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NATURAL PRODUCTION MONITORING AND EVALUATION

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Natural Production Monitoring and Evaluation

Project Progress Report

2002 Annual Report

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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 *Oncorhynchus mykiss*. 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 2001, smolt detections at the four main smolt collector dams in 2002, and adult detections at Lower Granite dam for spawn years 2002 and 2003 through April 22, 2003. During the summer of 2001, we tagged 6,792 wild steelhead trout juveniles. In 2002, the four main smolt collector dams detected 748 (11%) of the juveniles we tagged in summer 2001 and 336 of the juveniles we tagged in previous years. This project's tagging efforts resulted in 26 adult detections in spawn year 2002 and 33 adult detections for spawn year 2003 through April 22, 2003.

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INTRODUCTION

One of the primary causes of reduced smolt-to-adult return rates (SARs) in Snake River wild steelhead trout *Oncorhynchus mykiss* populations during the past 25 years is mainstem hydropower development (Nemeth and Kiefer 1999), although ocean productivity is also influential (Pearcy 1997). Commensurately, a major component of recovery efforts for Snake River wild steelhead trout is 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). Passive integrated transponder (PIT) tags that are applied to juvenile steelhead trout and subsequently recovered among returning adults currently provide 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 enables investigators to make SAR estimates that are more precise and representative of the entire Snake River wild steelhead population. This report covers tagging efforts in summer 2001, smolt detections in spring 2002, and adult detections for spawn years 2002 and 2003 through April 22, 2003.

METHODS

Study Area

The study area included streams in the Salmon and Clearwater river basins. Sampling was concentrated in important wild steelhead production areas: Lochsa River basin, Middle Fork Salmon River basin, Salmon River Canyon tributaries, and Salmon River tributaries downstream from the Salmon River Canyon (Figure 1). All streams were believed to have 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

Previous unpublished work conducted by IDFG demonstrated that angling is a more efficient collection method than electrofishing in small, high gradient, low conductivity streams. Our project captured wild steelhead trout juveniles by angling with flies from June through August 2001. Each angler carried a five-gallon bucket half filled with water to temporarily store captured fish while fishing. Water in the bucket was changed at least every 15-20 min when fewer than 10 fish were in the bucket and about every 10 min when 10 or more fish 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 1 km intervals throughout the stream.

PIT Tagging

We typically held collected fish in live-boxes overnight and tagged them the following morning. This allowed the fish to recover from collection stress and provided the coolest water temperatures for tagging. We anesthetized the fish and injected PIT tags into the body cavity using a 12-gauge hypodermic needle and modified syringe. PIT tags, needles, and syringes were sterilized by soaking them in a 70% alcohol solution for at least 10 min 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 nonmigratory resident fish (Partridge 1985). After being tagged, fish were returned to a live-box and allowed to recover for at least 1 h 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

We obtained juvenile detection and tagging information from the PTAGIS database on October 21, 2002 (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 (Figure 2). 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 (Kiefer and Lockhart 1997), only juveniles greater than 124 mm FL at tagging were used to calculate detection rates.

Emigration Timing

We 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 November 18, 2002 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 70 or more detections at LGR in 2002. 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 Growth Rates

The PIT-tagged fish recaptured a year later (±17 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

We accessed the PTAGIS database on April 22, 2003 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) on the Snake and Columbia Rivers (Figure 2). 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

We PIT tagged 6,792 juvenile wild steelhead trout during summer 2001; 5,285 (78%) of those were greater than 124 mm FL when tagged (Table 1). See Appendix A for information on collection sites and conditions. The mean length of steelhead tagged in 2001 ranged from 160 mm at Bargamin Creek to 142 mm at Chamberlain Creek.

There were 748 (11%) smolts detected in 2002 from this project's tagging in 2001. For those juveniles greater than 124 mm FL at tagging, 698 (13.2%) were detected. There were 336 detections in 2002 from wild steelhead trout PIT tagged by this project prior to 2001. 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 10,295 to 11,379 (9.5%) in migratory year 2002.

All streams fished in 2001 had high enough fish densities and PIT tag 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, North Fork Moose Creek, Sulphur Creek, Crooked Fork Creek, Bargamin Creek, Horse Creek, Whitebird Creek, and Slate Creek (Figure 3).

High detection rates (Figure 3) have been observed for wild steelhead juveniles PIT tagged in the Middle Fork Salmon River (MFSR) and tributaries (Marsh Creek, Pistol Creek, Rapid River, Sulphur Creek, and Wilson Creek). To date, wild steelhead PIT tagging efforts have been limited for this major wild production drainage. We propose increased project efforts in this drainage.

Emigration Timing

Steelhead trout smolt arrival timing at LGR was very similar for all smolts, PIT-tagged wild smolts, and PIT-tagged hatchery smolts (Figure 4). Major increases in the hydrograph corresponded with two major peaks in smolt arrival numbers (Figure 4). The PIT-tagged wild smolts were more predominant in the first peak, while PIT-tagged hatchery smolts were more predominant in the second peak. A similar trend was also observed in migration year 2001 (Kiefer et al. 2001). In 2002, 97% of the out-migration of all steelhead trout smolts was complete by June 10 (Figure 4). Migratory year 2002 was a moderate water year with average spill of 26.7% between 4/3/02 and 7/16/02 at LGR (FPC, 2002).

Stream-specific emigration timing to LGR showed more variation than the overall wild smolt run discussed above (Figure 5). Data from Whitebird and Slate Creek were combined to provide adequate sample size for this analysis. We justified combining data from these two streams because they are similar, in close proximity to one another, and with adequate sample sizes had very similar arrival times in 2001 (Kiefer et al. 2001). Among fish from all streams in this comparison, the first 10% of PIT tags detected at LGD occur during the second week of April. North Fork Moose Creek had the most compressed arrival timing and the earliest dates for both 50% and 90% of total detections. Similar to last year, Whitebird and Slate Creeks had the most protracted arrival timing at LGR (Figure 5).

Annual Growth Rates

Annual growth rates were significantly ($p < 0.01$) negatively correlated with fish size (Figure 6). Fish in the 100-150 mm range at tagging grew an average of 34 mm in a year; those in the 150-200 mm range grew an average of 25 mm, and those in the 200-250 mm range only grew an average of 14 mm. 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 1990-2000 (complete adult years) was 0.55% (Figure 7). The maximum SAR over this period was 1.75%, and the minimum was 0.08%. The 1-ocean adult returns are not yet complete, but to date, the SAR for migratory year 2001 is lower than the eight previous years (0.04%). Ocean age percentages of PIT-tagged adult returns were 45.4% 1-ocean, 54.2% 2-ocean, and 0.4% 3-ocean for migratory years 1990-1999. The SAR for migratory year 2000 is significantly higher than any of the previous 10 years. Since migratory year 1993, 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. PIT tag SARs are lower than SARs for the entire population, a result of this differential handling at the collector dams (Sandford and Smith 2002).

ACKNOWLEDGMENTS

We greatly appreciate the Natural Production tagging crew (James Gilbert, Howard Pennington, Travis Henke, and John Clark) 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.

Table 1. Wild steelhead trout actively collected (angling) and PIT tagged in the summer of 2001 and detected in 2002.

Stream	No. Tagged Total	No. Tagged >124 mm FL	No. Detected >124 mm FL	Detection Rate
Bargamin Creek	796	709	47	7%
Brushy Fork Creek	892	763	128	17%
Chamberlain Creek	2563	1705	264	15%
Crooked Fork Creek	136	110	25	23%
Horse Creek	454	336	31	9%
North Fork Moose Creek	748	705	137	19%
Slate Creek	471	395	25	6%
Sulphur Creek	88	53	9	17%
Whitebird Creek	644	509	32	6%
Total	6,792	5,285	724	14%

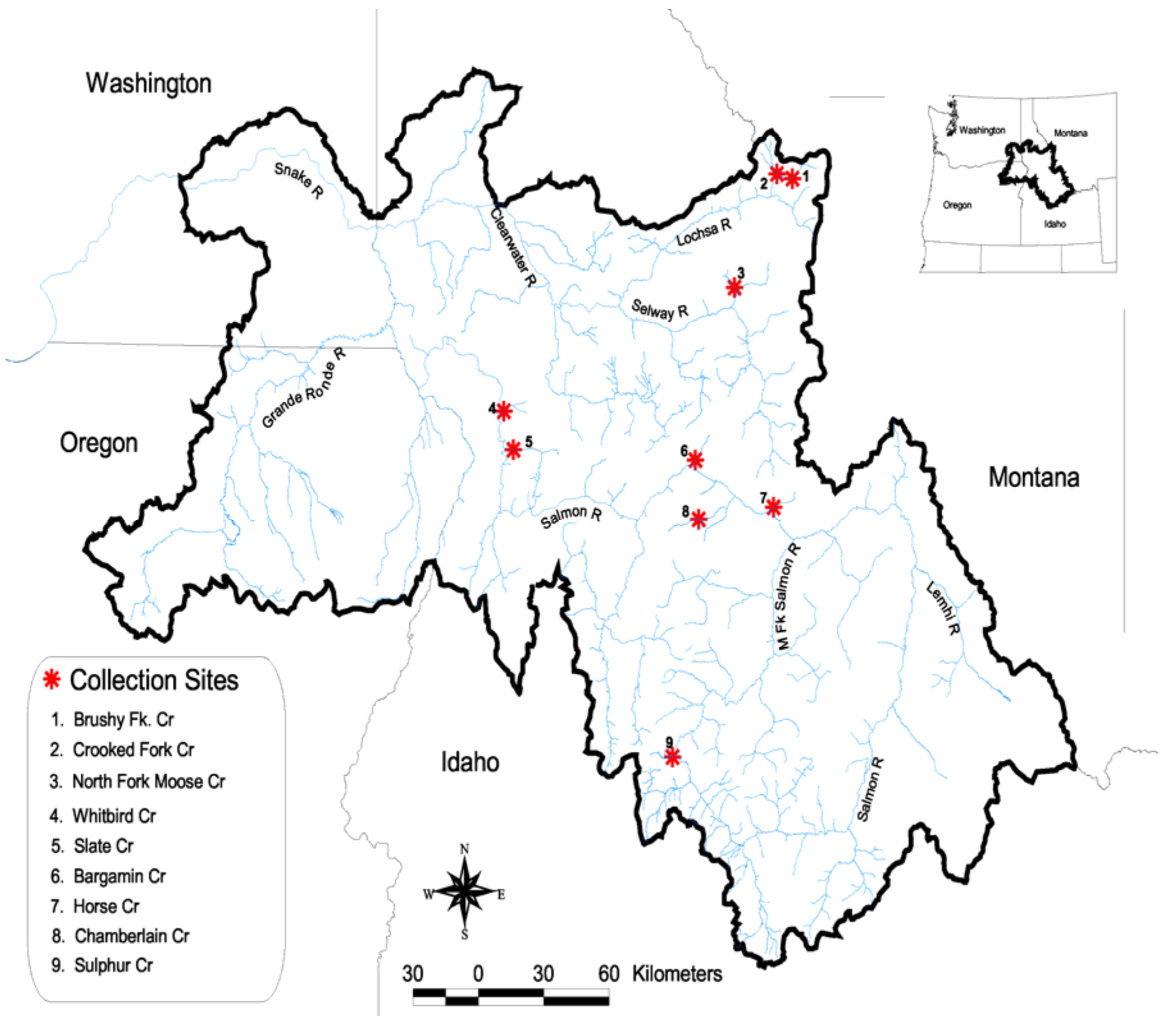

Figure 1. Snake River basin study area and rearing streams where juvenile wild steelhead trout were collected and PIT tagged in the summer of 2001.

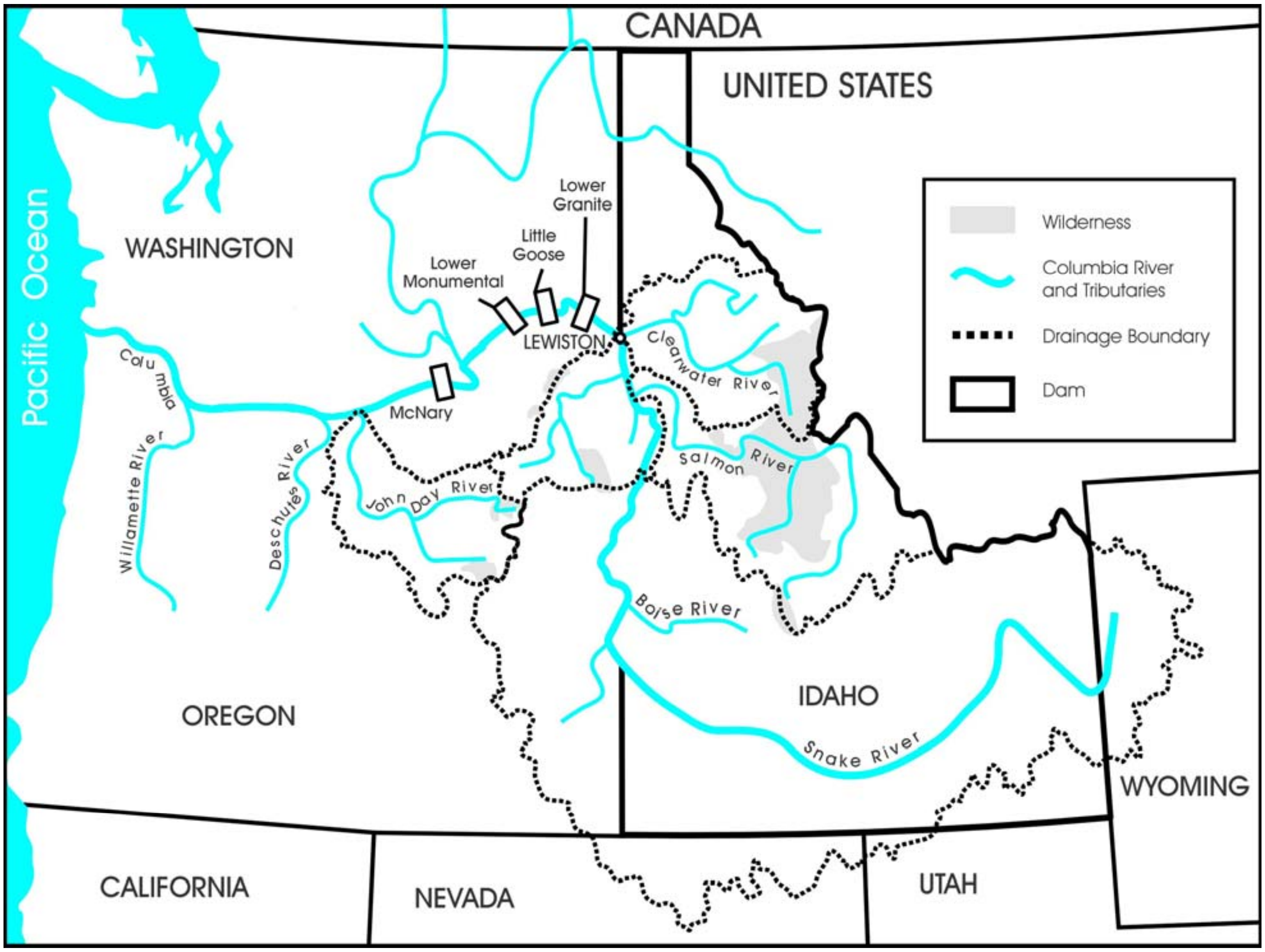

Figure 2. Map showing the locations of dams on the Snake River where PIT tags are detected during the juvenile out-migration.

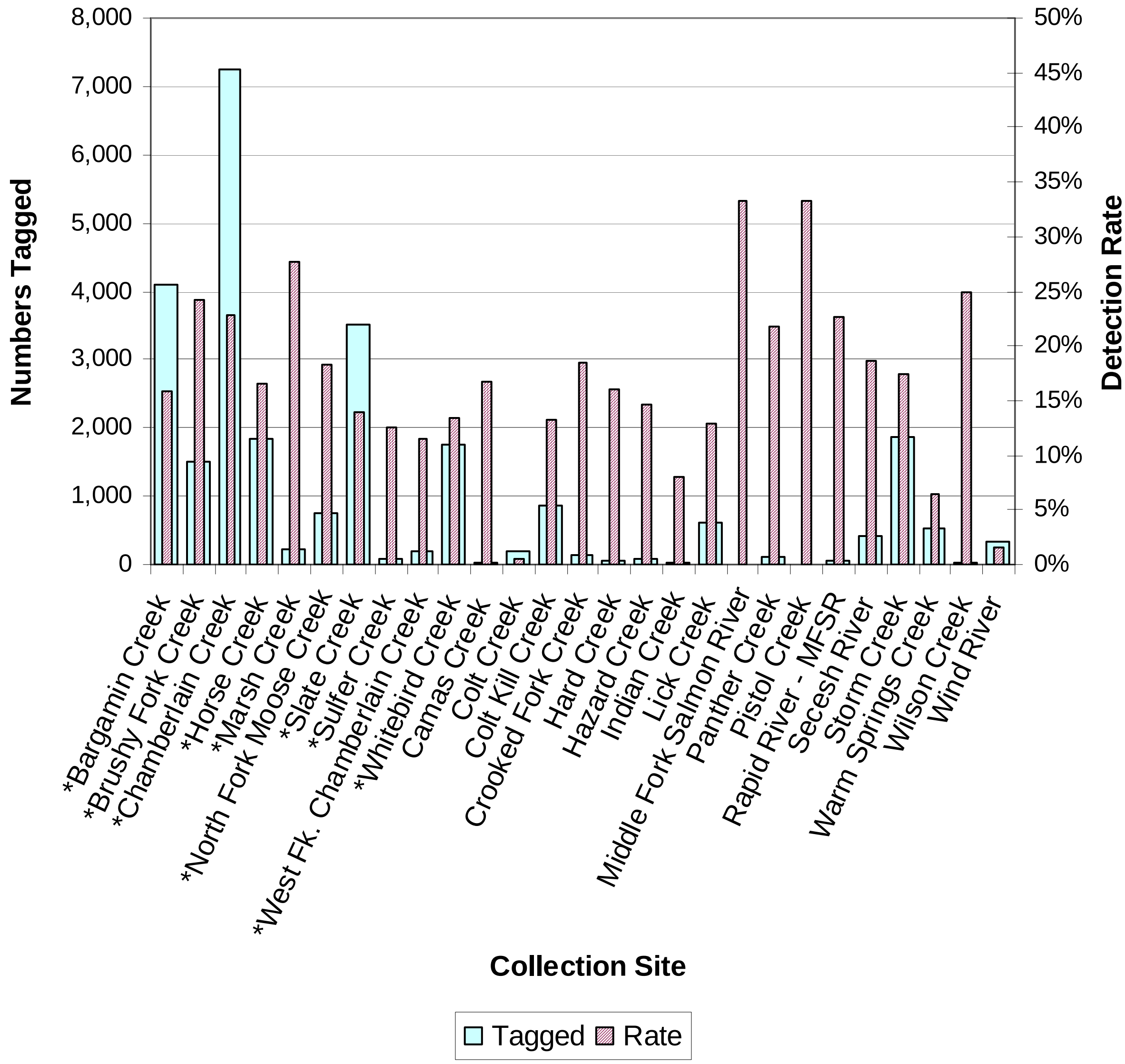

Figure 3. A summary of juvenile wild steelhead trout detection rates and numbers tagged, by collection site, covering the four years this project has operated. "*" = Sites selected for continued work.

