RESEARCH AND RECOVERY OF SNAKE RIVER SOCKEYE SALMON

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF APPENDICES (Cont.)

ABSTRACT

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

In 1994, we estimated the total September Redfish Lake O. nerka population at 51,529 fish (95% CI, ± 33,179). Total O. nerka density and biomass was estimated at 125 fish/hectare (± 81) and 2.1 kg/hectare, respectively. The Alturas Lake O. nerka population was estimated at 5,785 fish (± 6,919). The total density and biomass of Alturas Lake was estimated at 27 fish/hectare (± 33) and 0.7 kg/hectare, respectively. The total 0. nerka population estimate for Pettit Lake was 14,743 fish (± 3,683). We estimated total density and biomass for Pettit Lake at 128 fish/hectare (± 32) and 4.4 kg/hectare, respectively. Stanley Lake O. nerka total population size, density, and biomass was estimated at 2,695 fish (± 963), 37 fish/hectare (± 13), and 0.5 kg/hectare, respectively.

Estimated numbers of O. nerka outmigrant smolts passing Redfish Lake Creek and Salmon River trapping sites increased in 1994. We estimated 1,820 (90% CI 1,229 - 2,671) and 945 (90% CI 331 - 13,000) smolts left Redfish and Alturas lakes, respectively. The total PIT tag detection rate at mainstem dams for Redfish Lake outmigrants was 21% in 1994. No Alturas Lake outmigrants were detected at any of the downstream facilities with detection capabilities (zero of 50 fish).

We released 37 ultrasonic-tagged, maturing O. nerka adults into Redfish Lake in 1994. Tagged fish were tracked to identify spawning-related activity and to detect differences in survival between two principal release groups: (1) fish spawned from returning anadromous sockeye salmon in 1991 and reared to spawning age at Eagle Fish Hatchery (brood year 1991), and (2) O. nerka collected as outmigrants from Redfish Lake in 1991 and reared to spawning age at Eagle Fish Hatchery (outmigrant 1991). We made no observations of sustained site association or spawning-related activity for any of the 37 fish. Additionally, no stationary tags were located or recovered near areas of known or suspected beach spawning activity. Outmigrant 1991 broodstock adults exhibited significantly fewer incidences of stationary and absent tag status (potential mortality indices) and greater incidence of active tag status.

We captured primarily mountain whitefish Prosooium williamsoni (65.8%) in 96 h of trap netting in Redfish Lake. Bull trout Salvelinus confluentus and northern sguawfish Ptvchocheilus oreoonensis comprised 2.4% and 4.2% of the catch, respectively. Redside shiners Richardsonius balteatus, suckers Catostomus sp., brook trout Salvelinus fontinalis, and O. nerka comprised the remainder of the catch. Because we exceeded our incidental take of 0. nerka (under permit by the National Marine Fisheries Service), we were required to discontinue this activity.

We used otolith microchemistry to describe the life history of Redfish Lake O. nerka (progeny of 1991 and 1993 returning anadromous sockeye salmon with known lineage to anadromous female parents). Mean strontium/calcium ratio5 (Sr/Ca) in otolith nuclei of brood year 1991 progeny showed patterns consistent with ova development in saltwater (Sr/Ca ratio >0.0014). Mean Sr/Ca ratios in otolith nuclei of brood year 1993 progeny produced results less consistent with our expectations. Thirty-six percent (4 of 11 samples) of the Sr/Ca ratios fell between 0.0008 and 0.0014 suggesting that ova development in anadromous sockeye salmon may not be complete when fish enter freshwater. Other factors associated with this migration, such as stress and metabolic rate change, may also confound microchemistry results.

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INTRODUCTION

Numbers of Snake River sockeye salmon Oncorhvnchus nerka 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 anadromous run.

In the late 1800's, Evermann (1895) made observations on the distribution and abundance of sockeye salmon in Stanley Basin lakes. During his survey of 1894, he reported observing sockeye salmon in Redfish, Alturas, Pettit, and Stanley lakes. Sunbeam Dam, constructed in 1910 by the Golden Sunbeam Mining 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 occurred in 1942 when 200 adults were counted in Redfish Lake (Parkhurst 1950). Between 1954 and 1966 a two-way weir (Bjornn et al., 1968) was operated on Redfish Lake Creek. During these years, adult sockeye salmon escapement ranged from 11 fish in 1961 to 4,361 fish in 1955. Estimated smolt outmigration for this same period ranged from 2,133 fish in 1960 to 65,000 fish in 1957. Beginning in 1955, numbers of sockeye salmon reaching Stanley Basin lakes began to decline. By 1962, sockeye salmon were no longer returning to Stanley and Pettit lakes (Chapman et al. 1990). During the 1980's, the greatest adult escapement occurred in 1982 when 50 fish were observed over spawning gravel in Redfish Lake (Hall-Griswold, 1990). Between 1990 and 1993, a total of 13 adult sockeye salmon returned to Redfish Lake. In 1994, only one adult female returned.

The Idaho Department of Fish and Game (IDFG) Sawtooth Fish Hatchery (FH), constructed to mitigate for lower Snake River hydroelectric dams, began recording adult sockeye salmon returns in 1985. Between 1985 and 1989, five adult sockeye salmon were intercepted at the Sawtooth FH weir which lies approximately 2 kilometers upstream of the mouth of Redfish Lake Creek on the Salmon River. The last recording of an adult return at this facility occurred in 1989 when one fish was intercepted; presumably in route to Alturas Lake.

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 0. nerka resources (IDFG 1992). Under ESA, NMFS Permit Nos. 795 and 823 authorize IDFG to conduct scientific research on listed Snake River salmon. In 1991, the SBT along with 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 Sockeye Technical Oversight Committee (TOC), 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 O. nerka fisheries research. While objectives and tasks from both components overlap and contribute to achieving the same State goals, activities related to the captive broodstock program will appear under separate cover. In this report, we present information collected in 1994 efforts directed at Stanley Basin fisheries research. Specific activities covered include: Stanley Basin lake O. nerka population monitoring, Redfish and Alturas lake O. nerka smolt outmigration monitoring, Redfish Lake adult broodstock telemetry monitoring, Redfish Lake predator investigations, and otolith microchemistry analysis of wild and broodstock O. nerka.

The ultimate goal of IDFG sockeye salmon research and recovery is to reestablish sockeye salmon runs to Stanley Basin and provide for utilization of sockeye salmon and kokanee resources. The near term goal is to maintain Stanley Basin sockeye salmon through captive broodstock supplementation through one generation of captive breeding and rearing to prevent species extinction.

OBJECTIVES

Objective 1.0 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 Redfish, Alturas, Pettit, and Stanley lakes.

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

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

Objective 2.0 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 3.0 To identify location and time of spawning for natural sockeye salmon production in Redfish Lake through adult broodstock outplants.

Task 3.1 Conduct ultrasonic tracking on 1993 and 1994 adult broodstock outplants to Redfish Lake.

Task 3.2 Evaluate in-lake performance differences for broodstock outplants from different genetic sources.

Task 3.3 Document movement patterns, habitat selection, and activities associated with spawning.

Objective 4.0 To determine predator effects on O. nerka in relation to recovery options.

Task 4.1 Conduct trap netting on Redfish Lake to determine the efficacy of this gear in capturing bull trout Salvelinus confluentus.

Objective 5.0 To determine the parental lineage of wild and broodstock O. nerka to interpret outmigration success of supplementation fish.

Task 5.1 Continue otolith microchemistry analysis of wild and broodstock O. nerka.

Task 5.2 Integrate otolith microchemistry and genetic data.

STUDY AREA

The Stanley Basin lakes 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, Alturas, 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 salmon/kokanee, spring-summer chinook salmon O. tshawytscha, rainbow trout/steelhead O. mykiss, westslope cutthroat trout O. clarki lewisi, bull trout, sucker Catostomus sp., northern sguawfish Ptvchocheilus oreuonensis, mountainwhitefish Prosoniumwilliamsoni, redside shiner Richardsoniusbalteatus, dace Rhinichthvs sp., and sculpin Cottus sp. Non-native species include lake trout S. namavcush, and brook trout S. fontinalis.

METHODS

Total Population, Density and Biomass Estimation

To estimate O. nerka population, density, and biomass, we conducted night midwater trawling on four Stanley Basin lakes during the dark (new) phase of the moon. Redfish and Alturas lakes were sampled one night each in June and in September 1994. 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. Redfish Lake trawl activities are subject to the provisions of the ESA and fall under NMFS Permit No. 823. Modification No. 1 (Task 6) of this permit stipulates that no more than 65 juvenile Q. nerka may be lethally taken by trawling.

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 1.0 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 first lowered to the bottom of the predetermined sampling layer and fished for approximately 5 min. We then raised the trawl 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 targets had been sampled (one transect). We generally fished five transects per lake.

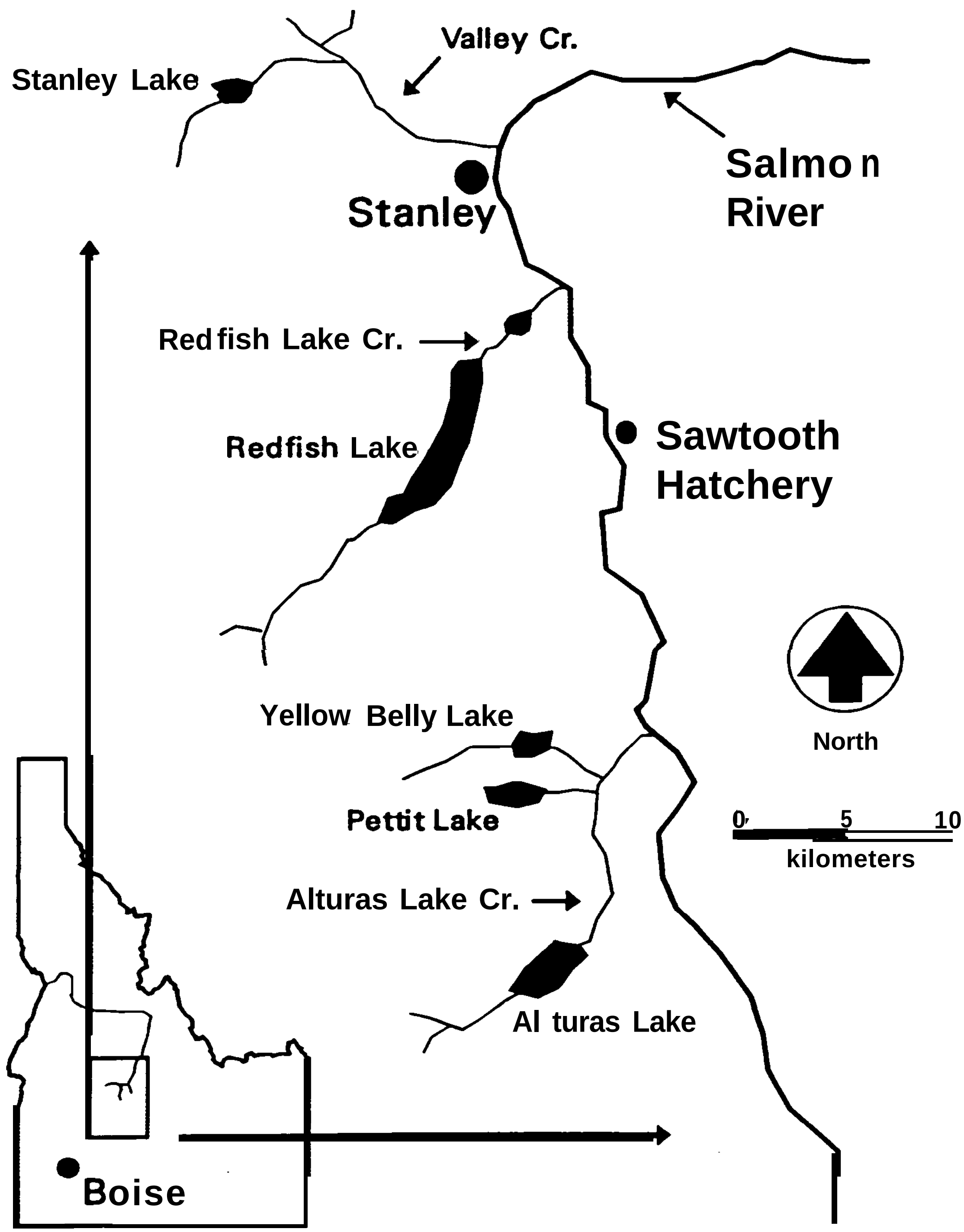

Figure 1. Stanley Basin study area map.

