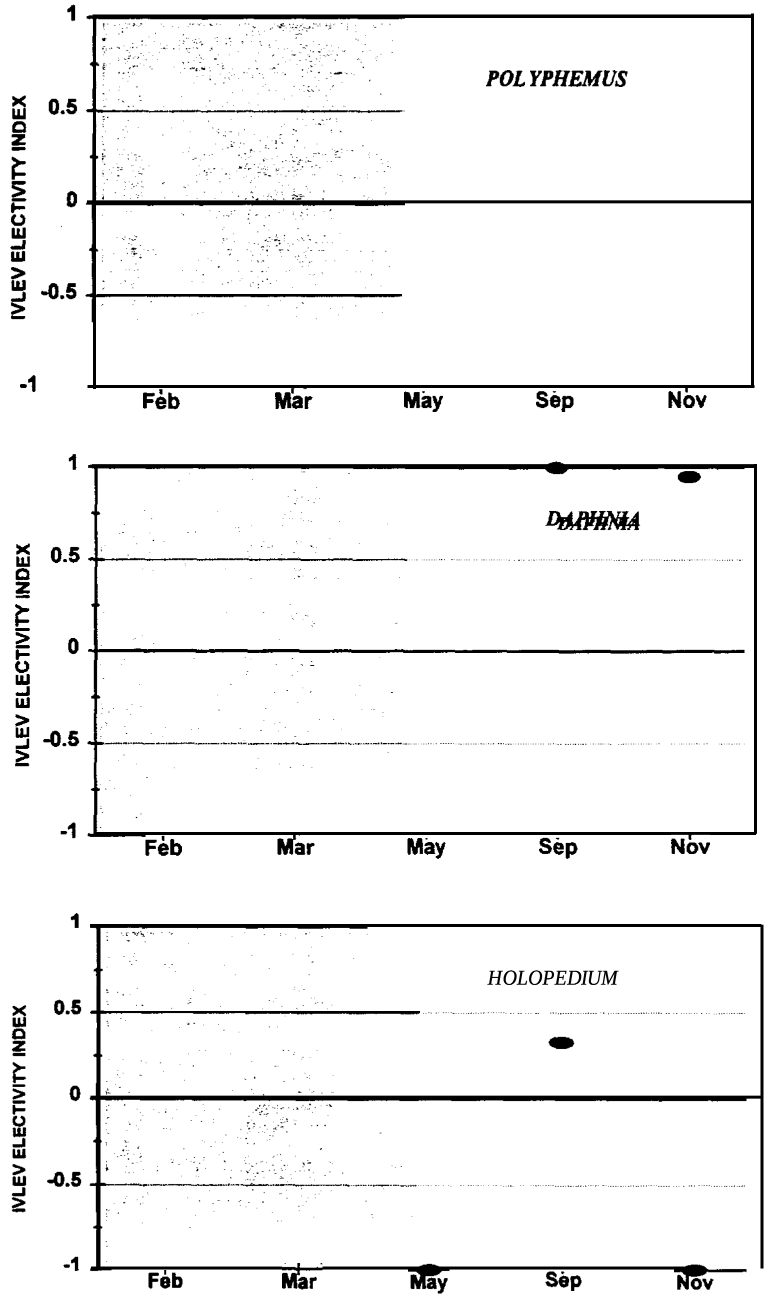

Figure 8. Ivlev **electivity** indices of mean percent biomass (ug/l) proportional to mean percent dry weight of gut content prey items. Positive values indicate selection, negative values indicate avoidance or inaccessibility and 0 is neither selection nor avoidance. Shaded areas denote ice-cover during sampling periods.

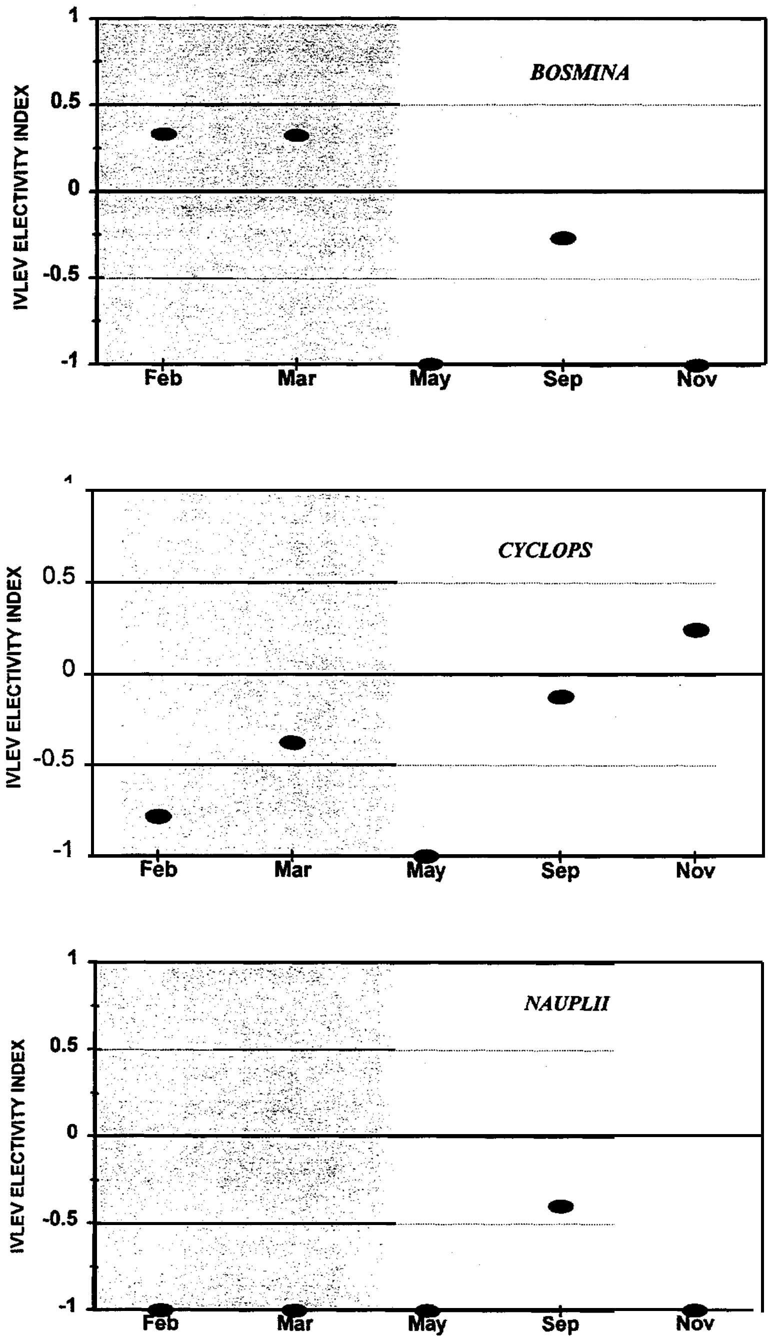

Figure 8 (continued). Ivlev electivity indices of mean percent biomass (ug/l) proportional to mean percent dry weight of gut content prey items. Positive values indicate selection, negative values indicate avoidance or inaccessibility and 0 is neither selection nor avoidance. Shaded areas denote ice-cover during sampling periods.

degree of accessibility (Ivlev, 1961). During the ice-cover period, when Daphnia biomass was low, kokanee selected for Bosmina due to high availability. Preference modes for selection indices were exhibited for holopedium, cylops and polyphemus in concert with daphnia during the period when there was no ice-cover.

Live Feed Training Experiment

No distinct differences were found between growth indices of the live prey and pellet-fed groups. Growth monitoring, from pre-ponding at Eagle Fish Hatchery to the Redfish Lake net pen release, found no notable differences in condition factor (Table 10).

The sockeye in the treatment pens at Redfish Lake yielded a loading density of 0.0001 $lbs./ft^3$, whereas maximum loading density for netpen growth management is 0.25 $lbs./ft^3$.

Net Pen Growth

Growth monitoring was conducted to track the relevant fitness of the 1996 net pen release strategy. Three net pens (16x16x40ft.ea.) were utilized for rearing. Two net pens contained experimental feeding designs consisting of a pellet-fed group (N=30) and a live-feed-trained (N=27) group. A mixed live-feed and pellet-fed group (N=1,869) was the principal release strategy group.

Table 10. Length, weight, STD, fish/pound (FPP), and condition factor (K) for both live feed trained (LF) and pellet fed (P) groups of net pen sockeye at release into Redfish Lake from the net pens.

Date	Location	Feed	FKL (mm)	Total Wt.(g)	STD	cv	Gms./fish	N	FPP	K-Factor
7 Oct	Redfish	LF/P	121	2,274	20.4	16.8	22.5	101	20.1	1.26
26 Jun	Eagle	LF/P	92	793	5.4	5.9	7.8	101	57.7	1.02
7 oct	Redfish	LF	110	381	4.4	3.9	14.1	27	32.1	1.07
26 Jun	Eagle	LF	91	216	7.6	8.4	8.0	27	56.7	1.05
7 Oct	Redfish	P	114	477	7.9	6.9	15.9	30	28.5	1.08
26 Jun	Eagle	P	90	218	8.7	9.7	7.3	30	62.4	1.01

Length (mm) and weight (g) samples were collected from fish prior to initial net pen impoundment and at time of release into Redfish Lake. A minimum of 100 fish were collected at release from the mixed live-feed and pellet-fed group. All sockeye from the two experimental pens were collected for sampling.

Growth analysis performed on the mixed feeding strategy group generated a distinct divergence, from pre-ponding at Eagle fish hatchery to the Redfish Lake release, in terms of several growth indices including; condition factor (K-Factor), coefficient of variation (CV), standard deviation (STD) and length frequency distributions (Table 10). Results suggest that current feed rates (l-2 times/day) are insufficient to produce smolts of equable size and fitness at time of release. Further experimental research is warranted to assess and institute a growth management plan to insure optimal rearing success and smolt release survival.

DISCUSSION

Results from 1996 indicate a need for additional work to further enhance our efforts towards recovery of Snake River sockeye. Among the most notable is a need for an accurate procedure to estimate rainbow trout populations in Pettit Lake and to evaluate feeding protocols for net pen rearing.

Our new design for estimating the rainbow trout population will include electrofishing. This will prevent violating assumptions that are required for a valid estimate using a Peterson mark/recapture estimate. If a pelagic release of the broodstock progeny is successful in enabling pre-smolts to avoid predation by rainbow trout, future population estimates may not be as critical.

Net Pen Monitoring

The 1997 Redfish Lake net pen release has a viable uniqueness of all the release strategies. The "controlled" rearing from hatchery fry ponding to smolt release provides an opportunity to produce smolts of equable size throughout the population. 1996 growth analysis (appendix B & C) suggests that in less than three months (from initial net pen ponding to release) length variation values escalate and condition factor (K-Factor) climb from an optimal value of 1.02 to 1.26. Also length frequency histograms do not show a normal distribution and release weight (g/fish) exceeds proposed target release weight. Projected net pen loading densities for 20K fish at 7 g/fish (65 Fish/Lb.) in 10,240 cubic feet (ft^3) yields 0.03 lbs./ft^3 at ponding. Release projections for the same number of smolts at 12 g/fish (37 Fish/Lb.) yields a loading density of 0.05 lbs./ft^3. These values are well below the prescribed 0.25 lbs./ft^3 loading density for net pen reared sockeye and constitute no spatial restrictions for optimal growth. In reducing K-Factor and bringing CV, STD values closer to 4.0, feed rates for juvenile sockeye on a pen by pen basis should be 6-12 times per day (Duplaga, WDFW., 1996 personal communication). The subsequent monitoring proposal is conservative in approach to diminish intervention impact such as stress related mortality. Various problems arise, from basic implementation of feed rates to the virtual impossibility of adjusting feed patterns due to the nature of automatic feeders and personnel limitations. Hopefully results for 1997, upon TOC approval, will progress to a full scale implementation, involving growth monitoring for all net pens and indexing of relative fish health. Eventual alignment with coded wire tagging protocol will accurately assess release strategies and research projects in the future.

Proposal

Initiate a growth monitoring strategy, in two net pens, throughout the rearing period for adjusting feed patterns and rates for the entire 1997 net pen release group. One net pen will adhere to previous feed rearing strategies, and the other will have feed rate adjustments. Experimental pens will be sampled l-2 times per month during the net pen rearing stage. Initial sampling for all net pen groups at ponding and release will be used for comparative success of the feed rate strategy. Objectives are to confine handling stress in the experimental pens to reduce intervention impact on the other net pen groups and determine mortality rate differences of the sampled pens vs. the non-sampled pens. Optimal alignment of STD, CV and K-factor values in concert with the production of normal length frequency distributions and consistent size at release will enhance smolt release survival and hopefully, adult escapement.

Methods

Collect 100 (minimum) lengths (mm) and weights (g) for each net pen from initial ponding to release. Sample one net pen through the rearing cycle 1-2 times per month.

Sampling techniques will entail a 0.9-l .5 m. diameter hoopnet affixed to a cross cable line. The hoopnet can be centered and lowered in a fixed position to sample the net pen. Fish will be either chummed or not, depending on the ease of obtaining samples. Once the columnar sample is obtained the hoopnet can be pulled near the walkway for processing while the fish remain in water. Mortality will be monitored on a pen by pen basis to track intervention impact on the monitored pen vs. the 3 untouched pens. Feed rates should be 6-12 times per day for optimal juvenile sockeye growth. Feed pattern adjustment (if possible) to coincide with growth management analysis.

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REFERENCES CITED

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

Bowler, B. 1990. Additional information on the status of Snake River sockeye salmon. Idaho Department of Fish and Game, Boise, Idaho.

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

Evermann, B. W. 1896. A report upon salmon investigations in the headwaters of the Columbia River, in the state of Idaho, in 1895, together with notes upon the fishes observed in that state in 1894 and 1895. Bulletin of the United States Fisheries Commission. 16:151-202.

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

McCauley, E. 1984. The estimation of the abundance and biomass of zooplankton in samples. In, J.A. Downing and F. Ringler (eds). Secondary production in freshwater, Second edition. Blackwell Scientific Publishing, Oxford.

Robinson, D.G., and W.E. Barraclough. 1978. Population estimates of sockeye salmon (*Oncorhynchus nerka*) in a fertilized oligotrophic lake. J. Fish. Res. Board Can. 35: 851-860.

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

Teucher D., and D. Taki. 1995. Snake River sockeye salmon habitat and limnological research. In, D. Teuscher and D. Taki (eds.). Snake River sockeye salmon habitat and limnological research. U.S. Department of Energy, Bonneville Power Administration, Portland, OR. Project number 91-71. pp. l-50.

Appendix A. 1996 Pettit Lake kokanee gut content analysis. Mean percent dry weight.

Date	N	Mean FKL(mm)	Mean Wt.(g)	Daph	Holo	Poly	Cycl	Chir Pup	Chir Lar	Amp	Naup	Ostra	L. Occi.
22Feb	10	142.3	31.4	0.0	0.0	0.0	6.1	0.0	0.0	0.0	0.0	0.0	0.0
19 Mar	12	154.6	50.0	0.0	0.0	0.0	23.0	0.0	0.0	0.0	0.0	0.0	0.0
22 May	2	302.5	na	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0
11 Sep	43	153.1	39.3	2.5	2.6	.05	16.0	25.4	0.3	1.4	.60	4.4	2.2
7 Nov	1	255.3	na	56.1	0.0	0.0	43.9	0.0	0.0	0.0	0.0	0.0	0.0

Daph: Daphnia

Holo: Holopedium

Bosm: Bosmina

Poly: Polyphemus

Cycl: Cyclopoids

Ch P: Chironomid Pupae

L. Occ:

Amphi: Amphipods

Naup: Nauplii

Ostra: Ostracoda

Appendix B. 1996 Kamloops rainbow trout gut analysis, mean percent dry weight.

Date	N	FKL(mm)	Prey Wt.(g)	Cyp	Unid Fish	Mol	Odon	Tric	Cole	Hem	Chir Pup	Terr Ins	Plant	Am	Ot
10 Jan	2	286-299	3.8	0.4	0.0	25.9	58.1	0.0	0.0	0.0	0.0	0.0	15.6	0.0	0.0
22 May	2	285-322	10.7	49.3	0.0	2.5	42.1	0.4	0.0	0.0	5.1	0.0	0.7	0.0	0.0
10 Jun	84	na	28.2	0.0	0.0	1.8	7.3	0.0	1.2	5.9	19.3	16.7	47.3	0.5	0.0
27 Aug	47	174-297	17.7	0.0	0.0	7.9	28.5	0.2	0.2	2.9	19.2	26.2	14.9	0.0	0.0
26 Sep	19	229-286	29.0	3.8	0.0	12.2	26.9	0.3	0.3	13.4	0.5	12.6	30.0	0.0	0.0
07 Nov	27	261-334	21.5	1.2	1.3	13.1	57.5	1.1	0.0	2.2	2.4	4.4	13.1	0.0	3.8
11 Feb	6	235-289	13.1	20.0	0.0	51.0	9.1	0.0	0.0	0.0	0.0	0.0	5.6	0.0	14.3

Appendix C. 1996 brook trout gut analysis, mean percent dry weight.

Date	N	FKL(mm)	Prey Wt.(g)	CYP	Unid Fish	Mol	Odon	Tric	Cole	Hem	Chir Pup	Terr Ins	Plant	Sal	Ot
22 May	9	227-335	15.2	15.74	9.3	0.0	67.2	7.2	0.0	0.0	0.0	0.0	0.5	0.0	0.2
28 Aug	2	211-218	1.2	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 Sep	4	179-278	0.6	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7 Nov	2	212-222	0.9	12.82	0.0	*0.0*	87.18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11 Feb	1	400+	16.1	0.0	14.6	*0.0*	*0.0*	0.0	0.0	0.0	0.0	0.0	0.0	85.4	0.0

Unid Fish: Unidentified

Mol: Mollusca

Odon: Odonata

Sal: Salmonid

Terr Ins: Terrestrial Insects

Cole: Coleoptera

Hemi: Hemiptera

Chir Pup: Chironomid Pupae

Cyp: Cyprinid

Amph: Amphipods

Ot: Other

Plant: Plant Matter

Tric: Trichoptera

Chapter 2

Limnology of the Sawtooth Valley Lakes

Bob Griswold[1]

INTRODUCTION

In December 199 1, Snake River sockeye salmon *Oncorhynchus nerka* were listed endangered by the National Marine Fisheries Service. During 199 1, the Shoshone-Bannock Tribes and the Idaho Department of Fish and Game began a cooperative effort to restore sockeye salmon to the Sawtooth Valley Lakes. As part of this effort, the Shoshone-Bannock Tribes contracted Utah State University (USU) to conduct limnological investigations from fall 1991 to fall 1995. From 1991 to 1994, USU studied five lakes: Redfish, Pettit, Alturas, Stanley and Yellowbelly. In 1995 Yellowbelly Lake was dropped from the program because of concerns for the westslope cutthroat trout *Oncorhynchus clarki lewisi* fishery and fish passage problems in Yellowbelly Creek had been identified. In October of 1995, a private consultant, Biolines, was contracted to monitor the four lakes in a move that was intended to be a reduction in both effort and cost. It was believed that after four years of intensive limnological research, enough data had been assimilated that a streamlined monitoring program could be put into effect that would meet recovery efforts. The monitoring protocol used in 1996 was based largely on techniques and methods used by USU during the initial phase of this project. (Budy et al. 1993, Steinhart et al. 1994, Budy et al 1995, Luecke et al 1996).

The purpose of this study was to monitor key limnological characteristics of four Sawtooth Valley Lakes (Redfish, Pettit, Alturas and Stanley), these include; water temperature, dissolved oxygen, water transparency, light, nutrient concentrations, chlorophyll *a*, primary productivity, and zooplankton density and biomass. Primary productivity work was contracted by Utah State University and is covered in a separate section of this report.

Monitoring efforts were intended to

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identify changes in physical and chemical characteristics and to assess productivity of the Sawtooth Valley Lakes. Data collected was used to model carrying capacity of 0. *nerka* for individual lakes in the Sawtooth Valley (Stockner 1997, unpublished).

METHODS

Lake sampling was conducted from November 1995 to November 1996. Four Sawtooth Valley Lakes: Redfish, Pettit, Alturas and Stanley were sampled once each month from October through May and twice a month from June through September. The stations were positioned along the longitudinal axes of the lakes, with the main station (A) mid-lake, station (B) near the south or west end (inlet), and station C near the north or east end (outlet).

In 1996, Redfish Lake was fertilized from 26 August to 12 October and sampling was performed every other week to comply with Idaho Division of Environmental Quality's (DEQ) consent order. Lakes were not sampled December 1995, April 1996 and December 1996 because ice conditions precluded travel on the lakes. Utah State University, contracted by the Shoshone-Bannock Tribes, studied these lakes extensively from 1991 to 1995. Data collected, compiled and reported by USU have been used throughout this report (Spaulding 1993, Teuscher et al. 1994, Teuscher et al. 1995, Teuscher and Taki 1996).

Profile Data

Temperature, dissolved oxygen and conductivity profiles were collected at the main station of each lake using a Hydrolab® Surveyor3™ equipped with a Hydrolab H20® submersible data transmitter. Temperature, dissolved oxygen and conductivity were recorded at 1-2 m intervals to the thermocline, then at 2-10 m intervals to the bottom. The instrument was calibrated each day prior to sampling. Calibration for dissolved oxygen was done using barometric pressure estimated from elevation and for conductivity using standards from the Myron L company.

Water transparency

Water transparency was measured at the main station of each lake with an 20 cm black and white Secchi disk. The disk was lowered into the water until it disappeared and the depth was noted. The depth at which the disk reappeared when raised was also noted and an average of the two values was recorded as water transparency (Koenings et al. 1987).

Light attenuation was measured at the main station of each lake. A LiCor® Li-1000 data logger was used 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 the 1% light level. Deck and sea cell readings were made simultaneously to correct for changes in ambient light. Depth of the 1% light level was estimated in the field to allow sampling at that depth.

Water chemistry

Water was collected for nutrient analysis each month except during fertilization when nutrient samples were collected every two weeks. Surface water was collected with a 25 mm diameter, 6m long lexan® tube. One end of the tube was weighted and lowered to 6 m, the end was plugged and the tube was rapidly retrieved. Discrete water samples were collected from various depths using a 3 L Van Dom bottle. Water was transferred to nalgene bottles, rinsed in 0.1 N HCL, then rinsed 5 times with sample water. Bottles were stored at 4° C while in the field. Ammonium, nitrate-nitrite nitrogen and orthophosphorous samples were filtered through 0.45 um acetate filters at 130 mm Hg vacuum in the lab. Water samples were frozen and shipped to the UC Davis Limnology Lab for analysis. Ammonium was assayed with the indophenol method, nitrate-nitrite with the hydrazine method, organic nitrogen using Kjeldahl nitrogen, the calorimetric method was used to determine orthophosphorous and total phosphorous was assayed by persulfate digestion. Replicates were generally run for surface (O-6 m) samples.

