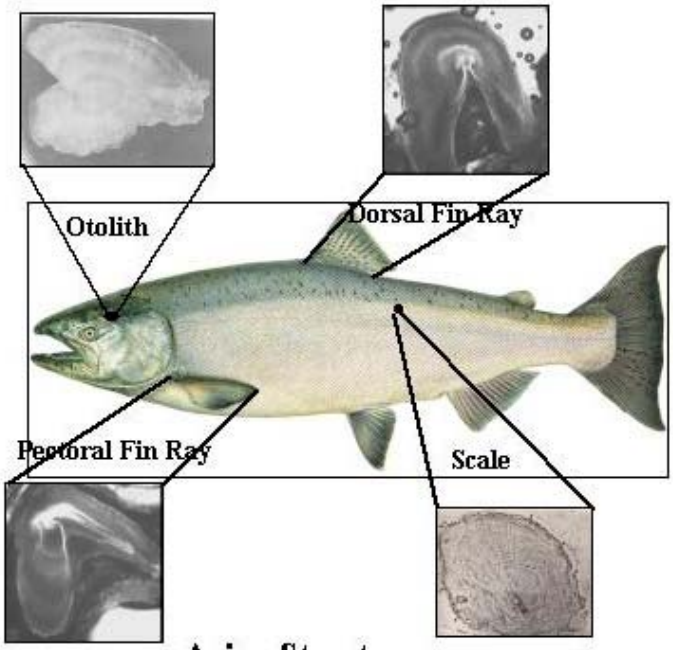
FISHERY RESEARCH

NATURAL PRODUCTION MONITORING AND EVALUATION

July 1, 2001–June 30, 2002



Aging Structures

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IDFG Report Number 02-24
June 2002

Natural Production Monitoring and Evaluation

Part 1—Improve wild steelhead trout smolt-to-adult survival rate information by PIT tagging additional wild steelhead trout juveniles.

Part 2—Estimating the stock-recruitment relationship for Snake River spring/summer chinook salmon and forecasting wild/natural smolt production.

Part 3—Monitoring age composition of wild adult spring and summer chinook salmon returning to the Snake River basin.

July 1, 2001—June 30, 2002

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Division of Fish and Wildlife
P.O. Box 3621
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Project Number 91-73
Contract Number DE-BI79-91BP21182

IDFG Report Number 02-24
June 2002

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ABSTRACT

The Passive Integrated Transponder tag has been an important tool for estimating smolt-to-adult return rates of Snake River anadromous fish. In 1998, we initiated an effort to increase the precision of these estimates for Snake River wild steelhead trout. Important wild steelhead trout production streams in the Salmon River and Clearwater River drainages were identified where juveniles were not currently being tagged by other research activities. A subset of these streams was selected for collection and tagging based on juvenile steelhead trout densities, accessibility, and relative contribution to basin-wide smolt production. This report covers tagging efforts in 2000, smolt detections at the four main smolt collector dams in 2001, and adult detections at Lower Granite dam for spawn years 2001 and 2002 through April 22, 2002. During the summer of 2000, we tagged 6,033 wild steelhead trout juveniles. In 2001, the four main smolt collector dams detected 1,307 (21.7%) of the juveniles we tagged in summer 2000 and 356 from juveniles we tagged in previous years. This project's tagging efforts resulted in six adult detections in spawn year 2001 and 26 adult detections for spawn year 2002 through April 22, 2002.

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INTRODUCTION

Snake River wild steelhead trout *Oncorhynchus mykiss* population declines during the past 25 years have resulted primarily from reduced smolt-to-adult return rates (SARs) caused by mainstem hydropower development (Nemeth and Kiefer 1999). Commensurately, a major component of recovery efforts for Snake River wild steelhead trout are directed at mitigating the negative effects of mainstem hydropower development on SARs. Estimating and monitoring SARs is the most effective way to evaluate the effectiveness of these hydrosystem mitigation efforts (Ward et. al 1997). The Passive Integrated Transponder (PIT) tag provides the most accurate method to estimate SARs for Snake River anadromous fish (Newman 1997). The Idaho Department of Fish and Game (IDFG) initiated efforts in 1998 to increase the number of PIT-tagged wild/natural (hereafter wild) steelhead trout smolts available to estimate SARs. Efforts were directed at tagging wild steelhead trout in important production streams in Idaho that were not being sampled by other research efforts. Tagging in streams not sampled by other projects increases the number of steelhead tagged and better represents SARs for the entire Snake River wild population. This report covers tagging efforts in summer 2000, smolt detections in spring 2001, and adult detections for spawn years 2001 and 2002 through April 22, 2002.

METHODS

Study Area

The study area included streams in the Salmon and Clearwater river basins. Sampling was concentrated in important wild production areas: Lochsa River basin, Salmon River Canyon tributaries, and Salmon River tributaries downstream from the Salmon River Canyon (Figure 1). All streams were believed to have no or minimal hatchery influence. Scouting and snorkeling of streams occurred prior to the tagging field season. Streams sampled offered the best combination of access, presumed age-2+ and older juvenile wild steelhead trout densities, and stream size to permit efficient juvenile wild steelhead trout collection by angling.

Sampling

Fisheries personnel captured wild steelhead trout juveniles by angling with flies from July through August 2000. Previous unpublished work conducted by IDFG demonstrated angling to be a more efficient collection method relative to electrofishing in small, high gradient, low conductivity streams. Each angler carried a five-gallon bucket half filled with water while fishing to temporarily store captured fish. Project personnel changed water in the bucket at least every 15-20 minutes when fewer than 10 fish were in the bucket and about every 10 minutes when 10 fish or more were in the bucket. Anglers transferred fish from buckets to submerged 1.0 m x 0.5 m x 0.7 m perforated plastic live-boxes placed at approximately one kilometer intervals throughout the stream.

PIT Tagging

Collected fish were usually held in live-boxes overnight before tagging the following morning. This allowed the fish to recover from collection stress and provided the coolest water temperatures for tagging. Project personnel anesthetized the fish with MS 222 or clove oil and injected PIT tags into the body cavity using a 12-gauge hypodermic needle and modified syringe. Project personnel sterilized PIT tags, needles, and syringes by soaking them in a 70% alcohol solution for at least 10 minutes before tagging. Wild steelhead trout between 65 mm fork length (FL) and 250 mm FL were tagged, while all others were released. Wild steelhead trout less than 65 mm FL were too small to tag. Wild steelhead trout larger than 250 mm FL were more likely to be non-migratory resident fish. Project personnel returned fish to a live-box and allowed them to recover for at least one hour before release. At the end of the summer when all tagging was complete, project personnel uploaded PIT tag data to the Columbia River Basin PIT Tag Information System (PTAGIS).

PIT Tag Detection Rates

Project personnel obtained juvenile detection and tagging information from the PTAGIS database on October 22, 2001 (http://www.psmfc.org/pittag/). The PTAGIS reports provided information on tagging and release dates, capture method, fork length, release site, and interrogation site. Interrogation reports from the four main smolt collection facilities (Lower Granite, Little Goose, Lower Monumental and McNary dams) were used and interrelated with tagging reports to calculate the detection rates of juvenile wild steelhead trout PIT tagged for this effort. The detection rate for each stream was calculated by dividing the number of fish from that stream detected at one or more of the four main collector facilities by the total number of unique fish tagged in that stream. Because smaller juvenile steelhead trout usually rear another year before smolting, only juveniles greater than 124 mm FL at tagging were used to calculate detection rates.

Emigration Timing

Personnel obtained emigration timing data for PIT-tagged wild steelhead trout through PTAGIS using the “first interrogation main” detection report. This study used only those fish tagged above Lower Granite Dam (LGR) and detected at LGR for migratory year 2001. Fish Passage Center online reports (http://www.fpc.org) accessed on December 13, 2001 provided stream flow, spill, and an index count of steelhead trout smolts arriving at LGR.

Juvenile wild steelhead trout arrival timing data are presented for each stream sampled by this project having 100 or more detections at LGR in 2001. For each of these streams, the dates when 10%, 50%, and 90% of total PIT tag detections at LGR occurred were calculated and graphically displayed.

Annual Mortality Rates

We compared juvenile detection rates in migratory years 2000 and 2001 for juveniles tagged in summer 1999 to estimate annual mortality for wild steelhead trout parr. Annual mortality was estimated for streams that had at least 20 juveniles tagged in each of at least 15 consecutive 5 mm length groups and at least five of the larger length groups only had detections

in 2000. To provide adequate sample size for this analysis, we combined data from Bargamin and Horse creeks, which are very similar and in close proximity to each other, into one data set. We calculated a mean detection rate in each stream for the larger length groups that only had detections in 2000. The following formula calculates a cumulative two-year detection rate for each of the smaller 5 mm length groups that had detections in 2001:

$$\text{Cumulative two-year detection rate} = D_1 + D_2\left(\frac{S_1}{S_2}\right)\left(\frac{1}{1-X}\right)$$

Where:

D_1 = detection rate in 2000
D_2 = detection rate in 2001
S_1 = detection rate of wild steelhead trout tagged at Snake River Trap in 2000
S_2 = detection rate of wild steelhead trout tagged at Snake River Trap in 2001
X = estimated annual mortality rate.

The ratio of detection rates from the Snake River smolt-monitoring trap (S_1/S_2) was used to correct for differences in collection efficiency between 2000 and 2001. Annual mortality was estimated by varying X until the mean of the cumulative two-year detection rates for the smaller length groups was equal to the mean detection rate of the larger length groups in 2000. For comparison, we also estimated annual mortality with this method for juvenile wild steelhead trout tagged in the fall of 1999 at the Fish Creek trap by the Idaho Steelhead Supplementation Studies research project (Byrne 2001). For this analysis we made the following assumptions: survival of tagged and untagged steelhead trout parr is similar; the tagged steelhead trout parr are representative of the entire population in that stream, and detection rates of wild steelhead trout smolts PIT tagged at the Snake River smolt monitoring trap are representative of the detection probabilities of wild smolts tagged as juveniles in tributaries.

Annual Growth Rates

The PIT-tagged fish recaptured a year later (±12 days) yielded data to calculate an annual growth rate (mm/year). Annual growth rate was plotted against fork length at initial tagging and analyzed for correlation.

Smolt-to-Adult Return Rates

The PTAGIS database was accessed on April 22, 2002 for adult and juvenile steelhead detection data. Smolt-to-adult return rates were estimated for each smolt migration year by dividing the number of adults detected at LGR by the total number of unique juveniles detected at the four main smolt collector dams (Lower Granite, Little Goose, Lower Monumental, and McNary). Adult returns from smolts not detected at the four main collector dams were not included in these SAR estimates.

RESULTS AND DISCUSSION

Wild Steelhead Trout Tagged & Detected

A total of 6,033 juvenile wild steelhead trout were PIT tagged by this project during summer 2000; 5,060 (84%) of those were greater than 124 mm FL when tagged (Table 1). Previous project research found that parr smaller than 125 mm FL usually rear another year in freshwater before smolting (Kiefer and Lockhart 1997).

There were 1,307 (21.7%) smolts detected in 2001 from this project's tagging in 2000. For the juveniles greater than 124 mm FL at tagging, 1,198 (23.7%) were detected. There were 356 detections in 2001 from wild steelhead trout PIT tagged by this project in previous years. This project's efforts increased the overall number of Snake River wild steelhead trout smolt PIT tag detections at the four main smolt collector facilities from 13,058 to 14,721 (13%) in migratory year 2001.

All streams fished in 2000 had high enough densities and detection rates to warrant future collection. Based on detection rates, fish density, and stream accessibility, streams to be fished in the future, in order of priority, are: Brushy Fork Creek, Chamberlain Creek, Bargamin Creek, Horse Creek, Whitebird Creek, Slate Creek, and Storm Creek (Figure 7).

High detection rates (Figure 7) have been observed for wild steelhead juveniles PIT tagged in the Middle Fork Salmon River (MFSR) and tributaries (Marsh Creek, Pistol Creek, Rapid River, and Wilson Creek). To date, wild steelhead PIT tagging efforts have been limited for this major wild production drainage. We propose increased project effort in this drainage.

Emigration Timing

Steelhead trout smolt arrival timing at LGR for all smolts, PIT-tagged wild smolts, and PIT-tagged hatchery smolts were very similar (Figure 3). Major increases in the hydrograph corresponded with two major peaks in smolt arrival numbers (Figure 3). The PIT-tagged wild smolts were more predominant in the first peak, while PIT-tagged hatchery smolts were more predominant in the second peak. In 2001, the out-migration of all steelhead trout smolts was 97% complete by June 14 (Figure 3). Migratory year 2001 was a very low water year with no spill at LGR (FPC, 2001). This resulted in higher detection rates than in normal water years with higher flows and spill.

Stream specific wild steelhead trout smolt emigration timing at LGR showed more variation than the overall wild smolt run discussed above (Figure 4). Brushy Fork Creek, the highest elevation stream in this analysis, had the most compressed arrival timing and the earliest arrival dates for both 50% and 90% of total detections. The two lowest elevation streams in this analysis, Whitebird and Slate creeks, had similar protracted arrival timings with the earliest 10% arrival dates. The three Salmon River Canyon tributary streams in this analysis, Chamberlain, Bargamin, and Horse creeks, had intermediate lengths of arrival timing with the latest arrival dates for the first 10% of total detections (Figure 4).

Annual Mortality Rates

Estimates of wild steelhead trout parr annual mortality were 63% for Bargamin and Horse creeks combined, 50% for Chamberlain Creek, and 62% for fall out-migrants from Fish Creek (Figure 5). Mortality rates estimated for Fish Creek are only for juveniles that out-migrated in the fall and are not necessarily the same as for the entire population.

Annual Growth Rates

Fish in the 100-150 mm range at tagging grew an average of 36 mm in a year; those in the 150-200 mm range grew an average of 23 mm, and those in the 200-250 mm range only grew an average of 13 mm. Annual growth rates were significantly ($p < 0.01$) negatively correlated with fish size (Figure 6). These results are consistent with the sigmoid pattern of increase in size with age generally exhibited by fishes (Bond, 1979).

Smolt-to-Adult Return Rates

The average SAR for PIT-tagged wild steelhead trout smolts detected in migration years 1990-1999 was 0.44% (Figure 2). The maximum SAR over this period was 0.92%, and the minimum was 0.08%. The SAR for migratory year 2000 is already at 1.08% (higher than the 10 previous years), and the 1-ocean adult returns are not yet complete. Ocean age percentages of PIT-tagged adult returns were 45% 1-ocean, 50% 2-ocean, and 5% 3-ocean for migratory years 1990-1998 (Figure 2). When the adult returns are complete for migratory year 2000, the SAR will most likely be significantly higher than any of the previous 10 years. Since migratory year 1994, PIT-tagged smolts collected at the collector dams have been handled differently than the run-at-large smolts; therefore, the PIT tag SARs may not be representative of the entire population. Recent research (Sandford and Smith, 2002) indicates that PIT tag SARs are lower than SARs for the entire population, a result of this differential handling at the collector dams.

ACKNOWLEDGMENTS

We greatly appreciate the Natural Production tagging crew (James Gilbert, Darrin Beckley, Josh Carpenter, and Howard Pennington) for their outstanding effort to collect and tag wild steelhead trout juveniles in some of the most difficult streams to access and work.

We thank Arnie Brimmer and his field crew for their cooperation with the PIT tagging effort in Chamberlain Creek.

Special thanks go to the Don Heckman and Ed Woslum families for allowing our field crew to access their properties on Whitebird Creek for this research.

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APPENDICES

Appendix A. Stream specific notes by system.

Lochsa River system

Brushy Fork Creek
Dates Fished: July 21-23, 2000
Stream Location Lat/Lon (mouth): 46.5784 N., -114.6119 W.
Section Fished: An 11.5 km section beginning at mouth.
Tagging Temperature: 15-16°C
Number Tagged: 615
Recaptures: N/A
Notes: Lower 5 km section had best steelhead habitat and densities

Colt Killed Creek
Dates Fished: July 23-24, 2000
Stream Location Lat/Lon (mouth): 46.5083 N., -114.6803 W.
Section Fished: A 6 km section beginning 14 km from mouth at 46.4739 N. and -114.5640 W.
Tagging Temperature: 11-12°C
Number Tagged: 67
Recaptures: 15
Notes: Section accessed via Elk Summit Road 360.