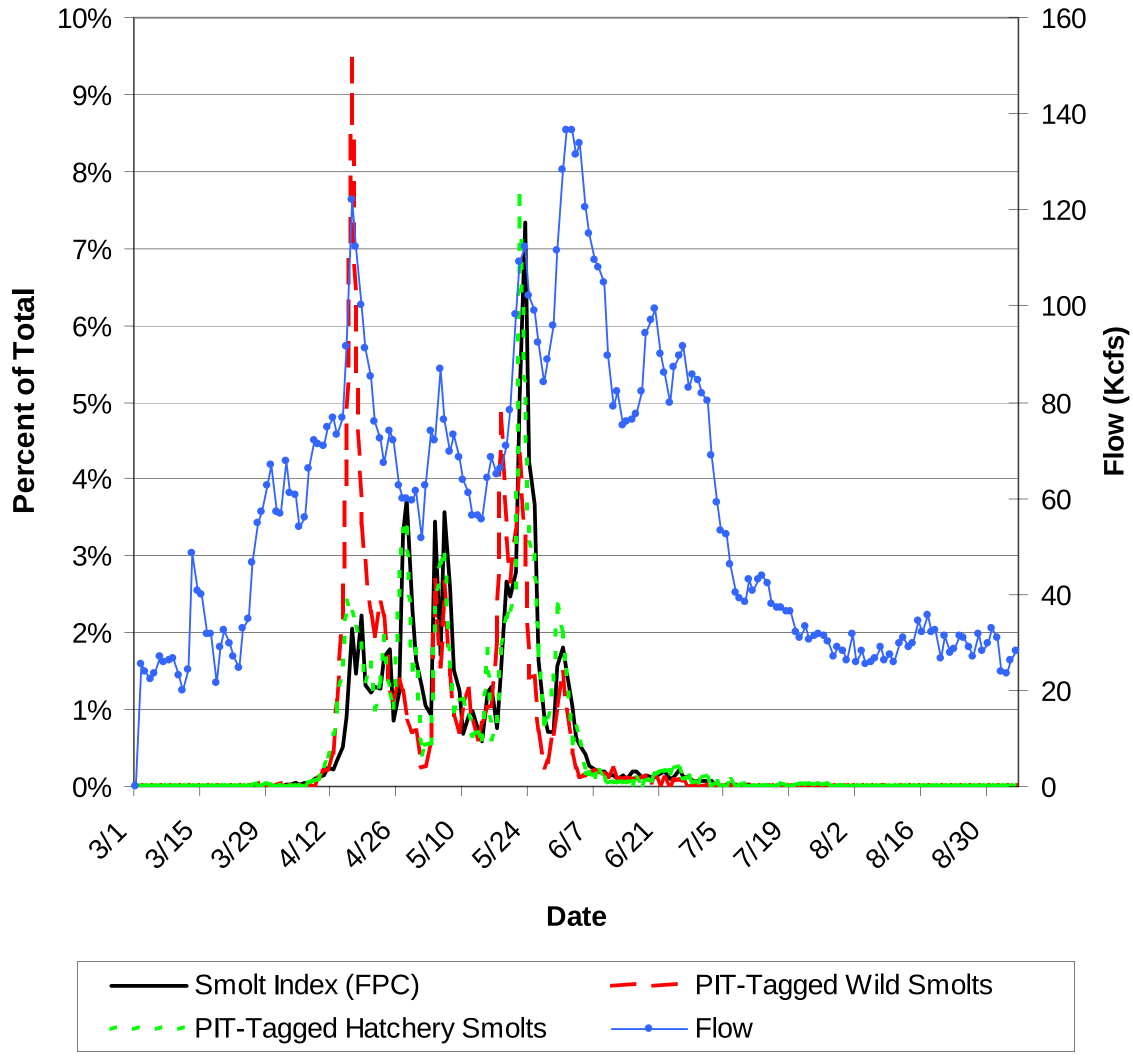

Figure 4. Steelhead trout smolt arrival timing and flow at Lower Granite Dam, 2002.

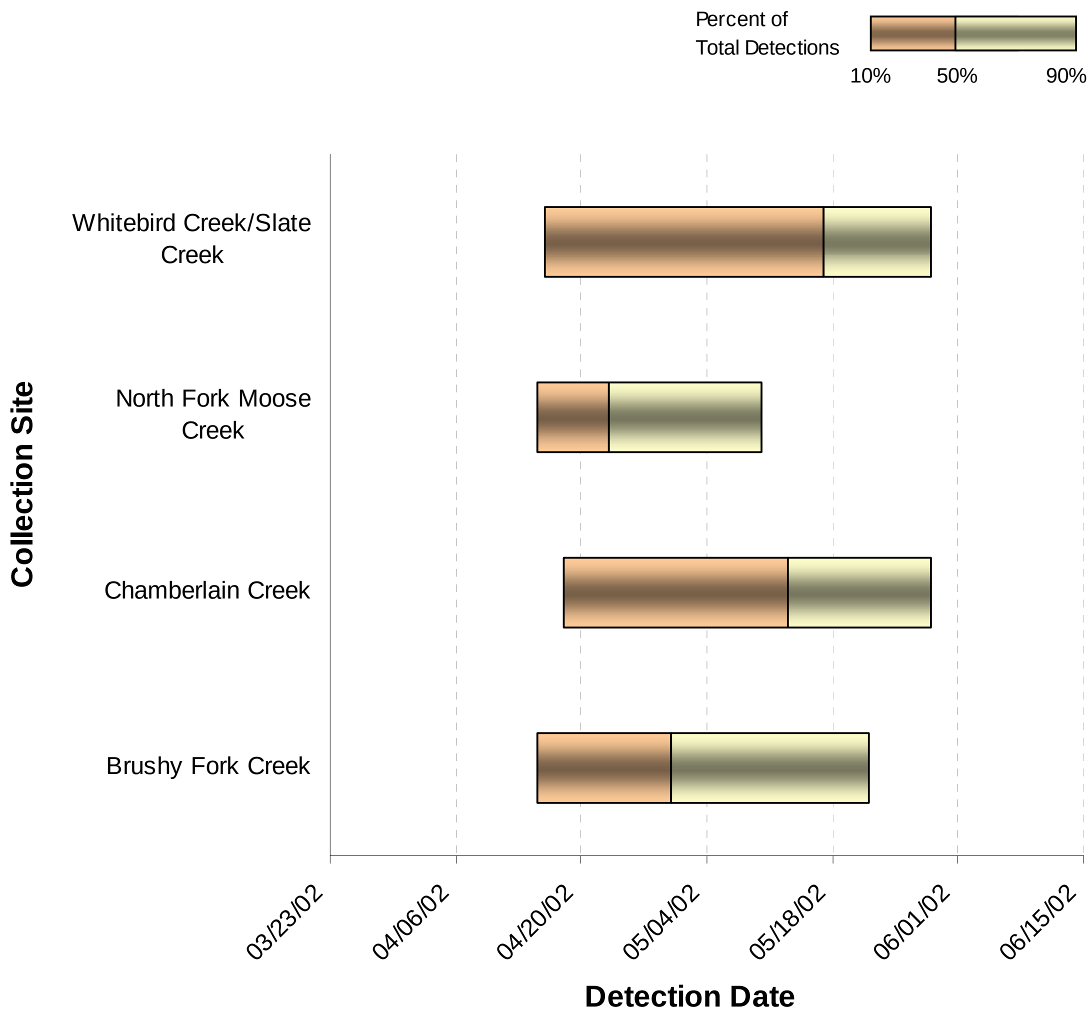

Figure 5. Arrival timing at Lower Granite Dam in 2002 for PIT-tagged wild steelhead trout tagged in summer 2001. Analysis includes only those streams with at least 70 detections at Lower Granite Dam.

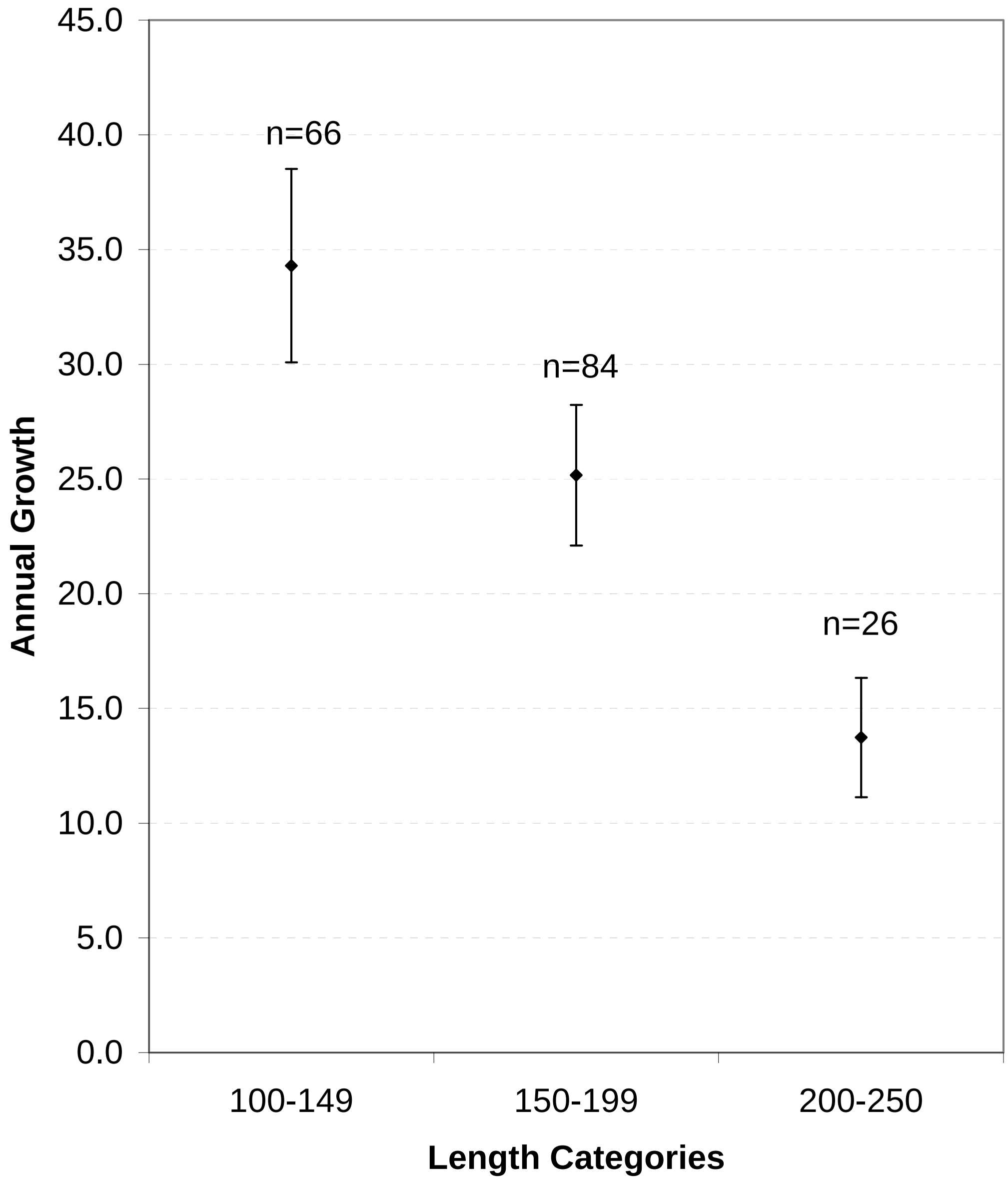

Figure 6. Annual growth rate and 95% confidence interval by length at tagging for PIT-tagged wild steelhead trout recaptured one year (±17 days) after tagging.

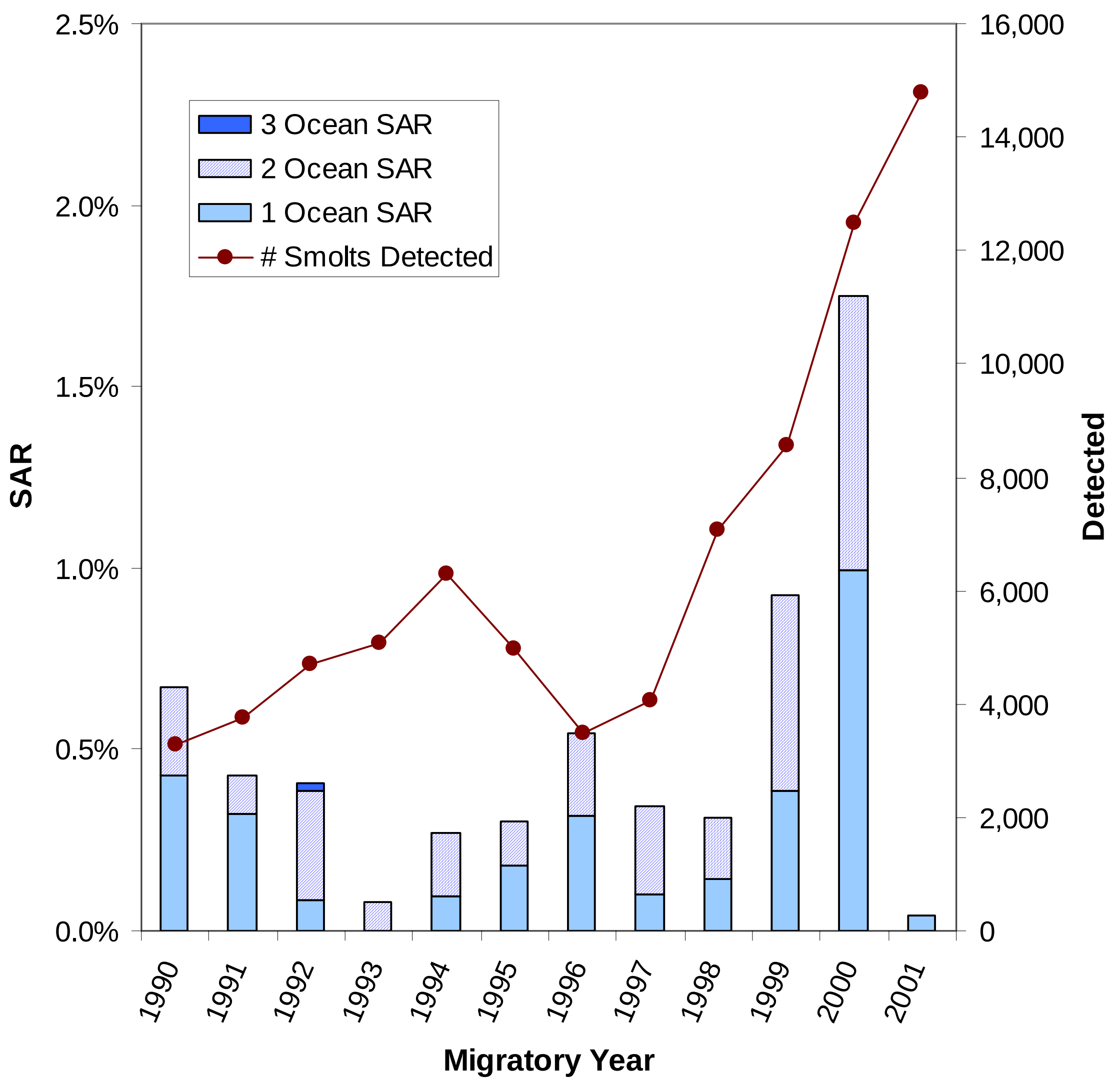

Figure 7. PIT-tagged wild steelhead trout smolt-to-adult return rates for smolts detected at one of the four main smolt collection dams. Years 2000 (3-ocean) and 2001 (2- & 3-ocean) are not complete.

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Appendix A. Stream specific notes by system.

Lochsa River system

Brushy Fork Creek
Dates Fished: August 2-5, 2001
Stream Location LLID (mouth): 1146985460025
Section Fished: A 6-km section beginning at mouth.
Tagging Temperature: 13-16°C
Number Tagged: 892
Recaptures: 26
Notes: Lower 5 km had best steelhead habitat and densities

Crooked Fork Creek
Dates Fished: August 6, 2001
Stream Location LLID (mouth): 1146808465082
Section Fished: A 2-km section beginning at mouth.
Tagging Temperature: 14°C
Number Tagged: 136
Recaptures: N/A

North Fork Moose Creek
Dates Fished: August 9-12, 2001
Stream Location LLID (mouth): 1148970461648
Section Fished: A 4-km section beginning 2 km up from mouth.
Tagging Temperature: 13-16°C
Number Tagged: 748
Recaptures: N/A

Mainstem Salmon River system

Bargamin Creek
Dates Fished: July 5-7, 2001
Stream Location LLID (mouth): 1151912455673
Section Fished: A 5-km section beginning at mouth.
Tagging Temperature: 12-14°C
Number Tagged: 796
Recaptures: 35
Notes: Lowest 5 km had highest steelhead densities and easiest access

Chamberlain Creek
Dates Fished: June 26-July 2, 2001 (Lower); July 19-22, 2001 (Upper)
Stream Location LLID (mouth): 1149310454542
Section Fished: A 23-km section beginning at mouth.
Tagging Temperature: 10-15°C
Number Tagged: 2,563
Recaptures: 19

Horse Creek
Dates Fished: July 8-9, 2001
Stream Location LLID (mouth): 1147320453953
Section Fished: A 6-km section beginning at mouth.
Tagging Temperature: 15-17°C
Number Tagged: 454
Recaptures: 46

Slate Creek
Dates Fished: June 21-23, 2001
Stream Location LLID (mouth): 1162843456397
Section Fished: A 11.5-km section beginning 7.2 km up from mouth.
Tagging Temperature: 11-14°C
Number Tagged: 471
Recaptures: 5
Notes: Section begins at Forest Service boundary

Whitebird Creek
Dates Fished: June 24-26, 2001
Stream Location LLID (mouth): 1163220457515
Section Fished: A 5-km section beginning 3.8 km from mouth at 45.7723 N. and -116.2872 W.
Tagging Temperature: 12-15°C
Number Tagged: 644
Recaptures: 0
Notes: Permission required for access. A high number of steelhead collected displayed cloudy eyes, which may be an indication of eye flukes.