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	160	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

We estimated total O. nerka population, density, and biomass using the TRAWL.WK1 spreadsheet for Lotus 123 developed by Rieman (1992). Estimates represent an extrapolation of actual trawl catch data to the total area of the lake mid-depth in the observed O. nerka stratum as detected by echosounding. Whenever possible, we estimated population and density by individual age-class (assuming representation in the trawl).

We recorded fork length (to the lowest whole 10 mm group) and weight (to the nearest gram) for all trawl-captured O. nerka. 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. Tissue samples were collected and preserved for genetic analysis by NMFS and University of Idaho technicians. Stomachs were removed and preserved for diet analysis by SBT biologists.

Outmigrant Enumeration

To estimate O. nerka outmigrant run size from Redfish and Alturas lakes, IDFG personnel operated smolt traps on Redfish Lake Creek and on the upper Salmon River at the Sawtooth FH. Trap operations on Redfish Lake Creek are subject to the provisions of ESA and are permitted by NMFS. Under NMFS Permit No. 795 (Modification No. 3), IDFG is authorized to capture and PIT tag up to 4,500 juvenile Snake River sockeye salmon. Of these, up to 450 may be released above the trap site for purposes of trap efficiency estimation, and up to 450 may be retained and transferred to the IDFG Eagle FH sockeye salmon captive broodstock program. The number of outmigrants retained for use in the captive broodstock program may not exceed one-half of the total number of outmigrants captured during the collection period.

The outmigrant trap on Redfish Lake Creek is located approximately 1.4 km downstream of the lake outlet. In 1994, the trap was placed in operation on April 13 and remained in place until June 1. Five of nine trap bays were operated with incline bar trap boxes. Bar spacing allowed debris and large fish to pass downstream while small fish were captured in the low velocity trap boxes. The trap was checked twice daily by IDFG personnel.

The outmigrant trap on the Salmon River at the IDFG Sawtooth FH is located 2 kilometers upstream of the confluence of Redfish Lake Creek and the Salmon River. The floating scoop trap, equipped with a 1.0 m wide inclined traveling screen, is installed directly below the permanent weir at the Sawtooth FH as part of IDFG natural production monitoring studies (Kiefer and Forster 1991). A picket weir, 3.1 m wide at the mouth, funnels fish through the trap; pickets are spaced 3.8 cm apart. In 1994, the trap was operated continuously between March 8 and June 9 and was checked twice daily by IDFG personnel.

Outmigrant O. nerka captured at both trap sites were anesthetized in buffered MS222, measured for fork length (mm) and injected with PIT tags. Any trapping or PIT tagging related mortalities were frozen to facilitate subsequent tissue removal for disease and genetic analysis and for ageing. All tagged fish were held several hours in live boxes at the tagging sites prior to being released. We determined the trapping efficiency at both sites by releasing PIT-tagged fish upstream for subsequent recapture. We estimated total emigration or outmigration run size by summing the products of trap efficiency and daily trap catch for five intervals within the total period of outmigration. We constructed 90% confidence limits around our point estimate by transforming recapture proportions for the five intervals into arcsine data to approximate a normal distribution (Kiefer and Lockhart, in progress). We noted total PIT tag interrogations (minimum survival estimate) and time of arrival at lower Snake and Columbia River dams. PIT tag interrogation data was recovered from the Columbia River Basin PIT Tag Information System (PTAGIS), a branch of the Pacific States Marine Fisheries Commission.

Natural Spawning Investigations

Natural spawning characteristics were evaluated by release and subsequent tracking of O. nerka adults implanted with ultrasonic transmitters. Telemetry investigations of adult broodstock O. nerka released to Redfish Lake are subject to the provisions of ESA and are permitted by NMFS. In 1994, Permit No. 795 (Modification No. 3) allowed IDFG to implant ultrasonic transmitters (tags) in up to 60 adult 0. nerka from the captive broodstock program and to conduct associated tracking and observation activities. The permit stipulated that no more than 20 of these fish could be progeny of the four anadromous sockeye salmon that returned to Redfish Lake as adults in 1991 (brood year 1991). In addition, no more than 40 fish could be outmigrants captured at the weir on Redfish Lake Creek between 1991 and 1993.

Releases of adult O. nerka from the captive broodstock program were initiated in 1993. In August of that year, 24 ultrasonic-tagged adults were released to Redfish Lake (Kline 1994). Several of these fish were still active at end of the 1993 tracking season. Prior to the commencement of 1994-release tracking, telemetry efforts focused on locating and determining the status of overwinter survivors from 1993.

In 1994, three adult broodstock releases were made to Redfish Lake. The first release (30 fish) occurred August 9 - 10 and incorporated O. nerka from three different broodstocks: 1) 11 adult progeny of the four anadromous sockeye salmon that returned in 1991 (brood year 1991), 2) two outmigrant 1992 adults captured at the Redfish Lake Creek weir in 1992 and reared at Eagle FH (outmigrant 1992), and 3) 17 outmigrant 1991 adults captured at the Redfish lake Creek weir in 1991 and reared at the Eagle facility (outmigrant 1993) (Appendix A). All brood year 1991 and outmigrant 1992 fish were fitted with ultrasonic transmitters. Eight of the outmigrant 1991 fish were fitted with ultrasonic transmitters. The second release (16 fish) occurred September 10 and consisted of nine brood year 1991 adult progeny and seven outmigrant 1991 adults (Appendix A). All fish in the second release group received ultrasonic transmitters. The third release occurred October 18 and consisted of 19 brood year 1992 residual O. nerka. These fish are the progeny of the beach-spawning residual component of Redfish Lake that were trapped over Sockeye Beach in 1992 for captive broodstock purposes. All of the residual broodstock releases were age 2+ males that matured earlier than their female counterpart. The absence of appropriate spawning partners necessitated their early release. None of the residual outplants were fitted with transmitters, however, each fish did receive an external tag to facilitate identification during subsequent snorkel investigations conducted in October and November, 1994.

We tested the hypothesis that end-of-season transmitter status would not differ between brood year 1991 and outmigrant 1991 release groups (χ^2 test of association, a = 0.10). Ultrasonic tags were indexed at the end of the 1994 tracking effort as stationary, absent from the lake, or still active . We used ending transmitter status as an index of performance. Stationary and missing transmitters were pooled for both release groups to satisfy test assumptions related to cell size. We compared mean fork lengths and weights (two-tailed independent sample t-tests, a = 0.05) and identified age differences between release groups prior to testing our hypothesis. Brood year 1992 outplants (N = 2) were not included in the analysis.

Tagging

We implanted transmitters in the Redfish Lake release groups on August 8 and September 8, 1994. Fish were individually anesthetized in a holding tank using buffered MS222, measured for fork length (to the nearest millimeter) and weighed (to the nearest gram). Tag implanting procedures were similar to those described by Winter (1989). We inserted ultrasonic 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 (1/2 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 smoothly through the gullet. All fish were held one to two days prior to release to ensure tag retention.

Tracking

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 out of water. Fish were tracked by boat using a Sonotronics model USR-5W receiver with model DH-2-10 directional hydrophone. We used the point of maximum transmitter signal strength to indicate location. Individual fish locations were mapped on USGS 7½ topographic maps using triangulation with known shoreline landmarks. We assumed that landmarks, from which we took bearings, were mapped correctly. A global positioning system (GPS) was also used to record individual fish positions and to relocate individual fish on successive survey dates.

Predator Investisations

In 1994, we set six trap nets in Redfish Lake on October 19 and 20 to capture predatory fish and to determine their potential impact on the O. nerka population. Trapping predatory fish species in Redfish Lake is permitted under Consultation No. 110, term and condition No. 3 through NMFS. Trap nets consisted of a single mesh lead (1.9 cm bar mesh) followed by a 1.9 m by 0.9 m trap box and five 0.9 m diameter hoops with fixed throats on the first and third hoops. When set, each net measured 3.2 m in overall length (exclusive of the central lead). Net leads were secured to rebar posts on shore; cod ends were anchored with weights and marked by surface floats. We set trap nets perpendicular to the shore in water approximately 1.8 m to 2.0 m deep so that the top of each net frame was near the water surface. Nets were set in the north end of the lake and south of the Point Campground along the west shore (Figure 2). We fished each trap net overnight for 9 hr on both dates. Captured fish were identified, enumerated and released. All captured bull trout were anesthetized in buffered MS222, measured for fork length (to the nearest millimeter), and weighed (to the nearest gram). We collected scale samples from bull trout captures and were prepared to lavage the stomach contents of all bull trout and northern squawfish.

Parental Lineage Investisations

We used otolith microchemistry to improve our knowledge of the parental lineage of wild and broodstock O. nerka. In 1994, sagittal otoliths were removed from 66 individuals to increase our sample size of known lineage otoliths to better define equivocal results from past analyses. Samples were collected from the one anadromous female adult that returned to Redfish Lake in 1994, 54 broodstock progeny of the four anadromous adults that returned to Redfish Lake in 1991 (brood year 1991), and 11 broodstock progeny of the eight anadromous adults that returned to Redfish Lake in 1993 (brood year 1993). In all cases, otolith samples represented either direct anadromous life history (anadromous female adult) or F_1 lineage to female anadromous parents (Table 2). We hypothesized that Strontium/calcium (Sr/Ca) ratios from otolith nuclei of fish with known lineage to female anadromous parents would reflect marine life history.

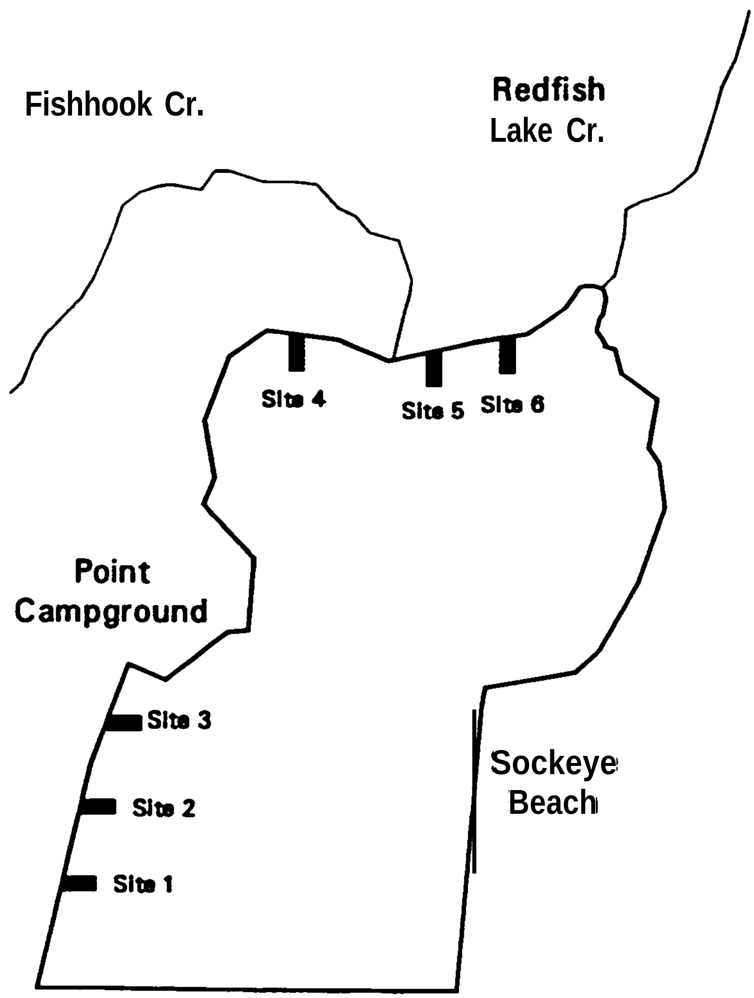

Figure 2. Location of Redfish lake trap net sampling, October 19-20, 1994

Table 2. Origin and number of Q. nerka sagittal otoliths selected for 1994 microchemistry analysis.

	Origin	Number analyzed
1994 adult return[a]	unknown	1
Brood year 1991 progeny[b]	known (anadromous)	55
Brood year 1993 progeny[c]	known (anadromous)	11

[a] Adult female sockeye captured at the Redfish Lake Creek weir in 1994.

