FISHERY RESEARCH

SNAKE RIVER SOCKEYE SALMON CAPTIVE BROODSTOCK PROGRAM RESEARCH ELEMENT

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SNAKE RIVER SOCKEYE SALMON CAPTIVE BROODSTOCK PROGRAM RESEARCH ELEMENT

2013-2015 Annual Project Progress Report

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EXECUTIVE SUMMARY

Sockeye Salmon returns to the basin have increased in recent years and the program has successfully prevented extinction and preserved the genetic lineage of the Redfish Lake stock. In 2013, 272 adults returned, 1,579 in 2014, and 91 in 2015 (35 were collected from Lower Granite Dam). Snake River Sockeye Salmon anadromous populations remain sporadic as a result of variable and oftentimes marginal in-river (e.g., 2015) and ocean environments, and the hatchery is needed to meet abundance and recovery criteria. While numbers have increased more recently, Snake River Sockeye Salmon are not considered recovered until the population is made up of natural-origin fish spawning in the wild in greater numbers, which will depend on increasing juvenile and adult survival.

Since initiation of the Captive Broodstock Program in the early 1990s, there has been an increasing trend in the number of Sockeye Salmon outmigrants from the Sawtooth Valley basin, mainly from the production and release of hatchery reared smolts. Differences in outmigration survival have been observed among some years between smolts leaving the lake (natural origin and presmolt releases) compared to hatchery-origin smolts released directly into the creek originating from the Sawtooth, Oxbow, and Springfield fish hatcheries. One possible hypothesis for these observed survival differences could be that full-term smolts released all at once (high densities) survive better to LGR through “predator saturation.” In 2015, survival estimates for Springfield Hatchery produced smolts was the lowest of the three hatchery produced groups and fish displayed external symptoms of gas bubble disease (GBD). Size and age at emigration observed for juvenile Sockeye Salmon emigrating from Redfish and Pettit lakes over the past 15 years imply acquisition of adequate dietary resources and nutrient availability.

Success of the program and the ability to maintain and increase population abundance in the natal lakes has been accomplished by using adult release strategies. Full-term captive and anadromous adults have been released for volitional spawning since 1993 and there has been a high correlation between the number of females released and estimated natural juvenile outmigrants. In years more females were released, we observed higher production of smolts. Smolt-to-adult return rates suggest that volitional spawning within Redfish Lake appears to be an important strategy to the success of the Snake River Sockeye Salmon Captive Broodstock Program. Natural production (primarily resulting from adult releases) occurring within Redfish Lake had the highest overall survival rates from the smolt-to-adult life stage despite having lower emigration survival from the Sawtooth Valley basin to Lower Granite Dam. The use of full-term hatchery smolt production (both the OFH and SFH) followed natural production as the second best release strategy with smolts reared at the Oxbow Hatchery outperforming smolts reared at the Sawtooth Hatchery some years. Future releases will focus on full-term hatchery smolt (primarily Springfield Fish Hatchery) and anadromous and captive adult releases. Full-term smolt production was observed to produce the highest number of R/S among the “spread-the-risk” release strategies and is important for population amplification and will continue to be an important recovery strategy as natural production remains sporadic.

Fishing pressure on Redfish Lake is low and approximately one-third of the angling is from shore targeting species other than *O. nerka*. There has not been a negative population level impact resulting from the non-listed resident kokanee fishery in Redfish Lake on the Snake River Sockeye Salmon population since it was reestablished in 1995.

PART 1—SNAKE RIVER SOCKEYE SALMON CAPTIVE BROODSTOCK PROGRAM OVERVIEW

The Idaho Department of Fish and Game (IDFG) initiated the Snake River Sockeye Salmon *Oncorhynchus nerka* Captive Broodstock Program in May 1991, in response to the decline of anadromous returns to the Sawtooth Valley basin in central Idaho. Historically, Redfish, Alturas, Pettit, Stanley, and Yellowbelly lakes supported Sockeye Salmon in the Sawtooth Valley basin (Chapman et al. 1990; Evermann 1895; Bjornn et al. 1968; Figure 1). Historical observations and discussions with local residents (Evermann 1895 and 1896) described the Sawtooth Valley basin lakes as being important spawning and rearing areas for Sockeye Salmon; however, actual adult escapement enumeration or estimations were not conducted at this time. Adult sockeye salmon escapement to Redfish Lake was enumerated from 1954 through 1966 by the IDFG, University of Idaho, and the United States Bureau of Commercial Fisheries. During this time, adult escapement ranged from a high of 4,361 in 1955 to a low of 11 in 1961 (Bjornn et al. 1968). Adult escapement enumeration was reinitiated in 1985 by the IDFG. Between 1985 and 1990, 61 adults were estimated to have returned to the Sawtooth Valley basin (Table 1). This number declined to zero anadromous adults or redds observed in Redfish Lake in 1990. Hydropower development, water withdrawal and diversions, water storage, harvest, predation, and inadequate regulatory mechanisms were outlined as factors contributing to the decline of Snake River Sockeye Salmon (Federal Register 1991).

As a result of the declines, the National Marine Fisheries Service (NMFS) listed Snake River Sockeye Salmon as an endangered evolutionarily significant unit (ESU) under the Endangered Species Act in November of 1991 (Federal Register 1991). To be considered an ESU for listing determinations, a stock must satisfy two criteria: 1) it must be reproductively isolated from other conspecific population units; and 2) it must represent an important component in the evolutionary legacy of the biological species (Waples 1991). At the time of listing, the Redfish Lake Sockeye Salmon population was the only remaining population of the Snake River Sockeye Salmon stock. Snake River Sockeye Salmon are also only one of three remaining stocks of Sockeye Salmon in the Columbia River system; the other two stocks, Okanogan Lake and Wenatchee Lake Sockeye Salmon, are located in tributaries of the upper Columbia River. Approximately 1,127 river kilometers separate Snake River Sockeye Salmon from the nearest Sockeye Salmon populations in the upper Columbia River. Genetic analysis showed genetic differentiation of Snake River Sockeye Salmon from the upper Columbia River stocks (Waples et al. 2011; Winans et al. 1996). Mitochondrial DNA analyses confirmed the genetic isolation of the upper Columbia River stocks from the Snake River Sockeye Salmon stock (Faler and Powell 2003). Sockeye Salmon returning to Redfish Lake travel a greater distance from the Pacific Ocean (1,448 river kilometers) and to a higher elevation (2,138 meters) than any other Sockeye Salmon population in the world. Additionally, Redfish Lake supports the species' southernmost population within its recognized range (Burgner 1991). Together these characteristics presented a strong argument for the reproductive discreetness and ecological uniqueness of the Snake River habitat and for the unique adaptive genetic characteristics of the Snake River Sockeye Salmon stock (Waples et al. 1991).

Three distinct life histories of *O. nerka* (Sockeye Salmon) have been observed in Redfish Lake. Anadromous *O. nerka* spawn on the shoals of the lake in October and November. Juveniles out-migrate during the spring at age-1+ or age-2+ and remain in the ocean for one to three years before returning to their natal area to spawn. Residual *O. nerka* can spawn with the anadromous life history on the shoals of the lake in October and November. Residual *O. nerka* spend their entire life in their nursery lake. Variable proportions of anadromous and residual progeny may conform to a residual life history pattern. Resident *O. nerka* (kokanee) also complete their life cycle in freshwater. They remain in Redfish Lake until maturation and spawn in Fishhook Creek, a tributary creek to Redfish Lake, in August and September. Kokanee are indigenous to Redfish Lake but were periodically stocked from a range of non-indigenous hatchery sources beginning in 1930 and continuing through 1972 (Bowler 1990). Redfish Lake anadromous, residual, and outmigrant Sockeye Salmon were determined to be genetically similar, whereas kokanee were found to be genetically different (Brannon et al. 1992, 1994; Cummings et al. 1997; Waples et al. 2011). Because of their genetic similarity, residual Sockeye Salmon were added to the ESU listing in 1992.

At the initiation of the program, IDFG collected fish from the following sources for broodstock and reintroduction purposes: 1) all anadromous adult returns that were trapped between 1991 and 1998 were retained for hatchery spawning, 2) residual adults trapped between 1992 and 1995 were retained for hatchery spawning, and 3) smolts trapped between 1991 and 1993 were reared until maturity and spawned in the hatchery. Both IDFG and National Oceanic and Atmospheric Administration (NOAA) Fisheries maintain Snake River Sockeye Salmon captive broodstocks. Groups of fish were reared at two facilities to avoid the potential catastrophic loss of the unique genetics of the stock. Idaho Department of Fish and Game rears annual captive broodstocks from the egg stage to maturity at Eagle Fish Hatchery (EFH) in Eagle, Idaho (Johnson 1993; Johnson and Pravecek 1995, 1996; Pravecek and Johnson 1997; Pravecek and Kline 1998; Kline and Heindel 1999; Kline et al. 2003a, 2003b; Kline and Willard 2001; Baker et al. 2005a, 2005b, 2006, 2007, 2009a). Additionally, NOAA Fisheries rears duplicate captive broodstock from the egg stage to maturity at the Manchester Research Station (MRS) and Burley Creek Hatchery (BCH) near Seattle, Washington (Flagg 1993; Flagg and McAuley 1994; Flagg et al. 1996, 2001; Frost et al. 2002, 2008). Historically, eyed eggs were shipped to two production hatcheries, including Oxbow Fish Hatchery (OFH) located near Cascade Locks, Oregon and Sawtooth Fish Hatchery (SFH) located near Stanley, Idaho. Starting in 2013, eyed eggs were also shipped to Springfield Hatchery (SFH) near Blackfoot, Idaho for rearing captive broodstock progeny (produced at EFH and BCH) to the full-term smolt life stage. The program is beginning to phase out juvenile rearing at the Oxbow and Sawtooth fish hatcheries and focus on rearing larger numbers of smolts at the Springfield Hatchery. In 2015, all eyed eggs were transferred to the Springfield Hatchery for juvenile rearing. History of egg and fish reintroductions from the Snake River Sockeye Salmon Captive Broodstock Program is summarized in Table 2.

PROJECT GOALS

The initial goals of the program were to utilize captive broodstock technology to avoid extinction and conserve genetic diversity of this unique ESU. Long-term programmatic goals include increasing the number of individuals in the population with future plans to recover and de-list the ESU and provide sport and treaty harvest opportunity. Draft ESA delisting criteria for Snake River Sockeye Salmon includes a minimum spawning abundance threshold measured as a ten-year geometric mean of 1,000 natural-origin spawners in Redfish and Alturas lakes and 500 natural-origin spawners in Pettit Lake (NMFS 2015). In addition, population growth needs to be stable or increasing with low to moderate risk ratings for spatial structure and diversity. Current research and monitoring focuses on quantifying natural production and producing Viable Salmonid Population (VSP) metrics used to evaluate delisting criteria.

PROJECT OBJECTIVES

1. Develop captive broodstocks from Redfish Lake Sockeye Salmon, culture broodstocks, and produce progeny for reintroduction.

2. Determine the contribution that hatchery-produced Sockeye Salmon make toward avoiding population extinction and increasing population abundance.

3. Describe *O. nerka* population characteristics for Sawtooth Valley basin lakes in relation to carrying capacity and broodstock program reintroduction efforts.

4. Utilize genetic analysis to discern family relationships, origin (e.g. release strategy), and age of natural and hatchery Sockeye Salmon to provide maximum effectiveness in their utilization within the broodstock program.

5. Transfer technology through participation in the technical oversight committee process, provide written activity reports, and participate in essential program management and planning activities.

Idaho Department of Fish and Game's participation in the Snake River Sockeye Salmon Captive Broodstock Program is comprised of three areas of effort: 1) captive broodstock culture, 2) hatchery and field research and evaluations, and 3) genetic evaluations. Although objectives and tasks from all three components overlap and contribute to achieving the same goals, work directly related to the culture of Snake River Sockeye Salmon captive broodstock appears under a separate cover (Baker et al. 2016). Research and genetic evaluation activities associated with Snake River Sockeye Salmon are permitted under NOAA permit No. 1124, FMEP, and 1454. This report describes the following research activities: *O. nerka* population monitoring and sport fishery investigations on Redfish Lake, Sockeye Salmon juvenile outmigrant monitoring and evaluation, and anadromous trapping and natural production monitoring and evaluations.

STUDY AREA

The program's recovery efforts focus on Redfish, Pettit, and Alturas lakes in the Sawtooth Valley basin located within the Sawtooth National Recreation Area (Figure 1). These lakes provide critical spawning and rearing habitat. Lakes in the Sawtooth Valley basin are glacial-carved and considered oligotrophic. The three lakes range in elevation from 1,996 m (Redfish Lake) to 2,138 m (Alturas Lake) and are located 1,448 km (Redfish Lake) to 1,469 km (Alturas Lake) from the Pacific Ocean. Redfish Lake is the largest of the three lakes (615 ha), Pettit Lake is the smallest (160 ha), and Alturas Lake (338 ha) is intermediate in surface area. Reintroduction efforts have been ongoing in Redfish Lake since 1993, Pettit Lake since 1995, and Alturas Lake since 1997.

In addition to *O. nerka*, numerous native and nonnative fish reside in the study lakes and streams within the Sawtooth Valley basin. Native fish present in Sawtooth Valley basin waters include: Chinook Salmon (*O. tshawytscha)*, Rainbow Trout/steelhead *(O. mykiss)*, Westslope Cutthroat Trout *(O. clarkii lewisi)*, Bull Trout *(Salvelinus confluentus)*, Sucker *(Catostomus* spp.*)*, Northern Pikeminnow *(Ptychocheilus oregonensis)*, Mountain Whitefish *(Prosopium williamsoni)*, Redside Shiner *(Richardsonius balteatus)*, Dace *(Rhinichthys* spp.*)*, and Sculpin *(Cottus* spp.*)*. Nonnative species present in Sawtooth Valley basin waters include Lake Trout *(S. namaycush* in Stanley Lake only) and Brook Trout *(S. fontinalis)*. Rainbow Trout were released into Pettit, Alturas, and Stanley lakes in the summer to increase sportfishing opportunities. No trout have been stocked in Redfish Lake since 1992. Non-native kokanee were periodically stocked into Redfish Lake from 1930 to 1987, and into Alturas Lake from 1921 to 1984, and into Pettit Lakes from the early 1932 to 1968 (Idaho Department of Fish and Game Stocking Database). Sportfishing on Pettit, Alturas, and Stanley lakes are covered by Idaho's statewide general fishing regulations, which allow harvest of six trout per day (excluding Bull Trout, which must be released if caught) and 25 kokanee per day. Sportfishing regulations on Redfish Lake restrict kokanee fishing/harvest to January 1 through August 7 to protect the residual component of the listed population.

Table 1. Trapped and observed anadromous adult Snake River Sockeye Salmon returns by origin to the Sawtooth Valley basin from 1985-2015.

Year	Anadromous adult trapped	Natural origin	Hatchery origin	Observed
1985	14	14	-	0
1986	29	29	-	0
1987	16	16	-	0
1988	1	1	-	0
1989	1	1	-	0
1990	0	0	-	0
1991	4	4	-	0
1992	1	1	-	0
1993	8	8	-	0
1994	1	1	-	0
1995	0	0	-	0
1996	1	1	-	0
1997	0	0	-	0
1998	1	1	-	0
1999	7	0	7	0
2000	243	10	233	14
2001	23	4	19	3
2002	15	6	9	7
2003	2	0	2	1
2004	24	4	20	3
2005	6	2	4	0
2006	3	1	2	0
2007	4	3	1	0
2008	598	140	458	51
2009	817	86	731	16
2010	1,322	178	1,144	33
2011	1,099	145	954	18
2012	242	52	190	15
2013	270	79	191	2
2014*	1,516	453	1,062	63
2015	91**	28	63	0

*one unknown origin (escaped while being handled from the trap).
**includes 35 Sockeye Salmon transported from Lower Granite Dam.

Table 2. Snake River Sockeye Salmon Captive Broodstock Program egg and fish reintroduction history 1993-2015.

Year of Reintroduction	Eyed Eggs	Presmolts	Smolts	Hatchery-Reared Adults	Anadromous Adults
1993	0	0	0	24	0
1994	0	14,119	0	63	0
1995	0	91,572	3,794	0	0
1996	105,000	1,932	11,545	120	0
1997	105,767	255,711	0	120	0
1998	0	141,871	81,615	0	0
1999	20,311	40,271	9,718	18	3
2000	65,200	72,114	148	71	200
2001	0	106,166	13,915	65	14
2002	30,924	140,410	38,672	177	12
2003	199,666	76,788	0	309	0
2004	49,134	130,716	96	244	0
2005	51,239	72,108	78,330	176	0
2006	184,596	107,292	86,052	465	0
2007	51,008	82,105	101,676	498	0
2008	67,984	84,005	150,395	396	570
2009	75,079	59,538	173,055	680	651
2010	59,683	65,851	179,278	367	1,209
2011	42,665	50,054	191,048	558	990
2012	0	11,354	166,652	622	173
2013	0	0	273,080	162	184
2014	0	0	296,389	1,098	1,073
2015	0	0	423,103	587	5
Total	**1,108,256**	**1,603,977**	**2,278,197**	**6,820**	**5,084**

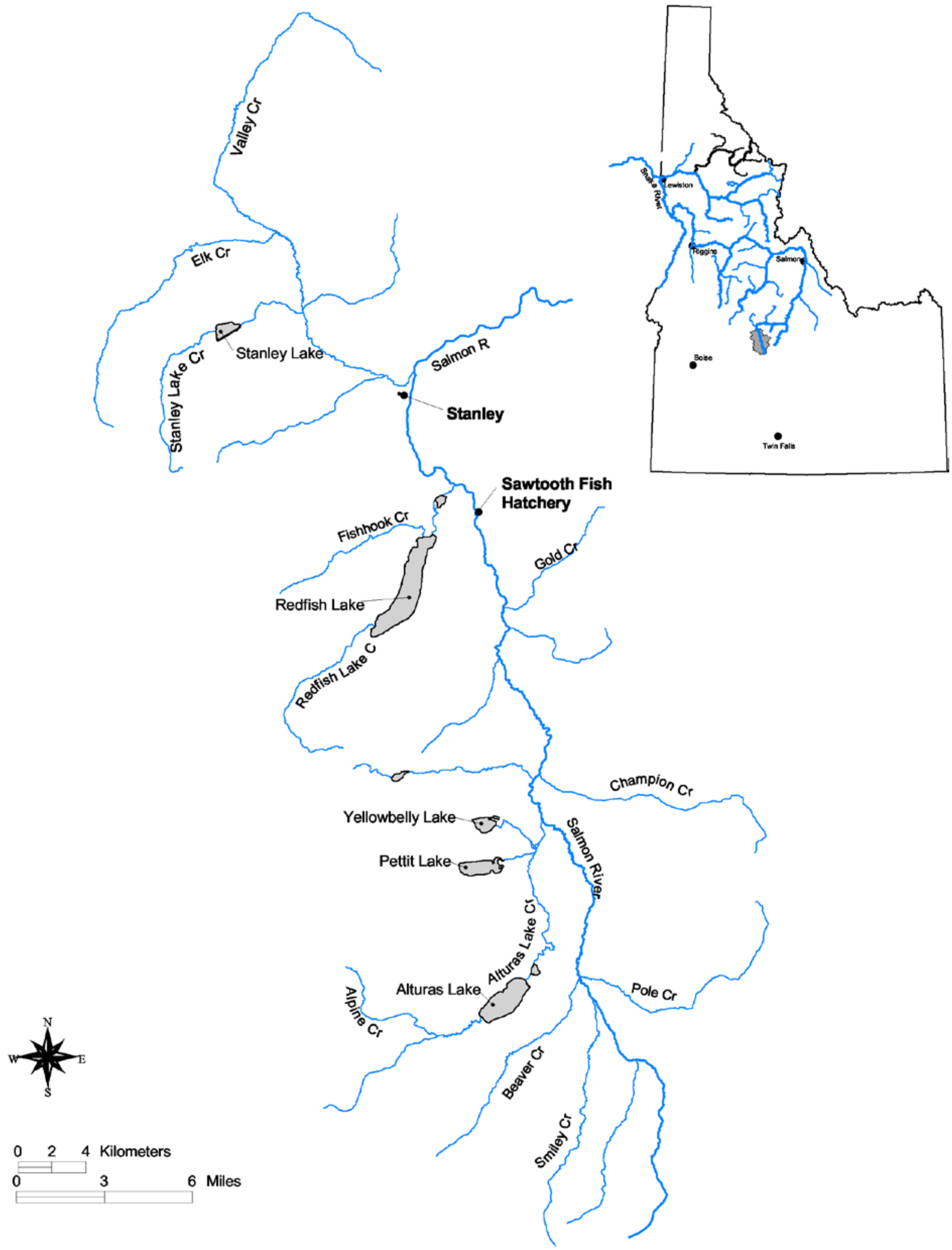

Figure 1. Map of the upper Salmon River watershed located in the Sawtooth Valley basin, Idaho.

PART 2—*ONCORHYNCHUS NERKA* POPULATION MONITORING AND REDFISH LAKE SPORT FISHERY INVESTIGATIONS

INTRODUCTION

Understanding the dynamics of *O. nerka* populations in the Sawtooth Valley basin lakes is a vital part of Sockeye Salmon restoration efforts. Knowledge of juvenile *O. nerka* abundance coupled with limnology data (collected and reported by the Shoshone-Bannock Tribes [SBT]) is important for understanding abundance, biomass, and the carrying capacity of each lake. All three historic Sawtooth Valley basin Lakes (Redfish, Alturas and Pettit lakes) currently support both ESA-listed Sockeye Salmon as part of the program's reintroduction efforts and non-listed resident, kokanee populations. Productivity in the lakes varies annually and the presence of kokanee in the nursery lakes can create increased competition for limited food sources between kokanee and Sockeye Salmon in these oligotrophic systems. During years in which a lake experienced low productivity and/or high kokanee abundance, the program has historically released hatchery-produced offspring into more productive lakes or actively controlled kokanee escapement. In this section, we report the use of midwater trawl techniques to collect biological sample data and generate annual estimates of abundance to identify trends. This was coupled with genetic and scale aging data to provide stock composition (by age and lake). As there can be limitations associated with midwater trawling (such as lake morphology or lake size), hydroacoustics can also be used to generate complementary data. Hydroacoustic data was collected and reported by the SBT under a separate report (Griswold et al. *in prep*). Currently, this information is used to gain important trend information regarding abundance, biomass, density, and assist with estimates of carrying capacity within the lakes.

The second part of this section describes the impacts from sportfishing for kokanee on the Snake River Sockeye Salmon population. Monitoring the kokanee sport fishery is another important monitoring component to understanding the dynamics of both the listed and unlisted *O. nerka* populations found within Redfish Lake. The kokanee fishery on Redfish Lake was closed in 1993 due to the presence of ESA listed residual Sockeye Salmon but was re-opened in 1995 (NOAA Fishery Management and Evaluation Plan; hereafter FMEP). The kokanee fishery was re-opened based on the recommendation of the SBSTOC to reduce kokanee competition with Sockeye Salmon by removing spawning age kokanee through angler harvest. NOAA Fisheries requires IDFG to monitor angler harvest of listed Sockeye Salmon in Redfish Lake during the kokanee fishing season. The kokanee season on Redfish Lake opens on January 1 and closes on August 7, when mature kokanee initiate spawning in Fishhook Creek, while residual Sockeye Salmon remain in the lake. A roving creel survey has been conducted yearly on Redfish Lake. This survey was designed to estimate total kokanee harvest and to collect tissue samples for genetic analysis from angler-harvested kokanee. Genetic analyses were used to estimate the number of unmarked Sockeye Salmon harvested incidental to the kokanee fishery within the lake.

METHODS

<u>*Oncorhynchus nerka* Population Monitoring</u>

Midwater trawling was conducted at night during the dark (new) phase of the moon in August to estimate total *O. nerka* (kokanee and Sockeye Salmon) abundance, density, and biomass in Sawtooth Valley basin lakes. Trawling was conducted in August to reduce the risk associated with collection or disturbance of post-released adults in the trawl catch. Surveys were also conducted in August because juvenile *O. nerka* were tightly stratified during this time of the year due to water temperatures. Trawling was performed in a stepped-oblique fashion as described by Rieman and Myers (1992) and Kline (1994). Pettit and Alturas lakes were towed for a total of six transects each. Trawl samples in Redfish Lake varied annually (Figure 2). Prior to 2012, 6-7 transects were conducted. Between 2012 and 2014, trawling effort increased to 18 transects and reduced to 7 transects in 2015. Due to the small surface area and width across the lakes, random towing direction and starting location for each transect was not possible. Therefore, the same transects each year were used utilizing GPS starting coordinates (Figure 2).

Total *O. nerka* abundance was estimated using a program developed by Rieman (1992). Abundance estimates generated by this program were extrapolations of actual trawl catch data to the total area of the lake mid-depth in the observed *O. nerka* stratum. Confidence intervals were calculated using the following formula from Scheaffer et al. (1996):

$$\bar{x} \pm t\sqrt{\frac{s^2}{n}}$$

Abundance, density, and biomass were also estimated. Fork length (to the nearest 1 mm) and weight (0.1 g) were recorded for all trawl-captured *O. nerka*; scales were removed from a subsample (a minimum of ten fish from every 10 mm length group over 50 mm) and returned to the laboratory. Research suggests that Sockeye Salmon start developing scales at a fork length ranging from 36-40 mm (Clutter and Whitesel 1956); therefore, fish under 50 mm were assumed to be age-0 for these analysis. Two program technicians aged scales to determine length ranges for age classification. Scales were mounted between microscope slides before aging and viewed with a microfiche. Stomachs were removed and preserved for diet analysis by SBT biologists. Fin clips were also taken from sampled individuals and delivered to the IDFG Genetics Laboratory for DNA analysis.

DNA was extracted using a Nexttec DNA isolation kit according to the manufacturer's instructions (http://www.nexttec.biz). Following DNA extraction, each sample was amplified with 16 microsatellite loci: One103, One104, One108, One111, One112, One114, One115, Oki1, One13, One110, One106, Omy77, Ots103, Omm1070, Ssa408, Ssa407 (Scribner et al. 1996; Smith et al. 1998; Beacham et al. 1998; Cairney et al. 2000; Olsen et al. 2000; Perry et al. 2001; Rexroad et al. 2001). Multiplex reactions were carried out for four combinations of loci (contact the authors for PCR concentrations and thermocycler profiles). Following amplification, PCR fragments were diluted at 1:30 ratio and size fractionated using an ABI3730 capillary DNA sequencer and internal size standard (GS500). Genotypes were scored by GeneMapper software version 3.0 (Applied Biosystems). Individuals representing ~10% of the sampled fish were re-amplified and scored a second time.