Middle Fork Salmon River system

Sulphur Creek
Dates Fished: July 13, 2001
Stream Location LLID (mouth): 1152974445546
Section Fished: A 0.5-km section beginning from mouth.
Tagging Temperature: 14°C
Number Tagged: 88
Recaptures: N/A

PART 2—DEVELOPING A STOCK-RECRUITMENT RELATIONSHIP FOR SNAKE RIVER SPRING/SUMMER CHINOOK SALMON TO FORECAST WILD/NATURAL SMOLT PRODUCTION

ABSTRACT

A stock-recruitment relationship for Snake River spring/summer Chinook salmon *Oncorhynchus tshawytscha* was derived by estimating females available for natural reproduction (FANR) and resulting wild/natural smolt production. This stock-recruitment relationship was developed from data collected at Lower Granite Dam from brood years 1990-2000. Smolts per female production during this period ranged from 92-403, with a mean of 240. I assumed the stock-recruitment relationship would be in the form of a Beverton-Holt function and plotted the data to estimate this relationship. For brood year 2001, I estimated FANR to be 51,902. Based on the estimated stock-recruitment relationship, I forecast those females will produce a mean of 1,696,787 smolts (90% confidence interval [CI] of 1,014,115–5,191,661). Therefore, smolts/female production should be 33 (90% CI of 20–100). There are several cautions I must make about this forecast. Foremost, FANR in brood year 2001 was more than four times greater than the highest value used to develop the relationship. Generally, it is unsafe to extrapolate from regression equations to outside the observed range of values used to develop the relationship. Also, the proportion of hatchery adults in the FANR was higher than in any of the years used to produce the relationship. Hatchery females may have higher prespawning mortality and produce fewer smolts than wild females. Therefore, this smolt production forecast should be viewed with extreme caution.

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INTRODUCTION

Survival during both fresh and saltwater life stages for Snake River spring/summer Chinook salmon must be well understood for decision makers to effectively select mitigation measures that have a reasonable probability of significantly contributing to recovery. An important tool to aid in understanding freshwater survival for anadromous fish is to develop stock-recruitment relationships that span the critical period of freshwater residence when density-dependent mortality defines the shape of the relationship (Solomon 1985). This stock-recruitment relationship allows for evaluating freshwater survival on a basinwide scale.

Stock-recruitment relationships for Columbia River Basin Chinook salmon are assumed to be 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 increasing the time needed for juveniles to grow through a particularly vulnerable size range causes declines in recruitment at higher stock densities (Ricker 1954).

I developed a stock-recruitment relationship between the number of adult spring/summer Chinook salmon passing Lower Granite Dam (LGR; Figure 8) that were females available for natural reproduction (FANR) and the resulting number of wild/natural smolts arriving at LGR one and a half years later. For this work, I assumed the stock-recruitment relationship of Snake River spring/summer Chinook salmon to be a Beverton-Holt relationship. This assumption is 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 1954). Smolt abundance at LGR was selected as the index of recruitment for two main reasons. First, smolts are the last life stage that encompasses all density dependent mortality before mainstem migration stresses and ocean productivity, which are highly variable in their effects on survival. 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).

METHODS

Females Available for Natural Production

The estimated number of adult spring and summer Chinook salmon (excluding jacks) passing LGR in 2001 was obtained from the Fish Passage Center website (http://www.fpc.org/adult_history/YTD-LGR) accessed on January 9, 2003. The total number of male (excluding jacks) and female spring and summer Chinook salmon captured at all Snake River hatchery traps and the number of females taken into hatcheries were obtained from Jeff Abrams (Idaho Department of Fish & Game, personal communication), Pat Keniry (Oregon Department of Fish & Wildlife, personal communication), and Ralph Roseburg (U.S. Fish & Wildlife Service, personal communication). For each run (spring or summer), the percentage of females captured at hatchery traps were applied to the LGR counts to estimate the total number of female Chinook salmon passing LGR. The number of females taken (spawned, culled, or prespawning mortalities) by the hatcheries was adjusted for 20% migration mortality and the estimated number of females harvested upstream of LGR was adjusted for 10% migration mortality based on telemetry studies (Chris Peery, University of Idaho, personal communication). To estimate FANR, the adjusted hatchery female number and the adjusted number of females harvested upstream of LGR were subtracted from the estimated number of females passing LGR. Spring- and summer-run FANRs were combined to estimate total FANR.

Smolt Production

Smolt production was estimated using fish passage data collected at LGR. This passage data consisted of daily counts of wild/natural smolts collected and estimated daily collection efficiencies. Daily smolt abundance was estimated by dividing the daily counts of smolts collected by that day's estimated collection efficiency. The daily numbers of wild/natural Chinook salmon smolts collected at LGR were obtained from the Fish Passage Center website (http://www.fpc.org/smoltqueries/CurrentDailyData.asp) accessed on January 7, 2003. The estimated daily smolt collection efficiencies at LGR were provided by Steve Smith (National Marine Fisheries Service, personal communication). For each brood year (1990-2000), I estimated smolts/females by dividing total smolt production by FANR.

Stock-Recruitment Relationship

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). To develop a stock-recruitment relationship for these fish, I regressed FANR for brood years 1990-2000 against the associated smolt production. I used the Beverton-Holt formula given as equation 11.20 in Ricker (1975):

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

where P = parent year spawning escapement (i.e. FANR), R = recruits (smolts) produced by parent year spawning escapement (P), α = a fitted parameter indicative of maximum reproductive rate for the population, and β = a fitted parameter indicative of compensatory mortality as a function of stock size.

Smolt Production Forecast

To forecast brood year 2001 smolt production, I used equation 11.23 in Ricker (1975) that transforms a Beverton-Holt relationship into a linear equation with a straightforward calculation of confidence intervals. I used the transformed Beverton-Holt stock recruitment formula, $\frac{P}{R} = \beta + \alpha P$ (Ricker 1975) to describe a linear regression of P/R on P. The estimated brood year 2001 FANR was applied to this regression to forecast a mean and 90% confidence interval of migratory year 2003 smolt production.

RESULTS AND DISCUSSION

Females Available for Natural Production

The estimated number of adult spring and summer Chinook salmon (excluding jacks) passing LGR in 2001 was 185,693. This is by far the largest adult return in this stock-recruitment dataset (Table 2). The female proportion of adults (excluding jacks) captured at Snake River hatchery traps was estimated separately for spring and summer Chinook salmon (Table 3). These estimated female proportions (0.518 for the spring run and 0.461 for the summer run) were applied to the estimated number of adults passing LGR for both runs to estimate that there were 76,243 female spring Chinook salmon and 17,758 female summer Chinook salmon that passed LGR in 2001 (Table 2). After accounting for females taken into the hatcheries (adjusted for 20% migration mortality) and harvest (adjusted for 10% migration mortality), I estimated that 41,710 female spring Chinook salmon and 10,192 female summer Chinook salmon were available for natural reproduction. Therefore, I estimated combined brood year 2001 FANR for Snake River spring and summer Chinook salmon to be 51,902 (Table 2).

Smolt Production

For brood years 1990-2000, estimated smolt production ranged from a low of 161,157 to a high of 1,560,298 (Table 2). During this period, smolts/female production averaged 240 smolts/female and ranged from 92-403 smolts/female (Table 2).

Stock-Recruitment Relationship

The stock-recruitment relationship for Snake River spring/summer Chinook salmon is shown in Figure 9. Smolt production was significantly correlated with FANR ($p < 0.01$). Although covering only 11 brood years, this data series appears sufficient to reasonably define the shape of the curve at lower adult escapements. Even with the currently depressed status of adult returns, this stock-recruitment relationship indicates density dependent mortality. Adult returns have been too low to determine if the type of relationship is actually a Beverton-Holt function (Beverton and Holt 1957) or a Ricker function (Ricker 1954). However, both Ricker and Beverton-Holt relationships produce similar curves in the lower range of adult escapements for which I have data.

Smolt Production Forecast

The linear regression of the transformed Beverton-Holt relationship indicates a correlation between spawner density and smolts/female production (Figure 10). Even with the depressed status of Snake River adult escapements during brood years 1990-2000, increased spawner density apparently results in lower smolts/female productivity. This is consistent with trends in the long-term data set used by Petrosky et al. (2001). Another statistic of interest from this regression (the y-intercept) is the estimate of mean density-independent rate of reproduction (352 smolts/female). I estimated brood year 2001 FANR to be 51,902. Based on the regression model $\frac{P}{R} = 0.00259617 + 5.39329\text{E-}07P$, this escapement will produce a mean of 1,696,787 smolts, with a 90% confidence interval of 1,014,115–5,191,661 smolts. Therefore, I forecast the smolt/female production will be 33, with a 90% confidence interval of 20-100.

There are several cautions I must make about this forecast. First and foremost, the FANR in brood year 2001 was more than four times greater than the highest value used to develop the relationship. As Zar (1999) states, “Generally, it is an unsafe procedure to extrapolate from regression equations—that is, to predict Y values for X values outside the observed range of Xs.” Zar (1999) does allow for exceptions, “If there is good reason to believe that the described function holds for X values outside the range of those observed, then we may cautiously extrapolate. Otherwise, beware.” Secondly, 2001 was a serious drought year and smolts/female production has been below what the relationship would predict in past drought years. Third, the high proportion of drought years in the data set I used to develop the regression may have caused the calculated relationship to reach carrying capacity at a much lower smolt production than the population can actually produce on average. Fourth, the proportion of hatchery adults in the females available for natural reproduction was higher than in any of the years used to produce the relationship, and hatchery females spawning naturally may produce fewer smolts than wild females. Therefore, this smolt production forecast should be viewed with extreme caution about its accuracy.

Table 2. Brood year 1990-2000 Snake River spring/summer Chinook salmon estimates of natural smolts per female production and brood year 2001 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	527,000		627,037		627,942		1,558,786		419,826	
# 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	161,157		599,159		1,560,298		1,344,382		500,700	
# Smolts per Female	324		383		131		361		307	

Brood Year	**2000**		**2001**	
Run	**Spring**	**Summer**	**Spring**	**Summer**
Dam Counts	33823	3933	147131	38562
% Females	57.3	51.5	51.8	46.1
# Females	19381	2025	76243	17758
# Females in Hatcheries[a]	5080	1226	7633	3093
# Females in Harvest	5790	577	26900	4473
Female Escapement	8511	222	41710	10192
Combined Female Escapement	8733		51902	
Combined w/n Smolts	1,173,566			
# Smolts per Female	134			

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

Table 3. Brood year 2001 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)			
Spring Sites	**Total**	**Male**	**Female**	**Unknown**	**Total**	**Male**	**Female**	**Unknown**
Rapid R.	13032	1568	2269	9195	5481	—	—	5481
Oxbow	0	—	—	—	—	—	—	—
Dworshak	4018	1255	1832	931	3088	1255	1832	1
Kooskia	2261	84	108	2069	1452	—	—	1452
S. Fk. Clearwater R.	3289	1341	1110	838	1971	547	579	845
Powell	2266	1108	685	473	825	168	184	473
Sawtooth	1876	1000	876	0	1018	561	457	0
East Fk.	0	—	—	—	—	—	—	—
Grande R.	51	23	18	10	30	12	8	10
Catherine C.	76	39	35	2	57	28	27	2
Lookingglass	106	59	47	0	2	2	0	0
Lostine	54	33	21	0	34	21	13	0
LGR to Lookingglass	0	—	—	—	—	—	—	—
Totals	27029	6510	7001	12518	13958	2594	3100	8264
% Female			**51.8**	**Est. Females Released = 3100 + (8264 X 0.518) = 7382**				
				Est. Females Taken =[7001 + (12518 X 0.518)] – 7382 = 6106				
Summer Sites								
McCall	9830	5626	4204	0	5598	2760	1787	1051
Pahsimeroi	1062	477	585	0	296	140	156	0
Imnaha R.	2823	1296	1527	0	2615	1200	1415	0
Totals	13715	7399	6316	0	8509	4100	3358	1051
% Female			**46.1**	**Est. Females Released = 3358 + (1051 X 0.461) = 3842**				
				Est. Females Taken =[6316 + (0 X 0.461)] – 3842 = 2474				

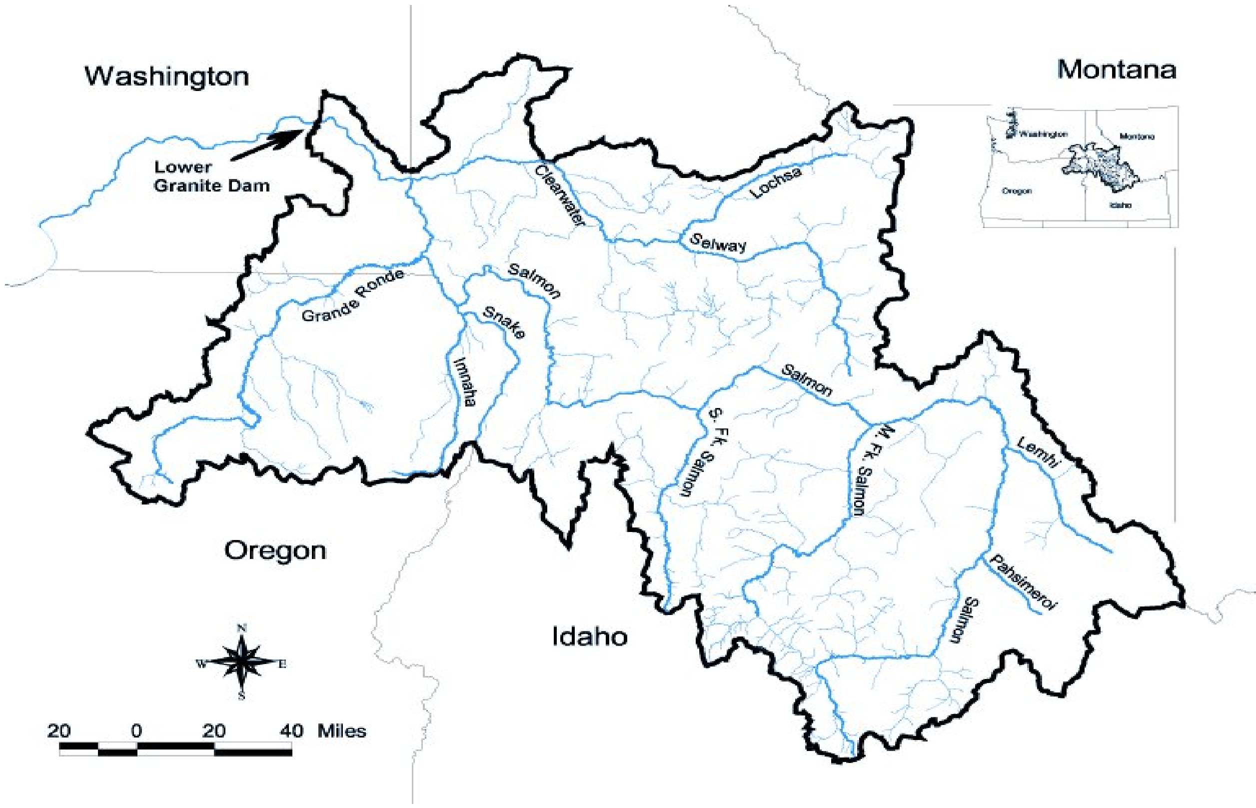

Figure 8. Snake River basin upstream of Lower Granite Dam that is currently accessible to spring/summer Chinook salmon.

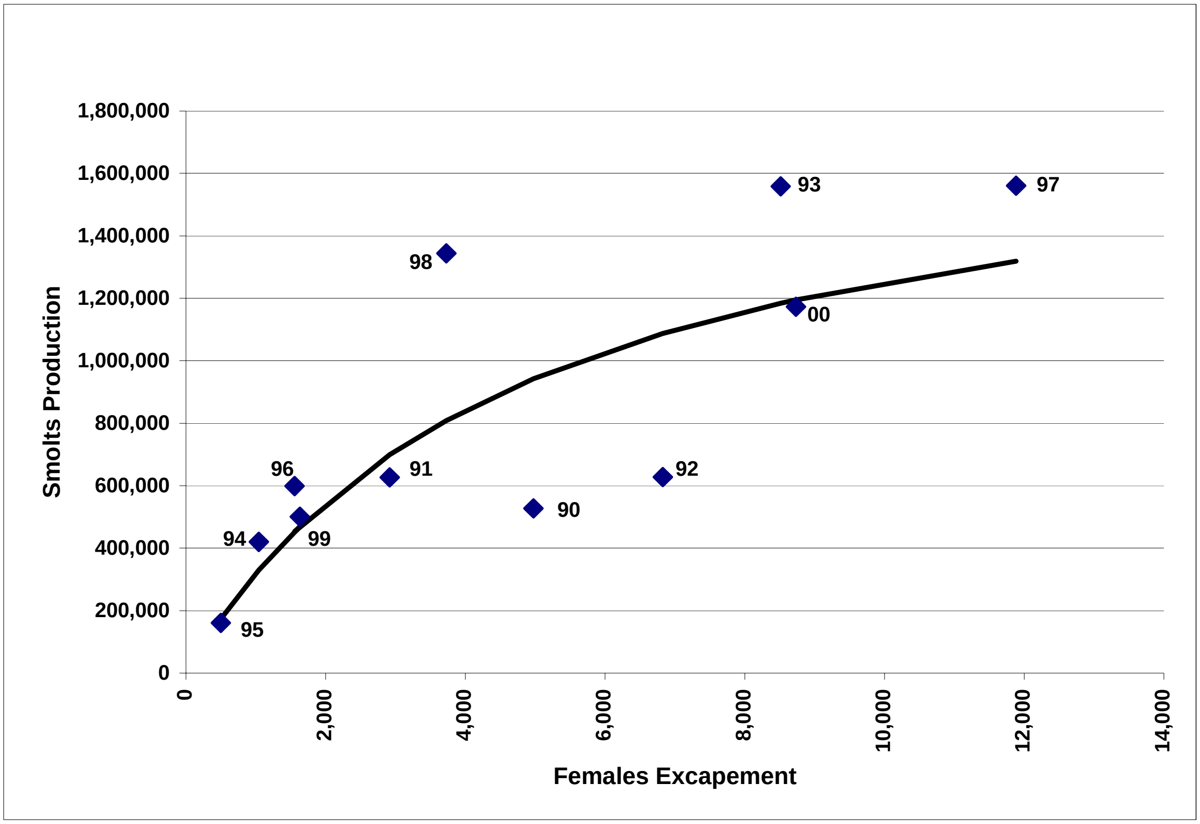

Figure 9. Snake River stock-recruitment relationship for spring/summer Chinook salmon female escapement and resulting wild/natural smolt production.