[b] Progeny of the four anadromous adults that returned to Redfish Lake in 1991 (1 female, 3 males).

[c] Progeny of the eight anadromous adults that returned to Redfish Lake in 1993 (2 females, 6 males).

Otoliths were collected from nine of the 54 brood year 1991 progeny and from the one anadromous adult following 1994 broodstock spawning activities at the Eagle FH. The remaining 45 brood year 1991 otoliths were collected from broodstock mortalities that occurred between May 5 and November 5, 1993. Brood year 1993 samples were collected from broodstock mortalities that occurred between February 16 and June 23, 1994. Otolith samples were cleaned of all associated tissue and stored dry in microcentrifuge tubes. Prior to preparing samples for analysis, we surface aged otoliths from the anadromous female adult using a dissecting microscope under reflected and/or transmitted light. It was not necessary to age otoliths from brood year fish.

Sample Preparation

The preparation of otoliths for microchemistry analysis followed techniques developed by 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 1200 grit wet-dry sandpaper. Final grinding was completed with 5.0 μ grit wet-dry paper. We finished all sample preparations by hand polishing with 1.0 and 0.05 μ 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.

Otolith samples from small fish (ages 0+ and 1+) were mounted sulcus-side-up in the adhesive. The grinding process for these samples began with 1200 grit wet-dry sandpaper. Final grinding and polishing followed the procedures outlined above.

Analysis

Otolith microchemistry analysis followed procedures outlined by Toole and Nielsen (1992). X-ray intensities of Sr and Ca were quantified using a Cameca SX-50 wavelength dispersive electronmicroprobe (Oregon State University, College of Oceanography, Corvallis, OR 97331-5503). Samples were washed with deionized water, dried, and coated with a 200 A carbon layer for surface conductivity. A 15 KV, 50 nA, and 7 μ electron beam was used for all analyses. Microprobe transects were run in otolith nuclei adjacent to the primordia for all samples. Ten microprobe sites were analyzed along each transect.

RESULTS

Total Population, Density, and Biomass Estimation

Population, density, and biomass results presented in this section of the report incorporate IDFG data from 1990 through 1994, where available. All reference to age-class segregation is from length-frequency interpretation based on direct sagittal otolith aging of sampling mortalities. June, 1994 trawl data from Redfish and Alturas lakes were not used to estimate spring O. nerka population as sample sizes were not sufficient to yield reliable estimates.

Redfish Lake

During the September 6 trawl of Redfish Lake, the majority of Q. nerka targets were stratified in the limnetic zone between 9.0 m and 24 m of depth. Cur September trawl catch consisted entirely of 0. nerka. We estimated the total Redfish Lake O. nerka population at 51,529 fish (95% CI, ± 33,179). Total O nerka density and biomass was estimated at 125 fish/hectare (± 81) and 2.1 kg/hectare, respectively (Table 3). Sixty percent of the total O. nerka catch consisted of age 0+ fish while 11% and 29% were age 1+ and 2+ fish, respectively (Table 4; 5). No age 3+ or older fish were captured in the September trawl. Age o+, 1+, and 2+ fish averaged 49.0 mm, 89.6 mm, and 163.2 mm in fork length, respectively (Figure 3). Mean weights for these age-classes were 1.3 g, 8.3 g, and 51.1 g, respectively (Appendix B).

Alturas Lake

O. nerka comprised 100% of the September, Alturas Lake trawl catch. Fish were stratified between 11 m and 28 m of depth although targets were visible to 38 m. Deeper targets (28 m - 38 m) did not exhibit a pattern of stratification and were not sampled during our September survey. We estimated the total Alturas Lake O. nerka population to be 5,785 fish (± 6,919). The total density of the September population was estimated at 27 fish/hectare (± 33). We estimated the total 0. nerka biomass to be 0.7 kg/hectare (Table 3). Age-classes 2 and 3 comprised the entire catch and were equally represented in the trawl. Because fork lengths for both age-classes overlapped, we did not estimate population or density by age-class (Figure 3). Intuitively, these data suggest the estimated O. nerka population of Alturas Lake consists of approximately equal numbers of age 2+ and 3+ fish. Fork lengths of age 2+ and 3+ trawl captures averaged 131.7 mm (range 125 mm to 139 mm) and 140.2 mm (range 137 mm to 146 mm), respectively. Mean weights of age 2+ and 3+ fish averaged 21.8 g and 27.9 g, respectively (Appendix B).

Pettit Lake

Pettit Lake fish targets were tightly stratified between 11 m and 22 m in depth during our September 8 survey. The majority of the fish captured were O. nerka, although one redside shiner was captured during the survey. The total population estimate for Pettit Lake was 14,743 fish (± 3,683). We estimated total O. nerka density and biomass at 128 fish/hectare (± 32) and 4.4 kg/hectare, respectively (Table 3). Age-classes 0 through 3 were represented in the trawl with age l+ fish comprising the majority (46%) of the sample (Table 4; 5). Mean fork lengths for age-classes 0 through 3 were 40.5 mm, 135.7 mm, 154.0 mm, and 251.0 mm, respectively (Figure 3). We recorded mean weights of 0.7 g, 31.2 g, 47.4 g, and 251.6 g, for these same groups, respectively (Appendix B).

Stanley Lake

The majority of limnetic targets observed during our September 6 survey of Stanley Lake were loosely stratified between the lake surface and 16 m in depth. Larger, unstratified, targets (that we did not attempt to sample) were noted below our identified fish layer and immediately above the lake bottom. Sixty-two percent of the total catch consisted of O. nerka; the remainder of the catch (38%) consisted of redside shiners. We estimated the total September O. nerka population of Stanley Lake to be 2,695 (± 963) fish. Total density and biomass

Table 3. 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% C.I.)	Density (± 95% C.I.)	Biomass
Redfish	9/06/94	51,529 (±33,179)	125.1 (i80.1)	2.11
Redfish	9/17/93	49,628 ---[a]	120.4 --[a]	2.34
Redfish	9/29/92	39,481 (±10,767)	95.9 (i26.1)	1.46
Redfish	8/20/90	24,431 (±11,000)	63.9 (i26.6)	1.30
Alturas	9/07/94	5,785 (±6,919)	27.1 (i33.6)	0.68
Alturas	9/17/93	49,037 (±13,175)	230.2 (±61.9)	4.12
Alturas	9/25/92	47,237 (±61,868)	222.8 (i291.8)	3.86
Alturas	9/08/91	125,045 (±30,708)	594.0 (i144.8)	6.33
Alturas	8/19/90	126,644 (±31,611)	597.0 (±154.0)	5.20
Pettit	9/08/94	14,743 (±3,683)	128.2 (±32.0)	4.40
Pettit	9/18/93	10,511 (±3,696)	101.0 (i33.9)	1.09
Pettit	9/27/92	3,009 (i2.131)	26.2 (±18.5)	3.50
Stanley	9/07/94	2,694 (i913)	36.9 (i12.5)	0.49
Stanley	9/16/93	1,325 (±792)	18.9 (ill.3)	0.57
Stanley	8/28/92	2,117 (±1,592)	29.0 (i21.8)	0.27

[a] Confidence limits not calculated - single transect estimate.

Table 4. Numbers of **O. nerka** by age-class, estimated from fall **midwater** trawls on four Stanley Basin lakes, 1990-1994. Values in parenthesis are 95% confidence limits.

Lake	0+	I+	II+	III+	IV+
Redfish 1994	30,449 (±25,780)	5,856 (±8,867)	15,224 (±18,884)	0 0	0 0
Redfish 1993	26,120 ---[a]	7,836 ---	15,672 ---	0 ---	0 ---
Redfish 1992	22,954 (±4,899)	5,509 (±8,415)	3,213 (±4,002)	3,902 (±1,655)	3,902 (±1,665)
Redfish 1990	10,048 (±7,308)	8,808 (±5,288)	3,338 (±2,595)	2,237 (±2,261)	0 0
Alturas 1994	0	0	5,785[b] (±6,919)		0
Alturas 1993	0 0	1,226 (±1,501)	39,842 (±12,412)	7,969 (±4,157)	0 0
Alturas 1992	0 0	1,377 (±2,368)	11,912 (±22,280)	32,667 (±57,612)	1,281 (±2,561)
Alturas 1991	5,556 (±1,657)	67,217 (±20,999)	48,569 (±22,146)	3,702 (±2,965)	0 0
Alturas 1990	39,065 (±17,888)	12,126 (±6,325)	55,439 (±28,284)	15,075 (±6,324)	4,948 (±2,850)
Pettit 1994	4,095 (±1,930)	6,826 (±2,730)	3,276 (±1,392)	546 (i668)	0 0
Pettit 1993	10,511 (±3,696)	0 0	362 (i725)	362 (i725)	362 (±725)
Pettit 1992	0 0	0 0	0 0	0 0	3,009 (±2,131)
Stanley 1994	2,087 (i796)	606 (i448)	0 0	0 0	O O
Stanley 1993	O O	714 (i516)	103 (±206)	509 (±565)	O O
Stanley 1992	O O	1,902 (±1,533)	0 0	215 (i429)	O O

[a] Confidence limits not calculated-single transect estimate.
[b] Alturas Lake population estimate not partitioned by age-class.

Table 5. Densities of ***O. nerka*** (fish per hectare) by age-class, estimated from fall **midwater** trawls on four Stanley Basin lakes, **1990-1994.** Values in parenthesis are 95% confidence limits.

Lake	0+	I+	II+	III+	IV+
Redfish	73.9	14.2	37.0	0	0
1994	(i62.2)	(i21.5)	(i45.8)	0	0
Redfish	63.4	19.0	0	38.0	0
1993	---•	---	---	---	---
Redfish	55.7	13.4	7.8	9.5	9.5
1992	(i11.8)	(±20.4)	(i9.7)	(i4.0)	(i4.0)
Redfish	26.3	23.1	8.7	5.9	0
1990	(i19.7)	(i14.6)	(i7.1)	(i7.2)	0
Alturas	0	0	27.1'	0	
1994		(i33.6)			
Alturas	0	5.7	187.1	37.4	0
1993	0	(i7.0)	(i58.3)	(i19.5)	0
Alturas	0	6.5	56.2	154.1	6.0
1992	0	(i11.2)	(ilOS.l)	(i271.8)	(i12.1)
Alturas	26.2	317.1	229.1	17.5	0
1991	(i7.8)	(±99.0)	(f104.5)	(i13.9)	0
Alturas	184.3	57.2	261.5	71.1	23.3
1990	(i82.4)	(i30.8)	(i122.0)	(i31.3)	(i13.4)
Pettit	35.6	59.4	28.5	4.8	0
1994	(i16.8)	(i23.7)	(i12.1)	(i4.9)	0
Pettit	91.4	0	3.2	3.2	3.2
1993	(i32.1)	0	(i6.3)	(i6.3)	(i6.3)
Pettit	0	0	0	0	26.2
1992	0	0	0	0	(i18.5)
Stanley	27.8	7.9	0	0	0
1994	(±10.8)	(±6.1)	0	0	0
Stanley	0	10.2	1.5	7.3	0
1993	0	(i7.4)	(±3.0)	(f8.1)	0
Stanley	0	26.1	0	2.9	0
1992	0	(±21.0)	0	(i5.9)	0

'Confidence limits not calculated-single transect estimate.
[b]Alturas Lake density estimate not partitioned by age-class.