Chlorophyll *a*

Water was collected for chlorophyll *a* analysis using the same techniques used to collect water for nutrient analysis. Surface water (O-6 m) was sampled at three stations and discrete depths were sampled at the main station of each lake. Water from the surface and 1% light level was consistently sampled, other discrete depths were sampled intermittently.

Samples were stored at 4° C then filtered onto 0.45 um cellulose acetate membrane filters with 130 mm Hg vacuum pressure. Filters were placed in centrifuge tubes and frozen (-25" C). Chlorophyll *a was* extracted in methanol for 12-24 hours. Flourescence was then measured with a Turner model 1 O-AU fluorometer calibrated with a chlorophyll standard obtained from Sigma Chemical Company. Samples were run before and after acidification to correct for phaeophytin. (Holm-Hansen and Rieman 1978).

Zooplankton

Zooplankton was collected one to two times per month. Vertical hauls were made with a 0.35 m diameter, 1.58 m long, 80 μm mesh conical net, with a removable bucket. The net was equipped with a release mechanism which allowed sampling at discrete depth intervals. A General Oceanics flow meter modified with an anti-reverse bearing was mounted in the mouth of the net. The flow meter was used to correct for net efficiency (clogging). The net was retrieved by hand at a rate of one meter per second. 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. 1993) using techniques and length-weight relationships developed by McCauley (1984) and Koenings et al. (1987).

Results

Above average precipitation and below average temperatures during 1996 resulted in higher annual discharge in the Salmon River. Precipitation at Stanley, Idaho (NOAA Cooperative weather station 108676) was 57.2 cm. This is 29% higher than the mean for the period of record (1963- 1996) and represents the wettest year since limnological monitoring began in 1991 (Figure 9). Mean seasonal air temperatures at Stanley, Idaho, for May through October 1996 was 9.11 "C, slightly lower than the 33 year average of 9.46 ° C (Figure 10).

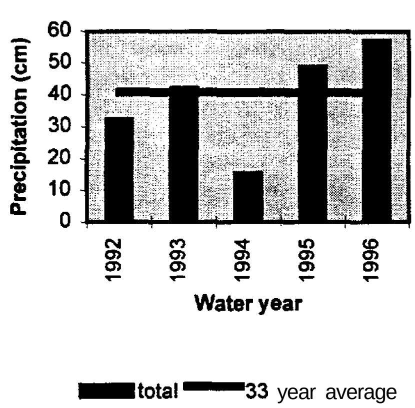

Figure 9. Precipitation (cm) at **Stanley, Idaho for** water **years (October-September) 1992 to 1996.**

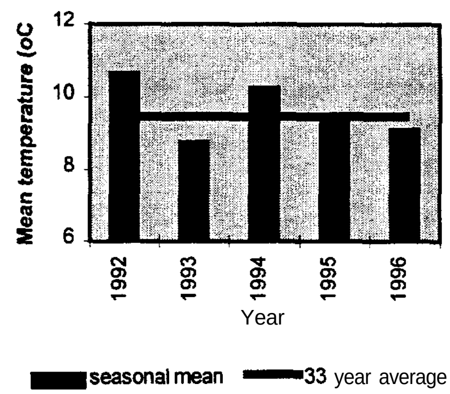

Figure 10. Seasonal mean air temperature (°C) at Stanley, Idaho (May - October), 1992- 1996.

Mean annual discharge of the Upper Salmon River measured at the town of Salmon (USGS gage 13302500) was 72.2 m^3/s (2550 f^3/s), 3 1% above the 83 year average mean annual discharge of 55.0 m^3/s (1942 f^3/s). This represented the highest mean annual discharge since limnological investigations began in 1991 (Table 11).

<u>Profile Data</u>

Lakes were inversely stratified and ice covered between January and April, 1996. The lakes mixed during May and were weakly stratified by June (Figure 11). In July and August the thermocline

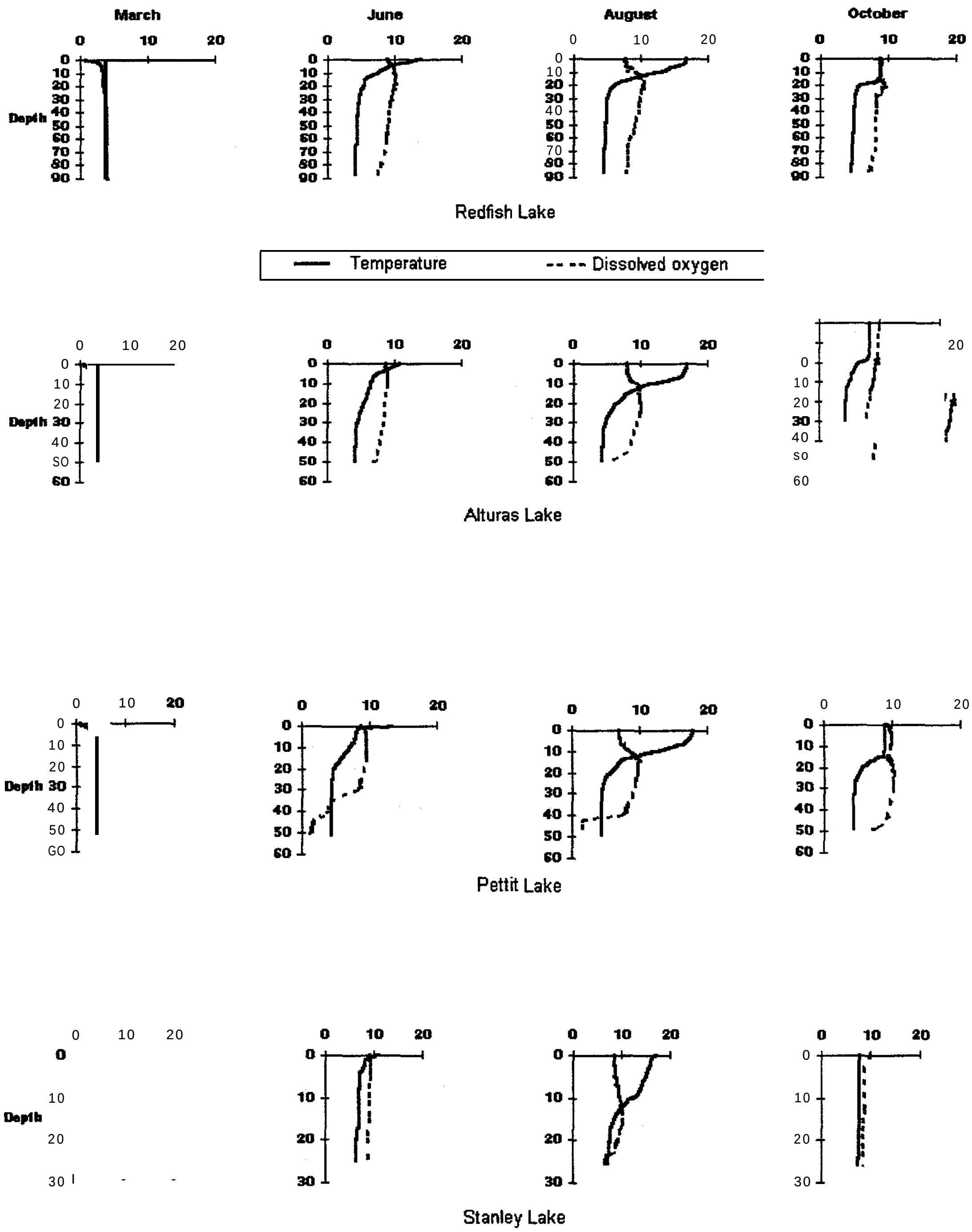

Figure 11. Temperature (^{o}C) and dissolved oxygen (mg/l) profiles for March, June, August and October, 1996 in Redfish, Alturas, Pettit and Stanley Lakes.

Table 11. Mean annual discharge for the Salmon River at Salmon, ID for 1990 through 1996. Mean, minimum, and maximum are for the period of record, 1913 to 1996.

water year	mean annual discharge (cfs)	mean annual discharge (m^3/s)
1990	1320	37.4
1991	1337	37.9
1992	1103	31.2
1993	1912	54.1
1994	1024	29.0
1995	2108	59.7
1996	2550	72.2
mean	1942	55.0
maximum	3163	89.6
minimum	1024	29.0

was well developed, and in late October the three largest lakes, Redfish, Alturas and Pettit, remained stratified, while Stanley Lake, the smallest, was well mixed. 0. *nerka* habitat was not limited by dissolved oxygen levels in Redfish, Alturas and Stanley Lakes. In meromictic Pettit Lake, low dissolved oxygen concentrations (<5 mg/l) in the bottom 10 m may have precluded use by 0. *nerka*. This would represent a loss of 10% (4.9 million cubic meters) in usable lake volume. Conductivity measures were approximately 20 μS/cm in Pettit, 25 μS/cm in Redfish, 45 μS/cm in Alturas and 30-40 ,&/cm in Stanley Lakes (Appendix 1). Conductivity measures were relatively consistent throughout the year and were similar to those reported by Luecke et al. (1996).

Water transnarencv

Secchi transparencies followed similar patterns as observed in the past (Budy et al. 1996). Transparencies were lowest during January and February when lakes were ice covered and in June after spring mixing stimulated phytoplankton production (Figure 12). Transparencies in all lakes increased throughout the summer and fall until fall turnover. Stanley Lake had the lowest transparencies (3.8-10.9 m), Alturas (4.6-13.8 m) and Pettit (5.0 to 17.5 m) were similar, although Pettit had higher transparencies during September and October. Redfish Lake had consistently higher transparencies than the other lakes ranging from 6.3 to 18.0 m. Late summer and fall transparencies in Redfish Lake were shallow compared to 1993 and 1994 and deeper than observed in 1995. Pettit and Alturas transparencies were similar to those observed in 1993-95. Stanley Lake had deeper transparencies than in 1994 and 1995.

Light

Depth of the one percent light level was deepest in Redfish Lake (20-25 m) followed by Pettit (19-20 m), Alturas (11.5-20.5 m) and Stanley Lakes (7.5-16 m). This was consistent with ranking found in 1995 (Luecke et al. 1996) (Figure 13).

Water chemistry

The Sawtooth Valley Lakes were characterized by extremely low nutrient concentrations. Soluble nutrient concentrations were generally below method detection levels (Table 12).

Orthophosphorous was sampled intermittently, except in Redfish Lake, because concentrations reported in past years have generally been below detection levels. Redfish surface (O-6 m) orthophosphorous concentrations were at or below method detection levels except during September and October (Figure 14).

Table 12. Nutrient assay methods with minimum detection levels (MDL) and 99% confidence interval. (C.I.) (Hunter et al. Unpublished)

assay	method	MDL (ug/l)	99%C.I.
ammonium	indophenol	3	± 0.3
nitrate	hydrazine	2	± 0.3
organic nitrogen	Kjeldahl	35	± 16.0
ortho-phosphorous	calorimetric	1	± 6.6
total phosphorous	persulfate digestion	2	± 0.5

During this time, orthophosphorous concentrations in the meta- and hypolimnion were also elevated above detection levels in Redfish Lake. While this coincided with fertilization of Redfish Lake it was probably not a result of nutrient additions to Redfish Lake since this pattern was observed in all four of the Sawtooth Valley Lakes monitored in 1995 (Luecke et al. 1996) (Appendix 3). Surface orthophosphorous levels in Pettit and Alturas Lakes were at or below detection levels throughout 1996. Ammonium (NH4) concentrations were low in surface waters of the Sawtooth

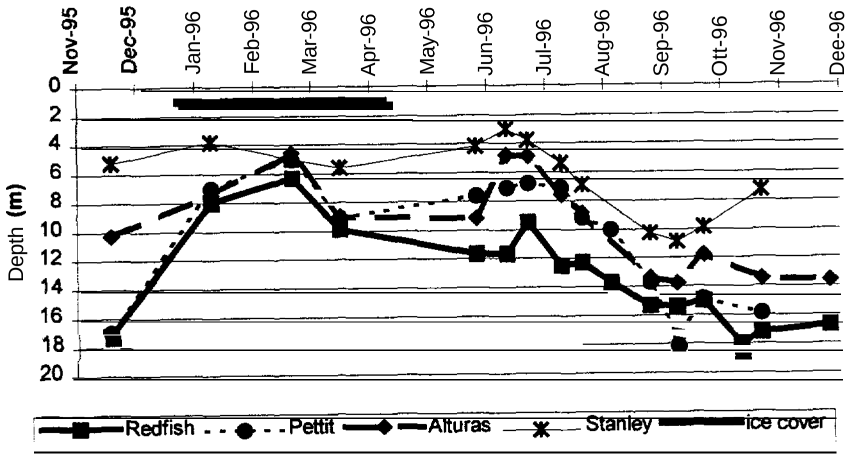

Figure 12. Secchi transparencies (m) for Redfish, Pettit, Alturas and Stanley Lakes, November 1995 through November, 1996.

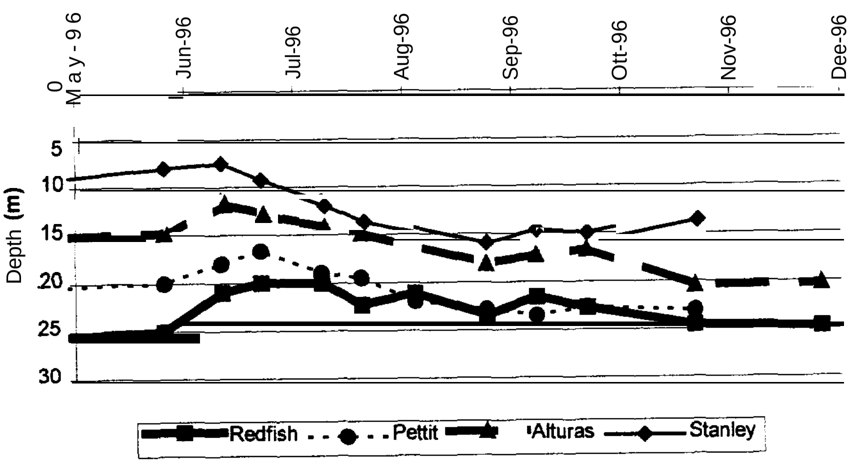

Figure 13. Depth of one percent light level (m) for Sawtooth Valley Lakes in 1995 and 1996.

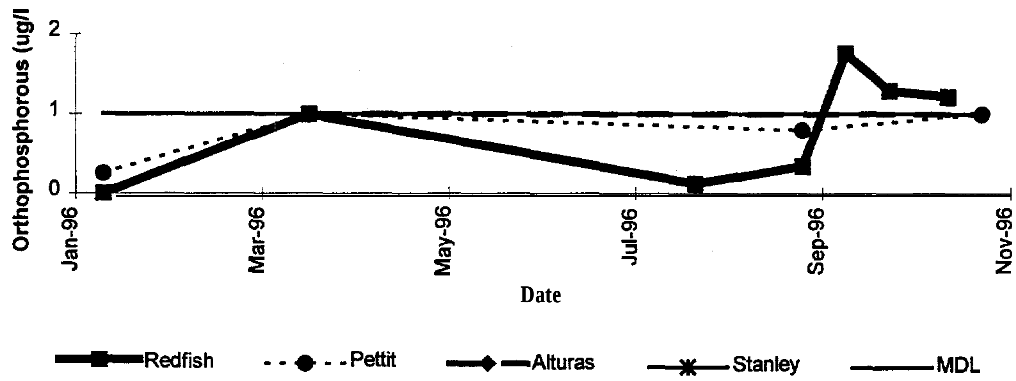

Figure 14. Surface (O-6 m) concentrations of orthophosphorous **(ug/l)** in the Sawtooth Valley Lakes, 1996.

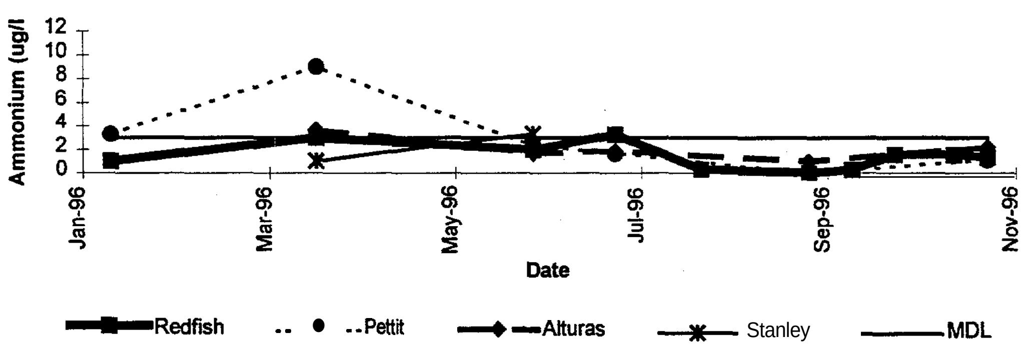

Figure 15. Surface (O-6 m) concentrations of ammonium **(ug/l)** in the Sawtooth Valley Lakes, 1996.

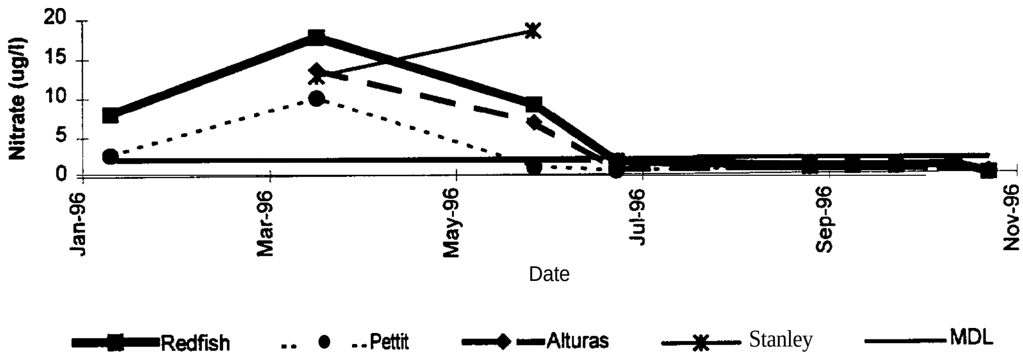

Figure 16. Surface (O-6 m) concentrations of nitrate-nitrite(ug/l) in the Sawtooth Valley Lakes, 1996.

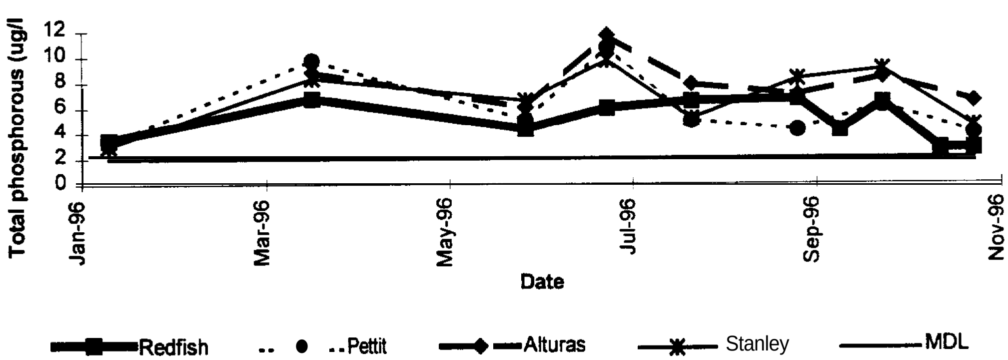

Figure 17. Surface (O-6 m) concentrations of total phosphorous (ug/l) in the Sawtooth Valley Lakes, 1996.

Lakes in 1996. Ammonium concentrations peaked between March and late June at levels barely exceeding method detection levels. The highest ammonium concentrations were found in Pettit Lake (9.0 ug/l), peaks in the other lakes ranged from 3.3 to 3.7 ug/l. (Figure 15).

Nitrate (NO3+NO2-N) peaked in March, then fell below the method detection level (2.0 ug/l) by late June where they remained for the rest of the year (Figure 16). Surface concentrations were highest in Stanley Lake (18.3 ug/l) and Redfish Lake (17.7 ug/l) and lowest in Pettit Lake (10.0 ug/l). Total phosphorous concentrations in surface waters of Pettit (10.7 ug/l), Alturas (11.6 ug/l) and Stanley Lakes (9.6 ug/l) peaked in June, 1996.

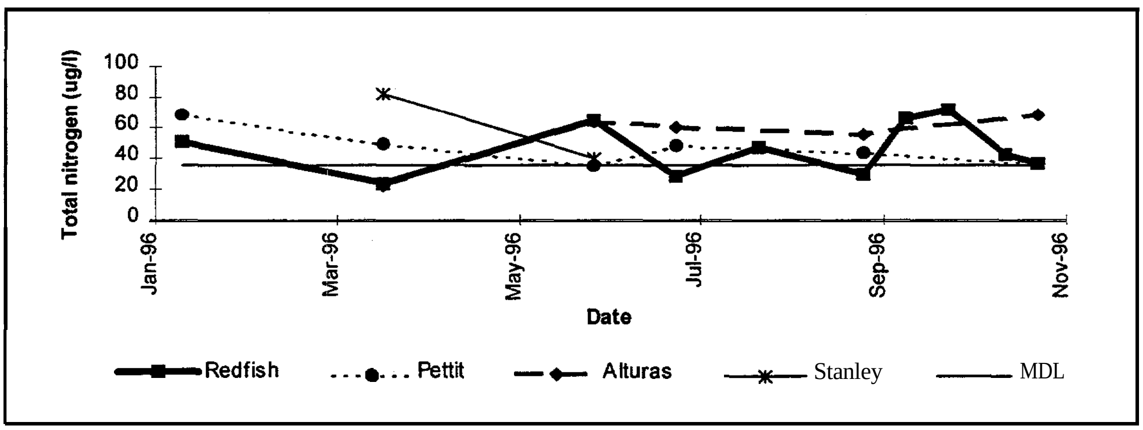

Figure 18. Surface (O-6 m) concentrations of total nitrogen (ug/l) in the Sawtooth Valley lakes, 1996.

Redfish Lake showed a less pronounced peak in July (6.5 ug/l) and August (6.6 ug/l), 1996 (Figure 17).

Total nitrogen concentrations were variable, most assays were above detection levels, except in Redfish Lake which intermittently fell below detection levels. Peak values were similar between the lakes, ranging from 82.0 ug/l in Stanley to 67.7 ug/l in Pettit Lake (Figure 18).

Chlorophyll *a*

Surface chlorophyll *a* (6-0 m) concentrations peaked during March in Redfish Lake, and during May in Pettit, Alturas and Stanley Lakes. Chlorophyll *a* concentrations declined until late August when levels began to increase (Figure 19). Concentrations ranged from 2.7 ug/l in Stanley Lake during May to 0.5 ug/l in Redfish Lake during August (Appendix 3).

Chlorophyll *a* at the one percent light level was highest in Redfish Lake during August, and lowest in Stanley Lake in September. In general, the lakes are ranked opposite of surface chlorophyll a levels with Redfish having the highest chlorophyll a concentrations, followed by Pettit, then Alturas and Stanley Lakes (Figure 20).