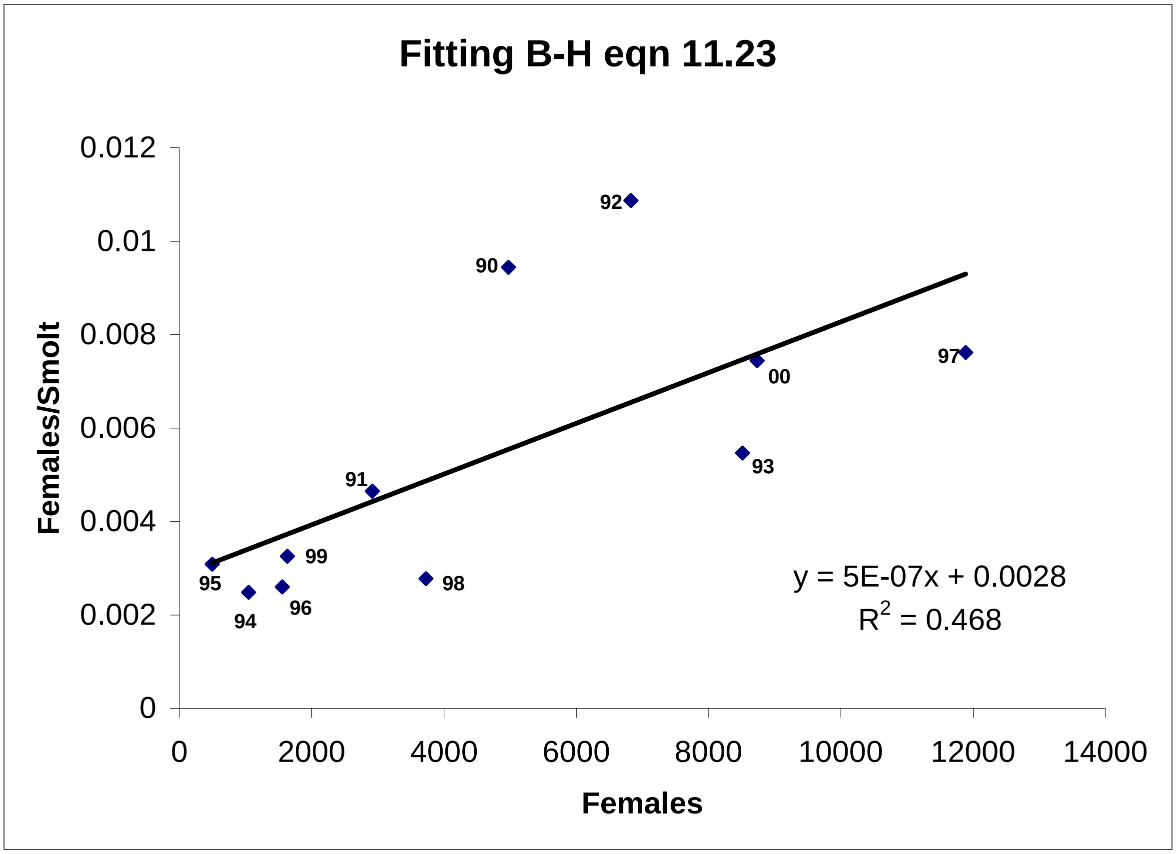

Figure 10. Linear regression of brood years 1990-2000 Snake River spring/summer Chinook salmon female escapement and female escapement divided by resulting smolt production used to forecast brood year 2001 smolts production with confidence intervals.

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

ABSTRACT

Accurate age data are crucial to accurate determination of ocean-age proportions of salmon runs and monitoring of trends. Fin rays collected and aged from adult Chinook carcasses (n = 696) were used to determine age composition of wild/natural spring/summer Chinook salmon returning to wild/natural spawning areas in the Snake River basin in 2002. Age at length was proportioned to 5 cm length groups. These proportions were applied to lengths from unmarked (adipose present) adults passing Lower Granite Dam to determine ocean-age proportions for the run at large. The majority of the 2002 returns were either two-ocean (52.8%) or three-ocean fish (45.0%). For carcasses collected from 1999 to 2002, fork length was significantly affected by run type (spring versus summer) and year for two-ocean fish and by run type for three-ocean fish (analysis of variance, $p \leq 0.03$). Smolt-to-adult return rates were calculated for migratory years 1996–2000 by applying adult return estimates to basinwide smolt production estimates reported in the stock-recruitment section of this report. Overall SARs varied from 0.35% to 3.01%. Adult run year reconstructions should consider run type in the analysis and that size at age can vary significantly between years for at least two-ocean Chinook. Results of this research can help improve the accuracy of run reconstructions for stock/recruitment analysis of wild stocks.

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INTRODUCTION

Accurate age data are an important tool for the management and recovery of wild/natural (hereafter referred to as wild) spring/summer Chinook salmon *Oncorhynchus tshawytscha* in the Snake River basin. This information is used to partition the run into brood years, and for calculating smolt-to-adult return rates and adult-to-adult return rates. Pacific salmon *Oncorhynchus sp*. are often aged by examining the circuli pattern on 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). In 1999, Idaho Department of Fish and Game (IDFG) personnel transported aging structures to the aging lab at Canada's Pacific Biological Station in Nanaimo, British Columbia and determined that dorsal fin rays would yield the most accurate ocean ages. Scales may still be used for determining the fresh water age; however, freshwater age in Snake River wild Chinook smolts is normally one year and is not necessary for determining out-migration year. This report covers results of collections in 2002 from wild Chinook salmon spawning areas throughout the Snake River basin and comparison of that data to previous samples.

STUDY AREA

The study area encompasses all streams in the Snake River basin upstream of Lower Granite Dam (LGR) that are currently accessible to wild/natural spring/summer Chinook salmon. Carcasses were sampled from spawning areas throughout the study area (Figure 11).

METHODS

Sampling

Training was provided in several forms to help ensure correct sample collection and data recording. We produced and distributed a spawning survey manual that illustrated the proper techniques for collecting aging structures and recording data. Onsite training for collecting aging structures was provided at the Sawtooth Hatchery and the interagency redd count training on Marsh Creek.

Personnel collected a dorsal fin and scales from carcasses for age analysis. A small piece of fin tissue was also collected for DNA analysis. Information collected included: 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. Dorsal fins were collected using a serrated knife. The fin was held at a 90-degree angle to the body and removed by making a cut level with the body of the fish while pulling upward on the fin. The fin was then inserted into a coin envelope with base exposed and the rays aligned perpendicular to the fin base. Individual scales were collected with forceps, moistened, and placed rough side up on gummed paper, five from each side of the fish from between the dorsal and anal fins, above the lateral line. The scales were collected for future freshwater analysis and were not included in this report. A small pencil-eraser-size piece (approximately 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 tissue samples were catalogued and stored for future DNA analysis.

Containers for aging structures and genetic samples were prelabeled with a unique number for each individual fish. Once collected, samples were placed in a Ziploc® bag and sealed. The identification number contained two digits to identify year, a dash, and four digits. The latter allowed identification of up to 9,999 unique carcasses sampled in a year. For example, sample containers for the 199th packet assembled for samples collected in 2002 would be labeled 02-0199. Samples were transported to the IDFG Fisheries Research Office in Nampa, Idaho, catalogued, and stored for later analysis. The fins were stored in a freezer until prepared for aging. The genetic and scale samples were catalogued, organized, and stored in the laboratory for future analysis.

The majority of samples were collected on spawning grounds from carcasses of wild adults 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 adult trapping weirs. In order to validate age readings, dorsal fins and scales were collected from known-age hatchery adults returning to Rapid River, McCall, and Dworshak hatcheries that were marked with passive integrated transponder (PIT) tags.

Data Storage

A Microsoft® Access database was used to catalogue and interrelate anadromous and resident fishery biological samples collected. 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

In preparation for analysis, a group of 25-30 Chinook dorsal fins were removed from the storage freezer. Each fin was adjusted so the base of the fin was perpendicular to the rays and placed upright on specially designed wooden racks. The racks kept the fins separated and allowed for air circulation, permitting the fins to dry thoroughly. After 24 hours of drying, excess materials (i.e. bones, loose skin, and flesh) and unneeded fin rays were removed. The fins were then individually coated with a 2-3 mm layer of epoxy and placed on waxed paper to harden overnight under a fume hood. After hardening, 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 unique identity (sample number) of each fin.

The next step in fin preparation involved slicing fins into cross-sections. This step requires both practice and precision to produce thin cross-sections that can be aged with a compound microscope. Multiple sections were obtained from each individual fin using a water-cooled Bronwill diamond grit saw. This saw features a moving carriage and metered hand wheel that allows great precision in obtaining cross-sections of exact thickness. To begin slicing, a prepared fin was clamped into a Vise-grip® locked in a chuck on the 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 0.30 mm diamond grit blade. The hand wheel was used to adjust the thickness of the slices to 1.3-1.5 mm. Each fin was sliced, repositioned for desired thickness, and resliced until an average of 10-12 cross-sections were obtained. Cross-sections were then dried and mounted on microscope slides under the fume hood using Flo-texx, 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 02-0199 would be placed on the first slide, which would be labeled 02-0199A. The next slide would be 02-0199B, 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 freshwater rearing areas before they smolt and migrate to the ocean. The bright freshwater annulus is near the center of the fin ray. It is kidney-shaped and has two curved lines below. Ocean winters are not as cold as those spent in freshwater, and some growth does occur. This causes the ocean annuli to be broader than 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 was comprised of fish that were tagged as smolts with PIT tags and recovered among adult returns.

All samples were independently aged by at least two readers trained in fin aging techniques. If there was disagreement in age determination, or if the determined age did not match what is normal for the fish's length, that fin was read again in a referee session. Normal was defined as the age group the majority of fish of that length would belong to based on the rest of the run. For example, a Chinook that is 81 cm in length has an 82% chance of being a two-ocean fish (Table 4). If this Chinook was aged as a three-ocean, it would be reviewed in a referee session. During a referee session, a camera was attached to the microscope and the image displayed on a television screen. Three trained readers then viewed the fin together and, if possible, reached a consensus on age. In some cases, fin samples were classified as unreadable.

Ocean-age Proportions at Lower Granite Dam

Video monitoring was used to determine the length frequency of wild Chinook salmon passing LGR. From May through August, a video camera recorded adults passing the viewing window at LGR for 24 hr 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. Based on the number of adults that passed LGR in the 2002 migration season and the number of minutes of videotapes, calculations were made to estimate the number of viewing minutes necessary to obtain approximately 400 digitized images. The first year this research was conducted, 400 images produced a representative length frequency distribution. In 2002, 42 min segments of each videotape were randomly selected for images of adults passing the viewing window. The video images of each adult observed passing the viewing window were examined for the presence of an adipose fin. Fish with a full adipose fin were assumed to be of wild/natural origin. Chinook missing all or part of the adipose fin were assumed to be of hatchery origin. The best image of each wild fish was digitized for length analysis. Criteria for image selection were 1) that the fish was straight, and 2) the tip of the snout and fork of the tail were clearly visible. Video editing software was used to calculate the ratio of each adult's image fork length to images of measuring sticks of known lengths (62 cm, 85 cm, and 100 cm). The image ratios were used to develop a regression between image length and actual length. This regression was used to estimate the actual FL from the digitized images of the unmarked adults passing LGR. Using estimated FLs, we developed a length frequency distribution for unmarked adults passing LGR in 5 cm intervals. 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 LGR each year. The ocean-age proportions of wild Chinook salmon adults passing LGR were applied to escapement estimates (United States v. Oregon Technical Advisory Committee [TAC]; Greg Mauser, IDFG, personal communication) to compute the number of adult returns for each ocean-age group.

Determining Length at Age Differences Between Spring and Summer Chinook

Summer Chinook spend more time in the ocean and should grow longer than spring Chinook, assuming they share a common area in the ocean. Carcass lengths collected from 1999-2002 were compared to determine whether differences existed for length at age between spring and summer Chinook over different years. SYSTAT® was used perform an analysis of variance (ANOVA) on fork length to examine the effect of run type, year, and their interaction (alpha = 0.05). Each ocean-age group was considered separately. Descriptive statistics were computed with Microsoft Excel®. This analysis provided the average mean length for each group based on age. It also shows maximum and minimum values in each data set and the number of samples in each group. This proved to be very important in our analysis. Knowledge of this data will assist biologists in apportioning Chinook back to their smolt year. This will result in more accurate smolt-to-adult return rates (SAR) based on run.

Estimating Aggregate Smolt-to-Adult Return Rates

Results of our carcass aging research and stock-recruitment analysis (Part 2) were combined to estimate an aggregate SAR estimate for Snake River wild Chinook salmon (LGR to LGR). For a particular smolt year, the estimate of wild/natural smolts arriving at LGR calculated for our stock-recruitment analysis was the denominator in the SAR estimates. This estimate was the product of daily smolt count in the bypass system at LGR and the daily collection efficiency, summed for the migratory year (see Methods, Smolt Production, in Part 2). The numerator was the sum of one-ocean adults that returned the year after the smolt year (smolt year +1), two-ocean adults that returned smolt two years after the smolt year, three-ocean adults that returned three years after the smolt year, and four-ocean adults that returned four years after the smolt year. Smolt-to-adult return rates were reported as a percentage. Smolt-to-adult-returns were reported with and without one-ocean returns (jacks). Since 1998 was the first year adult age composition was available, estimates could only be calculated for smolt year 1996 SAR without one-ocean adults. Smolt-to-adult return rate estimates are complete only through three-ocean returns for smolt year 1999 and two-ocean returns for smolt year 2000.

RESULTS AND DISCUSSION

Known-Age Adults

Thirty-two known-age unmarked fish and 42 known-age adipose-clipped fish were collected in 2002. Personnel aged 72 (97%) of the 74 known-age fish correctly. One unmarked fish was aged incorrectly, and reader comments noted that it was extremely difficult to age. One adipose clipped fish was incorrectly aged as two-freshwater, one-ocean rather than one-freshwater, two-ocean.

Fin ray aging is very accurate. Since we began to use this technique in 1998, 238 of 243 (98%) known-age adults have been aged correctly. Scales and fins have been collected for five years. Scales from Snake River Chinook have been difficult to age due to regeneration and the resorption of the outer edge of the scale. With the highly accurate aging of fins, we propose to stop collecting scales, with the one exception discussed in the following section.

Wild Adult Carcass Age Determinations

Overall, 772 fin rays were collected from unmarked Chinook in 2002. Personnel examined fin ray cross-sections from 740 unmarked adult carcasses collected in 2002; 44 (5.9%) were classified as unreadable. This is believed to be due to a combination of soft epoxy and motor problems with the saw, which caused a gray film on the fin rays. Spawning ground surveys and the videotapes from the LGR viewing window show that very few one-ocean fish returned. The length frequencies of one-, two-, and three-ocean fish were relatively distinct from each other, but the length frequency distribution of four-ocean fish overlapped with that of three-ocean fish (Figure 13). Using these data, we estimated the proportions of each age group by 5 cm length group (Table 5). We also separated the fish into spring and summer runs (Table 6).

There were two minor deviations from the common pattern of age and growth. First, a small percentage of the fish aged appear to have resided in freshwater for two years. This has been reported in the past (Kiefer et al. 2002). The majority of Chinook spend one year in freshwater. Second, minijacks were detected at Pahsimeroi Hatchery in 2002. Minijacks are male Chinook that do not grow to the typical length of one-ocean fish before returning to spawn. It is believed that they migrate downstream but stop short of the ocean, possibly in one of the mainstem reservoirs. They return after one or more years to spawn. Typical size range is from 30-45 cm.

A proportion of the South Fork Salmon River carcasses sampled in 2002 were hatchery fish without external marks. Of the 33 unmarked PIT tagged carcasses sampled at the South Fork Salmon River weir, nine (27%) were classified as hatchery fish from PIT tag interrogations. This indicates that the proportion of unmarked adults sampled above this weir may include unmarked hatchery Chinook. We recommend that scale collection from the South Fork of the Salmon River carcasses continue until it is determined if fin rays or scales allow classification of these Chinook. Hatchery fish tend to grow faster due to feeding and warmer/constant water temperatures at some hatcheries. This faster growth in the freshwater can be measured in the annuli of the scales. A discriminant analysis will be conducted in the future to determine if the origin of these samples can be classified as hatchery or wild. This will increase accuracy in the database by allowing the correct classification of wild and hatchery fish. With the new marking trailers, this need may disappear in a couple of years, as all hatchery fish should be properly clipped by computerized machines.

Estimated Ocean-age Proportions of Wild Adults Passing LGR

Four hundred twenty-five images of unmarked fish were digitized passing through the viewing window at LGR in 2002. A small percentage of adult returns with an adipose fin present were likely hatchery fish with missed clips or marks other than an adipose fin clip that could not be determined from the video images. We plotted a length frequency distribution of all wild salmon (Figure 14) and estimated the proportion of the run in each 5 cm length group (Table 4). By multiplying ocean-age proportions of each 5 cm length group (Table 5) by the estimated proportion at LGR for each length group (Table 4), we were able to estimate the overall proportions and number for wild adults passing LGR by ocean age (Table 7).

Length at Age Differences Between Spring and Summer Chinook

Summer-run Chinooks were consistently larger than spring-run fish of a similar age (Table 8, Figure 15). Three- and four-ocean Chinook were grouped together because of the small sample size of four-ocean adults and because the lengths of four-ocean fish were wholly within the length distribution of the three-ocean fish. Samples from 1998 were excluded from this analysis because of small sample sizes. Note that while the Chinook sample size in the one-ocean age group is considered large by statistical standards ($n > 30$), the sample size is only a fraction of the sample size of the two- and three-ocean groups. Overall differences in mean lengths between spring-run and summer-run fish of each age group range from 1.8 to 3.2 cm. These differences were statistically significant for most age groups (Table 9). Mean fork lengths did not differ significantly among any of the four years for one-ocean returns. Few one-ocean Chinook returned in 2002. Two-ocean summer Chinook had significantly larger mean fork lengths than spring Chinook in all four years. Differences by run type depended on year for two-ocean fish; summer Chinook fork lengths were significantly smaller in 2002 than any other years analyzed. Run type was also significant for older adults. Mean fork lengths of three-ocean and four-ocean summer Chinook combined were larger than spring Chinook in all years. The inability to detect a significant difference in three- and four-ocean adults combined was likely a result of small sample sizes in 1999, 2000, and 2001. It is worth noting that when this analysis was run before the 2002 samples were complete, the two-ocean age group showed significance only for run. The addition of samples in the 2002 return year changed the results to include year as significant for two-ocean Chinook.

Because there are significant differences between spring and summer Chinook with respect to size at age, we recommend that researchers using our data for run reconstructions of individual spawning populations partition populations by run type (spring or summer). In addition, because fisheries biologists know the age of one-ocean fish based on length frequency graphs, Chinook in this length group have not been sampled as intensively. Additional one-ocean fish should be collected in the future to more rigorously test for differences in length between spring and summer run Chinook.

Aggregate Smolt-to-Adult Return Rates

Estimates of Snake River aggregate wild Chinook salmon SARs (excluding jacks) ranged from a low of 0.35% for smolt year 1996 to a high of 2.91% for smolt year 1999 through three-ocean returns (Table 10). Past research has demonstrated that run-reconstructed SARs for wild Chinook, such as presented here, are comparable to those estimated with PIT tag data for the same four smolt years (Kiefer et al. 2001). Thus, accurate length-at-age data assists biologists in apportioning adult Chinook back to their smolt migration year, increasing the accuracy of SARs calculated.

ACKNOWLEDGMENTS

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Table 4. Estimated proportion of wild Chinook salmon adults passing Lower Granite Dam in each 5 cm fork length group, 2002.

Fork Length Group (cm)	Proportion
<50	0.0024
50-54	0.0000
55-59	0.0047
60-64	0.0071
65-69	0.0047
70-74	0.0706
75-79	0.2000
80-84	0.2541
85-89	0.1529
90-94	0.1106
95-99	0.1106
100-104	0.0494
>104	0.0329

Table 5. Estimated proportion of wild Chinook salmon adults collected on spawning grounds by age in each 5 cm fork length group, 2002.