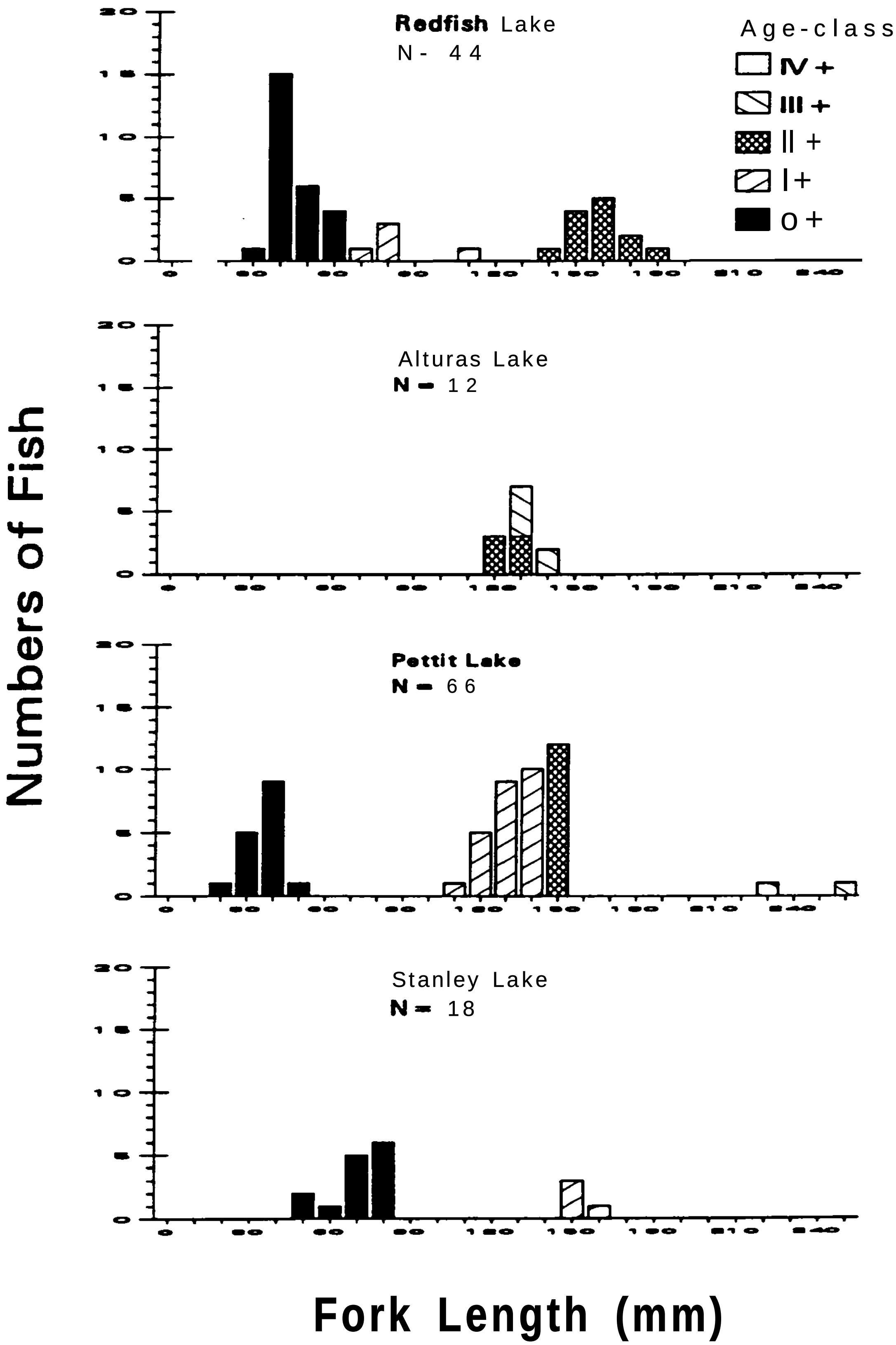

Figure 3. Length-frequency distributions from September 1994 midwater trawls of four Stanley Basin Lakes

were estimated at 37 fish/hectare (± 13), and 0.5 kg/hectare, respectively (Table 3). Age 0+ and 1+ fish comprised the entire O. nerka catch (78% and 22%, respectively) (Tables 4; 5). Mean fork lengths for age-classes 0 and 1 were 75.4 mm and 155.3 mm, respectively (Figure 3). Mean weights for these two age-classes were 5.2 g and 41.5 g, respectively (Appendix 8).

Trawl Data Corrections

We discovered a calculation error in Pettit Lake population estimates for 1992 and 1993. The correction affects the estimates reported by Kline (1994). Revised estimates of total population, density, and biomass as well as population density by age-class are presented in this report.

An ageing error was also identified in the 1993 Redfish Lake population and density estimates reported by Kline (1994). Revised estimates, based on re-ageing 1993 samples and reviewing SBT Fishhook Creek spawner ages, are presented in this report.

Outmigrant Enumeration

Redfish Lake Creek Trap

We trapped a total of 722 O. nerka outmigrants at the Redfish Lake trap site in 1994. As no anadromous adults have had access to Redfish Lake since 1989, these fish were progeny of the beach-spawning and creek-spawning stocks of Redfish Lake O. nerka. Trap captures occurred between April 19 and June 1 with peak emigration taking place the first week of May (Figure 4). Outmigration occurred primarily during night hours. The mean fork length of 1994 outmigrants was 96 mm.

We recorded five mortalities (0.7%) associated with netting and handling; there were no mortalities associated with PIT tagging. We determined the age of all trap mortalities as 1+. We estimated trapping efficiency at 39.6% for the Redfish Lake Creek site in 1994. Based on this efficiency, we estimated outmigrant run size at 1,820 (90% CI, 1,229 - 2,671) O. nerka.

Median travel times to lower Snake 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 [NcN] dams) are presented in Table 6. Median travel time to LGrD was 12.0 d in 1994. One hundred fifty-one detections were noted, from the release group of 717 PIT-tagged fish, at one of these downstream facilities yielding a cumulative interrogation rate of 21%. This number represents in-river minimum survival through McN dam and only documents the number of fish successfully diverted through and detected by the interrogation systems. It does not account for fish that avoid interrogation systems by successfully negotiating turbines or passing projects via spillways or locks.

Nine outmigrant chinook salmon smolts were intercepted at the Redfish Lake Creek trap in 1994. These fish were presumably the progeny of the one female and two male adult chinook salmon that were passed upstream of the adult weir on Redfish Lake Creek in 1992. Chinook salmon spawn in the lower reaches of Fishhook Creek. However, juvenile chinook salmon could migrate to areas upstream of the trap site from downstream locations and result as trap captures as they outmigrate. The extent to which the latter occurs is unknown. All captured juvenile chinook salmon were netted to facilitate identification and immediately released back to Redfish Lake Creek.

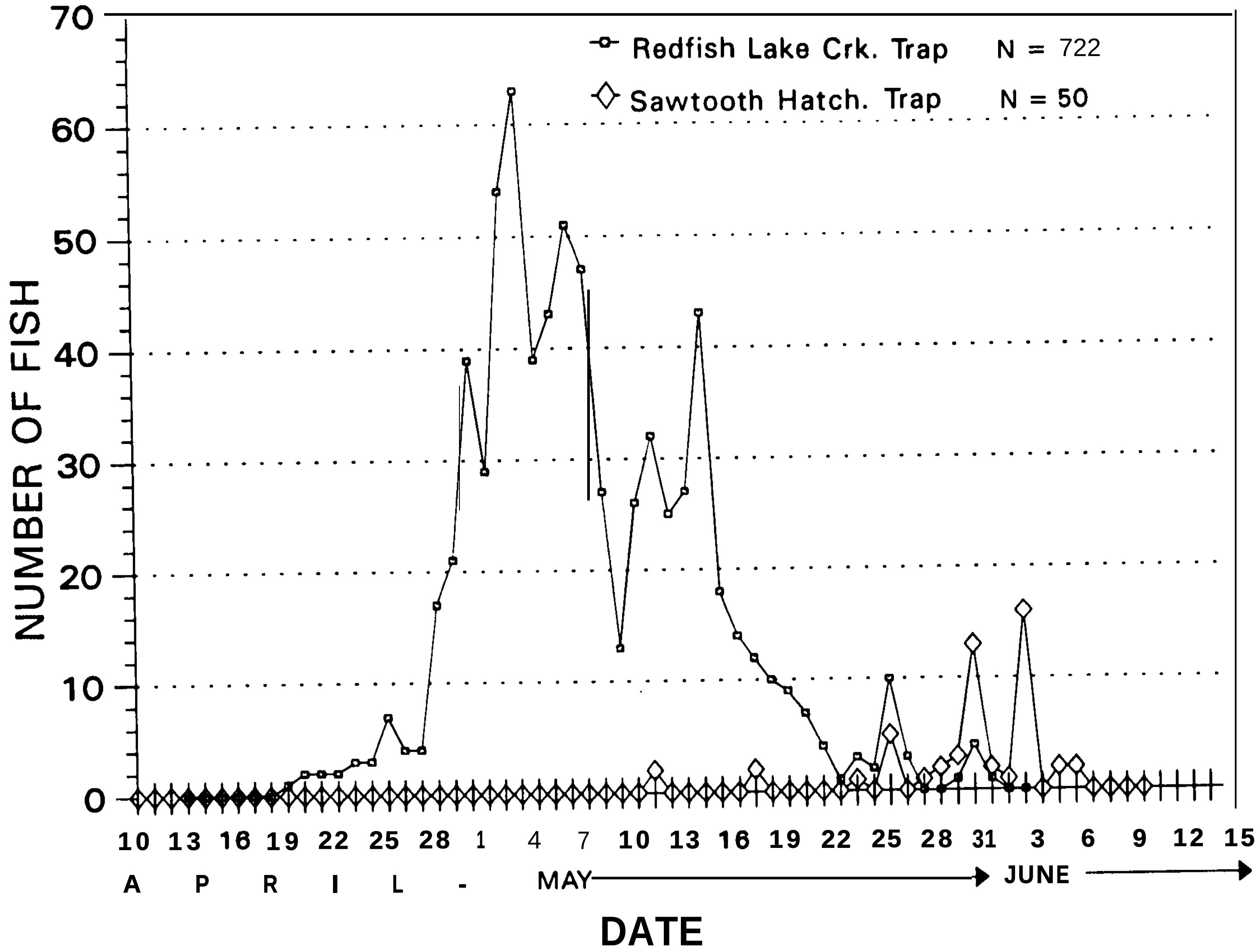

Figure 4. _0. nerka_ outmigrant trap records for Redfish Lake Creek and Sawtooth Hatchery, 1994.

Table 6. Median travel times and downstream detection rates for PIT-tagged *O. nerka* outmigrants released from Redfish Lake Creek in 1994.

Detection Location	Number of fish detected	Travel time (d)
Lower Granite Dam	38	12.0
Little Goose Dam	49	16.7
Lower Monumental Dam	32	21.5
McNary Dam	33	21.5
Total Detections	151	

Total number of PIT-tagged *O. nerka* released = 717

Total detection rate = 21%

Trap netting following ice-out might also prove unacceptable as O. nerka recruit to the lake from Fishhook Creek and lake shore spawning areas in early spring. Sockeye and kokanee fry remain littoral for an unknown period of time following their emergence and introduction to the lake community. During this time, they could be particularly susceptible to capture gear set in shallow water adjacent to the shore. Trap nets typically have smaller mesh in the containment area than on the lead or at the opening. Juvenile O. nerka that do not avoid the larger entry mesh could become trapped in the containment area.

Future efforts to estimate the bull trout population in Redfish Lake should concentrate on looking at specific life history aspects of the species during its association with Fishhook Creek. Adult spawner counts, redd counts, fecundity and egg-to-fry survival estimates could provide enough information to formulate an index of production. By answering questions about consecutive year spawning, term of stream residency by juveniles, and in-stream mortality, an estimate of bull trout recruitment to the lake could be generated.

Parental Lineage Investigations

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 (Kalish 1989,1990; Radtke 1989). 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; Rieman et al. 1993).

Otolith microchemistry has been used to discriminate individual fish from female parents of known anadromous and freshwater origin. Kalish (1990) reported that differences between Sr/Ca ratios in otolith primordia of sea-farmed and freshwater juvenile rainbow trout were great enough to identify individual life history (with respect to habitat location) during egg development. Mean nuclear Sr/Ca ratios reported by Kalish (1990) were between 0.0022 and 0.0052 for the progeny of sea-farmed rainbow trout. Rieman et al. (1993) reported mean nuclear Sr/Ca ratios between 0.0011 and 0.0020 for O. nerka progeny with known lineage to anadromous adults. Secor et al. (1994) used otolith microchemistry to describe the environmental life history of individual striped bass Morone saxatilis across a salinity gradient. They reported that mean nuclear Sr/Ca ratios between 0.0020 and 0.0030 were indicative of estuarine salinities and ratios >0.0035 were indicative of marine salinities.