Genetic assignment methods were used to assign each sample to either the Redfish Lake stock or Fishhook Creek kokanee stock. The microsatellite baseline used for this study included seven collections from the Sawtooth Valley basin (captive brood stock, n = 242; Alturas, n = 266; Deadwood Reservoir kokanee, n = 55; Pettit Lake kokanee, n = 42; Stanley Lake, n = 36; Warm Lake, n = 40; Fishhook Creek, n = 321). Samples were run in program GeneClass2 (Piry et al. 2004) to determine if unknown samples belonged to a respective group (either kokanee or Sockeye Salmon) within each collection in each sampled lake. First, we carried out direct assignment then used simulation analyses to calculate the likelihood of a genotype occurring within a distribution of simulated genotypes for each baseline population. If the individual genotype likelihood is below a given threshold (e.g., 0.05), the population is excluded as a possible origin of the individual. The proportions of Snake River Sockeye Salmon and kokanee were independently derived for each lake. The number of Snake River Sockeye Salmon and kokanee were estimated by applying the proportion to the total O. nerka abundance estimate.

Redfish Lake Sport Fishery Investigations

A roving creel survey was conducted from the end of May through mid-August on Redfish Lake. The creel census was stratified by 14-day intervals, broken into weekday and weekend day types and morning (0800 to 1400) and evening (1401 to 2000) instantaneous count periods. Prior to 2015, angler counts were conducted four weekdays, two weekend days, and any holiday during each 14-d interval. In 2015, angler counts were reduced to two weekdays, two weekend days, and any holiday during each 14-d interval. On each angler count day, the number of boats and bank anglers were counted from a boat for each day period (morning and evening strata). Angler count dates and times were selected randomly. Angler interviews were conducted following the completion of each instantaneous count. Anglers were asked how many fish they had harvested and/or released by species, how many hours they had fished, what their preferred target species was, whether or not they were aware of the Redfish Lake kokanee fishery, and the type of gear they used. All responses were recorded by creel personnel. Creel data were analyzed using the Creel Application Software computer program developed by Soupir and Brown (2002) and used to estimate angler effort, catch rates, and harvest.

Fin clips were taken from harvested *O. nerka* that were checked by creel survey personnel. Fin clips were stored in 100% ethanol and delivered to IDFG Genetics Laboratory personnel for DNA analysis. Depending on the number of tissue samples collected, genetic analyses were performed to determine the number and proportion of ESA listed Sockeye Salmon in the creel. The same genetic methods identified above were used to determine the proportion of Snake River Sockeye Salmon and kokanee populations in the harvest. This proportion was expanded to the harvest rate to determine the number of Snake River Sockeye Salmon that were incidentally harvested based on the proportion harvested annually in the creel, with the exception of 2014 where the proportion harvested was based on the 2006-2014 average.

RESULTS

Oncorhynchus nerka Population Monitoring

Redfish Lake

August trawl catch on Redfish Lake between 1990 and 2015 has been highly variable ranging from 11 (2000) to 122 (2012) *O. nerka*. The number of mid-water trawl transects conducted in 2015 was reduced to 7 from 18 transects in the prior year and resulted in the collection of 15 natural origin *O. nerka* (Appendix A). Based upon this catch data, *O. nerka* abundance was estimated at 13,432 fish (95% CI ± 10,141; Figure 3). The *O. nerka* population estimate in 2015 was one of the lowest estimates observed and was approximately 70% lower than the 1990-2014 average (45,221 fish). Density and biomass were estimated at 21.8 fish/ha and <0.1 kg/ha, respectively (Appendix A). Densities estimates of *O. nerka* in Redfish Lake average 80 fish/ha (1990-2015) but fluctuate annually ranging from 17 fish/ha (2000) to 150 fish/ha (1995). In 2015, age-0 *O. nerka* was the predominant age class represented in the Redfish Lake trawl sample (average 76%) followed by age-1 *O. nerka* (16%). Age-2 (5%), age-3 (2%), and age-4 (<1%) accounted for the remainder of the year classes represented in the trawl.

Fin samples that were collected from trawl captured *O. nerka* on Redfish Lake beginning in 2006 were analyzed using microsatellite techniques to make genetic assignments. Genotypes indicative of protected Snake River Sockeye Salmon ranged from 15% (2008) to 54% (2010) of the *O. nerka* sampled from trawling (Figure 4). Abundance estimates of ESA listed Sockeye Salmon based on genetically assigned proportions ranged from 3,943 ± 749 (2008) to 36,851 ± 11,424 (2007) and averaged 15,950 (2006-2015; Figure 5). Abundance estimates for Sockeye Salmon in Redfish Lake have generally declined over the last 10 years but have remained stable over the last 3 years of sampling ranging from 6,090 ± 792 (2013) to 6,842 ± 479 (2014; Figure 5). Scale aging and genetic assignment data indicated that higher proportions of age-0 Sockeye Salmon were observed in the trawl (70-90%) compared to age-1. None of the age-2 fish were identified as Sockeye Salmon.

Alturas Lake

Annual August trawl catch on Alturas Lake varied considerable ranging from 21 *O. nerka* sampled in 2010 to 285 sampled in 2000 (>10-fold increase). Estimates of *O. nerka* abundance, density, and biomass between 1990 and 2015 averaged 65,289 fish, 224 fish/ha, and 2.5 kg/ha, respectively (Figure 6, Appendix A). Trawl catch in 2015 included 43 natural origin *O. nerka* resulting in below average abundance estimates (Figure 6). Estimates of *O. nerka* abundance, density, and biomass in 2015 was 23,760 fish (95% CI ±17,222), 70.3 fish/ha, and 1.3 kg/ha, respectively. This followed two years of above average abundance: 104,095 (95% CI ± 93,237) in 2014 and 147,204 (95% CI ± 55,871) fish in 2013 (Figure 6, Appendix A). Across all years, age-0 fish made up 51% of the catch and age-1 and age-2, 33% and 12% of the catch, respectively. Between 2011 and 2014 age-0 *O. nerka* were the predominate age class represented in the trawl 70% (2013) to 95% (2014); however, 2015 was predominantly age-1 (59%) and age-2 (34%) fish.

Fin samples were analyzed from trawl captured *O. nerka* on Alturas Lake from 2006-2015 and none of the sampled fish have ever had genotypes indicative of protected Snake River Sockeye Salmon, although some samples could not be assigned. The proportion of samples that could not be assigned ranged from 9% (2007) to 0% (2010 and 2014). Eyed eggs were released in 2010 and 2011 and presmolts were released through 2010 (Appendix B), yet none of the midwater trawl sampled *O. nerka* were identified as Sockeye Salmon.

Pettit Lake

Due to the smaller size (surface area) of Pettit Lake, August trawl catch and corresponding abundance estimates are typically the lowest of the 3 lakes sampled. Average estimates of *O. nerka* abundance, density, and biomass across all years sampled was 17,795 fish, 122.4 fish/ha, and 4.6 kg/ha, respectively (Appendix A). Abundance estimates have generally declined over the past 10 years with 2014 and 2015 being the two lowest observed (Figure 7). Estimates of *O. nerka* abundance, density, and biomass in 2015 was 1,842 fish (95% CI ± 2,282), 11.5 fish/ha, and <0.1 kg/ha, respectively (Appendix A). *O. nerka* abundance was estimated to be 1,862 (95% CI ± 1,765) in 2014 and 11,978 (95% CI ± 4,468) in 2013. Across all years age-2 and age-3 *O. nerka* represented 32% in the trawl sample, respectively, followed by age-0 (19%), age-3 (15%), and age-4 (2%); however, the age structure of trawl caught fish between years was variable.

Genotypes indicative of protected Snake River Sockeye Salmon from samples that were collected in the trawl on Pettit Lake ranged from 29% (2011) to 89% (2010) and averaged 57%. Between year comparisons were insignificant due to small sample sizes (2006-2015; Figure 4). Adjusted abundance estimates of ESA-listed Sockeye Salmon based on genetically assigned proportions ranged from 801 ± 236 (2014) to 19,283 ± 2,700 (2006) and averaged 6,587 (2006-2015; Figure 5). Abundance estimates for Sockeye Salmon in Pettit Lake in 2015 (1,105 ± 359) were lower than average but statistically similar to 2014 (801 ± 240) and significantly lower than 2013 (7,426 ±1,411). Scale aging and genetic assignment data indicated that the proportion of age-0 and age-1 Sockeye Salmon observed in the trawl sample was 56% and 27%, respectively, in 2013, and 72% (age-0) and 28% (age-1) in 2014. Of the 3 assigned Sockeye Salmon captured in the trawl during 2015, 66% were age-2 (n = 2) and 33% were age-1 (n = 1).

Redfish Lake Sport Fishery Investigations

Anglers spent approximately 2,048 hours ± 744 hours (95% CI) fishing Redfish Lake in 2015 and caught an estimated 78 *O. nerka* (55 harvested, 23 released; Figures 8 and 9). Estimates were generated from data collected during 53 angler party interviews (113 individual anglers). Angler effort during the 2015 (2,048 hours) season was 23% lower than the average effort estimated from 1996 to 2014 (2,996 hours; Figure 8). This estimated effort represents a 50% decrease in fishing pressure between 2015 and 2014 and a 30% decrease in fishing pressure compared to 2013 (Figure 8). No hatchery produced Sockeye Salmon (adipose-clipped) were observed by creel crews from Redfish Lake in 2015 and one Sockeye Salmon was illegally harvested in 2014.

The season catch rate for *O. nerka* caught (harvested + released) generally declined over the past 20 years ranging from 0.56 fish/hour (1.8 hours/fish) in 1997 to 0.02 fish/hour (i.e., 50 hours/fish) in 2010 and 2013 (Figure 9). Total catch rate in 2015 for *O. nerka* was 0.04 fish/hour (0.03 fish/hour harvested + 0.01 fish/hour released). This represented an approximate 5-fold decrease in *O. nerka* catch rates in 2014 (0.19 fish/hour) but were more in line with the lower catch rates observed since 2008 (Figure 9). Bull Trout catch and release rates have been observed since monitoring began in 1996 with catch rates exceeding those of *O. nerka* over the past 15 years (IDFG regulations prohibit harvesting Bull Trout). Average catch and release rates for Bull Trout since 2001 were 0.27 fish/hour while those for *O. nerka* during the same period were 0.13 fish/hour (Figure 9). Bull Trout catch rates in 2015 (0.26 fish/hour) and 2013 (0.25 fish/hour) were similar to the 15-year average. Bull trout catch rates were about half the 15-year average in 2014 (0.11 fish/hour) and approximately 2-3 times higher than this 15-year average from 2009-2011 (Figure 9).

The direct impact of the kokanee fishery on residual Sockeye Salmon (through incidental harvest) was evaluated using genetic analysis of tissue samples (if available) collected from *O. nerka* in the creel. Nine fin clips were taken from nine *O. nerka* observed in the creel by research personnel for genetic analysis in 2015. Two samples did not genotype. Twenty-nine percent of *O. nerka* (2 of 7) collected in 2015 were identified as Sockeye Salmon (Table 3). The seven samples have been analyzed and are included in the samples collected between 2006 and 2015 (n = 48 samples; Table 3).

Using the best available information obtained from genetic samples obtained from *O. nerka* sampled in the creel, ESA-listed Sockeye Salmon represented 29% of the samples collected from 2006-2015 (Table 4). The number of *O. nerka* sampled in the creel was low (n <10) in most years and the proportion of the samples identifies at ESA-listed Sockeye Salmon ranged from 0% (2007 and 2011) to 70% (2014). In 2014, we used an average across years (2006-2014) to estimate the proportion of Sockeye Salmon harvested (21%) within the creel because 1) the proportion of Sockeye Salmon in the creel (70%) was 2-3 times higher than previous years, 2) creel personnel contacted two fishing parties with nearly half (46%) of the harvested catch, and 3) only 10 of the 59 harvested samples were collected for genetic analyses from one group. We recognize that this average may not be the most appropriate methodology given that proportions of Sockeye Salmon, and namely residual production can change within the lake but it is the best available data. Harvest estimates for ESA-listed Sockeye Salmon between 2006 and 2015 have ranged from 15 (2008) to 117 (2014) fish (Table 4). Exploitation rates of *O. nerka* in Redfish Lake are generally low (<1%) compared to abundance estimated using trawl methods (Table 4).

DISCUSSION

***Oncorhynchus nerka* Population Monitoring**

Midwater trawl surveys have been conducted annually to quantify *O. nerka* abundance, density, and biomass within Redfish, Alturas, and Pettit lakes since 1990. The mean abundance of *O. nerka* since 1990 for Redfish, Alturas, and Pettit lakes has been 43,776, 65,289, and 17,795 *O. nerka* within each lake, respectively. Estimates of abundance, density, and biomass that were produced for each lake during this reporting period (2013-2015) are highly variable but generally fall within the lower end of the range observed from 1990-2012 at Redfish and Pettit lakes. In 2013 and 2014, the fish detected in the midwater trawl were all naturally produced juveniles and none of the 11,354 presmolts released into Redfish Lake in the summer of 2012 were detected, indicating that these fish may have already emigrated from the lake, had poor survival, or were at low density and were not captured using the midwater trawl gear (or a combination of all three scenarios). Presmolts have not been released into Pettit or Alturas Lake since 2010 and in Redfish Lake since 2012. Eyed egg releases (egg boxes) were discontinued at Redfish Lake in 1997 and Pettit and Alturas lakes in 2009 and 2011, respectively.

These population estimates represent both the non-listed resident kokanee and Snake River Sockeye Salmon stocks found within the lakes. The lack of morphological or phenotypic differences (e.g., no size differences at age) makes it difficult to differentiate between stocks. However, incorporating the use of genetic microsatellite DNA analysis has led to the development of proportions for each stock identified within our trawl sample and overall abundance by stock within each lake. While total *O. nerka* abundance fell within the range of *O. nerka* estimates and was similar to past years, the abundance estimate for the Snake River Sockeye Salmon in Redfish Lake the past three years was lower than previous years (2006-2012) despite the large number of adults released into Redfish Lake in 2011 (n = 1,548; 691 females and 857 males). Estimated abundance was lower in 2013 and 2015 due to low numbers of *O. nerka* captured in the trawl, and 2014 resulted in a low estimate because fewer *O. nerka* were genetically assigned as Sockeye Salmon. These lower abundance estimates in Redfish Lake reflect the discontinuation of presmolts releases beginning in 2013 and the relative low number of presmolts released in 2012 (11,354 fish; Appendix B). The abundance estimate of Sockeye Salmon in Pettit Lake in 2014 and 2015 was also lower than previous years due to reduced catch rates. No presmolts or eyed eggs were released into Pettit Lake since 2010, so this estimate reflects a small number of natural (e.g., residual) spawners that may be present within the lake. In Alturas Lake, none of the fish captured using trawl equipment were assigned to Snake River Sockeye Salmon stock. Snake River Sockeye Salmon have not been observed in trawl samples from Alturas Lake since initiating genetic monitoring in 2006. However, samples collected in 2008 indicated that Snake River Sockeye Salmon were in the smolt outmigration (after being planted as eyed eggs in December of 2006) and made up 22% of the total outmigration. This suggests that fish present in the lake may not always be sampled and some caution may be warranted before interpretation of these numbers. Furthermore, juvenile Sockeye Salmon abundance estimates derived from trawling were very poor predictors of outmigration (see Part 2). Taking into account the age composition (trawl catch and outmigration), trawl catch explained about 5% of the variability in the following year's emigration for Redfish and Pettit lakes.

There are a variety of reasons why fish may not be sampled. Two possible scenarios (or a combination of both) may be responsible for some of the difficulty of collecting samples in Pettit Lake. First, *O. nerka* become more difficult to sample at lower densities (Rieman 1992) and it appears that densities have decreased significantly since 2013. Second, we have observed that the *O. nerka* layer that we target for sampling has been relatively shallow (within 5 m of the surface) and *O. nerka* may be sounding to avoid the net when the boat approaches. Parkinson et al. (1994) suggested this was not a problem for kokanee within Coeur d'Alene Lake; however, they did not identify how deep the kokanee layer was observed. Some marine species have been found to sound to avoid sampling vessels (Olsen et al. 1983). Investigations should continue to identify possible causes for the decreased sampling rate observed within Pettit Lake. There may also be size selectivity (Rieman 1992; Parkinson et al. 1994) where both small fish were falling through larger mesh net panels and larger fish may be able to avoid the net altogether (Rieman 1992). Rieman (1992) estimated the least-biased abundance estimates using midwater trawl methods were for fish between 50 mm and 220 in length. Within Redfish Lake over the past 3 years between 16% and 49% of the *O. nerka* collected were smaller than 50 mm in length (Appendix A), suggesting that small fish may be captured but it was uncertain as to how many additional smaller fish may not have been sampled, potentially causing our estimate to be biased low for the age-0+ component of the population. A fry net was deployed in 2014 and resulted in catches of similar size structure to that of the trawl and was discontinued in 2015. Size-selectivity should continue to be investigated to identify the biases associated with our estimates.

Acknowledging that there may be some biases in our midwater trawl estimates, the long-term data set still provides an opportunity to identify drastic changes in abundance, densities, and biomass within the surveyed lakes. Prior to 2006, midwater trawling methods ranged from conducting one tow up to six tows per lake. Beginning in 2006, Redfish, Alturas, and Pettit lakes were standardized to use a minimum of six tows per lake. Standardization has been shown to be important to produce data sets that can be used to infer changes within the *O. nerka* population over time (Parkinson et al. 1994). Sampling has been conducted at nearly the same time of the year (within the new moon period of August), using the same equipment, trawling the same speed for each tow, and the *O. nerka* layer was completely surveyed to reduce any additional biases that may occur. With the high variance surrounding trawl catches (Rieman 1992; Parkinson et al. 1994), increased sampling occurred in 2012 in an effort to reduce our confidence bounds surrounding the estimates and provide for greater precision in estimating the proportions of each stock. Sampling effort increased to 18 tows on Redfish Lake; however, we did not see the anticipated change in our confidence bounds around the total estimate, which remained similar to the estimates for 2011 (Peterson et al. 2012b). Subsequently trawl efforts were reduced to seven transects on Redfish Lake in 2015. We were able to get a larger sample size for genetic analyses but the sample size was still low; given the low densities of *O. nerka* within the lake. Additional analyses may be needed to estimate how many tows and samples are needed at different population densities to identify a specific population change once the desired level of precision has been identified and the low densities within these lakes may preclude rigorous analyses of changes through time (Zach Klein, personal communication). *O nerka* abundance monitoring, using midwater trawl and genetic microsatellite DNA analysis, should remain a priority for the program to understand abundance, stock proportions, and changes within the two stocks present in the Sawtooth Valley basin lakes. Our understanding of how these sympatric *O. nerka* populations change and interact will become paramount as we move forward with adaptive management. This long-term data set and standardized methods should allow for interpretations of trend information that may emerge regardless of sampling biases associated with the methodology (Rieman 1992).

Redfish Lake Sport Fishery Investigations

Fishing pressure within Redfish Lake has been trending down since 1999 (Figure 8). Reduced fishing pressure limits the number of *O. nerka* captured in the fishery and the number of tissue samples collected by creel personnel to monitor potential impacts to the listed Sockeye Salmon population. The purpose of the kokanee fishery on Redfish Lake was to reduce competition for resources between non-listed resident kokanee and Snake River Sockeye Salmon. There has not been a negative impact resulting from the non-listed resident kokanee fishery within Redfish Lake on the Snake River Sockeye Salmon population since it was reestablished in 1995, and this fishery should continue to be a fisheries option in the upper Salmon River Basin.

Fishing pressure on Redfish Lake is comparatively low and approximately one-third of the angling is from shore targeting species other than pelagic *O. nerka*. Historically, incidental catch of Sockeye Salmon is low and the average *O. nerka* harvest estimates have declined 3-fold over the past 10 years (Figure 1). Low catch rates suggest that our creel survey design is sufficient to monitor the fishery impacts on the Snake River Sockeye Salmon population. Perhaps, if fishing pressure or *O. nerka* catch rates increases, the use of alternative methods to collect additional catch information and potential modifications to the current survey design may be warranted. Monitoring of the *O. nerka* fishery on Redfish Lake will continue and creel personnel will continue to collect genetic samples from angler caught *O. nerka* during the 2016 creel survey to approximate the proportion of Sockeye Salmon harvested.

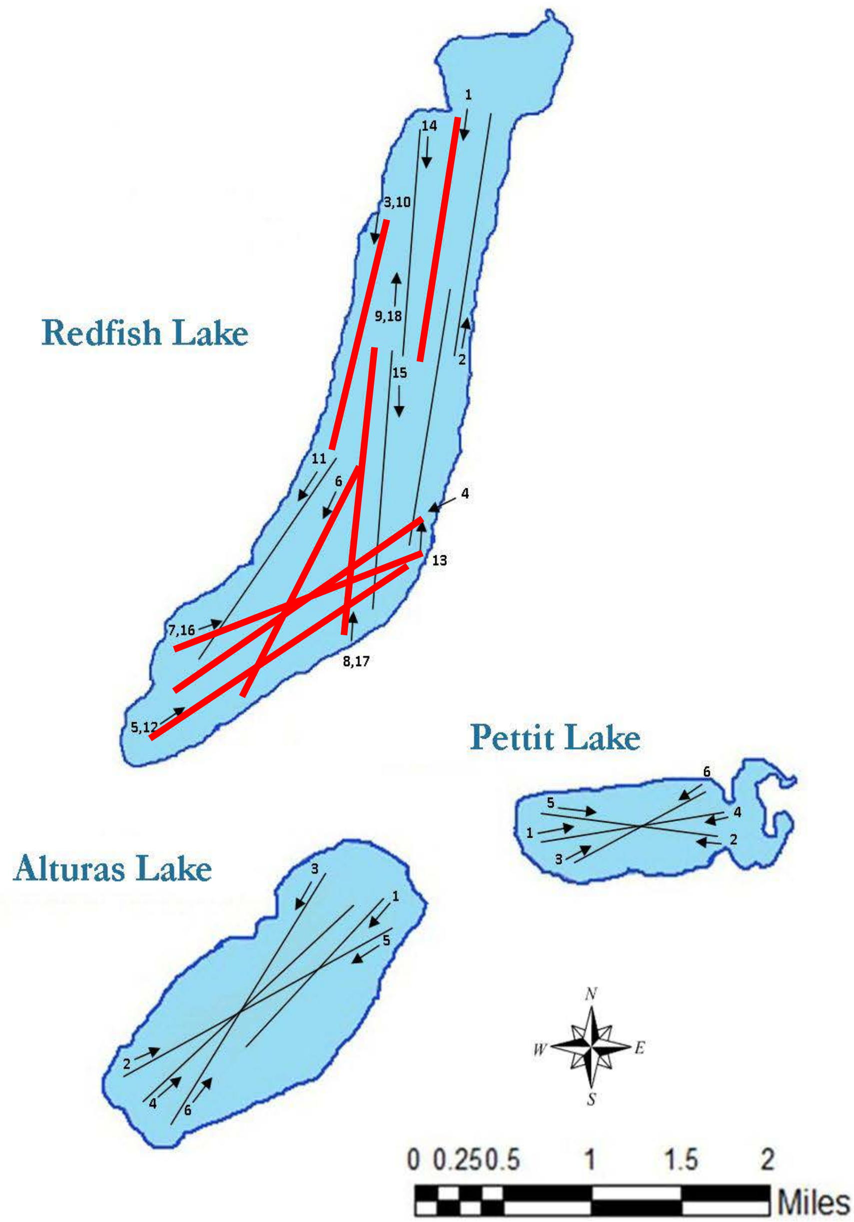

Figure 2. Map of the Sawtooth Valley basin lakes and the arrows indicated the location and approximate distance of the mid-water trawl transects. Note: only seven transects were conducted on Redfish Lake in 2015 (red lines).

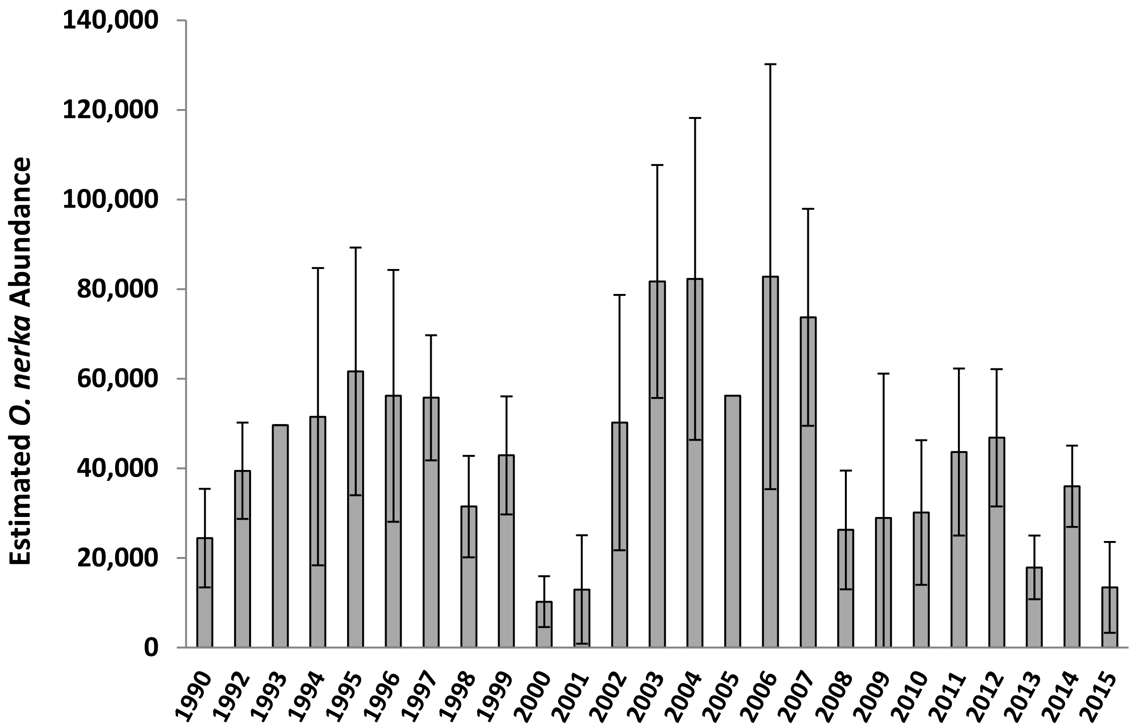

Figure 3. *O. nerka* population estimates for Redfish Lake, 1990 to 2015.