Fork Length Group (cm)	# Aged	1-Ocean	2-Ocean	3-Ocean	4-Ocean
<50	1	1.00	0.00	0.00	0.00
50-54	4	1.00	0.00	0.00	0.00
55-59	5	1.00	0.00	0.00	0.00
60-64	3	0.67	0.33	0.00	0.00
65-69	30	0.07	0.93	0.00	0.00
70-74	71	0.00	1.00	0.00	0.00
75-79	130	0.00	0.98	0.02	0.00
80-84	124	0.00	0.82	0.18	0.00
85-89	88	0.00	0.26	0.72	0.02
90-94	111	0.00	0.03	0.97	0.00
95-99	69	0.00	0.03	0.96	0.01
100-104	34	0.00	0.00	0.97	0.03
>104	18	0.00	0.00	0.89	0.11

Table 6. Estimated ocean-age proportion by 5 cm fork length groups for Snake River wild Chinook salmon carcasses sampled, 2002.

Fork Length (cm)	Spring					Summer				
	N	1-Ocean	2-Ocean	3-Ocean	4-Ocean	N	1-Ocean	2-Ocean	3-Ocean	4-Ocean
<50	0	0.00	0.00	0.00	0.00	1	1.00	0.00	0.00	0.00
50-54	1	1.00	0.00	0.00	0.00	3	1.00	0.00	0.00	0.00
55-59	3	1.00	0.00	0.00	0.00	2	1.00	0.00	0.00	0.00
60-64	2	0.50	0.50	0.00	0.00	1	1.00	0.00	0.00	0.00
65-69	21	0.05	0.95	0.00	0.00	9	0.11	0.89	0.00	0.00
70-74	48	0.00	1.00	0.00	0.00	23	0.00	1.00	0.00	0.00
75-79	81	0.00	0.99	0.01	0.00	49	0.00	0.96	0.04	0.00
80-84	71	0.00	0.76	0.24	0.00	54	0.00	0.91	0.09	0.00
85-89	65	0.00	0.22	0.75	0.03	23	0.00	0.39	0.61	0.00
90-94	83	0.00	0.01	0.99	0.00	28	0.00	0.07	0.93	0.00
95-99	42	0.00	0.02	0.98	0.00	27	0.00	0.04	0.93	0.04
100-104	27	0.00	0.00	0.96	0.04	7	0.00	0.00	1.00	0.00
>104	6	0.00	0.00	0.83	0.17	12	0.00	0.00	0.92	0.08

Table 7. Estimated proportion and total numbers of wild Chinook salmon adults passing Lower Granite Dam for each ocean-age group in each 5 cm fork length group in 2002.

Fork Length Group (cm)	1-Ocean	2-Ocean	3-Ocean	4-Ocean
<50	0.0024	0.0000	0.0000	0.0000
50-54	0.0000	0.0000	0.0000	0.0000
55-59	0.0047	0.0000	0.0000	0.0000
60-64	0.0047	0.0024	0.0000	0.0000
65-69	0.0003	0.0044	0.0000	0.0000
70-74	0.0000	0.0706	0.0000	0.0000
75-79	0.0000	0.1954	0.0046	0.0000
80-84	0.0000	0.2090	0.0451	0.0000
85-89	0.0000	0.0400	0.1095	0.0035
90-94	0.0000	0.0030	0.1076	0.0000
95-99	0.0000	0.0032	0.1058	0.0016
100-104	0.0000	0.0000	0.0480	0.0015
>104	0.0000	0.0000	0.0293	0.0037
Totals	0.0121	0.5279	0.4498	0.0102
# Adults	463	20219	17228	390

Table 8. Comparison of spring Chinook and summer returning adult Chinook lengths for each ocean-age group from carcass samples collected from 1999 through 2002.

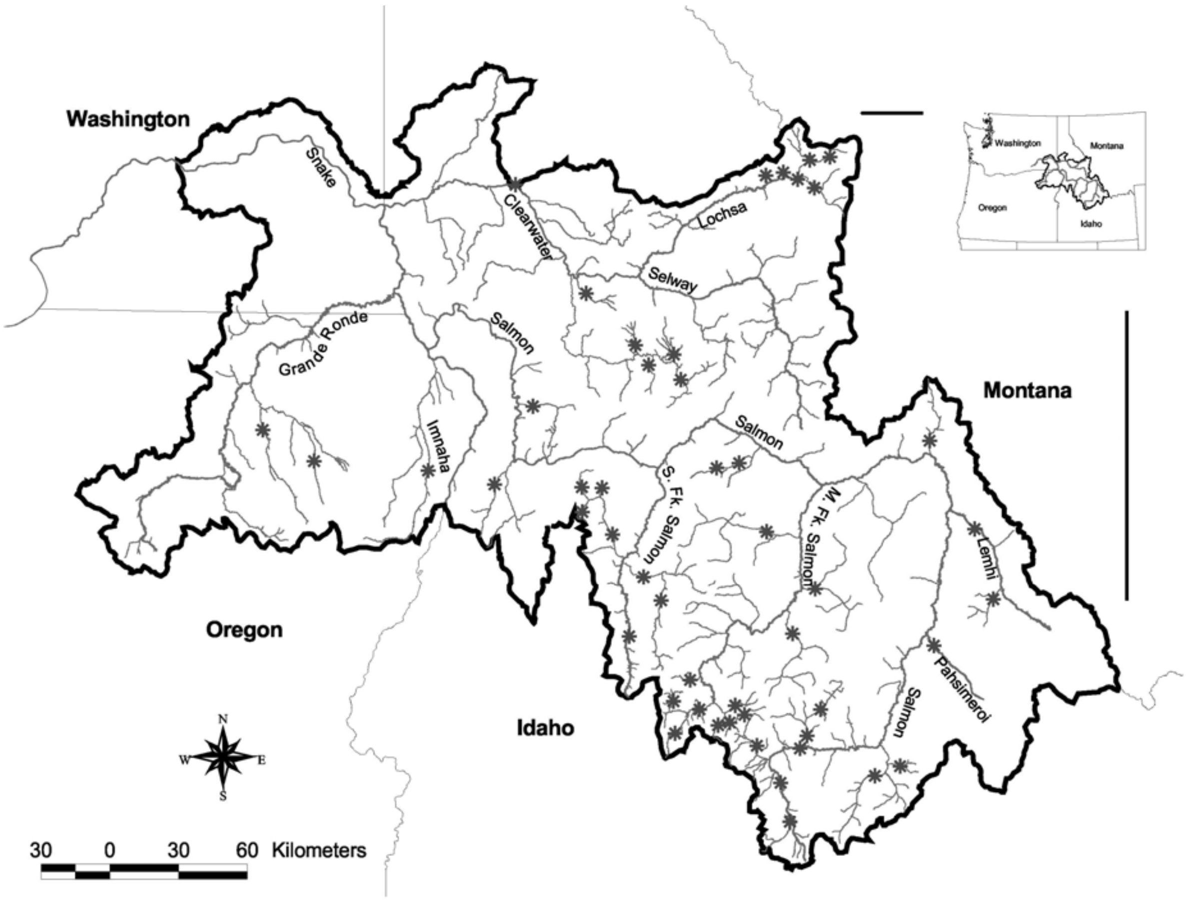
Statistic	1-Ocean		2-Ocean		3-Ocean	
	Spring	Summer	Spring	Summer	Spring	Summer
Sample Size	35	48	936	678	296	164
Mean Fork Length (cm)	54.5	56.3	77.1	80.0	92.5	94.3
Standard Deviation	5.6	4.7	5.4	5.5	6.6	7.1
Minimum	45.0	46.0	60.0	59.0	69.0	75.0
Maximum	67.0	66.0	95.0	99.0	110.0	114.0
Confidence Level (95.0%)	1.9	1.4	0.3	0.4	0.8	1.1

Table 9. Significance and p-values of analysis of variance on fork length of each age group. Run type, year, and their interaction were considered as factors.

	1-Ocean	2-Ocean	3-Ocean
Alpha = .05	n = 83	n = 1614	n = 460
Run	Not Significant *P = .22*	**Significant** *P <.01*	**Significant** *P = .03*
Year	Not Significant *P = .26*	**Significant** *P = .02*	Not Significant *P = .22*
Spring Run & Year Combined	Not Significant *P = .67*	Not Significant *P = .067*	Not Significant *P = .95*
Summer Run & Year Combined	Not Significant *P = .84*	**Significant** *P = <.01*	Not Significant *P = .59*

Table 10. Estimates of aggregate Snake River wild Chinook salmon smolt migration, adult returns, and smolt-to-adult return rates (SARs).

Smolt Year	1996	1997	1998	1999	2000	2001
# Smolts	419,826	161,157	599,159	1,560,298	1,344,382	500,700
Adults						
Smolt year +1	—	189	235	1,496	1,227	463
Smolt year +2	997	2,155	6,925	28,168	20,219	—
Smolt year +3	456	408	833	17,228	—	—
Smolt year +4	0	22	390	—	—	—
SAR w/jacks	0.35%	1.72%	1.40%	3.01%	1.60%	0.09%
SAR w/out jacks	0.35%	1.60%	1.36%	2.91%	1.50%	—



Snake River Basin

Figure 11. Spawning streams denoted with an ∗ indicate where wild/natural spring/summer Chinook salmon adult carcass data were collected in 2002.

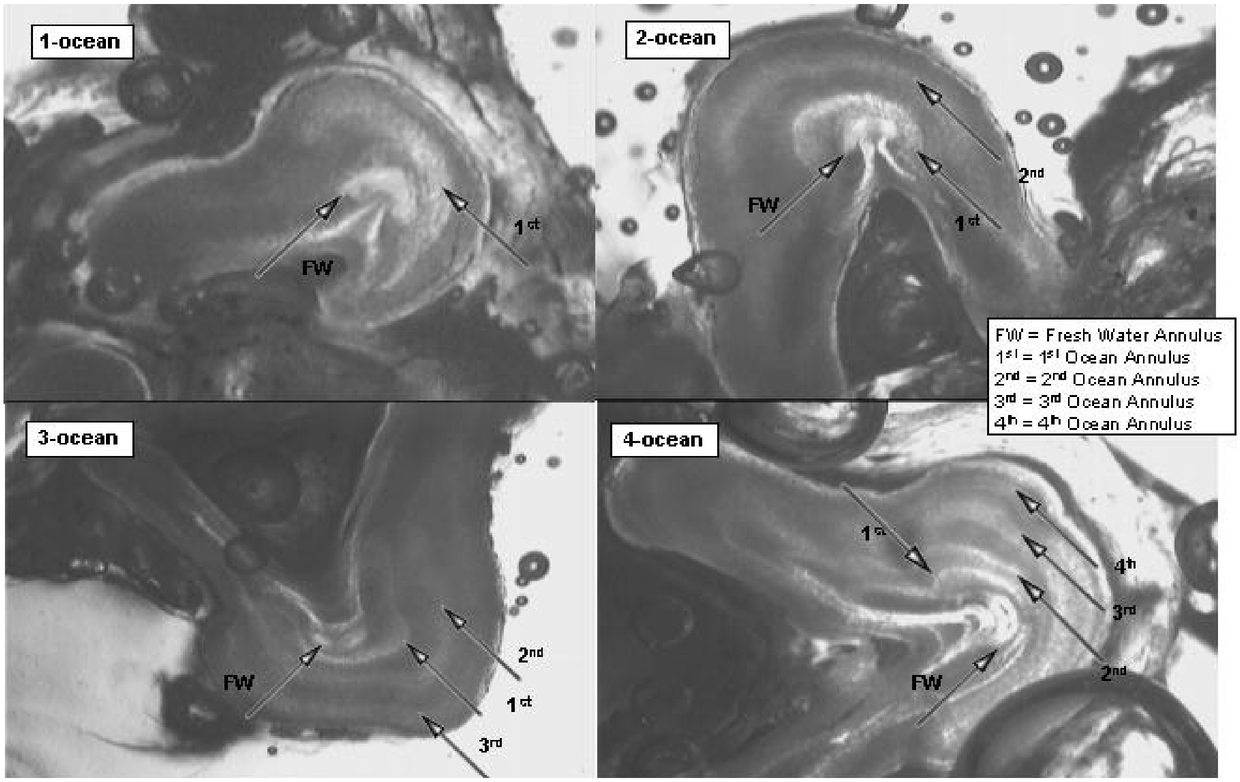


Figure 12. Representative dorsal fin ray cross sections from the four different ocean ages observed for Snake River wild/natural spring/summer Chinook salmon adult returns.

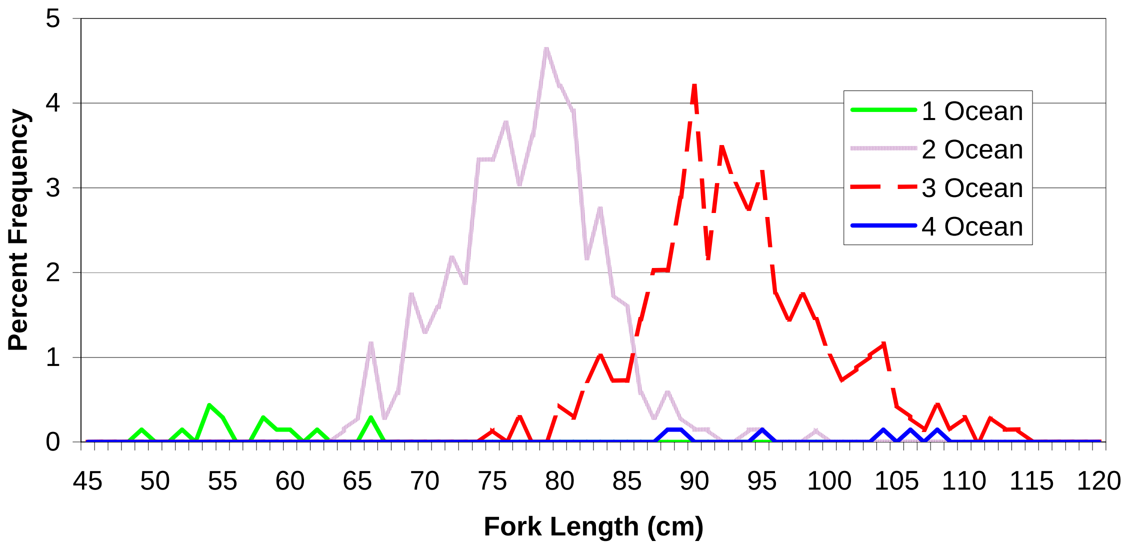


Figure 13. Snake River wild Chinook salmon carcass fork lengths and ocean-ages determined from dorsal fin ray cross sections, 2002.

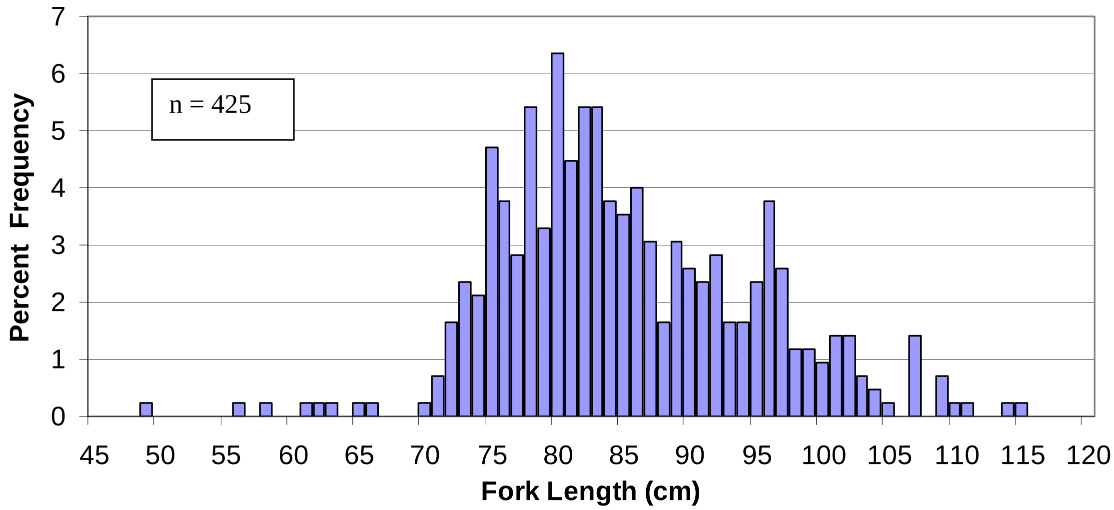


Figure 14. Estimated fork length distribution of Snake River spring/summer wild Chinook crossing Lower Granite Dam, 2002.

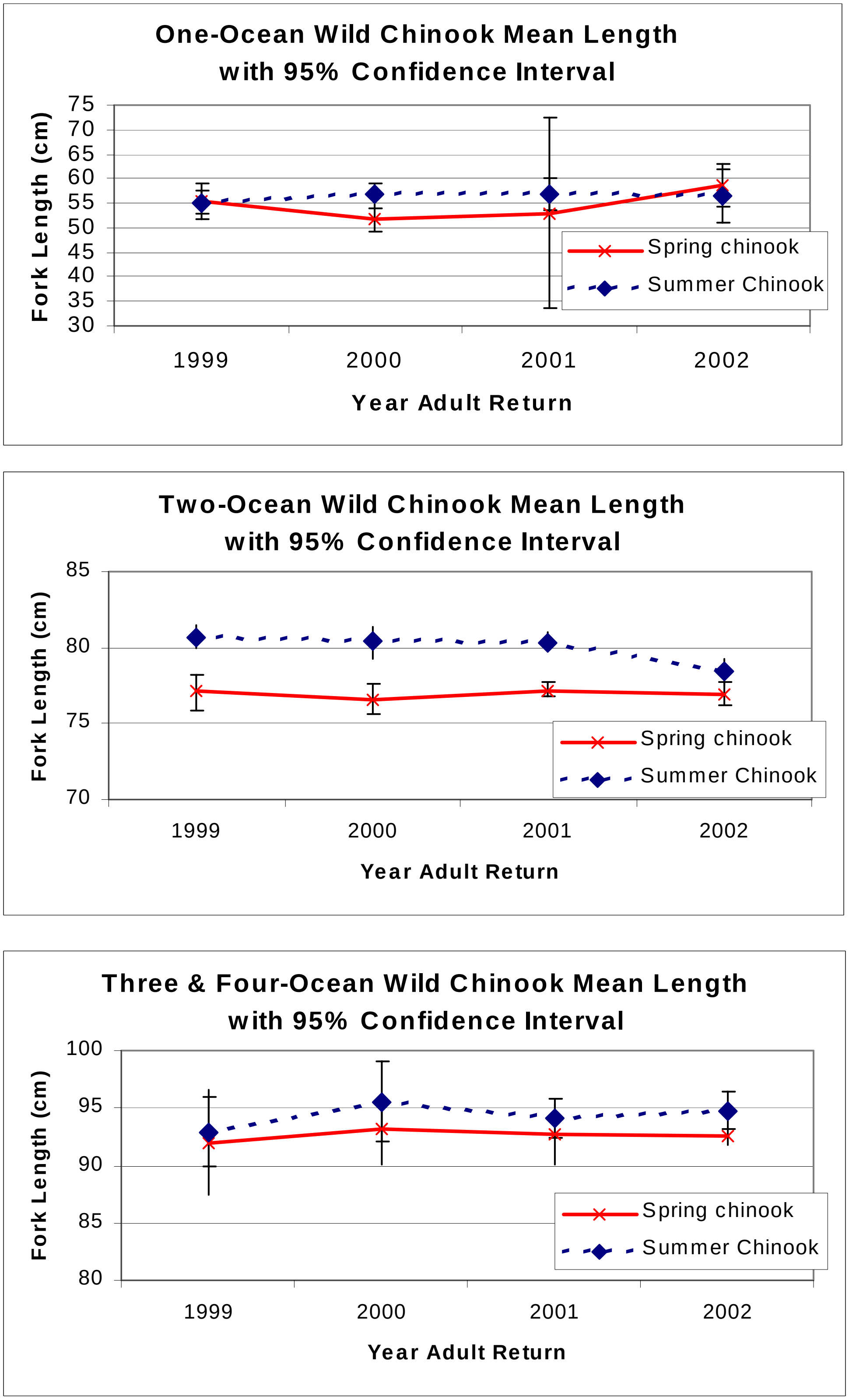


Figure 15. Wild Chinook mean lengths with 95% confidence intervals for each ocean-age group.

