ANNUAL PROGRESS REPORT

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INTRODUCTION

In most years the Willamette and Sandy rivers support intense recreational fisheries for spring chinook salmon (*Oncorhynchus tshawytscha*). Fisheries in these basins rely primarily on annual hatchery production of 5-8 million juveniles. Hatchery programs exist in the McKenzie, Middle Fork Willamette, North and South Santiams, Clackamas, and Sandy rivers mainly as mitigation for dams that blocked natural production areas. Some natural spawning occurs in all the major basins and a few smaller tributaries upstream of Willamette Falls.

The Oregon Fish and Wildlife Commission adopted a wild fish management policy to reduce adverse impacts of hatchery programs on wild native stocks (ODFW 1992). The main goal of the policy is to protect the genetic diversity of these stocks recognizing that genetic resources are a major component, not only in sustaining wild stocks, but also in perpetuating hatchery programs and the fisheries they support.

In the past, spring chinook salmon management in the Willamette and Sandy basins focused on hatchery and fish passage issues. Limited information was collected on the genetic structure among basin populations, abundance and distribution of natural spawning, or on strategies for reducing risks that large hatchery programs pose for wild salmon populations. This study is being implemented to gather this information. A schematic of the study plan is presented in **Appendix A**.

Work in 1998 was conducted in the mainstem Willamette River at Willamette Falls, and in the Middle Fork Willamette, McKenzie, North and South Santiams, Clackamas, and Sandy rivers. Basin descriptions and background information on management and fish runs can be found in subbasin plans developed by the Oregon Department of Fish and Wildlife (ODFW 1988, ODFW 1992a, ODFW 1992b, and ODFW 1996). Task headings below cross reference the study plan outlined in **Appendix A.** This report covers work completed in 1998 including some analyses of data collected in 1997.

TASK 1.1-- GENETIC SAMPLING

We completed collections of naturally-produced ("wild") spring chinook salmon in the Sandy, Clackamas, North Santiam, and McKenzie rivers for genetic analyses. Samples in the Sandy, Clackamas, and McKenzie rivers were collected in 1996 and 1997 (Table 1) (Grimes et al. 1996, Lindsay et al. 1997). The North Santiam River sample was collected with a screw trap placed at Mehama (RM 27) in December 1997. Because these fish were smaller than required for genetic testing (i.e. < 65 mm), they were reared until June 1998 at Marion Forks Hatchery. They were then processed for shipment by methods described by Lindsay et al. (1997) and shipped to the National Marine Fisheries Service (NMFS) in Port Orchard, Washington. The National Marine Fisheries Service conducted allozyme analyses by methods of Aebersold et al. (1987). These data are being used by NMFS in their ongoing status review of chinook salmon and have been included in NMFS's Pacific coast allozyme database. This database is primarily used for stock identification in mixed stock fisheries (David Teel, NMFS, personal communication December 8, 1998). Our primary interest in the analyses was to determine if genetic differences might be evident among natural and hatchery spring chinook salmon populations in the Willamette and Sandy basins. Hatchery spring chinook salmon collected at Dexter (Middle Fork Willamette), McKenzie, Marion Forks (North Santiam), and Clackamas hatcheries from 1982 to 1990 had been previously analyzed by NMFS.

Allozyme analyses showed that our samples of wild fish clustered with earlier samples of hatchery fish from Dexter, McKenzie, Marion Forks, and Clackamas hatcheries (David Teel, NMFS, personal communication December 8, 1998). Hatchery and wild fish were all of upper Willamette River origin. Upper Willamette spring chinook salmon are genetically distinct from two other major groupings of Columbia Basin chinook salmon, an ocean-type group and a stream-type group (David Teel, NMFS, personal communication December 8, 1998). The ocean-type group migrates as sub-yearlings and includes populations of spring and fall chinook in the lower Columbia River, summer and fall chinook in the mid and upper Columbia River, and fall chinook in the Snake River. The stream-type group migrates as yearlings and includes populations of spring chinook in the mid and upper Columbia River and spring and summer chinook in the Snake River.

Although samples of wild and hatchery spring chinook were genetically similar in the upper Willamette group, statistical tests showed that paired samples of hatchery and wild fish were not genetically homogenous (David Teel, NMFS, personal communication December 8, 1998). This suggests that groups of hatchery and wild fish within sub-basins could be genetically distinct. However, allozyme analysis is not sensitive enough to detect genetic differences at this level because electrophoretically detected alleles appear to be selectively-neutral, genetic markers (Utter et al. 1987).

In the Sandy River, spring-run salmon did not cluster with fall-run salmon, which has been the usual case with spring and fall chinook populations in lower Columbia River and Pacific coast tributaries (David Teel, NMFS, personal communication December 8, 1998). Sandy River fall chinook were clustered with the ocean-type group, whereas Sandy spring chinook were clustered with the upper Willamette group. Based on genetic distance values, Sandy spring chinook were most similar to spring chinook salmon in Clackamas, McKenzie, Dexter, and Kalama hatcheries and to the wild sample from the McKenzie River (David Teel, NMFS, personal communication December 8, 1998). The similarity of Sandy spring chinook salmon with those of upper Willamette River origin is likely a result of extensive stocking for many years of spring chinook salmon from Clackamas Hatchery into the Sandy River. However, by using DNA analysis, Bentzen et al. (1998) found that Sandy River spring chinook salmon were genetically distinguishable from Clackamas Hatchery chinook, although the level of differentiation was low. Bentzen et al. (1998) suggested that the Sandy River wild spring chinook population might retain a native genetic component.

Table 1. Naturally-produced spring chinook salmon collected from the Sandy, Clackamas, McKenzie, and North Santiam rivers and sent to NMFS for genetic analysis.