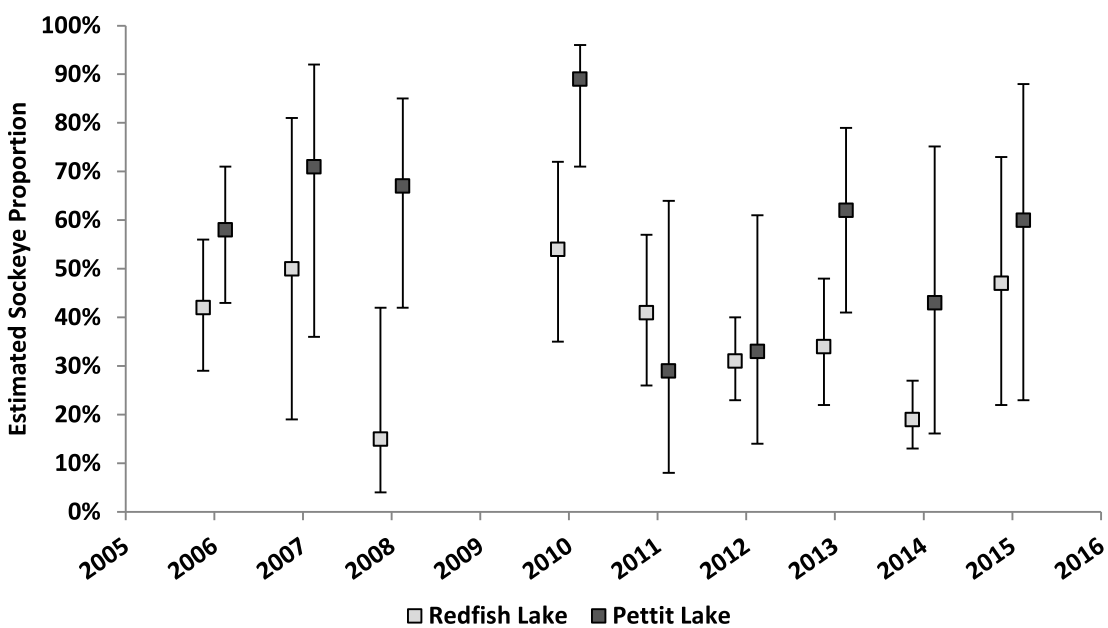

Figure 4. Proportions of Snake River Sockeye Salmon (assigned genetically) out of the total *O. nerka* population within Redfish and Pettit lakes collected using mid-water trawl from 2006-2015 (primary axis). Error bars represent 95% confidence intervals around the proportions.

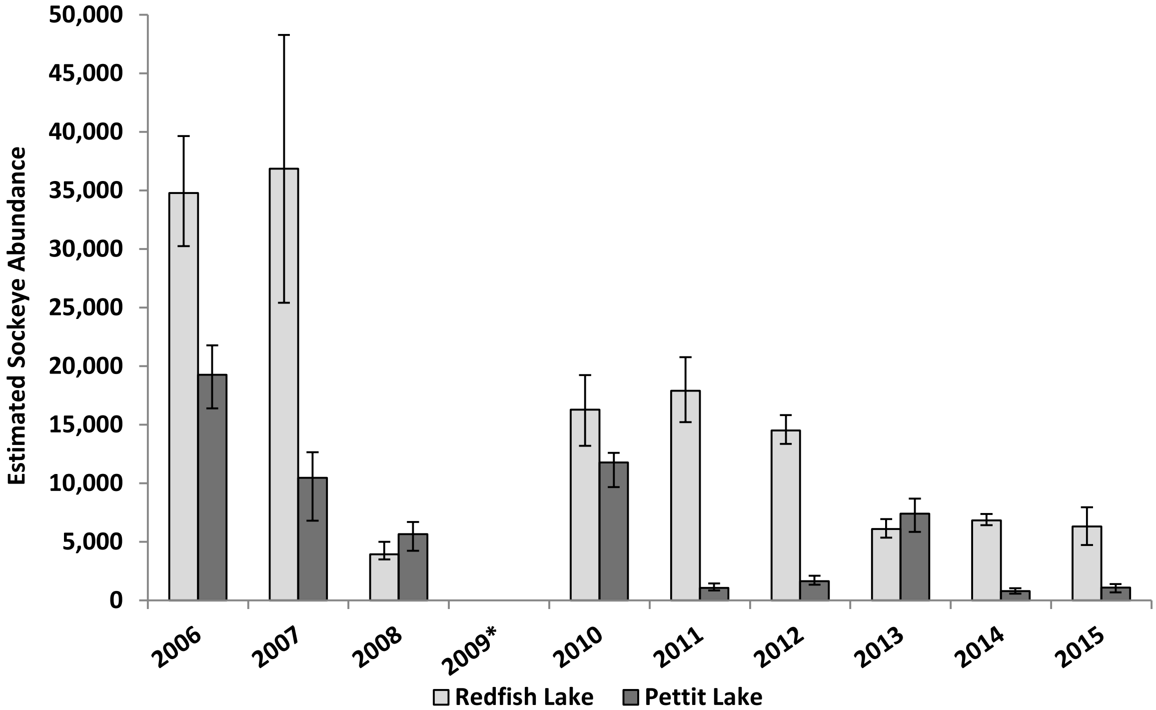

Figure 5. Abundance of Snake River Sockeye Salmon (assigned genetically) within Redfish and Pettit lakes collected using mid-water trawl from 2006-2015. Abundance data in 2009 is not reported due to sample contamination.

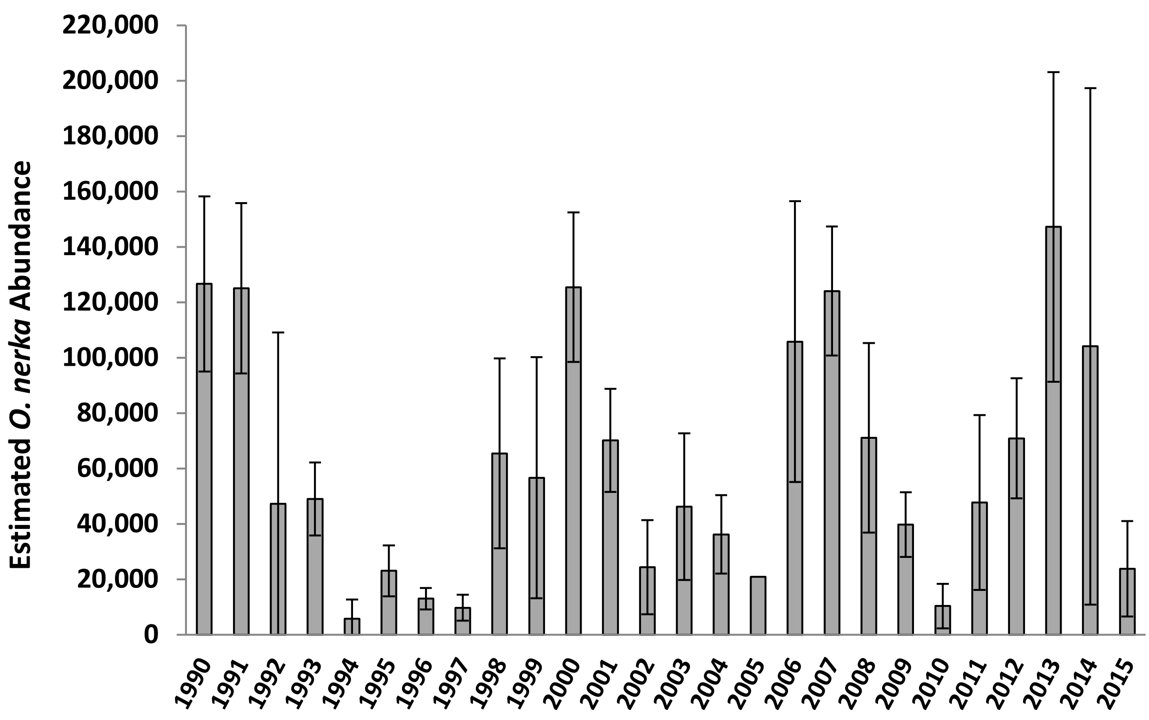

Figure 6. *O. nerka* population estimates for Alturas Lake, 1990 to 2015.

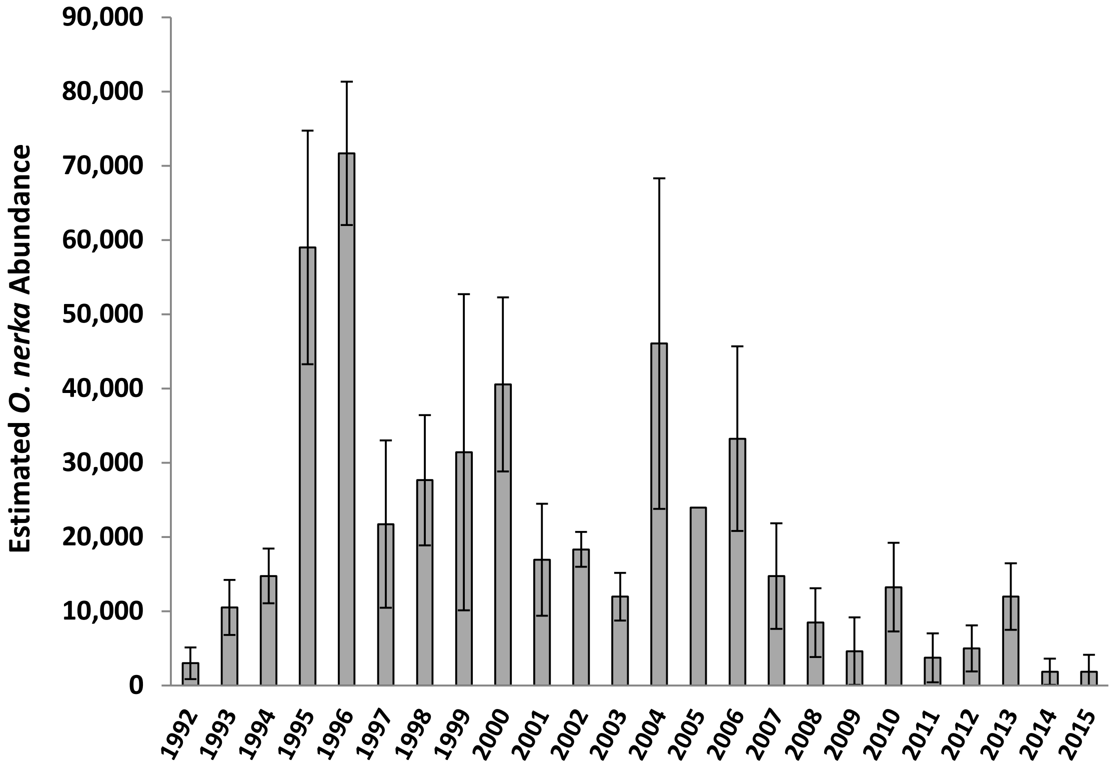

Figure 7. *O. nerka* population estimates for Pettit Lake, 1992 to 2015.

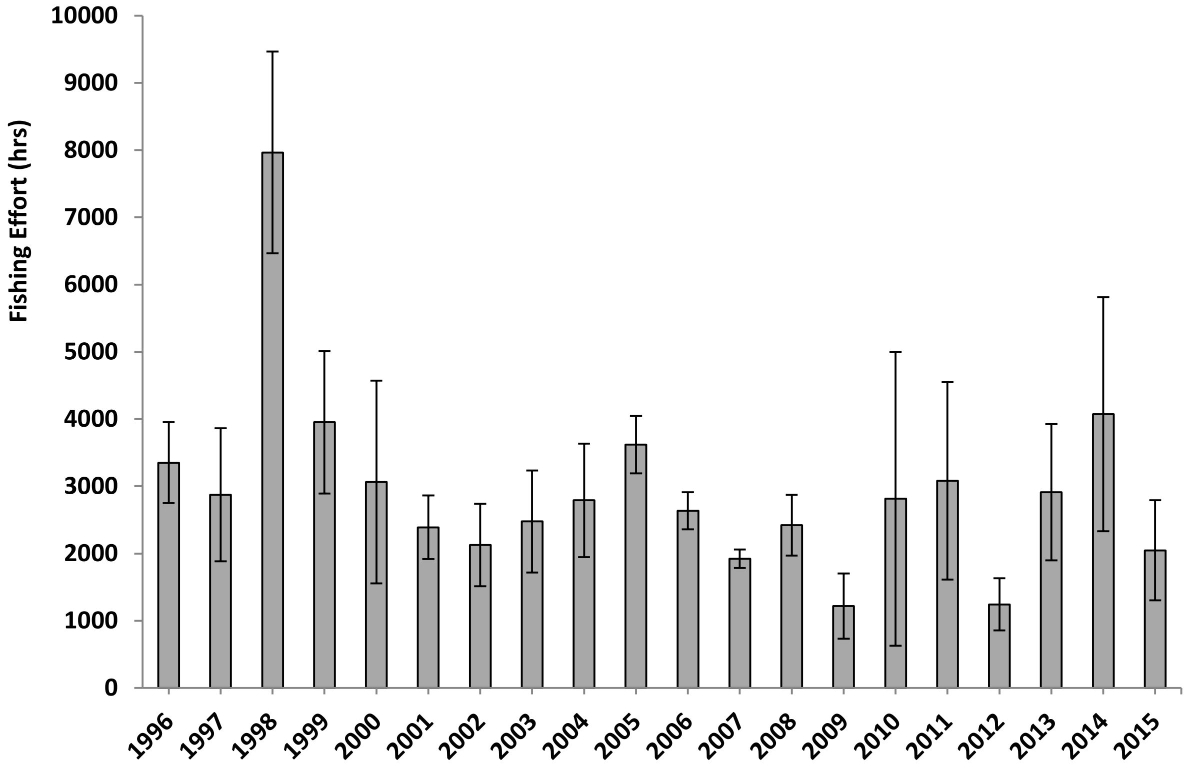

Figure 8. Estimates of fishing pressure on Redfish Lake derived from creel data from 1996-2015.

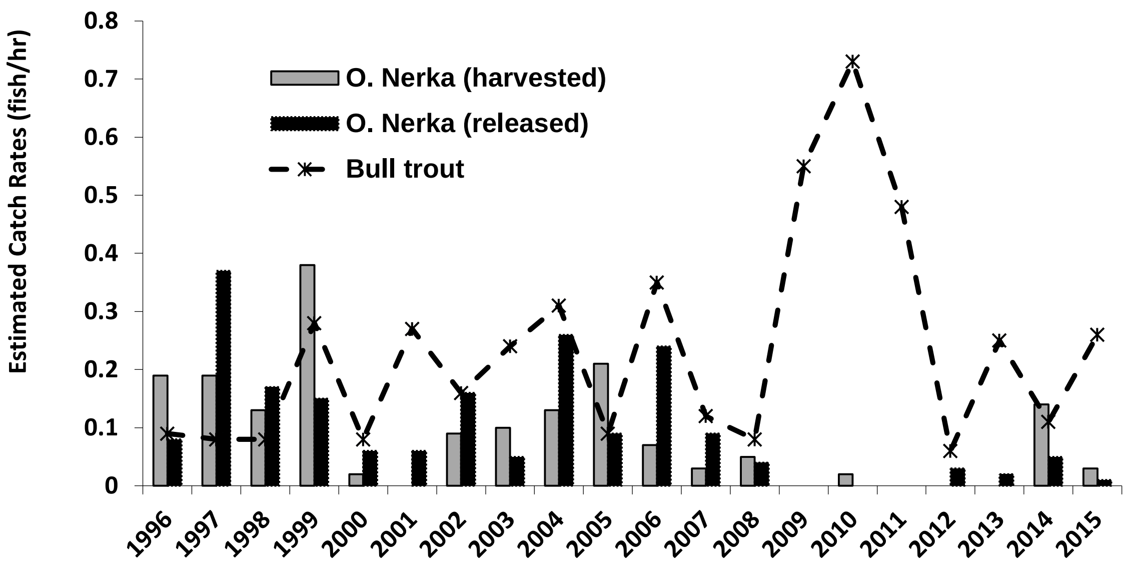

Figure 9. Estimated bull trout and *O. nerka* catch rates derived from creel data from 1996-2015 on Redfish Lake.

Table 3. Sample sizes for *O. nerka* collected for genetic analyses within Redfish Lake creel using the microsatellite genetic marker.

Collection Year	Sample Size	No. Sockeye Salmon Detected	% Sockeye Salmon Detected
2006	20	4	20%
2007	2	0	0%
2008	8	1	14%
2009	0	0	na
2010	0	0	na
2011	1	0	0%
2012	0	0	na
2013	0	0	na
2014	10	7	70%
2015	7	2	29%

Table 4. Population estimate of adult *O. nerka* in Redfish Lake, total harvest estimate during the kokanee fishery, and estimated % ESA-listed Sockeye Salmon in harvest, 1997-2015.

Year	Population Estimate* (*O. nerka*)	Harvest Estimate (*O. nerka*)	± 95% CI	Exploitation Rate** (*O. nerka*)	Estimated ESA Harvest	Genetic Marker
1997	55,762	866		1.6%	9 (1%)	Mitochondrial
1998	31,486	1,362		4.3%	14 (1%)	Mitochondrial
1999	42,916	1,187	843	2.8%	12 (1%)	Mitochondrial
2000	10,268	67	110	0.7%	1 (0.8%)	Mitochondrial
2001	12,980	0	na	0.0%	na[b]	Mitochondrial
2002	50,204	129	179	0.3%	1 (0.8%)	Mitochondrial
2003	81,727	424	215	0.5%	1 (0.3%)	Mitochondrial
2004	82,258	621	887	0.8%	2 (0.3%)	Mitochondrial
2005	56,220	785	678	1.4%	4 (0.3%)	Mitochondrial
2006	82,796	222	33	0.3%	44 (20%)	Microsatellite
2007	73,702	56	18	0.1%	0 (0%)	Microsatellite
2008	26,284	106	92	0.4%	15 (14%)	Microsatellite
2009	28,923	0	na	0.0%	na[b]	Microsatellite
2010	30,194	0	na	0.0%	na[b]	Microsatellite
2011	43,671	0	na	0.0%	0 (0%)	Microsatellite
2012	46,861	0	na	0.0%	na[b]	Microsatellite
2013	17,911	7	na	0.0%	na[b]	Microsatellite
2014	36,013	559	370	1.6%	117 (21%[a])	Microsatellite
2015	13,432	55	22	0.4%	16 (29%)	Microsatellite

* *O. nerka* population estimates are derived using mid-water trawl.
** No. harvested/population estimate.
[a] Estimated harvest (%) is based on 2006-2014 average.
[b] No fish sampled in creel.

PART 3—SOCKEYE SALMON JUVENILE OUTMIGRANT MONITORING AND EVALUATION

INTRODUCTION

The development of reintroduction plans has followed a “spread-the-risk” philosophy incorporating multiple release strategies and multiple lakes over the course of the program (Hebdon et al. 2004). Both adults and juveniles produced in excess of broodstock needs have been re-introduced into the environment to provide opportunities to increase the abundance and fitness of the population with returning anadromous adults. Progeny from the Captive Broodstock Program were reintroduced to Sawtooth Valley basin waters at different life stages using a variety of release options including: 1) eyed egg plants to in-lake incubator boxes in Alturas and Pettit lakes (1996-2011), 2) presmolt releases into all three lakes (1994-2012), 3) smolt releases to outlet streams (1995-2015), and 4) prespawn adult releases primarily in Redfish Lake (1993, 1994, 1996, 1997, 1999-2015) with some in Pettit (1997, 2000, 2014, 2015) and Alturas lakes (1997, 2000, 2011). Prespawn full-term captive-reared Sockeye Salmon adults were first released back to the wild in 1993. Beginning in 1999, anadromous Sockeye Salmon have been released into valley lakes (when available) along with captive adult Sockeye Salmon. In addition to natural production (resulting from eyed egg and prespawn adult releases), hatchery-produced juveniles (smolts) are annually released into Redfish Lake Creek and the mainstem Salmon River. These hatchery releases constitute the largest proportion (between 80-95%) of outmigrants from the Sawtooth Valley basin each year. The program has phased out eyed egg (2011) and presmolt releases (2012) and is beginning to phase out juvenile rearing at Sawtooth (2015) and Oxbow (2016) fish hatcheries and focus on rearing a larger number of juveniles at the Springfield Hatchery.

Monitoring and evaluation of the release strategies has been an important part of the "spread-the-risk" philosophy and research program (Hebdon et al. 2004). All hatchery-reared presmolt and smolt release groups were uniquely marked to identify release strategy and origin. Natural origin fish cannot be physically marked but currently are genetically marked (e.g. parental based tagging or PBT) to differentiate release strategies. Current evaluations of juvenile Sockeye Salmon focus on trapping outmigration juveniles from each of the three lakes and providing estimates of outmigration timing, smolt size, age composition, and abundance. The Shoshone Bannock Tribe conducts outmigration monitoring on Alturas and Pettit lakes each year while IDFG conducts outmigration monitoring on Redfish Lake. Outmigration monitoring allows for the tagging of natural-origin fish with PIT tags for subsequent analyses of survival and travel time from the nursery lakes to Lower Granite Dam (LGR) and through the Federal Columbia River Power System (FCRPS). This information was used to compare the effectiveness of each release strategy in terms of survival and continue to characterize and build baseline data on naturally emigrating smolts. In this chapter, outmigration monitoring activities for Redfish Lake are described as well as the outmigration estimates and PIT tag data produced by the Shoshone Bannock Tribe for Alturas and Pettit lakes.

METHODS

Redfish Lake Creek Trap

The outmigrant trap on Redfish Lake Creek (RLCTRP) was located 1.4 km downstream from the lake outlet at a permanent weir site. The trap functions as a juvenile trap for out-migrating fish, and with minor modifications, as a trap for returning adults (Craddock 1958; Bjornn et al. 1968; Kline 1994; Kline and Younk 1995; Kline and Lamansky 1997; Hebdon et al.

2000, 2002, 2003; Willard et al. 2004, 2005; Peterson et al. 2008, 2010, 2012a). The trap was operated from early April until fish stopped emigrating from the lake in mid-June. The trap contains nine bays, five of which were fitted with traps consisting of an adjustable 1.70 m wide by 1.74 m long aluminum trap box on a winch and pulley system. The trap boxes were constructed of 3 mm aluminum sheeting and framework and 1.9 cm diameter hollow aluminum bars. The 30.5 cm x 169.5 cm x 30.5 cm live wells were also constructed of 3 mm aluminum with 5 mm holes drilled for aeration and water exchange in the live well. Bar spacing (19 mm) allowed debris and large fish to pass downstream, while low velocity water swept *O. nerka* smolts across the bars and into the live well for holding until personnel were able to empty the trap (Kline 1994).

All Sockeye Salmon smolts captured at RLCTRP were anesthetized in a 50 mg/L solution of buffered tricaine methanesulfonate (MS-222), measured for fork length (nearest 1 mm), weighed (nearest tenth of a gram), and scanned for a PIT tag. Scales were removed from a subsample of natural origin and adipose fin-clipped hatchery reared *O. nerka* (ten per 5 mm length group) and returned to the laboratory for aging. In the lab, scales were pressed between microscope slides. Two program employees individually aged the scales, and a third person viewed the image with the original two employees to finalize discrepancies (similar to Schrader et al. 2013). The proportions of age-1+ and age-2+ outmigrants were determined by using the RMIX computer program developed by MacDonald and Green (1988). MIX software uses known ages (the scale ages in this case) and fits mixture distributions to grouped data by utilizing a maximum likelihood estimator. All captured non-target species were counted and released immediately. Fin-clip samples were taken from up to 50 natural smolts/day for future genetic analyses.

Between 50 and 100 natural origin Sockeye Salmon smolts were PIT tagged daily and released approximately 250 m upstream of the weir one-half hour after sunset to estimate trap efficiency. All remaining fish were scanned for PIT tags, counted, and released 15 m downstream of the weir one-half hour after sunset. Flow-through live boxes with locking lids were used to hold fish until the evening release. Trapping efficiencies were calculated for natural origin Sockeye Salmon smolts. Stream velocity was measured below the trap weekly. Outmigrant run size was derived using a modified Bailey estimator and 95% bootstrap confidence intervals using methods described by Steinhorst et al. (2004). In this methodology, trapping was divided into intervals. Intervals were selected based on stream discharge similarities and the number of PIT-tagged smolts released upstream of the weir that were available for recapture (trap efficiencies).

Alturas Lake Creek Trap

Sockeye Salmon outmigrant trapping and PIT tagging on Alturas Lake Creek was conducted by the SBT. The Alturas Lake Creek screw trap was located 13 km downstream from the Alturas Lake outlet and was operated from late April to late May. The Alturas Lake outmigrant population estimate was derived using daily estimates of captured, marked, and recaptured fish to estimate trap efficiency (Griswold et al. *in prep*). Activities conducted by the SBT are reported under a separate cover (Griswold et al. *in prep*).

Pettit Lake Creek Trap

Sockeye Salmon outmigrant trapping and PIT tagging on Pettit Lake Creek was conducted by the SBT. The Pettit Lake Creek trap was located 1 km downstream from the Pettit Lake outlet at a permanent weir site and was operated from late April to late May. The Pettit

Lake Creek weir traps at 100% efficiency under low spring flow conditions (D. Taki, Shoshone Bannock Tribes, personal communication); therefore, outmigration run size for Pettit Lake was based on the census number of smolts trapped. However, during normal to high flow years, the trap must be removed and other means are used to estimate the number of outmigrants. Activities conducted by the SBT are reported under a separate cover (Moreno et al. 2016 *in prep*).

SURPH Survival and Travel Time Estimation

A portion of the Sockeye Salmon smolts were transported (if collected in juvenile facilities within the hydrosystem corridor) and released below Bonneville Dam according to a USACE PIT tag study (methods and results can be found in BioMark and Quantitative Consultants, Inc. 2010). As a result, migration corridor survival evaluations were only conducted to Lower Granite Dam (LGR) for this project. Sockeye Salmon smolt survival and travel time to LGR for each release group was evaluated using PIT tag interrogation data collected at PIT tag detection facilities throughout the Snake and Columbia rivers. Interrogation data were retrieved from the PIT Tag Information System (PTAGIS) maintained by the Pacific States Marine Fisheries Commission (Portland, Oregon). This data was used by PitPro (Westhagen and Skalski 2009) to develop a data file for analysis using program SURPH (Lady et al. 2010), which estimates survival to LGR. These models utilize PIT tag detections at various dams to develop a Cormack/Jolly-Seber estimate of survival to LGR. PitPro also uses PIT tag detection data to estimate average travel time to LGR. Total smolt outmigration (for each smolt production, natural origin, and presmolt outmigrant group) to LGR was estimated using the SURPH survival estimate (for each respective release group) multiplied by the outmigration estimate of each release group at the outmigration trap sites found in the Sawtooth Valley basin. Weighted survival was calculated by dividing the outmigration estimate (per group) by the total number of smolts leaving the Sawtooth Valley basin, then multiplied by the survival (by group) and summing all groups together. The weighted SURPH survival provides a point estimate of survival for each year to monitor trends in survival.

