# RESEARCH AND RECOVERY OF SNAKE RIVER SOCKEYE SALMON

ANNUAL REPORT 1993

Prepared by:

Paul Kline

Idaho Department of Fish and Game
Nampa, Idaho 83686

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U. S . Department of Energy
Bonneville Power Administration
Division of Fish and Wildlife
P.O. Box 3621
Portland, OR 97208-362 1

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## ABSTRACT

On November 20, 1991, the National Marine Fisheries Service listed Snake River sockeye salmon Oncorhvnchus nerka as endangered under the Endangered Species Act of 1973. In 1991, the Shoshone-Bannock Tribe along with the Idaho Department of Fish and Game initiated the Snake River Sockeye Salmon Sawtooth Valley Project to conserve and rebuild populations in Idaho.

We estimated total O. nerka population, density and biomass in Redfieh and Alturas lakes increased by 20% and 9%, respectively, in 1993. Estimates for Stanley Lake decreased by 37% while estimates for Pettit Lake increased by 300% over 1992 levels. Total population, density, and biomass estimates for Stanley and Pettit lakes remained comparatively low.

Numbers of O. nerka outmigrants declined in 1993 at the Redfieh Lake Creek and Salmon River traps. We estimated 569 smolts left Redfish Lake in 1993 compared to 1,234 and 4,500 in 1992 and 1991, respectively. In 1993, we trapped no outmigrants from Alturas Lake at the Sawtooth Fish Hatchery. We estimated 2,720 and 914 smolts left Alturas Lake in 1992 and 1991, respectively. Total PIT tag detection at mainstem dams for Redfish Lake outmigrants was 44% in 1993.

We identified lake and tributary spawning locations using biotelemetry on adult O. nerka (1991 outmigrants reared to adults in captivity) outplanted from the captive broodstock program to Redfish and Alturae lakes. The majority of Alturas Lake outplants spawned in Alturas Lake Creek, the primary tributary to the lake. We observed Redfish Lake outplants over three areas of potential resident/residual O. nerka beach spawning activity. One observation of spawning was made for two outplants in the Sockeye Beach area of Redfish Lake. One Redfish Lake outplant spawned in Fishhook Creek, the primary resident kokanee O. nerka spawning tributary to the lake.

We captured primarily suckers Catostomus sp. in 57 h of gillnetting on Redfish Lake. Bull trout Salvelinus confluentus, northern squawfish Ptvchocheilus oreaonensis, andmountainwhitefieh Prosooiumwilliamsonicomprised the remainder of the catch. We captured no "carryover" hatchery rainbow trout O. mvkiss in the effort.

We used otolith microchemistry to describe origin and life history patterns of Redfish Lake O. nerka. Strontium/Calcium ratios (Sr/Ca) in otolith primordia of fish from known origin (1991 brood year progeny of anadromous adults) showed patterns consistent with life history (Sr/Ca ratio > 0.00140). Strontium/Calcium ratios in otolith primordia of fish from unknown origin (beach-spawning residual adults, 1991 lake outmigrants, 1993 anadromoue adult returns) showed patterns consistent with both freshwater and anadromoue life history. Twenty-five, 40, and 50% of otolith samples from anadromous adults, residual adults, and 1991 lake outmigrants, respectively, fell into the range below 0.00080 reflecting lineage

to freshwater female parents. Sixty-three, 10, and 22% of otolith samples from anadromoue adults, residual adults, and 1991 outmigrants, respectively, fell into the range above 0.00140 reflecting lineage to anadromous female parents. Twelve, 50, and 28% of otolith samples from these sources, respectively, fell into the range between 0.00080 and 0.00140 making definitive identification of origin difficult.

Author:
Paul Kline
Fishery Research Biologist

# INTRODUCTION

Numbers of Snake River sockeye salmon <u>Oncorhvnchus</u> <u>nerka</u> have declined dramatically over the years. In Idaho, only the lakes of the upper Salmon River (Stanley Basin) remain as potential sources of production. Historically, five Stanley Basin lakes (Redfish, Alturas, Pettit, Stanley, and Yellow Belly lakes) supported sockeye salmon (Bjornn et al. 1968). Currently, only Redfish Lake receives a remnant anadromoue run.

In the late 1800'0, Evermann (1895) made observations on the presence and abundance of sockeye salmon in Stanley Basin lakes. During his survey of 1894, he reported observing sockeye salmon in Redfieh, Alturas, Pettit, and Stanley lakes. Sunbeam Dam, constructed in 1910 by the Golden Sunbeam Hining Company, was operating at full pool by 1911. Built on the Salmon River approximately 35 km downstream from the mouth of Redfish Lake Creek, the dam remained intact until it was intentionally breached in 1934. During these years, upstream salmon passage was doubtful (Chapman et al. 1990). Following breaching, the first account of sea-run sockeye salmon returning to the Stanley Basin was reported in 1942 when 200 adults were counted in Redfish Lake (Parkhurst 1950). Bjornn et al. (1968) present the most thorough assessment of Redfish Lake sockeye salmon for the period of 1954 to 1964. During these years, adult escapement to Redfish Lake ranged from 11 fish in 1961 to 4,361 fish in 1955. Numbers of sockeye salmon reaching Stanley Basin lakes began to decline sharply following 1955. By 1962, sockeye salmon had been eliminated from Stanley and Pettit lakes (Chapman et al. 1990). During the 1980's, observations of adult spawners in Redfish Lake reached a high of 50 fish in 1982 (Hall-Griswold, 1990). Between 1990 and 1993, zero, four, one, and eight, sockeye salmon returned to Redfish Lake, respectively.

The Idaho Department of Fish and Game (IDFG) Sawtooth Fish Hatchery (FH), constructed to mitigate for lower Snake River hydroelectric dams, recorded adult sockeye salmon returns between 1985 and 1989. Numbers of adult returns to the hatchery weir ranged from zero fish in 1986 to three fish in 1985. The last recording of an adult return to the STH was made in 1989 when one fish was observed.

On April 2, 1990, the National Marine Fisheries Service (NMFS) received a petition from the Shoshone-Bannock Tribe (SBT) to list Snake River sockeye salmon as endangered under the Endangered Species Act (ESA) of 1973. On November 20, 1991, NMFS declared Snake River sockeye salmon endangered. Section 4(f) of the ESA requires the development and implementation of a recovery plan for listed species. At the time of this writing, a seven member team (appointed by NMFS) is in the process of preparing the final draft of this document.

The IDFG, as part of their five-year management plan, is charged with the responsibility of reestablishing sockeye salmon runs to historic areas with emphasis placed on efforts to utilize Stanley Basin sockeye salmon and kokanee <u>O</u>. <u>nerka</u> resources (IDFG 1992). Under ESA, NMFS Permit No. 795 authorizes the IDFG to conduct scientific research on listed Snake River salmon. In 1991, the SBT along with the IDFG initiated the Snake River Sockeye Salmon Sawtooth Valley Project (Sawtooth Valley Project) with funding from Bonneville Power

Administration (BPA). The goal of this program is to conserve and rebuild Snake River sockeye salmon Populations in Idaho. Various elements of the recovery effort are already in progress. Coordination of this effort is carried-out under the guidance of the Stanley Basin Technical Oversight Committee (SBTOC); a team of biologists representing the agencies involved in the recovery and management of Snake River sockeye salmon.

IDFG participation in the Sawtooth Valley Project falls under two general areas of effort: the sockeye salmon captive broodstock program and Stanley Basin 0. nerka fisheries research. While objectives and tasks from both components overlap and contribute to achieving the same State goals, work directly related to the captive broodstock program will appear under separate cover. In this report, we present information collected in 1993 efforts directed at Stanley Basin fisheries research.

The goal of IDFG sockeye salmon research is to reestablish sockeye salmon runs to Stanley Basin and provide for utilization of sockeye salmon and kokanee resources.

## OBJECTIVES

Objective 1. To estimate O. nerka population in four Stanley Basin lakes to interpret population response to captive broodstock supplementation.

Task 1.1 Estimate total O. nerka population, density, and biomass by midwater trawl in Redfieh, Alturas, Pettit, and Stanley lakes.

Task 1.2 Trawl sufficient to estimate population and density by age-class.

Task 1.3 Take scale and otolithe from all trawl captures. Preserve flesh and blood for genetic evaluation.

Objective 2. To evaluate emigration characteristics of O. nerka smolts at two Stanley Basin locations.

Task 2.1 Estimate total O. nerka outmigrant run size for Redfish and Alturas lakes. Coordinate trapping with SBT Biologists.

Task 2.2 PIT tag outmigrant O. nerka from Redfish and Alturas lakes. Determine trap efficiencies.

Task 2.3 Determine travel time and cumulative interrogation rates for PIT-tagged O. nerka smolts to lower Snake River dams.

Objective 3. To identify location and time of spawning for natural sockeye salmon production in Redfieh and Alturas lakes through adult broodstock outplants.

Task 3.1 Conduct ultrasonic and radio tracking on 1993 adult broodstock outplants to Redfish and Alturas lakes.

Objective 4. To assist the SBT in estimating predator populations of bull trout Salvelinus confluentus, lake trout S. namavcush, and northern squawfish Ptvchocheilua oreaonensia in Stanley Basin lakes. Determine predator effects on O. nerka in relation to recovery options.

Task 4.1 Conduct gillnetting on Redfieh Lake to document the presence/absence of "carryover" hatchery rainbow trout O. mvkiss. Quantify the concentration of predators near outlets or spawning areas.

Objective 5. To determine the origin of Stanley Basin and broodstock O. nerka. Identify parental lineage of broodstock progeny to facilitate comparison of performance.

Task 5.1 Continue otolith microchemistry work on broodstock adults selected for spawning in 1993, Redfieh Lake residuals, and 1993 returning adults.

Task 5.2 Begin the develoment of a study plan for the evaluation of outmigrant progeny.

## STUDY AREA

The Stanley Basin lake5 are located within the Sawtooth National Recreation Area (SNRA)(Figure 1). Basin lakes are glacial-carved and receive runoff from the east side of the Sawtooth and Smoky mountains. Physical and morphometric data for Redfish, Alturae, Pettit, Stanley, and Yellow Belly lakes are presented in Table 1. All Basin lakes drain to the upper Salmon River which flows into the Snake River and ultimately the Columbia River. Redfish Lake is located approximately 1,450 river kilometers from the confluence of the Columbia River with the Pacific Ocean.

Fish species native to study area lakes and outlets include sockeye ealmon/kokanee, spring-summer chinook salmon O. tehawvtscha, rainbow trout/steelhead O. mvkiss, westslope cutthroat trout O. clarki lewisi, bull trout, sucker Catoetomus sp., northern squawfish, mountain whitefish Prosopium williamsoni, redside shiner Richardeonius balteatus, dace Rhinichthvs sp., and sculpin Cottus sp. Non-native species include lake trout, and brook trout S. fontinalis.

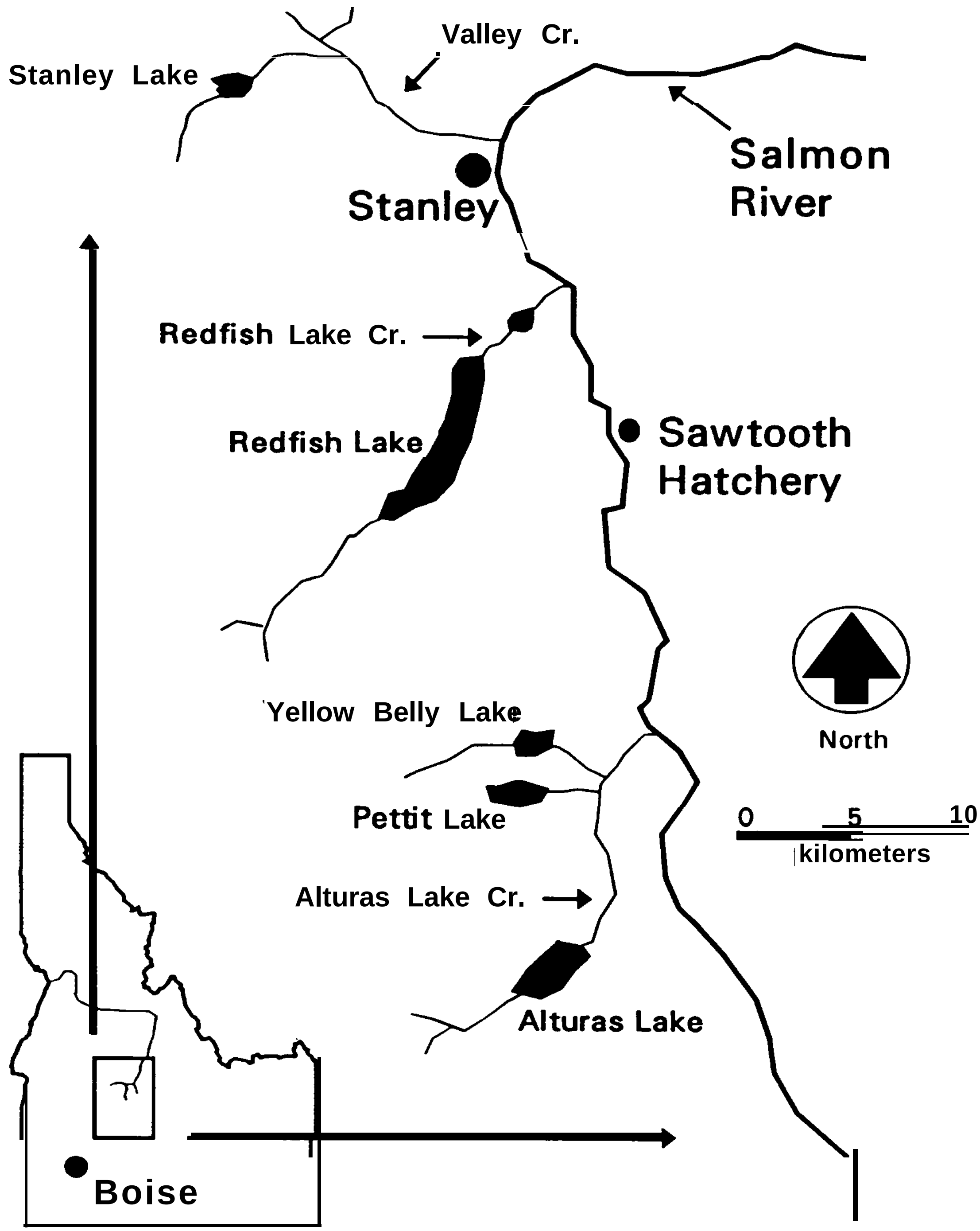


Figure 1. Stanley Basin study area map.