Zooplankton

Total peak zooplankton biomass in 1996 was highest in Stanley Lake (46.6 ug/l), and lowest in Redfish Lake (19.8 ug/l). Alturas and Pettit were intermediate with 24.8 ug/l and 22.7 ug/l, respectively (Figure 21). Redfish Lake zooplankton biomass was similar to that observed in 1993, when biomass began to increase in July and peaked in late August. Compared to 1995, a similar year climatically, zooplankton biomass increased and peaked earlier in the season.

Ranking of the lakes by zooplankton biomass was different than in previous years. Prior to 1995, Pettit and Stanley Lakes had the highest biomass and Alturas had the lowest. In 1995, Pettit zooplankton populations were the lowest of the Sawtooth Lakes. In 1996, Pettit zooplankton remained depressed, although it was higher than in 1995. Zooplankton biomass in Alturas lake was higher than in any year previously observed and exceeded levels in Redfish and Pettit Lakes.

Redfish Lake zooplankton species composition was similar to that observed in 1995 with the summer/fall community dominated by *Bosmina, Daphnia* and *Holopedium* (Figure 22). Winter biomass was dominated by Cyclopoid copepods in 1995 and 1996. Density peaked with approximately two Daphnia per liter, similar to 1994 and 1995 and higher than observed in 1993 (Appendix 4). In early September, 1996, coinciding with the seasonal decline in biomass, we observed dead zooplankton floating in mats on the surface of Redfish Lake. Samples of the zooplankton were collected and identified as being almost exclusively *Daphnia*. Ephippia (resting eggs), which could have explained this die-off were not observed. Pettit zooplankton biomass remained depressed compared to 1993 and 1994, when biomass peaked at 40 to 50 μg/l.. (Figure 23). Biomass was higher in 1996 than in 1995 and was dominated by *Cyclopoid* copepods and *Bosmina*. Daphnia biomass was below 0.2 μg/l in both years.

Alturas Lake zooplankton biomass was the highest and most diverse observed during this study. Prior to 1996, the zooplankton community was almost exclusively *Bosmina*, whereas in 1996 Cyclopoid copepods, Calanoid copepods, *Daphnia* and *Bosmina* were well represented (Figure 24). Zooplankton numbers continued to be dominated by Bosmina, but the larger bodied Daphnia reached a density of 2 per liter and a biomass of over 10 ug/l.

Stanley Lake zooplankton biomass was similar to 1995, with most biomass represented by Daphnia, Holopedium and Calanoid copepods (Figure 25).

Discussion

In general, 1996 was cool and wet, similar to 1993 and 1995. Based on water quantity in the basin, relatively high nutrient loading would be expected (Gross 1995). Increased discharge would also reduce lake retention time and could impede lake warming. Comparisons of seasonal means (May-October) shows mean epilimnetic temperatures were the coolest observed since 1991 (Table 5).

Secchi transparencies were low, similar to the wet cool years 1993 and 1995, and surface chlorophyll *a* levels were higher than previously observed. Similar to what was observed in 1993 and 1995, high discharge and the expected increase in nutrient loading did not result in high

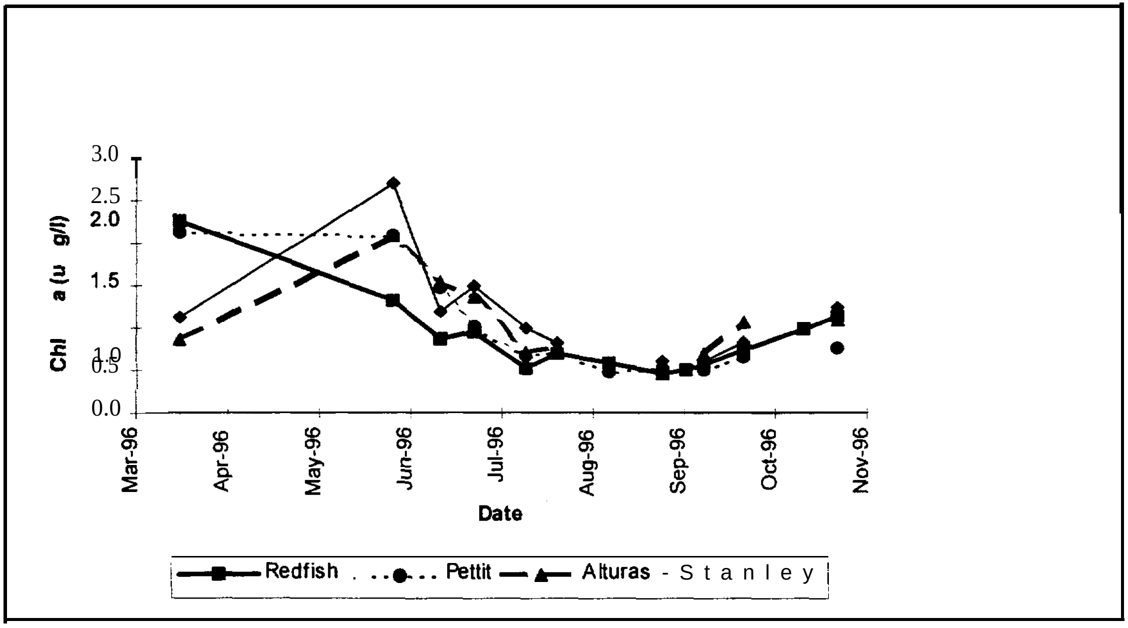

Figure 15Figure 19. Surface chlorophyll a concentrations (ug/l) in the Sawtooth Valley lakes, 1996.

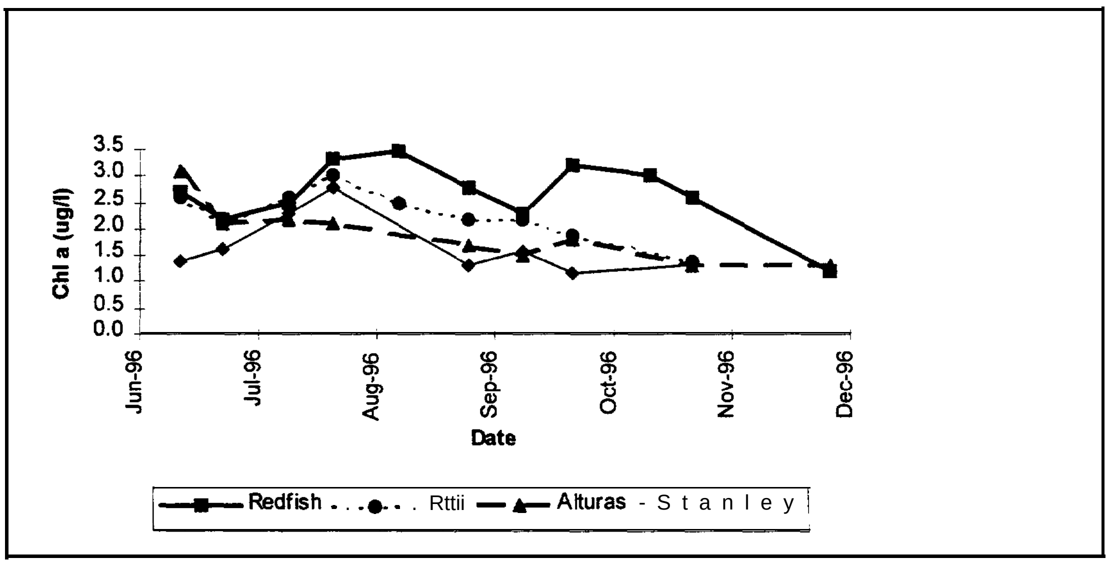

Figure 16Figure 20. Chlorophyll a concentrations (ug/l) at the one percent light level in the Sawtooth Valley lakes, 1996.

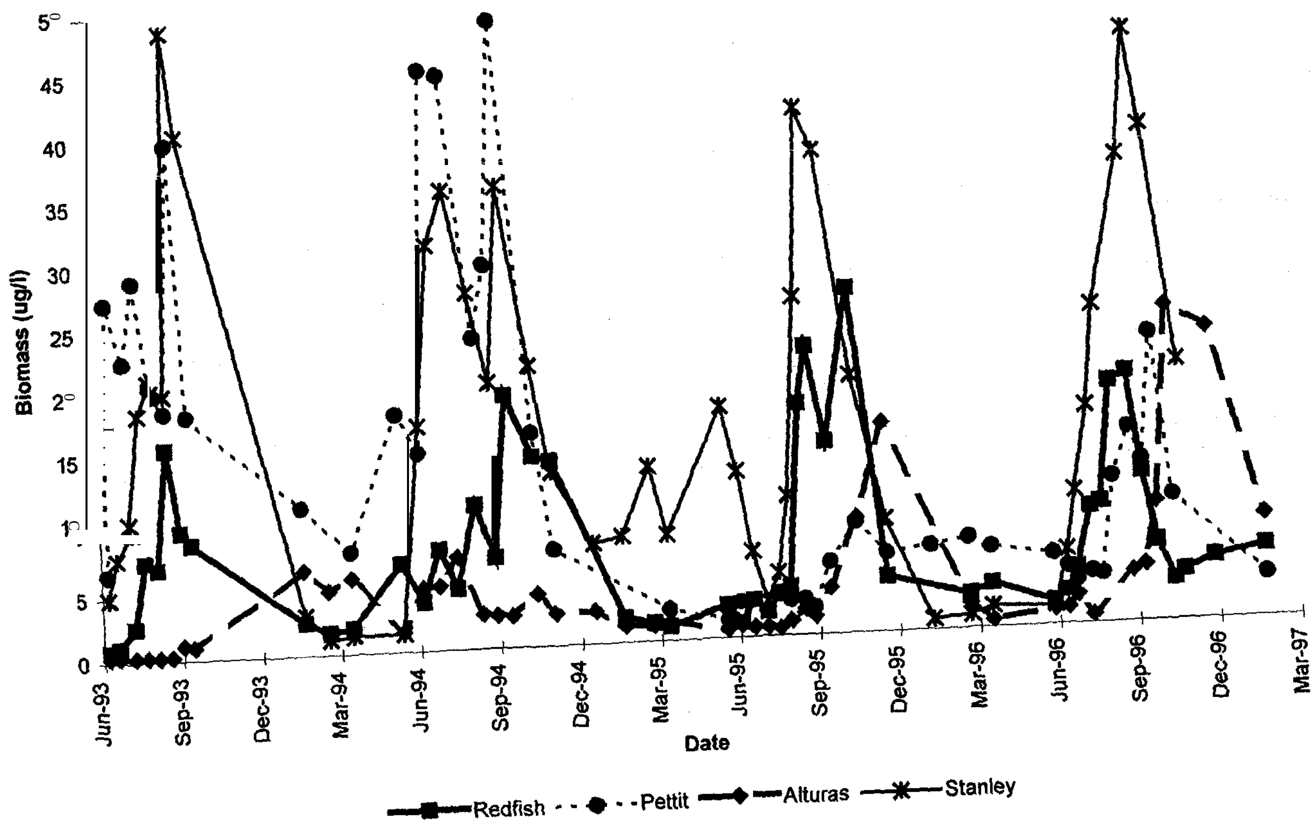

Figure 21. Total zooplankton biomass (ug/l) weighed by lake volume for the Sawtooth Valley Lakes, 1993 to 1996.

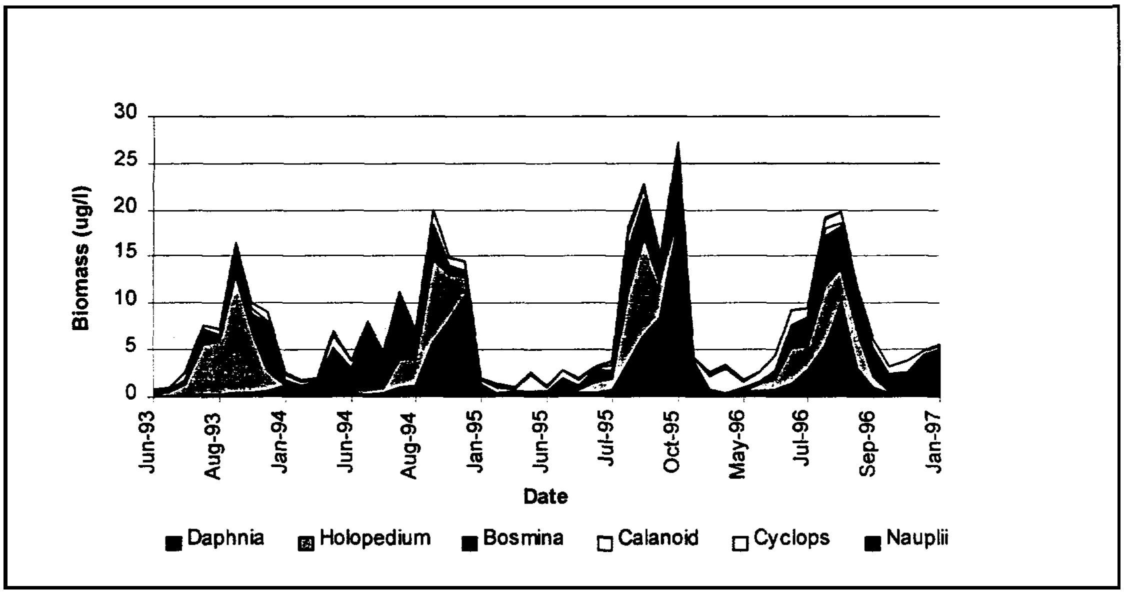

Figure 22. Redfish Lake zooplankton biomass (ug/l) weighted by lake volume, 1993-1996.

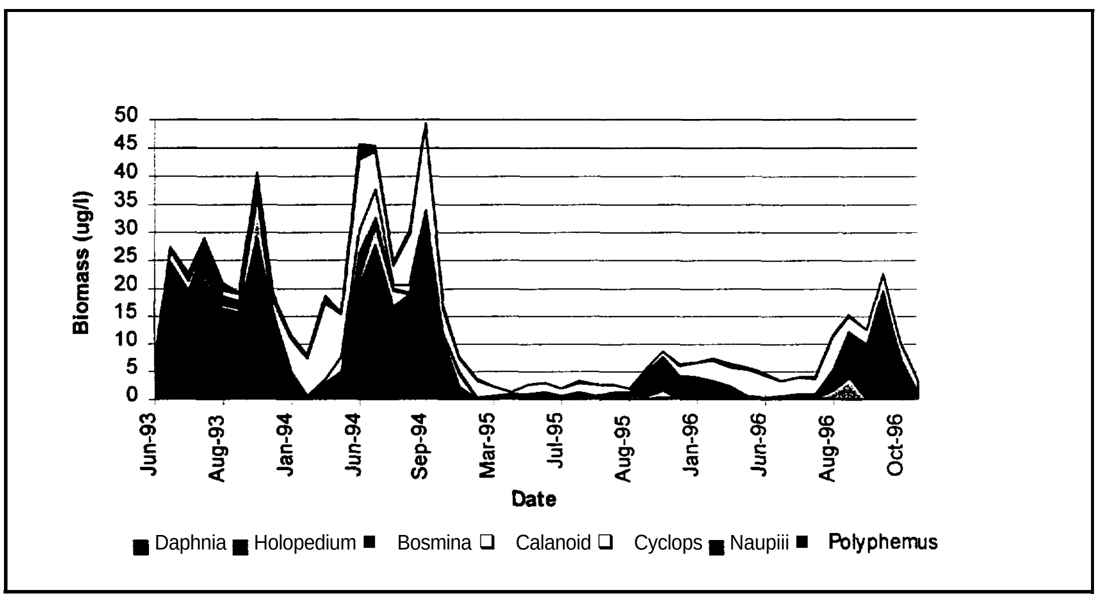

Figure 23. Pettit Lake zooplankton biomass (ug/l) weighted by lake volume, 1993-1996.

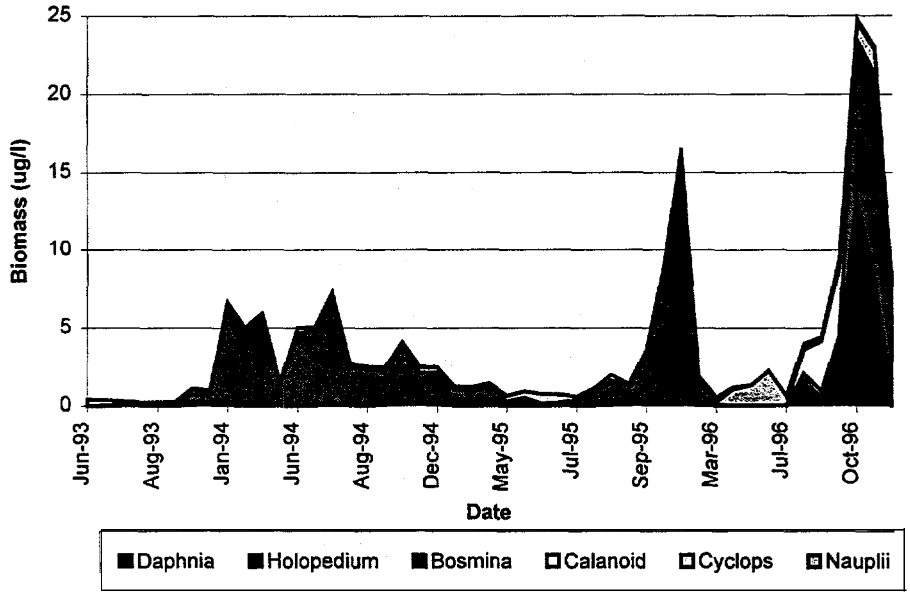

Figure 24. Alturas Lake zooplankton biomass (ug/l) weighed by lake volume, 1993-1996.

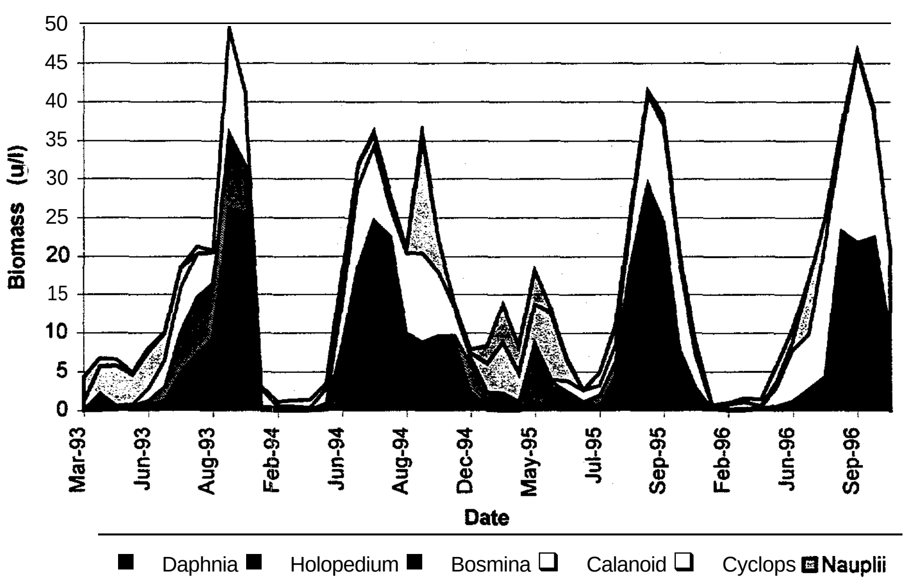

Figure 25. Stanley Lake zooplankton biomass (ug/l) weighed by lake volume, 1993-1996.

zooplankton biomass, rather high mean seasonal zooplankton biomass appears to be associated with warm dry years such as 1992 and 1993. This may be a result of delayed zooplankton reproduction caused by low water temperatures. Pennak (1989) reports cladoceran reproduction is initiated when temperatures reach 6- 12 °C.

In Redfish Lake inter-annual trends were obfuscated by the addition of nutrients. In 1995, nutrients were applied from June to October, Secchi transparencies and temperatures were similar to 1993 but zooplankton biomass was the highest ever observed. This was probably a response to lake fertilization (Luecke et a1.1995). Chlorophyll *a* levels were low, similar to 1992 and 1994, a result of higher zooplankton biomass and the resultant increased grazing pressure. In 1996, nutrients were applied to Redfish Lake for a shorter duration (August to October). This abbreviated application appeared to increase primary production (Wurtsbaugh, this report) but not zooplankton biomass. Redfish Lake zooplankton biomass was less than observed in 1994, a warm dry year, and in 1995 a cool, wet year with fertilization. In general high transparencies are associated with low surface chlorophyll a concentrations, however this was not the case in Redfish in 1996. This may have been a result of changes in the way seasonal means were calculated. In past years simple means of all parameters measured during regular limnology were used. This tends to weight more heavily toward summer values when sampling was conducted more frequently. Because not all years were sampled the same number of times each month, in 1996 seasonal means were calculated from monthly means (Table 13).

In 1997, approximately 500,000 of age 0+ sockeye salmon are scheduled for release into the Sawtooth Valley Lakes (Sockeye technical oversight committee, March 1997 minutes). Recent changes in zooplankton populations have altered the outlook for 0. *nerka* growth and survival in the different lakes. Zooplankton populations in Pettit Lake collapsed in 1995. This was an apparent response to intense grazing pressure by approximately 15 kg of *O. nerka* biomass/ha (>360/ha) in 1995 and 1996. (P. Kline memo to Stockner). 0.

Table 13. Seasonal means (May - October) for secchi transparency, epilimnetic temperature, surface chlorophyll a, and total zooplankton biomass.

Lake	Year	Secchi [1] Transparency (m)	Epilimnetic [1] temperature (°C)	Surface [1] chl a (ug/l) (ug/l)	Whole-lake [2] zooplankton biomass (ug/l)
Redfish	1992	13.3	14.4	0.5	4.7
Redfish	1993	12.6	12.2	0.7	7.0
Redfish	1994	15.0	14.0	0.4	10.3
Redfish	1995	11.8	12.9	0.5	11.8
Redfish	1996	14.1	11.3	0.8	7.8
mean		**13.4**	13.0	0.6	8.3
Pettit	1992	15.0	14.9	0.4	30.7
Pettit	1993	13.5	12.7	0.6	22.4
Pettit	1994	14.1	14.5	0.3	31.0
Pettit	1995	12.0	12.7	0.4	3.9
Pettit	1996	11.1	11.1	1.0	9.1
mean		13.1	13.2	0.6	**19.4**
Alturas	1992	13.0	14.3	0.5	4.7
Alturas	1993	9.5	11.8	0.9	0.6
Alturas	1994	14.2	13.4	0.5	3.9
Alturas	1995	9.4	12.0	0.4	2.7
Alturas	1996	10.8	10.5	1.1	6.6
mean		**11.4**	**12.4**	**0.7**	**3.7**
Stanley	1992	8.6	14.2	0.8	32.1
Stanley	1993	7.0	11.1	1.3	18.8
Stanley	1994	7.9	14.1	0.5	24.6
Stanley	1995	5.2	11.4	0.9	19.5
Stanley	1996	7.0	10.0	1.3	21.8
mean		**7.1**	**12.2**	**1.0**	**23.4**

[1] 1992- 1995 from simple means, 1996 from monthly means

[2] 1992 from simple means, 1993-1 996 from monthly means

nerka biomass is expected to remain at this level through 1997, which will continue to suppress zooplankton populations. In Alturas Lake, zooplankton populations increased in late 1996. This represents a recovery of zooplankton populations in Alturas Lake believed to have been suppressed by large *O. nerka* populations. In 1990 and 1991, biomass was 3.26 and 3.97 kg/ha and densities were 374.7 and 369.9 0. *nerka* / ha , respectively. It should be noted that while zooplankton populations declined when biomass of 0. *nerka* was 15 kg/ha in Pettit and 3.3-4.0 kg/ha in Alturas, densities of 0. *nerka* were similar in both lakes with over 360/ha. Alturas lake zooplankton populations required over 5 years for recovery, which should caution managers to avoid overstocking theses lakes.