RESULTS

Sawtooth Valley basin

Since initiation of the Captive Broodstock Program in the early 1990s, there has been an increasing trend in the number of Sockeye Salmon outmigrants from the Sawtooth Valley basin, mainly from the production and release of hatchery reared smolts (Figure 10). Total estimated outmigration in 1993 was 569 fish (all from natural production) and has steadily increased to 436,998 fish in 2015 (423,103 hatchery and 13,885 naturally produced fish from Redfish, Alturas, and Pettit lakes). Prior to 2015, Sawtooth and Oxbow fish hatcheries produced smolts have been the main contributors to the outmigration population. Sawtooth Hatchery has produced approximately 1.2 million smolts and the Oxbow Hatchery has produced >800,000 smolts (Figure 10). In 2015, the Springfield Hatchery released 211,205 smolts of which 49,307 were PIT tagged (23%; Figure 11). The total number of Sawtooth Hatchery fish PIT tagged increased in 2009 from approximately 1,000 to approximately 50,000 fish (Figure 11). PIT tagging rates also increased for Oxbow Hatchery reared fish from ~1,000 to ~10,000, although the number tagged have since dropped to 2,000 or less since 2013.

Redfish Lake Creek Trap

Since 1999, 40,549 outmigrants have been trapped and 13,077 (approximately 32%) of those trapped have been marked and released upstream of the weir to estimate trapping efficiency (Figure 12). A total of 3,665 Sockeye Salmon smolts were trapped during the 2015 outmigration season and 2,089 (57%) were PIT tagged. In 2013 and 2014, 13% and 85% of the trapped emigrants were PIT tagged and released upstream of the weir, respectively. Based on observed trapping efficiencies and discharge during outmigration monitoring, between one and five trapping intervals (typically 1-3) were used to develop the estimate for natural origin smolt outmigration. Annual trapping efficiencies ranged from 18% (2006) to 56% (2003) and averaged 34% over the study years (Figure 12). Total natural origin Sockeye Salmon smolt outmigration from Redfish Lake in 2015 was estimated at 9,734 fish (95% CI 9,113-10,374; Table 5), a nearly 3-fold increase over the 2014 natural origin migration estimate of 3,583 (95% CI 3,343-3,853). Natural outmigrant estimates vary considerably from year to year ranging from <1,000 fish in 6 of 9 years between 1993 and 2001 (1993, 1995, 1996, 1997, 2000, and 2001) to >5,000 fish in the last 9 of 11 years (2005, 2006, 2007, 2008, 2010, 2011, 2012, 2013, and 2015) and >10,000 fish in 2010, 2012, and 2013 (Table 5). Outmigrant ages determined from scales collected during outmigration indicated that most fish emigrated from Redfish Lake 1+ years after hatching (Figure 13). The proportion of 1+ and 2+ natural origin smolts ranged from 63% (2011) to 98% (2010 and 2013).

Alturas Lake Creek Trap

Due to the limited number of outmigrants trapped from Alturas Lake in 2013 (n = 16) and 2014 (n = 16), expansion estimates were not generated. In 2015, 265 outmigrants were trapped and tagged at the Alturas Lake Creek weir (Griswold et al. *in prep*). Migrant timing, length, and age information for the 2015 emigration is are reported in Griswold et al. *in prep.*

Pettit Lake Creek Trap

The total number of natural origin outmigrant Sockeye Salmon smolts trapped and PIT tagged at the Pettit Lake Creek weir in 2013 and 2014 was 494 and 376, respectively (see SBT annual report for further information regarding age structure and lengths, Moreno et al. 2014). In 2015, one natural-origin migrant was trapped and PIT tagged (Griswold et al. *in prep*).

SURPH Survival and Travel Time Estimation

The total estimate of Sockeye Salmon smolts that out-migrated from the Sawtooth Valley basin and survived to LGR in 2015 was estimated to be 169,572 smolts (66,107 Springfield Hatchery smolts, 66,284 Sawtooth Hatchery smolts, 32,826 Oxbow Hatchery smolts, 3,602 Redfish Lake naturals, and 753 Alturas Lake naturals; Figure 14, 15, and 16). Estimated numbers of Sockeye Salmon smolts surviving to LGR over the past five years averaged 151,750 smolts ranging from 124,160 (2012) to 169,572 fish (2015; Figures 14, 15, and 16).

Outmigration survival was estimated to LGR for natural origin and hatchery origin Sockeye Salmon smolt groups using PIT tag interrogation data. Estimates reflect numbers of smolts that arrived at LGR based on results from data analyses using the SURPH model. Survival among hatchery origin release groups ranged from a low of 16% ± 1.5% (Sawtooth Hatchery releases) and 21% ± 6.1% (Oxbow Hatchery releases) in 2010 to a high of 73% ± 1.4% (Sawtooth Hatchery releases) and 77% ± 4.2% Oxbow Hatchery release in 2011 (Figure 17). The average survival across all years was 49% (2002-2015) for Sawtooth Hatchery smolts and 50% (2006-2015) for Oxbow Hatchery smolts. SURPH estimates were significantly higher in 2009 for Sawtooth Hatchery smolts (47% ± 1.9%) compared to Oxbow Hatchery smolts (30% ± 3.9%) and significantly higher (49% ± 8.2%) than Springfield Hatchery smolts (31% ± 5.35) in 2015 (Figure 17). Juvenile survival estimates for natural origin smolts was generally lower (2000-2015 average = 42%) than those of hatchery produced smolts (49% Sawtooth Hatchery and 50% Oxbow Hatchery smolts; Figure 18). Survival of naturally produced smolts was significantly lower than Sawtooth Hatchery produced smolts in 2007, 2009, 2011, 2012, and 2013 and significantly lower than Oxbow Hatchery produced smolts in 2007, 2011, 2012, and 2013. Juvenile survival from the Alturas Lake Creek trap to LGR was highly variable due to low outmigration estimates and subsequent low recapture rates at LGR. The median survival estimate (1998-2015) for Alturas Lake naturals was 37% and ranged from 0% (1998, 2001, 2003, 2004, 2010, 2011, 2012, and 2014) to 89% (2013; Figure 19). The median survival estimate (1998-2015) for Pettit Lake naturals was 22% and ranged from 0% (1998-2001, 2003, 2004, and 2015) to 63% (2006; Figure 19). The 2006-2015 SURPH estimate for all the release groups (weighted) was 51% to LGR. The weighted SURPH estimate in 2015 was 39%, a 12% decrease from the 10-year average and a 13% and 14% decline from 2014 (52%) and 2013 (53%) weighted averages, respectively.

Estimated annual mean travel times for Sawtooth Hatchery smolts ranged from 7.7 d (2007) to 17.9 d (2009) with an average of 11.2 d (2002-2015). Estimated annual mean travel times for Oxbow Hatchery smolts ranged from 7.5 d (2006) to 15.9 d (2010) with an average of 10 d (2006-2015). Mean travel time for Springfield Hatchery smolts was 11.5 d compared to 9.5 d for Sawtooth Hatchery and 10.3 d for Oxbow Hatchery smolts during the 2015 outmigration. Annual mean travel times for Redfish Lake natural origin fish ranged from 8.7 d (2011) to 12 d (2001, 2002, and 2015) and averaged 10.9 d (2000-2015). For juvenile hatchery produced Sockeye Salmon, we observed negative correlations between survival and the mean number of days to migrate to Lower Granite Dam. Mean travel time explained 20% of the variability in survival to LGR for Sawtooth Hatchery smolts and 58% of the variability for Oxbow Hatchery released smolts (Figures 20 and 21). Travel time was however weakly correlated (R^2 = 0.03) to survival for natural origin migrants (Figure 22).

DISCUSSION

The IDFG and Tribal cooperators monitor natural populations of Sockeye Salmon in Redfish, Alturas, and Pettit lakes as a way to monitor population status. In addition to natural spawning, hatchery-produced juveniles, and adults are reintroduced annually to increase population abundance. Beginning in the late 1990s the IDFG began research using PIT-tagged emigrants to estimate total natural-origin abundance and to estimate survival of natural origin and hatchery-reared emigrants from the Sawtooth Valley basin to Lower Granite Dam in order to evaluate these different release strategies.

Understanding differences between release groups and factors that affect survival to LGR continues to be an important component of the research program. Differences in outmigration survival have been observed among some years between smolts leaving the lake (natural origin and presmolt releases) compared to hatchery-origin smolts released directly into the creek originating from the Sawtooth, Oxbow, and Springfield fish hatcheries. One possible hypothesis for these observed survival differences could be that full-term smolts released all at once (high densities) survive better to LGR through “predator saturation” (Liermann and Hilborn 2001; Furey et al. 2016) compared to smolts emigrating from the lake that were exposed to the same predators but tend to leave the lake in much lower densities per day and over a longer period of time. A concurrent study using PIT tag and radio telemetry to investigate the variability observed between years and to try to identify areas where mortality occurred found that groups of juvenile Sockeye Salmon released first had a lower survival rate. The analyses performed herein indicate that travel time explained 3% of the variability in survival for natural origin outmigrants, ~20% of the variability in survival for Sawtooth Hatchery produced smolts, and 58% of the variability in Oxbow Hatchery produced smolts (removing 2010 which resulted in 21% SURPH and mean of 15.9 d travel time reduced the R^2 to 0.45). Weak correlation between survival and travel time supports the hypothesis that predation effects are more immediate in the upper river for the lower density natural outmigrants. Three additional reaches were identified with lower survival and where characterized as having high densities of avian predators or where river flows slowed and juveniles traveled at a slower rate (Axel et al. 2016 *in prep*). It is also important to note other factors likely affect survival within this section of the migration corridor including competition with non-native species, environmental conditions, and rearing and release strategies. Differences in survival between juveniles reared at Sawtooth and Oxbow hatcheries were insignificant all years except for 2009. In 2015, survival estimates for Springfield Hatchery produced smolts was the lowest of the three hatchery produced groups. Observations by IDFG personnel during the release indicated fish displayed external symptoms of gas bubble disease (GBD), including fin occlusion, distended bodies, and exophthalmia (Popeye) presumably from exposure to gas supersaturated water during transit from the Springfield Fish Hatchery to the release site. Further research is warranted to identify whether smolt size at release impacts survival in the migration corridor between the Sawtooth Valley basin and LGR for Snake River Sockeye Salmon.

Trap efficiency data was a very important component used to estimate outmigration each season. The development of proper stratification with homogeneous trappabilty is important for developing accurate outmigration estimates. At the Redfish Lake Creek trap, predation and flow are the largest contributors to variability in trapping efficiencies. Predation of released smolts, primarily by Hooded Mergansers and Bull Trout continued to be observed (also reported in Axel et al. 2016 *in prep*); however, predation rates are undocumented. Predation above the trap on released PIT-tagged fish could result in an artificial inflation of the number of natural outmigrants. Flow may further confound trap efficiency estimates. While the lake buffers the creek during snow runoff events, high discharge events periodically cause the trap to overflow resulting in tagged fish being undetected. Trap efficiencies were typically generated over a period of weeks instead of days; therefore, the effects of non-detections over a short time interval (e.g., one evening) likely has less of an impact on outmigration estimates then seasonal predation upstream of the trap.

Bjornn et al. (1968) conducted smolt outmigration and adult return monitoring between 1954 and 1966; their work provides a detailed account of Sockeye Salmon life history in Redfish Lake. Sockeye Salmon smolt outmigration from Redfish Lake typically begins in early April, peaks in mid-May, and concludes by mid-June. Smolts out-migrate at either age-1 or age-2 and the proportions vary every year. Bjornn (1968) observed a positive relationship between the age that juvenile Sockeye Salmon migrated from Redfish Lake and their growth during the first summer. When mean length of a year class approached 100 mm, over 90% migrated as yearlings. During their 11-year study, Bjornn et al. (1968) noted a dominance of age-1 smolts for six of the 11 years. The dominance of age 1+ smolts has been observed over the past 15 years (2001-2015) for smolts emigrating from Redfish Lake and the mean length of age 1+ fish has ranged from 96 mm (2006) to 111 mm (2007). Percentage of a year class migrating as yearlings appears to be controlled by growth not population density (Bjornn et al. 1968), and smolt size is positively related to adult survival (Ricker 1962). Size and age at emigration suggest acquisition of adequate dietary resources and nutrient availability for juvenile Sockeye Salmon in Redfish and Pettit despite fluctuations in abundance of kokanee salmon or releasing full-term captive and anadromous Sockeye Salmon adults for volitional spawning. In addition to forage quality and quantity, these growth rates indicate favorable conditions in terms of water temperatures and intra- and interspecific competition (Brett 1995; Schindler et al. 2005).

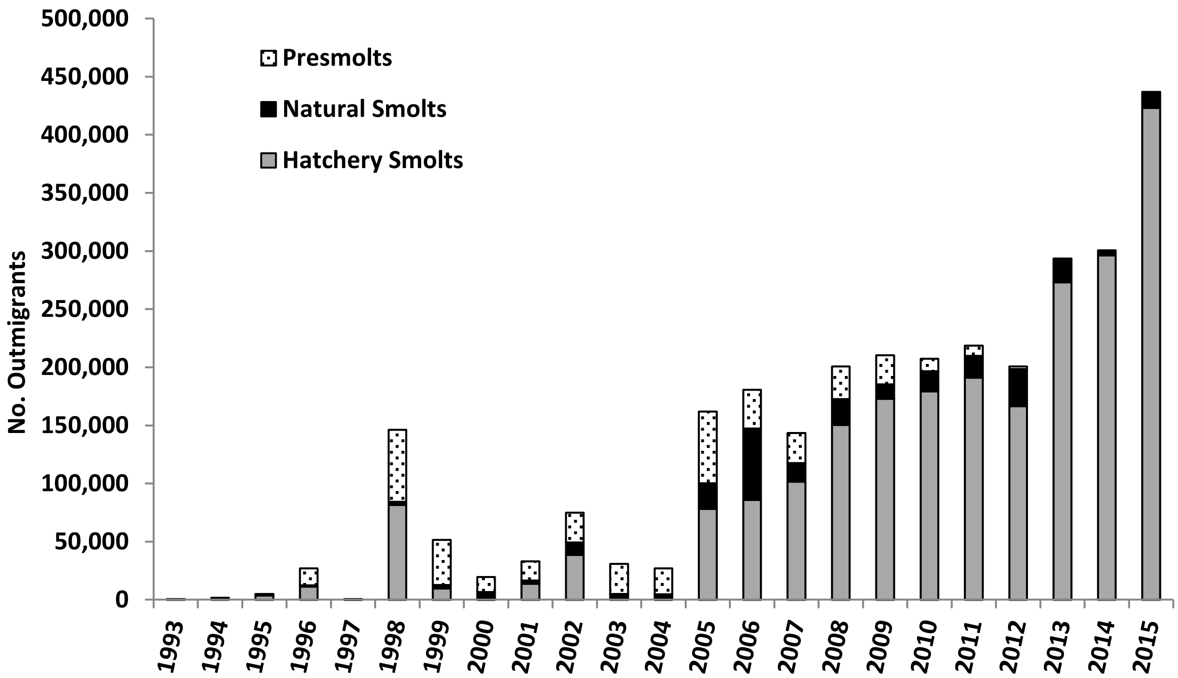

Figure 10. Estimated annual numbers of Sockeye Salmon smolt outmigrants from the Sawtooth Valley basin. This includes all hatchery smolt releases, known outmigrants originating from hatchery presmolt out plants, and estimates of unmarked juveniles migrating from Redfish, Alturas, and Pettit lakes.

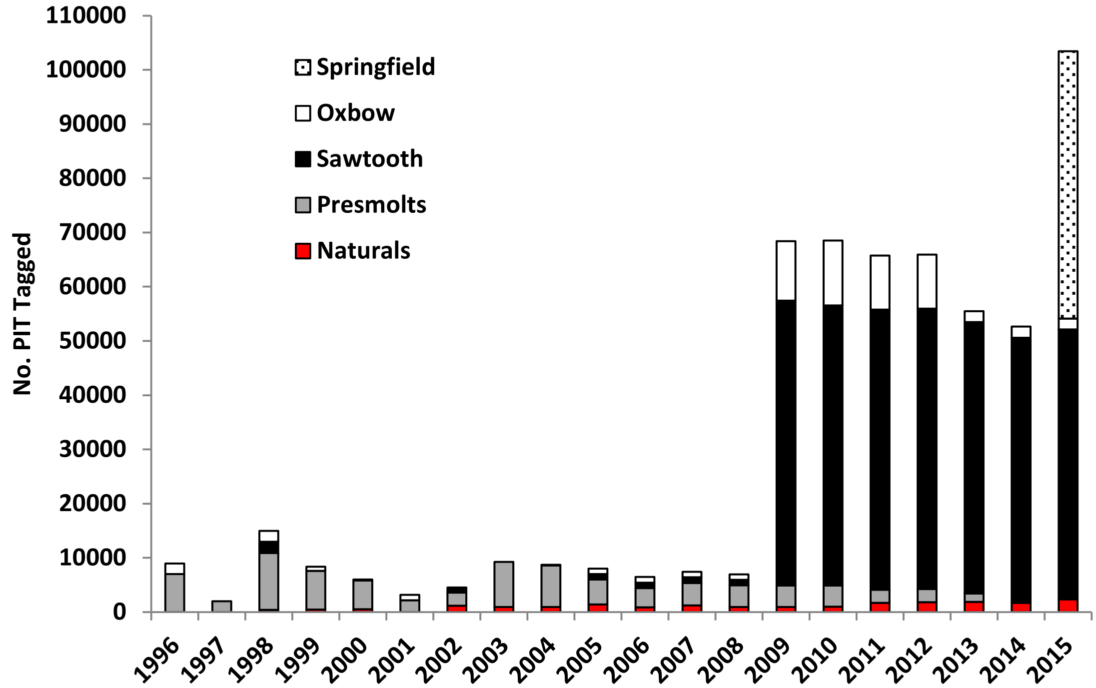

Figure 11. Total number of juvenile outmigrants PIT tagged in the Sawtooth Valley basin between 1996 and 2015. This includes all hatchery smolt and presmolt releases, outmigrants originating from hatchery presmolt out plants, and natural juveniles migrating from Redfish, Alturas, and Pettit lakes.

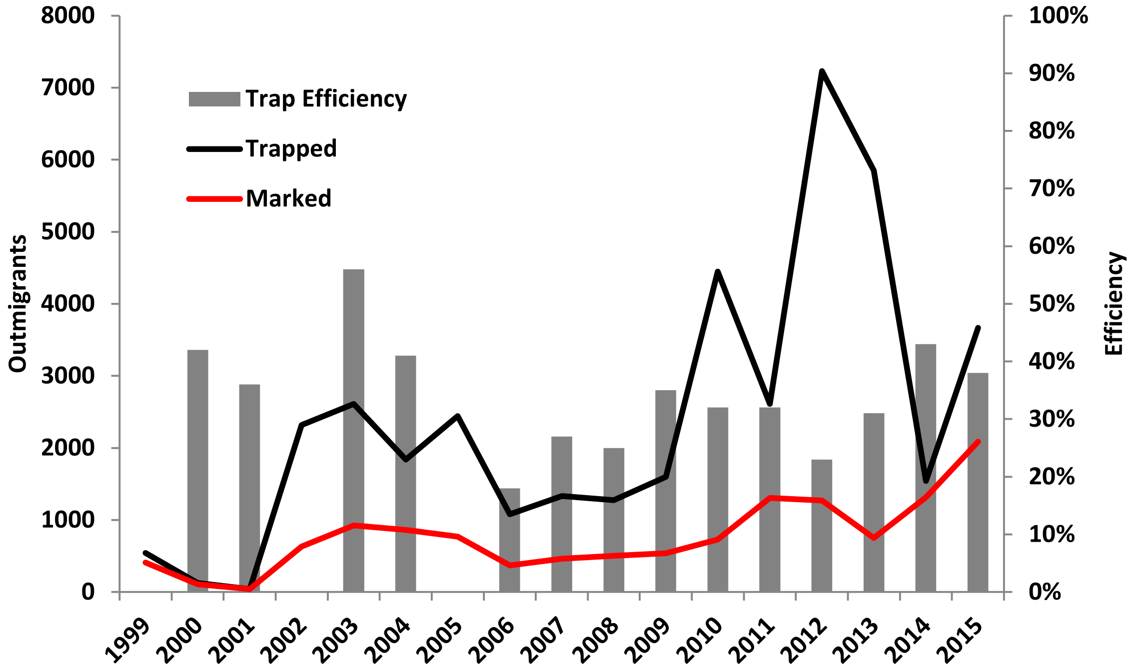

Figure 12. Number of Sockeye Salmon outmigrants trapped and PIT tagged and the trap efficiency at the Redfish Lake Creek trap.

Table 5. Estimated numbers of natural origin Sockeye Salmon smolts emigrating from Redfish Lake Creek, Alturas Lake Creek, and Pettit Lake Creek traps. Includes outmigrants from egg box releases and any natural production within the lakes. Note: juvenile outmigrant trap on Pettit Lake Creek is not operated every year.

	Estimated Unmarked Outmigration RFL	Confidence Interval (Upper)	Confidence Interval (Lower)	Estimated Unmarked Outmigration Pettit[b]	Estimated Unmarked Outmigration Alturas[b]
1993[a]	569				
1994[a]	1,820				
1995[a]	357				
1996[a]	923				
1997[a]	304				
1998[a]	2,799				
1999	1,936	2,401	1,607		1,172
2000	302	400	237		6,300
2001	110	189	71	13	2,641
2002	4,951	5,471	4,524	1,067	6,176
2003	4,637	4,935	4,360	29	286
2004	4,476	4,894	4,122	93	74
2005	7,870	8,538	7,255	7,518	6,747
2006	6,065	7,504	4,837	36,336	18,911
2007	5,280	6,352	4,504	1,749	8,994
2008	6,237	7,624	5,210	100	15,903
2009	4,552	5,125	4,051	3,008	4,869
2010	14,012	15,621	12,615	3,476	45
2011	6,879	7,748	6,144	11,890	19
2012	31,297	38,338	27,463	502	22
2013	18,673	20,918	16,790	1,473	59
2014	3,583	3,853	3,343	623	33
2015	9,734	10,374	9,113	4,159	2

[a] Confidence limits not readily available.
[b] Trapping activities conducted by Shoshone-Bannock Tribes.

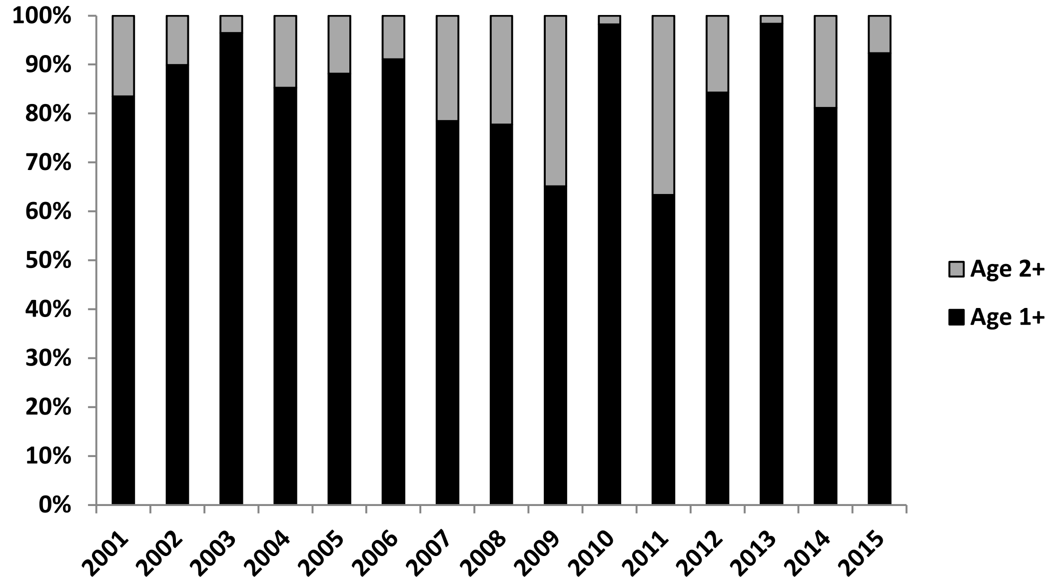

Figure 13. Proportion of age 1+ and 2+ natural origin smolt emigration from Redfish Lake. Ages were determined from scales collected from Sockeye Salmon smolts at the Redfish Lake Creek trap during outmigration.

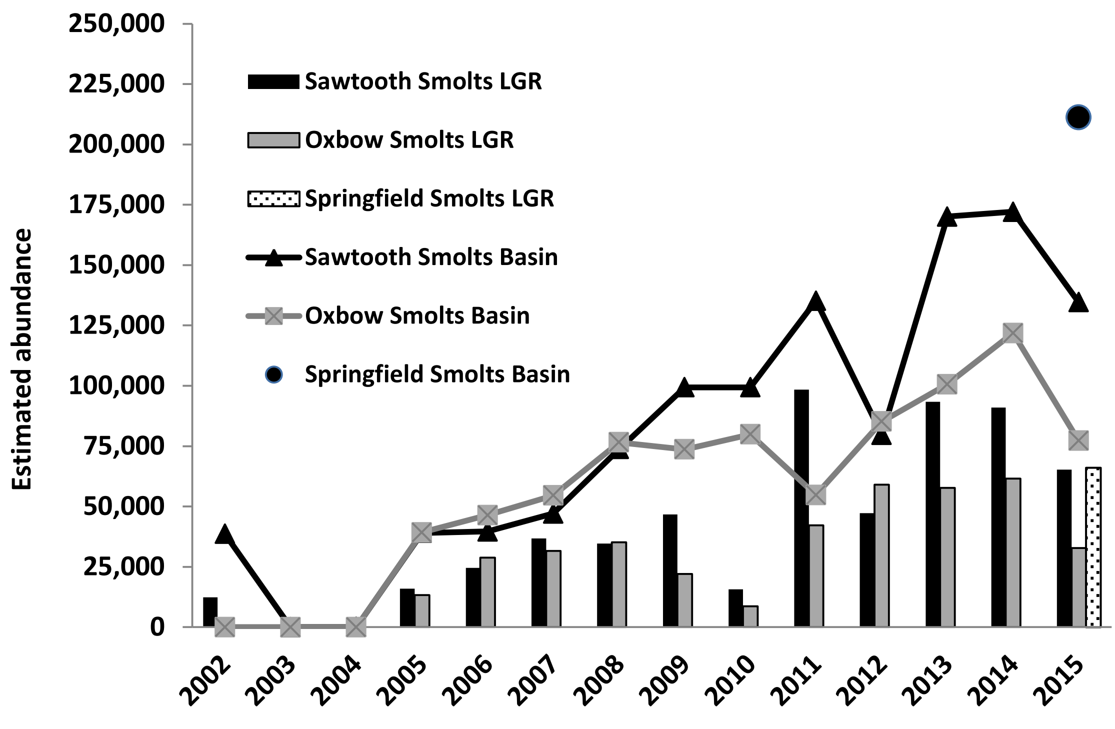

Figure 14. Estimated abundance of Oxbow full-term hatchery smolts (main production release group only), Sawtooth full-term hatchery smolts (main production release group only,) and Springfield full-term hatchery smolts leaving the Sawtooth basin and abundance estimates at LGR, 2002-2015.