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PART 4—NATURAL PRODUCTION MONITORING AND EVALUATION: EVALUATING THE EFFECTIVENESS OF HABITAT ENHANCEMENT PROJECTS

ABSTRACT

Previous attempts to evaluate habitat enhancement projects directed at anadromous salmonids in Idaho were plagued by low adult escapement into the state. Following high returns in 2001, we attempted to determine Chinook salmon *Oncorhynchus tshawytscha* parr density and measure physical habitat variables at selected monitoring and mitigation sites in 2002. Most sites had parr densities in the fair or poor categories of the rating system we used. No stream exhibited a consistent pattern of parr density relative to enhancement projects. Fine sediments have increased in the study streams. However, the habitat evaluation protocols used in this and previous surveys have not been consistently followed. Additionally, appropriate spatial scales and potential confounding factors were not incorporated into the survey design. These problems compromise our ability to definitively evaluate our results. More thought should be put into a process-oriented design before proceeding further.

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INTRODUCTION

Approximately 5,687 miles of streams were once available to anadromous fish in Idaho, of which some 40% became inaccessible after dams were constructed on the Snake and North Fork Clearwater rivers (Mallet 1974). The Clearwater River and Salmon River drainages presently account for virtually all of Idaho's wild and natural production of steelhead and spring/summer Chinook salmon. While a majority of the available habitat in these drainages is of high quality, anthropogenic activities have degraded many streams. Mining, grazing, irrigation, logging, and road building have all contributed to increased sedimentation and water temperatures and decreased flows and vegetative cover. To mitigate for these effects, the U.S. Forest Service (USFS), U.S. Fish and Wildlife Service (USFWS), Shoshone-Bannock and Nez Perce tribes, and the Idaho Department of Fish and Game (IDFG) have cooperated to plan and implement habitat improvements for anadromous fish.

Habitat enhancement projects are designed to increase the amount of available habitat and/or its carrying capacity through a variety of methods, including barrier removal, sediment source reduction, in-stream structures, channel reconstruction, livestock fencing, and revegetation. The majority of habitat enhancement projects in Idaho were designed to increase the carrying capacity for juvenile salmon and steelhead. Starting in 1983, the Bonneville Power Administration (BPA) has funded a large number of these projects in the Clearwater and Salmon drainages to partially mitigate for impacts of the federal hydrosystem on anadromous fish in Idaho.

Although habitat improvement projects generally are thought to increase juvenile production, actual increases and relative benefits have seldom been quantified in the field. Following the Northwest Power Planning Act in 1980, and under the subsequent Columbia Basin Fish and Wildlife Program, measuring benefits has been necessary to establish credit for offsite mitigations in the Columbia River drainage and to compensate for losses within the basin. In 1984, IDFG began an evaluation of existing and proposed habitat enhancement projects for anadromous fish in the Clearwater River and Salmon River drainages (Petrosky and Holubetz 1987). As adult escapement continued to decline from the mid 1980s thru the 1990s, measuring increases in carrying capacity became unfeasible. The evaluation program adopted a monitoring focus. There simply were not enough salmon and steelhead juveniles to determine if the habitat enhancement projects had indeed increased the juvenile carrying capacity. With the increased number of Chinook salmon adults available for natural reproduction in 2001, an opportunity arose to evaluate these projects changes in juvenile Chinook carrying capacity. The objective of this study was to determine parr density in selected mitigation and monitoring sites and to update physical habitat data for the mitigation sites. Due to subsequent study design problems, statistical analysis was not attempted; instead, the data were simply compared.

METHODS

Evaluation Approach

The previous focus of IDFG mitigation evaluations has been estimating anadromous parr densities and measuring selected habitat variables at established monitoring sites (Petrosky and Holubetz 1987). Sampling sites were established in paired treatment and control groupings in some streams with habitat enhancement projects. Other such streams did not have a paired-site design. Monitoring sites were also sampled to provide data on the status and trends of salmonid populations. These streams can be used as watershed-level controls for streams with mitigation projects but were not sampled for habitat variables. Sampling sites were typically 100 m long with boundaries at defined breaks between habitat types and including at least one riffle-pool sequence. Four major Chinook salmon production areas were selected for this evaluation. These drainages (and streams sampled) were: South Fork Clearwater River (Crooked River, Red River and American River), South Fork Salmon River (Lake Creek, Johnson Creek), Middle Fork Salmon River (Big Creek, Bear Valley Creek, Cape Horn Creek, Marsh Creek), and Upper Salmon River (mainstem Salmon River, Pole Creek, Valley Creek) (Figure 16). Sites on these streams include a variety of mitigation and comparison types (Table 11).

Parr Density Monitoring

Nine sites were sampled to determine parr density (Table 11). Parr densities were estimated from snorkel counts. Most anadromous fish production streams in Idaho are clear and have low conductivity that decreases the effectiveness of electrofishing for fish surveys and makes snorkeling the more efficient method for collecting parr data. Snorkel counts have the potential to underestimate parr density, because smaller fish concentrate in shallower stream margins, but previous comparisons of snorkeling and electrofishing methods (Petrosky and Holubetz 1987; Hankin and Reeves 1988) did not find a negative bias. Snorkel methods follow Petrosky and Holubetz (1986). Sites were snorkeled by divers working upstream, with the number of divers varying according to stream size and visibility. Observers snorkeled slowly, identifying and counting all fish seen. Anadromous and resident salmonids (i.e. bull trout, cutthroat trout, whitefish) were tallied. Other species observed were noted as present. Chinook salmon parr were defined as age-0 salmon with fork lengths (FL) 45-99 mm. Steelhead trout parr are defined as age-1+ rainbow trout 80-120 mm FL. Parr densities for these two groups were expressed as number observed by divers divided by the area searched and expanded to 100 m^2.

Parr density was also evaluated relative to carrying capacity. Petrosky and Holubetz (1987) estimated streams with excellent habitat should support 108 Chinook parr per 100 m^2. This carrying capacity estimate was indexed to standard smolt capacity ratings developed by the Northwest Power Planning Council for poor, fair, good, and excellent habitat (NPPC 1986). This gave expected parr carrying capacities of <12/100 m^2 for poor habitat, 12-44/100 m^2 for fair habitat, 44-77/100 m^2 for good habitat, and >77/100 m^2 for excellent habitat. This system provides a subjective but consistent means to evaluate habitat quality and carrying capacity if enough adults return to fully seed the available habitat.

Physical Habitat

Physical habitat evaluations in 2002 focused on headwater streams of the upper Salmon River and Middle Fork Salmon River (Table 11). These streams were identified in a 1985 inventory of riparian and aquatic habitat conditions, which recommended various treatments to control sediment inputs potentially affecting the quality of spawning and rearing habitat for Chinook and steelhead (OEA Research 1987a, 1987b). Physical habitat data were collected for the sections according to the transect method derived from Platts et al. (1983). The standardized variables were channel type (Rosgen 1985), section length (measured midstream), percent gradient, width, depth, percent habitat type (pool, run, pocket water, riffle, and backwater) as described by Shepard (1983), and percent substrate composition (sand, gravel, rubble, boulder, and bedrock) as defined by Torquemada and Platts (1988). Transects were established systematically at 10 m intervals except where a redd or spawning adult was observed. In that case, the 10 m interval was extended to avoid the redd or spawner. Stream width was measured at each transect. At the quarter, half, and three-quarter point of each transect, flow and depth data were measured using a Swoffer© Model 3000 current meter and wand, and substrate composition was visually estimated.

The initial sampling protocol in the baseline evaluation period of the mid-1980s was not followed consistently in subsequent sampling years. Apparently, some of the habitat surveyors in 1991 (Bear Valley, Marsh, and Valley creeks) incorrectly ascribed some “fines” to the “gravel” category. We found an error in the data sheets used that year which probably lead to this misclassification. Additionally, the categorization of microhabitat units (pool, run, riffle, pocket water, or backwater) was inconsistent among sampling periods, making it difficult to distinguish if increased deposition of sand in pools has occurred. More contemporary sampling protocols restrict evaluation of fine sediments to pool tail crests and riffles, or further restrict sampling to habitat units meeting spawning or overwintering criteria. Therefore, we selected only three physical habitat variables to present for this report: percentage fines, percentage gravel, and width-to-depth ratio.

RESULTS

Parr Density Monitoring

The three streams in the South Fork Clearwater drainage had different longitudinal patterns in parr density (Figure 17). Red River had deceasing parr density downstream, while density was low and did not vary much in Crooked River. Density in American River was much higher than in the other streams and did not show a consistent pattern. The four streams in the Middle Fork Salmon drainage had relatively flat parr density patterns compared to the South Fork Clearwater streams (Figure 18 and lower panel of Figure 19). The exceptions were one high-density site each on Bear Valley Creek and Big Creek. Parr densities in these two streams were more variable than in Cape Horn or Marsh creeks. Big Creek exhibited a declining pattern otherwise. The two streams in the South Fork Salmon drainage also showed disparate patterns (Figure 19, upper and middle panels). Parr densities in Johnson Creek were low and declined downstream. Lake Creek had higher-density sites upstream and downstream; the middle three sites had much lower parr densities.

The majority of parr density ratings by site were in the fair category (Table 12). American River was the only stream with all sites rated as good or excellent. No sites in the Middle Fork Salmon drainage were rated as excellent. Conversely, sites rated as poor were in the minority, but several were found in each drainage.

Physical Habitat

Estimated percentage of surface fines apparently increased through the years. Overall, percentage fines in sites in the upper Salmon drainage were low (<30%) but tended to increase slightly though time (Figure 20). The exception was Pole Creek, where fines had declined since the 1990s to levels comparable to the initial survey in 1987. Sites in the Middle Fork Salmon drainage showed large increases in percentage fine sediment since the initial evaluations (Figure 21). This was contrary to our expectations, given reduction of cattle grazing and habitat projects aimed at reducing fine sediments. It is possible that fine sediments take longer than 10 years to work through these systems, or that particle classifications were not consistent between periods.

Percentage of gravel was much more variable. Upper Salmon sites showed a drop in gravel percentage in the early 1990s, but in 2002, we found it to be similar to the initial evaluations (Figure 22). Gravel was less prevalent in the substrate of Middle Fork Salmon sites (Figure 23). There was no trend in gravel percentage in Marsh Creek. Most sites in Bear Valley Creek showed some increases since the 1990s, but percentages were still below those found in the upper Salmon drainage.

The width/depth ratio has stayed fairly constant during the past ten years for half of the sites measured in 2002. These ratios were stable in the range of 40-60. In the upper Salmon drainage, the overall trend was a slight increase (Figure 24). In the Middle Fork drainage, width/depth ratio in Marsh Creek decreased but the pattern was inconsistent in Bear Valley Creek (Figure 25). Changes in time were not very large except for site 2B in Bear Valley Creek. Increased width/depth ratios suggest that habitat conditions worsened because increasing bank erosion and/or increasing bedload transport tend to cause larger width/depth ratios. Only one of the 12 sites measured (Salmon River 7B) appeared to have improving habitat conditions as indicated by a decline in the width-to-depth ratio.

DISCUSSION

Parr Density Monitoring

Most sampling sites had parr densities <44/100 m^2 in the fair or poor categories according to our adaptation of the NPPC (1986) ratings. Previous research estimated Chinook salmon parr carrying capacity in Snake River rearing streams to be 108/100m^2 (Petrosky and Holubetz 1987). Of the streams we snorkeled in 2002, only American River had Chinook salmon parr densities at or above this estimated carrying capacity (Figure 17). These ratings provide a consistent, though subjective, assessment of habitat quality and carrying capacity within Idaho subbasins. The much higher densities we observed in American River indicate that these ratings are for qualitative comparisons because predicted carrying capacity may be exceeded in some streams.

The data suggest that habitat in the study area was underseeded in 2002. However, we were three weeks behind schedule putting this field crew together and were unable to snorkel these sites during their recommended times. It is possible that significant numbers of Chinook salmon parr out-migrated from these rearing areas before we snorkeled them. Reports from juvenile out-migrant trap operators indicate this occurred at least to some degree (Jody Brostrom, IDFG, personal communication; Brian Leth, IDFG, personal communication; Jerry Lockhart, Nez Perce Tribe, personal communication). The tendency of parr to migrate from their natal areas complicates estimation of productivity. Timing must be precise or surveys should incorporate a more coarse spatial scale.

No stream exhibited a consistent pattern of parr density relative to an enhancement project. In the Red River in strata 4, there may have been an increase of 30-40 parr per 100 m^2 in Chinook salmon carrying capacity associated with the habitat enhancement treatments (Figure 17). However, the next treatment site downstream (strata 5) had the lowest density we observed in Red River. The observed effect in strata 4 may have been due to its proximity to an area of high redd density. Thus, a reach-level or site-level comparison such as this will likely be confounded by spatial autocorrelation. Future evaluations should take this into account.

Physical Habitat

Habitat variables limiting fish production have been widely described and addressed in the primary literature (e.g. Rosgen 1985, Bjornn and Reiser 1991) and the regional reports documenting the initial conditions at sites we surveyed in 2002 (OEA Research 1987a and 1987b). Substrate composition and width/depth ratios are useful indicators of changes in sediment regime and stream channel morphology but are measured differently in the newer studies than protocols utilized here. These differences complicate comparison of our data to other studies.

Fine sediments are an important habitat variable to monitor because of their negative impacts on egg-to-fry and macroinvertebrate (fish food) survival. In 1987, 85% of Salmon River sites had <25% surface fines (Petrosky and Holubetz 1988). By 2002, only 60% of the sites fell into this category, meaning that a greater percentage of each sampled location was composed of sand or fine sediments (Table 13). A weighted average of 83% of all sites sampled prior to and including 1990 were <25% fines, while in 2002 only 60% of all sampling locations were in the same category. Similarly, Overton et al. (1995) found approximately 50% of C channel stream reaches in the Salmon River basin had >25% accumulation of fine sediments. Chinook salmon egg-to-fry survival declines as percentage surface fines increases above 30% and drops dramatically when greater than 40% (Scully and Petrosky 1991). It is a concern to us that all four sites sampled in the upper Salmon River in 2002 had percentage fines near 30% and that, of the five Middle Fork Salmon River sites sampled, three were above 40% and the other two were 30%-40%. If our study sites overlap with spawning sites, this would indicate a decline in the productivity of the area.

It is difficult to determine whether actual changes in physical habitat conditions have occurred since monitoring began in the late 1980s. First, there are methodological issues, e.g. the data sheet error and changes in the protocol mentioned in the Methods. Second, a lag time of several years for sediment reduction is expected. The transport of channel bed particles coarser than 0.062 mm is largely dependent on the capacity of the flow and is increasingly intermittent with increasing grain size. Residence times of such sediments moving through even small drainages are likely to be very large (Knighton 1998). Diversion of water for irrigation and altered hydrographs would likely increase residence times as frequency of flushing flows decreased. Under such a scenario, only fine sediments are likely to be recruited into the channel and moved downstream.

Physical habitat conditions for salmon and trout have worsened in the upper Salmon River and upper Middle Fork Salmon River tributaries since the 1980s. We base this statement on consistent findings of increased amounts of surface fines over the years. The habitat enhancement projects do not appear to have halted this trend. Even with past efforts to protect and enhance habitat for salmon and trout, conditions continued to decline in these two important production drainages. However, to detect any impact on salmon production, habitat changes need to be compared to parr densities.

RECOMMENDATIONS

We found that few sites in the study area supported parr densities indicative of good or excellent habitat. Concurrently, we found that habitat conditions have deteriorated since the 1980s. However, many factors compromise our ability to link these two results. Before proceeding further, more thought should be put into a study design that accounts for the processes that create and maintain habitat.

Stream-reach enhancement projects may not function well unless integrated into a watershed restoration program (Beschta 1997). Therefore, evaluations should also be planned and conducted at a watershed scale. Site-level examination of the mechanistic functioning of specific projects may be instructive, but these investigations need to be stratified by mitigation type and the expected effect. In addition, any evaluation would benefit greatly from an updated infrared aerial photographic record. Current images should be compared with existing file photos taken in 1984 to identify changes in stream morphology and riparian vegetation. Changes outside the immediate project areas and large-scale fluvial processes (e.g. channel migration) may compromise the ability of enhancement measures to increase salmonid production.

Additionally, low adult returns constrain our ability to estimate carrying capacity estimates or determine the effect of habitat restrictions. While adult returns to Idaho in 2001 were higher than during many previous years, we do not know how these fish spread over the available habitat. Some measure of relative escapement is needed for each drainage. To link habitat conditions to salmon production, we need better integration with actual behavior and habitat use. Reach-level or site-level comparisons will likely be confounded by spatial autocorrelation. Future evaluations should take this into account.

Lastly, it would be more economical to conduct future physical habitat sampling and analysis in concert with a land management agency (e.g., the USFS) or academic institution that has personnel with training and experience in this arena. Methodological issues identified in this report must be resolved before data will be useful. A thorough review of analytical and field methods should be completed.

Table 11. Selected streams sampled in 2002 with mitigation project type, sample site comparison design, and type of data collected.

Drainage	Stream	Mitigation type[a]	Sample design	Data collected
South Fork Clearwater River				
	American River	None	Monitoring	parr
	Crooked River	OCD, PS, IS, BCR	Control/treatment	parr
	Red River	BCR, IS, RR	Control/treatment	parr
South Fork Salmon River				
	Johnson Creek	PS	Treatment	parr
	Lake Creek	None	Monitoring	parr
Middle Fork Salmon River				
	Big Creek	None	Monitoring	parr
	Bear Valley Creek	SC, RR	Treatment	parr & habitat
	Cape Horn Creek	None	Monitoring	parr
	Marsh Creek	RR	Treatment	parr & habitat
Upper Salmon River				
	Pole Creek	PS, RR	Treatment	habitat
	Salmon River	FA, RR	Treatment	habitat
	Valley Creek	PS, RR	Treatment	habitat

[a] BCR = Bank/Channel Rehabilitation, FA = Flow Augmentation, IS = In-stream Structure, OCD = Off-channel Development, PS = Passage, RR = Riparian Re-vegetation, SC = Sediment Control.

Table 12. Percentage of sites in each parr density category by drainage and across all drainages. Criteria for each category are given in the text.