Table 1. Physical and morphometric characteristics of five Stanley Basin Lakes.

| Lake | Area (ha) | Elevation (m) | Volume ($m^3 x 10^6$) | Mean depth (m) | Maximum depth (m) | Drainage area ($km^2$) |
|---|---|---|---|---|---|---|
| Redfish | 615 | 1,996 | 269.9 | 44 | 91 | 108.1 |
| Alturas | 338 | 2,138 | 108.2 | 32 | 53 | 75.7 |
| Pettit | 162 | 2,132 | 45.0 | 28 | 52 | 27.4 |
| Stanley | 81 | 1,985 | 10.4 | 13 | 26 | 39.4 |
| Yellow Belly | 73 | 2,157 | 10.3 | 14 | 26 | 30.4 |

# METHODS

## Total Population, Density and Biomass Estimation

### Sampling

We conducted midwater trawling at night during the dark (new) phase of the moon. Redfish and Alturas lakes were sampled one night each in June and September 1993. Pettit and Stanley lakes were sampled one night each in September. We did not sample Yellow Belly Lake as it was not accessible to our trawl boat.

We used a midwater trawl with a cross-sectional mouth area of 9.25 $m^2$ and a length of 13.7 m. Net mesh in the body decreased in four panels from 32 mm (stretch measure) to 13 mm; mesh in the cod end measured 3 mm. We towed the trawl with an 8.5 m boat at 0.89 m/s.

Trawling was performed in a stepped-oblique fashion after Rieman (1992). We used echo sounding prior to sampling to identify the fish layer. The trawl was dropped initially to the bottom of the predetermined sampling layer and fished for approximately 5 min. The trawl was then raised to a new depth immediately above the previous depth and fished again for approximately 5 min. We repeated this procedure for each successive step until the entire layer containing O. nerka had been sampled. The number of trawl transects made per lake ranged between one and five.

We estimated total O. nerka population, density, and biomass using the TRAWL-WK1 spreadsheet for Lotus 123 developed by Rieman (1992). Whenever possible, we estimated population and density by individual age-class (assuming representation in the trawl).

### Data Collection

We recorded fork lengths (to the lowest whole 10 mm group) and weights for all O. nerka captured by trawling. Sagittal otoliths were removed from all trawl captures, cleaned, and stored dry in microcentrifuge tubes. We surface aged otoliths under transmitted and/or reflected light using a dissecting microscope.

## Outmigrant Enumeration

In 1993, IDFG personnel operated smolt traps on Redfish Lake Creek and on the upper Salmon River at the Sawtooth FH. Under NMFS Permit No. 795, IDFG is authorized to PIT tag trapped O. nerka outmigrants. Fifty percent of these individuals are to be released to the location of their initial capture while 50% may be retained for captive broodstock (450 maximum).

Smolts collected at the trap sites were transported to Sawtooth FH holding raceways. Fish were anesthetized in buffered MS222, injected with PIT tags, and held several hours for observation. Those individuals not retained for captive broodstock purposes were transported back to where they were initially captured, and released. We estimated trap efficiencies by releasing a percentage of the PIT-tagged individuals above the traps for subsequent recapture. We estimated total emigration or outmigration run size by summing the products of estimated trap efficiency and daily trap catch. We noted total PIT tag interrogations and time of arrival at lower Snake and Columbia River dams.

### Trap Facilities

An incline plane (bar) trap was placed in operation April 19 on Redfish Lake Creek and remained in place until June 7, 1993. The trap was located approximately 0.8 km downstream from the outlet of Redfish Lake. Five of nine potential trap bays were fitted with incline bar traps. Bar spacing (19.1 mm) allowed debris and large fish to pass downstream while small fish were captured in low velocity holding boxes in each of the operating bays. IDFG staff checked the trap twice daily.

A floating scoop trap equipped with a 1.0 m wide inclined traveling screen was installed directly below the permanent weir at the Sawtooth FH. The trap operated from April 3 to June 9, 1993, as part of IDFG natural production monitoring studies (Kiefer and Forster 1991). A picket weir, 3.1 m wide at the mouth, funnelled fish through the trap. Pickets were spaced 3.8 cm apart. IDFG staff checked the trap several times daily.

## Telemetry Investigations

### Transmitter Implanting

Outmigrant O. nerka captured in 1991 at Redfish Lake Creek and Sawtooth weirs, and incorporated into the captive broodstock program, were selected for outplanting (as adults) in 1993. In July 1993, we determined (using ultrasound) that 24 Redfish Lake and 20 Sawtooth weir individuals displayed the best potential to sexually develop this season. We implanted ultrasonic transmitters in fish destined for release in Redfish Lake and radio transmitters in fish destined for release in Alturas Lake. We assumed that Sawtooth weir outmigrant captures emigrated from Alturas Lake.

We implanted transmitters (tags) in the Redfish and Alturas lake release groups on August 7 and 8, 1993, respectively. Fish were individually anesthetized in a holding tank using buffered MS222 and measured for fork length to the nearest millimeter. Tag implanting procedures were similar to those described by Winter (1989). We inserted ultrasonic and radio tags through the mouth into the stomach with the aid of a plunger. We constructed the plunger by attaching a 15 cm length of solid (l/2 in diameter) PVC to a typical PVC "T" fitting that acted as a handle. A slight concave depression was made in the end of the solid length to cradle the tags during insertion. We lubricated the plunger with vegetable oil to slide through the gullet smoothly. All fish were held several days (for observation) prior to release to ensure tag retention.

Radio telemetry eguipment was purchased from Advanced Telemetry Systems Inc. (ATS), Insanti, Uinneeota. Individual transmitter frequencies ranged from 150.516 to 150.894 Mhz. The tags were 35 mm long, 12 mm in diameter, and weighed 6 g. All tags were manufactured with a 200 ran trailing whip antenna.

Ultrasonic telemetry equipment was purchased through Sonotronics, Tucson, Arizona. Individual transmitter frequencies ranged from 70 to 76 Khz. Tag frequencies were coded with unique, self-identifying codes allowing several tags to be assigned the same tracking frequency. The tags were 65 mm long, 18 mm wide and weighed 22 g.

### Redfish Lake Tracking

Ultrasonic-tagged O. nerka were released into Redfish Lake on August 10-12, 1993. We tracked fish primarily by boat using a Sonotronics model USR-SW receiver with model DH-2-10 directional hydrophone. Specific fish were located by triangulation with known shoreline landmarks and mapped on USGS 7% min topographic maps. We assumed that landmarke, from which the bearings weretaken, were mapped correctly. We used the point of maximum signal strength to indicate actual fish location.

Upon commencement of spawning, we noted redd locations and any observed pairing by individuals. The dates for all Redfish Lake tracking are listed in Appendix A.

### Alturas Lake Tracking

Radio-tagged O. nerka were released into Alturas Lake on August 19, 1993. We tracked fish by boat and on foot using an ATS model R2100 receiver with a three element Yagi directional antenna. Location of individuals within the lake was determined by triangulation as described for Redfish Lake. We used ground tracking to locate fish in Alturas Lake Creek, the primary inlet to Alturas Lake. The point of maximum signal strength or actual visual observations of fish (in Alturas Lake Creek) were used to map locations. Notes regarding spawning-related activities were also recorded. The dates for all Alturas Lake tracking are presented in Appendix A.

## Predator Investiaations

We set gill nets in Redfiah Lake on August 2-5, 1993 to sample for "carryover" hatchery rainbow trout and to determine the feasibility of this technique in capturing other piscivorous species of fish. All gillnetting occurred during daylight hours to minimize the potential for mortality. We used four gill nets: two - 50 m sinking 25 mm and 50 mm mesh (stretch measure) nets, one - 50 m sinking experimental mesh net, and one - 50 m floating experimental mesh net. We tied up all mesh panels less than 25 mm in measure on experimental gill nets pursuant to permit specifications. Nets were set at eight different sampling locations in a perpendicular direction to the shoreline (Figure 2) We noted all species captured in this effort and measured all bull trout (total length) to the nearest millimeter.

We attempted to lavage the stomachs of all captured bull trout. Following anesthetization of individual fish using buffered MS222, water was injected past the esophagus ejecting stomach materials for collection. If prey fish were present, we attempted to identify species and to quantify their frequency of occurrence.

## Otolith Microchemistry

### Otolith Samples

We obtained sagittal otoliths from 38 O. nerka selected for fall, 1993 spawning in the IDFG captive broodstock program. Our sample of individuals included anadromous adults, 1991 Redfish Lake outmigrants, Redfish Lake residuals, and 1991 brood year progeny of the four anadromous adults that returned to Redfish Lake Creek in 1991 (Table 2). The Redfish Lake outmigrants and the brood year progeny were reared at the IDFG Eagle Hatchery. Redfish Lake residuals were trapped over known beach spawning areas of the lake in October, 1993. Otolith samples from anadromous adults were collected from the eight sockeye salmon that returned to Redfish Lake Creek in 1993.

We collected otoliths from all individuals following spawning. Samples were cleaned of all associated tissue and stored dry in microcentrifuge tubes. Prior to analysis, we surface aged all otoliths under a dissecting microscope in reflected and/or transmitted light.

### Sample Preparation

The preparation of otoliths for microchemistry analysis followed techniques developed Kalish (1990) and Rieman et al. (1993). Otoliths were cleaned in deionized water, dried and mounted sulcus-side-down on glass slides with Crystal Bond 509 adhesive (Aremeco Products Inc.). Care was taken to insure that a relatively level mount was achieved. Using 600, then 1200 grit wet-dry sandpaper, we ground all otoliths in the sagittal plane to a level near the primordia. Sample slides were then heated (liquefying the Crystal Bond) and the otolith samples repositioned sulcus-side-up in the adhesive. We ground all samples in the sagittal plane to the approximate level of the primordia with

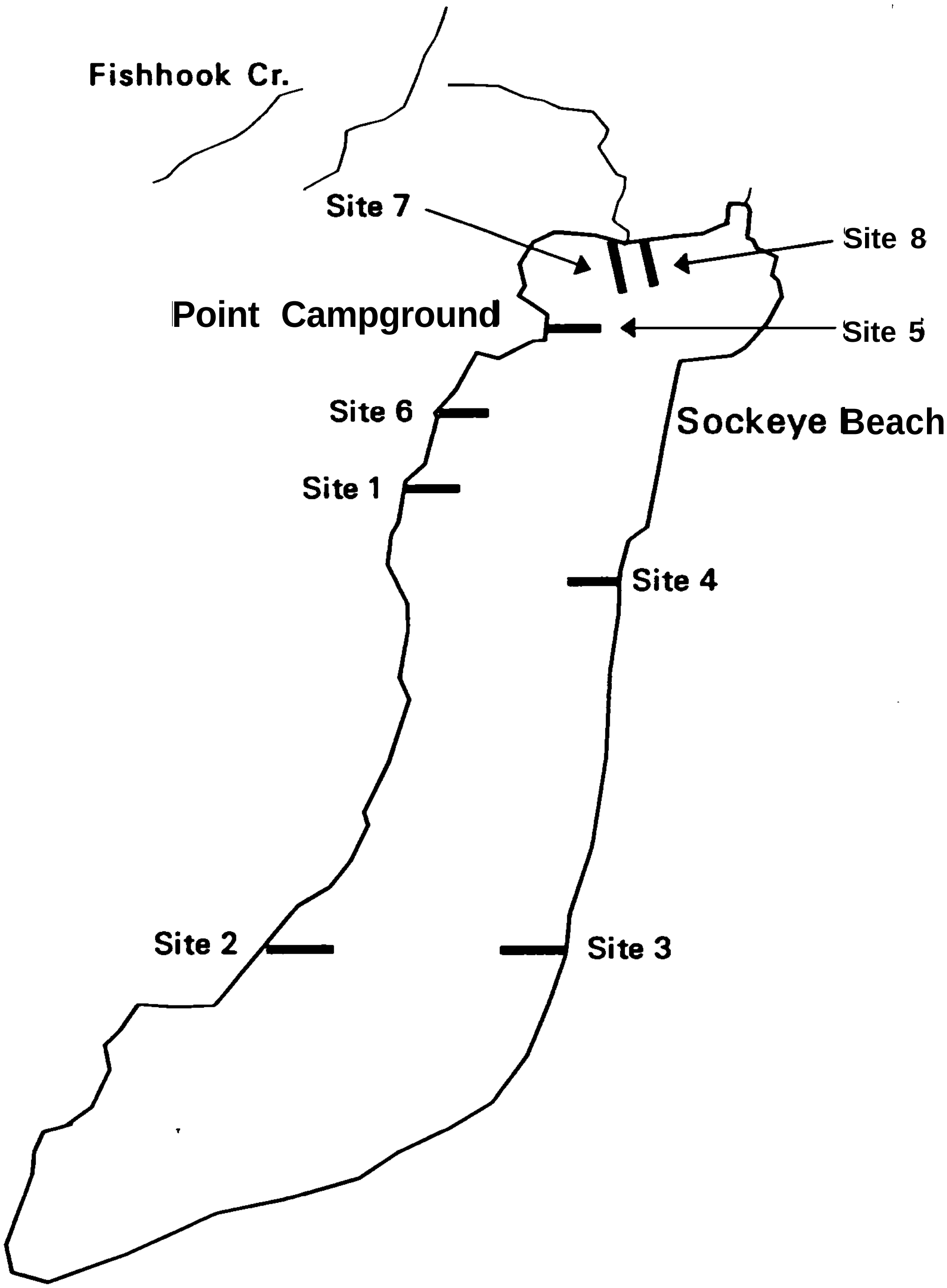


Figure 2. Location of Redfish Lake gill net sampling, August 2-5, 1993.