Storm Creek
Dates Fished: July 24-26, 2000
Stream Location Lat/Lon (mouth): 46.4631 N, -114.5480 W.
Section Fished: A 4 km section beginning at mouth.
Tagging Temperature: 13-16°C
Number Tagged: 404
Recaptures: 33
Notes: Lower 4 km had highest densities of steelhead; meadow section contained mostly cutthroat beginning 4.2 km from mouth at 46.4903 N. and -114.5266 W

Mainstem Salmon River system

Bargamin Creek
Dates Fished: August 2-5, 2000
Stream Location Lat/Lon (mouth): 45.5676 N., -115.1913 W.
Section Fished: A 5 km section beginning at mouth.
Tagging Temperature: 14-16°C
Number Tagged: 514
Recaptures: 2
Notes: Lowest 5 km section had highest steelhead densities and easiest access

Chamberlain Creek
Dates Fished: July 18-21, 2000
Stream Location Lat/Lon (mouth): 45.4544 N., -114.9317 W.
Section Fished: A 5 km section beginning at mouth.
Tagging Temperature: 15-17°C
Number Tagged: 1,310
Recaptures: 4

Horse Creek
Dates Fished: August 5-8, 2000
Stream Location Lat/Lon (mouth): 45.3960 N., -114.7323 W.
Section Fished: A 7.5 km section beginning at mouth.
Tagging Temperature: 15-17°C
Number Tagged: 41
Recaptures: 15

Slate Creek
Dates Fished: July 8-12, 2000
Stream Location Lat/Lon (mouth): 45.6400 N., -116.2833 W
Section Fished: An 11.5 km section beginning 7.2 km from mouth at 45.6308 N. and -116.6308 W.
Tagging Temperature: 14-15°C
Number Tagged: 970
Recaptures: 14
Notes: Section begins at Forest Service boundary

Whitebird Creek
Dates Fished: July 5-8, 2000
Stream Location Lat/Lon (mouth): 45.7517 N., -116.3211 W.
Section Fished: A 5 km section beginning 3.8 km from mouth at 45.7723 N. and -116.2872 W.
Tagging Temperature: 14-17°C
Number Tagged: 1,104
Recaptures: N/A
Notes: Permission required for access

Middle Fork Salmon River system

Marsh Creek
Dates Fished: August 14-17, 2000
Stream Location Lat/Lon (mouth): 44.4491 N., -115.2298 W
Section Fished: A 5 km section beginning 3 km from mouth at 44.4370 N. and -115.2041 W.
Tagging Temperature: 8-16°C
Number Tagged: 227
Recaptures: N/A

Table 1. Wild steelhead trout actively collected (angling) and PIT tagged in the summer of 2000 and detected in 2001.

Stream	No. Tagged >124 mm FL	No. Detected >124 mm FL	Detection Rate	No. Tagged Total
Bargamin Creek	464	139	30%	514
Brushy Fork Creek	480	173	36%	615
Chamberlain Creek	1,148	427	37%	1,310
Horse Creek	677	143	21%	822
Marsh Creek	216	44	20%	227
Slate Creek	837	100	12%	970
Storm Creek	367	33	9%	404
Colt Killed Creek	60	11	18%	67
Whitebird Creek	811	128	16%	1,104
Total	**5,060**	**1,198**	**24%**	**6,033**

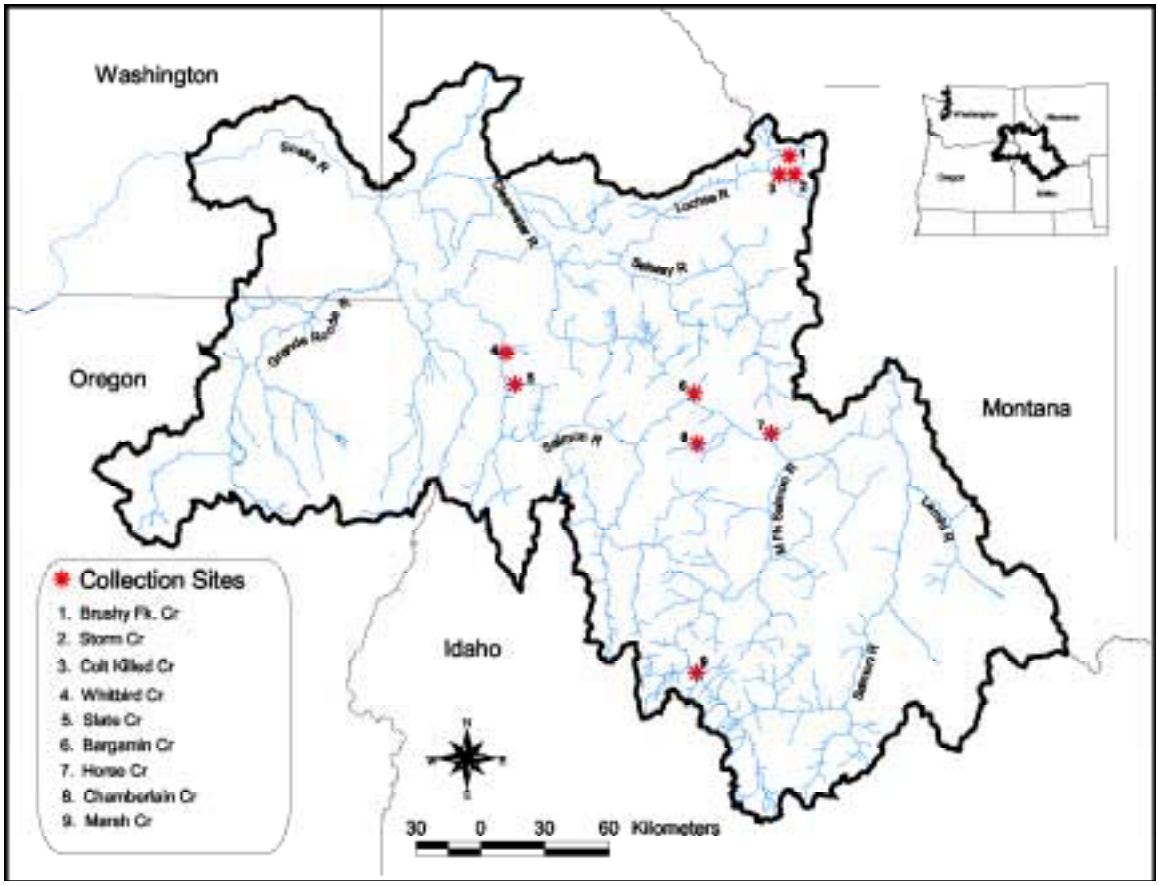

Figure 1. Snake River basin study area and rearing streams where juvenile wild steelhead trout were collected and PIT tagged in the summer of 2000.

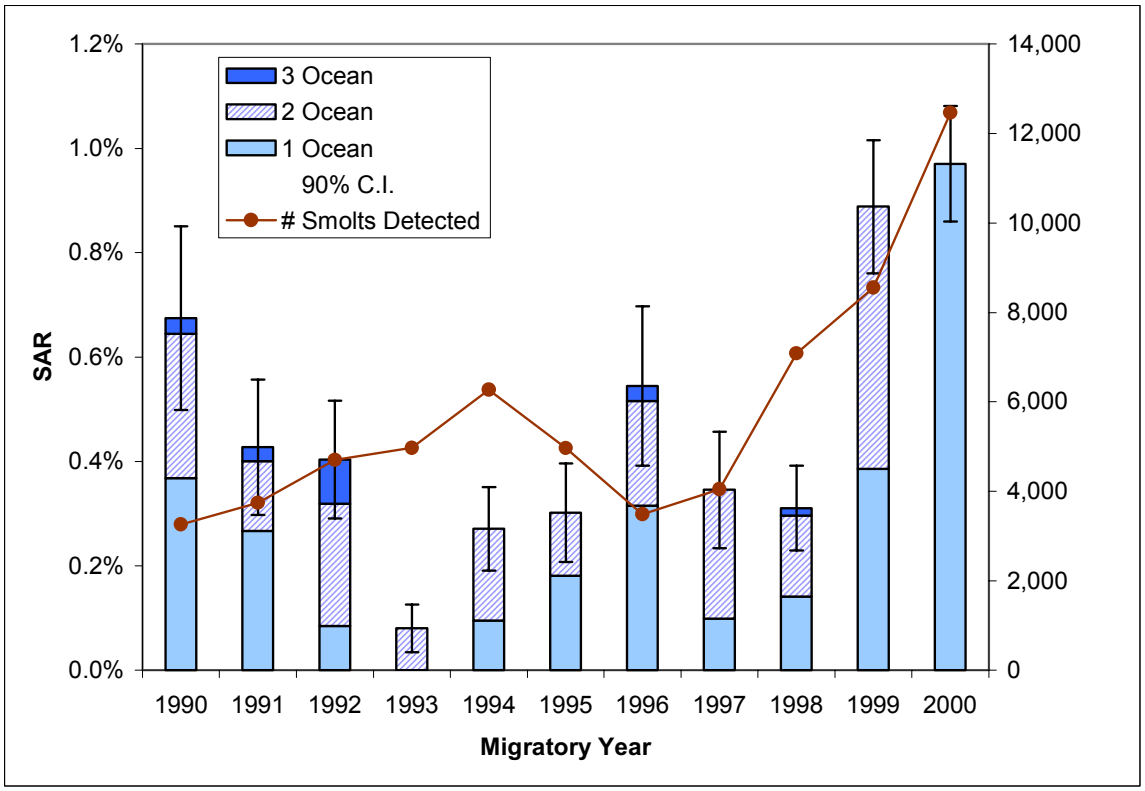

Figure 2. PIT-tagged wild steelhead trout smolt-to-adult return rates for smolts detected at one of the four main smolt collection dams. Year 1999 (3-ocean) and 2000 (2- & 3-ocean) are not complete.

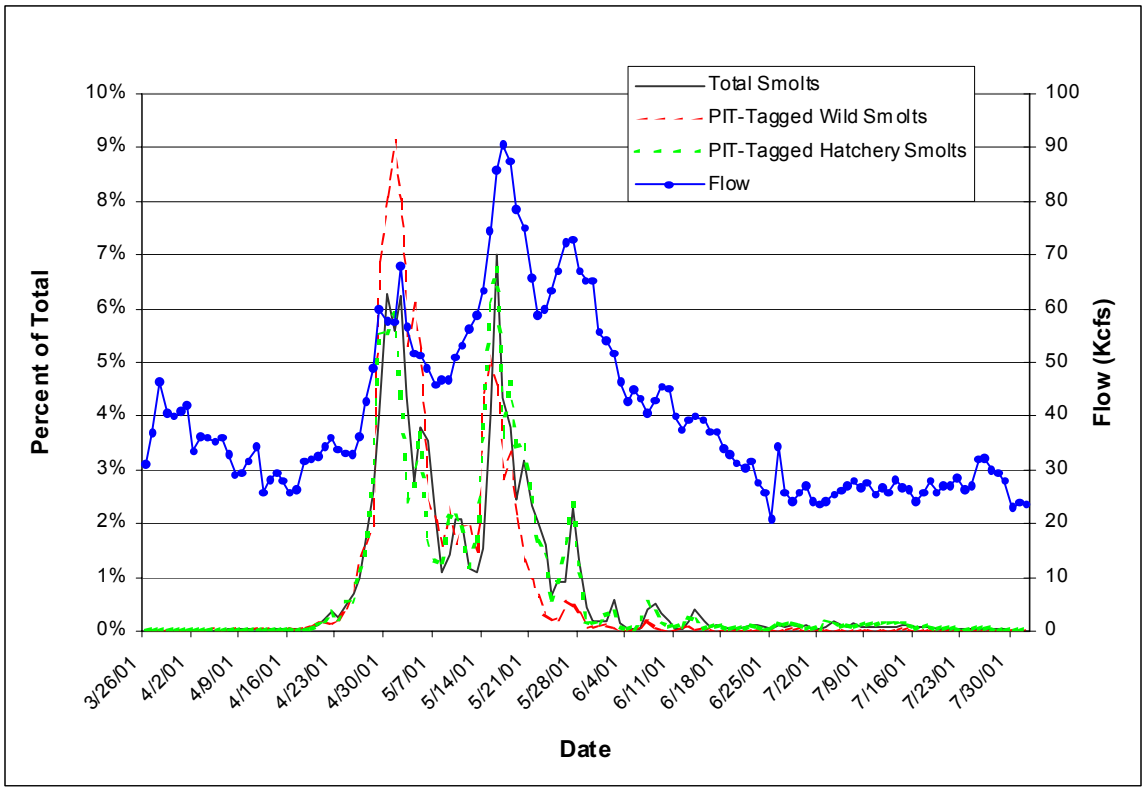

Figure 3. Steelhead trout smolt arrival timing and flow at Lower Granite Dam, 2001.

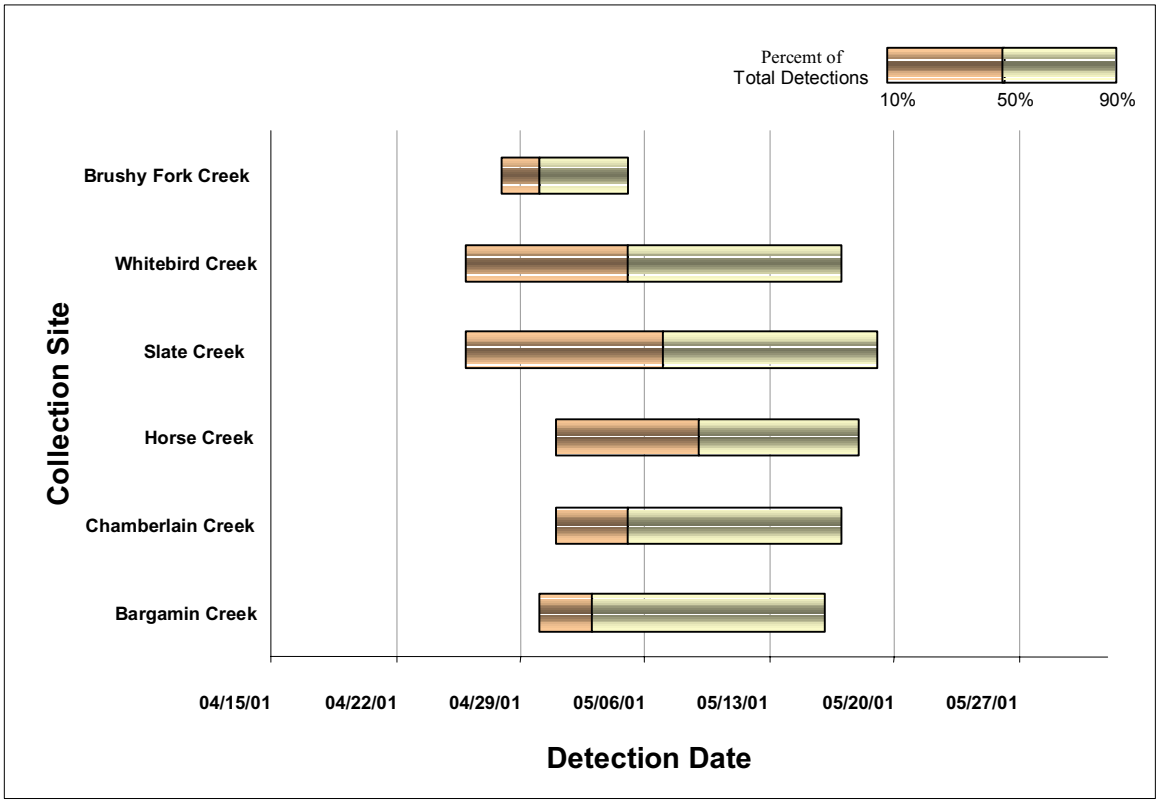

Figure 4. Arrival timing at Lower Granite Dam in 2001 for PIT-tagged wild steelhead trout tagged in summer 2000. Analysis includes only those streams with at least 100 detections at Lower Granite Dam.