	Density category			
Drainage	Excellent	Good	Fair	Poor
South Fork Clearwater	24	14	48	14
Middle Fork Salmon	0	11	72	17
South Fork Salmon	10	10	40	40
All drainages	12	12	55	20

Table 13. Percentage summary of the number of substrate samples that were observed to be composed of 25% or less fine sediments.

Stream	Pre-2002	2002
Salmon River	85%	60%
Valley Creek	76%	71%
Pole Creek	97%	91%
Bear Valley Creek	58%	36%
Weighted Average	83%	60%

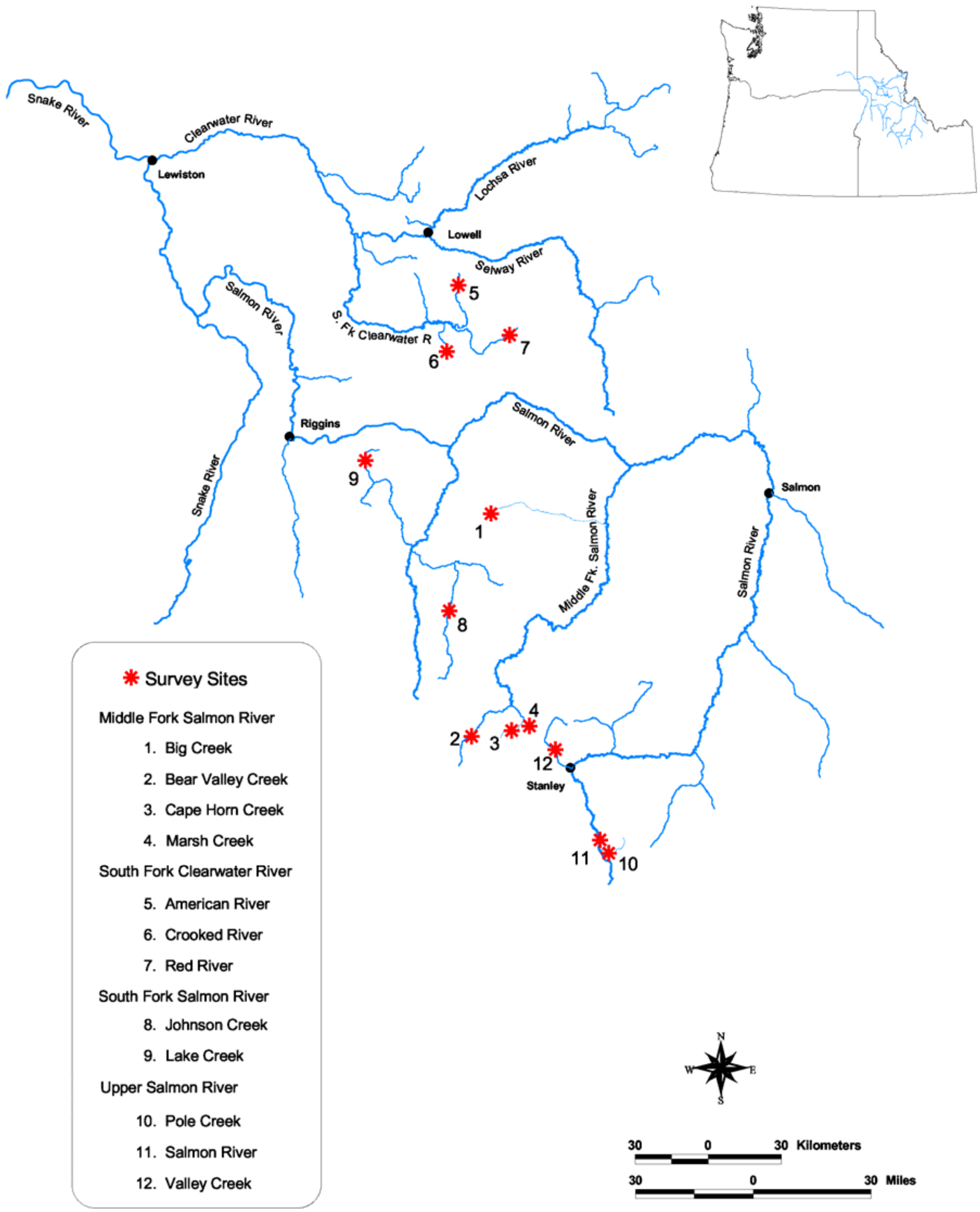


Figure 16. The four major Chinook salmon production drainages and associated streams selected for evaluating the effectiveness of habitat enhancement projects.

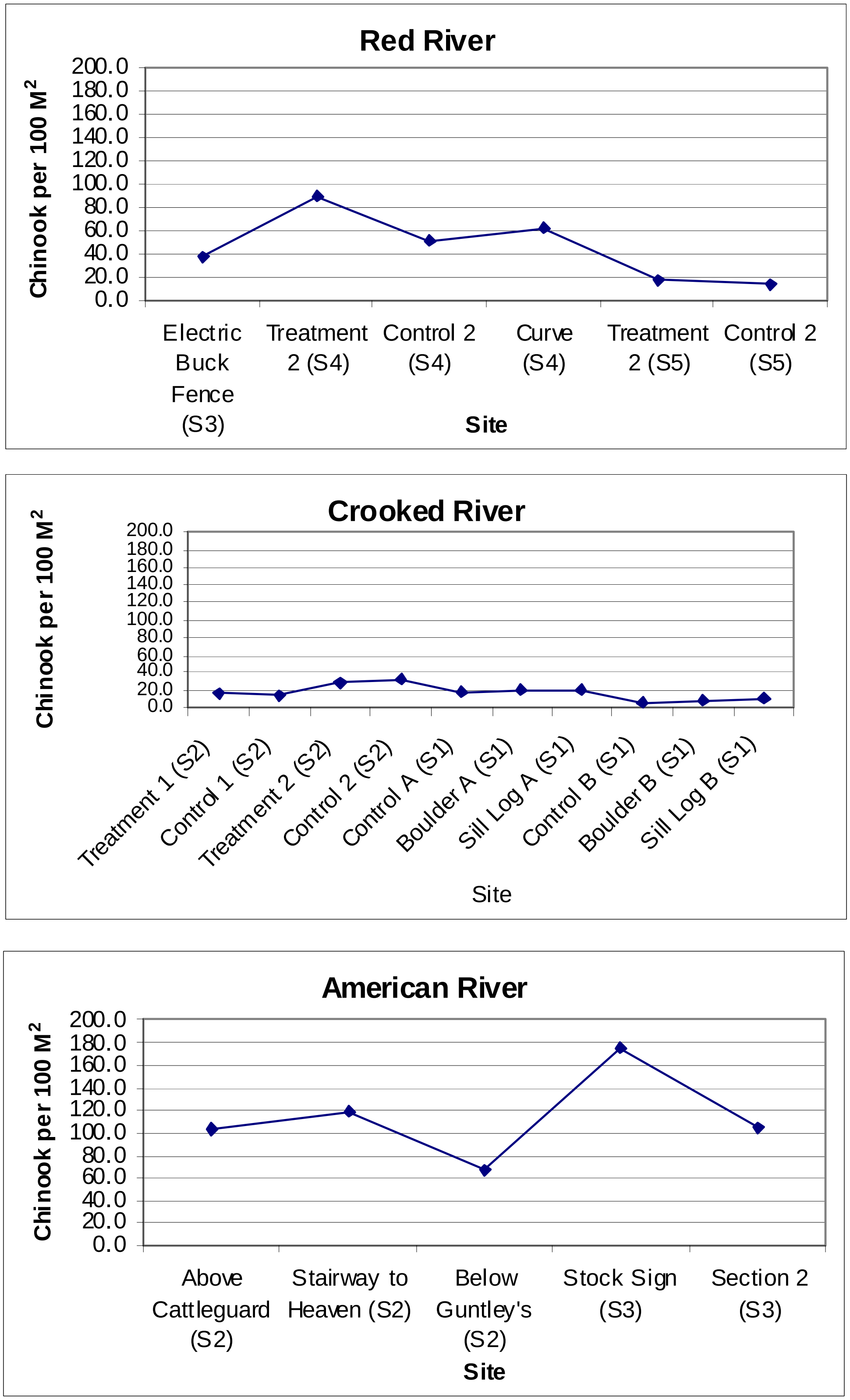
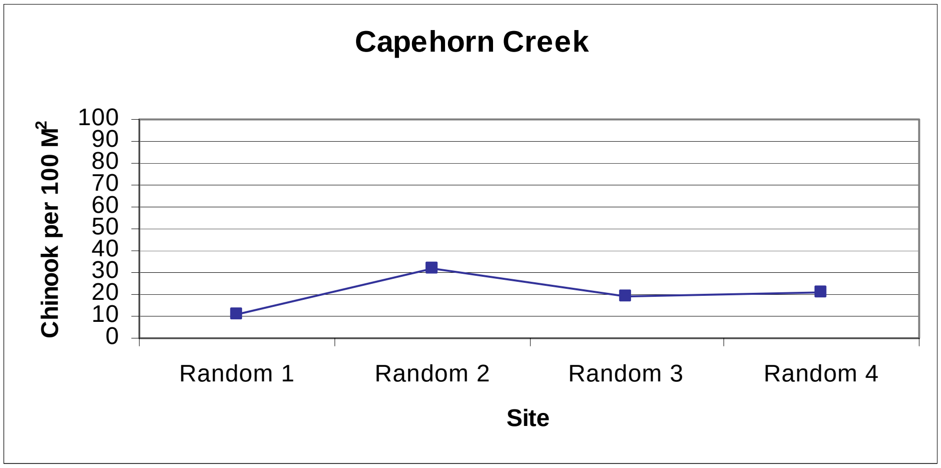
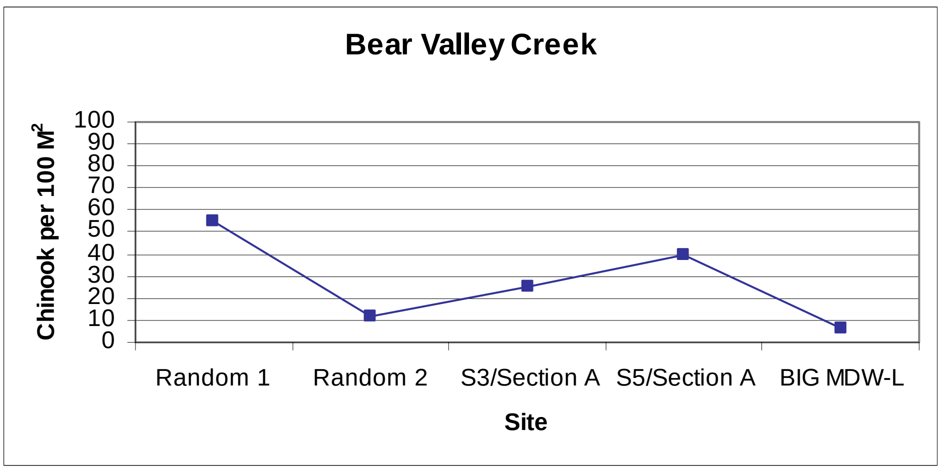


Figure 17. Observed Chinook salmon parr densities at South Fork Clearwater River study sites snorkeled in 2002.





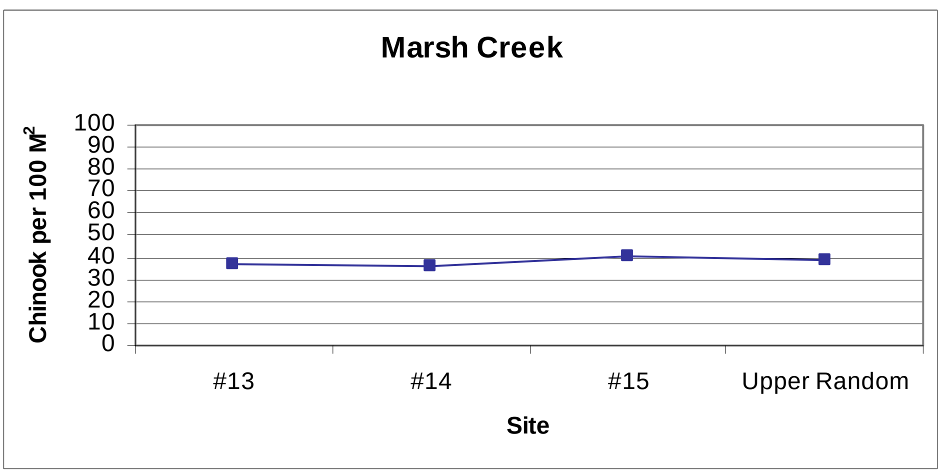
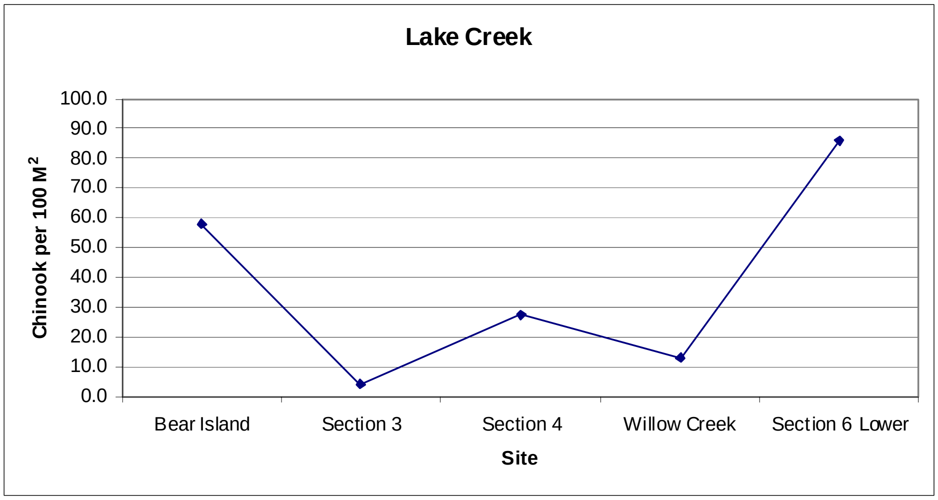
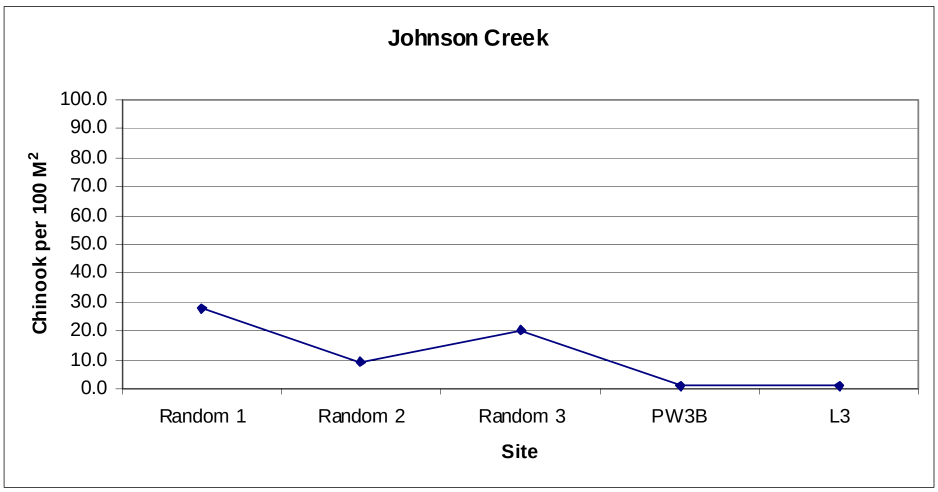


Figure 18. Observed salmon parr densities at upper Middle Fork Salmon River study sites snorkeled in 2002.





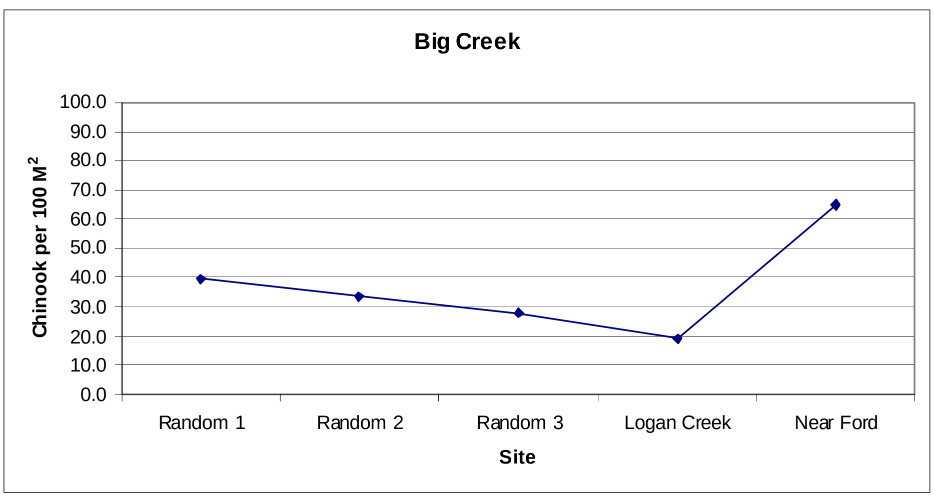


Figure 19. Observed Chinook salmon parr densities at sites snorkeled in the South Fork Salmon River drainage and Big Creek (lower Middle Fork Salmon River drainage) in 2002.