Table 2. Origin and number of sagittal otoliths for microchemistry analysis from Redfish Lake *O. nerka* selected for fall, 1993 spawning in the captive broodstock program.

| | Origin | Number analyzed |
|---|---|---|
| 1993 adult returns | unknown | 8 |
| Progeny of 1991 adult returns | known (anadromous) | 2 |
| Residual adults | unknown | 10 |
| 1991 outmigrants | unknown | 18 |

TABLE2

1200 grit wet-dry sandpaper. Final grinding was completed with 5.0 $\mu$ grit wet-dry paper. We finished all sample preparations by hand polishing with 1.0 and 0.05 $\mu$ alumina paste to remove all surface scratches left behind by the grinding process. All sample preparations were washed with deionized water, dried, and photographed at magnifications of 140X and 280X. Photographs were marked to identify locations selected for microanalysis.

### Analysis

Otolith microchemistry analysis followed procedures outlined by Toole and Nielsen (1992). Analyses were made with a Cameca SX-50 wavelength dispersive microprobe at Oregon State University. Samples were washed with deionized water, dried, and coated with a 200 A carbon layer for surface conductivity. A 15 XV, 50 nA, and 7 $\mu$ electron beam was used for all analyses.

Sampling regions for otolith preparations are presented in Table 3. Microprobe transects were run in otolith nuclei adjacent to the primordia for all samples. Microprobe transects were also completed in the freshwater growth zone for all samples and in the saltwater growth tone for the anadromous adults. We sampled 10 microprobe sites along single transects within each nucleus for all 38 samples. Freshwater growth zone sample sites for Redfish Lake outmigrant 199l,.broodyear 1991, and 1993 residual fish were run along transects from the point of hatch (outside the nucleus) to the margin of the otolith (freshwater growth zone). Ten microprobe readings were taken along each transect for each of these groups. We sampled 20 microprobe points along similar transects (freshwater and saltwater growth zones) for samples from the eight anadromous adults.

## RESULTS

### Total Population. Densitv. and Biomass Estimation

Population, density, and biomass results presented in table format in this section of the report incorporate IDFG data from 1990 through 1993, where available. All reference to age-class segregation is from length-frequency interpretation based on direct sagittal otolith aging of trawl mortalities.

We estimated the total Redfish Lake O. nerka population to be 38,257 and 49,620 fish, respectively, for June and September, 1993 trawl dates. Total density estimates for these dates were 100.2 and 120.4 fish/hectare, respectively. We estimated total O. nerka biomass for the September trawl at 2.34 kg/hectare (Table 4). Sixty-eight percent of the total population estimate for September consisted of age 0+ and l+ fish. No age 2+ or 4+ O. nerka were captured in the trawl (Tables 5 and 6). Length-frequency data for September sampling are presented in Figure 3.

Table 3. Location of transects and number of microprobe sample points for sagittal otolith microchemistry analysis of Redfish Lake *O. nerka* selected for fall 1993 spawning in the captive broodstock program.

| | Location of Transects | | |
|---|---|---|---|
| | Nucleus and primordia | Freshwater growth zone | saltwater and freshwater growth zones |
| 1993 adult returns | 10 | | 20 |
| Progeny of 1991 adult returns | 10 | 10 | |
| Residual adults | 10 | 10 | |
| 1991 outmigrants | 10 | 10 | |

TABLE3

Table 4. Estimated total population, density (fish per hectare), and biomass (kilograms per hectare) for O. nerka in four Stanley Basin lakes.

| Lake | Date | Total population (± 95% CL) | Density (± 95% CL) | Biomass |
|---|---|---|---|---|
| Redfish | 6/17/93 | 38,257 (±32,980) | 100.2 (i86.3) | --[b] |
| Redfish | 9/17/93 | 49,628 --[a] | 120.4 --[a] | 2.34 |
| Redfish | 8/26/92 | 20,777 (±10,813) | 50.4 (±26.2) | 0.97 |
| Redfish | 9/29/92 | 39,481 (±10,767) | 95.9 (i26.1) | 1.46 |
| Redfish | 8/20/90 | 24,431 (±11,000) | 63.9 (±26.6) | 1.30 |
| Alturas | 6/17/93 | 23,655 (± 7,243) | 111.6 (i34.2) | --[b] |
| Alturas | 9/17/93 | 49,037 (±13,175) | 230.2 (±61.9) | 4.12 |
| Alturas | 8/27/92 | 65,052 (220,822) | 306.9 (±98.2) | 4.93 |
| Alturas | 9/25/92 | 47,237 (±61,868) | 222.8 (±291.8) | 3.86 |
| Alturas | 9/8/91 | 125,045 (±30,708) | 594.0 (±144.8) | 6.33 |
| Alturas | 8/19/90 | 126,644 (±31,611) | 597.0 (±154.0) | 5.20 |
| Petit | 9/18/93 | 16,173 (± 5,431) | 101.0 (±33.9) | 1.09 |
| Petit | 9/27/92 | 4,187 (22,964) | 26.2 (±18.5) | --[b] |
| Stanley | 9/16/93 | 1,325 (± 792 ) | 18.9 (±11.3) | 0.57 |
| Stanley | 8/28/92 | 2,117 (±1,592) | 29.0 (±21.8) | 0.27 |

[a] Confidence limits not calculated - single transect estimate.
[b] Biomass not calculated - weights for trawl sample not recorded.

TABLE4

Table 5. Numbers of O. nerka, by age-class, estimated from fall midwater trawls on four Stanley Basin lakes, 1990-1993. Values in parenthesis are 95% confidence limits.

| Lake | O+ | | II+ | III+ | IV+ |
|---|---|---|---|---|---|
| Redfish | 26,120 | 7,836 | 0 | 15,672 | 0 |
| 1993 | ---’ | --- | --- | --- | --- |
| Redfish | 22,954 | 5,509 | 3,213 | 3,902 | 3,902 |
| 1992 | (±4,899) | (±8,415) | (±4,002) | (±1,655) | (±1,665) |
| Redfish | 10,048 | 8,808 | 3,338 | 2,237 | 0 |
| 1990 | (±7,308) | (±5,288) | (±2,595) | (±2,261) | 0 |
| Alturas | 0 | 1,226 | 39,842 | 7,969 | 0 |
| 1993 | 0 | (±1,501) | (±12,412) | (±4,157) | 0 |
| Alturas | 0 | 1,377 | 11,912 | 32,667 | 1,281 |
| 1992 | 0 | (±2,368) | (±22,280) | (±57,612) | (22,561) |
| Alturas | 5,556 | 67,217 | 48,569 | 3,702 | 0 |
| 1991 | (±1,657) | (220,999) | (±22,146) | (±2,965) | 0 |
| Alturas | 39,065 | 12,126 | 55,439 | 15,075 | 4,948 |
| 1990 | (±17,888) | (±6,325) | (±28,284) | (±6,324) | (±2,850) |
| Pettit | 14,625 | 0 | 504 | 504 | 504 |
| 1993 | (±5,142) | 0 | (±1,009) | (±1,009) | (±1,009) |
| Pettit | 0 | 0 | 0 | 0 | 4,187 |
| 1992 | 0 | 0 | 0 | 0 | (±2,964) |
| Stanley | 0 | 714 | 103 | 509 | O |
| 1993 | 0 | (±516) | (±206) | (±565) | O |
| Stanley | 0 | 1,902 | 0 | 215 | O |
| 1992 | 0 | (±1,533) | 0 | (±429) | O |

. Confidence limits not calculated - single transect estimate.

Table 6. Densities of O. nerka (fish per hectare), by age-class, estimated from fall midwater trawls on four Stanley Basin lakes, 1990-1993. Values in parenthesis are 95% confidence limits.

| Lake | o+ | I+ | II+ | III+ | IV+ |
|---|---|---|---|---|---|
| **Redfish** | 63.4 | 19.0 | 0 | 38.0 | 0 |
| 1993 | ---* | --- | --- | --- | --- |
| **Redfish** | 55.7 | 13.4 | 7.8 | 9.5 | 9.5 |
| 1992 | (±11.8) | (±20.4) | (±9.7) | (±4.0) | (±4.0) |
| **Redfish** | 26.3 | 23.1 | 8.7 | 5.9 | 0 |
| 1990 | (f19.7) | (±14.6) | (i7.1) | (±7.2) | 0 |
| Alturas | 0 | 5.7 | 187.1 | 37.4 | 0 |
| 1993 | 0 | (f7.0) | (i58.3) | (±19.5) | 0 |
| Alturas | 0 | 6.5 | 56.2 | 154.1 | 6.0 |
| 1992 | 0 | (±11.2) | (f105.1) | (±271.8) | (±12.1) |
| Alturas | 26.2 | 317.1 | 229.1 | 17.5 | 0 |
| 1991 | (i7.8) | (±99.0) | (±104.5) | (i13.9) | 0 |
| Alturas | 184.3 | 57.2 | 261.5 | 71.1 | 23.3 |
| 1990 | (i82.4) | (f30.8) | (±122.0) | (±31.3) | (f13.4) |
| Pettit | 91.4 | 0 | 3.2 | 3.2 | 3.2 |
| 1993 | (i32.1) | 0 | (i6.3) | (±6.3) | (f6.3) |
| Pettit | 0 | 0 | 0 | 0 | 26.2 |
| 1992 | 0 | 0 | 0 | 0 | (±18.5) |
| Stanley | 0 | 10.2 | 1.5 | 7.3 | 0 |
| 1993 | 0 | (±7.4) | (f3.0) | (±8.1) | 0 |
| Stanley | 0 | 26.1 | 0 | 2.9 | 0 |
| 1992 | 0 | (±21.0) | 0 | (±5.9) | 0 |

* Confidence limits not calculated - single transect estimate.

**TABLE6**

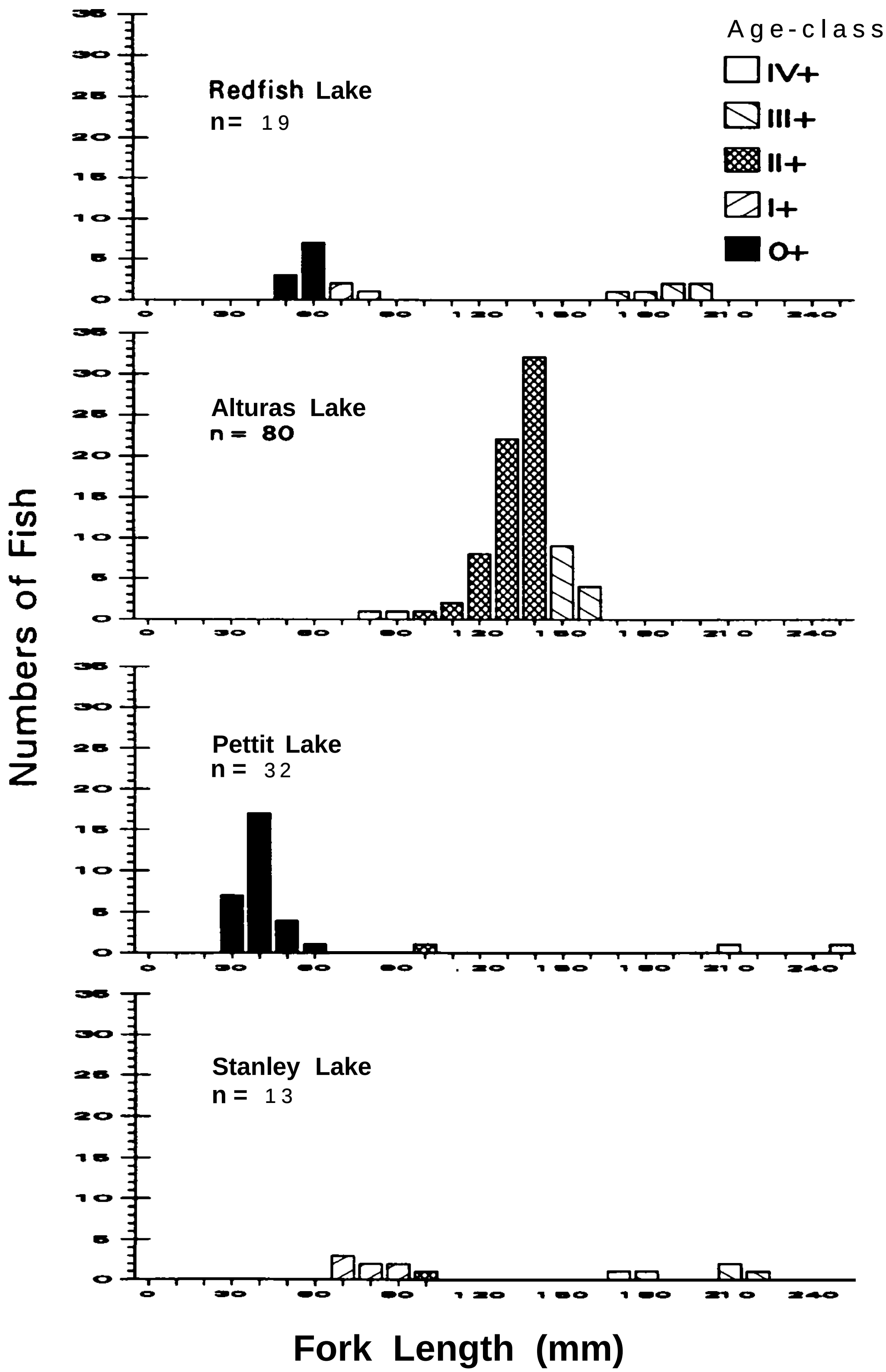


**Figure 3. Length-frequency distributions from September 1993 midwater trawls of four Stanley Basin lakes.**

We estimated the total Alturas Lake O. nerka population, for June and September, 1993 trawl dates, at 23,655 and 49,037 fish, respectively. Total density estimates for the June and September dates were 111.6 and 230.2 fish/hectare, respectively. We estimated total O. nerka biomass for the September sampling date at 4.12 kg/hectare (Table 4). Population and density estimates by age-class are presented in Tables 5 and 6, respectively. Ninety-seven percent of the estimated September population consisted of age 2+ and 3+ fish. No 0+ or 4+ O. nerka were captured in the September trawl (Figure 3).