	Sandy	Clackamas	McKenzie	North Santiam
Date sampled:	Aug 1997	Nov, Dec 1996; Apr, May 1997	Oct 1997	Jun 1998
Location:	Salmon River	North Fork Dam	Leaburg Dam	Mehama
Method:	Seine	Trap	Trap	Trap
Number:	93	81	102	100
Mean fork length (mm):	81	131	Fingerling	86

TASK 1.2—THE PROPORTION OF WILD FISH IN NATURAL SPAWNING POPULATIONS

Implementation of Oregon's Wild Fish Management Policy (ODFW 1992), requires information on the hatchery and wild (naturally produced) components of fish runs. However, only a portion of the hatchery spring chinook salmon in the Willamette Basin had been fin clipped (adipose clip with coded-wire tags, AD+CWT) prior to the 1997 brood when all smolts were clipped and tagged. The use of scales to differentiate hatchery from wild fish was examined in 1996 and 1997 with little success (Lindsay et al. 1997). We are also evaluating the feasibility of using otoliths to separate hatchery fish from naturally produced fish. A program was begun in 1991 to place thermal marks in the otoliths of hatchery spring chinook by manipulating water temperatures during incubation by using methods of Brothers (1990) and Volk et al. (1990). Although all smolts beginning with the 1997 brood were supposed to be externally marked, several factors will result in some adults returning without clips (e.g. fish missed during marking, fin regeneration, release of unmarked pre-smolts). Otoliths may be useful in identifying hatchery fish that are not externally marked.

We began evaluating the quality of thermal marks in 1997 by analyzing (through the Washington Department of Fish and Wildlife) otoliths of juvenile fish that had been collected since 1993 as reference samples. Results of these analyses were used to recommend changes in marking procedures at the hatcheries. Work in 1998 included otolith analysis of juvenile salmon from the 1995-97 broods, and otolith collection and analysis of adult fish. Otoliths collected from adults in 1997 and 1998 are listed in **APPENDIX B.**

Methods

Water temperatures were manipulated at McKenzie, Marion Forks, and Willamette hatcheries to place a thermal mark on the otoliths of hatchery fish (Brothers 1990; Volk et al. 1990). Following experimental marking of the 1991 brood, hatchery releases have been thermally marked since the 1993 brood at McKenzie Hatchery and since the 1995 brood at Marion Forks Hatchery (Table 2). Thermal marking at Willamette Hatchery began with the 1997 brood. Clackamas and South Santiam stocks of spring chinook salmon have been incubated and thermally marked at McKenzie or Willamette hatcheries.

Juvenile fish, collected from 1995-97 broods, were sent to the Washington Department of Fish and Wildlife (WDFW) laboratory for analysis in 1998 (Table 2). Wild juvenile fish from the McKenzie River collected from the 1990, 1991, 1995, and 1996 broods were also sent to the lab as reference collections. Preparation and analysis of the otoliths were by methods described in Volk et al. (1990). Otoliths were examined with a compound microscope under 100x or 200x magnification to ascertain the presence or absence of thermal marks. Thermal marks were compared to temperature records and were evaluated for clarity.

We sent otoliths from 99 hatchery adult salmon of known age and origin (based on coded-wire tags) to the Washington lab to test their ability to detect thermal marks. Of these samples, 49 were 1993 brood McKenzie fish that should have had a thermal mark, and 50 were from hatchery releases that were not thermally marked (1992 brood McKenzie stock, and 1992 and 1993 brood Willamette stock). The otoliths were put into randomly numbered vials before being sent to the lab.

Results and Discussion

Juveniles

Analysis of the thermal marking conducted in the upper Willamette basin hatcheries indicated mixed results in placing an identifiable thermal mark on otoliths, although good thermal marks were more consistently seen in fish from recent brood years (Table 3). However, the analysis did indicate the persistence of some problems in marking fish.

Temperature differentials at McKenzie Hatchery were generally less than what is considered optimum, but thermal marks were recognized in fry (Table 3). Additional "marks" were seen in some of the samples, possibly because of natural temperature fluctuations or stresses during incubation. Although thermal marks can be created with temperature differentials of less than 8° F (Volk et al. 1990), extra time is required to prepare and analyze the otoliths, and recognizable patterns can still be difficult to identify (Grimm and Volk, 1998).

Table 2. Data on thermal marking of spring chinook salmon in Willamette River hatcheries and collection of reference samples. Reference samples were salmon fry (35-50 mm).

Brood year	Stock	Reference sample size	Treatment (hrs on/off)	Temperature differential[a] (°F)	Cycles	Comments
1997	McKenzie	31	Chilled (24/48)	5-8	4	Marked at McKenzie H.
	McKenzie	20	Heated (48/48)	9-12	4	Marked at Willamette H.
	N. Santiam	30	Heated (24/24)	8-10	5	
	Willamette	25	Heated (48/48)	5-9	4	Early egg take
	Willamette	26	Heated (48/48)	13-16	4	Late egg take
	Clackamas	20	Heated (48/48)	8-10	4	Marked at Willamette H.
1996	McKenzie	21	Chilled (24/72)	5-6	6	
	N. Santiam	34	Heated (24/24)	10-12	4	
1995	McKenzie	26	Chilled (24/72)	5-6	4	
	N. Santiam	48	Heated (24/24)	11-14	4	
1994	McKenzie	17	Chilled (24/72)	5-6	5	
	N. Santiam	21	Heated[b]	2-9	b	Uneven cycles
1993	McKenzie	30	Chilled (24/96)	3-6	4	Marked at McKenzie H.
	McKenzie	29	Heated (12/48)	4-6	8	Marked at Marion Forks H.
	N. Santiam	c	Heated[c]	2-14	c	Uneven cycles

[a] *Difference in temperature between heated or chilled treatment and ambient incubation water..*
[b] *9 days on/2 days off, 10 days on/3 days off, 20 days on.*
[c] *2-20 days on heated water, with 1-2 days on unheated water for three groups; 12-13 days on heated water for two groups; no samples were collected.*

Although thermal marks at Willamette Hatchery were generally good (Table 3), additional "marks" were also seen in some of these samples. The additional marks in otoliths may mask the presence of a thermal pattern in adults and may increase the difficulty in identifying induced marks. Thermal marking improved at Marion Forks Hatchery in the 1995-97 broods compared to previous years, and good thermal marks were seen in the otoliths (Table 3). However, the thermal pattern was compact (i.e. several thermal events in a short period of time), which could make recognition of marks in adults difficult.