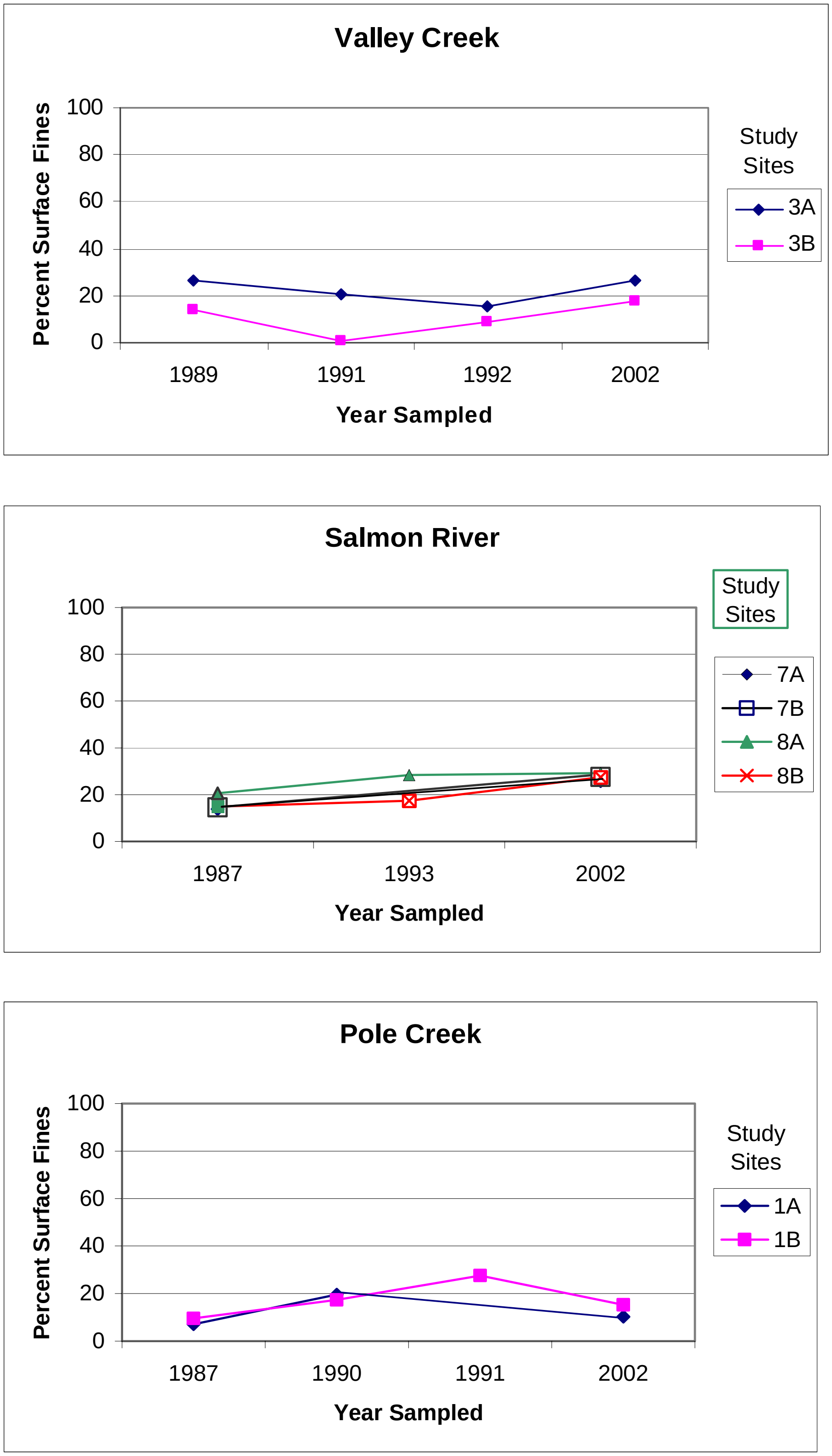


Figure 20. Estimated percent surface fines at upper Salmon River study sites sampled at least 10 years prior and again in 2002.

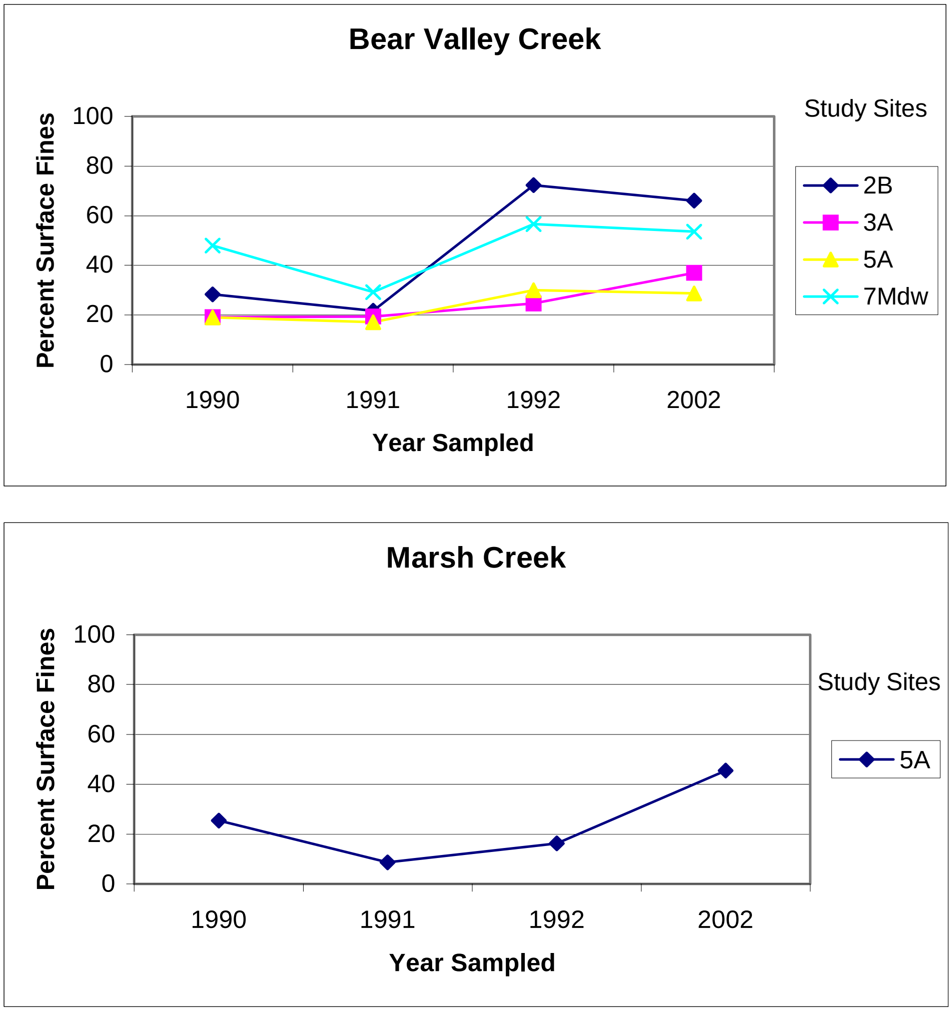


Figure 21. Estimated percent surface fines from upper Middle Fork Salmon River tributary stream study sites that were sampled at least 10 years prior and again in 2002.

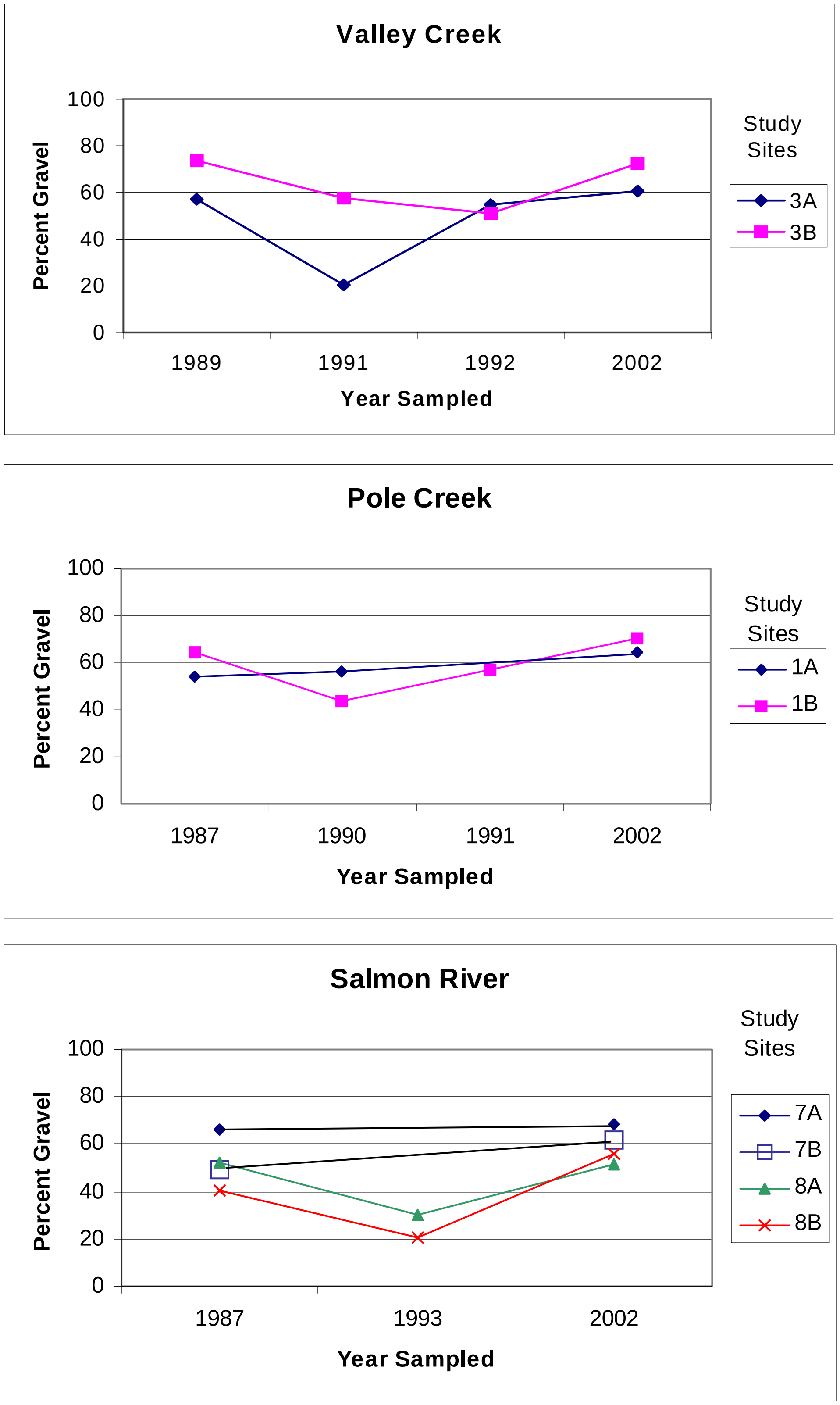
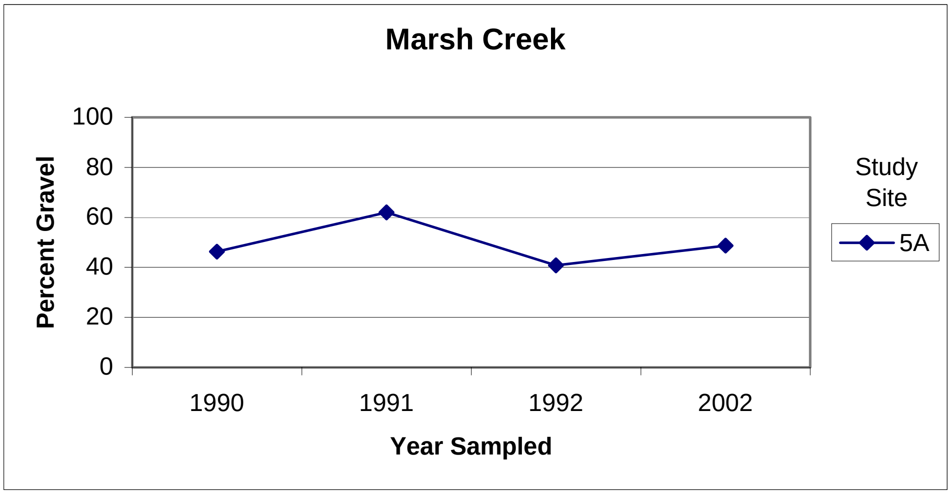


Figure 22. Estimated percent gravel from Upper Salmon River study sites that were sampled at least 10 years prior and again in 2002.



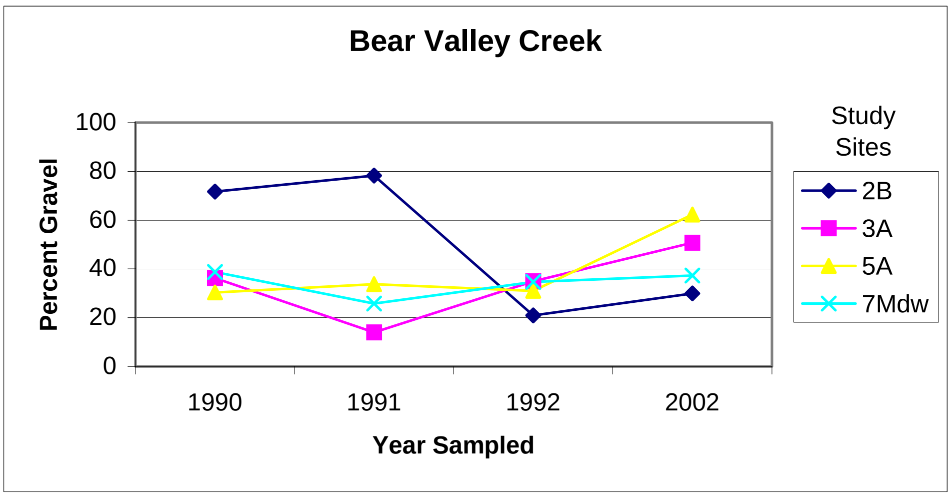


Figure 23. Estimated percent gravel from upper Middle Fork Salmon River tributary stream study sites that were sampled at least 10 years prior and again in 2002.

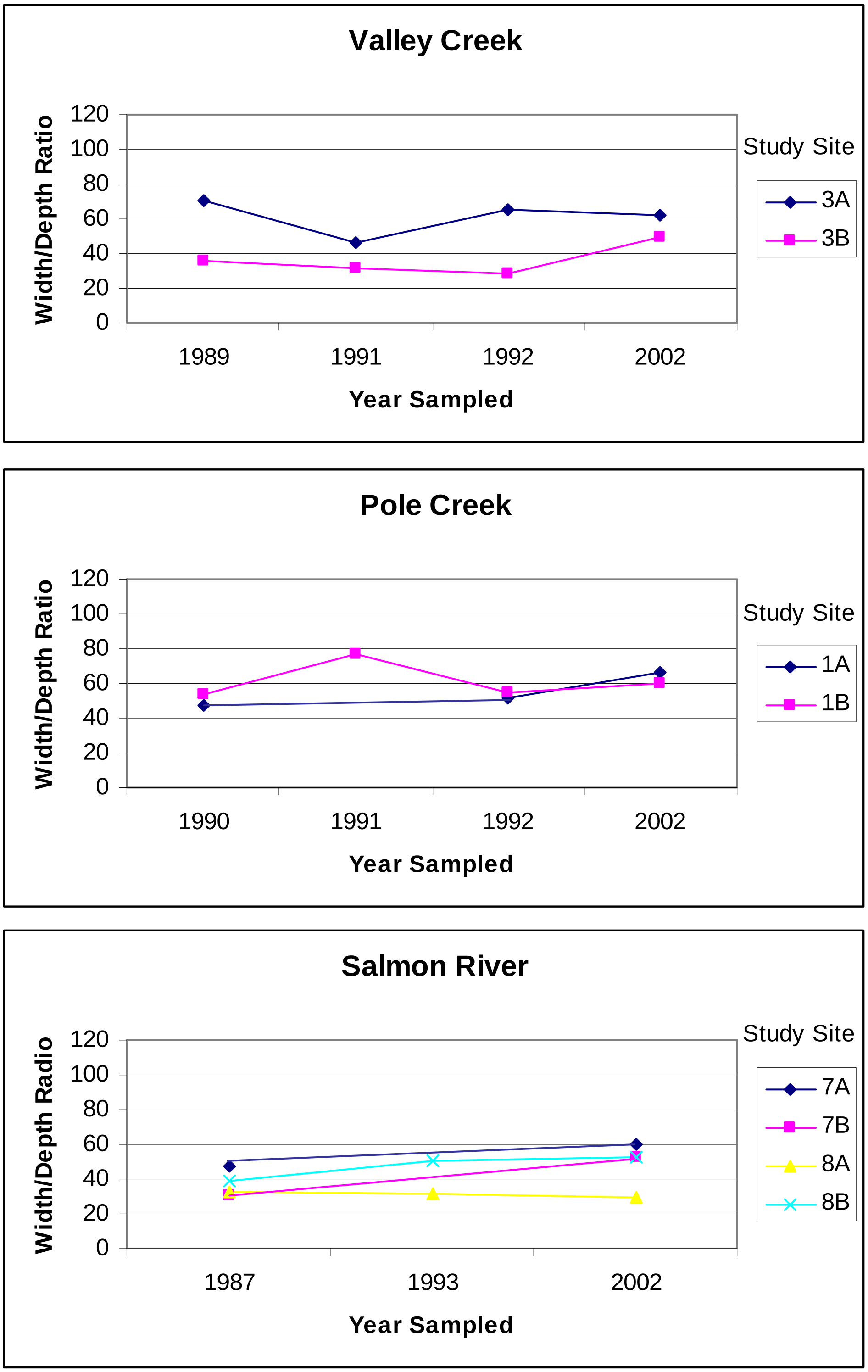
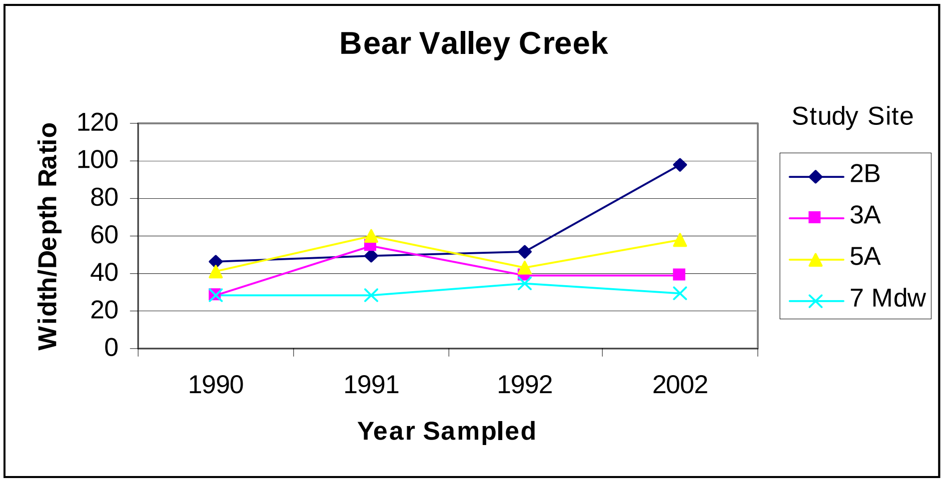


Figure 24. Width/depth ratios for the upper Salmon River drainage study sites that were sampled at least 10 years prior and again in 2002.



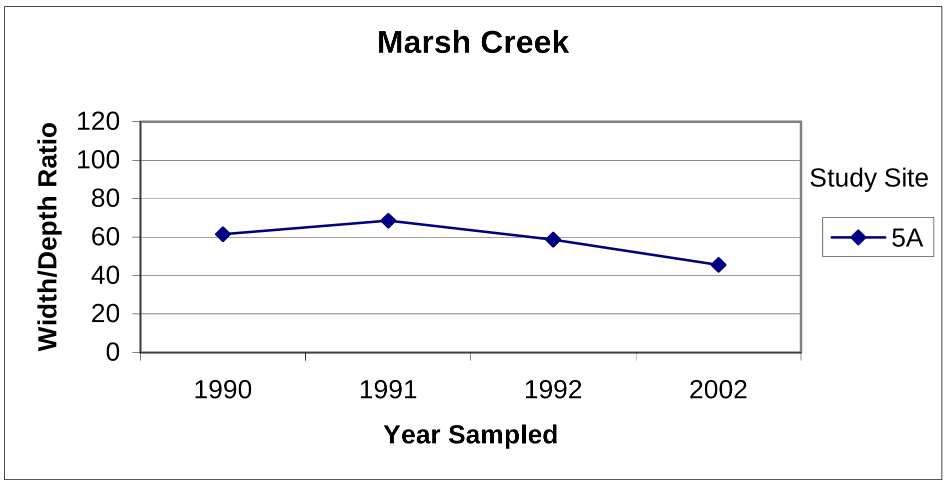


Figure 25. Width/depth ratios for upper Middle Fork Salmon River tributaries that were sampled at least 10 years prior and again in 2002.

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