Rieman et al. (1993) observed mean nuclear Sr/Ca ratios >0.0014 in otoliths of the five anadromous adults that returned to Redfish Lake in 1991 and 1992. They concluded that all five adult sockeye salmon were direct descendants of female anadromous parents that completed egg development in saltwater. Kline (1994) reported, however, that two of the eight anadromous adults that returned in 1993 exhibited microchemistry results suggesting direct lineage to freshwater female parents (<0.0008). Kline (1994) speculated these data could link anadromous adults to the freshwater residual O. nerka component of Redfish Lake. One of the eight anadromous adults analyzed by Kline (1994) exhibited mean, nuclear Sr/Ca results indicative of uncertain lineage (0.0008 - 0.0014).

Otolith microchemistry results from the one anadromous female sockeye salmon that returned to Redfish Lake in 1994 reflected direct lineage to an anadromous female parent (mean nuclear Sr/Ca >0.0014). The age of this individual (4+)

We were unable to identify any clear pattern of fish distribution during the 1994 telemetry effort. No consistent assemblages of individual fish or association with specific lake regions were observed from week to week. With very few exceptions, we recorded active fish in new locations on each survey date.

No observations of sustained site selection or fidelity with areas of known or suspected lake spawning activity were made in 1994. Snorkel and boat surveys of beach spawning areas conducted in October and November were unsuccessful in recording any observations of pairing or spawning for either 1994 broodstock releases or for the two surviving 1993 outplants. No observations of the 19 brood year 1992 residual outplants were recorded during October and November snorkel and boat surveys of known and suspected spawning locations.

We recovered three (8.1%) of the 37 transmitters implanted in broodstock outplants in 1994 (Table 7). One transmitter was recovered from a carcass September 9 in 1 m deep water near the southwest shore of the lake. Subsequent tag identification and carcass inspection identified this individual as a brood year 1991 female. We observed no indication that this fish had spawned based on the large number of eggs present in the body cavity. This individual represents our only known mortality within the 1994 release groups as the other two recovered tags were not associated with carcasses.

At the termination of 1994 tracking efforts on November 22, 12 of the 37 transmitters (32.4%) implanted in 1994 were not emitting signals from Redfish Lake (Table 7). Eight of these transmitters had been implanted in brood year 1991 progeny. Three and one of these transmitters had been implanted in outmigrant 1991 and 1992 fish, respectively. Twenty-two of the 37 transmitters were emitting in-lake signals on the final day of tracking (Table 3). Eleven of these signals (29.7%) were stationary and had been for a minimum of three consecutive tracking dates. The remaining 11 transmitter signals (29.7%) were still active. Of the 11 stationary transmitters, seven and four had been implanted in brood year 1991 progeny and outmigrant 1991 fish, respectively. Eight and three of the active transmitters had been implanted in outmigrant 1991 fish and brood year 1991 progeny, respectively.

A significant difference was found between mean fork lengths (t = 3.353, P = .002) and weights (t = 2.291, P = .028) of outmigrant 1991 and brood year 1991 adult broodstock fish implanted with ultrasonic transmitters. Outmi'grant 1991 and brood year 1991 broodstock outplants averaged 579 g and 538 g in weight and 2,916 mm and 2,443 mm in fork length, respectively. Outmigrant 1991 fish were also approximately 2 years older than brood year 1991 fish. We detected a significant difference in the final transmitter status of release groups (χ^2 = 4.953, P = .026) with respect to our comparison of the number of fish with stationary and missing transmitter status compared to active status at the end of the tracking effort.

Predator Investigations

We captured 167 fish in 96 hr of trap netting on Redfish Lake. The total catch per unit effort (CPUE) was 1.74 fish per trap net hour for the two night survey (Table 8). Mountain whitefish comprised the majority of the catch (65.8%). Northern squawfish and bull trout represented 4.2% and 2.4% of the total catch, respectively. Redside shiners, mountain suckers, brook trout, and _O. nerka_ comprised the remainder of the catch. Of these four species, redside shiners were the most prevalent representing 18.0% of the total catch.

Bull trout fork lengths ranged from 120 mmto 288 mm; all northern squawfish captured during the survey were less than 190 mm in fork length. We did not attempt to lavage the stomach contents of these two species as we felt, due to their small size, they would not withstand the procedure.

outmigrants, it is reasonable to assume that the 1995 outmigration from Alturas Lake will remain depressed.

The availability of lower Snake River PIT tag detection data for Sawtooth FH weir releases is limited to 1992 and 1994 when total detection rates of 11% and 0%, respectively, were noted for O. nerka smolts presumably of Alturas Lake origin. Alturas Lake outmigrant detections in 1992 were 50% lower than Redfish Lake detections for the same year. In 1994, no Alturas Lake outmigrants were detected downstream compared to a 21% total detection rate for Redfish Lake outmigrants. Although only two years of data are available for direct comparison, this difference in detection rates suggests that O. nerka emigrants from Alturas Lake do not survive migration to mainstem dams as well as outmigrants from Redfish Lake (assuming similar outmigration and arrival timing).

Natural Spawning Investigations

Telemetry investigations conducted on Redfish Lake in 1994 generated information relevant to evaluating performance differences observed among adult broodstock releases with differing life histories and broodstock origins. In addition, the future direction and design of this release strategy will depend, in part, on the data collected to date.

Telemetry investigations of 24 ultrasonic-tagged, captive broodstock adults released to Redfish Lake in 1993 identified three general areas of site selection: (1) Sockeye Beach, (2) Point Campground, and (3) the southwest shore (Kline 1994). During November 1993 snorkel investigations, one pair of broodstock outplants was observed guarding a redd near the southwest shore of the lake (TOC Minutes - November, 1993). Two transmitters were subsequently located in the vicinity of this activity.

During 1994 telemetry efforts, we made no observations of sustained site association or spawning-related activities for any of the 37 ultrasonic-tagged release fish. Additionally, no stationary tags were located near areas of known or suspected spawning activity. At the termination of 1994 telemetry efforts, 29.7% of the transmitters (11 of 37 tags) were still active. Kline (1994) reported similar findings (33.3% active, eight of 24 tags) at the termination of the 1993 tracking investigation. Active signals most likely represent broodstock fish that did not mature. While very limited observations of spawning-related activity were observed during both years of investigation, we can not assume that additional activity and spawning success did not occur. The weekly periodicity of SBT and IDFG spawning surveys does suggest that spawning-activities could simply have been missed. Recovered transmitters represent the only known mortalities. Absent transmitter signals could represent additional mortality, tag failure, poor or obscured signal strength, fish migration to tracking-restricted locations (e.g., inlet and outlet streams), or out-of-lake transmitters. Predation and illegal angler harvest are suspected as possible explanations for absent transmitter signals. One report of one angler catching and releasing what was reportedly a broodstock outplant was received by IDFG in 1994 (Brent Snyder, IDFG, Stanley, Idaho). Although Redfish Lake receives limited angling effort, the possibility remains that additional broodstock outplants were lost to illegal angling harvest. Stationary signals could represent additional mortality, out-of-fish transmitter status, or stationary fish. The latter condition was carefully investigated during both years of this effort. Transmitters identified as stationary rarely initiated movement following three successive weeks of stationary status. We suggest that stationary signals represent out-of-fish transmitter status. However, without knowing ii tag expulsion occurred (or to what degree), we cannot speculate further as to whether out-of-fish signals represent mortalities.

The performance differences we identified with respect to final transmitter status for brood year 1991 and outmigrant 1991 outplants are significant, yet,

Table 8. Relative species composition and catch rates for six trap net locations in Redfish Lake, October 26-27, 1994.

Site	Hours Fished	Species Composition[a] (Numbers of Fish) MW	RS	MS	NS	BLT	BKT	HRS	WRS
1	16	0	9	7	4	3	1	0	1
2	16	0	3	2	3	0	0	0	0
3	16	0	0	0	0	0	0	0	0
4	16	62	18	0	0	1	1	1	0
5	16	7	0	0	0	0	0	0	0
6	16	41	0	0	0	0	1	2	0
TOT.	96	110	30	9	7	4	3	3	1
Species CPUE[b]		1.15	0.31	0.09	0.07	0.04	0.03	0.03	0.01
% Species comp[c]		65.8	18.0	5.4	4.2	2.4	1.8	1.8	0.6

Total CPUE = 1.74

Total fish captured = 167

[a] MW = mountain whitefish; RS = redside shiner
MS = mountain sucker; NS = northern squawfish
BLT = bull trout; BKT = brook trout
WRS = wild residual sockeye; HRS = hatchery residual sockeye

[b] Catch per unit effort (CPUE) expressed as the number of fish caught per trap net hour.

[c] Percent composition of the total catch by species.

Trawl estimates of population and density improve with increasing 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. Generally, increasing the number of trawl transects has the effect of reducing the sample variance associated with estimates of total population and density. As the number of transects increase, poor individual transect variance is frequently compensated for. In 1994, we generally fished five transects per lake, per night.

Outmigrant Enumeration

Monitoring O. nerka outmigrant runs from Stanley Basin lakes will play an increasingly important roll in recovery efforts as captive broodstock progeny are outplanted to mature and migrate volitionally. Information collected from Redfish and Alturas lake outmigrants has contributed to our knowledge of outmigrant characteristics and provided insight into continuing efforts to differentiate stocks. Gutmigrant O. nerka captured between 1991 and 1993 also represent a major element in the captive broodstock recovery program.

Redfish Lake Creek Trap

The number of O. nerka estimated to have outmigrated from Redfish Lake in 1994 increased three-fold over the 1993 estimate. As no anadromous sockeye salmon have spawned in Redfish Lake since 1989, outmigrants from 1993 and 1994 are progeny of either the beach-spawning residual sockeye salmon or Fishhook Creek-spawning kokanee stocks of Redfish Lake (assumes that outmigration year 1992 is the last year associated with the production of outmigrants with direct lineage to anadromous parents). At the present time, we do not know what relative contributions are being made by residual sockeye salmon or resident kokanee with respect to the production of outmigrants. However, the current line of thinking is that residual progeny represent a significant component of the outmigration. The three-fold increase observed in 1994 outmigration run size is difficult to speculate on without further knowledge of outmigrant lineage or residual spawner escapement. If outmigrants are largely the progeny of residual beach spawners, their numbers should remain depressed as fewer than 100 adults were estimated to have spawned in 1993 and 1994 (Teuscher and Taki 1995).

Efforts to enumerate outmigration from Stanley Basin lakes prior to 1991 are scarce. Between 1955 and 1966, Bjornn et al. (1968) operated a two-way weir on Redfish Lake Creek collecting information on adult escapement as well as juvenile outmigration. During this period, they observed a range in Redfish Lake outmigrant run size from 2,133 fish (1960) to 65,000 fish (1957). Estimates of outmigrant run size exceeded 20,000 fish in seven of their 12 years of investigation. Bjornn et al. (1968) observed peak outmigration to occur during the first three weeks of May. In 1994, we observed the largest numbers of fish leaving Redfish Lake during this same time period. Cutmigration data from 1991 through 1993 generally conform to this pattern as well.