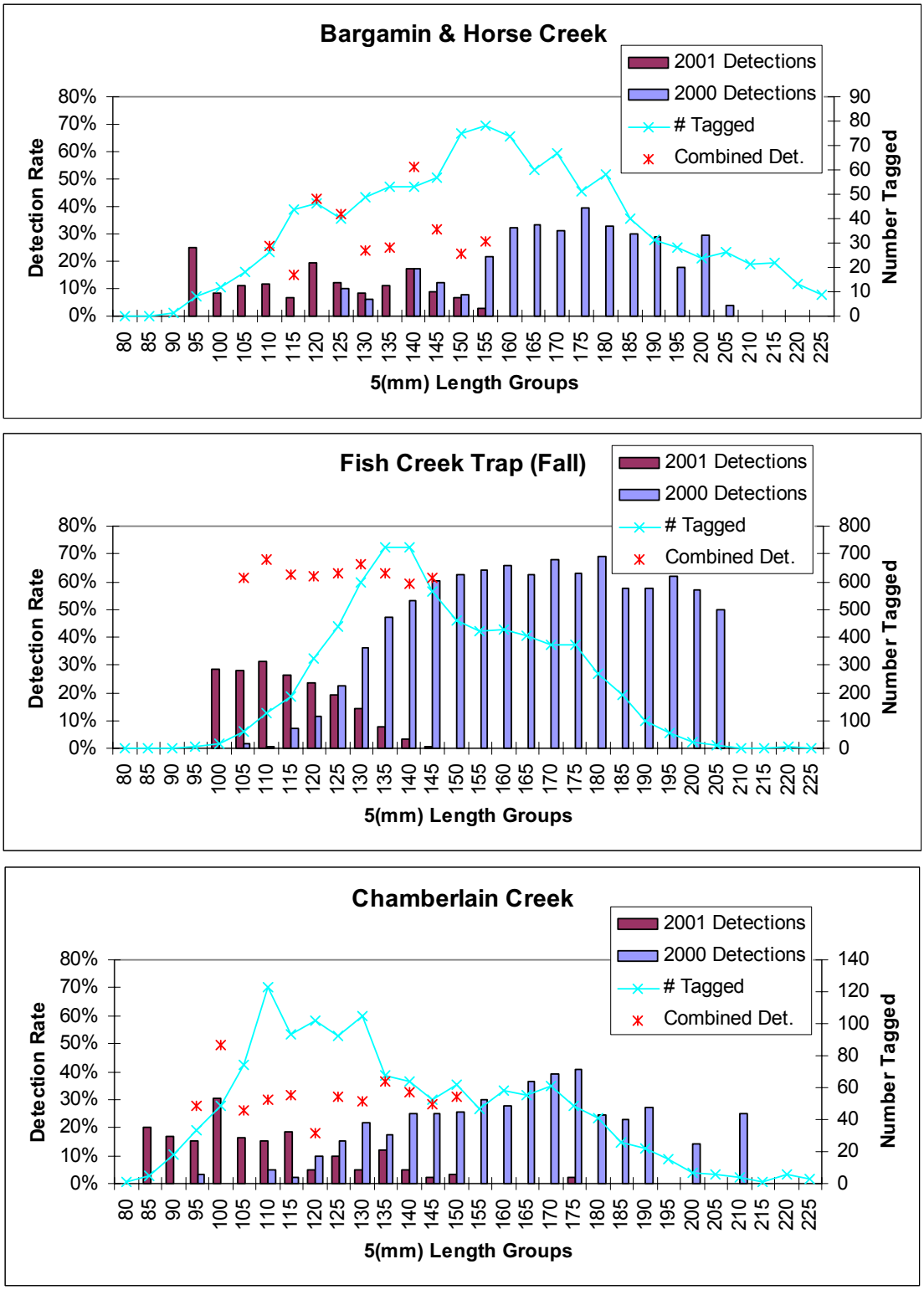

Figure 5. PIT-tagged wild steelhead trout detection rates at the four main smolt collector dams in 2000 and 2001 used to estimate annual mortality of juveniles tagged in 1999.

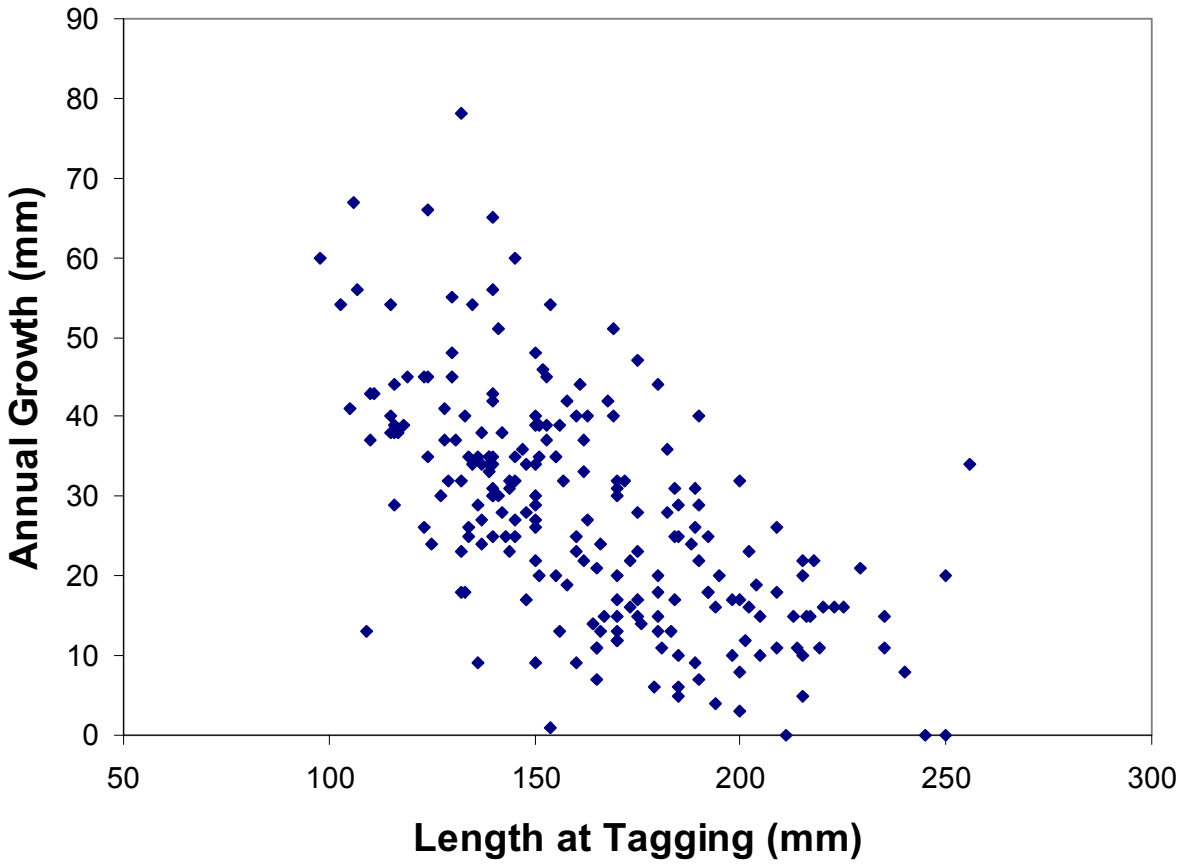

Figure 6. Annual growth rate by length at tagging for PIT-tagged wild steelhead trout recaptured one year (±12 days) after tagging.

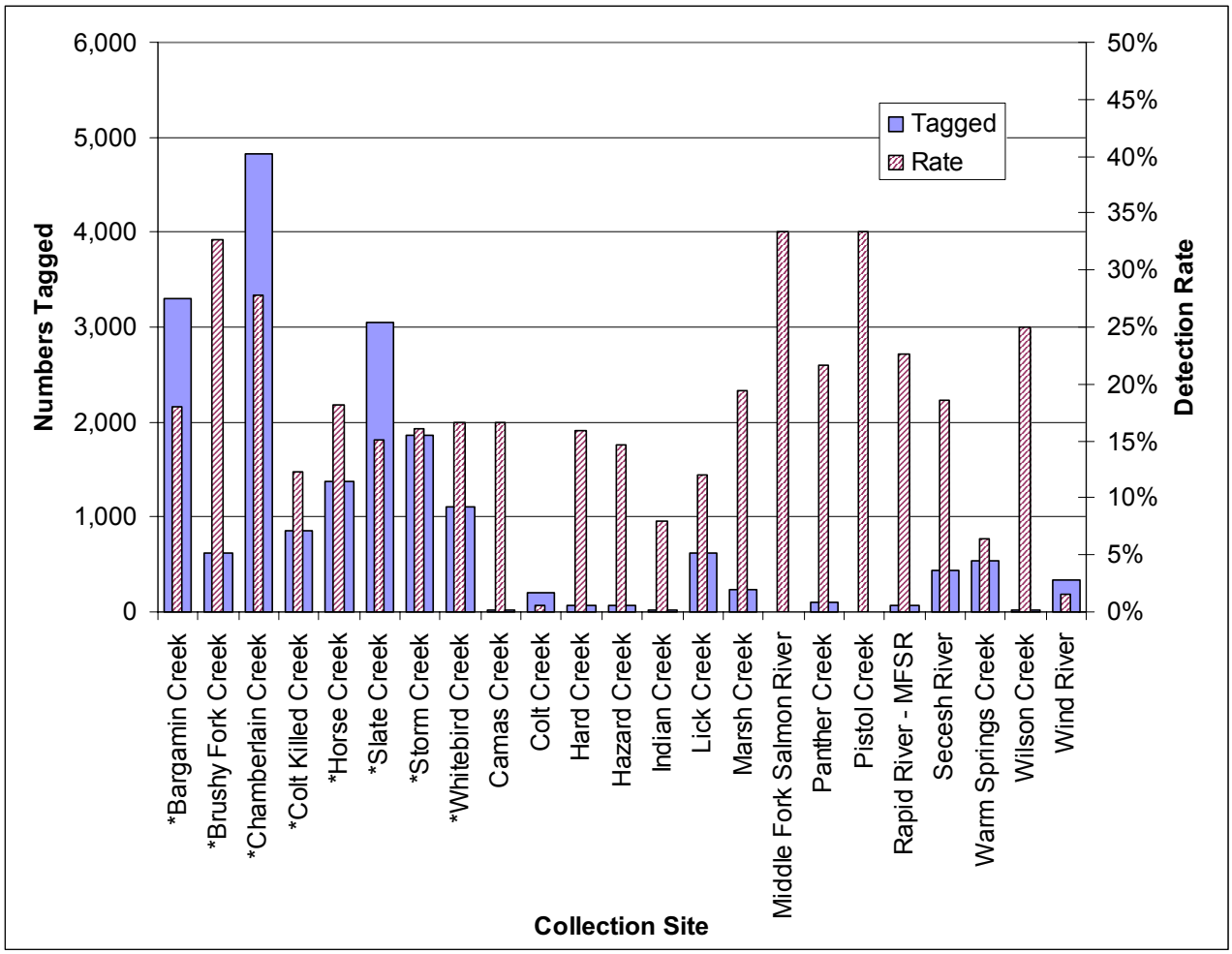

Figure 7. A summary of juvenile wild steelhead trout detection rates and numbers tagged, by collection site, covering the three years this project has operated. "*" = Sites selected for continued work.

PART 2—ESTIMATING THE STOCK RECRUITMENT RELATIONSHIP FOR SNAKE RIVER SPRING/SUMMER CHINOOK SALMON AND FORECASTING WILD/NATURAL SMOLT PRODUCTION

ABSTRACT

Defining the stock-recruitment relationship for a fish population is critical to understanding its life cycle survival and productivity. I used data collected at Lower Granite Dam from brood years 1990-1999 to develop a stock-recruitment relationship for Snake River spring/summer chinook salmon *Oncorhynchus tshawytscha*. In this analysis, the parents (stock) were the females passing Lower Granite Dam that were available for natural reproduction. The recruits were the resulting wild/natural smolt production arriving at Lower Granite Dam two years later. The stock-recruitment relationship was assumed to be in the form of a Beverton-Holt function. The data were fitted with the following relationship:

$$recruits = \frac{1}{5.3715E-07 + 0.00259932/parents}\text{; } P < 0.01.$$

To provide a forecast with confidence intervals of the number of brood year 2000 wild/natural smolts that will arrive at Lower Granite Dam in 2002, the stock-recruitment data was transformed to fit a linear regression. Females available for natural reproduction were the independent variable regressed against the dependant variable of the natural log transformation of resulting smolts/female production. During this period, smolts/female production ranged from 92–403, with a mean of 251. This regression resulted in the following equation:

Natural log (smolts/female) = -0.0001(females available for natural reproduction) + 5.8731; $r^2 = 0.53$ and $P < 0.01$.

For brood year 2000, I estimated 8,733 females were available for natural reproduction and forecast they would produce 1,196,421 smolts (90% C.I. 545,116 - 3,152,613).

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INTRODUCTION

Survival during both fresh and saltwater life stages for Snake River spring/summer chinook salmon must be well understood to effectively develop mitigation measures that have a reasonable probability of significantly contributing to recovery. An important tool in understanding freshwater survival for anadromous fish is the development of stock-recruitment relationships that span the critical period of freshwater residence when density-dependent mortality defines the shape of the relationship (Solomon 1985). I developed a stock-recruitment relationship between the number of female adult spring/summer chinook salmon passing Lower Granite Dam (LGD) that were available for natural reproduction (females ANR) and the resulting number of wild/natural smolts arriving at LGD two years later.

This stock-recruitment relationship allows for evaluating freshwater survival on a basinwide scale (Figure 8). Smolt abundance at LGD was selected as the index of recruitment for two main reasons. First, smolts are the last life stage that encompasses all density-dependent mortality prior to encountering highly variable mainstem migration and ocean productivity conditions. Secondly, smolts are the freshwater life stage for which abundance can be most accurately estimated on a Snake River basinwide scale. An additional advantage to this approach is that stock-recruitment relationships derived on a basinwide scale will yield curves reflecting the balance of good and suboptimal habitat in the basin (Crozier and Kennedy 1995).

The stock-recruitment relationships for Columbia River basin chinook salmon are assumed to be either in the form of a Beverton-Holt function (NPPC 1986) or a Ricker function (Petrosky et al. 2001). In a Beverton-Holt function, the relationship is regulated by density-dependent mortality and hyperbolic in shape, with the asymptote representing carrying capacity (Beverton and Holt 1957). In a Ricker function, a regulatory mechanism such as greater density increases the time needed for juveniles to grow through a particularly vulnerable size range causing declining recruitment at higher stock densities (Ricker 1975).

I assumed that the adult-to-smolt stock-recruitment relationship for Snake River spring/summer chinook salmon would be in the form of a Beverton-Holt function (Beverton and Holt 1957). This assumption was based on my belief that the regulatory mechanism for Snake River spring/summer chinook salmon smolt production is more likely to be a ceiling of abundance imposed by available food or habitat rather than greater density increasing the time needed by young fish to grow through a particularly vulnerable size range (Ricker 1975). However, both Ricker and Beverton-Holt relationships produce similar curves in the lower density of adult escapements like those that the Snake River has experienced during this period.

I adapted the method described by Chadwick (1982) to forecast brood year 2000 smolt production. This method allows for a straightforward approach to forecasting a mean and confidence interval for next spring's smolt production. In addition, the relationship between female escapement and smolts/female productivity (density-dependent mortality) is illuminated. Another statistic of interest from this method is the estimate of mean density-independent rate of reproduction in units of smolts/female (Chadwick 1982).

METHODS

Females Available for Natural Production

The estimated number of adult spring and summer chinook salmon (excluding jacks) passing LGD in 2000 were obtained from the Fish Passage Center website (http://www.fpc.org/adult_history/YTD-LGR) accessed on December 20, 2001. The total number of male (excluding jacks) and female spring and summer chinook salmon adults captured at all Snake River hatchery traps and the number of females taken into hatcheries were obtained from Jeff Abrams (Idaho Department of Fish and Game [IDFG], unpublished data), Pat Kinnery (Oregon Department of Fish & Wildlife, unpublished data), and Ralph Roseburg (U.S. Fish & Wildlife Service, unpublished data).

For each run of chinook salmon (spring or summer), the percentage of females captured at hatchery traps was applied to the LGD counts to estimate the total number of female chinook salmon passing LGD. No direct method was available to estimate the proportion of females of wild/natural adults passing LGD. I therefore assumed the percentages of females were the same for wild, natural, and hatchery adults for each run separately. The number of females taken (spawned, culled, or prespawning mortalities) in the hatcheries was adjusted for 20% migration mortality based on radio-tag studies (Ted Bjornn, University of Idaho, personal communication). To estimate the number of females ANR, the adjusted hatchery female number and the number of females harvested upstream of LGD estimated with creel surveys (Greg Mauser, IDFG, unpublished data) were subtracted from the estimated number of females passing LGD.

The estimated number of females harvested upstream of LGD was not adjusted for migration mortality. I made this decision based of the following: There was no direct estimate available; the rate would be variable depending on catch date; the rate would be lower than migration mortality to the hatcheries, and the resulting smolts/female estimate would be conservative. The brood year 2000 number of female spring and summer chinook salmon available for natural reproduction were combined to estimate total number of females ANR.