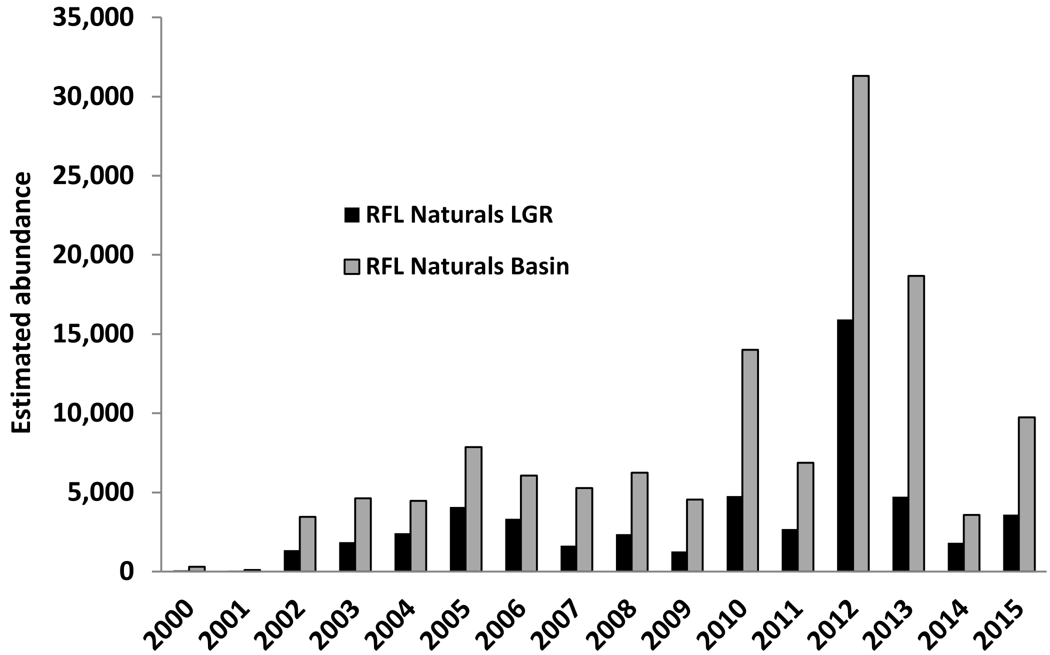

Figure 15. Estimated abundance for Redfish Lake natural smolts leaving the Sawtooth basin and abundance estimates at Lower Granite Dam, 2000-2015.

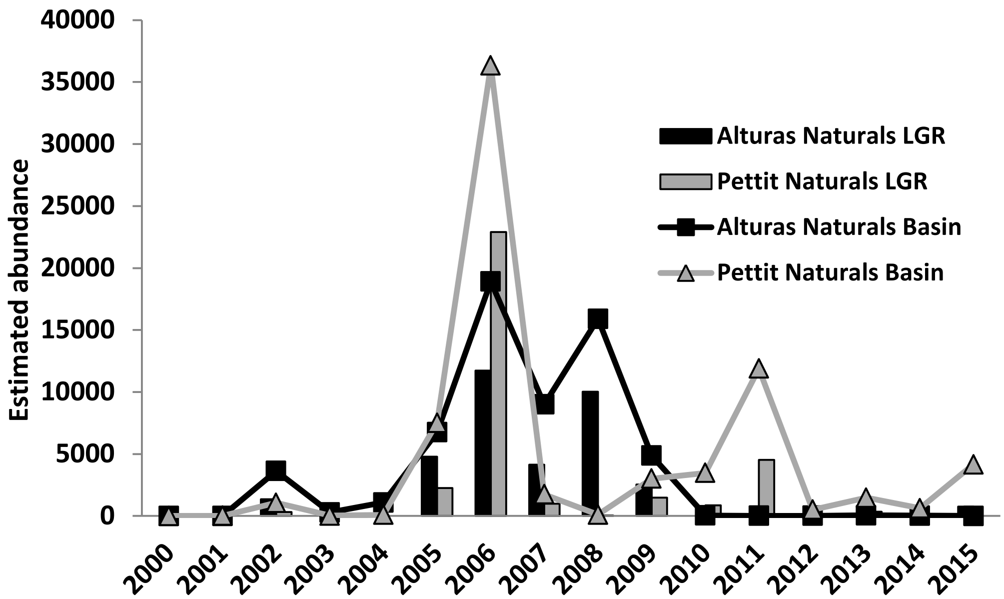

Figure 16. Estimated abundance for Alturas and Pettit Lake natural smolts leaving the Sawtooth basin and abundance estimates at Lower Granite Dam, 2000-2015.

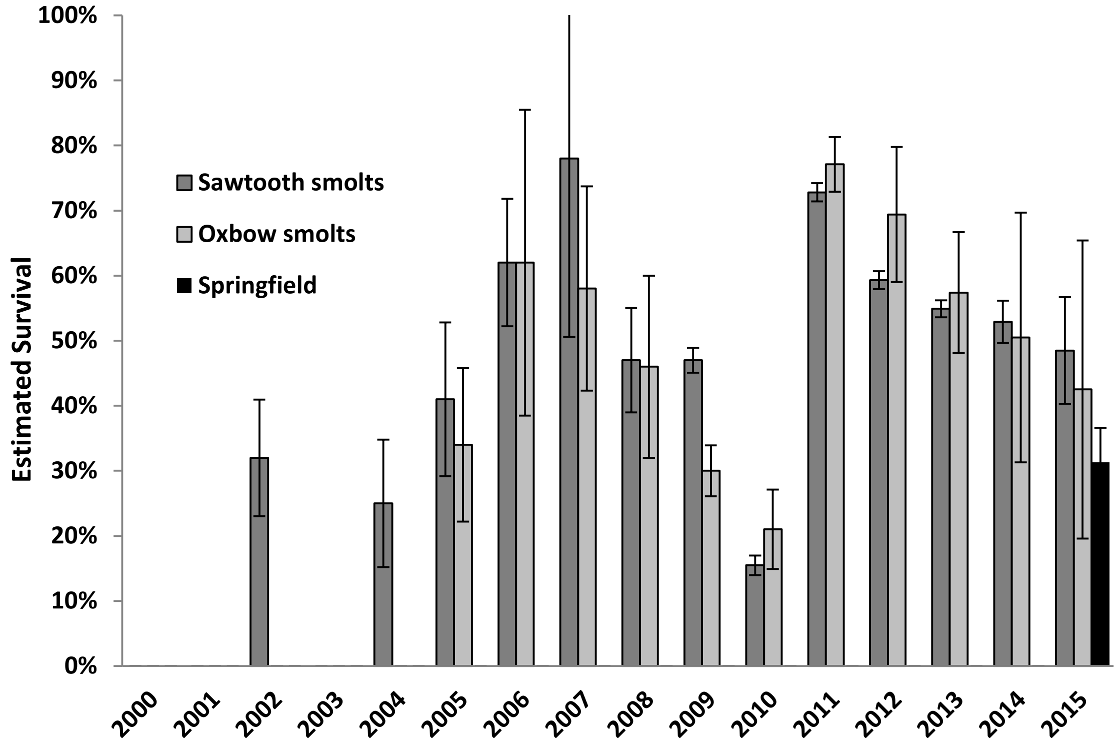

Figure 17. Estimated survival to Lower Granite Dam for Sawtooth hatchery smolts from 2002-2015 (dark grey bars), Oxbow Hatchery smolts from 2005-2015 (light grey bars), and Springfield hatchery smolts, 2015 (black bar). Error bars represent 95% CIs.

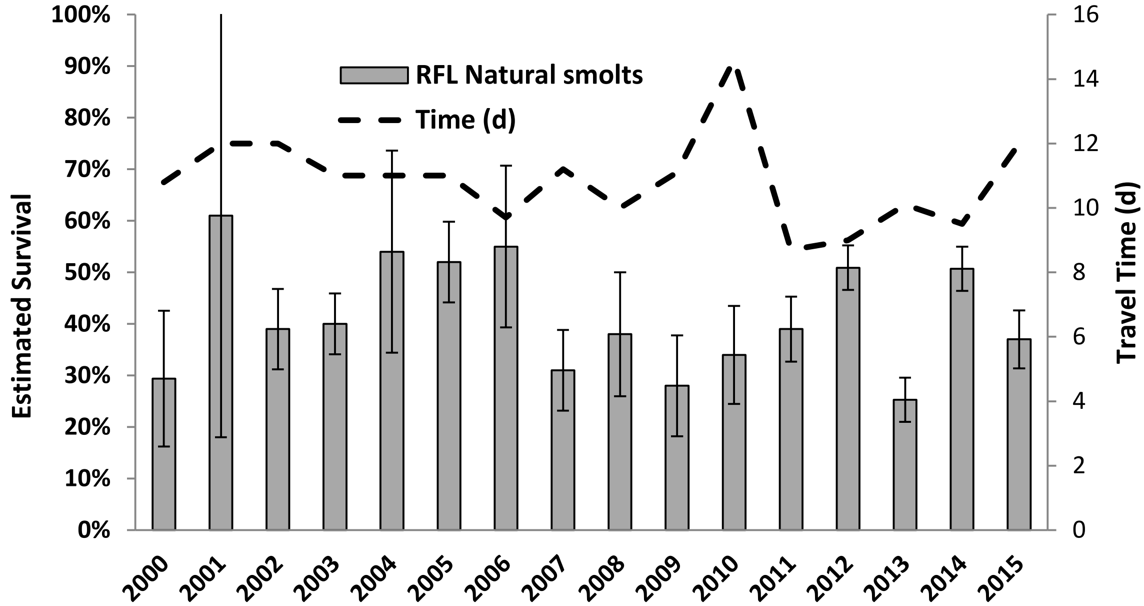

Figure 18. Estimated survival to Lower Granite Dam (grey bars) for Redfish Lake natural smolts, from 2000-2015 and the average travel time (broken line). Error bars represent 95% CIs.

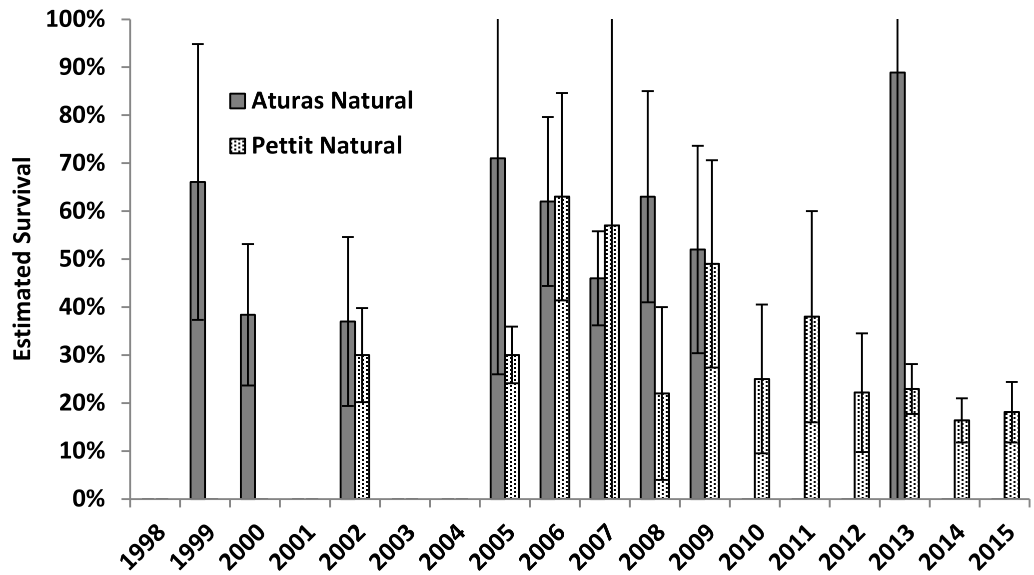

Figure 19. Estimated survival to Lower Granite Dam for Alturas Lake natural smolts (dark bars) and Pettit Lake natural smolts (pattern bars), from 1998-2015. Error bars represent 95% CIs.

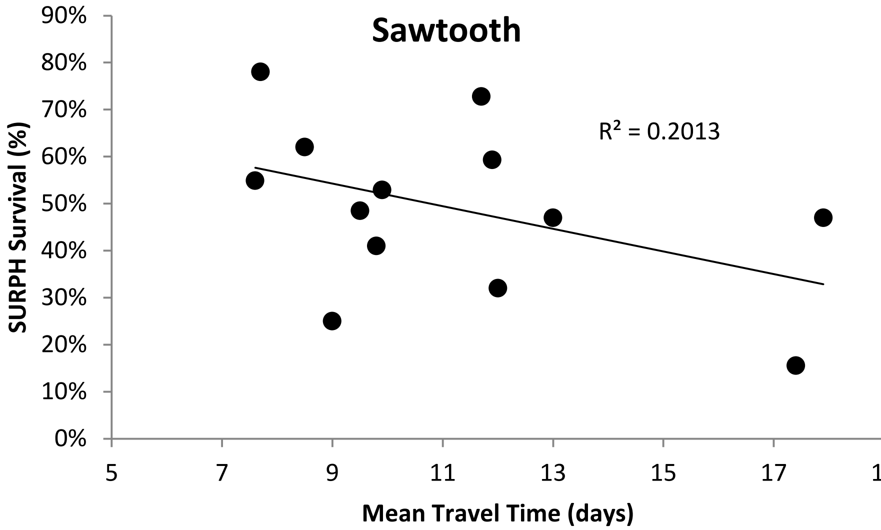

Figure 20. Survival from Sawtooth basin to Lower Granite Dam for Sawtooth Hatchery origin outmigrants 2002-2015 versus mean travel time.

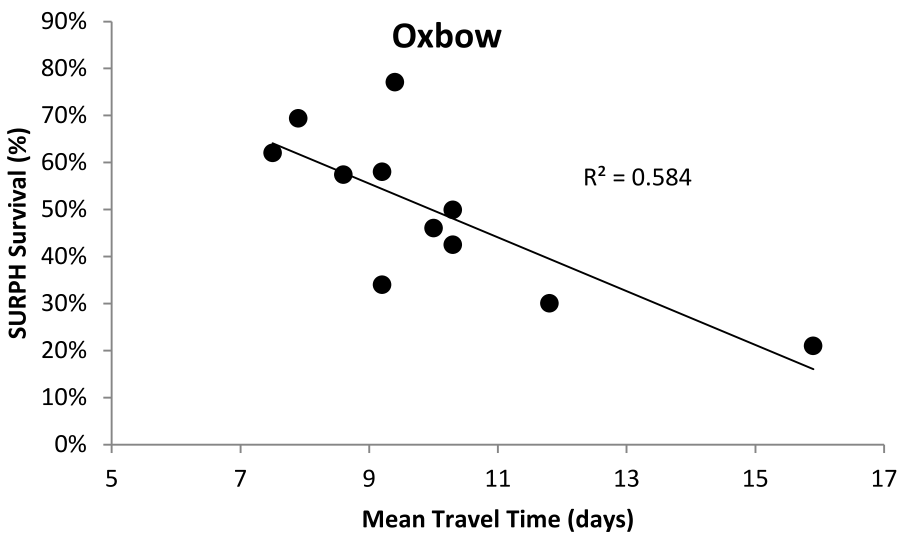

Figure 21. Survival from Sawtooth basin to Lower Granite Dam for Oxbow Hatchery origin outmigrants 2005-2015 versus mean travel time.

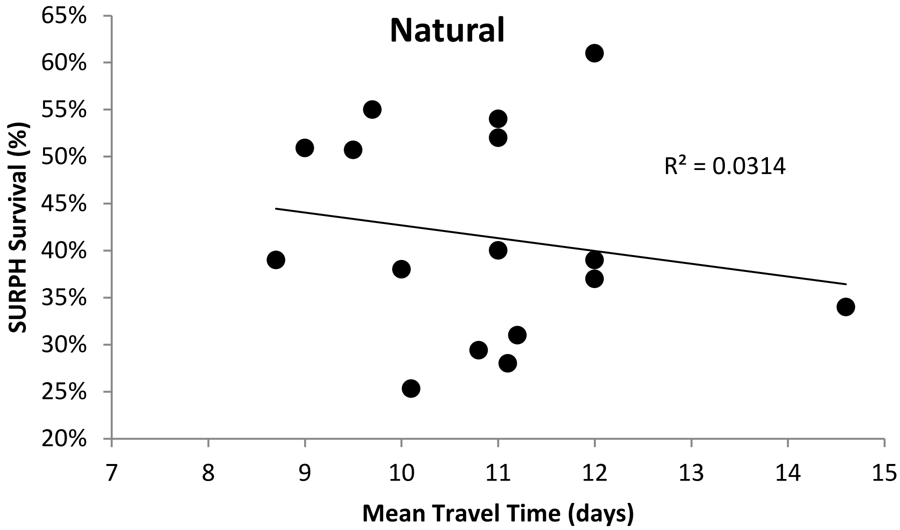

Figure 22. Survival from Sawtooth basin to Lower Granite Dam for Redfish Lake natural outmigrants 2000-2015 versus mean travel time.

PART 4—ANADROMOUS ADULT TRAPPING AND NATURAL PRODUCTION MONITORING AND EVALUATIONS

INTRODUCTION

Research on adult Snake River Sockeye Salmon focuses on collecting data to generate data for all four viable salmonid population (VSP) parameters: abundance, productivity or population growth rate, diversity, and spatial structure. The current focus of the program is centered on Redfish Lake as it offers the greatest production potential, but spatial structure and diversity has been addressed for this ESU by releasing fish at various life stages into nursery lakes (Alturas and Pettit). Spatial structure will become more of an emphasis in the recolonization phase of the program as adults are released into multiple lakes for natural spawning. A viable salmonid population is defined as a population that has a negligible risk of extinction due to threats from demographic, environmental, or genetic variation over a 100-year time period (McElhany et al. 2000). The recovery plan for Snake River Sockeye Salmon has been completed (NMFS 2015) and VSP information will be vital for future status assessments and the delisting or reclassification (e.g., from endangered to threatened) of this ESU. In order to meet biological and broad sense recovery goals, a minimum abundance threshold of 1,000 natural-origin spawners are needed for Redfish and Alturas lakes, while 500 natural-origin spawners are needed for Pettit Lake. In addition, the population growth rate must be stable or increasing and there must be a moderate risk rating for spatial structure and diversity for a viable population (NMFS 2015).

These parameters were measured by collecting information across a variety of life stages. Abundance of adults was measured as the number of returning anadromous adults trapped at each of the Sawtooth Valley basin weirs and LGR as well as the number of natural-origin and hatchery-origin adults released into Redfish and Pettit lakes for natural spawning. Collections of returning adults provide the program with basic biological metrics such as run timing, sex ratios, and age structure as well as estimates of adult survival from LGR to the Sawtooth Valley basin for the anadromous component. Evaluations of adult spawning (within the habitat) were measured by identifying the spatial distribution and quantifying redd production. Productivity was measured as the smolt-to-adult return ratio (SAR) and adult-to-adult recruits-per-spawner (R/S).

In this report, we provide information regarding trapping activities, adult releases, and genetic analyses to estimate abundance and productivity for natural and hatchery origin fish. Natural outmigration was estimated each year using juvenile weirs and traps (as described in Part 3) and is briefly summarized again here to develop SAR estimates. Estimates of juvenile survival, smolts-per-female, and recruits-per-spawner were also generated to monitor and evaluate the success of release strategies. Monitoring different life-stage survivals allows us to adaptively manage the Captive Broodstock Program.

METHODS

Trapping of Anadromous Adult Returns

Two adult collection facilities were used to capture anadromous returning adult Snake River Sockeye Salmon. The first trap was located on Redfish Lake Creek approximately 1 km downstream from the lake outlet. This trap also serves as a juvenile outmigration trap and with minor modifications was converted to a picket weir trap (Craddock 1958). The second trap was located at the Sawtooth Fish Hatchery on the upper Salmon River approximately 10.1 river km upstream from the town of Stanley, Idaho. The traps were placed into operation on the descending limb of the hydrograph and operated until no adults had been trapped for 5-7 consecutive days or until weather prohibited trap operation.

Traps were checked upon arrival each morning. Adults that were collected were either transported from the Sawtooth Valley basin to EFH or directly released upstream of the Redfish Lake Creek trap. Prior to being directly released at Redfish Lake or transported to EFH, fish were anesthetized in a 50 mg/L solution of MS-222 and checked for a the presence of a PIT or coded wire (CWT) tag. Fork length (mm), sex, differential marks (such as adipose clips), and body injuries (if present) were recorded. Genetic samples were collected using a paper hole punch in the dorsal fin (or another fin) for genetic analysis. Adults collected in the SFH weir also received a caudal fin punch to facilitate identification of trapping location at EFH. Adults that were directly released were placed into recovery holding boxes in Redfish Lake Creek. Once the fish had regained equilibrium, it was released or transported to another release location. Some adults are brought to EFH for spawning. These fish were assigned a PIT tag (shrink wrapped to a cable zip tie) so individuals could be tracked to release for volitional spawning or incorporated into the Captive Broodstock Program pending results from genetic analysis.

Scales from natural-origin adults were collected (approximately 4-5) immediately above the lateral line and slightly posterior to the dorsal fin (as identified in Devries and Frie 1996). The scales were transferred to a paper insert and placed in a scale envelope. Project personnel mounted the scales between two glass microscope slides. The best scales for aging returning adults were selected based on the presence of a complete focus and minimal or no scale regeneration. The entire scale was imaged using a microfiche reader on 24 and 48 x magnifications. Increased magnification was used to determine when the fish out-migrated as a juvenile (after one or two years) and the total age of the fish. Two technicians independently viewed each image to assign ages without reference to fish length. If there was no age consensus among the readers, a third reader viewed the image and all readers collectively examined the image to resolve their differences before a final age was assigned. If a consensus was not attained, the sample was excluded from further analysis (Schrader et al. 2011). These data were then compared to the genetically derived ages (methods below).

Utilizing the data collected from adult trapping locations and SFH, upriver conversion (e.g., survival or escapement) rates were estimated from LGR to the Sawtooth Valley basin employing three different methods: 1) to account for the degree of fallback and determine if window counts needed to be adjusted for fallback rates, 2) based on PIT tag interrogation data, and 3) supplementing window count data with nighttime video counts. Adult Sockeye Salmon counted at the window (day only or day and night combined) were divided by the total number of adults trapped to generate conversion rates (of trapped adults only) from LGR back to the Sawtooth Valley basin. Window and nighttime counts generated at LGR were queried through the Columbia River DART website (http://www.cbr.washington.edu/dart/query/adult_daily). Estimated conversion rates using only PIT-tagged adults, which were calculated by dividing the number of PIT-tagged adults observed at LGR by the number of PIT-tagged adults collected at the Sawtooth Valley basin traps, were also calculated (similar to Crozier et al. 2014). Finally, the conversion rate was estimated after adjusting adult numbers at LGR using PIT tag fallback percentage (the proportion of PIT-tagged individuals that were detected passing LGR more than once) data queried from the DART website (methods for these calculations can be found at http://www.cbr.washington.edu/fallback/). This was estimated by dividing the final trapped number by the adjusted passage counts at LGR. For years when fallback data was available (2008-2015), window counts were adjusted by the percentage of fallback to represent the number of adults crossing the dam. An additional investigation using a PBT mark-recapture analysis was conducted in 2013 and 2014 to determine if PIT tag data represents accurate estimates of adults passing LGR and to validate conversion estimates based on PIT tag data. Tissue samples were collected and genotyped from adults trapped in the LGR fishway and compared to those sampled at Sawtooth Valley basin traps. Genotypes compared for duplicates had to match 15 loci out of 15 loci or 16 out of 16 loci.

Not all anadromous adult Sockeye Salmon that returned to the Sawtooth Valley basin were trapped and fish have been observed straying into other tributaries. Tributary spawning ground surveys were conducted on Stanley Lake Creek (to the confluence with Valley Creek), Valley Creek (from the confluence of Stanley Lake Creek to the confluence with the main Salmon River), Redfish Lake Creek (below the trap to the confluence with the main Salmon River), and the Salmon River (from SFH to the mouth of Redfish Lake Creek) weekly starting with the last week of August and continuing until the second week of October. The peak counts for each section (regardless of date) were summed together to estimate the number of adults present in the basin that were not trapped. These fish were reported in Baker et al. 2016.

Trap and Haul Operations

The Army Corp of Engineers, NOAA, and IDFG personnel began actively trapping adult Sockeye Salmon in the LGR adult fish trap between July 13 and August 5, 2015 (See R. Graves *in review* for details). Emergency trapping was initiated when water temperatures in the fish ladder exceeded 70°F. Additional fish were captured and transported to EFH between August 5 and August 13, 2015 when they were trapped as part of routine biological sampling. Adult Sockeye Salmon falling back over the dam were also collected from the juvenile fish separator. Genetic samples were taken from all of the fish, and scale samples were collected from the unmarked returns. Initial genetic analyses indicated that some of the adults trapped at LGR had alleles not present in the captive broodstock. Columbia River Intertribal Fish Commission (CRITFC) geneticists provided a larger baseline of *O. nerka* throughout the Columbia River Basin and fish collected at LGR were screened so that genetic assignments could be performed with this larger baseline.