Because the Willamette salmon hatcheries use stream water to incubate fish, natural daily fluctuations in water temperature can produce a visual pattern in otoliths that can mimic or obscure the induced marking pattern. Providing adequate temperature differentials is particularly important in these facilities. Many regularly spaced, 24-hour manipulations of temperature (e.g. eight 24-hour cold water events, each separated by two days of warm water) are needed to create a pattern that is discernable from the background pattern caused by natural temperature fluctuations (Grimm and Volk 1998). Thermal marking prior to hatching would also increase the distinctiveness of the hatchery-induced marks. An attempt was made to place pre-hatch marks on a group of 1997 brood Clackamas fish at Willamette Hatchery. However, eggs began hatching before the marking was completed and the marks were judged fair to good (Table 3). Hatching can cause a "mark" in otoliths.

Adults

Eighty-four percent of the otoliths from adult salmon that had been thermally marked were correctly identified in a test to determine the accuracy of detecting thermal marks (Table 4). However, just 34% of the fish that were not thermally marked were correctly identified (Table 4). The otolith readers tended to see thermal marks in both marked and unmarked samples (Table 4). The only known "unmarked" fish we had available for this test were hatchery fish from broods that were not thermally marked. Otoliths from hatchery fish can have patterns that faintly resemble induced marks because of temperature fluctuations and handling stresses during incubation. In addition, the thermal pattern in the 1993 brood McKenzie fish was judged "fair" in the fry reference collection. Therefore, this test may not be indicative of WDFW's ability to separate hatchery fish from wild fish based on thermal patterns in otoliths.

Table 3. Results of otolith analysis by Washington Department of Fish and Wildlife to detect thermal marks in juvenile spring chinook salmon from the 1993-97 brood years.

Brood year	Stock	Marking hatchery	Thermal marks?	Clarity
1997	McKenzie	McKenzie	Yes	Good
	McKenzie – middle egg take	Willamette	Yes	Fair - Good
	N. Santiam	Marion Forks	Yes	Good
	Willamette – early egg take	Willamette	Yes	Good
	Willamette – late egg take	Willamette	Yes	Good
	Clackamas – pre-hatch/hatch	Willamette	Yes	Fair - Good
1996	McKenzie	McKenzie	Yes	Fair
	N. Santiam	Marion Forks	Yes	Good
1995	McKenzie	McKenzie	Yes	Good
	N. Santiam	Marion Forks	Yes	Good
1994	McKenzie	McKenzie	Yes	Fair
	N. Santiam	Marion Forks	No	--
1993	McKenzie	McKenzie	Yes	Fair
	McKenzie	Marion Forks	Yes	Good
	McKenzie	Willamette	No	--

Otoliths from 44 wild juvenile salmon were collected from several brood years in the McKenzie River. Analysis of these samples indicated that naturally occurring otolith patterns were not present in most of the wild fish. However, two wild smolts in the sample of 1990 brood fish had otolith patterns similar to artificial thermal marks. A second test sample of otoliths from known wild and hatchery juvenile fish (1997 brood) was sent to the Washington lab for analysis in November 1998. Results should be available in March 1999 and should clarify the question of whether or not thermal marks in chinook from Willamette Basin hatcheries can be used to separate wild fish from hatchery fish that have not been externally marked.

Table 4. Results of analysis to identify thermal marks in the otoliths of 49 thermally marked and 50 unmarked adult spring chinook salmon, 1998. The otoliths were sent in randomly numbered vials to the WDFW lab for analysis.

	Classification	
Group, stock	Correct	Incorrect
Thermally marked:		
1993 McKenzie	41	8
Not thermally marked:		
1992 McKenzie	4	14
1992 Willamette	9	9
1993 Willamette	4	10

TASK 1.3-- DISTRIBUTION AND ABUNDANCE OF NATURAL SPAWNERS

We documented the geographic distribution, timing, and magnitude of natural spawning of spring chinook salmon in the North Santiam, Clackamas, and Sandy basins in 1998 similar to 1996 and 1997. The McKenzie River above Leaburg Dam was not surveyed in 1998. General methods used on spawning surveys were reported in Grimes et al. (1996) and Lindsay et al. (1997). In addition, in 1998 we added spawning surveys in the lower Clackamas River, the South Santiam River, the Santiam below the confluence of the north and south forks, the lower McKenzie River, the Middle Fork Willamette, and the mainstem Willamette below the confluence of the McKenzie River. Data collected from salmon carcasses during the surveys in 1998 were similar to that collected in 1996 (Grimes et al. 1996) and 1997 (Lindsay et al. 1997).

Spawning Ground Surveys in the North Santiam River Basin

Sections of the mainstem North Santiam River between Minto Dam (RM 43.5) and Greens Bridge (RM 3.0) were surveyed between two and nine times in 1998 (Table 5). We surveyed from Greens Bridge to the mouth only once. Migration is blocked at Minto Dam. Some spawning activity was found in all sections surveyed except in the 3.5-mile section above Gerren Island (RM 20) and the 5.5-mile section between Stayton (RM 16.7) and Shellburn (RM 11.2). Surveys began September 4 and ended on October 19.

Table 5. Summary of chinook salmon spawning surveys for the North Santiam River, 1998.