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References

Budy, P., C. Luecke, W.A. Wurtsbaugh, and H. Gross. 1993. Limnological conditions of Sawtooth Valley Lakes with respect to potential growth of juvenile Snake River Sockeye Salmon. *In* Teuscher, D., and D. Taki (eds). Snake River Sockeye Salmon (Oncorhynchus nerka) habitat/limnological research. Annual report 1992. U.S. Department of Energy, Bonneville Power Administration, Division of Fish and Wildlife. (91-71).

Budy, P., G. Steinhart, C. Luecke, and W.A. Wurtsbaugh. 1995. Limnological investigations of Sawtooth Valley Lakes, 1994. *In* Snake River Sockeye Salmon habitat and limnological research. Annual report 1994. U.S. Department of Energy, Bonneville Power Administration, Division of Fish and Wildlife. (91-71).

Budy, P., C. Luecke, and W.A. Wurtsbaugh. 1996. Limnology of Sawtooth Valley Lakes in 1995. *In* Snake River Sockeye Salmon habitat and limnological research. Annual Report 1995. U.S. Department of Energy, Bonneville Power Administration, Division of Fish and Wildlife. (91-71).

Budy, P., C. Luecke, and W.A. Wurtsbaugh. 1996. A comparison of four years of limnology in the Sawtooth Lakes with emphasis on fertilization in Redfish Lake. *In* Snake River Sockeye Salmon habitat and limnological research. Annual Report 1995. U.S. Department of Energy, Bonneville Power Administration, Division of Fish and Wildlife. (91-71).

Gross, H.P., W.A Wurtsbaugh, C. Luecke, and P. Budy. Nutrient limitation of phytoplankton in oligotrophic lakes of the Sawtooth Valley, Idaho. *In* Snake River Sockeye Salmon (Oncorhynchus nerka) habitat/limnological research. Annual report 1992. U.S. Department of Energy, Bonneville Power Administration, Division of Fish and Wildlife. (91-71).

Gross, H. P. 1995. Evaluation of lake fertilization as a tool to assist in the recovery of the Snake River Sockeye Salmon (Oncorhynchus nerka). M.S. Thesis, Utah State University, 151 p.

Holm-Hanson, 0. and B. Rieman, 1978. Chlorophyll a determination: improvements in methodology. Oikos 30:438-447.

Hunter, D.A., J.E. Reuter, and CR. Goldman. (Unpublished). Standard operating procedures. Lake Tahoe Interagency Monitoring Program. University of California at Davis, Tahoe Research Group. 35 p.

Koenings, ,J.P., J.A. Edmundson, G.B. Kyle, and J.M. Edmundson. 1987 Limnology field and laboratory manual: methods for assessing aquatic production. Alaska Department of Fish and Game. Fisheries Rehabilitation, Enhancement and Development Division. Limnology Section. Number 7 1: 212p.

Kline, P. 1996. Memo to Dr. John Stockner. Idaho Department of Fish and Game, Eagle Idaho.

Luecke, C., M. Slater, and P. Budy. 1996. Limnology of Sawtooth Valley Lakes in 1995. *In* Snake River Sockeye Salmon habitat and limnological research. Annual Report 1995. U.S. Department of Energy, Bonneville Power Administration, Division of Fish and Wildlife. (9 l-7 1).

McCauley, E. 1984. The estimation of the abundance and biomass of zooplankton in samples, Chapter 7, In A manual on methods of secondary productivity in freshwaters, Second Edition., J. A. Downings and F. Rigler [ed.]. Blackwell Scientific.

Pennak, R. W. 1989. Fresh-water invertebrates of the United States, protozoa to mollusca. Third Edition. John Wiley and Sons, Inc. 628 p.

Spaulding, S. 1993. Snake River Sockeye Salmon (Oncorhynchus nerka) habitat/limnological research. Annual Report 1992. U.S. Department of Energy, Bonneville Power Administration, Portland, OR. Project number 91-7 1.

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

Stockner, J.G. 1997. Unpublished report. Review: An assessment of rearing capacity OS Stanley Basin lakes for Sockeye Salmon (Oncorhynchus nerka); recommendations for enhancement by whole-lake fertilization: and comments on limnological monitoring. 19 p.

Teuscher, D., D. Taki, W.A. Wurtsbaugh, C. Luecke, P. Budy, H.P. Gross, and G. Steinhart. 1994. Snake River Sockeye Salmon habitat and limnological research. Annual Report 1993. U.S. Department of Energy, Bonneville Power Administration, Portland, OR. Project number 9 l-7 1.

Teuscher, D., D. Taki, W.A. Wurtsbaugh, C. Luecke, P. Budy, and G. Steinhart. 1995. Snake River Sockeye Salmon habitat and limnological research. Annual Report 1994. U.S. Department of Energy, Bonneville Power Administration, Portland, OR. Project number 91-71.

Teuscher, D., and D. Taki. 1996. Snake River Sockeye Salmon habitat and limnological research. Annual Report 1995. U.S. Department of Energy, Bonneville Power Administration, Portland, OR. Project number 9 l-7 1.

Wetzel, R.G. and G.E. Likens. 1991. Limnological Analyses. Springer-Verlag. 391 p.

Appendix 1. Temperature (°C), dissolved oxygen (mg/l) and conductivity (uS/cm) for the Sawtooth Valley Lakes, 1996.

Redfish Lake — November 21, 1995

Depth	Temp	D.O.	Cond	Depth	Temp	D.O.	Cond
0.0	5.9	9.7	25.2	30.0	5.1	9.9	26.9
1.0	5.9	9.7	25.2	35.0	5.0	9.9	27.0
2.0	5.9	9.7	25.2	40.0	4.9	9.6	27.1
3.0	5.9	9.7	25.2	45.0	4.9	9.3	27.1
4.0	5.9	9.7	25.2	55.0	4.8	9.1	27.1
7.0	5.9	9.7	25.2	66.0	4.8	9.0	27.2
10.0	5.9	9.7	25.2	80.0	4.6	8.9	27.2
15.0	5.9	9.7	25.2	86.0	4.6	8.9	27.3
20.0	5.9	9.7	25.2	87.0	4.5	8.7	27.3

Redfish Lake — February 22, 1996

Depth	Temp	D.O.	Cond	Depth	Temp	D.O.	Cond
0.0	0.3			7.0	3.1		
1.0	0.9			10.0	3.2		
2.0	2.3			20.0	3.5		
3.0	2.7			30.0	3.6		
4.0	2.8			40.0	3.8		
5.0	3.0			50.0	3.8		
6.0	3.0			90.0	4.0		

Redfish Lake — May 28, 1996

Depth	Temp	D.O.	Cond	Depth	Temp	D.O.	Cond
0.0	6.7	9.1		10.0	5.0	9.3	
1.0	6.0	9.4		12.0	5.0	9.3	
2.0	5.9	9.4		15.0	4.6	9.3	
3.0	5.8	9.4		20.0	4.4	9.2	
4.0	5.7	9.3		30.0	4.2	9.0	
5.0	5.6	9.4		40.0	4.1	8.8	
6.0	5.5	9.4		50.0	4.1	8.7	
7.0	5.3	9.3		70.0	3.9	8.5	
8.0	5.2	9.3		85.0	3.9	7.4	
9.0	5.1	9.3		85.7	3.9	6.6	

Redfish Lake — June 24, 1996

Depth	Temp	D.O.	Cond	Depth	Temp	D.O.	Cond
0.0	7.3	10.5	26.4	19.0	5.5	9.4	26.9
1.0	10.7	9.0	26.4	22.0	5.2	9.3	27.3
2.0	10.7	9.1	26.4	25.0	5.0	9.2	27.6
4.0	10.4	9.1	26.3	30.0	4.6	8.9	27.8
6.0	10.2	9.2	26.3	35.0	4.4	8.7	28.0
8.0	8.6	9.4	26.9	40.0	4.3	8.6	28.2
10.0	7.8	9.6	25.5	45.0	4.3	8.4	28.3
12.0	7.3	9.6	25.6	50.0	4.2	8.4	28.4

14.0	7.2	9.6	25.6
16.0	6.3	9.6	26.1
17.0	6.1	9.5	26.4
18.0	5.7	9.5	26.7
60.0	4.2	8.3	28.5
70.0	4.1	8.1	28.6
80.0	4.1	8.1	28.7

Redfish Lake July 22, 1996

Depth	Temp	D.O.	Cond
0.0	17.1	7.3	25.6
1.0	15.6	7.7	25.4
2.0	15.2	7.8	25.3
3.0	15.2	7.8	25.3
4.0	14.2	8.0	25.5
5.0	13.2	8.3	24.8
6.0	12.4	8.7	24.4
7.0	11.8	8.9	24.6
8.0	11.4	9.1	24.9
9.0	11.2	9.1	24.6
10.0	10.6	9.3	24.2
12.0	9.2	9.6	26.7
14.0	8.1	9.8	26.4
16.0	6.9	10.0	27.9
18.0	6.1	10.1	27.4
20.0	5.6	10.0	27.5
22.0	5.3	10.0	27.8
23.0	5.2	9.9	27.9
24.0	5.2	9.7	27.8
26.0	5.1	9.6	27.9
30.0	4.9	9.5	28.0
35.0	4.7	9.4	28.2
40.0	4.7	9.2	28.3
45.0	4.6	9.0	28.3
55.0	4.5	8.9	28.3

Redfish Lake August 26, 1996

Depth	Temp	D.O.	Cond
0.0	16.6	7.6	22.0
2.0	16.5	7.7	22.0
4.0	16.5	7.7	22.0
6.0	15.5	7.9	21.8
7.0	14.5	8.2	21.5
8.0	14.2	8.7	21.3
9.0	13.3	7.8	22.2
10.0	12.3	9.1	22.1
11.0	11.7	9.2	21.6
13.0	9.5	10.3	21.9
15.0	9.0	9.9	22.3
17.0	7.3	10.4	23.1
19.0	6.4	10.5	21.0
21.0	5.9	10.4	21.0
23.0	5.6	10.3	23.8
25.0	5.4	10.0	23.9
30.0	5.1	9.9	24.0
35.0	4.9	9.8	24.2
40.0	4.8	9.7	24.2
45.0	4.7	9.5	24.2
50.0	4.7	9.3	24.2
55.0	4.7	9.0	24.3
60.0	4.6	8.7	24.3
65.0	4.5	8.1	24.4
70.0	4.5	8.0	24.5
75.0	4.4	8.0	24.5
80.0	4.4	7.9	24.6
85.0	4.4	7.9	24.7
86.5	4.4	7.8	24.9

Redfish Lake September 23, 1996

Depth	Temp	D.O.	Cond
0.0	12.2	9.8	26.1
1.0	12.3	9.9	26.3
3.0	12.3	9.9	26.3
5.0	12.3	9.8	26.3
7.0	12.3	9.8	26.3
9.0	12.3	9.6	26.3
10.0	12.3	9.5	26.3
11.0	12.3	9.5	26.3
12.0	12.3	9.4	26.3
13.0	12.3	9.4	26.4
18.0	6.7	10.9	27.6
19.0	6.3	11.0	27.8
21.0	5.8	11.0	27.9
23.0	5.7	10.9	27.9
25.0	5.4	10.9	28.1
30.0	5.1	10.6	28.2
35.0	4.9	10.3	28.3
40.0	4.8	10.0	28.4
50.0	4.7	9.6	28.4
60.0	4.7	9.2	28.6

14.0	10.6	9.8	26.4
15.0	9.4	10.2	26.7
16.0	8.4	10.5	27.0
17.0	7.3	10.7	27.4
70.0	4.6	9.0	28.6
80.0	4.4	8.7	28.7
86.0	4.4	8.3	29.1

Redfish Lake — October 12, 1996

Depth	Temp	D.O.	Cond
0.0	11.9	9.2	23.3
2.0	11.8	9.0	24.6
4.0	11.8	9.0	24.4
8.0	11.7	8.9	24.4
12.0	11.6	8.9	24.4
13.0	11.0	9.1	24.4
14.0	10.6	9.3	24.7
15.0	10.2	9.3	24.5
16.0	8.1	10.0	25.2
17.0	7.2	10.1	25.3
18.0	6.8	10.2	25.4
20.0	6.4	10.3	25.5
25.0	5.4	10.4	25.8
30.0	5.0	10.2	25.9
35.0	4.9	9.9	26.0
40.0	4.8	9.6	26.1
45.0	4.8	9.4	26.1
50.0	4.7	9.2	26.2
60.0	4.7	8.8	26.2
70.0	4.6	8.7	26.2
80.0	4.5	8.4	26.3
85.0	4.4	8.3	27.7

Redfish Lake — November 27, 1996

Depth	Temp	D.O.	Cond
0.0	4.8	8.5	27.1
1.5	4.9	8.3	27.1
5.0	4.9	8.2	27.1
10.0	4.9	8.2	27.1
20.0	4.9	8.1	27.1
30.0	4.9	8.1	27.1
40.0	4.9	8.1	27.2
50.0	4.9	8.0	27.6
60.0	4.8	8.0	28.2
70.0	4.7	7.7	28.2
80.0	4.6	7.5	28.3
85.0	4.6	7.3	28.3
87.0	4.6	7.0	28.4

Pettit Lake — November 21, 1995

Depth	Temp	D.O.	Cond
0.0	5.1	10.2	19.5
1.0	5.5	9.5	20.4
2.0	5.5	9.4	20.4
3.0	5.5	9.4	20.4
4.0	5.5	9.5	20.3
5.0	5.5	9.5	20.3
6.0	5.5	9.5	20.3
7.0	5.5	9.7	20.3
9.0	5.5	9.7	20.3
11.0	5.5	9.7	20.3
15.0	5.5	9.8	20.3
20.0	5.5	9.8	20.4
24.0	5.2	9.3	22.2
25.0	5.0	8.8	22.9
26.0	4.7	8.5	23.0
27.0	4.6	8.3	23.0
28.0	4.5	8.3	23.1
29.0	4.4	8.0	23.1
30.0	4.3	8.0	23.3
32.0	4.3	7.8	23.6
34.0	4.3	7.5	23.8
36.0	4.3	6.5	23.9
40.0	4.2	5.8	23.6
45.0	4.2	5.1	31.5
48.0	4.2	4.3	34.7
49.0	4.3	3.2	36.5
50.0	4.3	2.5	38.7

Pettit Lake — February 22, 1996

Depth	Temp	D.O.	Cond
0.0	0.4		
1.0	0.6		
2.0	2.4		
3.0	2.9		
4.0	3.3		
5.0	3.3		
7.0	3.5		
9.0	3.5		
12.0	3.6		
15.0	3.6		
20.0	3.6		
25.0	3.7		
30.0	3.8		
35.0	3.9		
40.0	4.0		
45.0	4.1		
50.0	4.1		
53.0 bot			

Pettit Lake — May 28, 1996

Depth	Temp	D.O.	Cond
0.0	8.0	9.4	
1.0	6.3	9.7	
2.0	6.1	9.7	
3.0	6.0	9.9	
4.0	6.0	10.1	
5.0	5.8	9.6	
6.0	5.6	9.5	
7.0	5.2	9.3	
8.0	5.1	9.3	
9.0	5.0	9.5	
10.0	4.9	9.4	
12.0	4.7	9.3	
14.0	4.6	9.2	
16.0	4.5	9.1	
18.0	4.5	9.0	
20.0	4.4	8.9	
25.0	4.2	8.6	
30.0	4.2	8.1	
35.0	4.1	6.9	
40.0	4.2	5.6	
45.0	4.2	1.6	
50.0	4.3	0.9	
50.1	4.3	0.7	

Pettit Lake — June 25, 1996

Depth	Temp	D.O.	Cond
0.0	10.5	8.7	20.3
1.0	10.2	8.8	20.2
2.0	9.9	9.0	20.3
4.0	9.1	9.2	20.0
6.0	8.6	9.2	19.9
8.0	8.0	9.3	20.2
9.0	7.7	9.4	20.4
10.0	7.6	9.4	20.4
11.0	7.3	9.4	20.6
12.0	7.2	9.4	20.8
13.0	7.1	9.4	20.9
14.0	6.9	9.3	21.1
15.0	6.3	9.3	21.7
16.0	6.1	9.3	22.0
17.0	5.8	9.2	22.2
18.0	5.6	9.1	22.6
20.0	4.8	9.1	22.9
22.0	4.4	8.8	23.1
25.0	4.3	8.4	23.1
30.0	4.1	6.9	23.6
35.0	4.1	4.7	24.6
40.0	4.2	2.7	25.8
45.0	4.2	0.7	27.5
49.4	4.2	0.3	33.5

Pettit Lake	July 22, 1996						
Depth	Temp	D.O.	Cond	Depth	Temp	D.O.	Cond
0.0	17.0	7.9	20.4	12.0	8.3	9.9	21.5
1.0	17.0	8.0	20.4	13.0	7.9	10.1	21.8
2.0	16.4	7.9	20.2	14.0	7.6	10.0	21.9
3.0	15.8	8.0	20.3	15.0	7.1	9.8	22.5
4.0	14.8	8.1	20.1	17.0	6.2	9.7	23.2
5.0	13.4	8.5	20.2	20.0	5.1	9.7	23.8
6.0	13.1	8.7	20.0	25.0	4.4	9.6	23.9
7.0	12.7	8.7	20.0	30.0	4.2	8.8	24.1
8.0	12.0	9.0	20.0	35.0	4.2	8.5	25.3
9.0	11.1	9.1	20.2	40.0	4.2	8.2	26.5
10.0	10.0	9.4	20.8	45.0	4.2	3.0	27.6
11.0	9.4	9.5	21.0	49.5	4.2	2.4	34.8

Pettit Lake	August 26, 1996						
Depth	Temp	D.O.	Cond	Depth	Temp	D.O.	Cond
0.0	17.9	6.8	17.1	15.0	7.1	9.7	18.6
1.0	17.9	6.9	17.1	16.0	6.8	9.7	18.8
4.0	17.4	7.1	17.0	18.0	6.2	9.7	19.1
6.0	16.6	7.2	17.4	20.0	5.7	9.6	19.4
7.0	15.7	7.6	17.2	22.0	5.1	9.5	19.7
8.0	14.8	7.9	17.2	25.0	4.6	9.3	19.6
9.0	14.1	8.1	16.8	30.0	4.3	9.1	20.3
10.0	12.5	8.5	16.7	35.0	4.2	8.5	21.2
11.0	11.0	8.9	16.9	40.0	4.2	7.3	22.2
12.0	9.8	9.2	17.3	42.0	4.2	1.7	22.4
13.0	8.5	9.5	17.8	45.0	4.2	1.5	29.5
14.0	7.5	9.8	18.3	49.5	4.2	1.5	33.6

Pettit Lake	September 22, 1996						
Depth	Temp	D.O.	Cond	Depth	Temp	D.O.	Cond
0.0	13.2	8.6	21.1	15.0	7.6	10.2	22.3
1.0	13.2	8.4	21.1	16.0	6.9	10.4	23.0
3.0	13.1	8.4	21.1	18.0	6.1	10.7	23.5
5.0	13.1	8.3	21.1	20.0	5.4	10.7	23.9
7.0	13.0	8.3	21.1	22.0	5.1	10.5	23.9
9.0	13.0	8.3	21.1	25.0	4.6	10.0	23.6
10.0	12.8	8.3	21.2	30.0	4.3	9.5	24.1
11.0	11.7	8.6	22.0	35.0	4.2	8.9	25.5
12.0	10.2	9.0	21.3	40.0	4.2	4.2	26.4
13.0	8.9	9.5	21.6	45.0	4.2	3.5	34.8
14.0	8.1	10.1	22.2	49.6	4.3	2.4	43.9

Pettit Lake **October 24, 1996**

Depth	Temp	D.O.	Cond	Depth	Temp	D.O.	Cond
0.0	8.7	9.3	20.7	17.2	6.6	9.8	22.5
1.0	8.8	9.4	20.7	18.3	6.3	9.9	22.9
4.1	8.8	9.8	20.7	19.4	5.8	10.0	23.1
7.1	8.8	9.7	20.7	20.5	5.6	10.1	23.2
10.2	8.8	9.7	20.7	21.4	5.4	10.1	23.2
14.4	8.5	9.5	20.7	23.1	5.1	10.1	23.4
14.6	8.7	9.1	20.7	25.5	4.7	10.1	23.4
15.0	8.5	9.2	21.1	28.2	4.4	10.1	23.5
15.4	8.0	9.3	21.7	30.4	4.3	9.9	24.1
15.6	7.7	9.4	21.9	35.8	4.2	9.7	25.3
15.9	7.5	9.5	22.2	43.5	4.2	9.2	32.3
16.2	7.4	9.5	22.2	48.4	4.2	7.6	38.7
16.8	6.8	9.8	22.5	49.5	4.3	7.0	43.3

Alturas Lake **November 21, 1995**

Depth	Temp	D.O.	Cond	Depth	Temp	D.O.	Cond
0.0	5.1	10.2	45.5	lb.0	5.b	9.4	45.3
1.0	4.6	9.8	45.2	13.0	5.4	9.4	45.2
2.0	5.4	9.8	45.2	16.0	5.4	9.4	45.4
3.0	5.4	9.7	45.2	20.0	5.4	9.4	45.2
4.0	5.4	9.7	45.2	25.0	5.4	9.4	45.2
5.0	5.4	9.6	45.2	30.0	5.4	9.4	45.4
6.0	5.4	9.6	45.2	35.0	5.2	9.4	46.9
7.0	5.4	9.6	45.2	40.0	4.6	8.6	48.8
8.0	5.4	9.5	45.3	45.0	4.4	7.9	49.7
9.0	5.4	9.5	45.3	49.0	4.3	7.4	50.0

Alturas Lake **February 23, 1996**

Depth	Temp	D.O.	Cond	Depth	Temp	D.O.	Cond
0.0	0.5			9.0	3.4		
1.0	0.5			10.0	3.4		
2.0	2.2			15.0	3.5		
3.0	2.7			20.0	3.6		
4.0	3.0			30.0	3.7		
5.0	3.1			40.0	3.7		
6.0	3.2			50.0	3.7		
7.0	3.3			52.0	4.0		
8.0	3.3						