Much has been written on the relationship between the age at which juvenile sockeye salmon migrate and their growth during their first summer in the lake. Foerster (1968) noted that the number of sockeye salmon that remain in lakes for more than one year prior to seaward migration are not numerous in most of the prominent sockeye salmon rivers of British Columbia. In cases where age 2+ smolts are observed, the evidence suggests that the rate of growth is so slow that the young sockeye salmon are not sufficiently developed at the end of their first year to be stimulated to migrate seaward. Koenings and Burkett (1987) presented an empirical classification of sockeye salmon smolt production related to population characteristics for coastal and interior Alaskan Lakes. They determined that sockeye salmon smolts from rearing-limited lake systems were

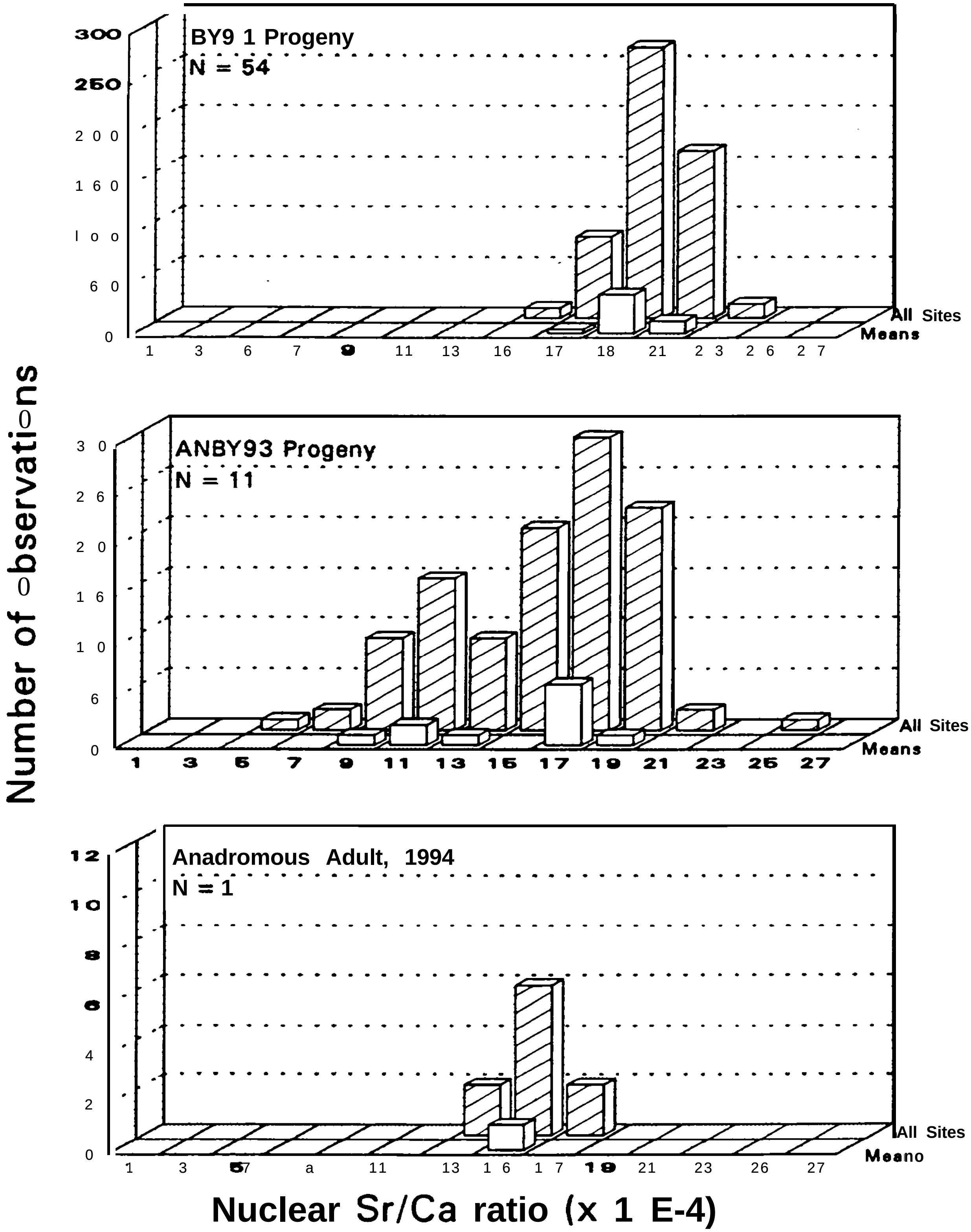

Figure 5. Frequency distributions of individual sites and mean Sr/Ca ratios measured in otolith nuclei from Redfish Lake O. nerka with differing life histories. ANBY93 = progeny of 1993 anadromous adult returns. BY91 = progeny of 199 1 anadromous adult returns.

be lower. The trawl population estimate for age 2+ and 3+ fish (combined) was 5,785 (± 6,919) fish and accounted for 100% of the total estimate.

Adult escapement and trawl population data suggest that 1995 recruitment to Alturas Lake will be comparatively high. Much of this production should also be detected in the September population estimate of age 0+ fish. Alturas Lake O. nerka year-class distribution, however, has not looked full for the past three years. The apparent failure of young-of-the-year, beginning in 1992, should begin to impact escapement beginning this year (age 3+ fish) and continue to effect recruitment through at least 1998. Koenings and Burkett (1987) and Koenings and Kyle (1994) documented similar responses in lakes where zooplankton resources had become depressed by excessive planktivory. Delayed recovery of over-grazed zooplankton resources caused reduced rearing efficiency for ensuing broods.

Pettit Lake

Pettit Lake trawl data from September 1994 indicate the total O. nerka population has increased approximately four-fold from 1992; the first year of Pettit Lake data collection. Age 0+ fish captured in the trawl were small in comparison to Redfish and Alturas lake young-of-the-year. These data suggest the possibility of late emergence and recruitment to the limnetic community. The SBT has not been able to document spawn timing for Pettit Lake O. nerka. Their hypothesis that Pettit Lake supports a late season, beach spawning community is supported by our observation of small age 0+ fish. September trawl data from 1992 and 1993 also indicate that young-of-the-year O. nerka were comparatively small. We captured two age 3+ O. nerka during the September 1994 trawl. Subsequent inspection during the removal of ageing structures and tissues for genetic evaluation identified one of these fish as a pre-spawn female. The relatively advanced stage of egg development we observed supports the hypothesis of a late-spawning population.

Pettit Lake is relatively productive in comparison to Redfish and Alturas lakes (Teuscher and Taki 1994). Comparatively fast growth is observed in older lake year-classes captured in the September trawl; this growth is reflected in Pettit Lake's comparatively high estimated lake biomass (4.40 kg/ha). Redfish and Pettit lake O. nerka densities, estimated from September 1994 trawl data, were comparable (125.1 and 128.2 fish/hectare, respectively). However, the estimated O. nerka biomass of Pettit Lake was approximately two times greater than the estimated biomass of Redfish Lake (2.1 kg/hectare).

The trend of increasing numbers of fish, density, and biomass observed in Pettit Lake since 1992 has, to date, been accommodated by the lake's ability to produce food resources. We have not observed density-dependent growth compensation or year-class failure as reported above for the Alturas Lake O. nerka population.

Stanley Lake

The estimated 1994 total O. nerka September population of Stanley Lake increased approximately two-fold over the 1993 estimate. With the exception of 1994 data from Alturas Lake, Stanley Lake exhibits the lowest total population, density, and biomass of the four basin lakes investigated. These data have been consistently low since the initiation of Stanley Lake trawling in 1992. Biomass estimates for Stanley lake are among the lowest in the State for oligotrophic waters supporting kokanee (Rieman and Myers 1991). Age 0+ and 1+ fish comprised 100% of the 1994 trawl sample. In 1992 and 1993, no age 0+ fish were captured in the trawl, however, age 1+ fish accounted for 90% and 54% of the catch for both years, respectively. The absence of older age-classes in our trawl catch be lower. The trawl population estimate for age 2+ and 3+ fish (combined) was 5,785 (± 6,919) fish and accounted for 100% of the total estimate.

Adult escapement and trawl population data suggest that 1995 recruitment to Alturas Lake will be comparatively high. Much of this production should also be detected in the September population estimate of age 0+ fish. Alturas Lake O. nerka year-class distribution, however, has not looked full for the past three years. The apparent failure of young-of-the-year, beginning in 1992, should begin to impact escapement beginning this year (age 3+ fish) and continue to effect recruitment through at least 1998. Koenings and Burkett (1987) and Koenings and Kyle (1994) documented similar responses in lakes where zooplankton resources had become depressed by excessive planktivory. Delayed recovery of over-grazed zooplankton resources caused reduced rearing efficiency for ensuing broods.

Pettit Lake

Pettit Lake trawl data from September 1994 indicate the total O. nerka population has increased approximately four-fold from 1992; the first year of Pettit Lake data collection. Age 0+ fish captured in the trawl were small in comparison to Redfish and Alturas lake young-of-the-year. These data suggest the possibility of late emergence and recruitment to the limnetic community. The SBT has not been able to document spawn timing for Pettit Lake O. nerka. Their hypothesis that Pettit Lake supports a late season, beach spawning community is supported by our observation of small age 0+ fish. September trawl data from 1992 and 1993 also indicate that young-of-the-year O. nerka were comparatively small. We captured two age 3+ O. nerka during the September 1994 trawl. Subsequent inspection during the removal of ageing structures and tissues for genetic evaluation identified one of these fish as a pre-spawn female. The relatively advanced stage of egg development we observed supports the hypothesis of a late-spawning population.

Pettit Lake is relatively productive in comparison to Redfish and Alturas lakes (Teuscher and Taki 1994). Comparatively fast growth is observed in older lake year-classes captured in the September trawl; this growth is reflected in Pettit Lake's comparatively high estimated lake biomass (4.40 kg/ha). Redfish and Pettit lake O. nerka densities, estimated from September 1994 trawl data, were comparable (125.1 and 128.2 fish/hectare, respectively). However, the estimated O. nerka biomass of Pettit Lake was approximately two times greater than the estimated biomass of Redfish Lake (2.1 kg/hectare).

The trend of increasing numbers of fish, density, and biomass observed in Pettit Lake since 1992 has, to date, been accommodated by the lake's ability to produce food resources. We have not observed density-dependent growth compensation or year-class failure as reported above for the Alturas Lake O. nerka population.

Stanley Lake

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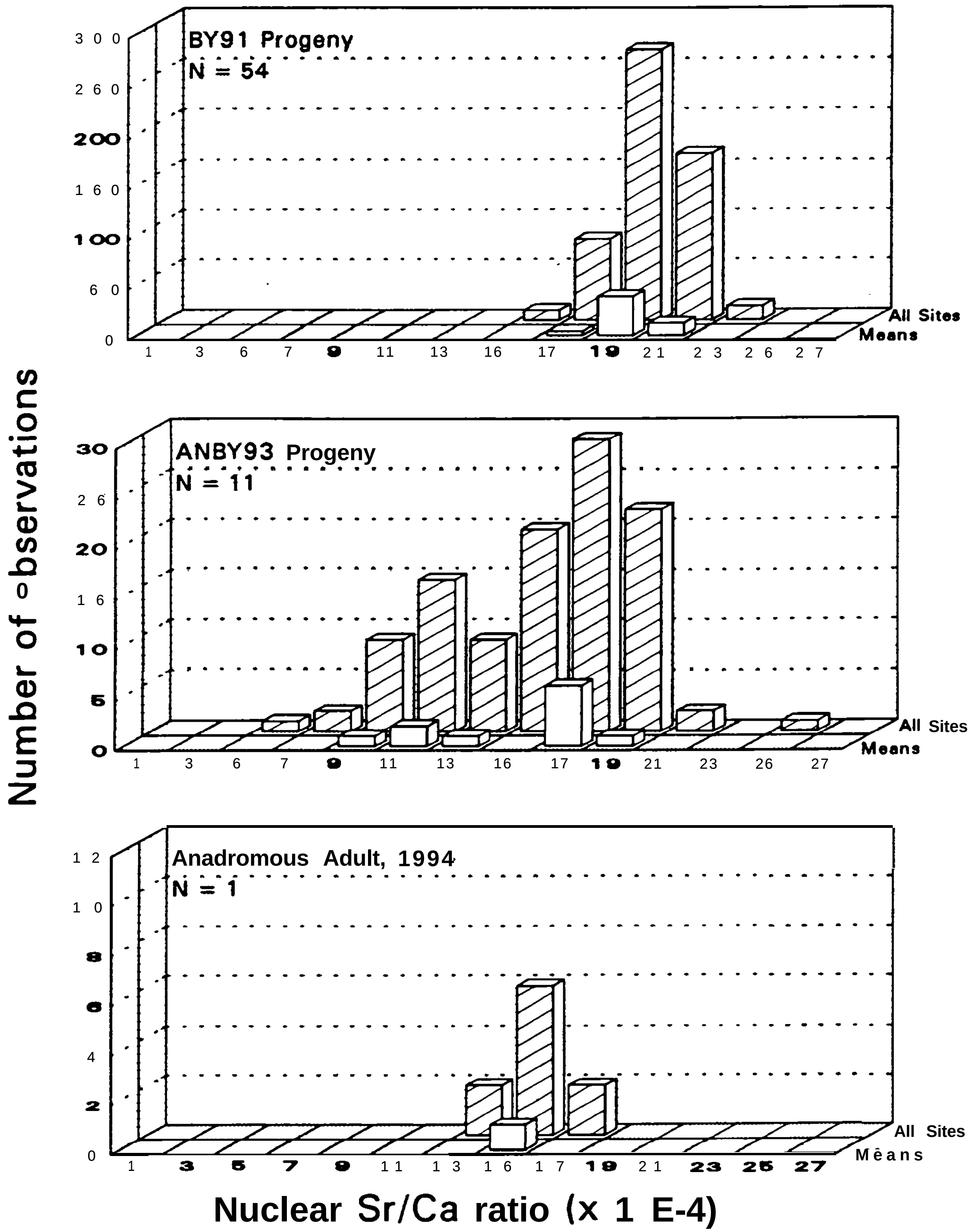

Figure 5. Frequency distributions of individual sites and mean Sr/Ca ratios measured in otolith nuclei from Redfish Lake O. nerka with differing life histories. ANBY93 = progeny of 1993 anadromous adult returns. BY91 = progeny of 199 1 anadromous adult returns.