The total population estimate for Pettit Lake was 16,173 fish (September 1993 only). We estimated total O. nerka density and biomass at 101.0 fish/ha and 1.09 kg/ha, respectively (Table 4). Age 0+ fish accounted for 90% of the total estimated population. Age 1+ fish were not represented in the trawl (tables 5 and 6). September, 1993 length-frequency data for Alturas Lake are presented in Figure 3.

Stanley Lake exhibited the lowest estimated total population, density, and biomass of the four Basin lakes investigated in 1993. We estimated the total O. nerka population to be only 1,325 fish. Total density and biomass estimates were 18.9 fish/hectare and 0.57 kg/hectare, respectively (Table 4). Estimated population and density by age-class are presented in tables 5 and 6. Age 0+ and 4+ fish were absent from the trawl. September length-frequency data for Stanley Lake are presented in Figure 3.

## Outmigurant Enumeration

### Redfish Lake Creek

We trapped a total of 96 O. nerka outmigrants at the Redfish Lake Creek trap site in 1993. Trap captures occurred between April 28 and June 1 with peak emigration taking place in mid May (Figure 4). Forty-eight of the 96 captured smolts were PIT-tagged and released to Redfish Lake Creek. Forty-one of these individuals were released above the trap to establish trap efficiency estimates for two different periods of flow. We estimated trap efficiencies of 22.2% for the period of April 19 through May 22 and 9.1% for the period of May 23 through June 7. Based on these efficiencies, the expanded run estimate for 1993 was 569 smolts. Travel times to lower Snake River and Columbia River dams and detection rates at four facilities with PIT tag interrogation systems (Lower Granite [LGrD], Little Goose [LGoD], Lower Monumental [LMoD], and McNary [McN] dams) are presented in Table 7. Twenty-two detections were noted (from the release group of 48 fish) at one of the downstream dam facilities. We reduced this number to 21 as one fish was intercepted at both LGoD and McN dams (counted twice). Cumulative interrogation for the four facilities was 44% for 1993 Redfish Lake outmigrants. Mean travel times to LGrD, LGoD, LMoD, and McN dams were 8.0, 15.5, 17.4, and 16.0 d, respectively.

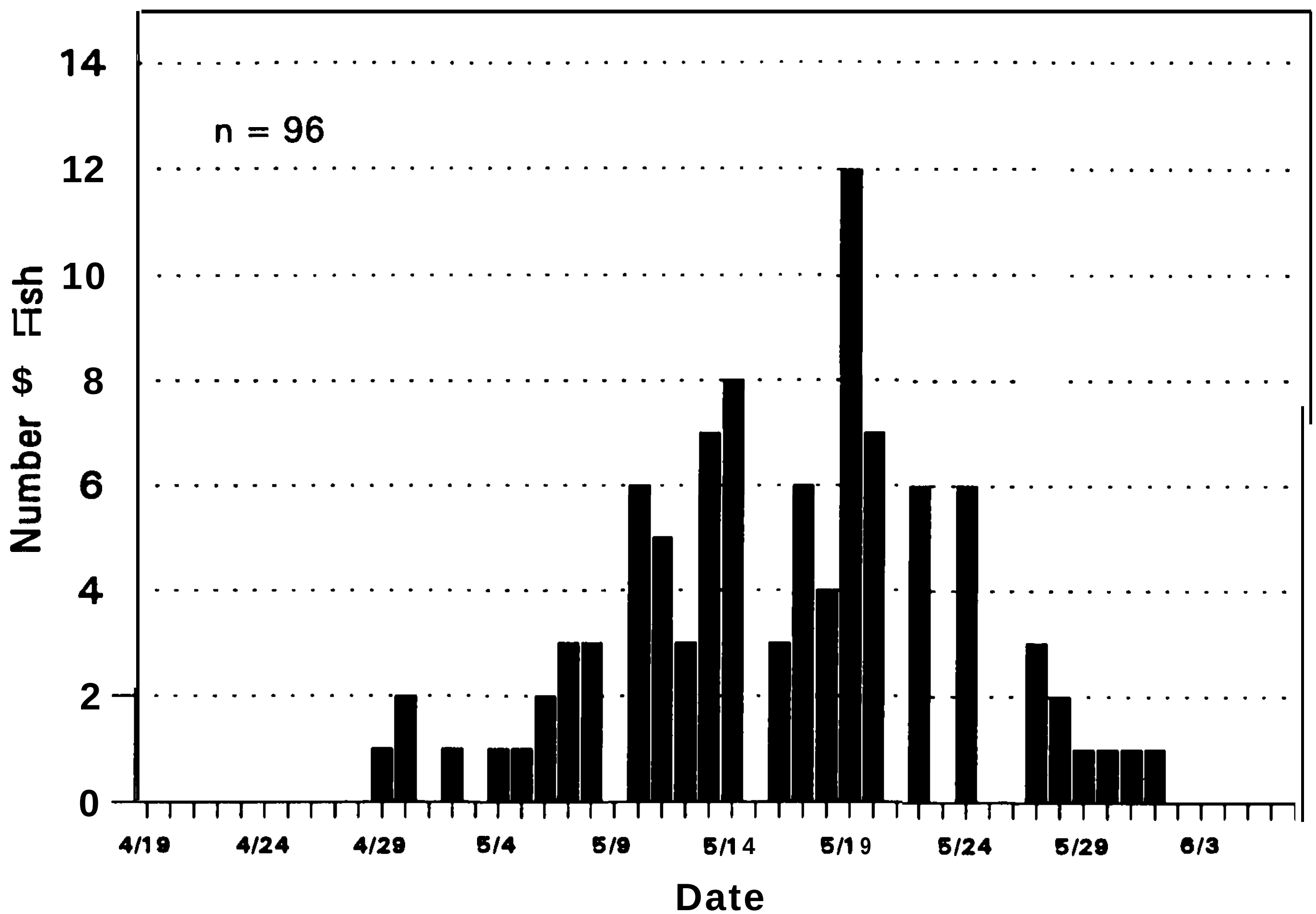


Figure 4. Numbers of O. nerka trapped and timing of capture for 1993 Redfish Lake Creek outmigrants.

Table 7. Travel times and downstream detection rates for PIT-tagged _O. nerka_ outmigrants released from Redfish Lake Creek in 1993.

| Detection Location | Number of fish detected | Travel time (d) |
|---|---|---|
| Lower Granite Dam | 6 | 8.0 |
| Little Goose Dam | 8 | 15.5 |
| Lower Monumental Dam | 5 | 17.4 |
| McNary Dam | 3 | 16.0 |
| Total Detections | 21[a] | |

Total number of PIT-tagged _O. nerka_ released = 48

Total percent detection = 44%

[a] Number of detections reduced by one as one fish was detected at two facilities (Little Goose and McNary dams).

TABLE7

Sawtooth Fish Hatchery

The outmigrant trap, located immediately downstream of the weir at the Sawtooth FH, was in operation between April 3 and June 9, 1993. No outmigrating O. nerka were captured at this facility in 1993.

## Telemetry Investigations

Redfioh Lake

Following the release of 24 ultrasonic-tagged O. nerka August 10-12, 1993, we noted (for the first five tracking dates: August 21, August 28, September 5, September 12, and September 25) that most fish remained in and around the area of release at the north end of the lake. During this period, we observed fish near three north end landmarks: the boat launch ramp on the northeast shore (Sockeye Beach area), the lodge area on the north shore, and the Point Campground area on the northwest shore. We observed fish to move freely among these three general locations.

The first deviation from this early pattern of distribution occurred the third week of tracking (September 5) when we located one tagged fish in Fishhook Creek, the principal inlet to Redfish Lake. Our observation of this particular individual coincided with kokanee spawning use of this tributary. We were unable to document spawning related activity by our tagged fish but we did recover the tag from the carcass. Subsequent inspection identified this individual to be a spawned-out male (individual fork lengths and sexes for all adult 1993 hatchery outplants are presented in Appendix B). Through the end of 1993 tracking efforte on December 2, this was our only observation of selection for non-lake habitat by any individual within our release group of 24 fish. On September 12 (fourth week of tracking), we noted our second deviation from the original pattern of distribution when one fish was located at the extreme south end of the lake.

Following the fifth week of tracking, we began to observe more definition in fish distribution at the north end of the lake. We also noticed an increasing pattern of selection for the south end of the lake. This pattern of greater north-end definition and increased south-end selection generally persisted through the remainder of our tracking effort (Figure 5).

We discontinued tracking efforts on December 2. To date, three of the 24 original tags have been recovered. One of the tags was recovered on November 23 in a moribund fish at the extreme south end of the lake. Following inspection, we identified this fish as a spawned-out female. We recovered a second tag (out of the fish) on December 2 in shallow later near the southeast shore of the lake. The third tag was recovered in Fishhook Creek as described above. As of December 2, eight signals remained missing from the lake. We suspect predation,

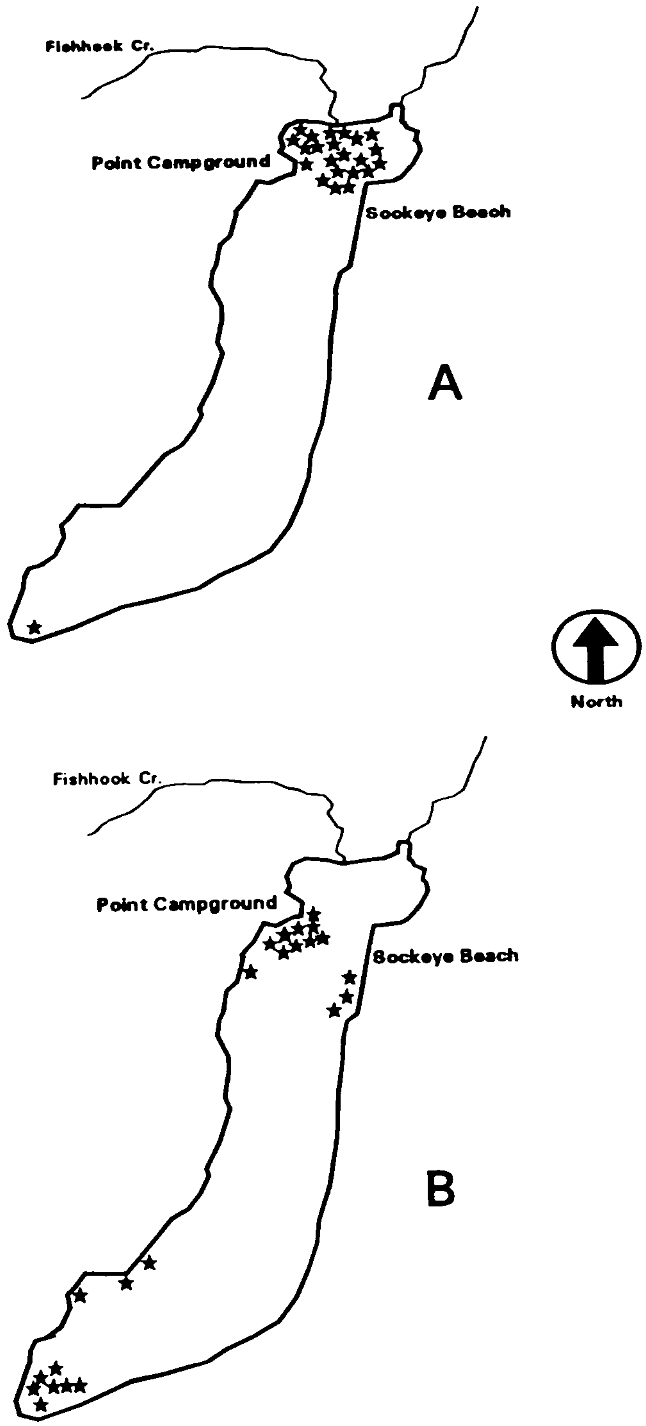


**Figure 5. Location of 23 Redfish Lake ultrasonic-tagged *O. nerka* on September 25, 1993 (A) and November 4, 1993 (B).**

rather than tag failure, as the most plausible explanation for these missing signals. Of the remaining 13 tagged fish, five were stationary and eight were active. We suspect that stationary signals indicate additional mortality. We will attempt to locate these fish following ice-out in the spring of 1994.

### Spawning-Related Observations

Through October and into early November, SBT biologists conducted lake perimeter spawning habitat surveys by boat and by snorkeling (SBTOC Minutes - October, November 1993). In October, O. nerka were observed in less than 1 m of water in the general vicinity of Sockeye Beach and in water approximately 8 m deep off the Point Campground. One O. nerka appeared to be guarding a redd at the Point Campground location. During the November survey, SBT biologists observed two hatchery outplant-sized O. nerka spawning in shallow water at the south end of the lake. Observations of multiple redds were also made at this location. Reconnaissance of waters off Sockeye Beach yielded observations of redds along with observations of residual-sized O. nerka.

Telemetry efforts did not coincide with spawning-related observations of suspected broodstock outplants at the south end of the lake. We were able, however, to distinguish outplants from resident or residual fish on the basis of size. Mean fork length for the 24 hatchery outplants was 499 mm (at release) while resident and/or residual fish (observed over areas of beach spawning) were estimated to be approximately 220 mm in length.

### Alturas Lake

We initiated radio tracking in Alturas Lake and Alturas Lake Creek on August 21, 2 d after the release date for this group of outplants. We located 15 of the 20 signals this first tracking date, including two fish in Alturas Lake Creek. On August 28 (second tracking date), we located 13 and 3 fish in Alturas Lake Creek and Alturas Lake, respectively. The three signals emanating from the lake were thought to be in deep water as signal audibility was poor. We located 11 tagged fish in Alturas Lake Creek on September 4 (third tracking date) including three new signals that we did not detect the previous tracking date. On September 25, the final day of tracking, one previously undetected signal was detected in Alturas Lake Creek. During the 35 d period over which tracking occurred, we accounted for 17 of the 20 frequencies in Alturas Lake Creek. We had limited success locating lake signals throughout the tracking effort.