Adult Spawning in Redfish, Alturas and Pettit lakes

Between mid-September and early October, adult Sockeye Salmon were released to Sawtooth Valley basin lakes for volitional spawning. In order to assist in identifying spawning locations, typically six male and six female (three of each sex for anadromous and full-term hatchery) Sockeye Salmon were fitted with gastric implant radio transmitters prior to release (Eiler 1990). Telemetry investigations of adult locations were not conducted in 2015 but in prior years began mid-September and continued weekly through early November. Fish locations were recorded weekly by tracking movements via powerboat. Redd construction observations were made while radio tracking adults near spawning locations beginning in September and continued through early November. Once adult spawning activity ceased within Redfish Lake, a final redd count was conducted. Areas of excavation (possible redds) were generally 3 m x 3 m in size and likely represented spawning events by multiple parents. The number of redds produced per female released was estimated by dividing the total number of redds by the number of females released. This metric assumes that all released females were capable of producing a redd within the lake and that all redds produced were visible and counted during the final count.

Genetic Parentage Based Tagging Method

Genetic analyses were used to determine the origin of fish (release strategy) and age of each returning fish. A tissue sample was taken for genetic analyses from all fish trapped at Redfish Lake Creek or Sawtooth Fish Hatchery weirs. All potential parents of these returns were genetically sampled in the hatchery prior to spawning or release into the natural environment (for released adults). Genomic DNA extractions were carried out using a Nexttec DNA isolation kit according to the manufacturer's instructions (http://www.nexttec.biz). Samples were genotyped with a panel of 16 microsatellite loci (see Chapter 2 and contact authors for loci and genotyping protocols). A minimum of nine loci per individual was needed for inclusion in the parentage analyses.

The parentage software, Cervus V. X (Kalinowski et al. 2007) was used to perform the parentage analyses using parents with known sex. Up to one mismatch was allowed and only two parentage assignments were accepted. Additionally, cross information and release year was used to validate assignments. Based upon this analysis, the release strategies and ages of the returning adults were generated. While parentage based tagging essentially tags 100% of the offspring, not every offspring will be assigned to two parents due to missing parents in the sample, inaccurate tagging rates, genotyping error rates, and mutation or recording errors. Ages for the unassigned fish were generated using an age-length key. Program R code developed by Derek Ogle (fishR Vignette-Age-Length keys to assign age from lengths) was used to assign an age to unaged (e.g. unassigned) fish using genetic age and length keys with the semi-random method (Ogle 2013). The ages and lengths of the hatchery and natural production groups (separately) were used to develop age-length keys. An age was generated for each fish with known length (and unknown age). The trapping location of the fish was used to determine which release strategy unassigned adults should be categorized for additional productivity metric development (discussed later).

The total number of adults returned (by release strategy) to both trap locations per day was divided by the total run size (by release strategy) to generate a daily proportion during the return. The daily proportions were progressively summed until the proportion equaled one (or the total run size by release strategy). Adults that were captured during the net capture event (known as the “Sockeye Salmon roundup”) below the SFH weir were not included in the run timing data because these individuals were not trapped and return timing was not available. This information was used to evaluate differences between hatchery and natural production.

Smolt-to-Adult Survival

With the completion of genetic analyses for the 2015 return year, we were able to finalize productivity metrics for the brood year 2010. SAR estimates for BY 2011 are only a minimum estimate, as they do not include any 5-year-old fish. In order to calculate SARs, both juvenile outmigration data (Part 3) and adult return data were needed. Individual brood year smolt production was summed using age-1+ and age-2+ smolt estimates emigrating from basin lakes for natural production for Redfish, Alturas, and Pettit lakes and using age-1+ release numbers for the full-term hatchery smolt components. Juvenile emigration data used to calculate SARs for BY04-11 are presented in Appendix C.

The adults used to calculate release strategy SARs were collected at the basin trap locations (described above) from 2006-2015. Adults returning to the Sawtooth Valley basin included marked (Ad-clipped) or tagged (CWT or PIT) hatchery-origin, or an unmarked or PIT-tagged group of natural-origin fish. In order to identify age and origin to each returning adult, both PBT aging and marks were used (2010-2015). The hatchery marks applied to different release strategies can be found in the Snake River Sockeye Salmon Captive Broodstock Program hatchery element reports (Baker et al. 2009a and 2009b). Natural production adults originating from Alturas and Pettit Lake collected at the SFH weir were added together in the SAR estimates since the lake of origin as emigrants was unknown when collected at the weir.

SAR estimates were generated by summing age-3, age-4, and age-5 returns from the appropriate release strategy or group and dividing by the estimated outmigration number from the appropriate BY for each release strategy or group. Confidence intervals for the natural production SAR was calculated using the following formula (Ben Sanford, NOAA, personal communication):

$$\hat{V}(\widehat{SAR}) \approx \frac{\widehat{SAR}(1-\widehat{SAR})}{\widehat{N}} + \frac{\sum_i V(h_i)}{\hat{N}^2} + \frac{\widehat{SAR}^2}{\widehat{N}^2}\hat{V}(\widehat{N})$$

Recruits-per-spawner (R/S) and recruits-per-female (R/F)

Returning adults that have been assigned to a specific brood year and release strategy were used to generate estimates of adult recruits-per-spawner and adult recruits-per-female. This was done by dividing the total number of returned adults (for the BY and release strategy) by the number of spawners (male and female for R/S) or female spawners (R/F) that produced the group. For the hatchery production groups, the numbers of spawners was generated from spawning records at the EFH and Burley Creek Fish Hatchery (BCH). For natural production within Redfish Lake, it was assumed that all of the released females had successfully spawned and that negligible residual spawning occurred.

RESULTS

Trapping Of Anadromous Adult Returns

A total of 91 anadromous Snake River Sockeye Salmon adults were trapped during 2015, 50 were trapped at the RFLC trap and 6 at the SFH weirs (11 natural origin and 45 hatchery origin; Figure 23). Of the 51 adults collected at LGR, 35 (69%) were assigned as Snake River Sockeye Salmon (natural origin = 3, hatchery origin = 32) and the remaining 16 (31%) were determined to be from Wenatchee or Okanogan stocks and were subsequently culled (Figure 24). There was no discernable difference in run timing distribution between Snake River and out of basin adults passing over LGR. This followed a year (2014) with the largest run of Snake River Sockeye Salmon since 1954 when 1,516 adult were trapped (1,479 at the RFLC trap and 34 at the SFH weirs and 1 unknown; Table 6) of which 453 were natural origin and 1,062 were of hatchery origin. In 2013, 270 adult Sockeye Salmon (79 natural origin and 191 hatchery origin) were trapped at Redfish Lake Creek (n = 222) and at the Sawtooth Fish Hatchery weir (n = 46; Table 6; Figure 23).

Adult Spawning

Since 1993, 6,820 hatchery-reared adults and 5,084 anadromous adult Sockeye Salmon have been released into these lakes (Figure 25). Prespawn adults from the Captive Broodstock Program have been released almost every year since 1993 and since 2008, larger numbers of anadromous fish have been released into the Sawtooth Valley basin lakes (Hebdon et al. 2004; Figure 25). The number of prespawn adult Sockeye Salmon released into Redfish, Alturas, and Redfish lakes has varied considerably in response to the high variability in returns to the Sawtooth basin (Figure 25). In 2013, 184 anadromous (51 female) and 162 captive adults (55 female) were released into Redfish Lake for volitional spawning. In 2014, 1,073 anadromous (486 female) and 1000 captive adults (608 female) were released, and in 2015, 494 captive adults (272 female) were released. The number of females released (anadromous and captive) explained 67% of the variability in the estimated number of outmigrants leaving Redfish Lake, taking into consideration the age of outmigration (Figure 30). Recent adult releases into Pettit Lake include 98 captive adults (50 females) in 2014 and 93 captive adults (51 females) and 5 anadromous adults (4 females) in 2015. No adults were released into Pettit Lake in 2013. Direct releases into Alturas Lake have not been conducted since 2000. Anadromous adult releases were comprised of 39% females and the captive reared adults from NOAA Burley Creek Hatchery (BCH) and EFH were 50% females, resulting in a slightly skewed male sex ratio (56% male overall). Sex was determined by ultrasound for hatchery reared adults and the use of phenotypic secondary sex characteristics for the anadromous returns (Burgner 1991).

During the final counts, redds (areas of excavation) were identified near the U.S. Forest Service Transfer dock, on the beach southeast of the Redfish Lake Creek inlet, within the southern snorkel transect area, at Sockeye Salmon Beach, and along the west shore approximately halfway down the lake (Figure 28). In 2013, 510 areas of excavation were observed in Redfish Lake and one redd was observed in Fishhook Creek and 106 females were released into Redfish Lake (4.8 redds/female). In 2014, 616 areas of excavation were observed in Redfish Lake and 1,094 females were released into the lake (0.6 redds/female) and in 2015, 157 redds were counted after releasing 272 captive females (0.6 redds/female). Across all study years (1993-2015) the number of females released (anadromous and captive) explained 59% of the variability in the number of redds observed later in the fall (Figure 29). While conducting redd surveys, redds were occasionally observed between Redfish Lake and the confluence of Redfish Lake Creek and in the Salmon River. No redds were observed in Valley Creek from the mouth of the Salmon River to the confluence of Stanley Lake Creek.

Genetic Parentage Based Tagging

In most cases (>90%) returning adults could be successfully assigned to two parents. In some cases, marks and tags were available so even if the fish could not be assigned to two parents, its origin was known. Using both mark information and assignment data, the composition of the returning adults (including fish captured at Lower Granite Dam in 2015) was primarily from Oxbow Fish Hatchery smolt releases (44% in 2012 to 60% in 2014; Table 7). Adult returns originating from Sawtooth Fish Hatchery smolt releases, adult releases, natural production, presmolt releases, and egg boxes have also been observed (Table 7). The age structure of returning adults based on PBT analysis and age length keys consisted mostly of 4-year-olds for all release strategies. However, we observed a higher proportion of 3-year-old hatchery returns (primarily from the Oxbow Fish Hatchery releases) and a higher proportion of 5-year-old natural returns (Figure 36).

Based on adult counts at the fish ladder observation window, anadromous adults begin passing Lower Granite Dam between late May and late June (2008-2015 average = June 19) and 90% of the fish have passed by the end of July (2008-2015 average = July 26); however, run timing can vary between years by a couple of weeks or more (Figure 31). In 2015, a few adults were first observed at Lower Granite Dam on May 26 and half the run had passed by July 13. In 2013, the run was later with the first adult observed on June 13 and 50% of the run passing by June 20. We observed less variation between years in run timing for those fish returning to Sawtooth basin traps (SBTs; Figure 32). Peak run timing for adult trapped in the Sawtooth Valley basin (50% cumulative run timing) ranged from August 11 (2014 and 2015) to August 22 (2012). We did observe a run timing shift in 2015 between Lower Granite Dam and the Sawtooth Valley basin with the earlier LGR run arriving later at traps in the Sawtooth Valley basin. Across years, over 90% of the cumulative returns to Sawtooth basin traps occurred between August 27 and September 13 (average = September 10).

Increases in the number of PIT-tagged hatchery fish released starting in 2009 has corresponded to increased PIT tag observations at Lower Granite and at Sawtooth Valley basin traps. Prior to 2010, 71 PIT- tagged adult Sockeye Salmon that were tagged as juveniles prior to outmigration were observed at LGR. Between 2011 and 2015, 713 PIT-tagged adults have been observed. Conversion rates (surrogate for survival) from Lower Granite Dam to the Sawtooth Valley basin over the past 5 years using PIT tag data (not adjusted for fallback) averaged 47% and ranged from 25% (2015) to 70% (2011) (Figure 27). Adjusted for fallback, conversion rates averaged 58% and ranged from 14% (2015) to 84% (2011). Conversion estimates using window counts conducted by the USACOE ranged from 13% (2015) to 73% (2011) and averaged 45% over the last 5 years and likely included adults that were counted multiple times at the window (Figure 27). Conversion using window counts and taking into consideration nighttime passage averaged 40% over the last 5 years, ranging from 12% (2015) to 65% (2011). Window counts (including nighttime counts) conversion rates in 2013 were 32% and 47% in 2014 (Figure 27). During 2013 and 2014, an investigation using a PBT mark–recapture analysis was conducted to estimate conversion rates of adults trapped at LGR back to the Sawtooth Valley basin as an independent measure of conversion rate to validate the estimates based upon PIT tags. Forty-four adults were trapped and genotyped at Lower Granite Dam between June 6 and July 10, 2013 and 68 adults were trapped and genotyped between June 22 and July 7, 2014. This corresponded with 48 (2013) and 46 (2014) Snake River Sockeye Salmon PIT tag detections at LGR during the same time period. Conversion rates from LGR to the Sawtooth Valley basin were lower for fish that were genetically sampled, 41% compared to 48% of those PIT tagged (2013) and 68% compared to 74% (2014); however, these differences were not statistically significant, $Z = -0.068$, $P = 0.49$ (2013), and $Z = -0.72$, $P = 0.47$ (2014).

<u>Productivity Estimates Per Release Strategy</u>

Productivity as measured by the number of smolts to adult returns (SARs) and recruits per spawner (R/S) are presented in Figures 33, 34, and Appendix C for brood years (BY) 2004-2011. Collectively, SARs for the natural-origin smolts migrating from Redfish Lake were the highest and averaged 1.23% over the past seven years (excluding 2011 since age-5 returning adults are not represented; Figure 33). SARs for natural-origin production from Alturas and Pettit lakes averaged 0.60% (BY 2004-2010) and ranged from 0.08% (BY 2005) to 2.72% (BY 2010). Oxbow Hatchery reared full-term smolts had intermediate SARs of 0.58% (BY 2004-2010) and SARs for Sawtooth Hatchery reared full-term smolts and juvenile Sockeye Salmon released as presmolts had consistently lower SARs, BY 2004-2010 average of 0.26% and 0.18%, respectively (Figure 33). Although incomplete, the SARs for BY 2011 range from 0.03% for Sawtooth-reared smolts to 0.27% for Oxbow-reared smolts (Figure 33). Current SARs for BY11 natural origin smolts from Redfish and Alturas and Pettit lakes (combined) are 0.13% and 0.08%, respectively.

The OFH production group returned the highest number of recruits-per-spawner (BY 2004-2010 average = 2.48) and natural production produced the lowest R/S (BY 2004-2010 average = 0.22 for Redfish Lake and 0.19 for Alturas and Pettit lakes; Figure 34). SFH smolts produced an intermediate R/S of 0.54. The average R/S for the program for BY11 (excluding 5-year-old 2016 returns) was 0.16 (363 recruits and 2,307 spawners; Figure 34). The number of recruits-per-female (R/F) followed the R/S trend. Recruits-per-female was the highest for the OHF production group (BY 2004-2010 average = 5.8) and lowest for the natural productions groups: 0.55 for RFL naturals and 0.46 for the Alturas and Pettit lake naturals. The average R/F for all release groups combined for BY 11 was estimated to be 0.56 (363 recruits and 1,035 females).

DISCUSSION

Anadromous Return

The incorporation of anadromous adults continues to be an important part of our program as these adults have been exposed to natural selective processes. Increases in the numbers of anadromous Snake River Sockeye Salmon returns over the past decade is likely the result of a combination of factors which includes increased hatchery production (primarily from full-term smolt releases) and favorable marine conditions (Williams et al. 2014). Some years, unfavorable in-river conditions during upstream migration also influence adult returns to the Sawtooth basin as they did in 2015 and 2013. High migration mortality for adults and juvenile Snake River Sockeye Salmon has been associated with temperature exposure (Mcdonald 2000; Keefer et al. 2008; Rand et al. 2006). Increased mortality for salmon migrating near their thermal tolerance limits can result from physiological effects to altered migrations timing (Mcdonald 2000; Rand et al. 2006). Survival has been observed to be lower for the later migrants as was the case in 2015. Keefer et al. (2008) observed a shift to complete mortality of radio-tagged adult Sockeye Salmon when Snake River water temperatures at Anatone, Washington reached 21°C. Unlike other species of *Oncorhynchus* it is not evident that Sockeye Salmon seek and use thermal refugia when water temperatures approach their lethal range (Goniea et al. 2006; High et al. 2006; Keefer et al. 2008). In 2015, Snake River Sockeye Salmon collected at LGR accounted for 38% of the overall return and almost doubled what we collected in the basin. Without this emergency trap and haul operation, it is likely that most if not all of the Snake River Sockeye Salmon adults that passed over LGR after July 16 would not have made it back to the Sawtooth basin (Figure 35). Emergency trapping and transport actions provided a mechanism to collect a larger and more representative sample of adults with anadromous experience (and their likely fitness benefits).

Adult return timing and age structure for each release strategy was generated to evaluate changes in population structure. Smolt production from Oxbow and Sawtooth fish hatcheries had a higher proportion of age-3 adult returns compared to natural production, which typically had a higher proportion of age-5 adult returns. The age-structure proportions observed for natural production within Redfish Lake were similar to data presented in Bjornn et al. (1968). Our results differed from the age structure observed overall at Bonneville Dam (representing primarily upper Columbia River stocks) indicating that Snake River Sockeye Salmon may have a different age structure than that observed within the upper Columbia stocks (Williams et al. 2014).

Implications of inaccurately estimating population size of anadromous returns

The use of PIT tag data has been integral to provide better estimates of survival in addition to the numbers of adults passing Lower Granite Dam and the overall survival rate (e.g., conversion rate) to LGR and the Sawtooth Basin. Window counts conducted at LGR provide an estimate of adults that migrate above the dam; however, using PIT tag data, observations have been made that some fish fallback and re-ascend multiple times, which likely inflates the number of adults observed in window counts (Naughton et al. 2006). Furthermore, fish that fallback multiple times may be associated with migration delays or less likely to return to their natal locations than those that do not (Boggs et al. 2004). Therefore, fallback percentages were estimated and used to adjust window counts to develop conversion rates. Conversion rates using the fallback adjusted window counts were significantly higher than the estimate derived from window count data and could potentially lead to different interpretations regarding survival and the effects of dam operations and harvest (Dauble and Mueller 2000; Boggs et al. 2004). Estimates of conversion rates using the PBT mark-recapture analysis in 2013 and 2014 were not significantly different from estimates using PIT tags. However, due to temperature constraints during trapping at LGR we only sampled the first 37% of the run in 2013 and 18% in 2014. Survival estimates using genetic recapture methods indicates PIT tag data does provide a reasonably good estimate of survival, at least for early returning fish, which generally have higher survival to the Sawtooth Valley basin. In 2015, we observed a 2-fold difference in survival between PIT tag counts and fallback adjusted window counts, which highlights the disadvantages of using PIT only data to calculate conversion during years when such a small sample size precludes accurate assessment of the population. Identifying high precision methodology to use for Sockeye Salmon will be important for calculating life-stage specific survival measurement, as the implications are important for harvest management (lower Columbia River) and escapement estimates. Currently, conversion estimates do not include adults observed within the Sawtooth Valley basin that were not trapped; due to uncertainty in the origin of these fish. Monitoring untrapped adults will continue to be important to quantify straying from trap location and pioneering of adults into additional habitats within the Sawtooth Valley basin.

Natural Spawning

Migration timing, spawning locations, and redd construction timing were similar among years (Plaster et al. 2007; Peterson et al. 2008, 2010, 2012a; 2014). The distribution of redds within the lake was similar to past years where the majority of redds counted occur in the south end of the lake near the southern snorkel transect (Figure 28; Peterson et al. 2008, 2010, 2012a, 2014). Final redd counts were conducted in one day at the end of the season which may explain, in part, some of the observed variability between the number of females released and the final redd counts (for example 2010 and 2013; Figure 25). There may be a variety of factors that affect our ability to accurately count redds during the final count and may include water clarity, viewing conditions (weather related issues such as storms vs. sunny), and adult densities released into the lake. The number of residual adults present on the spawning grounds may also skew our estimates because residual production was not estimated within Redfish Lake. Another factor was that some Sockeye Salmon redds averaged approximately 2 m^2 and may have represented multiple parents. Burgner (1991) suggests that mass spawning events within lakes may lead to multiple nests, or egg pockets, per female. Therefore, the number of redds and females per redd may be difficult to quantify.

Natural productivity metrics provides additional information to monitor the success of volitional spawning within the natural environment. Full-term captive and anadromous adults have been released for volitional spawning since 1993 and there has been a high correlation (R^2 = 0.69) between the number of females released and estimated natural juvenile outmigrants. In years more females were released, we observed higher production of smolts. Although strongly correlated, the contribution of outmigrants by residual Sockeye Salmon in Redfish Lake likely explains some of the variability observed between anadromous and captive females and the number of observed outmigrants. Rieman et al. 1994 reported that both anadromous and residual forms of *O. nerka* can produce either resident or anadromous offspring. Additional variability is likely attributed to annual differences in egg-to-fry survival, precision of outmigration estimates, and variability in outmigration age. Regardless, these results highlight the success of the program and the ability to increase effective population size using these adult release strategies.

Parentage Based Tagging

The PBT analysis provided key information regarding the age and origin of returning fish. In order to apply an age for all returning fish for productivity metrics, additional analyses were performed to generate ages for the unassigned fish. Generating accurate ages for adult returns was important to assigning fish back to a specific BY for SAR and R/S estimation. PBT assignments produce the accurate ages needed to estimate SARs for the release strategies but cannot account for all fish. The results of the genetic and scale comparison indicated that 32% of the scale ages were incorrect (Peterson et al. 2014). In general (using scales), younger adult returns (age-3) were overestimated and older aged adult returns (age-5) were underestimated. Similar patterns were observed in a steelhead study that validated the use of scale ages using PBT analysis (Seamons et al. 2009); however, the degree of error was lower. Overall, the age key was able to provide an age for each returning adult based upon a distribution of PBT ages and lengths and appears to be the best method available. The age key relies on having good age-length data and if data gaps exist in the known distribution, a fish was assigned to the age associated with the closest length. Since we have a relatively small number of unmarked fish returning, the distribution of known ages and lengths has gaps that may lead to some biases. Errors associated with aging can lead to differences in productivity metrics and potentially lead to inflations of weak cohorts or decreases of strong cohorts (Campana 2001; Copeland et al. 2007); therefore, it is important to attain accurate ages.

Brood Year Productivity Metrics

Smolt-to-adult return rates suggest that volitional spawning within Redfish Lake appears to be an important strategy to the success of the Snake River Sockeye Salmon Captive Broodstock Program. Natural production (primarily resulting from adult releases) occurring within Redfish Lake had the highest overall survival rates from the smolt-to-adult life stage despite having lower emigration survival from the Sawtooth Valley basin to Lower Granite Dam. Survival of smolt to returning adult at Redfish Lake were similar to those observed by Bjornn et al. (1968) between 1955 and 1964, which ranged from 0.14 to 1.83%. The use of full-term hatchery smolt production (both the OFH and SFH) followed natural production as the second best release strategy with smolts reared at the Oxbow Hatchery outperforming smolt reared at the Sawtooth Hatchery some years. Others have observed a similar survival pattern at the same life stage among natural and hatchery Chinook Salmon within the Snake River Basin (Buchanan et al. 2010; Cleary and Edwards 2011). Snake River SARs have been found to be lower than those from upper Columbia River populations (Williams et al. 2014). A larger proportion of juveniles from the Snake River are barged below Bonneville Dam compared to upper Columbia River juveniles that migrated in-river. Migration distance and altitude is also greater for Snake River Sockeye Salmon that represents a stock at its southernmost range. Differences in stocks productivity (such as size and growth), migration timing are also likely contributing factors (Williams et al. 2014). Current and future releases will focus on full-term hatchery smolt (primarily Springfield Fish Hatchery) and anadromous and captive adult releases. Egg-box and presmolt production were not as successful for producing anadromous adult returns. Based in part on this information, both egg-boxes and presmolt releases have been discontinued from the program.

Snake River Sockeye Salmon natural production remains sporadic as a result of variable and oftentimes marginal in-river and ocean environments, and the captive broodstock continues to be an important recovery strategy to rebuild the population. Full-term smolt production was observed to produce the highest number of R/S among the “spread-the-risk” release strategies and is important for population amplification. We observed a 7-fold advantage using full-term hatchery smolt production (combined SFH and OFH production group) over natural production within Redfish Lake. Our R/S results were similar to those observed by others investigating differences between hatchery and natural Chinook Salmon production. The Lostine River, Oregon Chinook Salmon supplementation program reported differences in recruits-per-spawner ratios of 8-16 times higher for hatchery production compared to natural Chinook Salmon (Cleary and Edwards 2011). Rabe and Nelson (2009) also observed R/S ratios approximately 8-times higher in Chinook Salmon hatchery production over natural production in the Johnson Creek, Idaho supplementation program. Artificial propagation has also successfully implemented in a couple of Bristol Bay natural Sockeye Salmon populations, the Kvichak stock, averaged 2.2 R/S, followed by the Togiak (3.0 R/S) and Egegik (5.1 R/S; Ruggerone and Link 2006).

Differences observed between SARs and R/S metrics highlighted important information to the program. Natural selection and fitness act differently on natural and hatchery reared smolts. Juveniles that are reared in the lake are exposed to selective pressures and produce adults that are better suited to the habitat, while hatchery produced and reared fish have higher survival (particularly during the early life stages) because of a controlled environment. Understanding that juvenile Snake River Sockeye Salmon produced from natural spawning events have been observed to survive better to the adult life stage (higher SARs) and utilizing full-term smolt production to provide the largest component of our anadromous adult returns (R/S benefits) has increased the overall abundance of anadromous adults, similar to what has been observed by other programs (Waples et al. 2007). This has also provided increased population stability and security within the ESU. Monitoring these VSP metrics should continue and should be investigated into the future in response to climate change and shift to hatchery releases of full-term smolts from the Springfield Fish Hatchery.

Adaptive Management—Lessons Learned

Captive broodstock technologies for Sockeye Salmon were considered experimental when the program was initiated; however, the program has taken advantage of the high fecundity of Pacific Salmon and survival benefits that aquaculture provides to successfully avoid population extinction. Over time, through adaptive management, the program has expanded in terms of re-establishing fish back into the natural environment, increasing population abundance and survival at different life-stages, and has conserved the genetic lineage of the population. Monitoring and evaluation has identified two strategies that result in the highest number of anadromous returns: 1) captive and anadromous adult releases, and 2) full-term smolt releases. Releasing captive and anadromous adults to volitionally spawn produces the greatest benefits in terms of smolt-to-adult returns (SARs) and springtime releases of full-term hatchery reared smolts (particularly Oxbow Fish Hatchery smolts) provides the greatest benefits in terms of recruits per spawner (R/S). This demonstrates the importance of using a two life stage approach to maximize recovery of this stock. Future plans involve releasing up to 1 million full-term smolts reared at the Springfield Fish Hatchery, which could result up to 10,000 anadromous adult returns to the Sawtooth Valley basin each year. The first release from Springfield Hatchery occurred in 2015 and generated important baseline information to guide future, larger releases from this hatchery. The anticipated increase in anadromous returns allows for the release of additional captive broodstock and anadromous adults into the lakes for volitional spawning, which will be an important step moving forward with recovery. Research, monitoring, and evaluation will continue to be a key component to understanding the contribution and characteristics of these hatchery releases in increasing population abundance and viability.