Race and survey section	Length (mi)	1998 Counts		1998 redds/ mile	1997 redds/ mile	1996 redds/ mile
		Carcasses	Redds			
Spring chinook:						
Minto - Fishermen's Bend	10.0	172	118	11.8	8.5	7.8
Fishermen's Bend - Mehama	6.5	79	28	4.3	2.5	3.5
Mehama - Stayton	10.3	7	4	3.6	1.7	2.0
Stayton - Greens Bridge[a]	13.7	4	5	0.4	1.1	0.1
Little North Santiam	17.0	8	39	2.3	0.5	0.0
Fall chinook:						
Stayton - Greens Bridge[a]	13.7	40	59	4.3	9.6	0.9
Greens Bridge – mouth	3.0	1	14	4.7	--	--

[a] *Total chinook redds and carcasses were apportioned into 8% spring and 92% fall race based on analysis of scales from carcasses.*

We collected scales from carcasses to separate chinook salmon into spring and fall races based on life history patterns (Table 6). Tule fall chinook salmon have a sub-yearling migrant life history while spring chinook salmon on the North Santiam have a yearling migrant life history pattern (Lisa Borgerson, ODFW Scale Analyst, personal communication).

Spawning activity for spring chinook was highest in the 10 mile reach from Minto to Fisherman's Bend (RM 33.5). Redd density for spring chinook in this uppermost section (11.8 redds/mile) was higher than any other surveyed in the North Santiam River. Spawning activity for fall chinook was highest in the eight-mile braided channel reach between Shellburn and Greens Bridge. The relative distribution of spring chinook redds within the North Santiam basin in 1998 was similar to that observed in 1996 and 1997, with the greatest number of spawners in the upper mainstem areas (Figure 1).

We surveyed sections of the Little North Fork Santiam River on three dates, between 30 September and 19 October. We observed 38 redds in the Little North Santiam and recovered eight carcasses. The number of redds was a 280% increase over 1997 levels. In contrast, the mainstem sections of the North Santiam River in 1998 increased just 16% increase over 1997 levels.

Table 6. Overlap of spring and fall chinook salmon in the Santiam River basin based on scale patterns from recovered carcasses, 1998.

Section	Number of carcasses: Fall chinook	Number of carcasses: Spring chinook	Percent spring chinook
North Santiam:			
Minto - Fishermen's Bend	3	127	95
Fishermen's Bend - Mehama	2	45	96
Little North Fork Santiam	0	7	100
Mehama – Gerren Island	0	3	100
Gerren Island - Stayton	1	2	67
Stayton - Greens Bridge	33	3	8
Green's Bridge – mouth	2	0	0

For the first time in the three years we have been surveying the North Santiam, the time of peak spawning varied between river sections (Table 7). Peak spawning of spring chinook in the uppermost section, Minto to Fishermen's Bend, occurred during September 15-19. This was similar to 1997 and about 1 week earlier than peak spawning in the same section in 1996 (Figure 2). Peak spawning for the other regularly surveyed section, Fishermen's Bend to Mehama, occurred three weeks later, October 5-8. The peak spawning time for sections downstream of Mehama and in the Little North Santiam could not be determined because they were not surveyed regularly.

ODFW district personnel sampled spring chinook salmon and steelhead at fishways on Upper and Lower Bennett dams on the North Santiam River near Stayton with methodology similar to that used in 1996 and 1997 (Grimes et al 1996, Lindsay et al 1997). Almost 1,200 spring chinook and 2,000 summer steelhead were handled at the fishways. A portion of the summer steelhead and spring chinook passed were

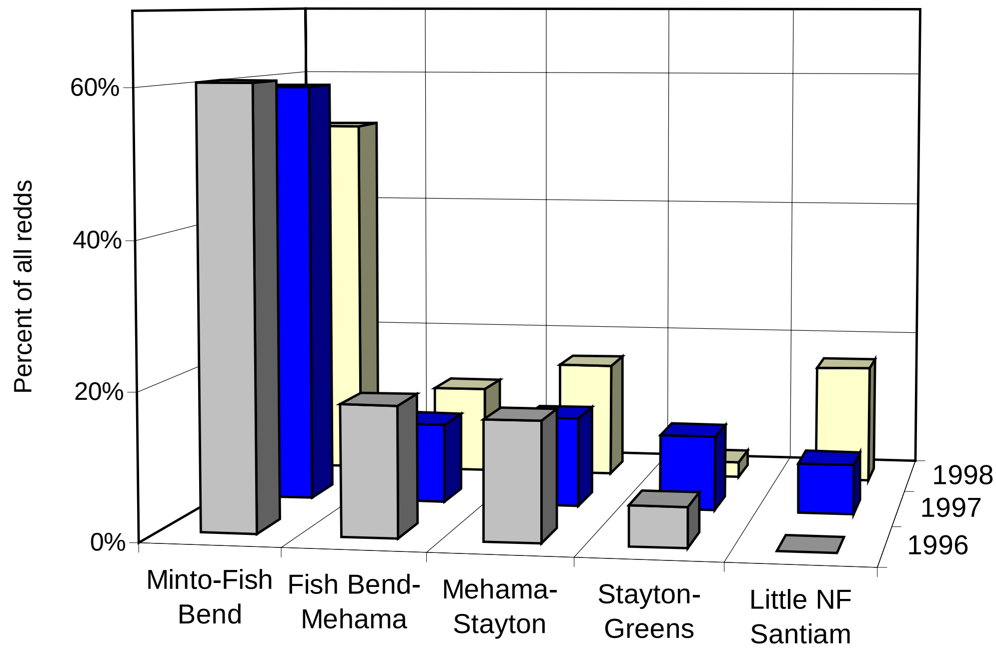

Figure 1. Distribution of spring chinook redds in the North Santiam by area for 1996-98.

Table 7. Redd counts of spring chinook salmon by survey date in sections of the North Santiam River, 1998. Only redds not previously counted were included in each survey cycle.