We recovered radio tags from six of the 17 fish that used Alturas Lake Creek. Two additional tags, that we were unable to recover, were located in animal burrows away from the creek. We suspect that the majority of unrecovered tags were carried off by scavengers or predators.

## Spawning-Related Observations

We made several observations in Alturas Lake Creek of pairing and spawning by hatchery outplant fish. Cur obeervations were made from the mouth of the creek up to the confluence of Alpine Creek (Figure 6). Sightings of hatchery outplanta spawning with other hatchery fish along with resident-sized male kokanee "sneaks" were frequent in the vicinity of Alpine Creek. Resident male kokanee were also observed spawning with female hatchery outplants (Bob Griswold, personal communication). Shoshone-Bannock tribe biologists recorded spawning-related observations for release group fish on three different survey dates between late August and mid September (SBTOC Minutes - September 1993).

## Predator Investigations

We captured a total of 118 fish in 59 h of daylight gillnetting in Redfish Lake. Mountain suckers Catostomus olatvrhvnchus comprised the majority of the catch with 108 individual captures. Bull trout, mountain whitefish, and northern squawfish made up the remainder of the catch with six, two, and two captures, respectively. No "carry-over" hatchery rainbow trout were taken in this effort. Relative species abundance and catch per unit effort are presented in Table 8. Sites 7 and 8 (adjacent to the mouth of Fishhook Creek) produced the highest catch rate; 7.5 and 12.0 fish/h, respectively.

The results from stomach content analysis (fish prey species only) of five bull trout and two northern squawfish captures are presented in Table 9. Northern squawfish stomachs contained digested material we could not identify. Bull trout stomachs contained three different species of fish in addition to fish skeletal material and partially digested fish tissue. The mean total length for bull trout captured by gillnetting was 405 mm (range = 296-454 mm). Three of the six bull trout did not survive capture and handling; only two fish were successfully lavaged and released. We did not attempt to lavage stomach contents from one bull trout as we felt it would not withstand the procedure. Of the five bull trout stomachs examined, three contained material we were able to identify. We successfully lavaged a 170 mm O. nerka from the stomach of a 445 mm bull trout. Three sculpin and one 200 mm rainbowtroutwere removed from the stomachs of bull trout measuring 375 and 450 mm, respectively.

## Otolitb Microchemistry

Results of otolith microchemistry analyses are presented with reference to (Strontium/Calcium) values developed by Rieman et al. (1993) reflecting known freshwater (Sr/Ca < 0.00080) and anadromous (Sr/Ca > 0.00140) life history (Appendix D).

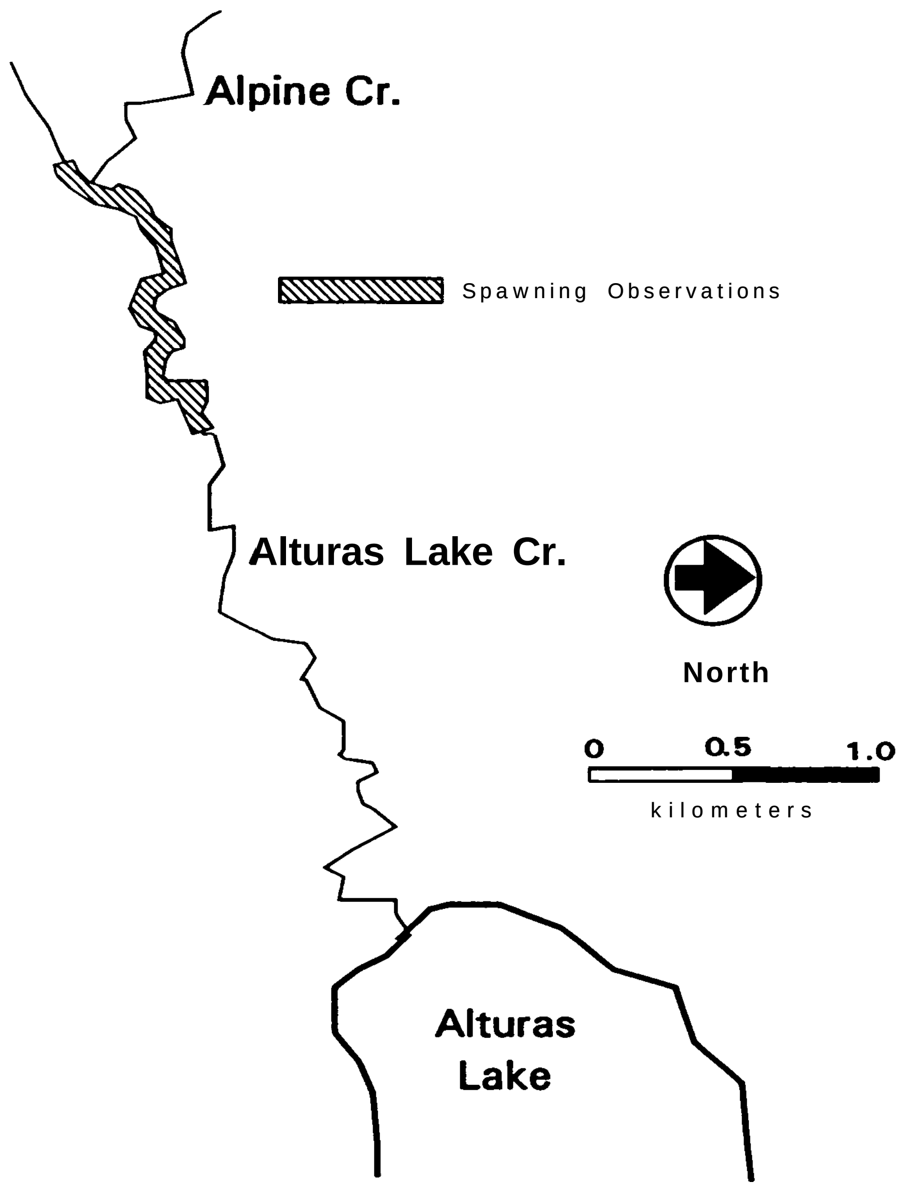


**Figure 6. Area map of Alturas Lake Creek showing location of spawning use by 1991 outmigrant radio-tagged O. nerka reared 2 years to maturation at Eagle Fish Hatchery.**

Table 8. Hours fished, net type, and number of captures by species for eight Redfish Lake gill net locations. Numbers in parentheses represent individual catch per unit effort by species and sample site.

| Site | Hours fished | Net type | Species Composition: Mountain sucker | Bull trout | Mountain whitefish | Northern suuawfish |
|---|---|---|---|---|---|---|
| 1 | 19 | sink. | 28 (1.47) | 3 (0.157) | 0 | 0 |
| 2 | 8 | sink. | 1 (0.125) | 1 (0.125) | 2 (0.25) | 0 |
| 3 | 8 | sink. | 3 (0.375) | 0 | 0 | 0 |
| 4 | 8 | float. | 0 | 0 | 0 | 0 |
| 5 | 4 | float. | 1 (0.25) | 0 | 0 | 0 |
| 6 | 4 | float. | 1 (0.25) | 0 | 0 | 0 |
| 7 | 4 | sink. | 30 (7.5) | 0 | 0 | 0 |
| 8 | 4 | sink. | 44 (12.0) | 2 (0.5) | 0 | 2 (0.5) |
| | 59 Total gill net hours | | | | | |
| Species Total | | | 108 | 6 | 2 | 2 |
| Species CPU[a] | | | 1.8 | 0.10 | 0.03 | 0.03 |

[a] Catch per unit effort (CPU) expressed as number fish per gill net hour.

TABLE8

Table 9. Summary of stomach content analyses of potentially piscivorous fish species captured by gillnetting in Redfish Lake, August 1993.

| Species | Fork Length (mm) | Description of Stomach Contents' |
|---|---|---|
| Bull trout | 296 | Fish skeletal material |
| Bull trout | 375 | Three sculpin & fish skeletal material |
| Bull trout | 407 | Partially digested fish flesh |
| Bull trout | 445 | One 170 mm O. nerka |
| Bull trout | 450 | One 200 mm rainbow trout |
| Bull trout | 454 | Released without lavaging |
| N. squawfish | --- | Uoderately digested material |
| N. squawfish | --- | Uoderately digested material |

• Fish prey species only.

TABLE9

### Residual O. nerka

Residual O. nerka trapped over beach spawning areas of Redfish Lake in October 1991 represent 10 of the 38 microchemistry samples. From the point of hatch to the time of capture, life history for these individuals is assumed as known (Redfish Lake residence). Individual sample ratios from otolith nuclei (adjacent to otolith primordia) ranged from 0.00050-0.00210. The sample means from otolith nuclei ranged from 0.00072-0.00197 (CV 0.12 to 0.24). Forty percent of the mean ratios taken from sample nuclei fell below 0.00080. Fifty percent of the sample ratios fell between 0.00080 and 0.00140 while 10% of the samples ratios fell above 0.00140 (Figure 7). Mean Sr/Ca ratios from microprobe sites along transects in the freshwater growth zone (Redfish Lake) of residual O. nerka were all less than 0.00080 (range 0.00064-0.00075, CV 0.06-0.35)(Figure 8). Individual Sr/Ca ratios measured along these transects were consistent with this portion of their life history (Figure 9).

### 1991 Out&grant O. nerka

Outmigrant O. nerka smolts, trapped while emigrating from Redfish Lake in 1991, and reared to maturity at the Eagle Fish Hatchery represent 18 of the 38 microchemistry samples. Life history for these individuals (following hatching) is known (l+ to 2+ years of lake residence and 2+ years of hatchery residence). Raturity was reached at age 3+ or 4+ depending on whether one or two years of lake residence occurred prior to outmigration (Appendix C). The Sr/Ca ratios from individual microprobe readings taken in otolith nuclei ranged from 0.00030-0.00250. Mean Sr/Ca ratios from outmigrant otolith nuclei were similar to ratios observed for residual fish (0.00054 to 0.00229, CV 0.06 to 0.25) (Figure 7). Fifty percent of the mean ratios fell below 0.00080 while 22% fell above 0.00140. Twenty-eight percent of the mean ratios from otolith nuclei fell between 0.00080 and 0.00140. Mean Sr/Ca ratios taken along transects from the point of hatch to the otolith margin (known life history) reflected two distinct patterns. Sample means from the lake growth zone ranged from 0.00060-0.00091 (CV 0.06 to 0.25) (Figure 8). Only one of the 18 mean ratio values was greater than 0.00080. Sample means from the Eagle Hatchery growth zone ranged from 0.00128-0.00156 (CV 0.05 to 0.19). Individual Sr/Ca ratios measured along transects reflecting Redfish Lake and Eagle Fish Hatchery life history were consistent with our expectations (Figure 9).

### Anadromous O. nerka

The anadromous adults that returned to Redfish Lake Creek in 1993 represent eight of the 38 microchemistry samples. Following l+ to 2+ years of lake residence, these individuals generally spend 2 to 3 winters in the ocean before returning as age 3+ to 5+ fish (Appendix C). Individual site Sr/Ca ratios from otolith nuclei ranged from 0.00050-0.00250. Mean Sr/Ca ratios from otolith nuclei ranged from 0.00071-0.00236 (CV 0.04 to O.25)(Figure 7). Hore than half (63%) of the mean ratios fell above 0.00140 while 25% and 12% fell below 0.00080

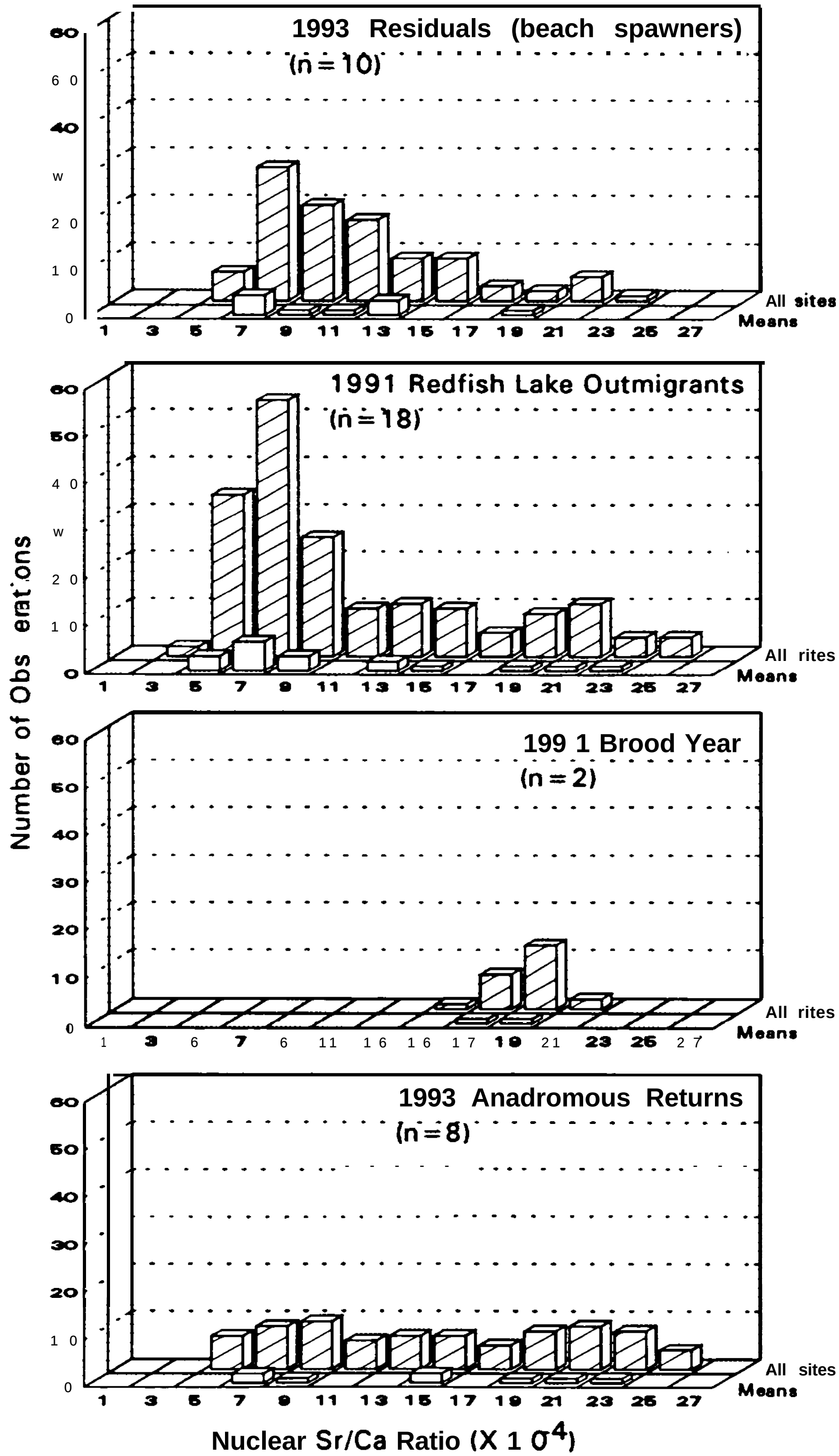


Figure 7. Frequency distributions of individual sites and mean Sr/Ca ratios measured in otolith nuclei from Redfish Lake *O. nerka* with differing life histories