Alturas Lake	May 29, 1996						
Depth	Temp	D.O.	Cond	Depth	Temp	D.O.	Cond
0.0	4.6	9.6		15.0	4.2	9.3	
1.0	4.7	9.6		20.0	4.1	9.2	
2.0	4.6	9.5		25.0	4.1	9.1	
3.0	4.6	9.5		30.0	4.1	9.1	
4.0	4.6	9.5		35.0	4.1	9.0	
6.0	4.5	9.5		40.0	4.0	8.5	
8.0	4.4	9.5		45.0	4.0	7.8	
10.0	4.3	9.5		50.0	4.0	7.3	

Alturas Lake	June 25, 1996						
Depth	Temp	D.O.	Cond	Depth	Temp	D.O.	Cond
0.0	11.1	8.5	42.6	16.0	6.5	8.9	42.8
1.0	9.6	9.1	42.7	19.0	6.0	8.9	43.8
2.0	9.2	9.0	42.5	24.0	4.9	8.5	46.4
4.0	8.6	9.1	42.2	30.0	4.5	8.4	47.2
6.0	8.4	9.1	42.2	35.0	4.3	8.1	47.2
8.0	7.5	9.1	42.1	40.0	4.2	7.8	47.5
10.0	7.3	9.1	42.0	45.0	4.2	7.6	47.7
13.0	6.9	9.1	42.4	49.2	4.1	7.4	47.7

Alturas Lake	July 23, 1996						
Depth	Temp	D.O.	Cond	Depth	Temp	D.O.	Cond
0.0	16.0	8.0	40.6	14.0	7.7	9.5	40.9
1.0	15.5	8.0	40.4	16.0	7.2	9.5	41.6
2.0	14.8	8.2	40.2	18.0	6.6	9.5	42.4
3.0	14.6	8.2	40.4	20.0	6.2	9.5	42.9
4.0	13.9	8.2	40.2	22.0	5.8	9.2	43.7
5.0	13.2	8.4	40.2	26.0	5.2	9.2	45.0
6.0	12.0	8.6	39.8	30.0	4.8	9.0	46.0
7.0	11.5	8.8	39.1	35.0	4.5	9.0	46.6
8.0	11.0	8.9	39.2	40.0	4.2	8.8	46.9
9.0	10.3	9.1	39.3	45.0	4.2	8.5	47.2
10.0	9.9	9.2	39.4	49.7	4.2	8.0	47.4
12.0	8.4	9.4	40.3				

Alturas Lake					August 27, 1996		
Depth	Temp	D.O.	Cond	Depth	Temp	D.O.	Cond
0.0	16.7	7.8	38.5	14.0	8.8	8.8	36.7
1.0	16.7	7.9	38.5	15.0	8.3	9.8	37.0
2.0	16.7	8.0	38.4	16.0	7.8	9.8	37.3
3.0	16.7	8.0	38.4	18.0	7.3	9.9	37.7
4.0	16.6	7.9	38.4	20.0	6.3	10.1	38.9
6.0	16.2	8.2	38.4	22.0	6.0	10.0	39.2
8.0	14.7	8.5	39.0	25.0	5.4	9.9	40.3
9.0	13.6	8.7	37.7	30.0	4.8	9.6	41.5
10.0	12.2	9.3	36.8	35.0	4.5	9.1	41.9
11.0	10.7	9.6	36.7	40.0	4.3	8.8	41.9
12.0	9.9	9.6	36.7	45.0	4.2	7.8	42.2
13.0	9.4	9.7	36.7	49.3	4.2	5.9	42.2

Alturas Lake					September 22, 1996		
Depth	Temp	D.O.	Cond	Depth	Temp	D.O.	Cond
0.0	12.1	8.1	45.3	16.0	7.9	9.5	44.1
1.0	12.1	8.8	45.3	17.0	7.8	9.4	44.3
2.0	12.1	8.6	45.3	19.0	6.9	9.6	45.0
3.0	12.1	8.6	45.3	21.0	6.4	9.5	45.7
5.0	12.1	8.6	45.3	23.0	5.8	9.5	46.3
7.0	12.1	8.6	45.4	25.0	5.4	9.4	47.1
9.0	12.1	8.5	45.3	30.0	4.8	9.2	48.2
11.0	12.1	8.5	45.2	35.0	4.4	8.9	48.9
13.0	11.9	8.5	45.3	40.0	4.3	8.3	49.4
14.0	10.0	9.3	44.5	45.0	4.2	7.8	49.3
15.0	8.7	9.3	43.9	48.7	4.2	6.5	48.9

Alturas Lake					October 23, 1996		
Depth	Temp	D.O.	Cond	Depth	Temp	D.O.	Cond
0.0	8.3	9.8	44.4	24.2	5.7	9.1	45.9
2.6	8.3	9.7	44.4	26.0	5.5	9.1	46.5
6.4	8.3	9.6	44.4	28.3	5.1	9.0	47.1
10.7	8.2	9.6	44.5	29.5	5.0	9.0	47.4
16.0	8.2	9.5	44.5	31.3	4.8	8.8	47.6
18.1	8.0	9.5	44.5	35.0	4.5	8.7	48.1
18.8	7.8	9.5	44.5	38.0	4.3	8.4	48.5
20.4	6.5	9.9	45.1	41.5	4.2	8.1	48.6
20.9	6.4	9.8	45.1	49.8	4.2	7.7	48.9
21.6	6.2	9.4	45.3				

Alturas Lake					November 27, 1996		
Depth	Temp	D.O.	Cond	Depth	Temp	D.O.	Cond
0.0	4.5	10.2	45.3	30.0	4.5	8.9	45.4

1.0	4.5	9.9	45.3
6.0	4.5	9.5	45.2
10.0	4.5	9.3	45.3
20.0	4.5	9.1	45.4
45.0	4.4	8.8	45.4
48.5	4.3	8.8	45.2
49.0	4.3	8.7	45.1

Stanley Lake — November 21, 1995

Depth	Temp	D.O.	Cond
0.0	4.6	10.0	39.8
1.0	4.6	9.9	39.8
2.0	4.6	9.9	39.8
3.0	4.6	9.8	39.8
5.0	4.6	9.8	39.8
7.0	4.6	9.8	39.8
9.0	4.6	9.7	39.8
11.0	4.6	9.7	39.8
16.0	4.6	9.7	39.8
21.0	4.5	9.7	40.0
25.0	4.4	9.7	40.1

Stanley Lake — February 24, 1996

Depth	Temp	D.O.	Cond
0.0	0.7		
1.0	1.2		
2.0	1.6		
3.0	1.7		
4.0	1.8		
5.0	1.9		
6.0	2.0		
7.0	2.4		
8.0	2.7		
9.0	2.9		
10.0	3.0		
12.0	3.2		
15.0	3.3		
20.0	3.4		
23.0	3.5		
25.0	3.6		
26.0	3.9		
27.3	4.0		

Stanley Lake — May 30, 1996

Depth	Temp	D.O.	Cond
0.0	7.0	9.9	
1.0	6.5	9.9	
2.0	6.3	9.9	
3.0	6.2	9.8	
5.0	6.1	9.7	
7.0	6.0	9.7	
10.0	5.7	9.6	
13.0	5.5	9.5	
15.0	5.4	9.5	
18.0	5.2	9.4	
20.0	5.1	9.2	
22.0	5.0	9.1	
22.8	4.9	9.1	

Stanley Lake — June 25, 1996

Depth	Temp	D.O.	Cond
0.0	8.5	8.6	33.0
1.0	7.6	8.9	32.8
2.0	7.5	9.2	32.7
4.0	7.4	9.1	32.7
6.0	7.2	9.1	32.6
8.0	7.2	9.1	32.7
10.0	7.0	9.1	32.7
12.0	7.0	9.2	32.7
14.0	6.9	9.2	32.8
16.0	6.7	9.2	32.8
18.0	8.7	9.2	32.7
20.0	6.7	9.2	32.7
22.0	6.7	9.1	32.7
24.0	6.7	9.0	32.9
26.0	6.6	8.9	33.3

Stanley Lake		July 23, 1996					
Depth	Temp	D.O.	Cond	Depth	Temp	D.O.	Cond
0.0	14.4	8.9	30.9	10.0	9.9	9.6	29.7
1.0	13.7	9.1	30.9	11.0	9.4	9.6	29.5
2.0	12.6	9.3	30.6	12.0	9.1	9.6	29.4
3.0	12.0	9.4	30.9	13.0	8.8	9.8	29.2
4.0	11.8	9.4	30.8	15.0	8.4	9.8	29.7
5.0	11.6	9.4	30.8	17.0	7.8	9.7	29.8
6.0	11.0	9.5	30.4	20.0	7.2	9.7	31.0
7.0	10.6	9.6	30.2	23.0	7.0	9.7	31.8
8.0	10.4	9.6	30.5	25.8	6.8	9.4	32.5
9.0	10.1	9.6	30.0				

Stanley Lake		August 27, 1996					
Depth	Temp	D.O.	Cond	Depth	Temp	D.O.	Cond
0.0	17.0	8.2	33.7	12.0	10.3	9.7	27.1
1.0	16.1	8.4	33.8	13.0	9.6	10.0	27.0
2.0	15.9	8.4	33.6	15.0	8.3	10.1	26.7
3.0	15.5	8.6	33.8	16.0	8.1	10.0	27.0
4.0	15.2	8.7	33.5	17.0	7.9	9.9	27.3
5.0	14.9	8.7	33.3	18.0	7.6	9.7	27.8
6.0	14.3	9.0	32.7	20.0	7.4	9.2	28.0
7.0	14.1	9.0	32.5	21.0	7.3	8.9	28.4
8.0	13.9	9.0	32.2	23.0	7.2	8.1	28.8
9.0	13.2	9.1	30.0	24.0	7.0	7.0	29.5
10.0	11.8	9.5	28.9	25.0	6.9	6.7	30.3
11.0	11.1	9.7	27.8	25.6	6.8	6.4	32.6

Stanley Lake		September 22, 1996					
Depth	**Temp**	**D.O.**	**Cond**	**Depth**	Temp	D.O.	Cond
0.0	11.8	8.6	39.6	13.0	10.3	9.0	34.8
1.0	11.8	8.6	39.7	14.0	9.3	9.2	32.7
3.0	11.8	8.7	39.7	15.0	8.7	9.2	32.8
5.0	11.8	8.7	39.7	16.0	8.1	9.2	33.4
7.0	11.8	8.7	39.7	17.0	7.8	8.9	33.5
9.0	11.8	8.7	39.7	19.0	7.5	8.6	33.9
11.0	11.7	8.7	39.7	21.0	7.2	7.6	34.3
12.0	11.4	8.7	39.6	23.9	7.0	4.8	36.4

Stanley Lake		October 25, 1996					
Depth	Temp	D.O.	Cond	Depth	Temp	D.O.	Cond
0.0	7.4	10.1	38.0	17.0	7.5	8.4	38.2
3.0	7.6	8.6	38.0	19.0	7.5	8.3	38.2
6.0	7.5	8.6	38.0	21.0	7.5	0.3	38.1

9.0	7.6	8.5	38.1	23.0	7.4	8.3	37.9
13.0	7.5	8.6	38.1	26.0	7.2	8.2	37.1
15.0	7.5	8.4	38.1				

Appendix 2. Sawtooth Valley Lakes nutrient data for 1996.

Lake	Date	Depth (m)	TP	TN	SRP	NO3	NH4	TKN
Redfish	11 -Jan-96	6-O	3.5	50.5	0.0	8.0	1.0	
Redfish	11 -Jan-96	10	3.0	76.0	0.0	8.0	1.0	
Redfish	1 l-Jan-96	20	2.0	60.0	0.0	9.0	1.0	
Redfish	18-Mar-96	6-O	6.7	23.0	1.0	17.7	3.0	
Redfish	18-Mar-96	25	6.0	40.0	1.0	14.0	6.0	
Redfish	18-Mar-96	55	7.0	62.0	1.0	33.0	0.0	
Redfish	28-May-96	6-O	4.3	65.0		9.0	2.0	
Redfish	28-May-96	25	5.0	56.0		12.0	2.0	
Redfish	28-May-96	55	5.0	110.0		17.0	3.0	
Redfish	24-Jun-96	6-O	5.9	28.4		1.6	3.3	26.8
Redfish	24-Jun-96	15	8.2	55.2		2.0	1.4	53.2
Redfish	24-Jun-96	20	7.3	32.7		3.6	2.6	29.0
Redfish	24-Jun-96	25	7.3	76.3		8.5	6.0	67.8
Redfish	24-Jun-96	35	6.6	22.6		12.7	3.8	9.8
Redfish	24-Jun-96	55	8.5	42.3		20.3	4.2	21.9
Redfish	24-Jun-96	85	5.7	65.2		30.5	7.4	34.7
Redfish	22-Jul-96	6-O	6.5	47.1	0.1	1.3	0.3	45.8
Redfish	22-Jul-96	22	7.9	83.6	0.1	3.2	0.7	80.5
Redfish	22-Jul-96	55	6.9	50.6	0.1	16.9	2.0	33.7
Redfish	26-Aug-96	6-O	6.6	29.0	0.3	0.8	0.0	28.2
Redfish	26-Aug-96	15	6.9	25.9	0.6	0.8	0.3	25.1
Redfish	26-Aug-96	23	8.5	34.1	1.0	0.9	1.2	33.2
Redfish	26-Aug-96	35	7.9	20.6	0.6	1.3	0.3	19.3
Redfish	26-Aug-96	55	6.3	44.1	0.8	19.7	2.0	24.4
Redfish	26-Aug-96	80	6.3	60.1	0.3	29.2	0.9	31.0
Redfish	09-Sep-96	6-O	4.2	65.9	1.8	0.9	0.3	65.0
Redfish	09-Sep-96	13	5.7	26.5	1.1	0.7	0.3	25.7
Redfish	09-Sep-96	55	10.6	73.4	1.8	17.2	0.9	56.2
Redfish	09-Sep-96	oufflow	4.8	80.9	1.3	0.9	0.1	80.0
Redfish	23-Sep-96	6-O	6.3	71.4	1.3	0.9	1.5	70.5
Redfish	23-Sep-96	16	6.3	33.6	1.3	0.9	1.3	32.7
Redfish	23-Sep-96	55	5.4	87.9	1.3	19.2	1.3	68.6
Redfish	23-Sep-96	oufflow	5.4	89.2	1.9	1.1	1.8	88.1
Redfish	12-Oct-96	6-O	2.8	42.2	1.2	1.0	1.6	41.2
Redfish	12-Oct-96	17	3.7	61.7	1.2	0.0	0.9	61.7
Redfish	12-Oct-96	55	3.1	62.7	1.0	23.9	2.0	38.8
Redfish	12-Oct-96	oufflow	3.4	86.0	1.1	0.2	0.7	85.8
Redfish	23-Oct-96	6-O	2.8	36.0		0.0	1.3	36.0
Redfish	23-Oct-96	15	3.1	55.8		0.0	0.3	55.8
Redfish	23-Oct-96	19	4.0	75.6		0.4	0.5	75.2
Redfish	23-Oct-96	25	4.0	89.5		3.3	0.5	86.2

Redfish	23-Oct-96	55	3.4	57.0	1.0	23.3	3.0	33.7

Lake	Date	Depth (m)	TP	TN	SRP	NO3	NH4	TKN
Pettit	1 O-Jan-96	6-O	3.3	67.7	0.3	2.7	3.3	70.3
Pettit	1 O-Jan-96	IO	3.0	77.0	1.0	1.0	3.0	76.0
Pettit	1 O-Jan-96	25	2.0	88.0	1.0	2.0	6.0	86.0
Pettit	1 O-Jan-96	40	3.0	109.0	2.0	11.0	38.0	98.0
Pettit	1 g-Mar-96	6-O	9.7	50.0	1.0	10.0	9.0	41.0
Pettit	1 g-Mar-96	25	8.0	55.0	1.0	7.0	12.0	48.0
Pettit	1 g-Mar-96	40	9.0	126.0	2.0	65.5	1.0	61.0
Pettit	28-May-96	6-O	5.0	35.0		1.0	2.3	34.0
Pettit	28-May-96	25	5.0	41.0		3.0	2.0	38.0
Pettit	28-May-96	40	6.0	117.0		35.0	17.0	82.0
Pettit	25-Jun-96	6-O	10.7	47.9		0.5	1.7	47.4
Pettit	25-Jun-96	17	10.0	39.3		0.5	1.4	38.8
Pettit	25-Jun-96	25	10.4	45.1		0.4	2.4	44.7
Pettit	25-Jun-96	35	10.0	66.4		29.9	13.3	36.5
Pettit	25-Jun-96	45	12.2	132.2		25.2	62.7	107.0
Pettit	22-Jul-96	6-O	5.0					
Pettit	26-Aug-96	6-O	4.2	43.4	0.8	0.8	0.0	42.7
Pettit	26-Aug-96	15	4.8	42.7	0.3	0.8	0.9	42.0
Pettit	26-Aug-96	23	6.3	30.9	0.3	0.6	0.3	30.3
Pettit	26-Aug-96	35	5.7	61.1	0.1	30.7	1.4	30.5
Pettit	26-Aug-96	45	12.1	83.3	0.1	3.2	100.9	80.1
Pettit	22-Sep-96	6-O	6.1					
Pettit	24-Oct-96	6-O	4.0	36.1	1.0	0.1	1.1	36.0
Pettit	24-Oct-96	16	4.3	30.1	1.0	0.0	0.0	30.1
Pettit	24-Oct-96	25	4.0	38.8	1.0	0.0	0.7	38.8
Pettit	24-Oct-96	45	13.1	77.6	1.0	1.6	108.2	75.9

Lake	Date	Depth (m)	TP	TN	SRP	NO3	NH4	TKN
Alturas	20-Mar-96	o-6	8.8	22.7	1.0	13.5	3.7	9.0
Alturas	20-Mar-96	25	9.0	52.0	2.0	16.0	0.0	36.0
Alturas	20-Mar-96	40	11.0	23.0	3.0	20.0	0.0	3.0
Alturas	29-May-96	O-6	6.0	63.7		6.7	1.7	57.0
Alturas	29-May-96	25	6.0	65.0		10.0	2.0	55.0
Alturas	29-May-96	45	6.0	95.0		18.0	3.0	77.0
Alturas	25-Jun-96	6-O	11.6	59.6		0.6	1.9	59.0
Alturas	25-Jun-96	12	13.8	68.3		0.6	1.2	67.8
Alturas	25-Jun-96	25	14.7	58.3		2.9	3.6	55.3
Alturas	25-Jun-96	35	13.4	46.1		6.0	4.2	40.1
Alturas	25-Jun-96	45	16.2	64.8		18.3	2.4	46.5
Alturas	23-Jul-96	6-O	7.8					
Alturas	27-Aug-96	6-O	6.9	55.8		0.8	0.9	55.0
Alturas	27-Aug-96	12	7.9	56.7		0.6	0.5	56.1
Alturas	27-Aug-96	18	7.6	62.8		0.6	0.1	62.3
Alturas	27-Aug-96	35	6.6	53.8		7.0	0.1	46.8
Alturas	27-Aug-96	45	9.1	65.8		16.9	0.1	48.9
Alturas	22-Sep-96	6-O	8.3					
Alturas	23-Oct-96	6-O	6.4	67.9	1.0	0.2	2.2	67.6
Alturas	23-Oct-96	19	5.8	78.7	1.0	0.0	0.5	78.7
Alturas	23-Oct-96	25	60.3	55.2	1.0	0.2	0.9	55.0
Alturas	23-Oct-96	45	5.0	64.9	3.0	16.2	2.1	48.7

Lake	Date	Depth (m)	TP	TN	SRP	NO3	NH4	TKN
Stanley	11-Jan-96	6-O	3.0	82.0	0.0	12.7	1.0	69.3
Stanley	11-Jan-96	10	3.0	93.0	0.0	11.0	5.0	82.0
Stanley	11-Jan-96	20	3.0	98.0	0.0	12.0	8.0	86.0
Stanley	20-Mar-96	6-O	8.3	39.6	1.0	18.3	3.3	21.3
Stanley	20-Mar-96	20	8.0	41.0	1.0	41.0	0.0	0.0
Stanley	30-May-96	6-O	6.5					60.7
Stanley	25-Jun-96	6-O	9.6					
Stanley	23-Jul-96	6-O	5.1					
Stanley	27-Aug-96	6-O	8.2					
Stanley	22-Sep-96	6-O	8.9					
Stanley	25-Oct-96	6	4.5					

Appendix 3. Chlorophyll a data for the Sawtooth Valley Lakes, 1996.