Location	Survey cycle								
	Aug 26-30	Sep 1-4	Sep 8-11	Sep 14-17	Sep 21-24	Sep 28-Oct 2	Oct 5-8	Oct 12-15	Oct 19-22
Minto-Fisherman's Bend	[a]	9	[a]	63	15	27	3	1	[a]
Fisherman's Bend-Mehama	0	0	0	1	6	7	11	3	0

[a] *No survey was conducted.*

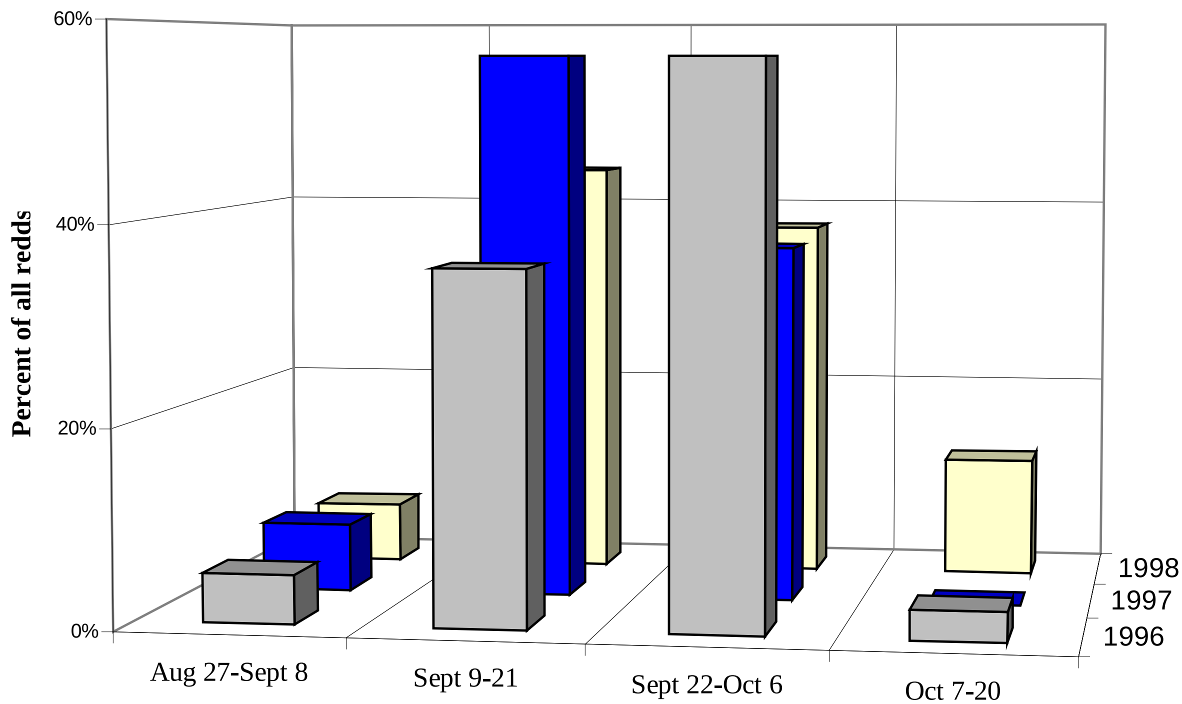

Figure 2. Timing of spring chinook spawning in the North Santiam River (RM 27-43.5) for 1996-98.

marked in the caudal fin with a paper punch to assess fallback at each dam. The fallback rate at Upper Bennett Dam was 4.5% for spring chinook and 15.4% for summer steelhead. The fallback rate at Lower Bennett Dam was 17.7% for summer steelhead but could not be determined for spring chinook because few used that fishway. An expansion of the fishway counts for unsampled days, adjusted for fallback, yielded passage estimates of 2,150 spring chinook and 3,182 summer steelhead above the dams. Passage for spring chinook at Upper and Lower Bennett dams peaked in late May and early June (Figure 3).

We were unable to estimate pre-spawning mortality in the North Santiam River above Stayton in 1998 with the methodology used in 1996 (Grimes et al. 1996). Previously we had used passage at Bennett dams, estimates of harvest mortality, sex ratio, and returns to Minto trap at Minto Dam (a collection facility used by Marion Forks Hatchery to collect broodstock for hatchery programs) to estimate the number of potential spawners. A comparison of that number to the number of redds we observed in the basin above Stayton allowed us to estimate the number of fish that died prior to spawning. However, in 1998 all the estimated escapement over Bennett dams could be accounted for in harvest and at Minto trap, yet we counted 189 redds above the dams.