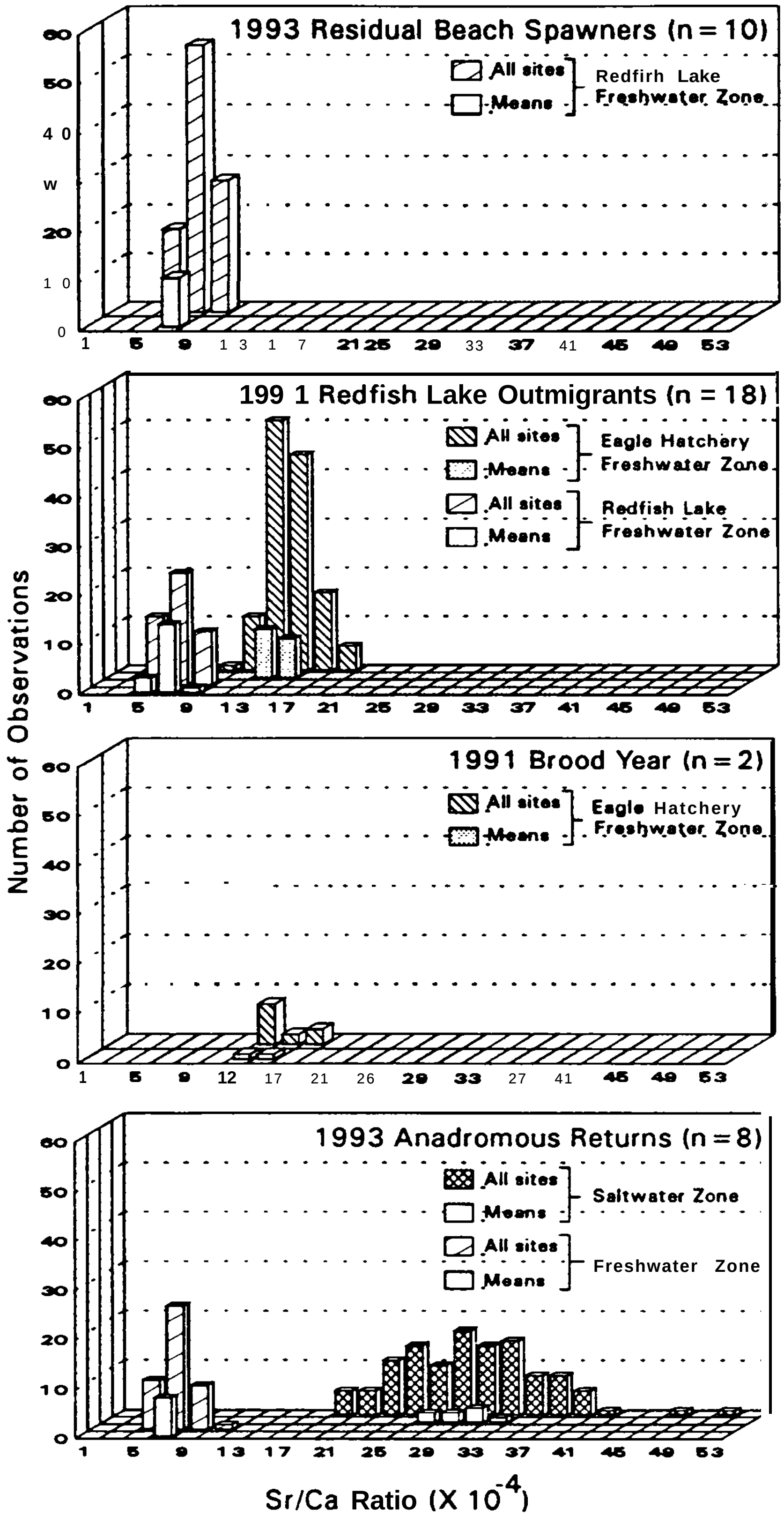


Figure 8. Frequency distributions of individual sites and mean Sr/Ca ratios measured in zones peripheral to otolith nuclei from Redfish Lake O. nerka with differing life histories.

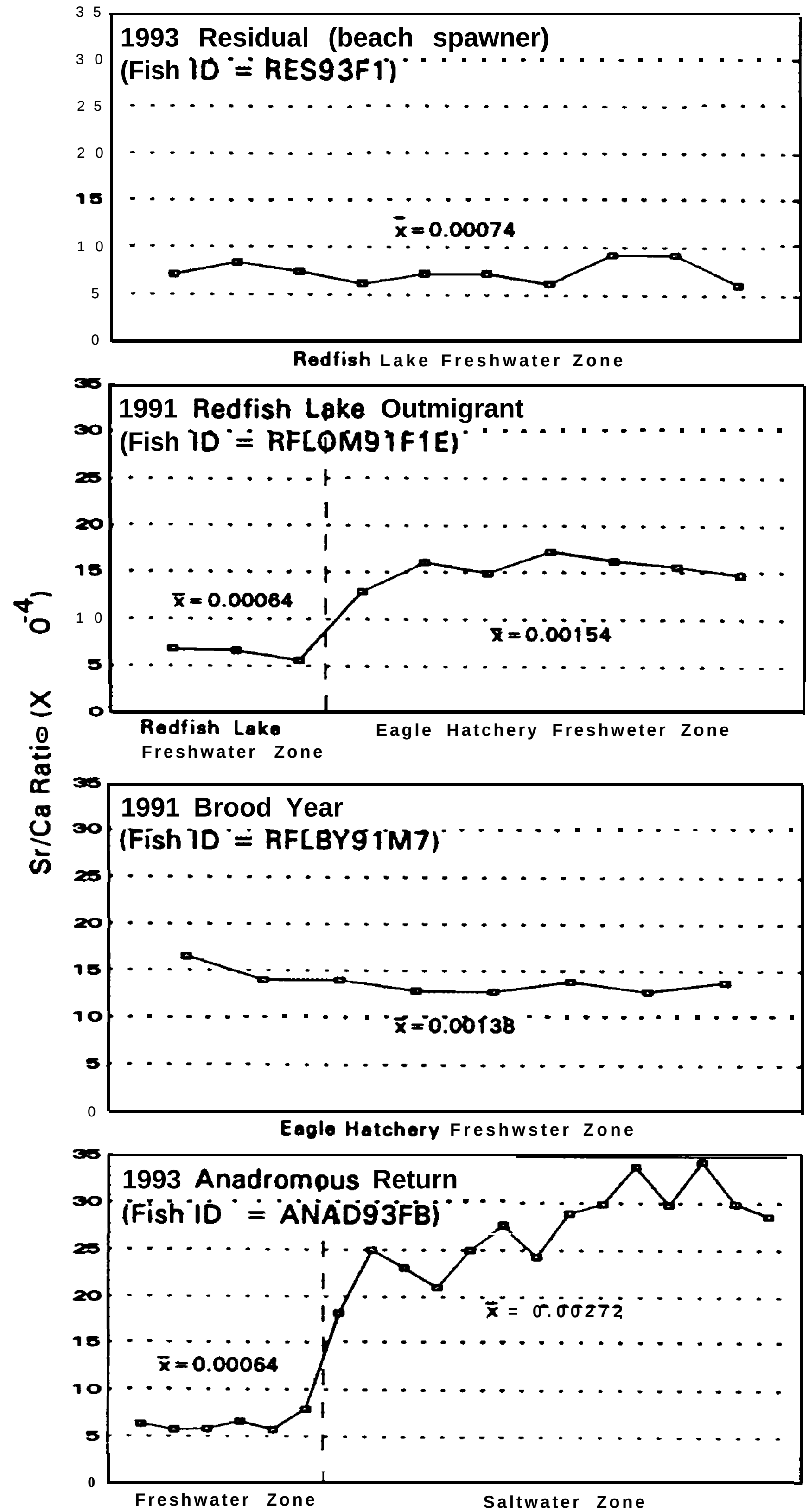


Figure 9. Sr/Ca ratios from sample sites along radial transects peripheral to otolith nuclei for four representative Redfish Lake O. nerka with differing life histories.

and between 0.00080 and 0.00140, respectively. Microchemistry results from growth zones outside of otolith nuclei (post-hatch) reflected two distinct periods of life history (Figure 9). Mean Sr/Ca ratios from the lake growth zone (pre-outmigration) ranged from 0.00064-0.00076 (CV 0.12 to 0.25). Mean Sr/Ca ratios from the saltwater growth zone ranged from 0.00267-0.00324 (CV 0.15 to 0.29).

**Brood Year 1991 O. nerka**

Two of the 38 microchemistry samples are from progeny of the four anadromous adults that returned to Redfish Lake Creek in 1991. These individuals represent our only example of known life history including parental lineage. Following hatching, all rearing of brood year 1991 fish occurred at the Eagle Fish Hatchery. The Sr/Ca ratios from individual sample sites within otolith nuclei ranged from 0.00145-0.00210. Mean Sr/Ca ratios from otolith nuclei ranged from 0.00179-0.00186 (CV 0.05 to 0.10) (Figure 7). Mean Sr/CA ratios from sample transects outside otolith nuclei (Eagle Fish Hatchery life history) ranged from 0.00138-0.00149 (CV 0.08 to O.l2)(Figure 8). Strontium/Calcium ratios from individual sample sites measured along transects outside otolith nuclei were consistent with known (Eagle Fish Hatchery) life history (Figure 9).

## DISCUSSION

### Total Population, Density and Biomass Estimation

Trawl data from 1993 represents the fourth consecutive year that IDFG has been involved with Stanley Basin lake O. nerka investigations. Data collected from these efforts will provide the foundation for our understanding of system response to future captive broodstock introductions.

Estimates of total O. nerka population, density, and biomass for Redfish Lake have increased by a factor of two (100%) since 1990. September estimates for 1993 show an increase of approximately 20% over September estimates for the previous year. These data correspond with fry recruitment and spawner escapement data collected by SBT biologists (S8TOC Minutes - October 1993). Kokanee emigration to Redfish Lake in 1993 was estimated at 160,000 fry. Thie number represents an increase of approximately 75% over estimates from the previous 2 years. The relatively high percentage of age 0 fish (53%) in the September 1993 trawl is largely attributable to the number of kokanee recruited to the lake the preceding Spring. An estimated 10,856 adult kokanee spawned in Fishhook Creek in 1993. This number represents an increase of approximately 12% and 36%, respectively, over escapement estimates for 1992 and 1991. Based on these data, we expect 1994 lake recruitment to be at or above the estimate generated in 1993. This level of proposed recruitment should also be reflected in strong age-class 0 representation in the 1994 fall trawl.

Alturas Lake _O. nerka_ populations have displayed greater variability than Redfish Lake populations for the 4 years of data on record. Estimates of total population and density for September 1993 represent a decline of approximately 69% over fall estimates made in 1990 and 1991. This year, we observed a population increase of approximately 9%. In both 1991 and 1992, SBT biologists estimated recruitment to Alturas Lake at approximately 7,000 fish (Spaulding 1993). Late winter conditions hampered efforts to collect recruitment data in 1993. Although the total population estimate for 1991 was comparatively high, less than 5% of the estimate consisted of age 0 fish. In 1992 and 1993, we captured no age 0 _O. nerka_ in September trawls. These data suggest that 1993 recruitment to Alturas Lake was similar to the previous 2 years. An estimated 62 and 243 adults escaped to Alturas Lake Creek in 1992 and 1993, respectively (SBTOC Minutes - September 1993). This increase in escapement should manifest itself in greater recruitment to the lake in 1994. Additionally, the age 0 component of the September 1994 trawl should be higher than it has been for the past 2 or 3 years.

Very little data are available with respect to kokanee spawner/recruit relationships in Pettit and Stanley lakes. Stanley Lake exhibits the lowest total density and biomass of the four Basin lakes investigated. Total population, and density estimates for Stanley Lake declined approximately 37% in 1993. Pettit Lake total population and density estimates for 1993 increased approximately 300% over estimates for 1992. Biomass estimates for Pettit and Stanley lakes are among the lowest in the State for oligotrophic waters supporting kokanee (Rieman and Meyers 1991).

Midwater trawling remains one the best methods of active sampling for obtaining information on population size, age, and size structure, and stock discrimination for limnetic species. However, several limitations associated with this methodology could affect the quality of the data. Trawling may not accurately reflect all size classes within a targeted population. Rieman (1992) suggests that trawling at speeds of approximately 1 m/s yield reliable estimates of abundance for fish between 50 mm and 220 mm in length. Small individuals (<50 mm) may not be fully represented in the trawl as they might pass through the mesh and avoid capture. Conversely, large individuals (>220 mm) might simply avoid the net, particularly as it is being retrieved. The significance of this potential limitation as it relates to our data is unknown.