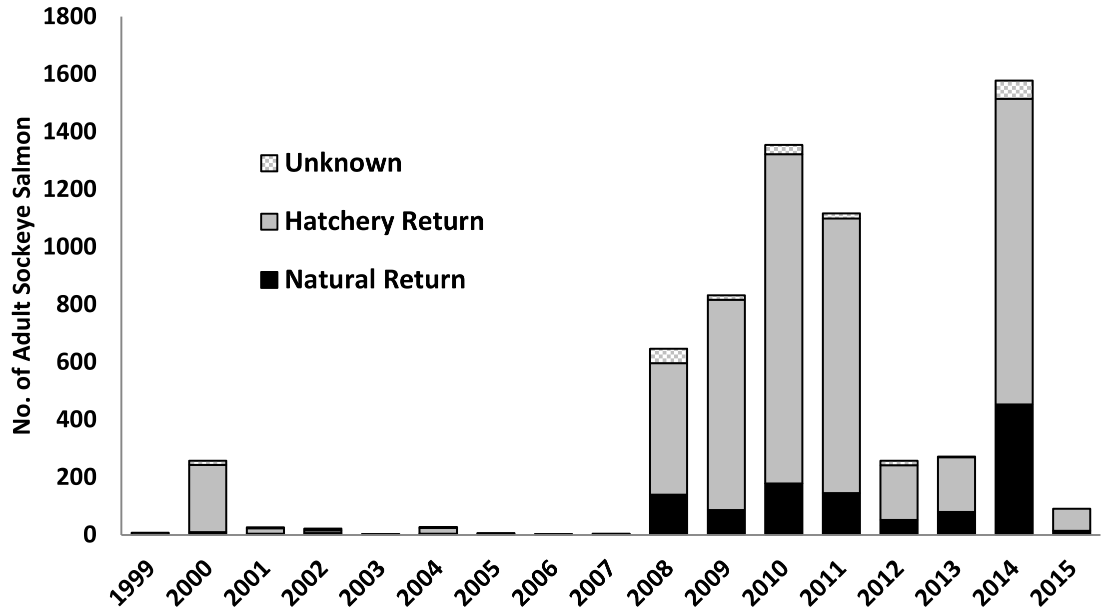

Figure 23. Anadromous Sockeye Salmon adults returning to the Sawtooth basin traps.

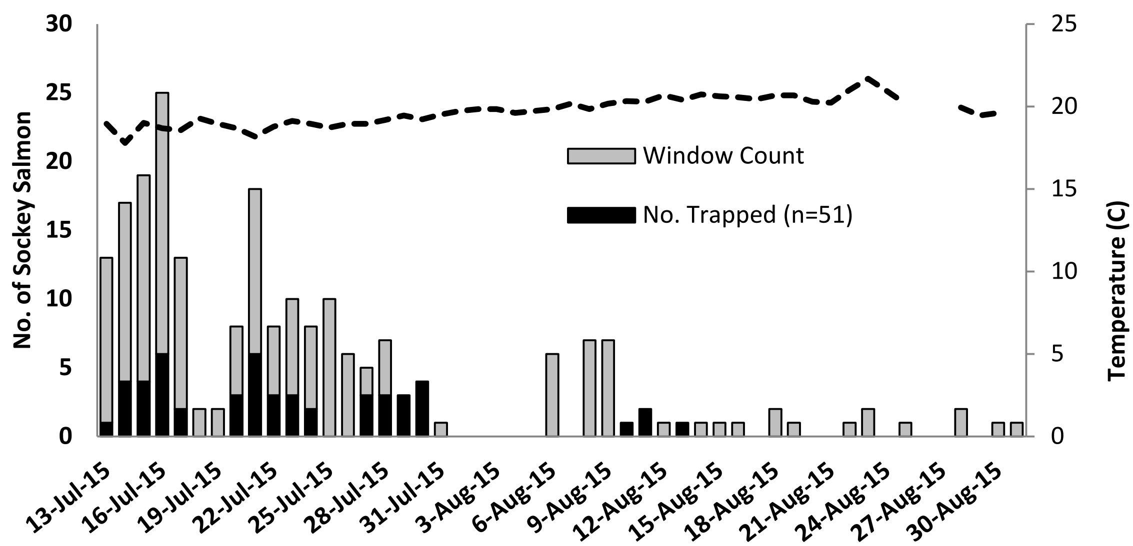

Figure 24. Number of adult Sockeye Salmon collected at Lower Granite Dam (LGR) and transported to the Eagle Fish Hatchery (EFH; black bars), daily adult window counts (grey bars), and water temperatures in the LGR forebay (broken line).

Table 6. Adult Sockeye Salmon return history to traps on Redfish Lake Creek (RFLC), Lower Granite Dam (LGR) and the upper Salmon River at Sawtooth Fish Hatchery (SFH).

Return Year	**RFL Trap**	**SFH Trap**	**LGR Trap**	**Other Traps***	**Observed** (Not Trapped)	**Total Return**
1954	998	NA	NA		0	998
1955	4,361	NA	NA		0	4,361
1956	1,381	NA	NA		0	1,381
1957	523	NA	NA		0	523
1958	55	NA	NA		0	55
1959	290	NA	NA		0	290
1960	75	NA	NA		0	75
1961	11	NA	NA		0	11
1962	39	NA	NA		0	39
1963	395	NA	NA		0	395
1964	335	NA	NA		0	335
1965	17	NA	NA		0	17
1966	61	NA	NA		0	61
No Data Collected between 1967-1984						
1985	3	11	0		0	14
1986	29	0	0		0	29
1987	16	0	0		0	16
1988	0	1	0		0	1
1989	0	1	0		0	1
1990	0	0	0		0	0
1991	4	0	0		0	4
1992	1	0	0		0	1
1993	8	0	0		0	8
1994	1	0	0		0	1
1995	0	0	0		0	0
1996	1	0	0		0	1
1997	0	0	0		0	0
1998	1	0	0		0	1
1999	0	7	0		0	7
2000	119	124	0		14	257
2001	15	8	0		3	26
2002	8	7	0		7	22
2003	2	0	0		1	3
2004	1	22	0	1	3	27
2005	2	4	0		0	6
2006	0	3	0		0	3
2007	1	3	0		0	4
2008	378	218	0		50	646
2009	567	249	0		16	832
2010	652	648	19	3	33	1355
2011	542	556	0	1	18	1117
2012	107	135	0	0	15	257
2013	222	46	0	2	2	272
2014	1479	34	0	3	63	1579
2015	50	6	35	0	0	91

*Other traps include: East for Salmon River (EFSR), Yankee Fork Salmon River (YFSR), and Hells Canyon Dam trap (HCD).

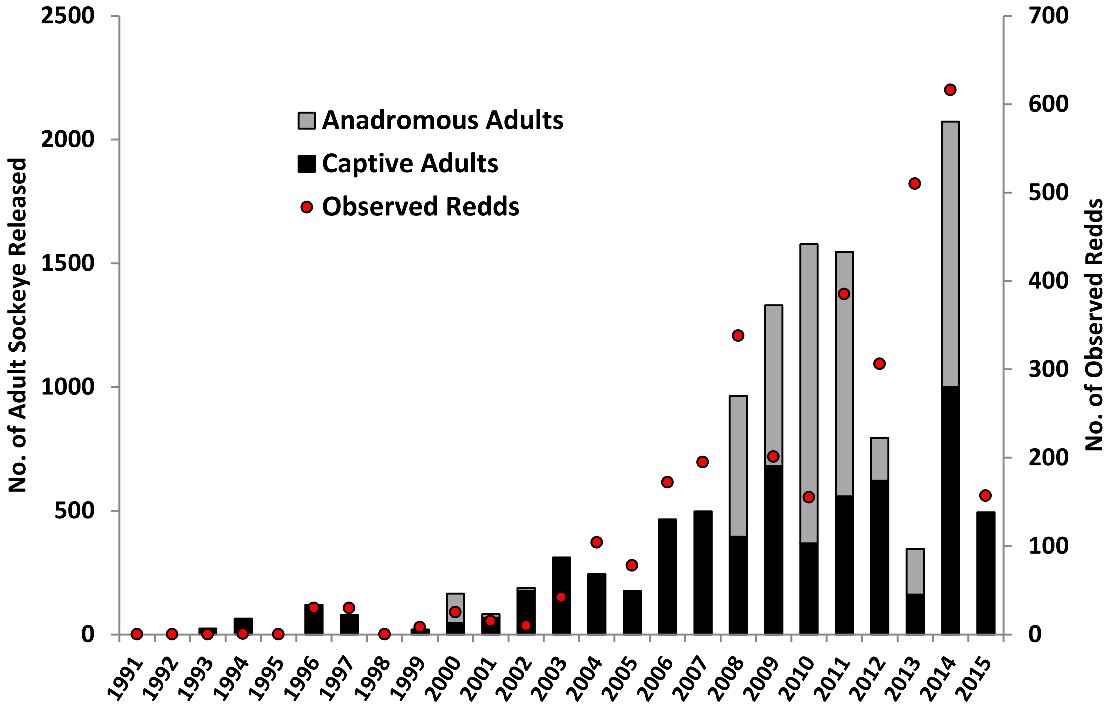

Figure 25. Releases of Snake River Sockeye Salmon from the captive brood program into Redfish Lake, Redfish Lake Creek and the Salmon River downstream of the Sawtooth weir.

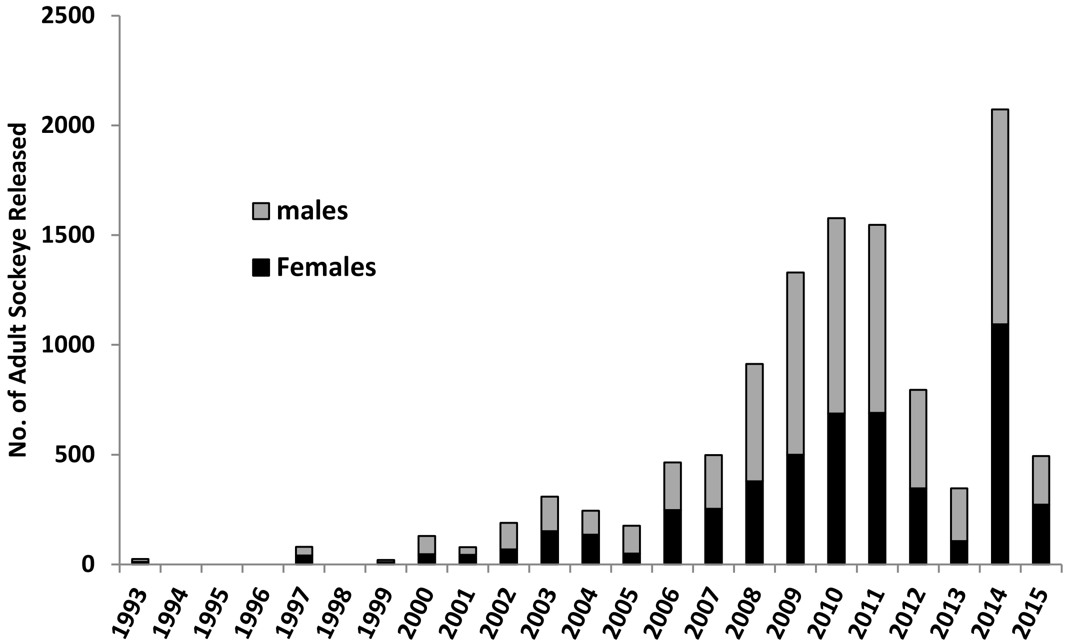

Figure 26. Sex ratio of prespawn Snake River Sockeye Salmon released into Redfish Lake. Includes outplants from the Captive Broodstock Program and anadromous returns from the RFLC trap.

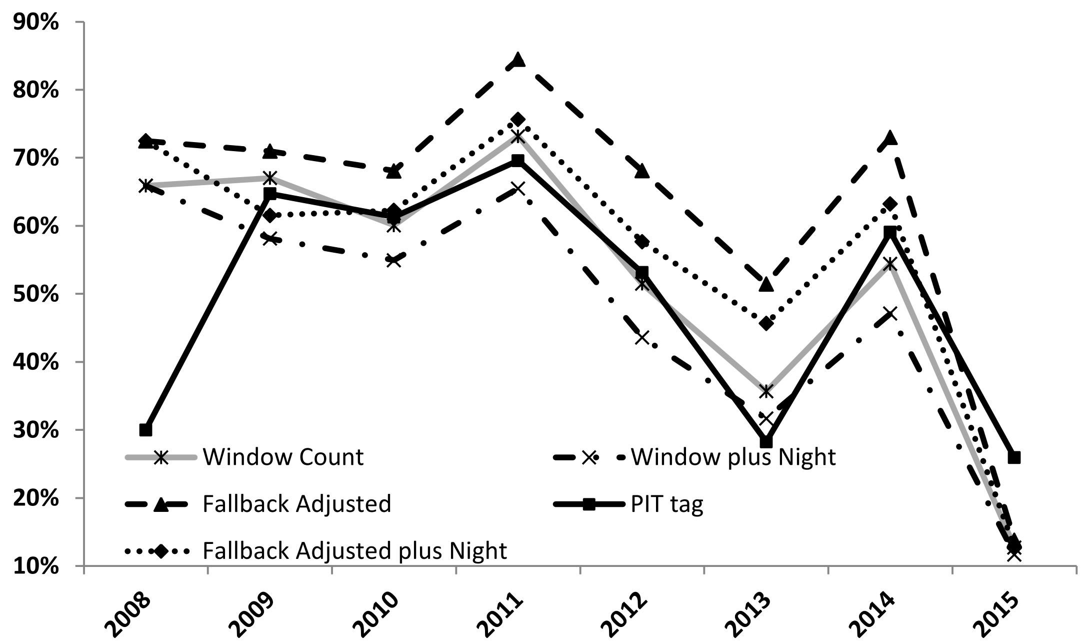

Figure 27. Adult Snake River Sockeye Salmon conversion rates from Lower Granite Dam to the Sawtooth Valley basin using window counts, adjusted counts, and PIT-tagged returns.

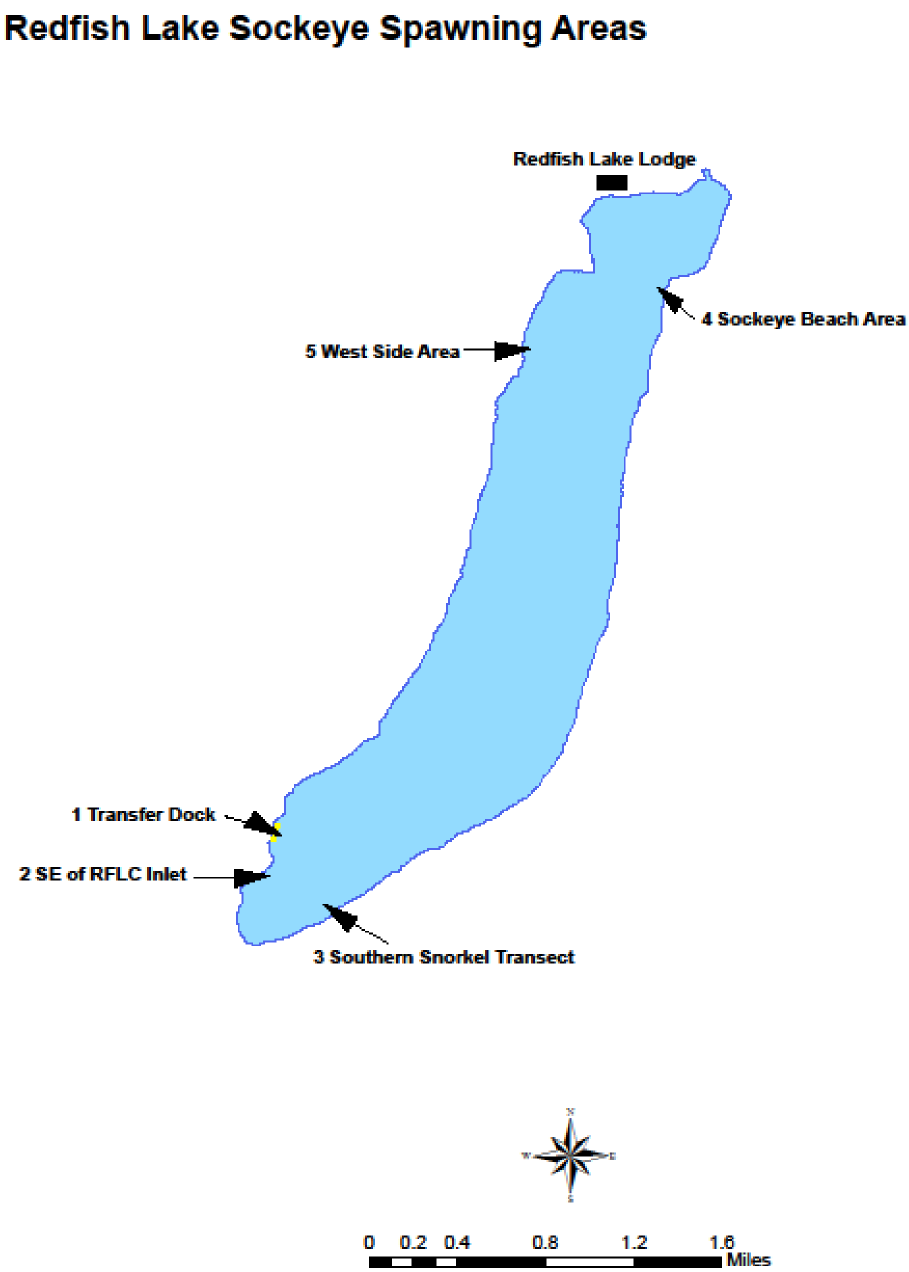

Figure 28. Spawning locations for Sockeye Salmon in Redfish Lake: 1) area near the U.S. Forest Service transfer camp dock, 2), area southeast of RFLC inlet, 3) southern snorkel transect area, 4) Sockeye Salmon Beach, and 5) west shoreline.

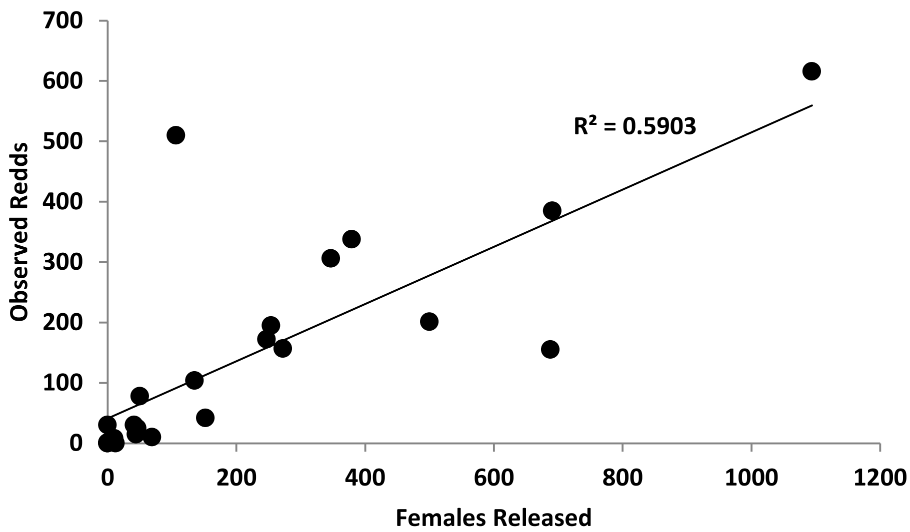

Figure 29. Relationship between the number of females released and the number of redds observed in Redfish Lake from 1993-2015.

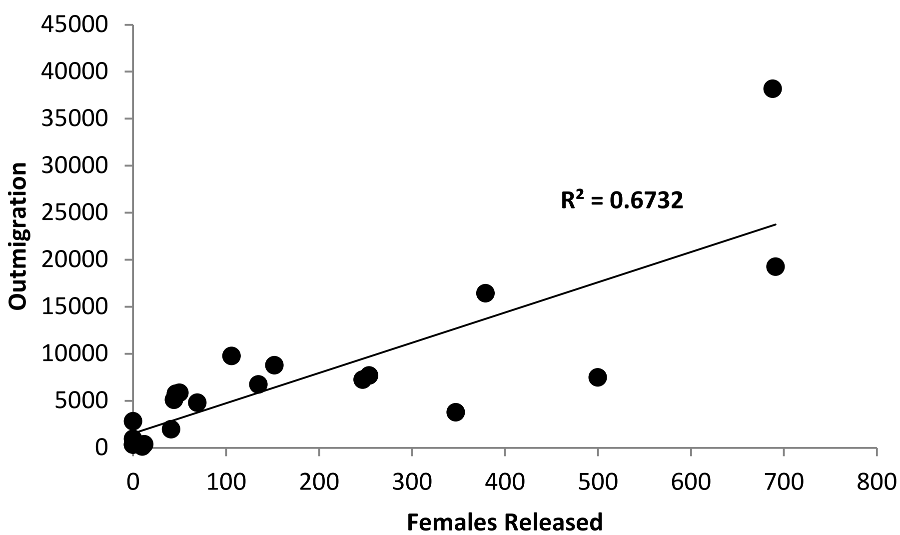

Figure 30. Relationship between the number of females released and the estimated number of outmigrants leaving Redfish Lake from 1993-2015.

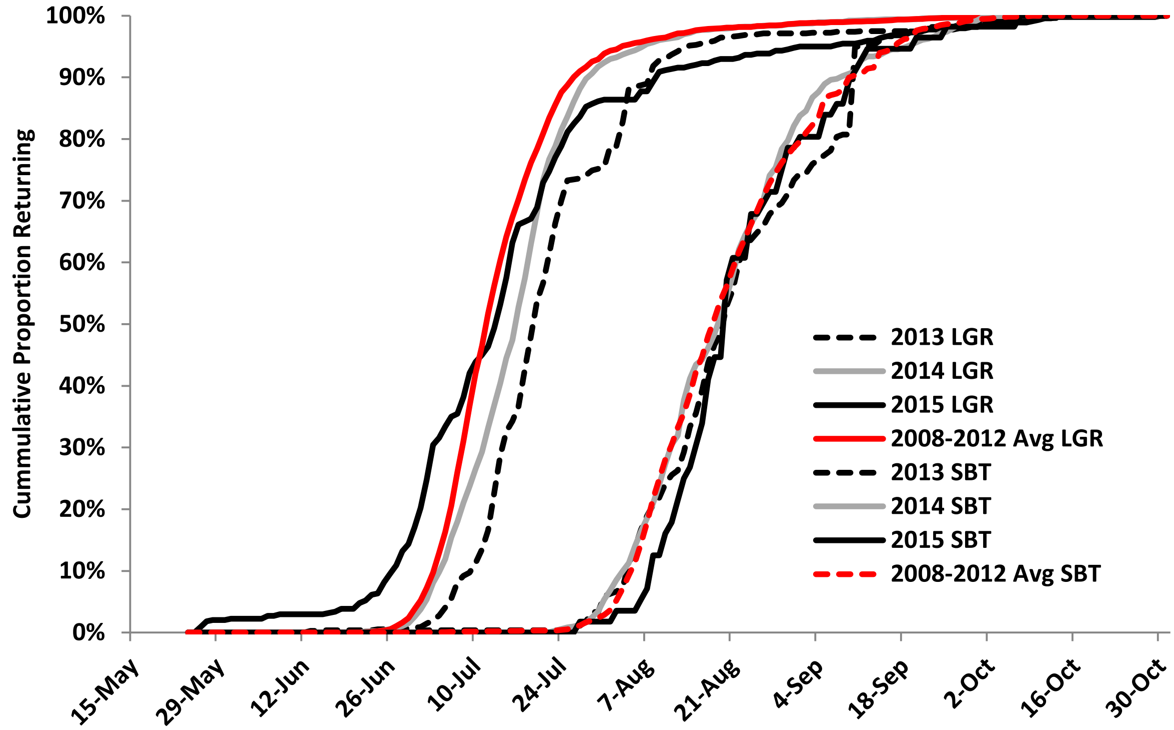

Figure 31. Adult Sockeye Salmon return timing to Lower Granite Dam (LGR) and Sawtooth basin traps (SBTs).

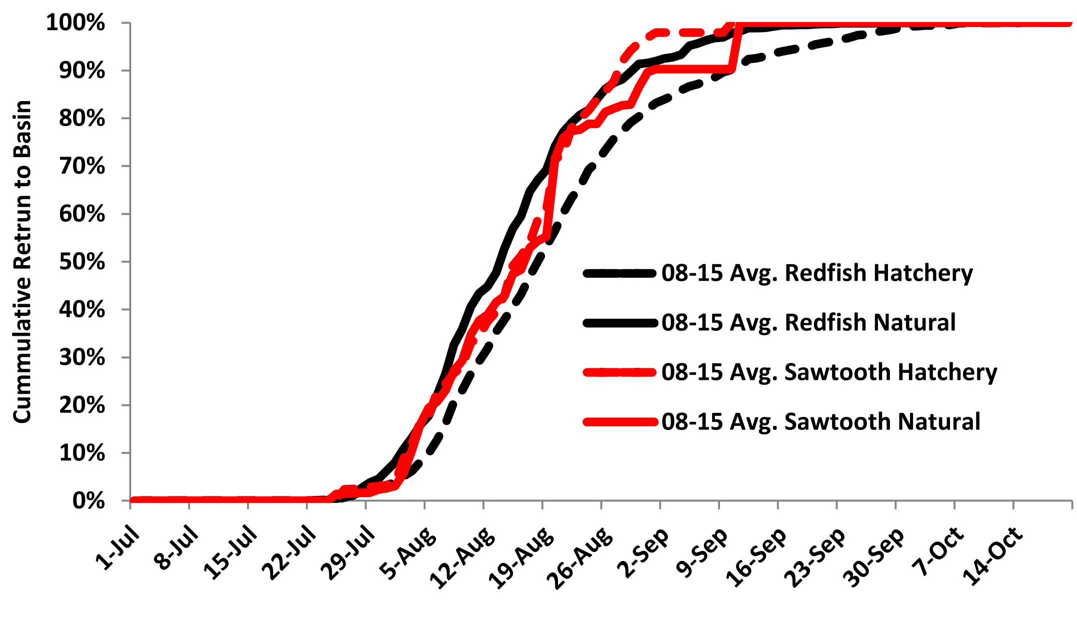

Figure 32. Adult Sockeye Salmon return timing to Sawtooth basin traps (SBTs).