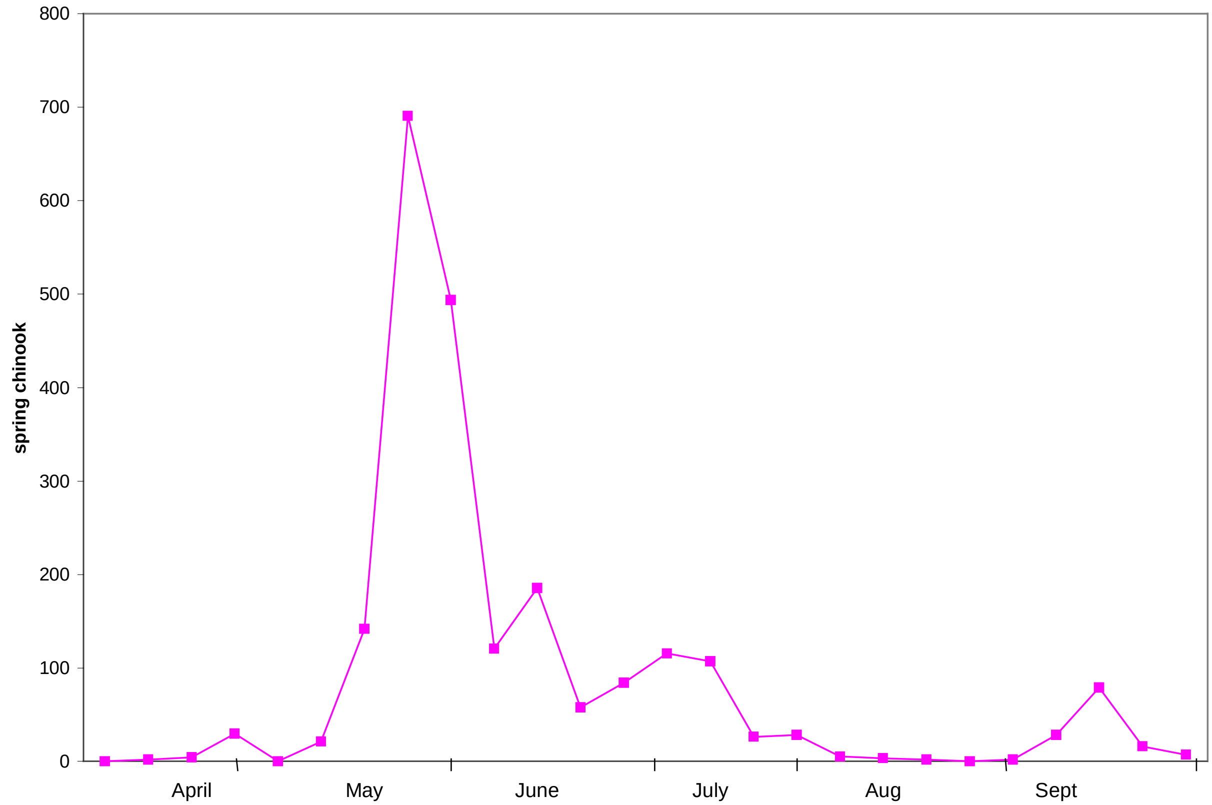

Figure 3. Weekly passage of spring chinook at Upper and Lower Bennett dams on the North Santiam, 1998.

Although passage counts over Bennett Dams near Stayton may have been in error, we believe fallback was adequately assessed and estimated passage has been adjusted accordingly. Our modeling estimate of 20% harvest (used in previous years) may be high, but 65 spring chinook were sampled in a creel survey program from the area above the Bennett dams. A harvest rate estimate for spring chinook salmon in the North Santiam has not been completed. A total of 2,067 spring chinook were processed at Minto trap. Some were used for broodstock (574), some were killed and buried (339), and some were passed above the barrier dam (1,297). We believe some hatchery adults released above the barrier dam at Minto fell back over the dam and were double counted upon re-entry into the trap facility. It is also likely that some of the 189 redds we counted were from fish that fell back over Minto Dam. The section of the North Santiam immediately below Minto dam is heavily used by spring chinook for spawning. We recommend that fish passed over the barrier dam at Minto be externally marked to identify those that fall back and spawn or re-enter Minto trap.

Spawning Ground Surveys in the Clackamas River Basin

Upper Clackamas River Basin

We surveyed nearly 67 miles of Clackamas basin streams above North Fork Dam in 1998, and counted 380 redds (Table 8). As in 1996 and 1997, sections of the mainstem Clackamas River were the most important spawning areas, accounting for 85% of the redds and 95% of the carcasses (Table 8).

The number of redds counted in the basin in 1998 was similar to 1997 counts and two times higher than the 1996 counts. We counted more redds in 1998 than in 1997 (range of 19% to 56%) in all sections of the mainstem Clackamas, with the exception of the section from Cripple Creek to South Fork Clackamas where the number of redds was 30% lower in 1998. We counted fewer redds in 1998 than in 1997 (range -10% to -50 %) in the Collawash and Roaring rivers and in Fish Creek. We recovered 88 carcasses in 1998 (Table 9), compared to 73 and 17 carcasses in 1997 and 1996, respectively.

The general distribution of redds in the basin was similar in all three years, although shifts of relative contribution between sections occurred (Figure 4). Several factors that could affect the relative distribution of redds in the basin include ongoing changes in gravel distribution following floods in 1996 and 1997, and differences in base stream flow and autumn rainfall between years.

We conducted an early survey (August 20) in the Sisi Creek - Forest Road 4650 section (commonly known as Big Bottom) in 1998 in an attempt to document early spring chinook spawners. In 1997 we counted redds in this area during our first survey in late August. However, in 1998 we did not see any spawning in the Big Bottom area until September 3. Spring chinook spawning in late summer and early fall has been observed historically in the Big Bottom area (personal communication, D. Cramer, Portland General Electric). Although we did not observe early spawning in 1998, the documentation of August spawning in 1997 suggests a small segment of these early spawners may persist. We also saw coho salmon in late September in the upper Clackamas just below the Big Bottom section. Spawning coho salmon were observed in the upper Clackamas River in 1997, using the same gravel areas as spring chinook salmon and digging redds on top of spring chinook redds in some instances.

Based on surveys in core sections, peak spawning in the upper Clackamas Basin occurred in late September to early October, during the third and fourth survey cycles (Table 10). Seventy-three percent of the total redds were counted during those three weeks. However, the percentage of redds counted during this time period varied among the individual sections from 51% in the Clackamas River below Cripple Creek to 96% in the Clackamas section immediately below the confluence with the Collawash (Table 10). Peak spawning for spring chinook salmon occurred during the same two-week period in 1996-98 (Figure 5). In all three years, spawning in the tributary streams began after significant rainfall in mid to late September.

Table 8. Summary of spawning surveys for spring chinook salmon in the Clackamas River above North Fork Dam, 1998. Data for shorter survey sections are shown in **APPENDIX C**.