Time of year selected for trawling might also bias data. With respect to Idaho waters, kokanee stocks in Stanley Basin lakes are characterized as "early spawning". Adult spawners are generally absent from the lake as early as the beginning of August. Naturally, the majority of these individuals are lost to the trawl once they begin their migration into lake tributaries. Emergent fry generally emigrate to the lake between late April and mid June. There is some question as to when these fish are fully recruited to the limnetic community. Spring trawling will potentially sample older age-classes yet under sample the not-yet-recruited age 0 component. Fall sampling will not capture older age-classes lost to spawning but will more accurately reflect numbers of recently recruited age 0 fish. Biomass estimates will also vary by time of year sampled. Late season or fall sampling will reflect fish condition at the end of the growing season (e.g. greater biomass). Fall trawl dates will also take advantage of the time of year when kokanee patterns of vertical distribution are relatively narrow. In most cases, except where noted, our data reflect late August through late September (fall) sampling.

Trawl estimates of population and density improvewithincreasing precision. To achieve reliable estimates of number and density of fish by age-class, multiple trawl transects are generally required. Rieman (1992) suggests that a minimum of seven transects be employed whenever possible. The range in number of trawl transects for 1993 Stanley Basin lake surveys was between two and five per lake, per night. Estimates presented for the September 1993 sampling of Redfish Lake were prepared from a single trawl transect.

## Outmigrant Enumeration

Estimates of outmigrant run size generated at the Redfish Lake Creek weir have declined steadily from 4,500 fish in 1991 to 569 fish in 1993. Accounts of past efforts to enumerate outmigrant characteristics for Stanley Basin lakes are scarce. Between 1955 and 1966, Bjornn et al. (1968) observed a range in Redfish Lake outmigrant run size from 2,133 fish (1960) to 65,000 fish (1957). During their years of investigation, estimates of outmigrant run size exceeded 20,000 fish in 7 of the 12 years. Adult escapement for this period ranged from 11 fish (1961) to 4,361 fish (1955). Adult returns exceeded 300 fish in 6 of the 12 years investigated.

Adult sockeye salmon access to Redfish Lake was circumvented in 1991 by the installation of an upstream adult trap on Redfish Lake Creek; an integral component of the recovery effort. Between 1988 and 1990, the IDFG did not operate the upstream trap and adult sockeye salmon escapement to the lake was possible. Eased on adult detections at LGrD no sockeye salmon were believed to have reached Redfiah Lake in 1990. In 1988 and 1989, 23 and 2 adult sockeye salmon were detected at LGrD, respectively. Actual observations of sockeye spawning in Redfish Lake for this period are scarce. However, it is likely that successful lake spawning did occur in 1988 and 1989 (Hall-Griswold, 1990). The dominant age of 1993 Redfish Lake outmigrants (as determined by sagittal otolith aging) is l+. Data reported by Bjornn et al. (1968) support this finding. It follows that Redfish Lake outmigrants from 1991 represent the 1989 brood year; the last year thought to support lake spawning by anadromous adults. Therefore, 1991 represents the last year that progeny with direct lineage to anadromy contributed significantly to the outmigration.

Alturas Lake outmigrant run size was estimated at 914, 2,720, and 0 fish for the years 1991 through 1993, respectively. Outmigrants generally left the lake as age 2+ fish, although l+ fish were present. Population estimates for age-class I fish generated from trawl data for the preceding year represent the best indicator of potential outmigrant strength. In 1993, we estimated the age-class I component of the population at 1,223 fish. This estimate compares to estimates of 12,126, 67,217 and 11,912 age-class I fish for the years 1990 through 1992, respectively. Based on these data, it would appear that the 1994 outmigration from Alturas Lake will remain depressed.

Monitoring O. nerka outmigrant runs from Stanley Basin lakes will play an increasingly important role in recovery efforts as captive broodstock progeny are outplanted to mature and migrate volitionally. Information collected to date has contributed to our knowledge of outmigrant characteristics and provided source material for continuing efforts to differentiate stocks. Outmigrant O. nerka captured between 1991 and 1993 represent a major element in the captive broodstock recovery program.

We observed relatively high total PIT tag detections in 1991 and 1993 at downstream Snake and Columbia River dams for Redfish Lake O. nerka smolts (57% and 44%, respectively). Total PIT tag detections recorded for 1992 for Redfish Lake releases were lower (22%). The availability of PIT detection data for Sawtooth weir releases is limited to 1992 when a total detection rate of 11% was noted for O. nerka smolts presumably of Alturas Lake origin. The observed high level of 1991 detections for Redfish Lake outmigrants agrees with data reported by Kiefer and Lockhart (1993). In 1991, they noted increased downstream dam detections for chinook salmon smolts released from the Sawtooth weir. Kiefer and Lockhart (1993) associated this increase in detections with elevated mainstem streamflows that occurred during outmigration. Relatively high streamflows during outmigration were also noted in 1993. To what extent this contributed to the observed high level of downstream detections for Redfish Lake smolts is unknown. Alturas Lake outmigrant detections for 1992 were 50% lower than Redfish Lake detections for the same year. Although only one year of data are available for direct comparison, this difference in detection rates suggests that O. nerka emigrants from Alturas Lake (Sawtooth weir) do not survive migration to LGoD as well as outmigrants from Redfish Lake. This assumes that they arrive at LGoD at the same time, since arrival timing can affect detection rates. Alturas and Redfish Lake outmigrants appear genetically different based on the results of protein electrophoresis (Waples 1992). Alturas Lake outmigrants are more closely aligned with the kokanee component of Redfish Lake while Redfish Lake outmigrants appear to be more genetically similar to the known anadromous component of the lake. If this distinction is correct, our suggestion of differential outmigration mortality agrees with the findings of Taylor and Foote (1991). Following an investigation of critical swimming velocities, they concluded that sockeye salmon are superior swimmers to both kokanee and sockeye salmon x kokanee hybrids.

## Telemetry Investigations

Telemetry investigations conducted on Redfish and Alturas Lake8 in 1993 produced information relevant to the process of stock differentiation and to the identification of potential areas of natural sockeye salmon production.

Prior to the turn of the century, Evermann (1895) made reference to August spawning activity by sockeye salmon in Redfish Lake. Although he made no specific reference to the location of this activity, based on spawn timing, it is possible these fish were utilizing Fishhook Creek. Following the observational reports of Evermann, sockeye salmon spawning in Redfiah Lake appears to have become restricted to October activity in the area of Sockeye Beach (Hauch 1955; Hall-Griswold 1990; Bowler 1990). Observations of 24 1993 captive broodstock outplants to Redffah Lake support the current consensus. Several observations of hatchery outplants and suspected residual O. nerkq were made in this location. However, telemetry played a critical role in identifying two additional areas of potential spawning not previously documented in the literature; waters off the Point Campground and at the south end of the lake.

Part of the rationale for differentiating Redfiah Lake O. nerka stocks involves observations of spatial and temporal differences as they relate to spawning. One of the 24 adult outplants Selected to run up Fishhook Creek during the same time window used by resident kokanee. Subsequent inspection of the recovered carcass identified this fish as a male that appeared to have successfully spawned. This particular broodstock outplant displayed characteristics associated with the resident kokanee component of the lake. The remaining 23 fish exhibited characteristics associated with the beach spawning component of the lake (anadromous and residual forms). Considering that all 1993 hatchery outplants were recruited into the captive broodstock program from Redfish Lake Creek outmigrant trapping in 1991, this deviation represents a very small segment of the release group (<5%). Results of electrophoretic analysis of 1991 Redfish Lake outmigrants partially support this degree of stock separation (Waples 1992). Findings to date suggest that a substantial fraction of Redfish Lake outmigrants come from a gene pool other than the resident form of kokanee that spawn in Fishhook Creek in August. Otolith microchemistry investigations have reached similar findings but not to the degree observed in our release group. Rieman et al. (1993) reported that approximately 65% of the 1991 outmigrant group they investigated displayed analytical results indicative of non anadromous parental origin.

The 20 radio-tagged fish in the Alturas Lake release group displayed a different pattern of behavior than the Redfish Lake release group. Seventeen of the 20 fish selected to spawn in Alturas Lake Creek during the same spawning window selected by resident kokanee. This behavior was expected as there are no documented references of late, beach or creek spawning O. nerka in Alturas Lake.

We were not able to track (with any degree of confidence) the three release group fish that Selected to remain in Alturas lake. This difficulty was due to the use of radio frequency tags. We anticipated that the majority of the Alturas Lake release group would spawn in Alturas Lake Creek requiring the need to track individual fish on foot. Radio frequency tags were more appropriate for this effort.

## Predator Investigations

Relative species abundance data generated from August 1993 gillnetting in Redfish Lake are similar to data reported by Liter and Lukens (1992) from July 1991 Redfieh Lake gill net efforts. Bull trout and northern sguawfish (piscivorous species) comprised 5.1 and 1.6%, respectively, of the 1993 catch. Relative abundance for these species in 1991 was 5.4 and 6.5%, respectively. Mountain suckers comprised the majority of both catches with mountain whitefish representing the smallest component. The principal difference between samples for these 2 years was the absence of hatchery rainbow trout in our catch.

Liter and Lukena (1992) reported that 12% of their July gill net catch consisted of hatchery rainbow trout. The range in length of this component of their catch (210-339 mm) was consistent with that of hatchery plants made prior to their July efforts (Rick Alsager - IDFG, personal ccxmnunication). In conjunction with guidelines set forth by NMFS, no trout were planted in Redfish Lake in 1993. Consistent with this action, our gill net effort did not find any hatchery rainbow trout successfully over-wintering in Redfish Lake. A random check of one Redfish Lake angler did, however, produce one 355 mm hatchery rainbow trout in the fall of 1993 (Virgil Moore - IDFG, personal commnunication). Routine angler interviews and checks of Redfish Lake anglers conducted by IDFG conservation officers produced no observations of rainbow trout in 1993 (Gary Gadwa - IDFG, personal communication).

Cur stomach content analyses of predatory species identified one O. nerka in the five samples. More complete dietary analyses have recently been completed by the SBT (SBTOC Minutes - February 1993). Recent findings from Alturas Lake gill net samples (n = 11) indicate that approximately 80% (by weight) of the Stomach contents from captured bull trout consisted of O. nerka. Results from northern sguawfish samples (n = 112) indicate that approximately 18% of their diet consisted of O. nerka. These data are consistent with findings presented by Thompson and Tufts (1967) in their evaluation of the impact of Dolly Varden Salvelinus malma and northern sguawfish on hatchery released sockeye salmon in tributaries of Lake Wenatchee, WA. They observed that char preyed on natural and hatchery produced sockeye salmon fingerlings at a greater rate than northern sguawfish.

Our efforts to test the efficacy of gillnetting on bull trout and its relationship to potential capture and handling mortalities was disappointing. Our observed level of mortality of 50% was much higher than we anticipated considering constant (hourly) net tending. This level of mortality has not been observed by other investigators using similar gear (Liter and Lukens 1992; Doug Taki - SBT, personal communication). Our recommendation is to select alternate sampling gear if fish are to be anesthetized and, in particular, subjected to lavage procedures.

## Otolith Microchemistry

Otolith microchemistry has been used to discriminate individual fish from female parents of known anadromous and freshwater origin (Kalish 1990; Rieman et al. 1993). During the development of ova, vitellogenesis in anadromous fish begins while the female parent is in the ocean. Conversely, this process occurs entirely in freshwater for non-anadromous, non-marine species. Strontium can partially substitute for Ca in the formation of vitellogenin, the precursor to yolk in developing ova. As development continues, Sr can partially substitute for Ca in the aragonite matrix of the first calcified structures to form; the otolith primordia. As fish grow, Sr continues to interchange with Ca in the depositional process of otoliths (Kaliah 89,90; Radtke 89). Kalish (1990) and Rieman et al. (1993) concluded that Sr/Ca ratios in otoliths and ova reflect the relative amounts of Sr and Ca in the environment. Typically, Sr/Ca ratios are higher for marine waters than for fresh waters. Kalish (1990) reported typical

Sr/Ca ratios in marine and fresh waters of 0.0087 and 0.0019, respectively. Rieman et al. (1993) reported Sr/Ca ratios for Redfish Lake of less that 0.0012.

We found otolith microchemistry produced results consistent with different life history patterns of Redfish Lake O. nerka. While we were able to readily discern differences in post-hatch life history stages, female parental lineage of individuals as determined from Sr/Ca ratios observed in otolith nuclei and primordia was less clear. Rieman et al. (1993) reported Sr/Ca values from otolith nuclei for known freshwater and anadromous O. nerka from different Idaho and Washington waters. They determined that Sr/Ca ratios were less than 0.00080 for progeny of known freshwater female parents and were greater than 0.00140 for progeny of known anadromous female parents. These values were lower than those reported by Kalish (1990) for rainbow trout of known freshwater (<0.00170) and known seawater (>0.00220) origin.

Of the four life history groups we examined, only the brood year 1991 O. nerka were of known parental origin (progeny of 1991 anadromous adults). The Sr/Ca ratios observed in otolith nuclei for these individuals agreed with values reported by Rieman et al. (1993) for individuals of known anadromous origin. Samples of unknown origin analyzed by Rieman et al. (1993) included Redfish Lake 1991 outmigrants and adult sockeye salmon that returned to Redfish Lake Creek in 1991 and 1992. Approximately one-third of their outmigrant group exhibited mean Sr/Ca ratios indicative of freshwater lineage. An additional one-third exhibited ratio values indicative of anadromous lineage while the remaining one-third fell into the "grey" area between these two distinct zones. Mean Sr/Ca ratios observed in the nuclei of their anadromous adults fell into the range they identified as known anadromous origin.