Date	Lake	Depth	Chl a	Average surface Chl a
18-Mar-96	Redfish	6-O	2.3	2.3
18-Mar-96	Redfish	6-O	2.1	
18-Mar-96	Redfish	6-O	2.4	
18-Mar-96	Redfish	IO	1.2	
18-Mar-96	Redfish	25	0.5	
18-Mar-96	Redfish	55	0.3	
28-May-96	Redfish	6-O	1.2	1.3
28-May-96	Redfish	6-O	1.4	
28-May-96	Redfish	6-O	1.4	
28-May-96	Redfish	25	1.7	
28-May-96	Redfish	55	1.0	
1 I-Jun-96	Redfish-S	0.5	0.5	
11 -Jun-96	Redfish-S	0.5	0.5	
11 -Jun-96	Redfish-S	5	0.6	
1 I-Jun-96	Redfish-S	5	0.5	
1 I-Jun-96	Redfish-S	10	0.8	
1 I-Jun-96	Redfish-S	10	0.9	
11 -Jun-96	Redfish-S	15	1.3	
11 -Jun-96	Redfish-S	15	1.4	
1 I-Jun-96	Redfish-S	20	1.4	
1 I-Jun-96	Redfish-S	20	1.5	
11 -Jun-96	Redfish-S	25	1.6	
11 -Jun-96	Redfish-S	25	1.6	
1 I-Jun-96	Redfish-S	30	1.2	
1 I-Jun-96	Redfish-S	30	1.4	
11 -Jun-96	Redfish-S	35	2.0	

Date	Lake	Depth	Chl a	Average surface Chl a
01-Jul-96	Redfish-S	10	0.8	
01 -Jul-96	Redfish-S	10	0.8	
01 -Jul-96	Redfish-S	15	0.5	
01 -Jul-96	Redfish-S	15	0.4	
Ol-Jul-96	Redfish-S	20	1.9	
Ol-Jul-96	Redfish-S	20	2.0	
Ol-Jul-96	Redfish-S	25	1.9	
Ol-Jul-96	Redfish-S	25	0.0	
01-Jul-96	Redfish-S	30	1.4	
01-Jul-96	Redfish-S	30	1.4	
Ol-Jul-96	Redfish-S	37	1.1	
01 -Jul-96	Redfish-S	37	0.9	
01 -Jul-96	Redfish-N	0.5	0.4	
Ol-Jul-96	Redfish-N	0.5	0.5	
Ol-Jul-96	Redfish-N	5	0.8	
01-Jul-96	Redfish-N	5	0.7	
01 -Jul-96	Redfish-N	IO	0.9	
Ol-Jul-96	Redfish-N	IO	0.9	
Ol-Jul-96	Redfish-N	15	1.3	
Ol-Jul-96	Redfish-N	15	1.4	
01-Jul-96	Redfish-N	20	1.5	
01 -Jul-96	Redfish-N	20	1.7	
01-Jul-96	Redfish-N	25	1.7	
Ol-Jul-96	Redfish-N	25	1.7	
01-Jul-96	Redfish-N	30	1.5	
01-Jul-96	Redfish-N	30	1.4	
01-Jul-96	Redfish-N	37	1.8	

11 -Jun-96	Redfish-S	35	1.9	
11 -Jun-96	Redfish-N	0.5	0.3	
1 l-Jun-96	Redfish-N	0.5	0.3	
1 l-Jun-96	Redfish-N	5	0.7	
II-Jun-96	Redfish-N	5	0.6	
11 -Jun-96	Redfish-N	IO	1.2	
11 -Jun-96	Redfish-N	10	1.3	
11 -Jun-96	Redfish-N	15	1.9	
1 l-Jun-96	Redfish-N	15	1.8	
1 l-Jun-96	Redfish-N	18.5	1.4	
11 -Jun-96	Redfish-N	25	2.1	
1 l-Jun-96	Redfish-N	25	1.2	
11 -Jun-96	Redfish-N	30	0.7	
1 l-Jun-96	Redfish-N	35	0.6	
11 -Jun-96	Redfish-N	35	0.9	
13-Jun-96	Redfish	6-O	0.8	0.9
13-Jun-96	Redfish	6-O	0.9	
13-Jun-96	Redfish	6-O	1.0	
13-Jun-96	Redfish	1% 21m	2.7	
24-Jun-96	Redfish	6-O	1.0	1.0
24-Jun-96	Redfish	6-O	0.9	
24-Jun-96	Redfish	6-O	0.9	
24-Jun-96	Redfish	15	2.0	
24-Jun-96	Redfish	1% 20m	2.2	
24-Jun-96	Redfish	25	2.7	
24-Jun-96	Redfish	55	1.2	
24-Jun-96	Redfish	85	1.0	
Ol-Jul-96	Redfish-S	0.5	0.5	
01 -Jul-96	Redfish-S	0.5	0.5	
01-Jul-96	Redfish-S	5	0.7	
Ol-Jul-96	Redfish-	5	0.6	

Ol-Jul-96	Redfish-N	37	1 .1	
1 1-Jul-96	Redfish	6-O A	0.5	0.5
1 1 -Jul-96	Redfish	6-O A	0.6	
11 -Jul-96	Redfish	6-O B	0.6	0.5
1 1 -Jul-96	Redfish	6-O B	0.4	
1 l-Jul-96	Redfish	6-O C	0.5	0.5
1 l-Jul-96	Redfish	6-O C	0.5	
11 -Jul-96	Redfish	1% 20m	2.5	
1 l-Jul-96	Redfish	1% 20m	2.6	
22-Jul-96	Redfish	6-O A	0.7	0.7
22-Jul-96	Redfish	6-O B	0.6	
22-Jul-96	Redfish	6-O C	0.7	
22-Jul-96	Redfish	6-O C	0.7	
22-Jul-96	Redfish	1% 22.3m	3.3	
22-Jul-96	Redfish	1% 22.3m	3.3	
02-Aug-96	Redfish-S	0.5	0.4	
02-Aug-96	Redfish-S	0.5	0.3	
02-Aug-96	Redfish-S	2.5	0.3	
02-Aug-96	Redfish-S	2.5	0.4	
02-Aug-96	Redfish-S	5	0.6	
02-Aug-96	Redfish-S	5	0.3	
02-Aug-96	Redfish-S	10	0.4	
02-Aug-96	Redfish-S	10	0.5	
02-Aug-96	Redfish-S	15	1.2	
02-Aug-96	Redfish-S	15	1.1	
02-Aug-96	Redfish-S	20	1.8	
02-Aug-96	Redfish-S	20	1.8	
02-Aug-96	Redfish-S	25	2.2	
02-Aug-96	Redfish-S	25	2.3	
02-Aug-96	Redfish-S	30	1.9	
02-Aug-96	Redfish-S	30	1.9	

S

02-Aug-96	Redfish-N	0.5	0.4	
02-Aug-96	Redfish-N	0.5	0.5	
02-Aug-96	Redfish-N	2.5	0.5	
02-Aug-96	Redfish-N	2.5	0.5	
02-Aug-96	Redfish-N	5	0.5	
02-Aug-96	Redfish-N	5	0.5	
02-Aug-96	Redfish-N	10	0.6	
02-Aug-96	Redfish-N	IO	0.6	
02-Aug-96	Redfish-N	15	1.8	
02-Aug-96	Redfish-N	15	1.8	
02-Aug-96	Redfish-N	20	2.4	
02-Aug-96	Redfish-N	20	2.3	
02-Aug-96	Redfish-N	25	1.2	
02-Aug-96	Redfish-N	25	1.5	
02-Aug-96	Redfish-N	30	0.9	
02-Aug-96	Redfish-N	30	1.0	
08-Aug-96	Redfish	6-O A	0.6	0.6
08-Aug-96	Redfish	6-O B	0.6	
08-Aug-96	Redfish	6-O C	0.6	
08-Aug-96	Redfish	1% 21.1m	3.6	
08-Aug-96	Redfish	1% 21.1m	3.3	
26-Aug-96	Redfish	6-O A	0.4	0.5
26-Aug-96	Redfish	6-O B	0.6	
26-Aug-96	Redfish	6-O C	0.4	
26-Aug-96	Redfish	1% 23.4m	2.8	
26-Aug-96	Redfish	1% 23.4m	2.8	2.8
26-Aug-96	Redfish	80	0.7	
26-Aug-96	Redfish	80	0.6	

10-Sep-96	Redfish-S	18	0.6	
1 0-Sep-96	Redfish-S	22	1.6	
1 O-Sep-96	Redfish-S	22	1.3	
1 O-Sep-96	Redfish-S	28	2.0	
1 O-Sep-96	Redfish-S	30	2.2	
1 O-Sep-96	Redfish-N	0.5	0.4	
1 O-Sep-96	Redfish-N	0.5	0.4	
1 O-Sep-96	Redfish-N	3	0.4	
1 0-Sep-96	Redfish-N	3	0.4	
1 O-Sep-96	Redfish-N	6	0.4	
1 0-Sep-96	Redfish-N	6	0.4	
1 O-Sep-96	Redfish-N	10	0.5	
1 O-Sep-96	Redfish-N	10	0.5	
1 O-Sep-96	Redfish-N	13	0.6	
IO-Sep-96	Redfish-N	13	0.5	
1 O-Sep-96	Redfish-N	18	0.9	
1 O-Sep-96	Redfish-N	18	0.9	
1 O-Sep-96	Redfish-N	22	1.4	
1 O-Sep-96	Redfish-N	22	1.6	
1 O-Sep-96	Redfish-N	28	1.5	
1 O-Sep-96	Redfish-N	28	0.3	
22-Sep-96	Redfish	6-O A	0.7	0.7
22-Sep-96	Redfish	6-O B	0.8	
22-Sep-96	Redfish	6-O C	0.8	
22-Sep-96	Redfish	16	1.0	
22-Sep-96	Redfish	16	1.0	
22-Sep-96	Redfish	1% 22.7m	3.2	
22-Sep-96	Redfish	1% 22.7m	3.2	3.2
22-Sep-96	Redfish	55	1.0	

03-Sep-96	Redfish	6-O A	0.4	0.5
03-Sep-96	Redfish	6-O A	0.5	
03-Sep-96	Redfish	6-O B	0.6	
03-Sep-96	Redfish	6-O B	0.6	
03-Sep-96	Redfish	6-O C	0.5	
03-Sep-96	Redfish	6-O C	0.5	
03-Sep-96	Redfish	outflow	0.6	
03-Sep-96	Redfish	ouflow	0.6	
09-Sep-96	Redfish	6-O A	0.5	0.6
09-Sep-96	Redfish	6-O B	0.6	
09-Sep-96	Redfish	6-O C	0.6	
09-Sep-96	Redfish	13	0.7	
09-Sep-96	Redfish	13	0.7	
09-Sep-96	Redfish	1% 21.6m	2.3	
09-Sep-96	Redfish	1% 21.6m	2.4	2.3
09-Sep-96	Redfish	55	1.1	
09-Sep-96	Redfish	55	1.1	
09-Sep-96	Redfish	ouflow	0.5	
09-Sep-96	Redfish	ouflow	0.5	
1 O-Sep-96	Redfish-S	0.5	0.4	
1 0-Sep-96	Redfish-S	0.5	0.4	
1 O-Sep-96	Redfish-S	3	0.4	
1 O-Sep-96	Redfish-S	3	0.4	
1 O-Sep-96	Redfish-S	6	0.4	
1 O-Sep-96	Redfish-S	6	0.4	
1 O-Sep-96	Redfish-S	10	1.6	
1 O-Sep-96	Redfish-S	IO	0.4	
1 O-Sep-96	Redfish-S	13	0.6	
1 O-Sep96	Redfish-S	13	0.4	
1 0-Sep-96	Redfish-S	18	1.1	
25-Oct-96	Redfish-S	25	0.6	
25-Oct-96	Redfish-S	25	0.9	
25-Oct-96	Redfish-	30	1.6	

22-Sep-96	Redfish	55	1.0	
22-Sep-96	Redfish	outflow	0.6	
22-Sep-96	Redfish	ouflow	0.6	
12-Oct-96	Redfish	6-O A	0.9	1.0
12-Oct-96	Redfish	6-O B	1.1	
12-Oct-96	Redfish	6-O C	0.9	
12-Oct-96	Redfish	17	1.4	
12-Oct-96	Redfish	17	1.3	
12-Oct-96	Redfish	1% 24.5m	3.1	
12-Oct-96	Redfish	1% 24.5m	2.9	3.0
12-Oct-96	Redfish	ouflow	0.7	
12-Oct-96	Redfish	ouflow	0.7	
12-Oct-96	Redfish	LRB	0.0	
23-Oct-96	Redfish	6-O A	1.1	1.1
23-Oct-96	Redfish	6-O B	1.0	
23-Oct-96	Redfish	6-OC	1.1	
23-Oct-96	Redfish	1% 24.5m	2.6	
23-Oct-96	Redfish	1% 24.5m	2.5	2.6
23-Oct-96	Redfish	LRB	0.0	
25-Oct-96	Redfish-S	0.5	0.2	
25-Oct-96	Redfish-S	0.5	0.8	
25-Oct-96	Redfish-S	5	0.6	
25-Oct-96	Redfish-S	5	0.6	
25-Oct-96	Redfish-S	IO	0.3	
25-Oct-96	Redfish-S	IO	0.5	
25-Oct-96	Redfish-S	15	0.2	
25-Oct-96	Redfish-S	15	0.3	
25-Oct-96	Redfish-S	20	0.4	
25-Oct-96	Redfish-S	20	0.6	
12-Jun-96	Pettit	16.5	0.9	
12-Jun-96	Pettit	20	1.8	
12-Jun-96	Pettit	20	1.8	

S

25-Oct-96	Redfish-S	30	1.6	
25-Oct-96	Redfish-S	35	1.5	
25-Oct-96	Redfish-S	35	1.4	
25-Oct-96	Redfish-N	0.5	0.6	
25-Oct-96	Redfish-N	0.5	0.6	
25-Oct-96	Redfish-N	5	0.6	
25-Oct-96	Redfish-N	5	0.5	
25-Oct-96	Redfish-N	IO	0.6	
25-Oct-96	Redfish-N	IO	0.7	
25-Oct-96	Redfish-N	15	0.0	
25-Oct-96	Redfish-N	15	0.5	
25-Oct-96	Redfish-N	20	0.6	
25-Oct-96	Redfish-N	20	0.6	
25-Oct-96	Redfish-N	25	1.4	
25-Oct-96	Redfish-N	25	1.5	
25-Oct-96	Redfish-N	30	1.6	
25-Oct-96	Redfish-N	30	1.7	
25-Oct-96	Redfish-N	35	1.3	
25-Oct-96	Redfish-N	35	1.3	
27-Nov-96	Redfish	6-O A	1.1	0.9
27-Nov-96	Redfish	6-O B	1.1	
27-Nov-96	Redfish	6-O C	1.1	
27-Nov-96	Redfish	24.7	1.2	
27-Nov-96	Redfish	24.7	1.1	1.2
27-Nov-96	Redfish	55	0.6	
27-Nov-96	Redfish	55	0.5	
27-Nov-96	Redfish	LRB	0.0	
22-Jan-97	Redfish	6-O A	1.4	1.7
22-Jan-97	Redfish	6-O A	1.4	
22-Jan-97	Redfish	6-O C	2.0	
22-Jan-97	Redfish	6-O C	1.9	

12-Jun-96	Pettit	25	3.0	
12-Jun-96	Pettit	25	3.1	
12-Jun-96	Pettit	30	2.7	
12-Jun-96	Pettit	30	2.7	
13-Jun-96	Pettit	6-O A	1.5	1.5
13-Jun-96	Pettit	6-O B	1.6	
13-Jun-96	Pettit	6-O C	1.4	
13-Jun-96	Pettit	1% 18m	2.6	
25-Jun-96	Pettit	6-O A	0.9	1.0
25-Jun-96	Pettit	6-O B	1.2	
25-Jun-96	Pettit	6-0 C	0.9	
25-Jun-96	Pettit	1% 17m	2.1	
25-Jun-96	Pettit	25	3.1	
25-Jun-96	Pettit	35	0.8	
25-Jun-96	Pettit	45	0.5	
02-Jul-96	Pettit	0.5	0.4	
02-Jul-96	Pettit	0.5	0.4	
02-Jul-96	Pettit	2.5	0.5	
02-Jul-96	Pettit	2.5	0.5	
02-Jul-96	Pettit	5	0.6	
02-Jul-96	Pettit	5	0.6	
02-Jul-96	Pettit	IO	0.9	
02-Jul-96	Pettit	10	0.9	
02-Jul-96	Pettit	16	1.8	
02-Jul-96	Pettit	16	1.7	
02-Jul-96	Pettit	20	2.0	
02-Jul-96	Pettit	20	2.1	
02-Jul-96	Pettit	25	3.6	
02-Jul-96	Pettit	25	3.6	
02-Jul-96	Pettit	30	1.7	
02-Jul-96	Pettit	30	1.7	

22-Jan-97	Redfish	25	0.5	
22-Jan-97	Redfish	25	0.5	
22-Jan-97	Redfish	55	0.3	
22-Jan-97	Redfish	55	0.3	
22-Jan-97	Redfish	LRB	0.0	
1 g-Mar-96	Pettit	6-O A	2.1	2.1
1 g-Mar-96	Pettit	6-O B	2.2	
1 g-Mar-96	Pettit	6-O C	2.0	
1 g-Mar-96	Pettit	25	0.3	
1 g-Mar-96	Pettit	40	0.1	
28-May-96	Pettit	6-O A	2.1	2.1
28-May-96	Pettit	6-O B	2.2	
28-May-96	Pettit	6-O C	2.0	
28-May-96	Pettit	25	3.8	
28-May-96	Pettit	40	0.6	
12-Jun-96	Pettit	0.5	0.3	
12-Jun-96	Pettit	0.5	0.0	
12-Jun-96	Pettit	5	1.0	
12-Jun-96	Pettit	5	0.0	
12-Jun-96	Pettit	IO	1.3	
12-Jun-96	Pettit	IO	0.0	
12-Jun-96	Pettit	13	1.1	
12-Jun-96	Pettit	13	0.0	
01 dug-96	Pettit	14	1.1	
01 -Aug-96	Pettit	18	2.1	
01 dug-96	Pettit	18	2.0	
01 -Aug-96	Pettit	22	2.0	
Ol-Aug-96	Pettit	22	2.2	
01 dug-96	Pettit	25	2.5	
01 -Aug-96	Pettit	25	2.4	
06-Aug-96	Pettit	6-O A	0.5	0.5
06-Aug-96	Pettit	6-O B	0.5	
06-Aug-96	Pettit	6-O C	0.5	
06-Aug-96	Pettit	1% 21.9	2.5	
06-Aug-96	Pettit	1% 21.9	2.5	2.5
28-Aug-96	Pettit	6-O A	0.6	0.5
26-Aug-96	Pettit	6-O B	0.5	
26-Aug-96	Pettit	6-O C	0.6	
26-Aug-96	Pettit	1% 23.4	2.2	
26-Aug-96	Pettit	1% 23.4	2.2	2.2
08-Sep-96	Pettit	6-O A	0.5	0.5
08-Sep-96	Pettit	6-O B	0.5	

1 I-Jul-96	Pettit	6-O A	0.7	0.6
1 I-Jul-96	Pettit	6-O A	0.6	
11 -Jul-96	Pettit	6-O B	0.6	0.6
1 I-Jul-96	Pettit	6-O B	0.5	
11 -Jul-96	Pettit	6-O C	0.7	0.7
1 I-Jul-96	Pettit	6-O C	0.6	
1 I-Jul-96	Pettit	1% 19m	2.6	2.4
11 -Jul-96	Pettit	1% 19m	2.2	
22-Jul-96	Pettit	6-O A	0.7	0.7
22-Jul-96	Pettit	6-O B	0.7	
22-Jul-96	Pettit	6-O C	0.7	
22-Jul-96	Pettit	6-O	0.7	
22-Jul-96	Pettit	1% 19.5	2.9	
22-Jul-96	Pettit	1% 19.5	3.0	
01 -Aug-96	Pettit	0.5	0.4	
01 -Aug-96	Pettit	0.5	0.5	
01 -Aug-96	Pettit	3	0.6	
01 -Aug-96	Pettit	3	0.6	
01 -Aug-96	Pettit	6	0.5	
01 -Aug-96	Pettit	6	0.5	
01 -Aug-96	Pettit	IO	0.6	
01 -Aug-96	Pettit	10	0.5	
01 -Aug-96	Pettit	14	1.1	
24-Oct-96	Pettit	30	1.1	
24-Oct-96	Pettit	35	0.3	
24-Oct-96	Pettit	35	0.3	
24-Oct-96	Pettit	6-O A	0.8	0.8
24-Oct-96	Pettit	6-O B	0.8	
24-Oct-96	Pettit	6-O C	0.7	
24-Oct-96	Pettit	1% 23.0	1.4	
24-Oct-96	Pettit	1% 23.0	1.4	1.4
24-Oct-96	Pettit	LRB	0.0	
20-Mar-96	Alturas	6-O A	0.9	0.9
20-Mar-96	Alturas	6-O B	0.9	
20-Mar-96	Alturas	6-O C	0.9	
20-Mar-96	Alturas	25	0.1	
20-Mar-96	Alturas	40	0.1	
29-May-96	Alturas	6-O A	2.2	2.1
29-May-96	Alturas	6-O B	2.0	
29-May-96	Alturas	6-O C	2.1	
29-May-96	Alturas	25	1.6	
29-May-96	Alturas	40	1.1	

08-Sep-96	Pettit	6-O C	0.5	
08-Sep-96	Pettit	1% 23.5	2.2	
08-Sep-96	Pettit	1% 23.5	2.2	2.2
09-Sep-96	Pettit	0.5	0.3	
09-Sep-96	Pettit	0.5	0.4	
09-Sep-96	Pettit	3	0.3	
09-Sep-96	Pettit	3	0.3	
09-Sep-96	Pettit	7	0.3	
09-Sep-96	Pettit	7	0.4	
09-Sep-96	Pettit	10	0.4	
09-Sep-96	Pettit	IO	0.4	
09-Sep-96	Pettit	15	1.1	
09-Sep-96	Pettit	15	0.7	
09-Sep-96	Pettit	20	1.2	
09-Sep-96	Pettit	20	1.4	
09-Sep-96	Pettit	25	2.5	
09-Sep-96	Pettit	25	2.6	
09-Sep-96	Pettit	30	3.4	
09-Sep-96	Pettit	30	3.3	
22-Sep-96	Pettit	6-O A	0.7	0.6
22-Sep-96	Pettit	6-O B	0.6	
22-Sep-96	Pettit	6-O C	0.6	
22-Sep-96	Pettit	1% 22.6	1.9	
22-Sep-96	Pettit	1% 22.6	1.8	1.9
22-Sep-96	Pettit	LRB	0.0	
24-Oct-96	Pettit	0	0.4	
24-Oct-96	Pettit	0	0.4	
24-Oct-96	Pettit	5	0.4	
24-Oct-96	Pettit	5	0.4	
24-Oct-96	Pettit	10	0.4	
24-Oct-96	Pettit	10	0.4	
24-Oct-96	Pettit	15	0.5	
24-Oct-96	Pettit	15	0.5	
24-Oct-96	Pettit	20	0.9	
24-Oct-96	Pettit	20	0.9	
24-Oct-96	Pettit	25	0.9	
24-Oct-96	Pettit	25	0.8	
24-Oct-96	Pettit	30	1.2	
02-Jul-96	Alturas	14	2.0	
02-Jul-96	Alturas	14	1.9	
02-Jul-96	Alturas	17	2.6	
02-Jul-96	Alturas	27	2.6	
02-Jul-96	Alturas	20	3.0	
02-Jul-96	Alturas	20	3.1	
12-Jul-96	Alturas	6-0 A	0.7	0.7
12-Jul-96	Alturas	6-O A	0.6	

12-Jun-96	Alturas	0.5	0.5	
12-Jun-96	Alturas	0.5	0.5	
12-Jun-96	Alturas	2.5	0.6	
12-Jun-96	Alturas	2.5	0.0	
12-Jun-96	Alturas	5	0.9	
12-Jun-96	Alturas	5	1.0	
12-Jun-96	Alturas	8	1.5	
12-Jun-96	Alturas	8	1.5	
12-Jun-96	Alturas	11	1.6	
12-Jun-96	Alturas	11	1.5	
12-Jun-96	Alturas	15	1.8	
12-Jun-96	Alturas	15	1.8	
12-Jun-96	Alturas	20	1.8	
12-Jun-96	Alturas	20	1.9	
12-Jun-96	Alturas	25	1.6	
12-Jun-96	Alturas	25	1.7	
14-Jun-96	Alturas	6-O A	1.6	1.5
14-Jun-96	Alturas	6-O B	1.4	
14-Jun-96	Alturas	6-O C	1.7	
14-Jun-96	Alturas	1% 11m	3.1	
25-Jun-96	Alturas	6-O A	1.3	1.4
25-Jun-96	Alturas	6-O B	1.2	
25-Jun-96	Alturas	6-O C	1.6	
25-Jun-96	Alturas	1% 12.5	2.1	
25-Jun-96	Alturas	25	1.0	
25-Jun-96	Alturas	35	0.6	
25-Jun-96	Alturas	45	2.9	
02-Jul-96	Alturas	0.5	0.4	
02-Jul-96	Alturas	0.5	0.4	
02-Jul-96	Alturas	2.5	0.6	
02-Jul-96	Alturas	2.5	0.6	
02-Jul-96	Alturas	5	1.0	
02-Jul-96	Alturas	5	0.9	
02-Jul-96	Alturas	8	1.3	
02-Jul-96	Alturas	8	1.3	
02-Jul-96	Alturas	11	1.7	
02-Jul-96	Alturas	11	1.7	
09-Sep-96	Alturas	22	1.5	
09-Sep-96	Alturas	26	1.2	
09-Sep-96	Alturas	26	1.2	
22-Sep-96	Alturas	6-O A	1.1	1.1
22-Sep-96	Alturas	6-O B	1.1	
22-Sep-96	Alturas	6-O C	1.0	
22-Sep-96	Alturas	1% 16.7	1.8	
22-Sep-96	Alturas	1% 16.7	1.8	1.8