Survey section	Length (mi.)	Counts: Live fish	Counts: Carcasses[a]	Counts: Redds	1998 redds/ mile	1997 redds/ mile	1996 redds/ mile
Clackamas River:							
Sisi Creek - Forest Rd 4650	9.1	98	14	87	9.6	7.5	3.2
Forest Rd 4650 - Collawash River	8.0	110	12	56	7.0	5.9	4.1
Collawash River - Cripple Creek	8.5	190	46	97	11.4	7.3	6.1
Cripple Creek - South Fork	14.5	86	34	76	5.2	7.4	3.2[b]
South Fork - Reservoir	1.0	12	3	7	7.0	17.0	--
Collawash River:							
Collawash Falls - Mouth[c]	7.5	46	6	43	5.7	6.4	1.6
Hot Springs Fork:							
Pegleg Falls - Mouth[d]	5.0	0	0	0	0.0	0.2	0.0
Pinhead Creek:							
Last Creek - mouth	1.0	0	0	0	0.0	0.0	0.0
Roaring River:							
Falls - mouth	2.0	5	0	3	1.5	3.0	3.0
Fish Creek:							
Silk Creek - mouth	4.7	1	0	8	1.7	2.6	1.1[e]
South Fork Clackamas River:							
Falls - mouth	0.6	3	0	3	5.0	11.7	--
North Fork Clackamas River:							
Fall Creek - mouth	1.5	0	0	0	0.0	0.0	0.0
Total	63.4	551	115	380	6.0	6.0	2.9

[a] *Includes carcasses that were seen but not sampled.*
[b] *This section was 0.5 miles shorter in 1996.*
[c] *2.0 miles upstream of Collawash Falls were surveyed; no fish or redds counted.*
[d] *1.3 miles upstream of Pegleg Falls were surveyed; no fish or redds counted.*
[e] *This section was 0.2 miles shorter in 1996.*

Table 9. Information collected on spring chinook salmon carcasses in spawning ground surveys in the upper Clackamas and upper Sandy basins, 1998.

River, sex	Number	Mean length (mm)	Number unspawned	Adipose fin clips
Upper Clackamas:[a]				
Males	41	905	--	1
Females	44	857	4	0
Unknown	3	860	--	0
Lower Clackamas:[b]				
Males	11	921	--	1
Females	13	890	0	0
Unknown	0	--	--	0
Sandy:				
Males	91	918	--	2
Females	81	872	2	1
Unknown	3	800	--	0

[a] *Above North Fork Dam.*
[b] *River Mill Dam to mouth. Fall chinook salmon were also collected: 8 males (913 mm) and 19 females (859 mm).*

The ratio of the North Fork Dam adult count (1,382 one week prior to the last survey) to the redd count (380) was 3.6:1 in 1998, and the 1996-98 average was 3.8:1 (**APPENDIX C**). We were able to account for about 55% of the fish passing over North Fork Dam in 1998, compared to an average of 52% for the previous two years (Figure 6). These estimates assume that each redd we counted was made by two spawners and that the sex ratio is 1:1 (from Clackamas Hatchery counts). Based on the extensive surveys conducted in all three years, we believe there are not large spawning areas that remain to be identified in the basin. Although some redds in the survey areas could be missed entirely or may not be counted if multiple redds are present, we believe these are relatively minor sources of error. At this time, we believe most of the unaccounted spawners are lost to pre-spawning mortality.

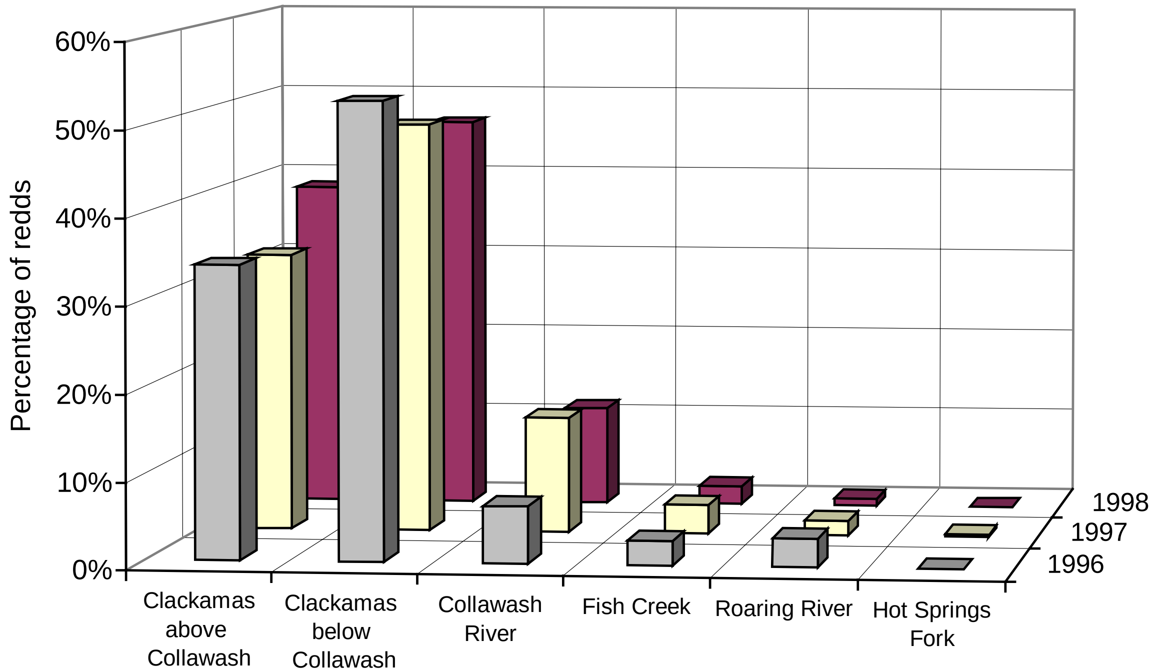

Figure 4. Geographical distribution of spawning for spring chinook salmon in the Clackamas River Basin upstream of North Fork Dam, 1996-98. Only for those areas surveyed in all three years.

Table 10. Redd counts of spring chinook salmon by survey cycle in core sections of the upper Clackamas River Basin, 1998. Only redds not previously counted were included in each survey period.