Smolt Production

Smolt production was estimated using passage data collected at LGD. The passage data used were daily estimates of wild/natural smolts collected and collection efficiency. Tom Berggren (Fish Passage Center, unpublished data) provided daily numbers of wild/natural chinook salmon smolts collected at LGD. Steve Smith (National Marine Fisheries Service, unpublished data) provided daily smolt collection efficiency estimates at LGD. Daily smolt abundance was estimated by dividing the daily count of smolts collected by that day's estimated collection efficiency. Smolt production was estimated by summing the daily smolt abundance estimates for an entire smolt migration season. For each brood year (1990–1999), smolts/female production was estimated by dividing total smolt production by females ANR.

Stock-Recruitment Relationship

Brood years 1990-1999 females ANR and the resulting wild/natural smolt production were applied to the Beverton-Holt formula 11.20 in Ricker (1975: 291):

$$R = \frac{1}{\alpha + \beta / P};$$

Where:

R = recruits (smolts),
P = parents (females),
α = inverse of estimated carrying capacity,
β = inverse of the slope at the origin.

The software package Microsoft® Excel was used to plot the data and draw the curve.

Smolt Production Forecast

To forecast brood year 2000 smolt production, I adapted the methods described by Chadwick (1982). To produce a linear regression, females ANR were used as the independent variable to regress against the dependent variable of natural log transformation (ln) of smolts/female production. I used the software package SYSTAT® to plot the regression and calculate the 90% confidence intervals. I then applied the estimated brood year 2000 females ANR to this regression to forecast smolts/female production with confidence intervals. This smolts/female forecast was multiplied by the estimated number of females ANR to forecast the number and 90% confidence interval of wild/natural smolts that will arrive at LGD in spring 2002.

RESULTS AND DISCUSSION

Females Available for Natural Production

The estimated number of adult spring and summer chinook salmon (excluding jacks) passing LGD in 2000 was 37,756, and for return years 1990–1999 ranged from a low of 1,799 to a high of 44,565 (Table 2). The estimated female proportions of adults (excluding jacks) captured at Snake River hatchery traps were estimated separately for spring and summer chinook salmon (Table 3). These estimated female proportions (0.573 spring chinook salmon and 0.515 summer chinook salmon) were applied to the estimated number of adults passing LGD for both runs to estimate that there were 19,381 female spring chinook salmon and 2,025 female summer chinook salmon that passed LGD in 2000 (Table 2). After accounting for females taken into the hatcheries (adjusted for 20% migration mortality) and harvest, I estimated that 8,511 female spring chinook salmon and 222 female summer chinook salmon were available for natural reproduction. I therefore estimated combined brood year 2000 females ANR for Snake River spring and summer chinook salmon to be 8,733.

Smolt Production

For brood years 1990–1999, estimated smolt production ranged from a low of 161,157 to a high of 1,558,786 (Table 2). During this period, smolts/female production averaged 251 smolts/female and ranged from 92-403 smolts/female (Table 2).

Stock-Recruitment Relationship

The stock-recruitment relationship I calculated for Snake River spring/summer chinook salmon is:

$$recruits = \frac{1}{5.3715E-07 + 0.00259932/parents}\text{; } P < 0.01.$$

The stock-recruitment data and calculated relationship are shown in Figure 9. Although fairly short, covering only 10 brood years, this data series appears sufficient to reasonably define the shape of the curve at lower adult escapements. Even with the current depressed status of adult returns, this stock-recruitment relationship indicates density-dependent mortality.

Smolt Production Forecast

The estimated linear regression between females ANR and the ln smolts/female production is:

$$ln(smolts/female) = -0.0001(females\ ANR) + 5.8731;\ r^2 = 0.53, \text{ and } P < 0.01.$$

Even with the current depressed status of Snake River adult escapements, increased spawner density apparently results in lower smolts/female productivity (Figure 10). Another statistic of interest from this regression (the y-intercept) is the estimate of mean density-independent rate of reproduction (355 smolts/female). I estimated brood year 2000 females ANR to be 8,733. The regression model predicts that 8,733 females ANR will produce 137 smolts/female measured at LGD, with a 90% confidence interval of 52 – 361 smolts/female (Figure 10). The forecast number of w/n smolts arriving at LGD in migration year 2002 will therefore be 1,196,421, with a 90% confidence interval of 454,116 – 3,152,613.

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Table 2. Brood year 1990-1999 Snake River spring/summer chinook salmon estimates of natural smolts per female production and brood year 2000 estimate of females available for natural reproduction.

Brood Year	1990		1991		1992		1993		1994	
Run	**Spring**	**Summer**	**Spring**	**Summer**	**Spring**	**Summer**	**Spring**	**Summer**	**Spring**	**Summer**
Dam Counts	17315	5093	6623	3809	21391	3014	21035	7889	3120	795
% Females	48	44	44	52	49	43	55	55	55	60
# Females	8311	2241	2614	1981	10482	1296	11569	4339	1716	477
# Females in Hatcheries[a]	4244	526	1663	315	3434	578	6076	660	858	205
# Females in Harvest	796	10	1	0	897	43	658	0	83	5
Female Escapement	3271	1705	1251	1666	6151	676	4835	3679	776	267
Combined Female Escapement	4976		2916		6826		8514		1043	
Combined w/n Smolts	527000		627037		627942		1558786		419826	
# Smolts per Female	106		215		92		183		403	

Brood Year	1995		1996		1997		1998		1999	
Run	**Spring**	**Summer**	**Spring**	**Summer**	**Spring**	**Summer**	**Spring**	**Summer**	**Spring**	**Summer**
Dam Counts	1105	694	4215	2608	33855	10709	9854	4355	3296	3260
% Females	41	52	48	40	55	44.5	54.1	53.9	47.8	48.7
# Females	453	361	2023	1043	18620	4766	5331	2347	1575	1588
# Females in Hatcheries[a]	191	125	1295	185	6879	1118	2786	456	688	749
# Females in Harvest	0	1	20	0	3183	322	643	67	61	36
Female Escapement	262	235	708	858	8559	3326	1902	1824	827	803
Combined Female Escapement	497		1556		11885		3726		1630	
Combined w/n Smolts	161157		599159		1560298		1344382		500700	
# Smolts per Female	324		383		131		361		307	

Brood Year	2000	
Run	**Spring**	**Summer**
Dam Counts	33823	3933
% Females	57.3	51.5
# Females	19381	2025
# Females in Hatcheries[a]	5080	1226
# Females in Harvest	5790	577
Female Escapement	8511	222
Combined Female Escapement	8733	
Combined w/n Smolts		
# Smolts per Female		

[a] Females taken into hatcheries adjusted for 20% migration mortality.

Table 3. Brood year 2000 Snake River spring/summer chinook salmon hatchery capture data used to estimate percent females and number of females taken into hatcheries.

	Captured (excluding jacks)				Released (excluding jacks)			
	Total	**Male**	**Female**	**Unknown**	**Total**	**Male**	**Female**	**Unknown**
Spring Sites								
Rapid R.	3162	1127	1406	629	1666	509	528	629
Oxbow	950	385	564	0	0	0	0	0
Dworshak	2981	694	908	1379	1735	117	179	1379
Kooskia	615	228	308	79	78	0	0	78
S. Fk. Clearwater R.	934	366	568	0	223	92	131	0
Powell	1092	349	743	0	160	38	122	0
Sawtooth	610	358	252	0	434	275	159	0
East Fk. Salmon R.	0	0	0	0	0	0	0	0
Grande Rhonde	17	0	0	17	15	0	0	15
Katherine C.	24	0	0	24	23	0	0	23
Lookingglass R.	218	102	96	20	214	99	95	20
Lostine R.	54	33	21	0	34	21	13	0
LGR to Lookingglass	721	296	425	0	0	0	0	0
Totals	**11378**	**3938**	**5291**	**2148**	**4582**	**1151**	**1227**	**2144**
% Female			**57.3**	**Est. Females Released = 1227 + (2144 X 0.573) = 2456**				
Summer Sites								
McCall	3396	1625	1771	0	1880	874	1006	0
Pahsimeroi	369	175	194	0	85	40	45	0
Imnaha R.	433	238	195	0	290	162	128	0
Totals	**4198**	**2038**	**2160**	**0**	**2255**	**1076**	**1179**	**0**
% Female			**51.5**					

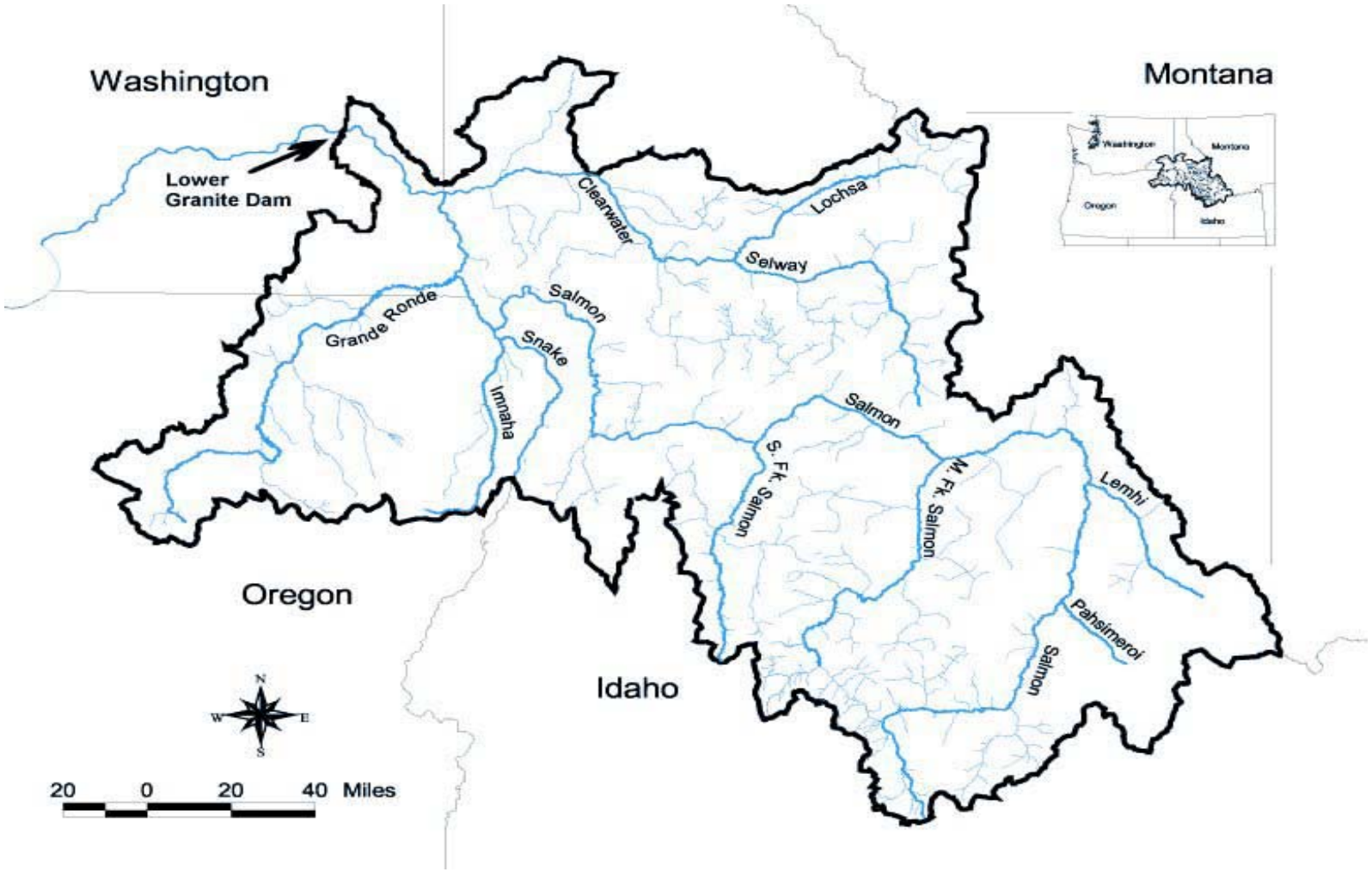

Figure 8. Snake River basin upstream of Lower Granite Dam that is currently accessible to spring/summer chinook salmon.

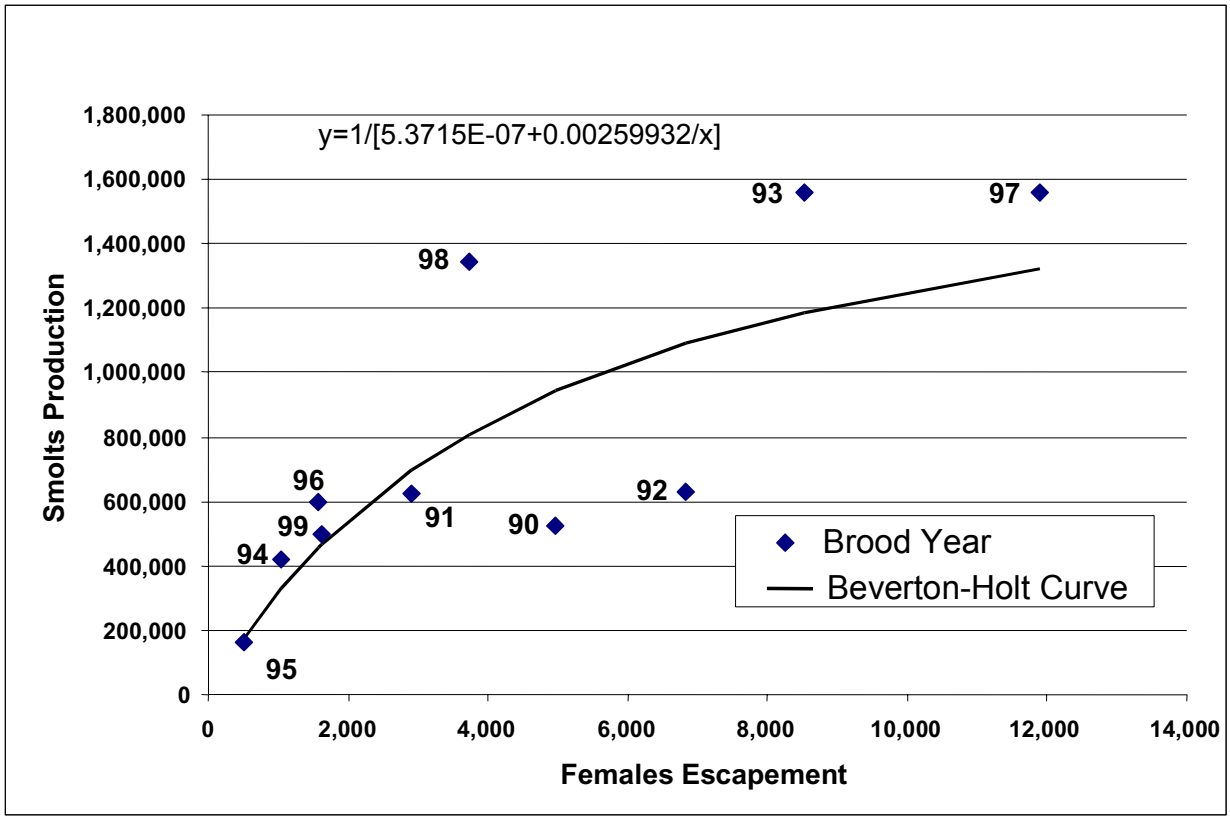

Figure 9. Snake River stock-recruitment relationship for spring/summer chinook salmon female escapement and resulting wild/natural smolt production.