Trawl estimates of population and density improve with increasing 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. Generally, increasing the number of trawl transects has the effect of reducing the sample variance associated with estimates of total population and density. As the number of transects increase, poor individual transect variance is frequently compensated for. In 1994, we generally fished five transects per lake, per night.

Outmigrant Enumeration

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

Redfish Lake Creek Trap

The number of O. nerka estimated to have outmigrated from Redfish Lake in 1994 increased three-fold over the 1993 estimate. As no anadromous sockeye salmon have spawned in Redfish Lake since 1989, outmigrants from 1993 and 1994 are progeny of either the beach-spawning residual sockeye salmon or Fishhook Creek-spawning kokanee stocks of Redfish Lake (assumes that outmigration year 1992 is the last year associated with the production of outmigrants with direct lineage to anadromous parents). At the present time, we do not know what relative contributions are being made by residual sockeye salmon or resident kokanee with respect to the production of outmigrants. However, the current line of thinking is that residual progeny represent a significant component of the outmigration. The three-fold increase observed in 1994 outmigration run size is difficult to speculate on without further knowledge of outmigrant lineage or residual spawner escapement. If outmigrants are largely the progeny of residual beach spawners, their numbers should remain depressed as fewer than 100 adults were estimated to have spawned in 1993 and 1994 (Teuscher and Taki 1995).

Efforts to enumerate outmigration from Stanley Basin lakes prior to 1991 are scarce. Between 1955 and 1966, Bjornn et al. (1968) operated a two-way weir on Redfish Lake Creek collecting information on adult escapement as well as juvenile outmigration. During this period, they observed a range in Redfish Lake outmigrant run size from 2,133 fish (1960) to 65,000 fish (1957). Estimates of outmigrant run size exceeded 20,000 fish in seven of their 12 years of investigation. Bjornn et al. (1968) observed peak outmigration to occur during the first three weeks of May. In 1994, we observed the largest numbers of fish leaving Redfish Lake during this same time period. Cutmigration data from 1991 through 1993 generally conform to this pattern as well.

Much has been written on the relationship between the age at which juvenile sockeye salmon migrate and their growth during their first summer in the lake. Foerster (1968) noted that the number of sockeye salmon that remain in lakes for more than one year prior to seaward migration are not numerous in most of the prominent sockeye salmon rivers of British Columbia. In cases where age 2+ smolts are observed, the evidence suggests that the rate of growth is so slow that the young sockeye salmon are not sufficiently developed at the end of their first year to be stimulated to migrate seaward. Koenings and Burkett (1987) presented an empirical classification of sockeye salmon smolt production related to population characteristics for coastal and interior Alaskan Lakes. They determined that sockeye salmon smolts from rearing-limited lake systems were

Table 8. Relative species composition and catch rates for six trap net locations in Redfish Lake, October 26-27, 1994.

Site	Hours Fished	Species Composition[a] (Numbers of Fish) MW	RS	MS	NS	BLT	BKT	HRS	WRS
1	16	0	9	7	4	3	1	0	1
2	16	0	3	2	3	0	0	0	0
3	16	0	0	0	0	0	0	0	0
4	16	62	18	0	0	1	1	1	0
5	16	7	0	0	0	0	0	0	0
6	16	41	0	0	0	0	1	2	0
TOT.	96	110	30	9	7	4	3	3	1
Species CPUE[b]		1.15	0.31	0.09	0.07	0.04	0.03	0.03	0.01
% Species comp[c]		65.8	18.0	5.4	4.2	2.4	1.8	1.8	0.6

Total CPUE = 1.74

Total fish captured = 167

[a] MW = mountain whitefish; RS = redside shiner; MS = mountain sucker; NS = northern squawfish; BLT = bull trout; BKT = brook trout; WRS = wild residual sockeye; HRS = hatchery residual sockeye

[b] Catch per unit effort (CPUE) expressed as the number of fish caught per trap net hour.

[c] Percent composition of the total catch by species.

outmigrants, it is reasonable to assume that the 1995 outmigration from Alturas Lake will remain depressed.

The availability of lower Snake River PIT tag detection data for Sawtooth FH weir releases is limited to 1992 and 1994 when total detection rates of 11% and 0%, respectively, were noted for O. nerka smolts presumably of Alturas Lake origin. Alturas Lake outmigrant detections in 1992 were 50% lower than Redfish Lake detections for the same year. In 1994, no Alturas Lake outmigrants were detected downstream compared to a 21% total detection rate for Redfish Lake outmigrants. Although only two years of data are available for direct comparison, this difference in detection rates suggests that O. nerka emigrants from Alturas Lake do not survive migration to mainstem dams as well as outmigrants from Redfish Lake (assuming similar outmigration and arrival timing).

Natural Spawning Investigations

Telemetry investigations conducted on Redfish Lake in 1994 generated information relevant to evaluating performance differences observed among adult broodstock releases with differing life histories and broodstock origins. In addition, the future direction and design of this release strategy will depend, in part, on the data collected to date.

Telemetry investigations of 24 ultrasonic-tagged, captive broodstock adults released to Redfish Lake in 1993 identified three general areas of site selection: (1) Sockeye Beach, (2) Point Campground, and (3) the southwest shore (Kline 1994). During November 1993 snorkel investigations, one pair of broodstock outplants was observed guarding a redd near the southwest shore of the lake (TOC Minutes - November, 1993). Two transmitters were subsequently located in the vicinity of this activity.

During 1994 telemetry efforts, we made no observations of sustained site association or spawning-related activities for any of the 37 ultrasonic-tagged release fish. Additionally, no stationary tags were located near areas of known or suspected spawning activity. At the termination of 1994 telemetry efforts, 29.7% of the transmitters (11 of 37 tags) were still active. Kline (1994) reported similar findings (33.3% active, eight of 24 tags) at the termination of the 1993 tracking investigation. Active signals most likely represent broodstock fish that did not mature. While very limited observations of spawning-related activity were observed during both years of investigation, we can not assume that additional activity and spawning success did not occur. The weekly periodicity of SBT and IDFG spawning surveys does suggest that spawning-activities could simply have been missed. Recovered transmitters represent the only known mortalities. Absent transmitter signals could represent additional mortality, tag failure, poor or obscured signal strength, fish migration to tracking-restricted locations (e.g., inlet and outlet streams), or out-of-lake transmitters. Predation and illegal angler harvest are suspected as possible explanations for absent transmitter signals. One report of one angler catching and releasing what was reportedly a broodstock outplant was received by IDFG in 1994 (Brent Snyder, IDFG, Stanley, Idaho). Although Redfish Lake receives limited angling effort, the possibility remains that additional broodstock outplants were lost to illegal angling harvest. Stationary signals could represent additional mortality, out-of-fish transmitter status, or stationary fish. The latter condition was carefully investigated during both years of this effort. Transmitters identified as stationary rarely initiated movement following three successive weeks of stationary status. We suggest that stationary signals represent out-of-fish transmitter status. However, without knowing if tag expulsion occurred (or to what degree), we cannot speculate further as to whether out-of-fish signals represent mortalities.

The performance differences we identified with respect to final transmitter status for brood year 1991 and outmigrant 1991 outplants are significant, yet, We were unable to identify any clear pattern of fish distribution during the 1994 telemetry effort. No consistent assemblages of individual fish or association with specific lake regions were observed from week to week. With very few exceptions, we recorded active fish in new locations on each survey date.

No observations of sustained site selection or fidelity with areas of known or suspected lake spawning activity were made in 1994. Snorkel and boat surveys of beach spawning areas conducted in October and November were unsuccessful in recording any observations of pairing or spawning for either 1994 broodstock releases or for the two surviving 1993 outplants. No observations of the 19 brood year 1992 residual outplants were recorded during October and November snorkel and boat surveys of known and suspected spawning locations.

We recovered three (8.1%) of the 37 transmitters implanted in broodstock outplants in 1994 (Table 7). One transmitter was recovered from a carcass September 9 in 1 m deep water near the southwest shore of the lake. Subsequent tag identification and carcass inspection identified this individual as a brood year 1991 female. We observed no indication that this fish had spawned based on the large number of eggs present in the body cavity. This individual represents our only known mortality within the 1994 release groups as the other two recovered tags were not associated with carcasses.

At the termination of 1994 tracking efforts on November 22, 12 of the 37 transmitters (32.4%) implanted in 1994 were not emitting signals from Redfish Lake (Table 7). Eight of these transmitters had been implanted in brood year 1991 progeny. Three and one of these transmitters had been implanted in outmigrant 1991 and 1992 fish, respectively. Twenty-two of the 37 transmitters were emitting in-lake signals on the final day of tracking (Table 3). Eleven of these signals (29.7%) were stationary and had been for a minimum of three consecutive tracking dates. The remaining 11 transmitter signals (29.7%) were still active. Of the 11 stationary transmitters, seven and four had been implanted in brood year 1991 progeny and outmigrant 1991 fish, respectively. Eight and three of the active transmitters had been implanted in outmigrant 1991 fish and brood year 1991 progeny, respectively.

A significant difference was found between mean fork lengths (t = 3.353, P = .002) and weights (t = 2.291, P = .028) of outmigrant 1991 and brood year 1991 adult broodstock fish implanted with ultrasonic transmitters. Outmi'grant 1991 and brood year 1991 broodstock outplants averaged 579 g and 538 g in weight and 2,916 mm and 2,443 mm in fork length, respectively. Outmigrant 1991 fish were also approximately 2 years older than brood year 1991 fish. We detected a significant difference in the final transmitter status of release groups (χ^2 = 4.953, P = .026) with respect to our comparison of the number of fish with stationary and missing transmitter status compared to active status at the end of the tracking effort.

Predator Investigations

We captured 167 fish in 96 hr of trap netting on Redfish Lake. The total catch per unit effort (CPUE) was 1.74 fish per trap net hour for the two night survey (Table 8). Mountain whitefish comprised the majority of the catch (65.8%). Northern squawfish and bull trout represented 4.2% and 2.4% of the total catch, respectively. Redside shiners, mountain suckers, brook trout, and O. nerka comprised the remainder of the catch. Of these four species, redside shiners were the most prevalent representing 18.0% of the total catch.

Bull trout fork lengths ranged from 120 mm to 288 mm; all northern squawfish captured during the survey were less than 190 mm in fork length. We did not attempt to lavage the stomach contents of these two species as we felt, due to their small size, they would not withstand the procedure.

Trap netting following ice-out might also prove unacceptable as O. nerka recruit to the lake from Fishhook Creek and lake shore spawning areas in early spring. Sockeye and kokanee fry remain littoral for an unknown period of time following their emergence and introduction to the lake community. During this time, they could be particularly susceptible to capture gear set in shallow water adjacent to the shore. Trap nets typically have smaller mesh in the containment area than on the lead or at the opening. Juvenile O. nerka that do not avoid the larger entry mesh could become trapped in the containment area.

Future efforts to estimate the bull trout population in Redfish Lake should concentrate on looking at specific life history aspects of the species during its association with Fishhook Creek. Adult spawner counts, redd counts, fecundity and egg-to-fry survival estimates could provide enough information to formulate an index of production. By answering questions about consecutive year spawning, term of stream residency by juveniles, and in-stream mortality, an estimate of bull trout recruitment to the lake could be generated.

Parental Lineage Investigations

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 (Kalish 1989,1990; Radtke 1989). 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; Rieman et al. 1993).