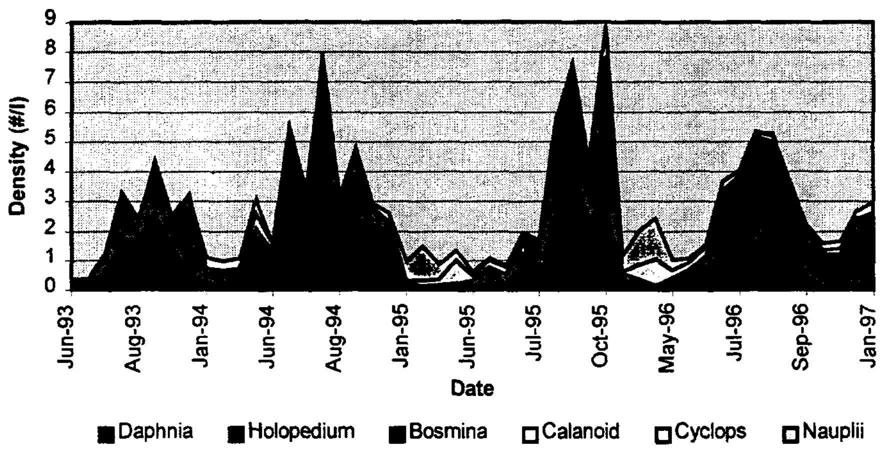
12-Jul-96	Alturas	6-O B	0.7	
12-Jul-96	Alturas	6-O B	0.6	
12-Jul-96	Alturas	6-O C	0.7	
12-Jul-96	Alturas	6-O C	0.6	
12-Jul-96	Alturas	1% 13.7	2.2	
12-Jul-96	Alturas	1% 13.7	1.9	
23-Jul-96	Alturas	6-O A	0.7	0.8
23-Jul-96	Alturas	6-O B	0.8	
23-Jul-96	Alturas	6-O C	0.8	
23-Jul-96	Alturas	1% 14.9	2.1	
23-Jul-96	Alturas	1% 14.9	2.1	2.1
01 -Aug-96	Alturas	0.5	0.7	
01 -Aug-96	Alturas	0.5	0.5	
Ol-Aug-96	Alturas	3	0.5	
01 -Aug-96	Alturas	3	0.5	
01 -Aug-96	Alturas	5	0.6	
01 -Aug-96	Alturas	5	0.0	
01 -Aug-96	Alturas	8	0.7	
01 -Aug-96	Alturas	8	0.8	
Ol-Aug-96	Alturas	11	1.5	
01 -Aug-96	Alturas	11	1.3	
01 -Aug-96	Alturas	15	1.6	
01 -Aug-96	Alturas	15	1.5	
01 dug-96	Alturas	19	1.6	
Ol-Aug-96	Alturas	19	1.7	
0 1 -Aug-96	Alturas	22	1.1	
01 -Aug-96	Alturas	22	1.2	
27-Aug-96	Alturas	6-O A	0.5	0.5
27-Aug-96	Alturas	6-O C	0.5	
27-Aug-96	Alturas	1% 18.1	1.7	
27-Aug-96	Alturas	1% 18.1	1.7	1.7
08-Sep-96	Alturas	6-O A	0.8	0.7
08-Sep-96	Alturas	6-O B	0.8	
08-Sep-96	Alturas	6-O C	0.7	
08-Sep-96	Alturas	1% 17.3	1.5	
08-Sep-96	Alturas	1% 17.3	1.6	1.5
09-Sep-96	Alturas	0.5	0.5	
09-Sep-96	Alturas	0.5	0.5	
09-Sep-96	Alturas	2.5	0.7	
09-Sep-96	Alturas	2.5	0.6	
09-Sep-96	Alturas	5	0.6	
09-Sep-96	Alturas	5	0.5	
09-Sep-96	Alturas	8	0.7	
09-Sep-96	Alturas	8	0.7	

24-Oct-96	Alturas	6-O A	1.1	1.1
24-Oct-96	Alturas	6-O B	1.1	
24-Oct-96	Alturas	6-O C	1.1	
24-Oct-96	Alturas	1% 20.5	1.4	
24-Oct-96	Alturas	1% 20.5	1.3	1.3
27-Nov-96	Alturas	6-O A	1.2	1.3
27-Nov-96	Alturas	6-O B	1.4	
27-Nov-96	Alturas	6-O C	1.3	
27-Nov-96	Alturas	1% 20.3	1.3	
27-Nov-96	Alturas	1% 20.3	1.3	1.3
27-Nov-96	Alturas	25	1.3	
27-Nov-96	Alturas	25	1.3	
27-Nov-96	Alturas	40	1.3	
27-Nov-96	Alturas	40	1.3	
27-Nov-96	Alturas	LRB	0.0	
21 -Jan-97	Alturas	6-O A	4.3	0.7
21 -Jan-97	Alturas	6-O A	3.7	
21 -Jan-97	Alturas	6-O B	2.5	
21-Jan-97	Alturas	6-O B	2.7	
21-Jan-97	Alturas	6-O C	3.5	
21 -Jan-97	Alturas	6-O C	3.2	
21 -Jan-97	Alturas	25	0.4	
21-Jan-97	Alturas	25	0.4	
21-Jan-97	Alturas	40	0.2	
21-Jan-97	Alturas	40	0.2	
21 -Jan-97	Alturas	LRB	0.0	
20-Mar-96	Stanley	6-O A	1.4	1.1
20-Mar-96	Stanley	6-O B	1.0	
20-Mar-96	Stanley	6-O C	1.0	
20-Mar-96	Stanley	20	0.2	
30-May-96	Stanley	6-O A	2.6	2.7
30-May-96	Stanley	6-O B	2.3	
30-May-96	Stanley	6-O C	3.1	
30-May-96	Stanley	20	1.3	
14-Jun-96	Stanley	6-O A	1.0	1.2
14-Jun-96	Stanley	6-O B	1.3	
14-Jun-96	Stanley	6-O C	1.4	
14-Jun-96	Stanley	1% 8m	1.4	
25-Jun-96	Stanley	6-O A	1.2	1.5
25-Jun-96	Stanley	6-O B	1.5	
25-Jun-96	Stanley	6-O C	1.8	
25-Jun-96	Stanley	1%	1.6	

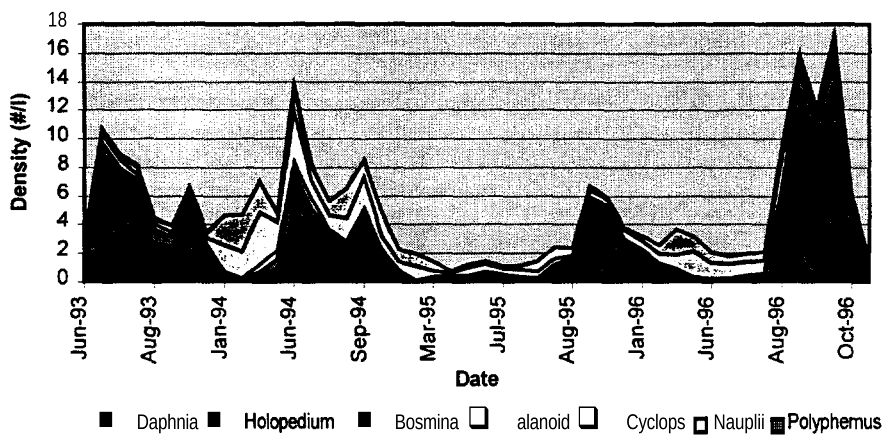
09-Sep-96	Alturas	12	1.0	
09-Sep-96	Alturas	12	1.0	
09-Sep-96	Alturas	18	1.4	
09-Sep-96	Alturas	18	1.4	
09-Sep-96	Alturas	22	1.5	
23-Jul-96	Stanley	6-O A	0.9	0.8
23-Jul-96	Stanley	6-O B	0.8	
23-Jul-96	Stanley	6-O C	0.8	
23-Jul-96	Stanley	1%	2.7	
		13.2m		
23-Jul-96	Stanley	1%	2.8	2.8
		13.2m		
27-Aug-96	Stanley	6-O A	0.6	0.6
27-Aug-96	Stanley	6-O B	0.6	
27-Aug-96	Stanley	6-O C	0.6	
27-Aug-96	Stanley	1%	1.3	
		16.0m		
27-Aug-96	Stanley	1%	1.3	1.3
		16.0m		
08-Sep-96	Stanley	6-O A	0.6	0.6
08-Sep-96	Stanley	6-O B	0.6	
08-Sep-96	Stanley	6-O C	0.6	
08-Sep-96	Stanley	1%	1.7	
		14.7m		
08-Sep-96	Stanley	1%	1.5	1.6
		14.7m		
22-Sep-96	Stanley	6-O A	0.7	0.8
22-Sep-96	Stanley	6-O B	0.9	
22-Sep-96	Stanley	6-O C	0.9	
22-Sep-96	Stanley	1%	1.2	
		15.0m		
22-Sep-96	Stanley	1%	1.1	1.2
		15.0m		
22-Sep-96	Stanley	LRB	0.0	
25-Oct-96	Stanley	6-O A	1.2	1.2
25-Oct-96	Stanley	6-O B	1.2	
25-Oct-96	Stanley	6-O C	1.3	
25-Oct-96	Stanley	1%	1.3	
		12.8m		
25-Oct-96	Stanley	1%	1.3	1.3
		12.8m		
25-Oct-96	Stanley	LRB	0.0	

		9.3m		
12-Jul-96	Stanley	6-O	1.3	1.0
12-Jul-96	Stanley	6-O	0.7	
12-Jul-96	Stanley	1%	2.3	
		11.5m		
12-Jul-96	Stanley	1%	1.9	
		11.5m		

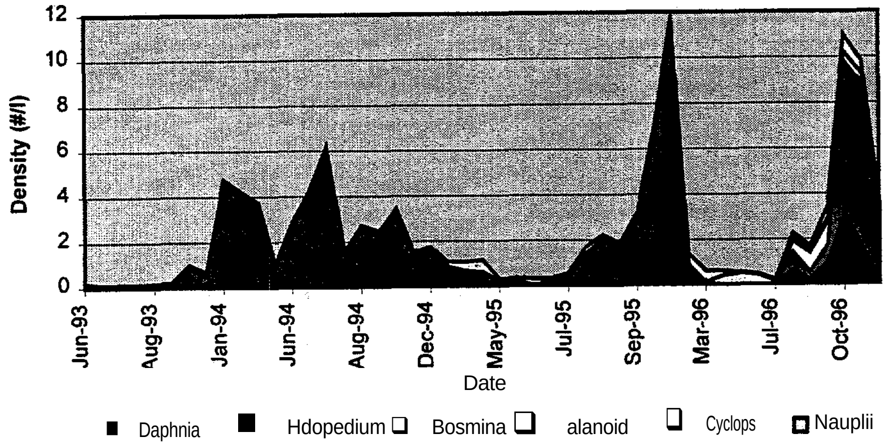
Appendix 4. Total zooplankton densities (#/l) weighed by lake volume in the Sawtooth Valley Lakes, 1993-1996.



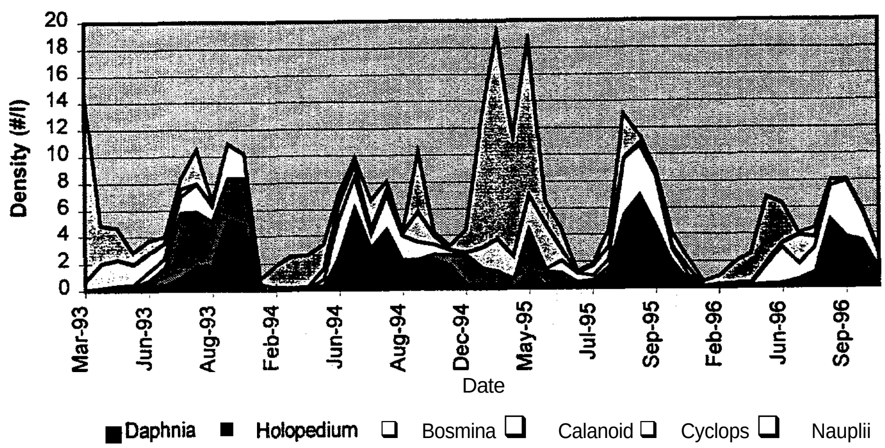
Redfish Lake zooplankton density (#/l)



Pettit Lake zooplankton density (#/l)



Alturas Lake zooplankton density (#/l)



Stanley Lake zooplankton density (#/l)

SPATIAL-TEMPORAL ANALYSIS OF PRIMARY PRODUCTIVITY IN THE MOUNTAIN LAKE HABITAT OF ENDANGERED SOCKEYE SALMON

1996 Annual Report to

Biolines, Incorporated

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INTRODUCTION

Primary productivity measurements provide the most direct and accurate way of assessing productive capacity of a lake (Wetzel 1983) because other measures such as chlorophyll levels or algal biomass fail to account for the turnover rate of the phytoplankton. This is important when considering the spatial distribution of primary production, because phytoplankton in the deeper strata of lakes will often have abundant phytoplankton, but light-limited rates of photosynthesis. Light limitation relative to algal bioamass is particularly important in mountain lakes such as those in the Sawtooth Mountains of Idaho, where deep-chlorophyll maxima in the metalimnia often exceed the chlorophyll levels in the epilimnion by 5-10 fold (Gross 1995). Additionally, recent work in the Sawtooth Mountain lakes of Idaho (Budy 1995) demonstrated that primary productivity measurements provided a more sensitive indicator of the effects of fertilization than did measures of chlorophyll or algal or zooplankton biomass.

In this study, primary production rates were measured in three Sawtooth Mountain lakes of Idaho during the summer of 1998. Limnological characteristics of the lakes are given in Budy et al. 1995. There were two primary objectives of the study. First, this work continued the limnological monitoring on these systems begun in 1991. It is hoped that the monitoring will help establish which of the lakes are most suitable for reintroduction of the endangered Snake River sockeye salmon *Oncorhynchus nerka*, and to help estimate appropriate fish stocking rates. The analysis of primary productivity was coordinated with the analysis of other limnological monitoring done by Biolines, Inc. and the Shoshone Bannock Indian Tribes. The second objective was to gain a better understanding of the roll of the deep-chlorophyll maxima in these mountain lakes. Because more than 50% of the primary production in these lakes occurs below the epilimnion (Gross et al. 1994), it is crucial that we understand factors controlling algal photosynthesis there.

METHODS

Primary productivity measurements were made monthly from June-October in Redfish and Pettit Lakes, and in all months except October in Alturas Lake. The measurements were made in two stations in Redfish Lake. One was located in 65 m of water at the southwest end of the lake (referred to as "south station"), and the other in 50 m of water near the northern end of the lake (north station). In Pettit and Alturas Lakes the stations were located near the center of each lake in approximately 50 m of water. During each month the two stations in Redfish Lake were completed on one day, and the measurements in Pettit and Alturas on another day.

Vertical profiles of productivity were measured with an *in* situ ^{14}C method (Wetzel and Likens 1990) at eight depths in the photic zone of each lake. Water from each depth was incubated in three 24-ml glass scintillation vials. Each vial was inoculated with 40 µl of 20 µCi/ml $^{14}CHO_3$, and one vial at each depth also received 150 µl of a saturated solution of a photosynthetic inhibitor, Diuron (dichloro-phenyl-dimethyurea; DCMU) to correct for non-photosynthetic ^{14}C uptake. The vials were incubated at the appropriate depths for ca. 4 h in clear acrylic plastic tubes. At the end of the incubation, the entire contents of each vial was filtered through a 0.45-µm cellulose nitrate filter and rinsed with 0.01-N HCL. They were then air dried, and subsequently counted by liquid scintillation spectrometry. Production rates were calculated by subtracting carbon uptake in the DCMU treatments from the light treatments. Dissolved inorganic carbon available in the environment was estimated on samples preserved with chloroform, and subsequently analyzed with a CHN analyzer by personnel at the University of California, Davis.

We used the procedure outlined by Wetzel and Likens (1990) to expand the data from the 4-hr incubation period to ***daily*** rates of primary production. Continuous digital insolation data were collected by placing HOBO®-light and HOBO®-temperature recorders at a depth of 10-m in Redfish Lake. The light and temperature data were integrated and recorded at 30-minute intervals. This light data was collected by R. Griswold of Biolines, Inc. On the day of the incubation an addition pair of HOBO® sensors placed at l-m depth in Redfish Lake recorded light and temperatures at 15-min intevals. The HOBO®-light sensors are highly sensitive to temperature. Consequently, we used the HOBO@-temperature data recorded simultaneously to correct the light data to a constant temperature. For this, a regression between temperature and light intensity was established, using data measured when light intensity was held constant. The primary production rates (PPR) from each **4-hr** incubation were expanded to a daily rate (PPR_{daily}) by assuming:

$$PPR_{daily} = PPR_{inc} \times F \qquad \textbf{where:}$$

PPR_{inc} = mean production during incubation period (μg C L^{-1} hr^{-1})

$$F = \frac{\text{lumens day}^{-1}}{\text{lumens hi' during incubation}}$$

The mean factors (F) used to expand to daily rates varied from 7.8 **(Redfish** Lake) to 9.0 (Alturas Lake), and averaged 8.3. The primary productivity data were further normalized by relating the insolation on the day of the incubation, to the average insolation during the month. In some cases, continuous light measurements were not available for the entire month. In June, no light data were available, so we assumed that daily primary productivity on the days of measurement were representative of the entire month. In other cases we used at least a **20-day** period bracketing the incubation date to estimate average "monthly" insolation.

The primary production estimates in 1996 were compared to those measured in 1993 (Steinhart et al. 1994) and 1995 (Luecke et al. 1996). Insolation was not, however, measured in 1994 and 1995. To estimate primary production on a daily rate for 1993 and 1995, we used the hourly to daily expansion factors **(F)** for each lake measured in 1996. These were: RF-7.8; Pettit-8.6; Alturas-9.2. For Stanley lake, where this factor was not available (no 1996 PPR or light data), we used the mean expansion factor for all of the lakes (F= 8.3). Because the 1993 and 1995 data were not corrected for an average insolation day, their individual daily values may not be representative of the monthly period. However, 'when averaged over an entire summer, they should provide a non-biased estimate of the primary productivity.

Samples for chlorophyll *a* analysis were collected from the same bottle casts as those used to sample water for primary production. Two replicate **50-ml** samples were filtered on cellulose acetate filters, frozen, and subsequently extracted in methanol and analyzed on a Turner Model **10AU fluorometer.** Chlorophyll determinations were done by R. Griswold of Biolines, Inc. Temperature, light and conductivity profiles were also recorded. These were usually done on the day of the primary productivity measurements, but on some occasions they were done 1-2 days prior to the incubations.

RESULTS AND DISCUSSION

Primary production in these oligotrophic lakes was distributed across deep photic zones (Figure 1). In Pettit and Redfish Lakes the photic zone usually extended to about 35 m, whereas in Alturas Lake it extended to between 20-25 m. Light intensities at these depths were near 1 $\mu E \cdot m^{-2} \cdot sec^{-1}$. On sunny days this was less than 0.1% of surface intensities. Photoinhibition was common in the upper 5-10 m of the water column, with maximum photosynthetic rates usually occurring between 5 and 15 m. For most of the profiles, more than 50% of the primary production occurred in the metalimnia where the deep chlorophyll layers were located (Figure 2).

Unusual productivity profiles were recorded on some dates. In July, the southern station in Redfish Lake had very low primary production at 15 m, whereas production was maximal at this depth in the northern station (Figure 1). Chlorophyll a concentrations were, however, consistent with the production profiles: low chlorophyll levels were found at 15 m a the south station, while high concentrations were found at this depth at the north station (Figure 2). Similarly, the low primary production that occurred at 10 m in Pettit Lake during August was accompanied by a relatively low chlorophyll level. The most unusual profile occurred at the north station of Redfish Lake in October, where a secondary maxima was recorded at depths of 25-35 m where light levels were less than 0.5% of surface values (Figure 1). It is possible that the primary productivity line tangled during deployment, with the lower bottles being incubated at depths shallower than they should have been. The chlorophyll levels at 25 m, however, also increased significantly, and were more than double those at the south station. Consequently, the secondary peak may not be erroneous. It is conceivable that nutrients from decomposing salmon in Fishhook Creek plunged into the lake and interflowed to the deeper strata and stimulated primary production there. Unfortunately, ancillary data from the creek are not available to test this hypothesis.