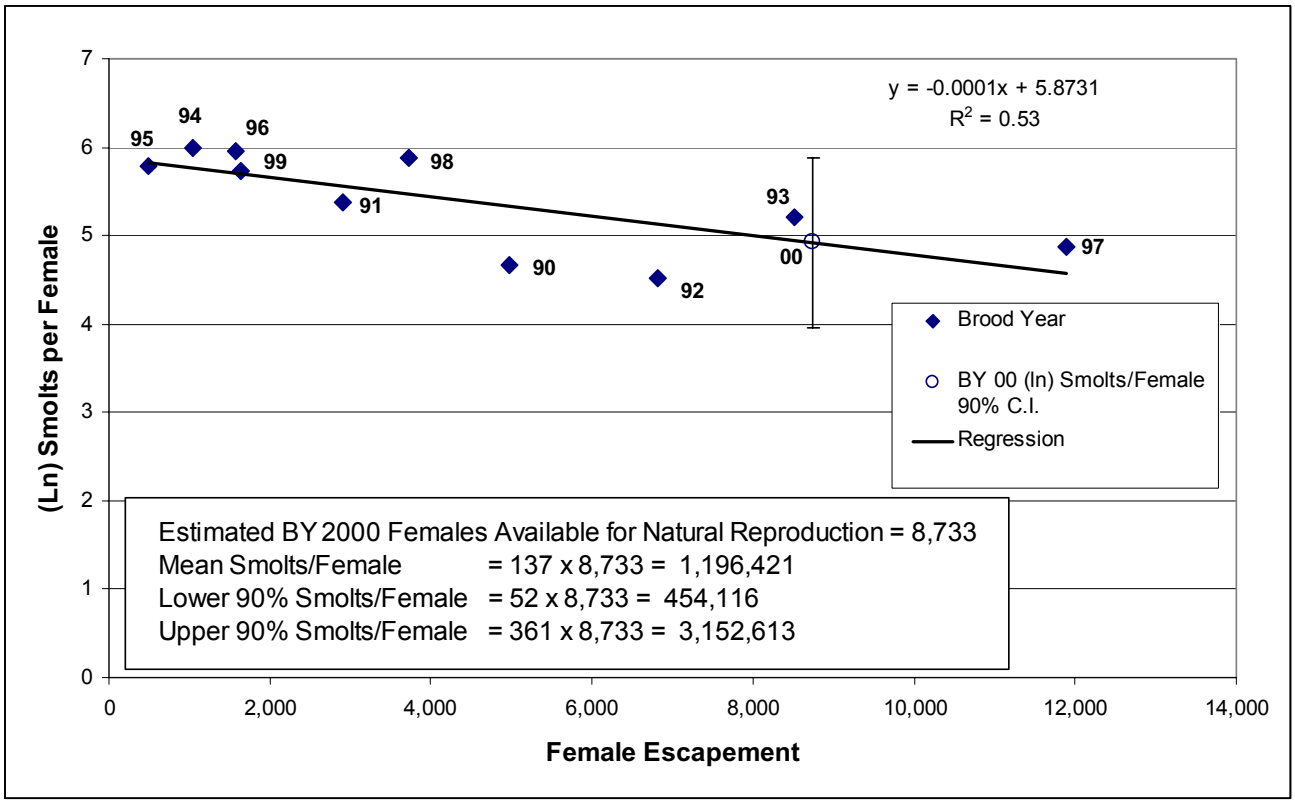

Figure 10. Linear regression of brood years 1990-1999 Snake River spring/summer chinook salmon female escapement and natural logarithmic transformation of resulting smolts per female production, and smolts per female forecast for brood year 2000.

PART 3—MONITORING AGE COMPOSITION OF WILD ADULT SPRING AND SUMMER CHINOOK SALMON RETURNING TO THE SNAKE RIVER BASIN

ABSTRACT

This report covers efforts to monitor age composition of wild/natural adult spring/summer chinook salmon returning to the Snake River basin from 1998 through 2001. Accurately determining the ocean age proportions of wild/natural adult spring/summer chinook salmon is important information for monitoring the status and trends of these species. Chinook salmon carcasses were sampled from representative wild/natural spawning areas throughout the Snake River basin. Ocean age proportions were determined for each 5 cm fork length group of carcasses sampled. These results were used to improve the accuracy of run reconstructions for spawner-to-spawner stock/recruitment analysis of wild index stocks. These ocean age proportions were also applied to the number and estimated length frequency distribution of wild chinook salmon adults passing Lower Granite Dam to estimate the number of wild adult returns for each ocean age group. Aggregate smolt-to-adult return rates for smolt migratory years 1996–1999 were calculated for Snake River wild/natural spring/summer chinook by applying these adult return estimates to basinwide smolt production estimates. The basinwide smolt production estimates were produced in the stock-recruitment section of this report.

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INTRODUCTION

Accurate age information is an important tool for the management and recovery of wild/natural Snake River spring/summer chinook salmon *Oncorhynchus tshawytscha,* hereafter referred to as wild chinook salmon. Pacific salmon *Oncorhynchus sp*. are usually aged by examining the circuli of scales (Nielsen and Johnson, 1983). However, as Pacific salmon leave the ocean for their spawning migration, they cease feeding, and scale material is resorbed. This resorption results in the loss of circuli and annuli on the periphery of scales, making accurate age determination difficult if not impossible for salmon with long spawning migrations such as Snake River wild chinook salmon (Chilton and Bilton, 1986). During the fall of 1998, a variety of aging structures (scales, otoliths, dorsal fins, and pectoral fins) were collected from Snake River wild chinook salmon carcasses to determine which structure was most suitable to meet project objectives. In spring 1999, Idaho Department of Fish and Game (IDFG) personnel transported a subset of these aging structures to the aging lab at Canada's Pacific Biological Station in Nanaimo, British Columbia. The objectives were to identify an aging structure that was at least 90% accurate and could be collected and stored relatively easily. Shayne MacLellan and her staff at the Pacific Biological Station provided training in sample preparation, structure aging, and aging data management. With the help of the Pacific Biological Station staff, it was determined that dorsal fin rays are the aging structure most suited to meet the objectives. This report covers results of aging structures collected in 1998–2001 from wild chinook salmon spawning areas throughout the Snake River basin.

STUDY AREA

The study area encompasses all streams in the Snake River basin upstream of Lower Granite Dam (LGD) that are currently accessible to wild/natural spring/summer chinook salmon (Figure 11). Carcasses were sampled from representative spawning areas throughout the study area (Figure 11). Because of low numbers of returning wild adults in some years, carcasses were not found in all spawning areas every year.

METHODS

Sampling

Training was provided in several forms to help ensure correct sample collection and data recording. A spawning survey manual and video were produced and distributed that illustrated the proper techniques for aging structure collection and data recording. On-site training for aging structure collection was provided at the Nez Perce Tribe's redd count training, Sawtooth Hatchery, and the interagency redd count training on Marsh Creek.

Several structures were collected from carcasses for age and DNA analysis. A dorsal or pectoral fin (aging fin) and scales were collected for age analysis. A small piece of fin tissue was also collected for DNA analysis. Biological sample collectors were asked to record stream name, fish species, run type, types of samples collected, date, marks, tag numbers, sex, fork length (FL), mid-eye to hypural length (MEH), collector name, and any noteworthy comments about the fish or samples.

Aging fins were collected using a serrated knife. The aging fin is held at a 90-degree angle to the body and is removed by making a cut level with the body of the fish while pulling upward on the fin. The aging fin is then inserted into a coin envelope with the fin base exposed and the fin rays aligned perpendicular to the fin base.

Individual scales were collected with forceps and carefully placed, rough side up, on gummed paper, five from each side of the fish. The scales were collected for the potential to develop scale resorption criteria for Snake River chinook salmon at a later date.

A small pencil eraser size piece ($\approx$16 mm^2) of fin (excluding adipose fin) with good color was collected from each carcass sampled and placed in a test tube filled with 95% ethanol. These DNA tissue samples were catalogued and stored for future analysis.

Sample containers for individual fish aging structures and DNA were prelabeled with one unique number. Once the samples were collected, they were placed in a Ziploc® bag and sealed. The identification number contained two digits to identify year, a dash, and four digits to uniquely identify up to 9,999 carcasses sampled in a year. For example, sample containers for the 199th packet assembled for samples collected in 1999 would be labeled 99-0199. Samples were transported to the IDFG Fisheries Research Office in Nampa, Idaho, catalogued, and stored for later analysis. The aging fins were stored in a freezer until prepared for aging. The DNA and scale samples were catalogued, organized, and stored in the lab for potential future analysis.

The majority of samples were collected on spawning grounds from wild adult carcasses that died naturally. Personnel also collected samples from the small percentage of wild adults captured and spawned at several of the chinook salmon hatcheries in Idaho. A few samples were also collected from wild adult carcasses that floated down to the front of adult trapping weirs. In addition to the wild adults sampled, aging fins and scales were collected from known-age hatchery adults that returned to Sawtooth, Rapid River, McCall, Dworshak, and Clearwater hatcheries.

Data Storage

Project personnel developed a Microsoft® Access database to catalogue and interrelate all current and future anadromous and resident fishery biological samples collected. While adding complexity and development time to the database needed for this project, one complete database will increase the overall efficiency for many research projects and provide better access to fishery information and sample tracking. Currently the database is only available to IDFG researchers at Nampa. A future goal is to have this database accessible through the IDFG intranet web page.

Fin Preparation

To begin fin preparation, a group of 25-30 chinook dorsal fins were removed from the freezer where they had been stored. Each individual envelope containing a dorsal fin was adjusted so the base of the fin was perpendicular to the fin rays, and then placed upright in specially designed wooden racks. The racks keep the fins separated and allow for air circulation, permitting the fins to dry thoroughly. After 24 hours of drying, the fins were brushed

clean of debris. Excess materials (i.e. bones, loose skin, and flesh) and unneeded fin rays were removed. When a group of 25-30 fins were cleaned, the fins were individually coated in a 2-3 mm thick layer of epoxy and placed on waxed paper to harden overnight under a fume hood. After the epoxy hardened, excess epoxy was trimmed from the fin margins, and the respective sample number was written on each fin. Throughout the entire fin preparation process, utmost care was taken to maintain the respective identity (sample number) of each fin.

Slicing fins into cross-sections was the next step of fin preparation. This step was critical in that it requires both practice and precision to produce cross-sections that could be aged with a compound microscope. Multiple sections were obtained from each individual fin using a water-cooled Bronwill diamond grit bone saw. This saw features a moving carriage and metered hand wheel that allowed great precision in obtaining cross-sections of exact thickness. To begin slicing, a prepared fin was clamped into a VISE-GRIP® that was then locked in a chuck on the moving carriage. The blade was positioned at the base of the fin ray for the first slice. The moving carriage was switched on and carried the fin to a 0.32 mm diamond grit blade. The hand wheel was used to adjust the thickness of the slices to 1.3–1.5 mm. With the carriage controls, a fin was sliced, repositioned for desired thickness, and re-sliced until an average of 10-12 cross-sections were obtained. Cross-sections were then dried and affixed onto microscope slides under the fume hood using a clear liquid mounting medium that improves resolution and preserves the sample. The cross-sections from one fish usually do not fit on one slide, so in addition to the sample number, a slide letter was also written on each slide with a permanent marker in order to maintain the order in which the slices were cut. For example, the first set of slices from fish 99-0199 would be placed on the first slide, which would be labeled 99-0199A. The next slide would be 99-0199B, and so on, until all sections were mounted on slides.

Fin Aging

Fins were aged with the use of a compound microscope and green filtered transmitted light. Light passing through the individual fin ray sections illuminated wide opaque zones alternating with narrower translucent zones (Figure 12). Opaque zones represent material deposited during the summer period of rapid growth, and translucent zones represent material deposited during the winter period of slow growth (Ferreira, et. al. 1999). The winter translucent zones (annuli) were counted to age the fish. Annuli develop from the center outward as the fish and the fin ray grow. Snake River wild spring/summer chinook usually spend one winter in the freshwater rearing areas before smolting and migrating to the ocean. The kidney-shaped freshwater annulus is near the center of the fin ray. With the very cold Snake River basin winters, the freshwater annulus translucent zone is narrow and fairly bright (Figure 12). Ocean winters are not nearly so cold, and some growth does occur, which causes the ocean annuli to be broader and not as bright as the freshwater annulus (Figure 12).

A reference collection of known age fish was developed to assist with reader training and to estimate the accuracy of our aging methods. This reference collection is comprised of PIT-tagged and coded wire-tagged hatchery returns, and PIT-tagged wild/natural returns. All samples were independently aged by at least two employees trained in fin aging techniques. If there was disagreement in age determination, or the determined age did not match what is normal for the fish's length, that fin was read again in a referee session. During a referee session, a camera was attached to the microscope and the image was displayed on a computer screen. Three trained employees then viewed the fin together and aged the fish if possible. In a few cases, fin samples were classified as unreadable.

Passive Integrated Transponder tag detections at the hatchery weir on the South Fork Salmon River (SFSR) indicated that a significant proportion of the adult chinook salmon passed upstream of the weir in 2001 were actually hatchery adults without external marks (Kim Apperson, Idaho Fish and Game, personal communication). We used discriminant analysis (Klecka 1980) to assign rearing types to the aging and DNA samples collected in the SFSR. Hatchery chinook salmon are usually larger than their wild counterparts going into their first winter when the freshwater annulus is formed. The size of the freshwater annulus should therefore usually be larger on hatchery adults than on wild adults. We used known SFSR hatchery samples to represent the population of hatchery fish and unmarked carcasses sampled on Lake Creek, Secesh River, and Johnson Creek to represent wild fish. We used a compound microscope and the software package AVM-1® for fin ray measurements. We measured the area of the largest triangle defined by three points on the outside edge of the freshwater annulus. Rearing type classification was assigned based on at least a 90% probability that a particular sample came from one of the two known populations (hatchery or wild).

Ocean Age Proportions at Lower Granite Dam

Video monitoring was used to determine the length frequency of adult wild/natural spring/summer chinook salmon passing LGD. From May through August, videos recorded adults passing the viewing window at LGD for 24 hours every third day. The initial start date for recording videos was randomly selected; this random start date established the video recording schedule for the rest of the season. At the end of adult migration season, the videotapes were shipped to the IDFG Nampa Fisheries Research Office for analysis. Each videotape was viewed every fourth hour for images of adults passing the viewing window at LGD. Personnel randomly selected which fourth hour to view for each videotape. The video images of each adult observed passing the viewing window were examined for the presence of an adipose fin. For those adults determined to be unmarked (adipose fin present), one image was digitized for length analysis. A small percentage of adult returns with an adipose fin present are actually hatchery fish (missed clips or other marks besides adipose fin clip) that could not be determined from the video images.

Video editing software was used to calculate the ratio of each adult's image fork length to the image length of vertical lines placed on the viewing window. Video images of measuring sticks of known lengths (62 cm, 85 cm, and 100 cm) were also digitized and image length ratios to the viewing window vertical lines were calculated. The image ratios from the measuring sticks were used to develop a regression between image length ratios and actual lengths. This regression was used to estimate the actual fork length from the digitized images of the unmarked adults passing LGD. A length frequency distribution for unmarked adults passing LGD was developed with these estimated actual fork lengths. The estimated ocean age proportions for each 5 cm length group developed from the fin aging work were applied to this length frequency distribution to estimate the ocean age proportions of all unmarked adults passing LGD each year. The ocean age proportions were applied to the United States v. Oregon Technical Advisory Committee (TAC) estimates of wild chinook salmon adults passing LGD to estimate the number of adult returns for each ocean age group.

Estimating Aggregate Smolt-to-Adult Return Rates

Results of our carcass aging research and stock-recruitment analysis were combined to estimate an aggregate smolt-to-adult return rate (SAR) estimate for Snake River wild chinook salmon. For a particular smolt year, the estimate of wild/natural smolts arriving at LGD from our stock-recruitment analysis was used as the denominator in the SAR estimates. The numerator was the addition of 1-ocean adults that returned the year after the smolt year (smolt year +1), 2-ocean adults that returned smolt year +2, 3-ocean adults that returned smolt year +3, and 4-ocean adults that returned smolt year +4. Smolt-to-adult return rates were reported as a percentage (%). We report SARs with and without 1-ocean returns (jacks). Since 1998 was the first year for which we had aging results, we were only able to estimate smolt year 1996 SAR without 1-ocean adults. Smolt-to-adult return rate estimates are complete only through 3-ocean returns for smolt year 1998 and 2-ocean returns for smolt year 1999.

RESULTS AND DISCUSSION

Known Age Adults

Samples collected in 1999 were analyzed and reported first (Kiefer et al. 2001). Twenty-six known age fish were collected in 1999, and they were prepared and aged first to test our methodologies and accuracy. We aged 23 (88%) of the 1999 known age adults correctly. As a group, aging personnel reviewed the 1999 known age fins that were not aged correctly. All three of these fins had a single ocean annulus that was split into two parts in some of the cross sections and had been misidentified as two separate annuli (Figure 13). Our aging training was adjusted to include reviewing the differences between a split annulus and two separate annuli. Since this adjustment to our methodologies, we have aged 139 known age adults and correctly determined the age of 137 (99%) of them. Overall, we have correctly aged 160 (97%) of the 165 known age adults sampled.

Wild Adult Carcass Age Determinations

Overall, we examined fin ray cross sections from 1,690 wild adult carcasses collected in 1998-2001, and only 24 (1%) of these were classified as unreadable. The number of wild adults sampled and aged from a particular return year ranged from a low of 173 in 1998 to a high of 905 in 2001. In the first year of this research (1998), we instructed collectors not to sample carcasses less than 70 cm FL, because we assumed they were all 1-ocean adults. While receiving aging training at the Pacific Biological Station, we were informed that 2-ocean adults could be less than 70 cm in FL. Beginning in 1999, we instructed the surveyors to collect samples from all sizes of carcasses and have aged adults less than 70 cm in FL as 2-ocean. We used the average of 1999–2001 ocean age proportions for FL groups less than 70 cm to represent those length groups in 1998.