Otolith microchemistry has been used to discriminate individual fish from female parents of known anadromous and freshwater origin. Kalish (1990) reported that differences between Sr/Ca ratios in otolith primordia of sea-farmed and freshwater juvenile rainbow trout were great enough to identify individual life history (with respect to habitat location) during egg development. Mean nuclear Sr/Ca ratios reported by Kalish (1990) were between 0.0022 and 0.0052 for the progeny of sea-farmed rainbow trout. Rieman et al. (1993) reported mean nuclear Sr/Ca ratios between 0.0011 and 0.0020 for O. nerka progeny with known lineage to anadromous adults. Secor et al. (1994) used otolith microchemistry to describe the environmental life history of individual striped bass Morone saxatilis across a salinity gradient. They reported that mean nuclear Sr/Ca ratios between 0.0020 and 0.0030 were indicative of estuarine salinities and ratios >0.0035 were indicative of marine salinities.

Rieman et al. (1993) observed mean nuclear Sr/Ca ratios >0.0014 in otoliths of the five anadromous adults that returned to Redfish Lake in 1991 and 1992. They concluded that all five adult sockeye salmon were direct descendants of female anadromous parents that completed egg development in saltwater. Kline (1994) reported, however, that two of the eight anadromous adults that returned in 1993 exhibited microchemistry results suggesting direct lineage to freshwater female parents (<0.0008). Kline (1994) speculated these data could link anadromous adults to the freshwater residual O. nerka component of Redfish Lake. One of the eight anadromous adults analyzed by Kline (1994) exhibited mean, nuclear Sr/Ca results indicative of uncertain lineage (0.0008 - 0.0014).

Otolith microchemistry results from the one anadromous female sockeye salmon that returned to Redfish Lake in 1994 reflected direct lineage to an anadromous female parent (mean nuclear Sr/Ca >0.0014). The age of this individual (4+)

Table 6. Median travel times and downstream detection rates for PIT-tagged O. nerka outmigrants released from Redfish Lake Creek in 1994.

Detection Location	Number of fish detected	Travel time (d)
Lower Granite Dam	38	12.0
Little Goose Dam	49	16.7
Lower Monumental Dam	32	21.5
McNary Dam	33	21.5
Total Detections	151	

Total number of PIT-tagged O. nerka released = 717

Total detection rate = 21%

susceptible to capture by trap nets and gill nets are presently restricted from use by NMFS. As an immediate means of tracking bull trout reproduction potential and trend, we recommend that adult spawner counts and redd counts be initiated in Fishhook Creek to establish baseline data in this regard.

3) We recommend that additional otolith microchemistry data be collected for 0. nerka progeny associated with known life history to help refine our interpretation of the origin of Stanley Basin O. nerka with uncertain life history.

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A P P E N D I C E S

Appendix A. Length, weight, lineage, and sex information for 1994 ultrasonic-tagged adult captive broodstock O. nerka outplants to Redfish Lake. OM91 = 1991 outmigrants. OM92 = 1992 outmigrants. BY91 = progeny of 1991 anadromous adults.

Codes[a]	Length[b] (mm)	Weight (g)	Lineage	Sex
97	555	2898	OM91	FM
13-3	610	3480	OM91	FM?
266	570	3070	OM91	FM
366	590	3074	OM91	M
455	570	2920	OM91	M
464	575	2910	OM91	FM
473	555	2580	OM91	FM
2228	595	3346	OM91	FM
2237	610	2000	OM91	M
2345	600	2732	OM91	M
2354	560	2862	OM91	M
2363	670	4310	OM91	M
2435	555	2372	OM91	M
2543	540	2410	OM91	FM
2633	528	2778	OM91	M
14-2	490	1516	OM92	FM
356	538	2118	OM92	FM
88	520	2200	BY91	FM
10-6	540	2250	BY91	FM
11-5	520	2190	BY91	FM
12-4	520	2215	BY91	FM
239	540	2440	BY91	M
248	540	2278	BY91	FM
285	480	1520	BY91	FM
293	510	1980	BY91	FM
338	595	3220	BY91	FM
347	515	2158	BY91	FM
374	580	3200	BY91	M
365	535	2092	BY91	FM
446	537	2704	BY91	FM
554	590	2890	BY91	M
555	580	2860	BY91	M
2273	535	2286	BY91	FM
2426	590	3090	BY91	M
3335	454	2642	BY91	M
3344	545	2390	BY91	FM
3434	530	2250	BY91	FM

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

Appendix B. Age, weight, and fork length of O. nerka captured in fall 1994 midwater trawls of four Stanley Basin lakes. RFL = Redfish Lake, ALT = Alturas Lake, PET = Pettit Lake, STA = Stanley Lake.

Lake/Fish No	Age	Weight (g)	Fork Length (mm)
RFL/01	0+	0.5	36
RFL/02	0+	0.7	41
RFL/03	0+	0.8	42
RFL/04	0+	1.1	42
RFL/05	0+	0.8	42
RFL/06	0+	0.8	43
RFL/07	0+	0.8	43
RFL/08	0+	0.8	44
RFL/09	0+	0.9	44
RFL/10	0+	0.9	44
RFL/11	0+	1.1	45
RFL/12	0+	0.9	45
RFL/13	0+	1.2	46
RFL/14	0+	1.1	47
RFL/15	0+	0.9	47
RFL/16	0+	1.0	47
RFL/17	0+	1.2	52
RFL/18	0+	1.3	53
RFL/19	0+	1.5	54
RFL/20	0+	1.9	55
RFL/21	0+	1.8	55
RFL/22	0+	2.2	58
RFL/23	0+	2.2	60
RFL/24	0+	2.5	62
RFL/25	0+	2.1	62
RFL/26	0+	3.3	66
RFL/27	1+	4.8	78
RFL/28	1+	5.3	81
RFL/29	1+	5.8	82
RFL/30	1+	7.5	89
RFL/31	1+	18.2	118
RFL/32	2+	34.6	144
RFL/33	2+	41.6	150
RFL/34	2+	43.7	154
RFL/35	2+	47.8	156
RFL/36	2+	48.6	157
RFL/37	2+	53.1	161
RFL/38	2+	49.9	163
RFL/39	2+	51.6	165
RFL/40	2+	54.2	167
RFL/41	2+	56.1	168
RFL/42	2+	54.9	174
RFL/43	2+	65.1	179
RFL/44	2+	63.7	183

Appendix B. Continued.

Lake/Fish No	Age	Weight (g)	Fork Length (mm)
ALT/O1	2+	17.8	123
ALT/O2	2+	20.4	125
ALT/O3	2+	21.2	129
ALT/O4	2+	22.2	136
ALT/O5	2+	24.0	138
ALT/O6	2+	25.4	139
ALT/O7	3+	25.6	137
ALT/O8	3+	27.3	138
ALT/O9	3+	28.1	138
ALT/1O	3+	27.3	139
ALT/11	3+	29.3	143
ALT/12	3+	29.6	146
PET/O1	O+	0.1	24
PET/O2	O+	0.4	35
PET/03	O+	0.4	39
PET/04	O+	0.5	39
PET/OS	O+	0.5	39
PET/06	O+	0.5	39
PET/07	O+	0.6	40
PET/08	O+	0.6	4O
PET/OS	O+	0.7	4O
PET/1O	O+	0.7	41
PET/11	O+	0.8	43
PET/12	O+	0.9	43
PET/13	O+	1.1	44
PET/14	O+	0.8	44
PET/15	O+	1.5	54
PET/16	O+	0.9	44
PET/17	1+	18.3	11.6
PET/18	1+	24.3	125
PET/19	1+	21.6	126
PET/2O	1+	24.7	128
PET/21	1+	28.0	129
PET/22	1+	28.7	129
PET/23	1+	26.7	130
PET/24	1+	27.9	131
PET/25	1+	29.6	131
PET/26	1+	29.2	132
PET/27	1+	28.9	133
PET/28	1+	29.2	134
PET/29	1+	28.6	135
PET/30	1+	38.0	137
PET/31	1+	30.1	139
PET/32	1+	32.6	140
PET/33	1+	34.8	142
PET/34	1+	37.3	142
PET/35	1+	34.2	144
PET/36	1+	35.6	144
PET/37	1+	38.4	144
PET/38	1+	33.8	144
PET/39	1+	42.6	145
PET/40	1+	39.7	146
PET/41	1+	37.5	147

Appendix B. Continued.

Lake/Fish No	Age	Weight (g)	Fork Length (mm)
PET/42	2+	44.9	150
PET/43	2+	43.9	150
PET/44	2+	42.1	150
PET/45	2+	42.7	151
PET/46	2+	48.3	153
PET/47	2+	46.0	153
PET/48	2+	43.1	154
PET/49	2+	43.1	154
PET/50	2+	52.5	156
PET/51	2+	53.5	159
PET/52	2+	54.0	159
PET/53	2+	54.5	159
PET/54	3+	189.4	237
PET/55	3+	305.9	265
STA/01	0+	1.4	52
STA/02	0+	2.2	54
STA/03	0+	2.7	69
STA/04	0+	3.1	70
STA/05	0+	4.3	73
STA/06	0+	5.1	75
STA/07	0+	6.3	76
STA/08	0+	5.2	78
STA/09	0+	6.8	82
STA/10	0+	6.7	83
STA/11	0+	7.8	85
STA/12	0+	6.5	85
STA/13	0+	6.7	85
STA/14	0+	8.1	88
STA/15	1+	36.1	150
STA/16	1+	40.0	154
STA/17	1+	41.6	155
STA/18	1+	47.0	162

Appendix C. Mean Sr/Ca ratios and standard deviations measured in otolith nuclei from Redfish Lake O. nerka with differing life histories. Fish ID indicates life history (BY91 = brood year 1991 progeny of 1991 anadromous adult returns, BY93 = brood year 1993 progeny of 1993 adult returns, AN94 = 1994 female adult return).

Fish ID	Nuclear Sr/Ca	SD
AN94-565	0.001456	0.000142
BY91-1	0.001774	0.000094
BY91-2	0.001715	0.000132
BY91-3	0.001937	0.000200
BY91-8	0.001812	0.000081
BY91-9	0.001669	0.000142
BY91-10	0.001832	0.000124
BY91-11	0.001929	0.000103
BY91-12	0.001849	0.000149
BY91-13	0.002104	0.000099
BY91-14	0.001839	0.000115
BY91-15	0.002061	0.000063
BY91-16	0.001953	0.000140
BY91-17	0.001787	0.000124
BY91-18	0.001729	0.000148
BY91-19	0.001964	0.000103
BY91-20	0.001972	0.000082
BY91-21	0.001888	0.000131
BY91-22	0.001870	0.000163
BY91-24	0.001911	0.000103
BY91-25	0.001913	0.000078
BY91-26	0.001937	0.000142
BY91-27	0.001896	0.000140
BY91-28	0.001934	0.000124
BY91-29	0.002009	0.000124
BY91-30	0.001828	0.000154
BY91-31	0.001935	0.000115
BY91-32	0.001909	0.000078
BY91-33	0.001755	0.000117
BY91-34	0.001840	0.000096
BY91-35	0.001945	0.000084
BY91-36	0.001906	0.000094
BY91-37	0.001924	0.000117
BY91-38	0.001875	0.000094
BY91-39	0.001887	0.000133
BY91-40	0.001961	0.000096
BY91-41	0.002001	0.000115
BY91-42	0.001936	0.000096
BY91-43	0.002020	0.000073
BY91-44	0.001827	0.000141
BY91-45	0.001768	0.000113
BY91-46	0.002058	0.000082
BY91-47	0.001935	0.000157
BY91-48	0.001818	0.000132
BY91-49	0.001969	0.000141
BY91-50	0.001973	0.000082
BY91-304	0.001894	0.000081
BY91-305	0.001787	0.000091
BY91-307	0.001846	0.000117
BY91-308	0.001772	0.000070
BY91-309	0.001791	0.000119
BY91-310	0.001794	0.000073
BY91-312	0.001878	0.000078

Appendix C. Cont.

Fish ID	Nuclear Sr/Ca	SD
BY91-313	0.001697	0.000155
BY91-314	0.001940	0.000115
BY93-1	0.001734	0.000094
BY93-3	0.001645	0.000117
BY93-4	0.001665	0.000105
BY93-5	0.001770	0.000188
BY93-6	0.001307	0.000144
BY93-7	0.001089	0.000115
BY93-8	0.001083	0.000109
BY93-9	0.000801	0.000128
BY93-10	0.001742	0.000126
BY93-11	0.001625	0.000296
BY93-12	0.001560	0.000117

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