Mean Sr/Ca ratios measured in otolith nuclei of our unknown origin samples (Redfish Lake residuals, 1991 outmigrants, 1993 anadromous adults) were similar to those reported by Rieman et al. (1993). However, the proportion of our samples that fell into ratio zones reflecting freshwater, anadromous, and uncertain origin (grey) did differ from what Rieman et al. (1993) observed. We observed that 50% of the 18 Redfish Lake outmigrants displayed direct lineage to freshwater female parents. This represents an increase of approximately 17% over findings presented by Rieman et al. (1993) for fish from this same source. Twenty-two percent of the nuclear Sr/Ca ratios from our lake outmigrants fell into the range indicative of direct lineage to anadromous female parents while 28% of our results represented uncertain origin. This represents a decrease of approximately 11 and 5%, respectively, over what Rieman et al. (1993) reported. It is possible that with a larger sample size, our findings would have followed a distribution closer to that reported by Rieman et al. (1993). Our data indicate, however, (as did Rieman et al.) that both resident and anadromous fish were present among the 1991 outmigrants.

Sixty-three percent of the mean Sr/Ca ratios from otolith nuclei of the 1993 anadromous adults (five of eight individuals) fell into the range indicative of direct lineage to female anadromous parents. Two of the adults (25%) displayed mean nuclear Sr/Ca ratios indicative of direct lineage to female freshwater parents while one individual (12%) was associated with uncertain lineage. Rieman et al. (1993) reported that all of their anadromous adults displayed direct lineage to female anadromoua parents. Our data indicate that the resident/residual component(s) of Redfish Lake is producing anadromoue progeny. We aged the two fish that fell into the range of freshwater origin at 3+ years. This represents brood year 1989, the last year anadromoue sockeye salmon were allowed to escape to Redfish Lake.

Forty percent of the mean Sr/Ca ratios from otolith nuclei of the 10 Redfish Lake residual fish investigated in 1993 produced data reflecting direct lineage to female freshwater parents. Pifty percent of our data for this group fell within the area of uncertain origin between the upper ratio value for freshwater lineage and the lower value for anadromoue lineage. One of the 10 fish, however (l0%), produced a mean nuclear Sr/Ca ratio reflecting direct lineage to an anadromoue female parent. This indicates this fish was the progeny of an anadromoue female and anadromoue male or an anadromoue female and a resident/residual male. We aged this individual at 3+ years. This age represents brood year 1989, the last year adult sockeye salmon had access to Redfish Lake.

The analysie of Sr/Ca content of otolithe through the use of a wavelength dispersive electron microprobe has the potential to discriminate O. nerka with differing life histories. We observed differences in Sr/Ca ratios consistent with the different life history patterns of residual, outmigrant, anadromoue, and captive broodstock O. nerka. Cur data indicate that residual and/or resident fish are successfully producing anadromous adults and that some residual fish are the direct progeny of anadromoue adults. Cur data also indicate that both resident and anadromoue fish were present among fish that outmigrated from Redfish Lake in 1991.

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# A P P E N D I C E S

Appendix A. Summary of 1993 telemetry observation dates for Redfish and Alturae lakes.

| Redfish Lake | Alturas Lake |
|---|---|
| 08/21/93 | 08/21/93 |
| 08/28/93 | 08/28/93 |
| O9/O5/93 | 09/04/93 |
| 09/12/93 | 09/25/93 |
| 09/25/93 | |
| 10/07/93 | |
| 10/14/93 | |
| 10/21/93 | |
| 10/28/93 | |
| 11/04/93 | |
| 11/11/93 | |
| 11/18/93 | |
| 11/23/93 | |
| 12/02/93 | |

**Appendix B.** Summary of length and sex information for August 1993 adult captive broodstock outplants to Redfieh and Alturae Lakes. Ultrasonic and radio frequencies are reported for Redfieh and Alturas Lakes, respectively.

| Redfish Lake | | | Alturas Lake | | |
|---|---|---|---|---|---|
| Codes[a] | Length (mm)[b] | sex | Frequency (Khz) | Length (mm)[b] | sex |
| 249 | 525 | F | 150.516 | 540 | M |
| 258 | 518 | F | 150.535 | 445 | F |
| 267 | 495 | M | 150.555 | 445 | M |
| 276 | 480 | M | 150.574 | 452 | M |
| 285 | 528 | F | 150.595 | 462 | M |
| 294 | 505 | M | 150.615 | 450 | F |
| 339 | 552 | F | 150.635 | 438 | M |
| 348 | 465 | M | 150.655 | 378 | M |
| 357 | 520 | F | 150.674 | 420 | M |
| 366 | 492 | M | 150.696 | 508 | F |
| 375 | 492 | M | 150.714 | 485 | M |
| 384 | 480 | M | 150.734 | 518 | F |
| 447 | 488 | M | 150.756 | 470 | F |
| 456 | 518 | F | 150.775 | 465 | F |
| 465 | 544 | F | 150.796 | 470 | F |
| 2246 | 530 | F | 150.815 | 420 | M |
| 2255 | 475 | F | 150.834 | 442 | F |
| 2264 | 508 | M | 150.855 | 505 | F |
| 2273 | 480 | M | 150.870 | 485 | F |
| 2327 | 485 | F | 150.894 | 504 | M |
| 2444 | 465 | M | | | |
| 2453 | 490 | F | | | |
| 2525 | 440 | M | | | |
| 2534 | 492 | F | | | |

a Frequencies are 70 to 76 Khz ± 2 Khz
b Fork length

Appendix C. Age and fork length of Redfish Lake (RFL) O. nerka selected for otolith microchemistry analysis; Fish ID indicates life history type (RES = residual, OM = outmigrant, BY = brood year and ANAD = anadromous return), year of collection, sex, and the sequence digit or the last two digits of PIT tag code (for outmigrants only).

| Fish ID | Age | Fork length (mm) |
|---|---|---|
| RES93Ml | 3+ | 222 |
| RES93M2 | 3+ | 214 |
| RES93M3 | 3+ | 215 |
| RES93M4 | 3+ | 225 |
| RES93Fl | 3+ | 208 |
| RES93F2 | 3+ | 215 |
| RES9SMlO | 3+ | 215 |
| RES93Mll | 3+ | 208 |
| RES93M9 | 3+ | 210 |
| RES93M12 | 3+ | 225 |
| | | |
| RFLOM9lFlC | 3+ | 522 |
| RFLOM91FSC | 3+ | 528 |
| RFLOM91F76 | | 468 |
| RFLOM91F46 | 3+ | 465 |
| RFLOM91F5B | 4+ | 585 |
| RFLOM9lF4C | 3+ | 529 |
| RFLOM91F65 | 3+ | 459 |
| RFLOM91FOF | 3+ | 551 |
| RFLOH91F54 | 3+ | 520 |
| RFLOM91F19 | 3+ | 514 |
| RFLOM9lF4E | 3+ | 498 |
| RFLOM9lFlE | 3+ | 467 |
| RFLOM91F53 | 3+ | 508 |
| RFLOM91F07 | 3+ | 515 |
| RFLOM9lF7A | 3+ | 526 |
| RFLOM91F69 | 3+ | 480 |

Appendix C. Continued.

| Fish ID | Age | Fork length (mm) |
|---|---|---|
| RFLOM9lM8 | 3+ | 452 |
| RFLOM9lM9 | 3+ | 530 |
| | | |
| RFLBY9lM7 | 3+ | 372 |
| RFLBY91MlO | 3+ | 400 |
| | | |
| ANAD93FA | 3+ | 505 |
| ANAD93FB | 3+ | 505 |
| ANAD93Ml | 3+ | 575 |
| ANAD9 3M2 | 3+ | 555 |
| ANAD93M3 | 3+ | 503 |
| ANAD93M4 | 3+ | 524 |
| ANAD93M5 | 3+ | 543 |
| ANAD93M6 | 4+ | 607 |

Appendix D. Mean Sr/Ca ratios and standard deviations measured in otolith nuclei and in zones peripheral to the nuclei from Redfish Lake (RFL) _O. nerka_ with differing life histories. Fish ID indicates life history type (RES = residual, OM = outmigrant, BY = brood year and ANAD = anadranous return), year of collection, sex, and the sequence digit or the last twodigits of PIT tag code (for outmigrants only).

| Fish ID | Nuclear Sr/Ca | SD | Freshwater Zones: Lake Sr/Ca | SD | Freshwater Zones: Eagle Sr/Ca | SD | Saltwater Zone Sr/Ca | SD |
|---|---|---|---|---|---|---|---|---|
| RES93Ml | 0.00079’ | 0.00010 | 0.00069 | 0.00008 | | | | |
| RES93M2 | 0.00064’ | 0.00009 | 0.00069 | 0.00014 | | | | |
| RES93M3 | 0.00072’ | 0.00011 | 0.00072 | 0.00013 | | | | |
| RES93M4 | 0.00130[b] | 0.00021 | 0.00072 | 0.00005 | | | | |
| RES93Fl | 0.00088[b] | 0.00011 | 0.00074 | 0.00012 | | | | |
| RES93F2 | 0.00197' | 0.00024 | 0.00075 | 0.00012 | | | | |
| RES93M10 | 0.00125[b] | 0.00030 | 0.00074 | 0.00011 | | | | |
| RES93M11 | 0.00121[b] | 0.00018 | 0.00069 | 0.00015 | | | | |
| RES93M9 | 0.00116[b] | 0.00019 | 0.00072 | 0.00009 | | | | |
| RES93M12 | 0.00069’ | 0.00011 | 0.00064 | 0.00017 | | | | |
| RFLOMSlFlC | 0.00204’ | 0.00013 | 0.00075 | 0.00006 | 0.00138 | 0.00012 | | |
| RFLOM9 IF5C | 0.00061’ | 0.00011 | 0.00076 | 0.00027 | 0.00151 | 0.00022 | | |
| RFLOM91F76 | 0.00086[b] | 0.00010 | 0.00091 | 0.00000 | 0.00136 | 0.00016 | | |
| RFLOM91F46 | 0.00083[b] | 0.00012 | 0.00055 | 0.00007 | 0.00129 | 0.00017 | | |
| RFLOM9lFSB | 0.00068’ | 0.00009 | 0.00072 | 0.00019 | 0.00130 | 0.00015 | | |
| RFLOM9 IF4C | 0.00068’ | 0.00010 | 0.00075 | 0.00004 | 0.00136 | 0.00014 | | |

APPENDD

Appendix D. Continued.

| Fish ID | Nuclear Sr/Ca | SD | Freshwater Zones: Lake Sr/Ca | SD | Freshwater Zones: Eagle Sr/Ca | SD | Saltwater Zone Sr/Ca | SD |
|---|---|---|---|---|---|---|---|---|
| RFL0M9 IF65 | 0.00229’ | 0.00016 | 0.00079 | 0.00015 | 0.00151 | 0.00021 | | |
| RFLOM9 1FOF | 0.00059’ | 0.00012 | 0.00073 | 0.00009 | 0.00137 | 0.00023 | | |
| RFLOM91F54 | 0.00065’ | 0.00013 | 0.00065 | 0.00016 | 0.00156 | 0.00024 | | |
| RFLOM9lF19 | 0.00059’ | 0.00015 | 0.00071 | 0.00022 | 0.00140 | 0.00026 | | |
| RFLOM91F4E | 0.00054’ | 0.00010 | 0.00072 | 0.00011 | 0.00148 | 0.00013 | | |
| RFLOM91F1E | 0.00070’ | 0.00007 | 0.00064 | 0.00006 | 0.00154 | 0.00014 | | |
| RFLOM9lF53 | 0.00095[b] | 0.00010 | 0.00059 | 0.00007 | 0.00144 | 0.00013 | | |
| RFLOM91F07 | 0.00145’ | 0.00019 | 0.00070 | 0.00006 | 0.00131 | 0.00017 | | |
| RFLOM91F7A | 0.00191’ | 0.00015 | 0.00071 | 0.00012 | 0.00149 | 0.00008 | | |
| RFLOM91F69 | 0.00060’ | 0.00012 | 0.00065 | 0.00019 | 0.00155 | 0.00016 | | |
| RFLOM91M8 | 0.00134[b] | 0.00012 | 0.00060 | 0.00006 | 0.00138 | 0.00011 | | |
| RFLOM91M9 | 0.00136[b] | 0.00027 | 0.00074 | 0.00013 | 0.00128 | 0.00010 | | |
| RFLBY91M7 | 0.00186[d] | 0.00010 | | | 0.00138 | 0.00012 | | |
| RFLBYSlMlO | 0.00179[d] | 0.00018 | | | 0.00149 | 0.00018 | | |
| ANAD93FA | 0.00204’ | 0.00018 | 0.00071 | 0.00011 | | | 0.00267 | 0.00051 |
| ANAD93FB | 0. 00097[b] | 0.00019 | 0.00064 | 0.00009 | | | 0.00272 | 0.00046 |
| ANAD93Ml | 0.00236’ | 0.00010 | 0.00071 | 0.00013 | | | 0.00318 | 0.00093 |

APPENDD

Appendix D. Continued.

| Fish ID | Nuclear Sr/Ca | SD | Freshwater Zones: Lake Sr/Ca | SD | Freshwater Zones: Eagle Sr/Ca | SD | Saltwater Zone Sr/Ca | SD |
|---|---|---|---|---|---|---|---|---|
| ANAD93M2 | 0.00063' | 0.00012 | 0.00066 | 0.00010 | | | 0.00308 | 0.00060 |
| ANAD9 3M3 | 0.00143' | 0.00033 | 0.00069 | 0.00008 | | | 0.00281 | 0.00049 |
| ANAD93M4 | 0.00141' | 0.00014 | 0.00076 | 0.00014 | | | 0.00296 | 0.00045 |
| ANAD93M5 | 0.0007~ | 0.00018 | 0.00073 | 0.00018 | | | 0.00324 | 0.00052 |
| ANAD93M6 | 0.00197' | 0.00017 | 0.00072 | 0.00017 | | | 0.00303 | 0.00047 |

a Inferred freshwater origin
b Unknown origin
c Inferred saltwater origin
d Known saltwater origin

Submittad by:

Paul Kline
Fishery Research Biologist

**Approved** ***by:***

IDAHO DEPARTMENT *OF* FISH AND GAME

**Steven M. Huffaker, Chief**
Bureau of Fieheries

**Virgil K. Moore**
Fisheries Research Manager

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