The fork lengths and ocean age determinations for each return year sampled are displayed in Figures 14 and 15. Because collectors are more likely to find larger carcasses, we must caution that the ocean age proportions of the carcasses collected and aged may not be the same as the ocean age proportions of the entire population. Due to a disproportionately large number of 2-ocean returns in 2001, we instructed the collectors to sample carcasses

<70 cm and carcasses >85 cm at a higher rate than they randomly would. The ocean age proportions for each 5 cm fork length group calculated from these results are displayed in Table 4.

A small percentage of the fish aged appear to have resided in freshwater for two years (Figure 16). Jerry Lockhart (Nez Perce Tribe, personal communication) has observed this life history in wild chinook salmon in the South Fork Salmon River drainage. This unusual life history should not affect our ocean age or SAR analysis. Because the fin readers were focused on determining ocean age, and the two freshwater annuli were sometimes hard to see, there may be more two freshwater adults than we identified. We believe scales would be a better structure for estimating the proportion of two freshwater annuli in chinook salmon returns.

We compared ocean age proportion estimates of the Idaho long-term index stocks (Marmorek et al. 1998) using the previous length-at-age criteria (Beamesderfer et al. 1997) and the fin age method developed here (Table 5). Both methods provided similar estimates for the proportion of 1-ocean adults for the three years compared. Relative to the fin age determinations presented here, Beamesderfer et al. (1997) length-at-age criteria underestimated 2-ocean returns, overestimated 3-ocean returns, and did not account for 4-ocean returns (Table 5). This apparent error with the previous method of run reconstruction would cause individual brood years recruits per spawner analysis to be incorrect. However, over time these errors will balance out, an overestimate of adult returns from one smolt year results in an underestimate in another smolt year. Therefore, the long-term trend analysis of recruits per spawner in Beamesderfer et al. (1997) would not be greatly affected.

The discriminant analysis indicated that a significant proportion of the SFSR carcasses sampled in 2001 were hatchery fish without external marks. Of the 51 unmarked carcasses sampled in the SFSR, the discriminant analysis was able to classify 38 (75%) as to rearing type. Of the 38 carcasses that could be classified, 18 (47%) were classified as hatchery fish (Figure 17). The rearing type field in the biological samples database has been updated based on the results of the discriminant analysis. The 13 fish that the discriminant analysis did not classify were listed as unknown rearing type in the database.

Estimated Ocean Age Proportions of Wild Adults Passing LGD

We digitized the video images of a random sub-sample of wild chinook salmon adults passing through the viewing window at LGD in return years 1998-2001. With these images, we estimated the fork length frequency (Figure 18) and the proportion in each 5 cm length group (Table 6) for wild chinook salmon adults passing LGD in 1998-2001. We multiplied the estimated ocean age proportions for each length group (Table 4) by the estimated proportion at LGD in that length group (Table 6) to estimate the overall ocean age proportions for wild adults passing LGD (Table 7). For each return year, we multiplied the TAC estimates (Greg Mauser, IDFG, unpublished data) for the number of wild adults passing LGD by the estimated ocean age proportions at LGD (Table 7) to estimate the number of wild adult returns for each ocean age (Table 8).

We investigated the impacts to ocean age proportion estimates at LGD from two different options to reduce the high personnel costs associated with this effort. The first option was to collect the current individual stream maximum of 60 samples in only the Snake River index streams used for upstream/downstream productivity analysis (Marmorek et al. 1998). The second option was to collect only a maximum of 30 samples from an individual stream instead

of the current maximum of 60. We reran the analysis of the 1998-2001 samples using only data from the index streams and by randomly selecting 30 samples from any stream that had more than 30 samples in a particular year. Compared to our current effort, using only the index streams resulted in an average of 4.5% difference (range 2-7%) in the ocean age proportions estimated at LGD (Table 9). The 30 sample maximum option resulted in less than a 2% average difference (range 0-3%) in these estimates (Table 9). We used the reduction in number of samples with these two options (Table 9), to estimate the reduction in workload that would result from adopting one of them. The estimated reductions in workload were approximately 50% for the index stream only option and 25% for the maximum 30-sample option. Both options result in cost effective reductions in workload without compromising the main objective of accurately estimating ocean age proportions at LGD. An additional benefit of this effort is the collection of DNA samples from the majority of significant spawning areas for federally listed Snake River wild chinook salmon. The stock structure of these listed fish is currently not well understood (Mathews and Waples, 1991). These DNA samples should be invaluable for developing a much better understanding the stock structure of these listed fish. We therefore plan to implement the maximum 30-sample option in the future.

Aggregate Smolt-to-Adult Return Rates

Estimates of Snake River aggregate wild chinook salmon SARs (excluding jacks) ranged from a low of 0.34% for smolt year 1996 to a high of 1.80% for just the 2-ocean returns for smolt year 1999 (Table 10). These SAR estimates were very similar (Figure 19) to those produced with Passive Integrated Transponder tags for the same four smolt years (Kiefer 2001).

ACKNOWLEDGMENTS

We would like to gratefully acknowledge several agencies and the large number of people without whom we would not have been able to accomplish this work. We are grateful to the Bonneville Power Administration and our contracting officer Debbie Docherty for their support and funding of this research. We thank Steve Richards and his crew with the Washington Department of Fish and Wildlife for helping us set up the video schedule and protocols and for operating the video cameras for this work. We thank the U.S. Army Corps of Engineers for allowing us to conduct the video work at Lower Granite Dam. Special thanks go to the many folks working for the Nez Perce Tribe, the Shoshone-Bannock Tribes, Oregon Department of Fish and Wildlife, U.S. Fish and Wildlife Service, U.S. Forest Service, and other IDFG projects for collecting the aging fins and associated carcass data. We are very grateful to Shayne MacLellan and her staff at the Pacific Biological Station in Nanaimo, BC for the large amount of assistance they provided in determining what structure was most suitable for our needs and providing us hands-on training in collecting, preparing, reading, and managing aging data. We are very appreciative of the high quality fin preparation and aging work performed by Dave Anderson, Jim Hulme, Terry Antonich, Ken Cole, and Bill Stewart. We also thank the Columbia River Inter-Tribal Fish Commission for loaning the video editing equipment used to digitize the video images.

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Table 4. Estimated ocean age proportion by 5 cm fork length groups for Snake River wild chinook salmon carcasses sampled, 1998-2001.

	1998					1999					2000					2001				
FL	N[a]	1 Ocean	2 Ocean	3 Ocean	4 Ocean	N	1 Ocean	2 Ocean	3 Ocean	4 Ocean	N	1 Ocean	2 Ocean	3 Ocean	4 Ocean	N	1 Ocean	2 Ocean	3 Ocean	4 Ocean
<50	N/A	1[b]	0[b]	0[b]	0[b]	5	1	0	0	0	5	1	0	0	0	2	1	0	0	0
50-54	N/A	1[b]	0[b]	0[b]	0[b]	5	1	0	0	0	10	1	0	0	0	5	1	0	0	0
55-59	N/A	1[b]	0[b]	0[b]	0[b]	12	1	0	0	0	10	1	0	0	0	4	0.75	0.25	0	0
60-64	N/A	0.82[b]	.18[b]	0[b]	0[b]	3	1	0	0	0	7	0.86	0.14	0	0	5	0.60	0.40	0	0
65-69	N/A	0.14[b]	.85[b]	0.01[b]	0[b]	5	0.20	0.80	0	0	26	0.04	0.96	0	0	37	0.05	0.92	0.03	0
70-74	1	0	1	0	0	24	0	0.96	0.04	0	42	0	1	0	0	181	0	0.99	0.01	0
75-79	5	0	1	0	0	80	0	0.98	0.03	0	83	0	1	0	0	247	0	0.99	0.01	0
80-84	15	0	0	0.93	0.07	68	0	0.93	0.07	0	45	0	0.96	0.04	0	230	0	0.99	0.01	0
85-89	40	0	0.03	0.95	0.03	26	0	0.81	0.19	0	53	0	0.92	0.08	0	90	0	0.90	0.09	0.01
90-94	54	0	0.02	0.96	0.02	24	0	0.29	0.63	0.08	14	0	0.21	0.79	0	46	0	0.46	0.54	0
95-99	34	0	0	0.94	0.06	10	0	0.10	0.60	0.30	9	0	0	1	0	33	0	0.12	0.82	0.06
100-104	14	0	0	0.64	0.36	6	0	0	1	0	5	0	0	1	0	3	0	0	1	0
>104	9	0	0	0.22	0.78	3	0	0	0.67	0.33	2	0	0	1	0	4	0	0	1	0

[a] N/A = Not Applicable

[b] Surveyors were instructed not to sample carcasses <70 cm fork length in 1998. Average results from 1999-2001 were used for these length groups.

Table 5. Comparison of index stock run reconstructions using the length-at-age criteria of Beamesderfer et al. (1997) (OLD) and our fin age analysis (NEW).

			1998		1999		2000	
			OLD	**NEW**	**OLD**	**NEW**	**OLD**	**NEW**
Poverty Flat	Run year proportion	Age-3	0.023	0.022	0.139	0.139	0.213	0.215
		Age-4	0.070	0.082	0.389	0.756	0.447	0.723
		Age-5	0.907	0.799	0.472	0.091	0.340	0.062
		Age-6	0.000	0.096	0.000	0.014	0.000	0.000
Johnson	Run year proportion	Age-3	0.000	0.000	0.185	0.185	0.258	0.265
		Age-4	0.016	0.031	0.296	0.632	0.581	0.699
		Age-5	0.984	0.908	0.519	0.151	0.161	0.037
		Age-6	0.000	0.061	0.000	0.032	0.000	0.000
Bear Valley	Run year proportion	Age-3	0.000	0.000	0.067	0.095	0.000[b]	0.000
		Age-4	0.091	0.105	0.342	0.519	0.810	0.957
		Age-5	0.909	0.823	0.591	0.326	0.190	0.043
		Age-6	0.000	0.073	0.000	0.059	0.000	0.000
Marsh	Run year proportion	Age-3	0.000	0.000	0.000[a]	0.000	0.000[b]	0.000
		Age-4	0.000	0.016	0.000	0.000	0.810	0.957
		Age-5	1.000	0.916	0.000	0.000	0.190	0.043
		Age-6	0.000	0.068	0.000	0.000	0.000	0.000
Sulphur	Run year proportion	Age-3	0.000	0.000	0.000[a]	0.000	0.000[b]	0.000
		Age-4	0.020	0.035	0.000	0.000	0.810	0.957
		Age-5	0.980	0.893	0.000	0.000	0.190	0.043
		Age-6	0.000	0.072	0.000	0.000	0.000	0.000

[a] No carcasses found
[b] Carcass data from three Middle Fork Salmon River index stocks combined because of low sample size in each individual stream

Table 6. Estimated proportion of wild chinook salmon adults passing Lower Granite Dam in each 5 cm fork length group, 1998-2001.

	Adult Return Year			
Length Group	**1998**	**1999**	**2000**	**2001**
<50	0.004	0.009	0.032	0.001
50-54	0.008	0.034	0.055	0.014
55-59	0.004	0.029	0.053	0.007
60-64	0.008	0.002	0.032	0.022
65-69	0.013	0.034	0.076	0.120
70-74	0.047	0.121	0.250	0.320
75-79	0.051	0.268	0.324	0.322
80-84	0.118	0.221	0.103	0.136
85-89	0.269	0.125	0.029	0.034
90-94	0.254	0.074	0.037	0.015
95-99	0.160	0.049	0.008	0.006
100-104	0.051	0.018	0.000	0.001
>104	0.015	0.016	0.003	0.001

Table 7. Estimated ocean age proportions of wild chinook salmon passing Lower Granite Dam in each ocean age group, 1998-2001.

	Adult Return Year			
	1998	**1999**	**2000**	**2001**
1-Ocean	0.023[a]	0.081	0.170	0.040
2-Ocean	0.100	0.737	0.784	0.931
3-Ocean	0.805	0.157	0.046	0.027
4-Ocean	0.059	0.026	0	0.001

[a] Surveyors were instructed not to sample carcasses <70 cm in fork length in 1998. Average results from 1999-2001 were used for these length groups.

Table 8. Estimated number of wild chinook salmon passing Lower Granite Dam in each ocean age group, 1998-2001.

	Adult Return Year			
	1998	**1999**	**2000**	**2001**
1-Ocean	189[a]	235	1,496	1,227
2-Ocean	997	2,155	6,925	28,168
3-Ocean	6,526	456	408	833
4-Ocean	479	76	0	22

[a] Surveyors were instructed not to sample carcasses <70 cm in fork length in 1998. Average results from 1999-2001 were used for these length groups.

Table 9. Evaluation of two options to reduce aging workload on estimates of ocean proportions at Lower Granite Dam.

	Migratory Year											
	1998			**1999**			**2000**			**2001**		
	Current Effort	**Max-30**	**Index Only**	**Current Effort**	**Max-30**	**Index Only**	**Current Effort**	**Max-30**	**Index Only**	**Current Effort**	**Max-30**	**Index Only**
# Sampled	172	139	121	272	235	130	309	220	85	900	646	268
% 1-Ocean	0.00	0.00	0.00	0.08	0.08	0.07	0.17	0.17	0.17	0.04	0.04	0.03
% 2-Ocean	0.10	0.09	0.05	0.74	0.72	0.76	0.79	0.79	0.76	0.93	0.93	0.92
% 3-Ocean	0.80	0.81	0.82	0.16	0.17	0.15	0.05	0.04	0.07	0.03	0.03	0.03
% 4-Ocean	0.06	0.07	0.05	0.03	0.03	0.02	0.00	0.00	0.00	0.00	0.00	0.00

Table 10. Estimates of aggregate Snake River wild chinook salmon smolt-to-adult return rates (SAR).

Smolt Year	1996	1997	1998	1999
# Smolts	419,826	161,157	599,159	1,560,298
Adults				
Smolt year +1	NA	189	235	1,496
Smolt year +2	997	2,155	6,925	28,168
Smolt year +3	456	408	833	
Smolt year +4	0	22		
SAR w/ jacks	NA	1.72%	1.33%	1.90%
SAR w/out jacks	0.34%	1.60%	1.29%	1.81%

Snake River Basin

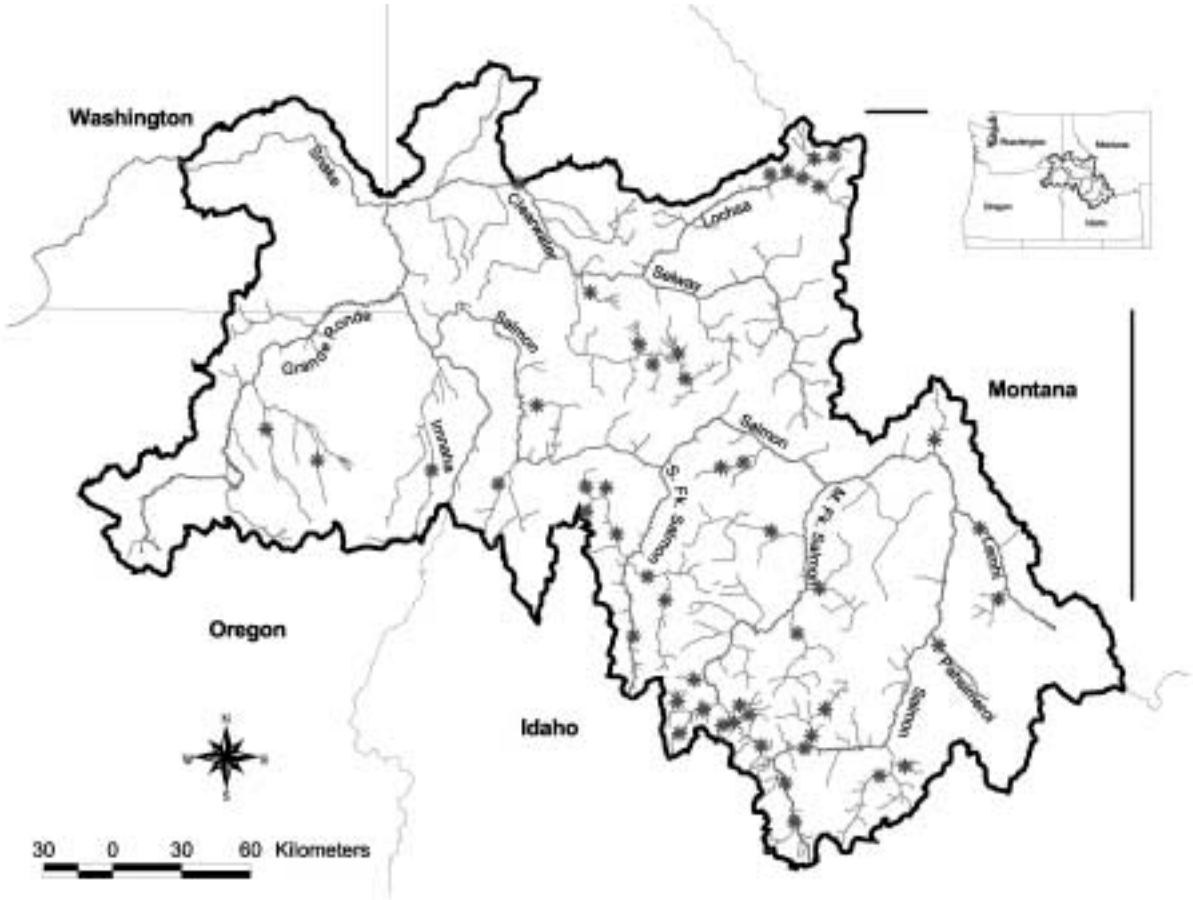


Figure 11. Spawning streams denoted with an ∗ indicate where wild/natural spring/summer chinook salmon adult carcass aging fins were collected in 1998-2001.