Integral primary production rates in the lakes were very low on all dates (Figure 3), ranging from 68 to 285 $mg \cdot m^{-2} \cdot day^{-1}$ (Table 1; Appendix 1). In this year's results, there were no seasonal trends in production, except at the north station in Redfish Lake where productivity increased progressively throughout the study period. In 1996 rates of primary production differed between lakes. In Redfish

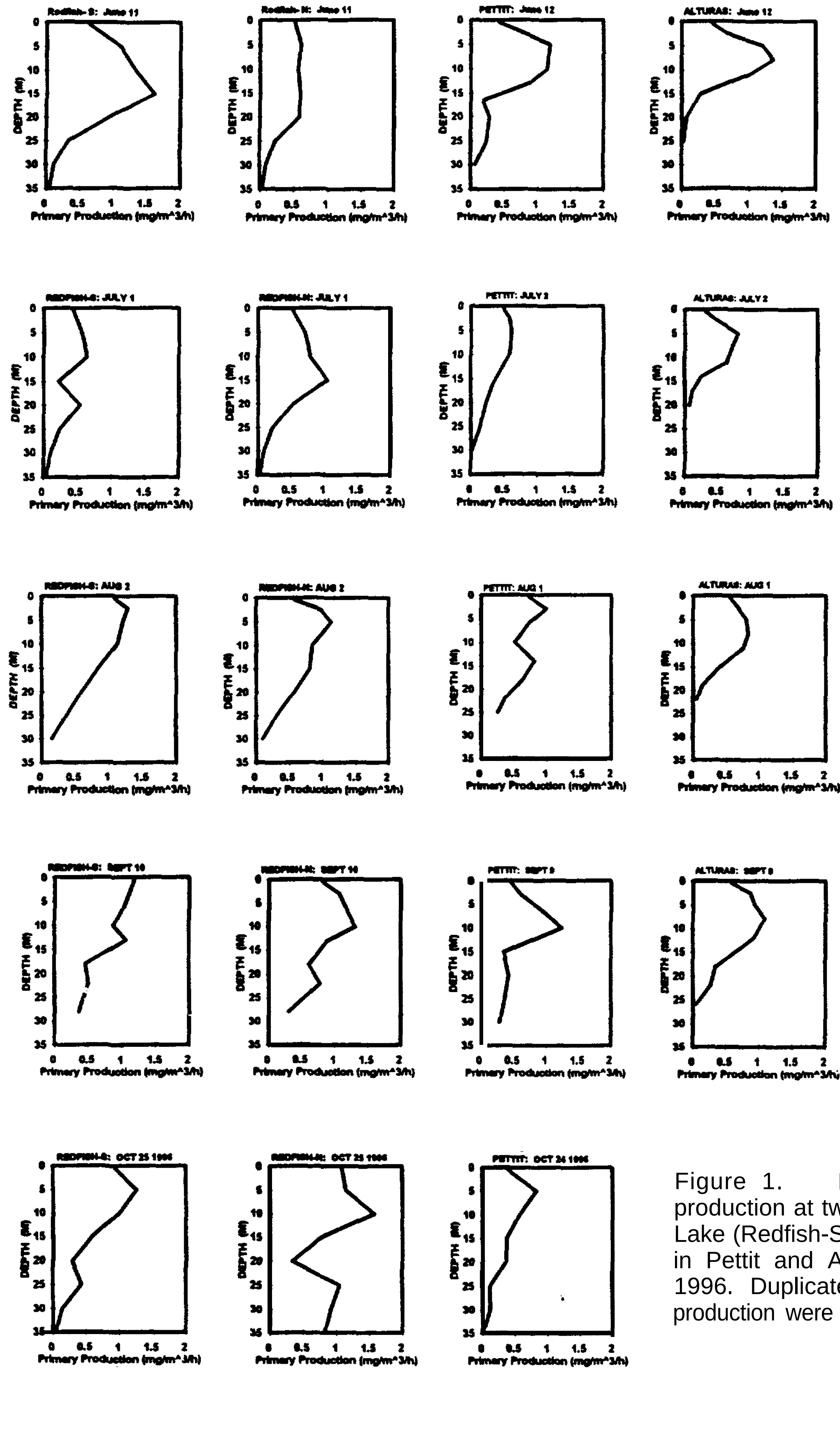

Figure 1. Profiles of primary production at two stations in **Redfish** Lake (Redfish-S and **Redfish-N),** and in Pettit and Alturas Lakes during 1996. Duplicate measurements of production were made at each depth.

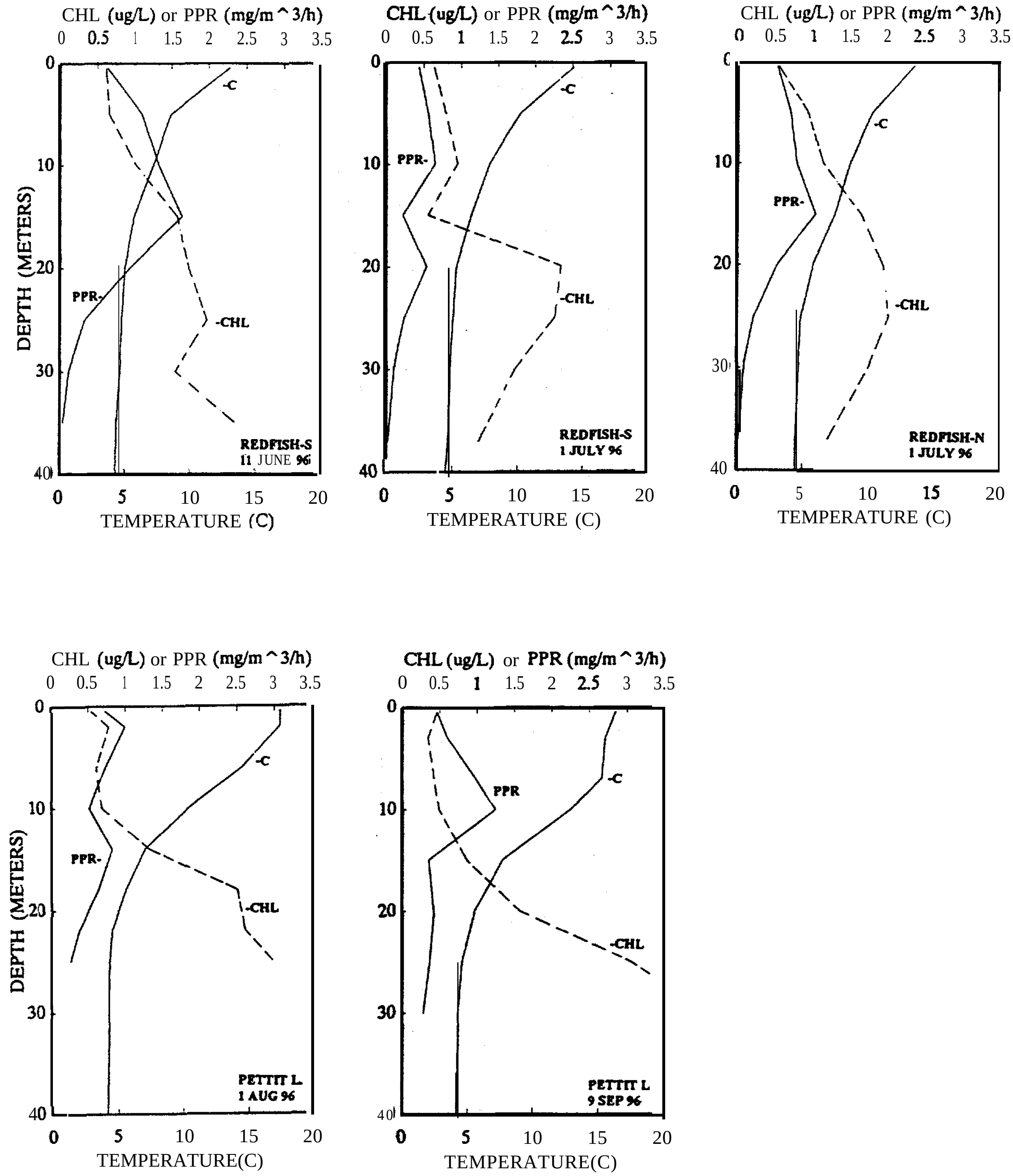

Figure 2. Example profiles of primary production (PPR), chlorophyll a ***(CHL)***, and temperature (C), in the Sawtooth Basin lakes during **1996.**

Table 1. Primary productivity (ppr) at two stations in Redfish Lake (RF-S, RF-N) and in Pettit and Alturas Lakes during 1996. On each date, productivity was measured at eight depths, and areal productivity estimated by integrating under the depth-ppr curve.

A. Productivities measured during the midday incubations.

	Primary Production (mg/ m2 /h)					
	JUN	JUL	AUG	SEP	OCT	MEAN
RF-S	27.3	11.7	21.6	19.7	18.6	19.8
RF-N	13.5	17.0	17.9	22.5	33.0	20.8
PET-TIT	17.1	9.5	15.1	16.6	11.8	14.0
ALTURA	13.3	8.6	10.8	14.7	-	9.5

B. Productivities corrected to total daily rates.

	Primary Production (mg/ m2 /day)					
	JUN	JUL	AUG	SEP	OCT	MEAN
RF-S	234	105	168	138	115	152
RF-N	116	151	152	154	211	157
PETTIT	143	77	133	161	93	121
ALTURA	132	63	124	120	-	88

C. Productivities normalized to average daily irradiance for each month.
Because irradiance data was not available for June, estimates for that month assume light levels on the days of the ppr incubations were representative of the entire month
Annual rates assume a 200 d &free production period, and discount under-ice ppr.

	Primary Production (mg/ m2 /day)						Annual (200 d) (g/m2/yr)
	JUN	JUL	AUG	SEP	OCT	MEAN	
RF-S	234	88	181	157	155	163	32.6
RF-N	116	127	164	175	285	173	34.7
PET-TIT	143	83	123	134	118	120	24.0
ALTURA	132	68	114	100		104	20.7

\96ppr2.wb2

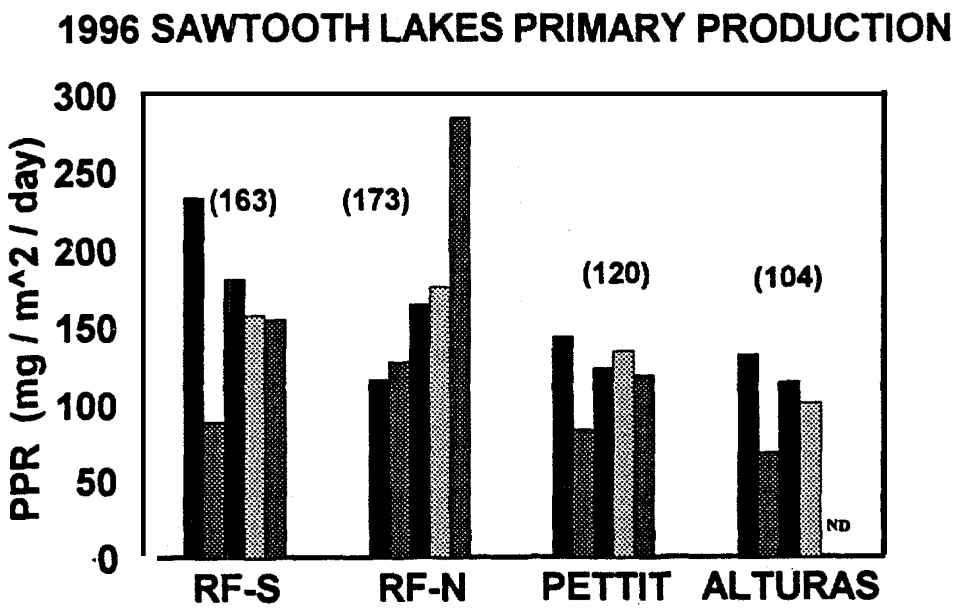

Figure 3. Integral primary productivity in the Sawtooth Basin Lakes during the summer of 1996. Data are for **Redfish** Lake south station (RF-S), **Redfish** north station (RF-N), Pettit, and Alturas Lakes. Each set of bars shows production for June, July, August, September and October (left to right; no Oct. data for Alturas Lake). See text for an explanation of the high primary production rate for the RF-N station in October. Rates shown here are normalized to an average irradiance for each month. Numbers in parentheses show mean PPR rates for the summer season.

Lake, markedly different rates were recorded at the two stations on different dates, but the mean summer rates at the two locations differed by only 7%. Primary production rates in Pettit Lake and Alturas lakes were only 70% and 60% of the mean level found in Redfish Lake. Redfish Lake was, however, fertilized during the summer of 1996, and this probably contributed to its higher production.

Mean rates of primary production estimated from the long-term data set (1993, 1995, 1996) indicated that rates of primary production have been relatively similar in the Stanley Basin lakes (Redfish, Pettit, Alturas, Stanley). When data for months when Redfish Lake was fertilized are excluded, mean daily production of the four lakes range from only 113 in Stanley Lake to 135 $mg \cdot m^{-2} \cdot day^{-1}$ Pettit Lake (Figure 4; Appendix 1). It is curious that rates in Stanley Lake were the lowest, given that it has the highest nutrient loading rates (Gross and Wurtsbaugh 1994) and sometimes the highest chlorophyll levels. However, the rates in Stanley Lake must be interpreted cautiously, as relatively few measurements have been done there. It is also important to note, that in Redfish and Pettit Lakes, production and chlorophyll is spread over a 35-m thick photic zone, whereas in Stanley Lake productivity is concentrated in the upper 15-20 m.

Fertilization of Redfish Lake appears to have stimulated primary production substantially (Figure 4; Appendix 1). Mean primary productivity rates for incubations done when the lake was not fertilized were only 121 $mg \cdot m^{-2} \cdot day^{-1}$, whereas rates during periods of fertilization averaged 223 $mg \cdot m^{-2} \cdot day^{-1}$ (a 92% increase) . Fertilization during 1995 stimulated production more than in 1996 (Figure 4). This is likely because fertilization was continuous in 1995, but intermittent between August and October 1996 (D. Taki, personal communication). The influence of fertilization on primary production in 1996 is consistent with the analysis of Budy (1994; 1996), who found that primary production, as well as chlorophyll, zooplankton and fish growth in Redfish Lake were stimulated by nutrient additions to the lake in 1995.

In summary, the results suggest that primary productivity levels in the Sawtooth Lakes are very low (113-135 $mg \cdot m^{-2} \cdot day^{-1}$). If annual rates are calculated by assuming that nearly all the production occurs during a 200 day ice-free period, then production varies from 23 to 27 g C m^{-2} year" (Appendix 1). These low rates are consistent with the very low epilimnetic chlorophyll a concentrations ($< 1\ \mu g \cdot L^{-1}$), and categorize the lakes as ultra-oligotrophic (Mason 1996). Fettiliition of Redfish Lake in the summer of 1995, and partially in 1996, appears to have increased production.

PRIMARY PRODUCTION IN. THE STANLEY BASIN LAKES

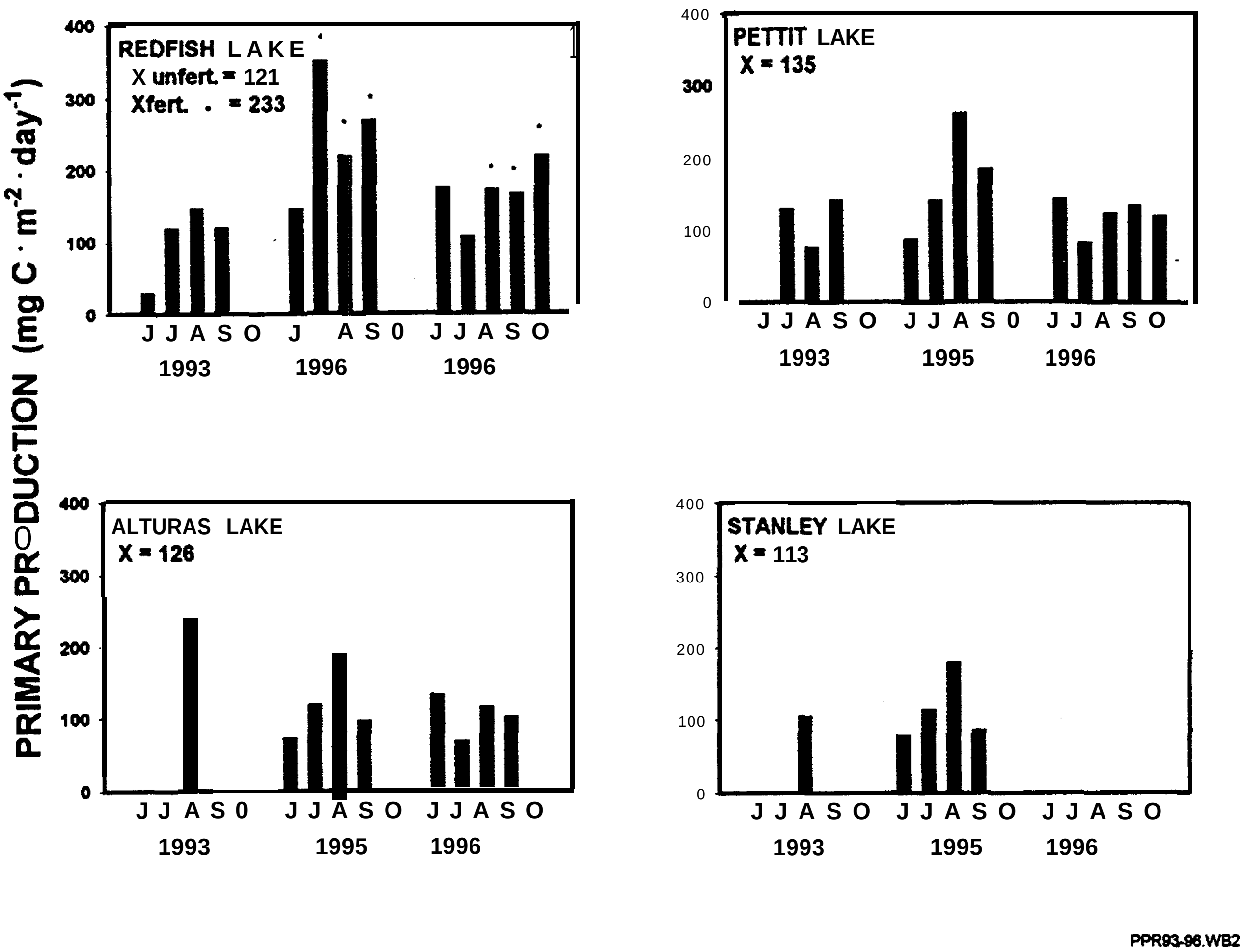

Figure 4. Summary of rates of primary production from four Sawtooth Basin lakes from 1993-l 996. Rates for 1996 were normalized to average monthly insolation using light measurements during that year. Rates for 1993 and 1995 are not normalized to monthly means, and thus individual daily rates may be high or low depending on insolation characteristics for that date (see text). Months when Redfish Lake was fertilized on or before the incubation for that month are indicated with asterisks. Mean daily rates for each lake are shown.

REFERENCES

Budy, P.B. 1996. Adding nutrients to enhance the growth and production of endangered sockeye salmon: trophic transfer in an oligotrophic lake. Ph.D. Dissertation. Utah State University. Logan. 225 p.

Budy, P.B., C. Luecke, W. Wuttsbaugh, and H. Gross. 1994. Effects of nutrient enhancement on juvenile sockeye salmon growth. Lake and Reservoir Management **9:140-145.**

Budy, P.B., C. Luecke, W. Wurtsbaugh, and H. Gross. 1995. Limnology of Sawtooth Valley Lakes with respect to potential growth of juvenile Snake River Sockeye Salmon. Northwest Science **69:133-150**.

Budy, P.B., G. Steinhart, C. Luecke and W. A. Wurtsbaugh. 1996. Limnological investigations of Sawtooth Valley lakes, 1994. pp. **54-65** ***in*** D. Teuscher and D. Taki (eds.) Snake River sockeye salmon habitat and limnological research: Annual Report 1995. Bonneville Power Administration DOE/BP-22548-3.

Gross, H.P. 1995. Evaluation of lake fertilization as a tool in the recovery of Snake River sockeye salmon. M.S. Thesis, Utah State University, 151 p.

Gross, H.P., W.A. Wurtsbaugh, C. Luecke, and P. Budy. 1994. Nutrient limitation of **phytoplankton** in oligotrophic lakes of the Sawtooth Valley, Idaho. pp. **29-52** *in* S. Spalding (ed.) Snake River sockeye saimon **(*Oncorhynchus nerka*) habitat/limnologic** research. Bonneville Power Administration, DOE/BP-22548-2.

Gross, **H.G. and** W. Wurtsbaugh. 1994. Water and nutrient budgets of the Sawtooth Valley Lakes. pp. 7-29 in D. Teuscher et al., Snake River sockeye salmon habitat and limnological research: Annual Report 1993. Bonneville Power Administration DOE/BP-2548-2.

Luecke, C., M. Slater and P. Budy. 1996. Limnology of Sawtooth Valley Lakes in 1995. pp. 76-l 16 *in* D. Teuscher and D. Taki (eds.). Snake River sockeye salmon habitat and limnological research. Annual Report 1995. Bonneville Power Administration. DOE/BP-22548-4.

Mason, C. 1996. Biology of freshwater pollution. 3rd ed. Longman. 356 p.

Steinhart, G., H.P. Gross, P. Budy, C. Luecke and W.A. Wurtsbaugh. 1994. Limnological investigations and hydroacoustic surveys of Sawtooth Valley lakes. pp. 30-61 *in* D. Teuscher et al. (eds.). Snake River sockeye salmon habitat and limnological research. Annual Report 1993. Bonneville Power Administration. DOE/BP-22548-2.

Teuscher et al. 1994. Snake River sockeye salmon habitat and limnological research. Annual report 1994. US Dept. Energy, Bonneville Power Administration, Portland, Oregon,

Wetzel, R.G. and G.E. Likens. 1990. Limnological analyses. 2nd ed. Springer-Verlag. 39ip.

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Appendix 1.
1993-l 996 PRIMARY PRODUCTION SUMMARY

A. Light intensity data for expanding the incubation-period primary production rates were available only **1996.** To estimate primary production on a daily rate for the other years, I used the hourly to daily expansion ratios for each lake that were measured in **1996.** These were: RF-7.8; Pettit-8.6; Alturas-9. For Stanley lake, where this factor was not available (no 1996 PPR or light data), I used the mean expansion factor for all of the lakes (8.3 x **hourly** PPR).

The July-October **1996** data were further corrected to represent primary production on an average irradiance day. Because the 1993 and 1995 data are not corrected for an average day, their individual daily values may not be representative of the monthly period. However, taken over the whole period, average rates should be representative.

		DAILY PRIMARY PRODUCTION (MG / M^2/DAY)					
YEAR	LAKE	JUN	JUL	AUG	SEP	OCT	MEAN
1993	**REDFISH**	29	119	147	121		104
1993	**PETTIT**		130	76	142		116
1993	ALTURAS			240			240
1993	STANLEY			105			105
1995	**REDFISH**	147	350	220	269		246
1995	PET-TIT	87	141	262	184		169
1995	ALTURAS	74	119	190	97		120
1995	STANLEY	80	115	179	**86**		115
lQQ6	REDFISH-S	234	88	181	157	155	163
1996	REDFISH-N	**116**	127	164	175	285	173
1996	PET-TIT	143	83	123	134	118	120
1996	ALTURAS	132	68	114	100		104

B. Mean rates of primary production in the Stanley Basin lakes during **1993, 1995,** and **1996.** Note that the number of measurements in a lake varied widely between years. To estimate "annual" production, we multiplied the mean daily rates times an assumed ice-free period of 200 days, and assumed that under-ice PPR was negligible. Production in **Redfish** Lake was also calculated for months when the lake was fertilized and months when it was not fertilized. N = number of months measured.

	PRIMARY PRODUCTION			
LAKE	MEAN (mg / m^2 / day)	SE	N	"ANNUAL" RATE (a / m^2 / 200 d)
REDFISH AVERAGE	173	22	13	35
UNFERTILIZED	***121***	17	7	24
FERTILIZED	233	28	6	47
PETTIT	135	14	12	27
ALTURAS	**126**	19	9	25
STANLEY	113	18	**5**	23

PPR93-96.WB2