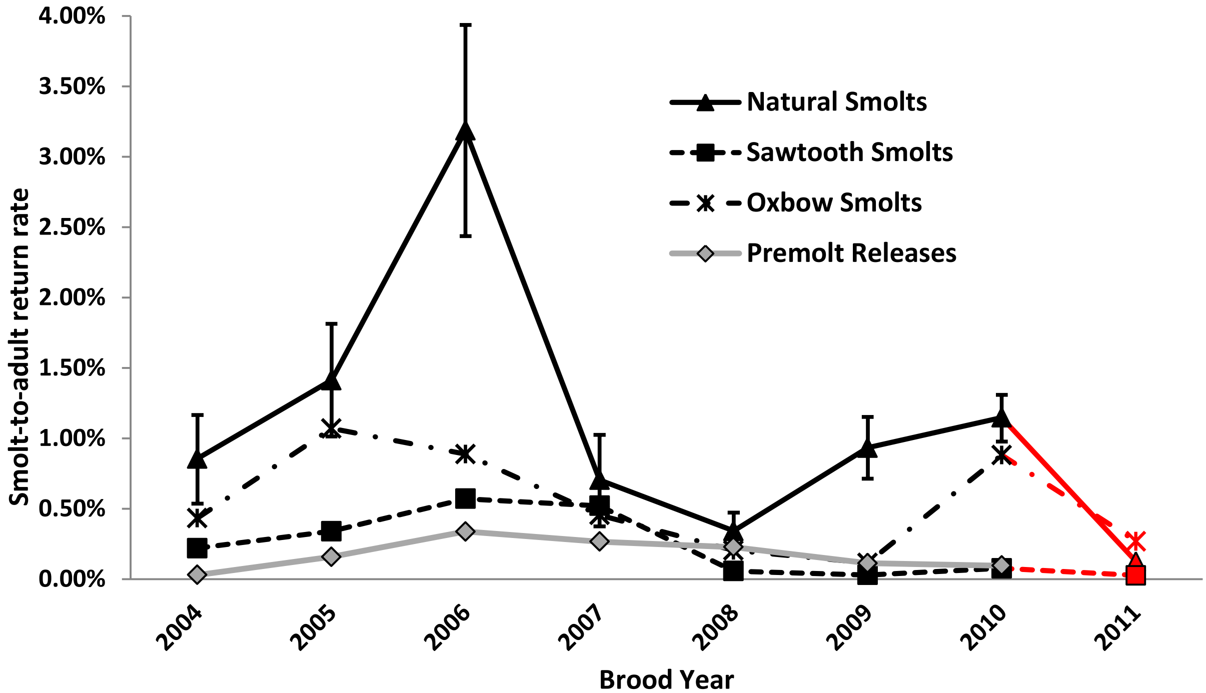

Figure 33. Basin-to-basin estimates of smolt-to-adult return rates. These estimates are considered minimum estimates of survival for the different production strategies as they do not include fish observed but not trapped within the Sawtooth Valley basin.

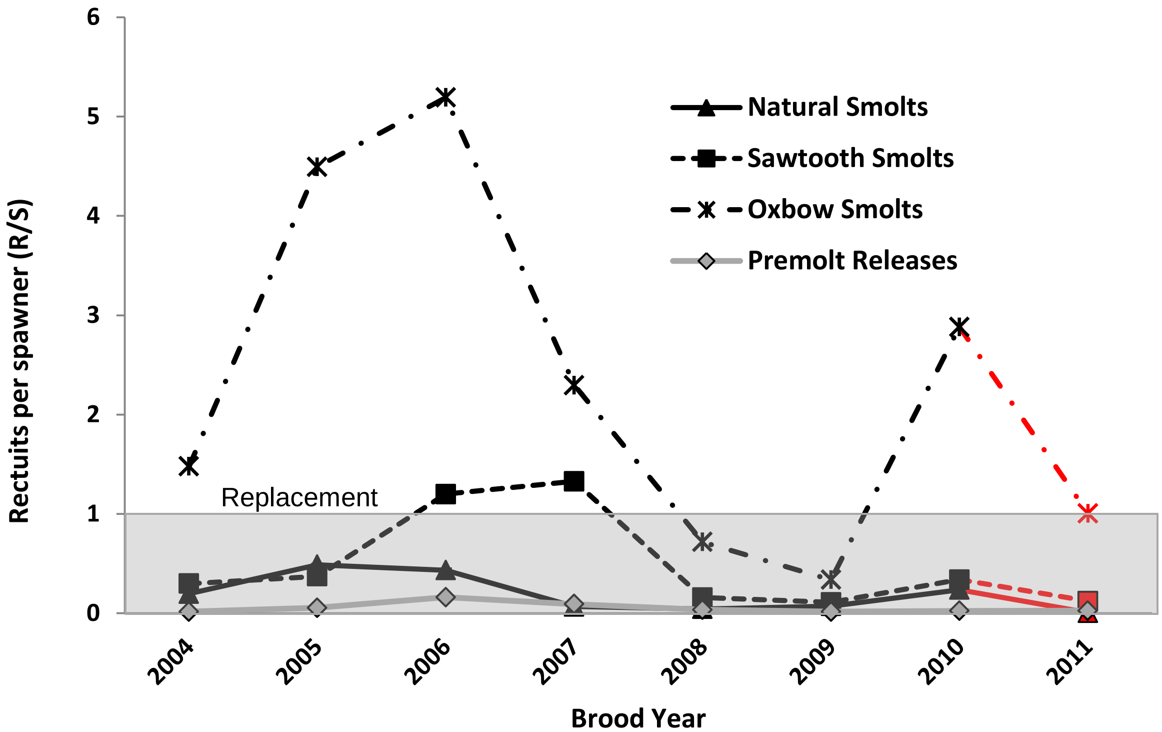

Figure 34. Recruit-per-spawner estimates. These estimates are considered minimum for the different production strategies as they do not include fish observed but not trapped within the Sawtooth Valley basin.

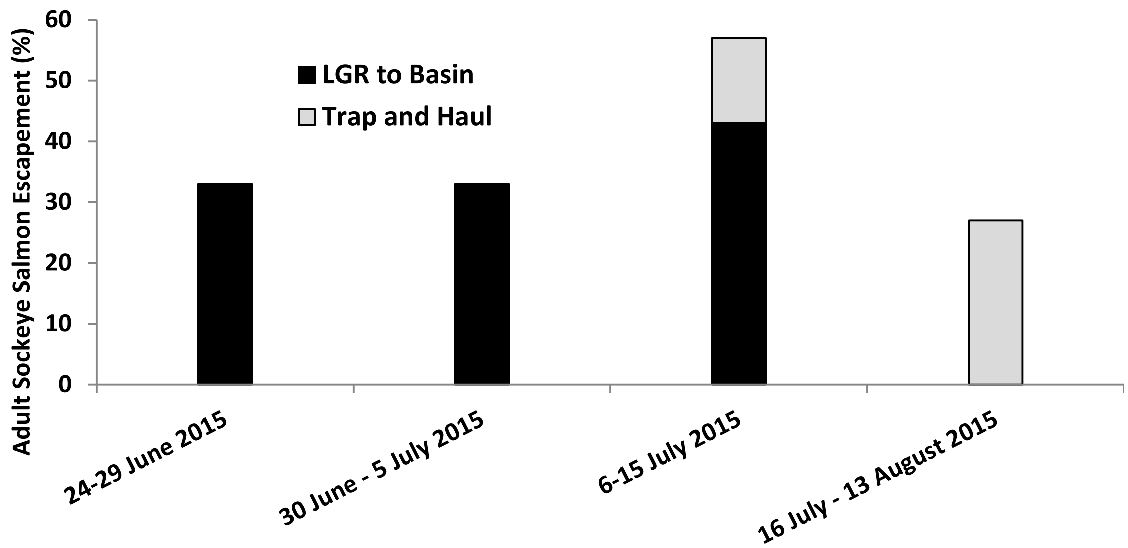

Figure 35. Adult Sockeye Salmon escapement from LGR to the Sawtooth basin (estimates based on PIT tag data).

Table 7. Origin of anadromous Snake River Sockeye Salmon returning to the Sawtooth Valley basin from genetic assignments.

Year	Oxbow FH	Sawtooth FH	Adult Rel.	Presmolt	Egg-Boxes	Unassigned
2012	44% (107)	26% (64)	11% (26)	7% (17)	3% (7)	9% (21)
2013	53% (142)	14% (39)	5% (14)	4% (10)	4% (10)	20% (55)
2014	60% (918)	6% (86)	24% (362)	1% (17)	1% (9)	8% (124)
2015*	48% (44)	35% (32)	13% (11)	NA	NA	4% (4)

*includes 35 Sockeye Salmon transported from Lower Granite Dam

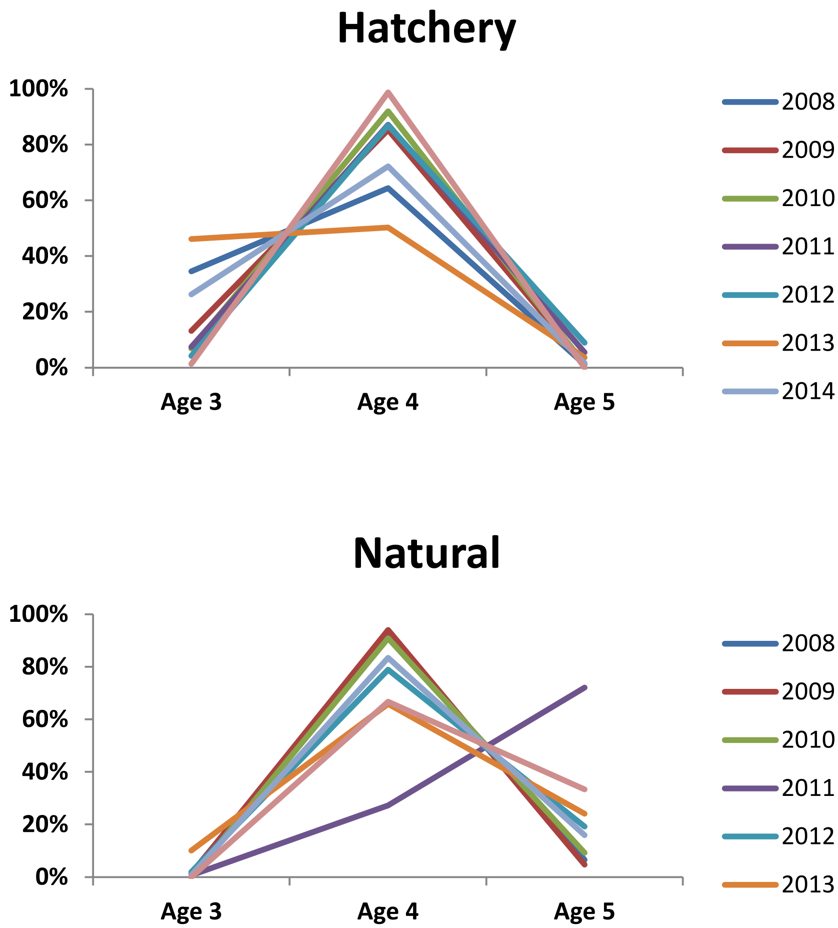

Figure 36. Age of Snake River Sockeye Salmon returning to the Sawtooth basin. Hatchery: age-3 (17.5%), age-4 (79.6%), age-5 (2.9%). Natural: age-3 (2.0%), age-4 (74.9%), age-5 (23.1%).

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Appendix A. Numbers and mean length and weights of *O. nerka* captured during August trawls in Redfish Lake (615 surface ha) and the estimated abundance, density (fish/ha), and biomass (kg/ha) in the lake.

Year	**No. Captured**	**Mean Length (mm)**	**Mean Weight (g)**	**Abundance**	**95% CI High**	**95% CI Low**	**Density (fish/ha)**	**Biomass (kg/ha)**
1990	NA	NA	NA	24431	35431	13431	63.9	1.3
1991	NA	NA	NA	NA	NA	NA	NA	NA
1992	NA	NA	NA	39481	50248	28714	95.9	1.5
1993	NA	NA	NA	49628	NA	NA	120.4	2.3
1994	NA	NA	NA	51529	84708	18350	125.1	2.1
1995	NA	NA	NA	61646	89285	34007	149.6	6.5
1996	NA	NA	NA	56213	84315	28111	91.4	2.8
1997	NA	NA	NA	55762	69723	41801	90.7	2.5
1998	NA	NA	NA	31486	42835	20137	51.2	1.8
1999	53	NA	NA	42916	56093	29739	70	0.9
2000	11	NA	NA	10267	15942	4592	17	<0.1
2001	16	NA	NA	12980	25060	900	21	0.1
2002	44	NA	NA	50204	78689	21719	81.6	1.0
2003	85	NA	NA	81727	107723	55732	133	1.6
2004	102	NA	NA	82258	85743	78772	133	0.3
2005	65	NA	NA	56220	60412	52028	91.4	0.3
2006	70	NA	NA	82796	130203	35389	135	2.4
2007	53	NA	NA	73702	97897	49507	119.8	0.8
2008	20	NA	NA	26284	39510	13058	42.7	0.3
2009	20	58.7	2.3	28923	61120	0	47.0	0.1
2010	25	105.4	17.3	30194	46333	14055	49.1	0.2
2011	37	55.6	1.6	43671	62301	25041	71	0.1
2012	122	55	2.2	46861	62171	31551	76.2	0.2
2013	47	65	4.2	17911	25017	10805	29.1	0.1
2014	98	70.7	6.2	36013	45063	26963	58.6	0.4
2015	15	58.2	1.9	13432	24573	3291	21.8	<0.1

Appendix A. Numbers and mean length and weights of *O. nerka* captured during August trawls in Redfish Lake (615 surface ha) and the estimated abundance, density (fish/ha), and biomass (kg/ha) in the lake.

Year	No. Captured	Mean Length (mm)	Mean Weight (g)	Abundance	95% CI High	95% CI Low	Density (fish/ha)	Biomass (kg/ha)
1990	NA	NA	NA	126644	158255	95033	597	5.2
1991	NA	NA	NA	125045	155753	94337	594	6.3
1992	NA	NA	NA	47237	109105	0	222.8	3.9
1993	NA	NA	NA	49037	62212	35862	230.2	4.1
1994	NA	NA	NA	5785	12704	0	27.1	0.7
1995	NA	NA	NA	23061	32243	13879	108.7	2.6
1996	NA	NA	NA	13012	16872	9152	38.5	1.4
1997	NA	NA	NA	9761	14425	5097	28.9	2.1
1998	NA	NA	NA	65468	99751	31185	193.7	1.4
1999	91	NA	NA	56675	100152	13198	167.7	0.4
2000	285	NA	NA	125463	152500	98426	371	2.1
2001	116	NA	NA	70159	51517	88801	208	2.4
2002	51	NA	NA	24374	41342	7406	72.1	2.2
2003	25	NA	NA	46234	72676	19792	137	5.5
2004	29	NA	NA	36206	38785	33627	107	2.0
2005	32	NA	NA	20956	23092	18820	98.8	0.3
2006	150	NA	NA	105779	156481	55077	313	3.5
2007	176	NA	NA	124073	147400	100746	367.1	3.4
2008	85	NA	NA	71088	105277	36899	210.3	2.7
2009	54	133.8	29.4	39781	51478	28084	117.7	3.5
2010	21	146.8	48.1	10366	18413	2319	30.7	1.4
2011	81	54.4	2.4	47739	79259	16219	141.2	0.3
2012	120	62.9	3.5	70895	92553	49237	209.8	0.7
2013	257	64.4	4.7	147204	203075	91333	435.5	2.0
2014	180	71.6	3.6	104095	197332	10858	308	1.1
2015	43	116	18.3	23760	40982	6538	70.3	1.3

Appendix A. Numbers and mean length and weights of *O. nerka* captured during August trawls in Redfish Lake (615 surface ha) and the estimated abundance, density (fish/ha), and biomass (kg/ha) in the lake.

Year	No. Captured	Mean Length (mm)	Mean Weight (g)	Abundance	95% CI High	95% CI Low	Density (fish/ha)	Biomass (kg/ha)
1991	NA	NA	NA	NA	NA	NA	NA	NA
1992	NA	NA	NA	3009	5140	878	26.2	3.5
1993	NA	NA	NA	10511	14207	6815	101	1.1
1994	NA	NA	NA	14743	18426	11060	128.2	4.4
1995	NA	NA	NA	59002	74737	43267	513.1	20.8
1996	NA	NA	NA	71654	81312	61996	447.8	15.3
1997	NA	NA	NA	21730	32992	10468	135.8	5.1
1998	NA	NA	NA	27654	36418	18890	172.8	9.7
1999	58	NA	NA	31422	50944	11900	196.4	6.4
2000	75	NA	NA	40559	45750	35369	253	10.3
2001	30	NA	NA	16931	33862	0	106	6.1
2002	36	NA	NA	18328	20679	15977	114.5	12.1
2003	24	NA	NA	11961	15216	8706	75	3.3
2004	44	NA	NA	46065	49354	42777	288	9.8
2005	44	NA	NA	23970	25699	22241	150	2.2
2006	54	NA	NA	33246	45662	20830	208	7.4
2007	20	NA	NA	14746	21845	7647	92.2	3.8
2008	17	NA	NA	6933	10726	3140	43.3	1.1
2009	9	60	2.1	4623	9159	87	40.2	0.1
2010	26	120.2	10.3	13246	19207	7285	82.8	0.6
2011	7	88.1	10.5	3733	7040	426	23.3	0.2
2012	12	132.7	26.5	4995	8114	1876	31.2	0.8
2013	28	112.3	27.3	11978	16446	7510	74.9	2.1
2014	5	72.8	5.7	1862	3627	97	11.6	0.1
2015	5	84.2	11.7	1842	4124	0	11.5	0.1

Appendix B. Total number of presmolts released into Redfish Lake, estimated smolt outmigration into Redfish Lake Creek, and survival to Lower Granite Dam from 1996-2013.

Year	Total Released (year prior)	Smolt outmigration estimate	Estimated SURPH survival at LGR	SURPH 95% CI (±)	Estimated no. at LGR
Redfish Lake					
1996	83,045	12,075	10.9%	1.9%	9,052
1997	1,932	401	9.9%	2.7%	40
1998	152,322	NA	4.3%	1.3%	6,550
1999	95,248	NA	5.3%	1.1%	5,048
2000	23,886	6,962	11.4%	3.9%	2,723
2001	48,051	9,616	31.0%	1.9%	2,981
2002	83,003	20,239	41.0%	3.9%	8,298
2003	106,501	12,226	35.0%	3.9%	4,280
2004	59,810	16,289	41.0%	1.9%	6,679
2005	79,887	28,001	51.0%	9.8%	14,281
2006	NA	NA	NA	NA	NA
2007	61,804	14,256	37.0%	7.8%	5,275
2008	62,015	17,034	49.0%	12.0%	8,347
2009	57,093	14,090	40.0%	5.9%	5,636
2010	34,561	5,972	31.0%	8.2%	1,851
2011	31,413	5,236	50.0%	5.6%	2,618
2012	50,054	2,208	43.4%	7.9%	958
2013	11,354	31	17.3%	16.6%	5
2014	NA	NA	NA	NA	NA
2015	NA	NA	NA	NA	NA

Appendix B. Total number of presmolts released into Redfish Lake, estimated smolt outmigration into Redfish Lake Creek, and survival to Lower Granite Dam from 1996-2013.

Year	Total Released (year prior)	Smolt outmigration estimate	Estimated SURPH survival at LGR	SURPH 95% CI (±)	Estimated no. at LGR
Alturas Lake					
1996	NA	NA	NA	NA	NA
1997	NA	NA	NA	NA	NA
1998	94,746	NA	NA	2.0%	16,391
1999	39,377	11,847	47.1%	11.8%	5,580
2000	12,955	4,416	39.6%	15.1%	1,749
2001	11,989	5,010	38.0%	5.9%	1,904
2002	12,113	3,674	22.0%	7.8%	809
2003	6,123	553	0.0%	0.0%	0
2004	2,017	728	0.0%	0.0%	0
2005	20,129	16,422	41.0%	9.8%	6,734
2006	16,949	6,356	64.0%	25.5%	4,068
2007	26,994	6,897	78.0%	33.0%	5,380
2008	9,977	5,273	59.0%	16.0%	3,111
2009	16,864	5,278	89.0%	25.5%	4,697
2010	9,994	899	44.0%	20.0%	396
2011	16,363	923	65.4%	31.7%	604
2012	NA	2	NA	NA	0
2013	NA	NA	NA	NA	NA
2014	NA	NA	NA	NA	NA
2015	NA	NA	NA	NA	NA

Appendix B. Total number of presmolts released into Redfish Lake, estimated smolt outmigration into Redfish Lake Creek, and survival to Lower Granite Dam from 1996-2013.

Year	**Total Released (year prior)**	**Smolt outmigration estimate**	**Estimated SURPH survival at LGR**	**SURPH 95% CI (±)**	**Estimated no. at LGR**
Pettit Lake					
1996	8,527	NA	31.0%	14.7%	2,643
1997	NA	NA	NA	NA	NA
1998	8,643	NA	6.1%	3.4%	527
1999	7,246	4,478	39.1%	4.3%	2,833
2000	3,430	NA	55.0%	7.4%	1,887
2001	12,074	1,969	16.0%	5.9%	316
2002	11,050	1,803	34.0%	17.6%	614
2003	27,786	13,337	26.0%	11.8%	3,468
2004	14,961	5,227	12.0%	3.9%	628
2005	30,700	17,051	43.0%	11.8%	7,332
2006	15,289	9,860	45.0%	9.8%	4,437
2007	18,494	4,695	55.0%	17.6%	2,582
2008	10,113	5,962	31.0%	6.0%	1,848
2009	10,048	5,484	64.0%	50.9%	3,510
2010	14,983	3,634	35.0%	24.7%	1,272
2011	18,075	2,745	32.0%	22.0%	878
2012	0	163	7.0%	9.6%	11
2013	NA	NA	NA	NA	NA
2014	NA	NA	NA	NA	NA
2015	NA	NA	NA	NA	NA

Appendix C. Estimates of smolt-to-adult return survival rates (SAR) for natural outmigrants and smolts released for the different production strategies into the Sawtooth Valley basin for BY2004-BY2012. These are considered minimum estimates since they do not include fish observed in the basin that were not trapped.

Release Strategies and Brood Year		**Adult returns by year and age**			**SAR**
Brood Year 2004	**Smolts**	**2007 (age 3)**	**2008 (age 4)**	**2009 (age 5)**	
Presmolt releases	32,141	0	18	0	0.06%
Oxbow Smolts	46,430	1	192	9	0.44%
Sawtooth Smolts	39,622	0	85	2	0.22%
Natural Production (RFL only)	5,609	0	45	3	0.86%
Natural Production (Pettit and Alturas)	55,247	0	83	1	0.15%
Brood Year 2005	**Smolts**	**2008 (age3)**	**2009 (age 4)**	**2010 (age 5)**	
Presmolt releases	26,756	2	31	14	0.18%
Oxbow Smolts	54,582	127	458	0	1.07%
Sawtooth Smolts	47,094	29	132	0	0.34%
Natural Production (RFL only)	6,088	1	70	15	1.41%
Natural Production (Pettit and Alturas)	10,743	1	8	0	0.08%
Brood Year 2006	**Smolts**	**2009 (age3)**	**2010 (age 4)**	**2011 (age 5)**	
Presmolt releases	28,334	1	79	17	0.34%
Oxbow Smolts	76,587	90	589	1	0.89%
Sawtooth Smolts	73,808	5	382	34	0.57%
Natural Production (RFL only)	6,338	1	124	77	3.19%
Natural Production (Pettit and Alturas)	14,957	0	24	26	0.33%
Brood Year 2007	**Smolts**	**2010 (age3)**	**2011 (age 4)**	**2012 (age 5)**	
Presmolt releases	24,306	1	64	3	0.28%
Oxbow Smolts	73,681	70	265	0	0.45%
Sawtooth Smolts	99,374	7	498	13	0.52%
Natural Production (RFL only)	4,822	0	27	7	0.71%
Natural Production (Pettit and Alturas)	7,877	0	12	3	0.19%

Brood Year 2008	**Smolts**	**2011 (age3)**	**2012 (age 4)**	**2013 (age 5)**	
Presmolt releases	10,237	4	14	3	0.21%
Oxbow Smolts	79,886	63	99	1	0.20%
Sawtooth Smolts	99,392	3	51	3	0.06%
Natural Production (RFL only)	12,558	1	29	13	0.34%
Natural Production (Pettit and Alturas)	3,521	0	12	6	0.51%
Brood Year 2009	**Smolts**	**2012 (age3)**	**2013 (age 4)**	**2014 (age 5)**	
Presmolt releases	8,999	0	7	9	0.18%
Oxbow Smolts	54,761	8	55	0	0.12%
Sawtooth Smolts	135,614	0	34	7	0.03%
Natural Production (RFL only)	10,502	1	28	69	0.93%
Natural Production (Pettit and Alturas)	12,160	0	24	3	0.22%
Brood Year 2010	**Smolts**	**2013 (age3)**	**2014 (age 4)**	**2015 (age 5)**	
Presmolt releases	2,088	0	2	0	0.10%
Oxbow Smolts	85,741	86	669	0	0.88%
Sawtooth Smolts	80,130	2	59	0	0.08%
Natural Production (RFL only)	32,582	6	366	4	1.15%
Natural Production (Pettit and Alturas)	551	2	12	1	2.72%
Brood Year 2011	**Smolts**	**2014 (age3)**	**2015 (age 4)**	**2016 (age 5)**	
Presmolt releases	25	1	4	na	20.0%
Oxbow Smolts	100,655	248	43**	na	0.29%
Sawtooth Smolts	170,086	26	29**	na	0.03%
Natural Production (RFL only)	13,771	3	8	na	0.07%
Natural Production (Pettit and Alturas)	1,264	0	1	na	0.08%

* Does not currently include Alturas returns since uncertain of age, assume 4 year old.

**Current SAR includes LGR trap and haul sample.

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