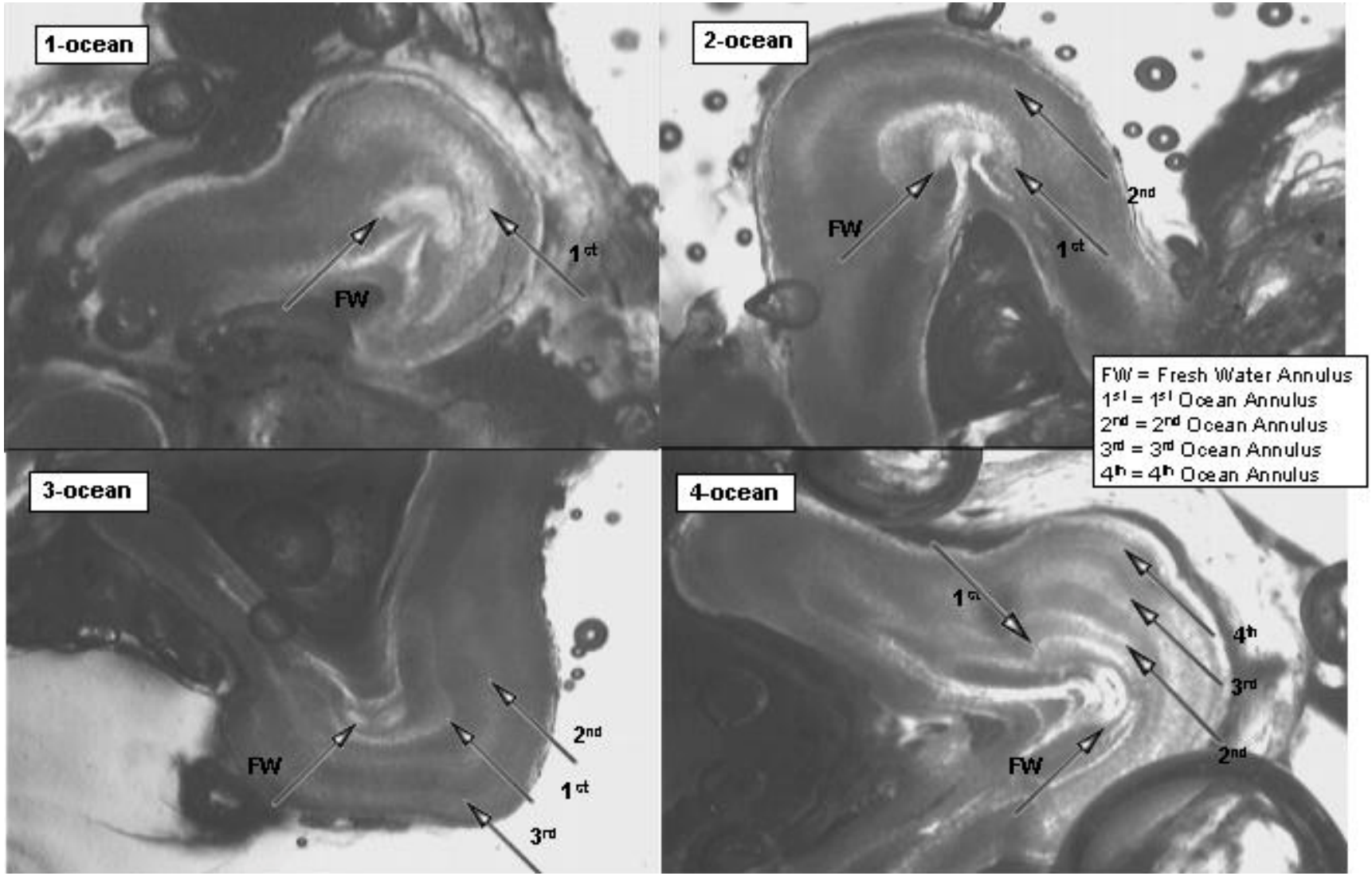


Figure 12. Representative dorsal fin ray cross sections from the four different ocean ages observed for Snake River wild/natural spring/summer chinook salmon adult returns.

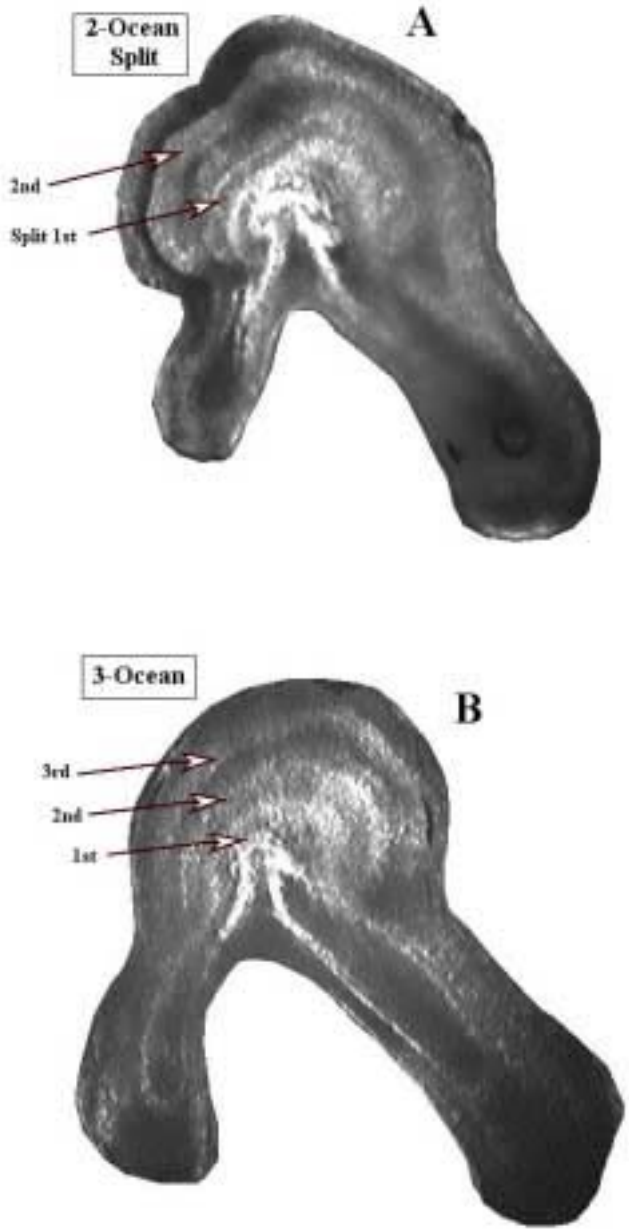
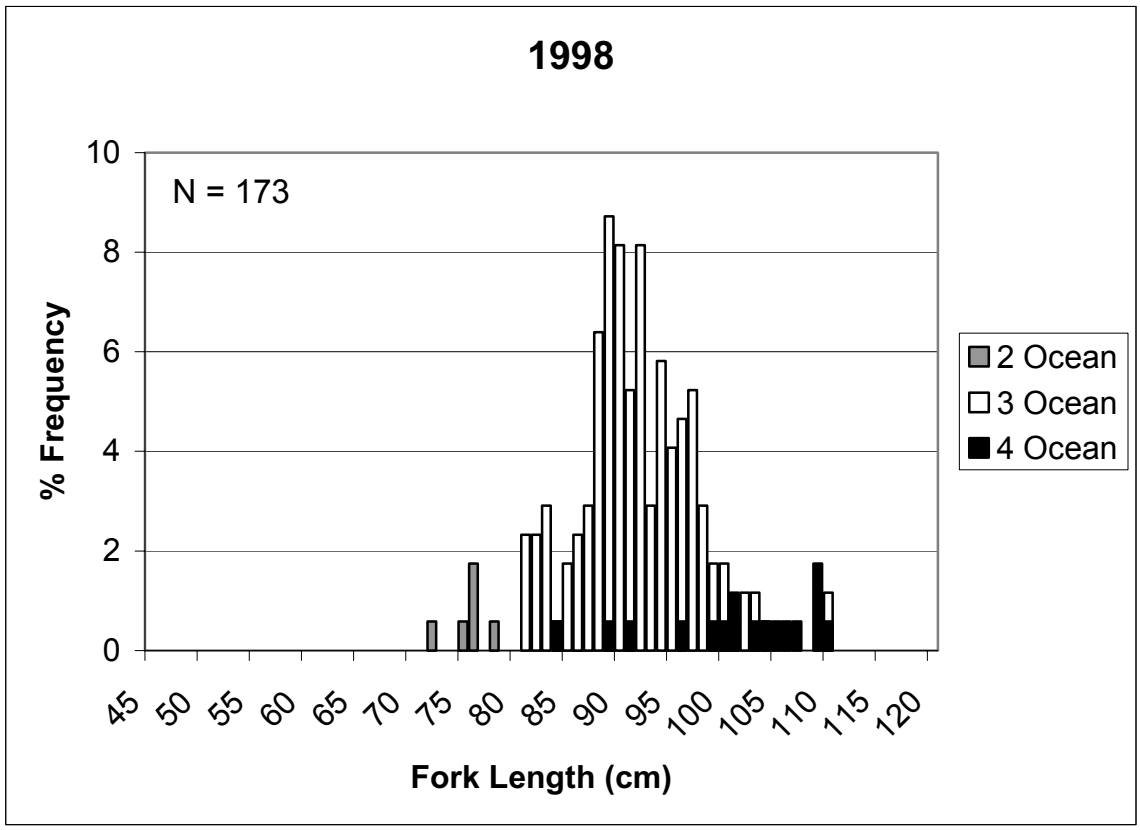


Figure 13. Comparison of chinook salmon dorsal fin cross sections from a known age 2-ocean adult with a split 1st ocean annulus (A) and a known age 3-ocean adult (B).



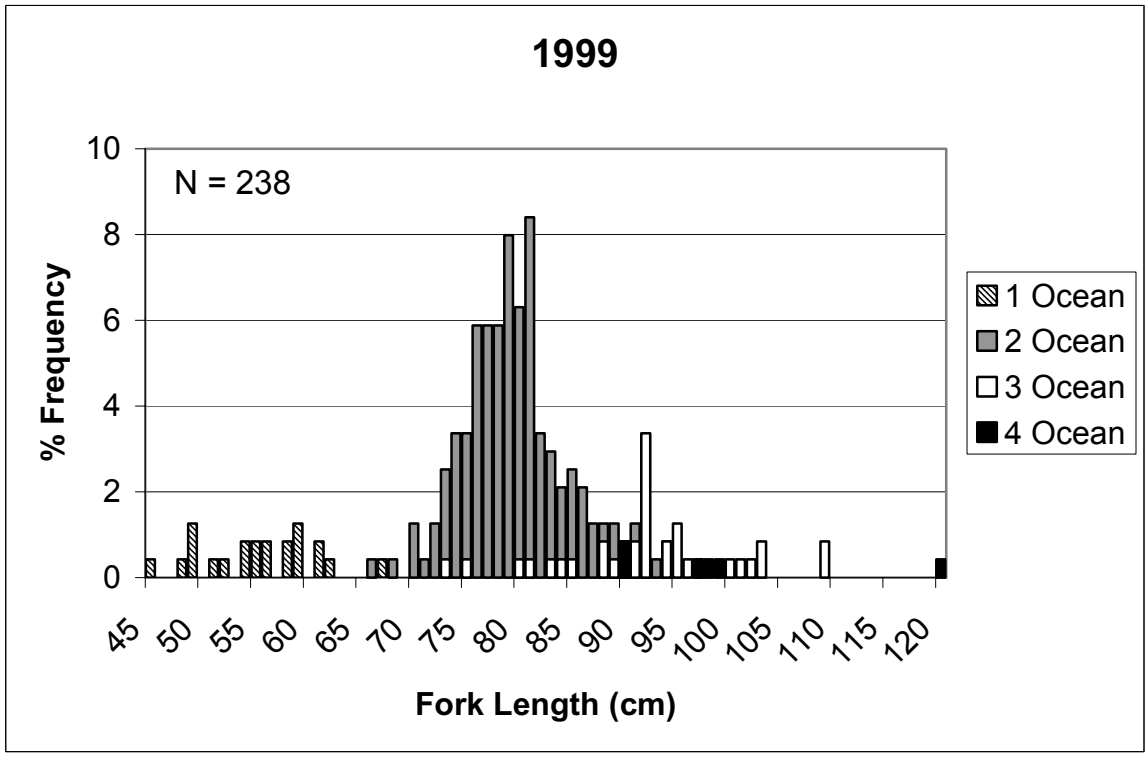
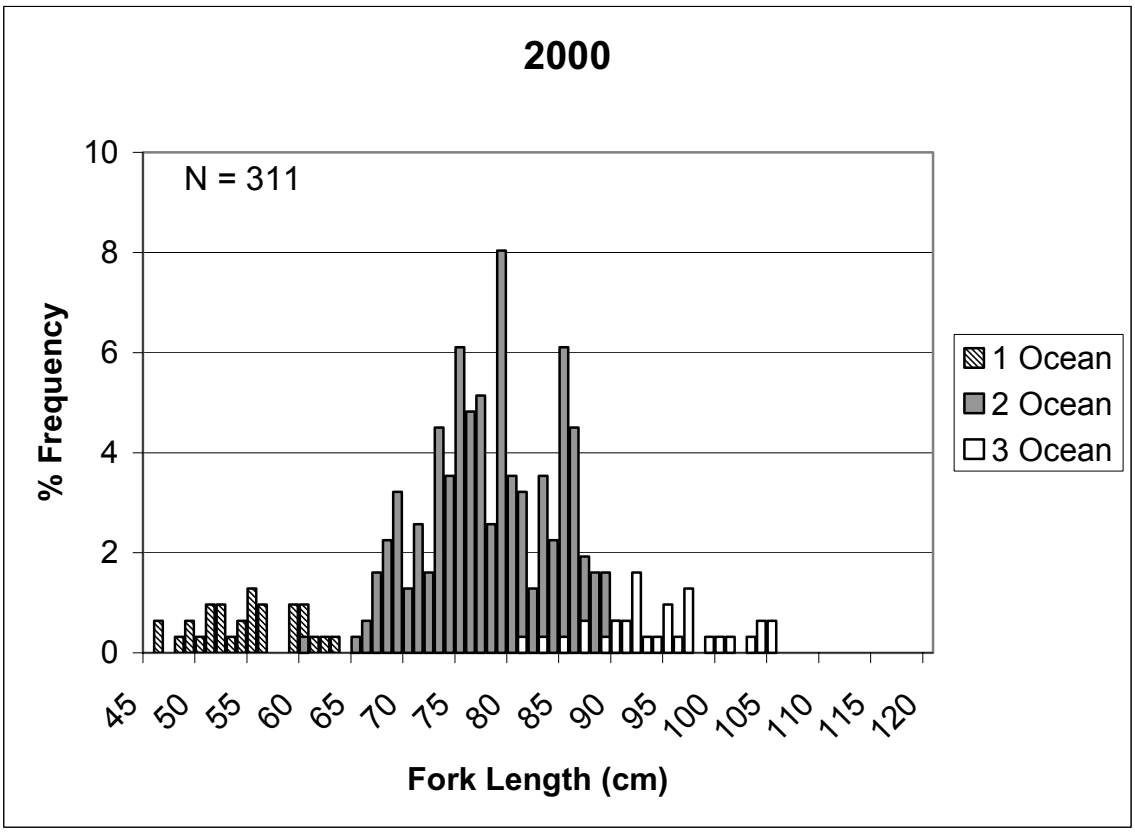


Figure 14. Snake River wild chinook salmon carcass fork lengths and ocean ages determined from fin cross sections, 1998 and 1999. Note: Surveyors were instructed not to sample carcasses <70 cm in 1998.



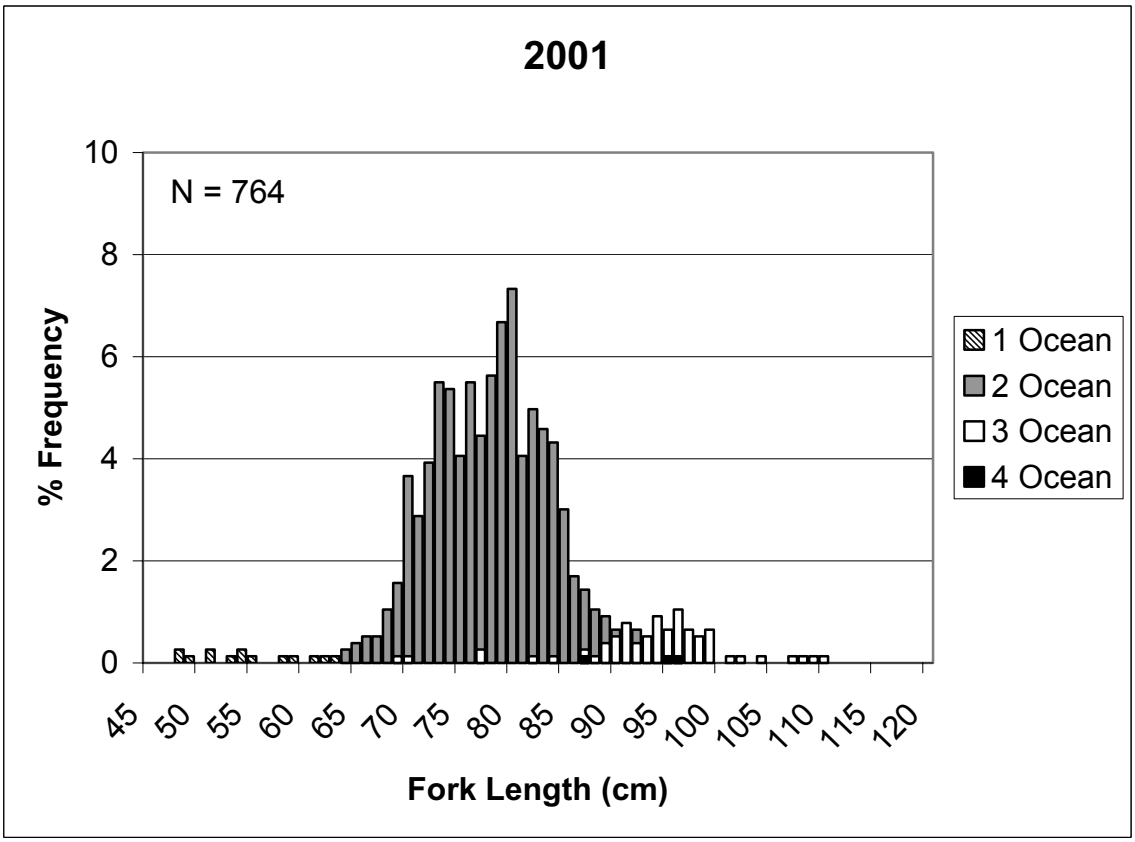


Figure 15. Snake River wild chinook salmon carcass fork lengths and ocean ages determined from fin cross sections, 2000 and 2001.

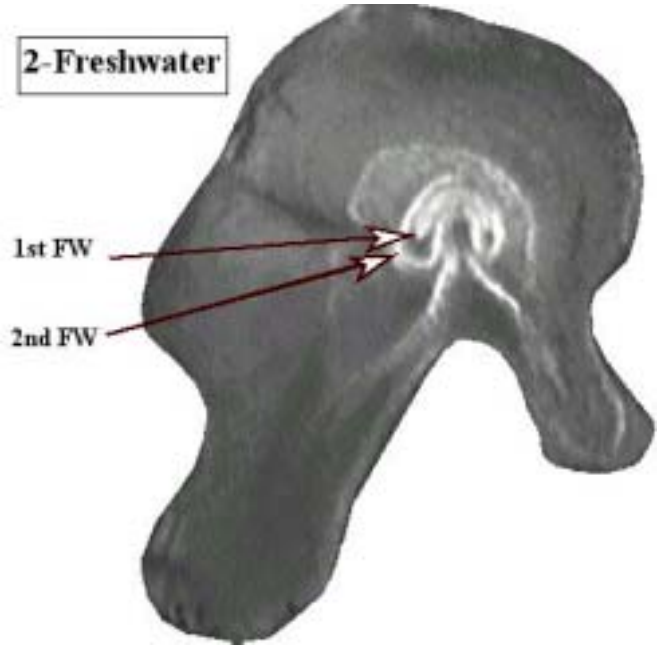


Figure 16. Snake River wild chinook salmon dorsal fin cross section showing two freshwater annuli.

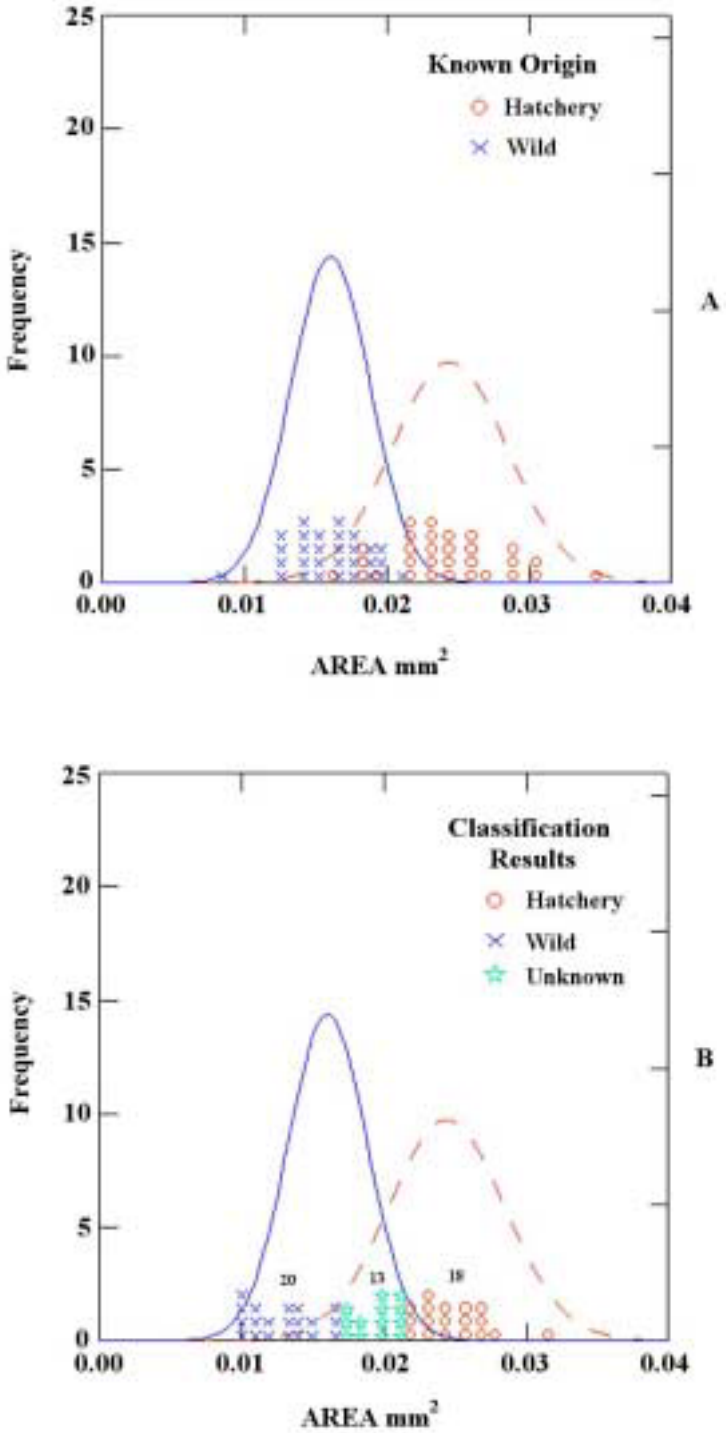


Figure 17. Results of dorsal fin ray freshwater annulus discriminant analysis for South Fork Salmon River chinook salmon in 2001. (A) Freshwater annulus areas and probability distributions from known hatchery and wild adults. (B) Probability distributions from known adults and classification results for the unknown adults.

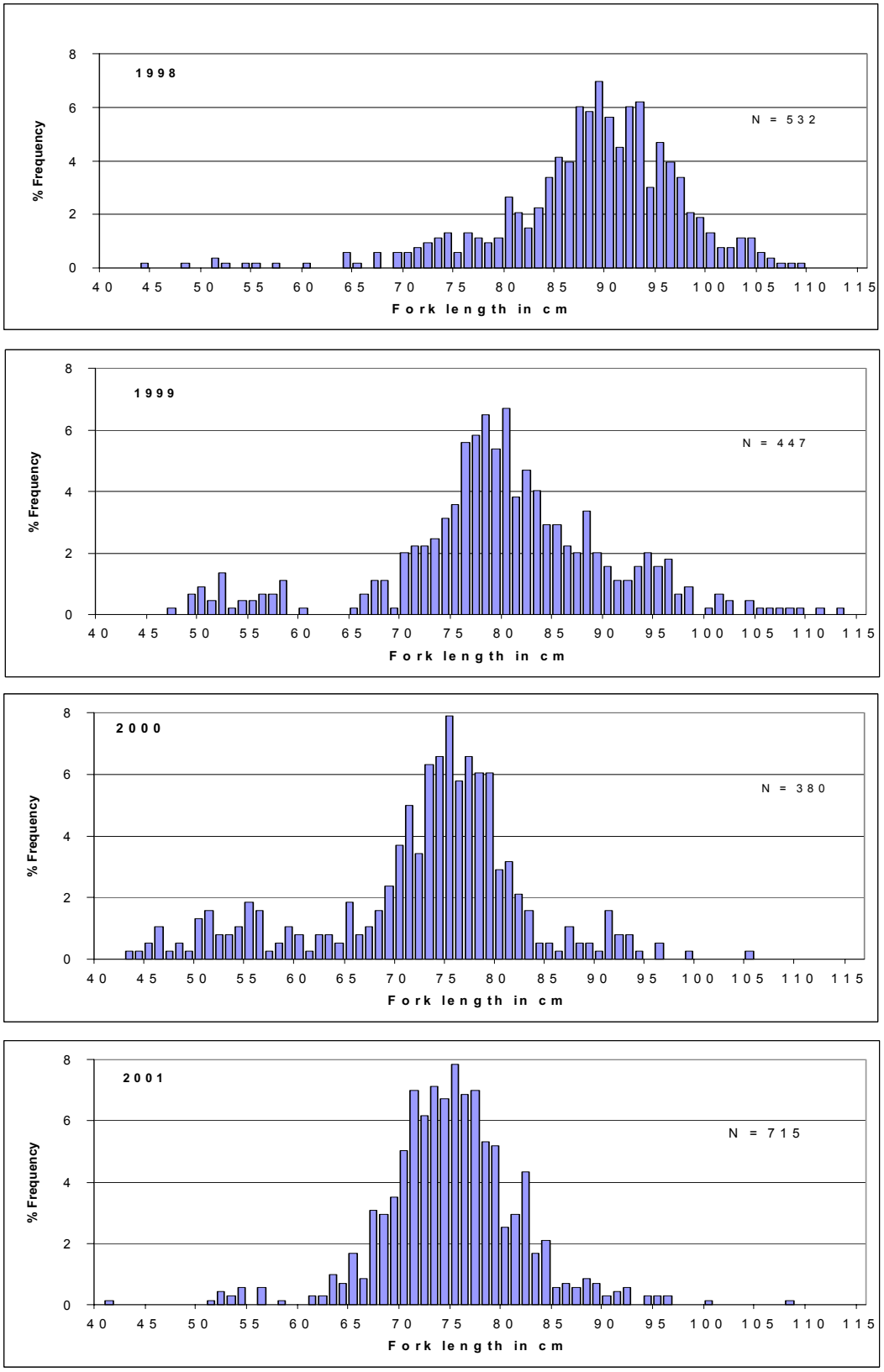


Figure 18. Length frequency distributions of unmarked adult spring/summer chinook salmon passing Lower Granite Dam in return years 1998-2001.

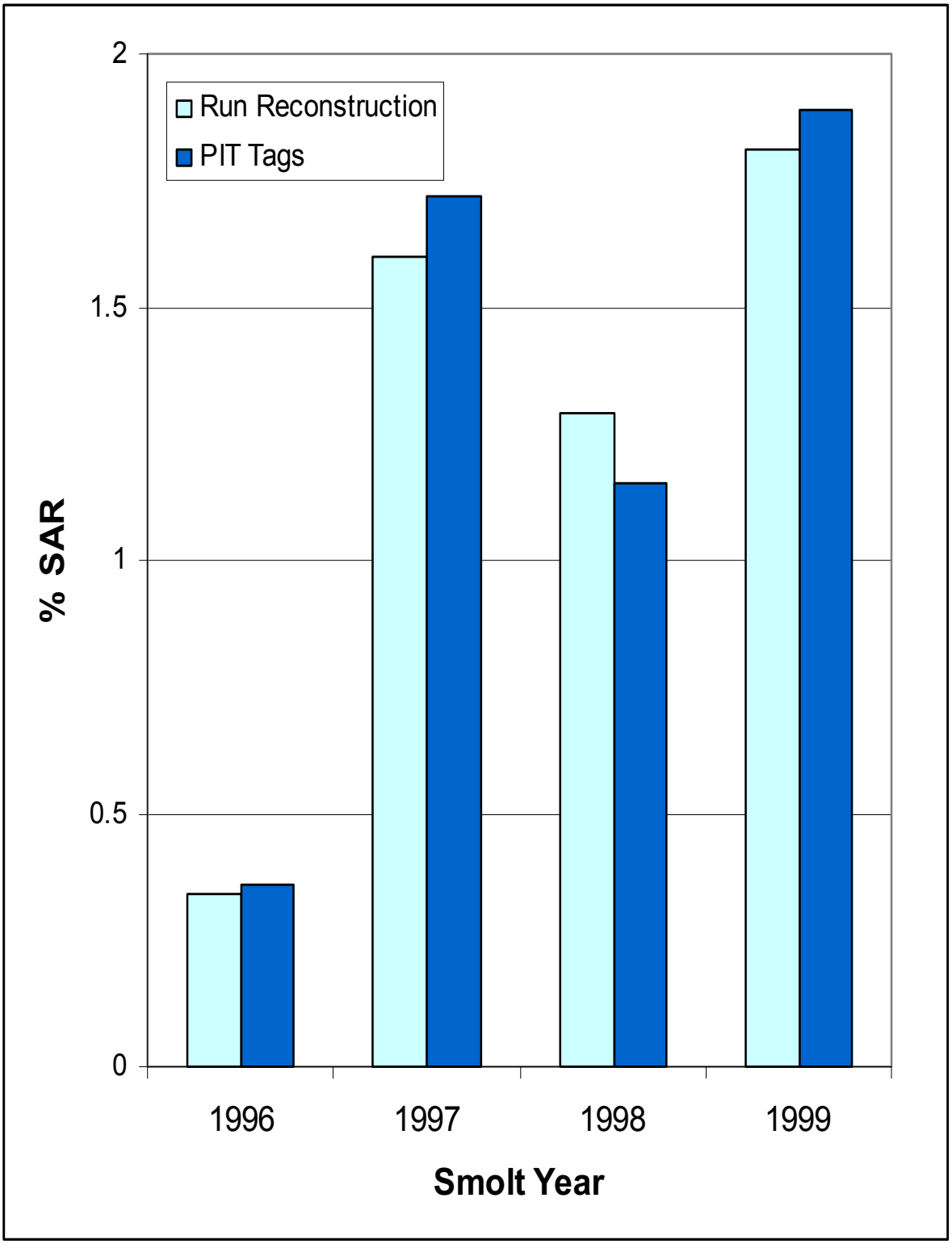


Figure 19. Comparison of Snake River wild chinook salmon smolt-to-adult return rate (SAR) estimates from basin-wide run reconstructions and PIT tag detections.

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