	Survey cycles					
Survey section	Aug 22-Sep 2	Sep 3-14	Sep 15-26	Sep 27-Oct 8	Oct 9-20	Oct 21-Nov 1
Pinhead Creek - Road 4650	1	28	34	23	2	--
Road 4650-Collawash River	--	7	35	10	4	0
Collawash- Cripple Creek	--	0	62	31	4	--
Cripple Cr.– South Fork Clackamas	--	13	30	9	22	2
Collawash River[a]	--	1	18	12	10	2
Total	1	49	179	85	42	4

[a] *Hot Springs Fork to mouth.*

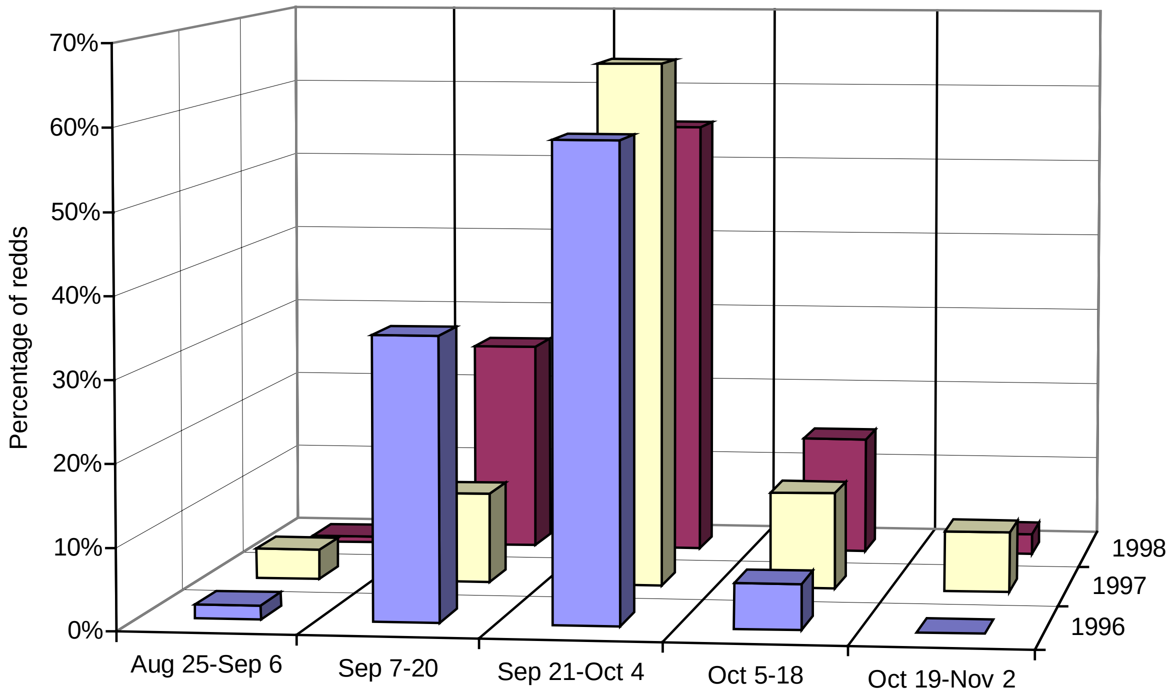

Figure 5. Timing of spring chinook salmon spawning in the Clackamas River Basin upstream of North Fork Dam, 1996-98.

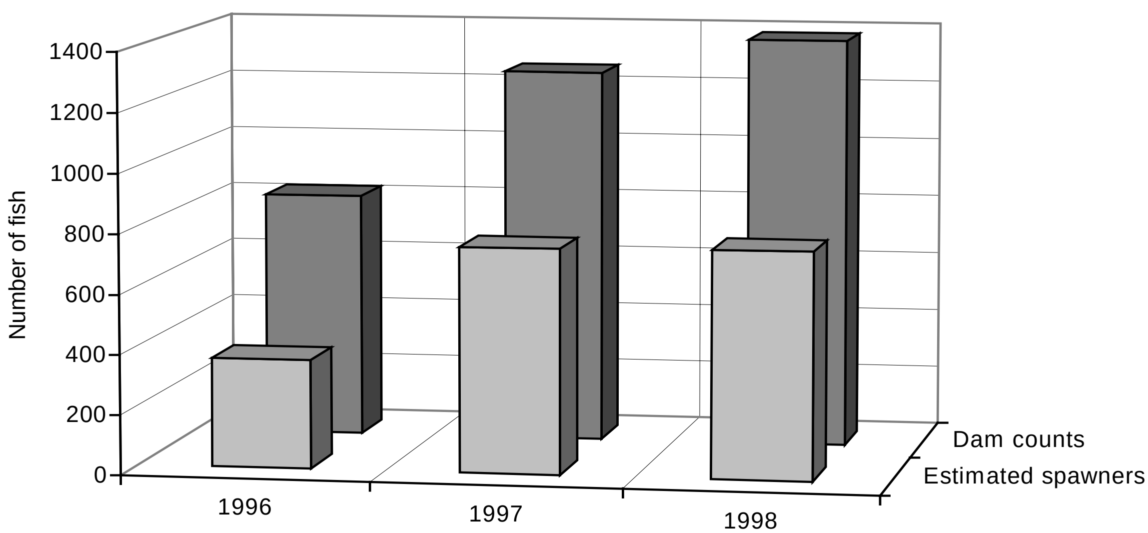

Figure 6. Comparison of spring chinook salmon passing over North Fork Dam on the Clackamas River and the estimated number of spawners above the dam, 1996-98. Dam counts are the total adult fish past the dam up to one week before the last spawning survey. Spawners are estimated from redd counts assuming a 1:1 sex ratio and two fish per redd.

Lower Clackamas River

We conducted a survey on 30 September and 1 October in the Clackamas River from River Mill Dam (RM 23) to the mouth. We counted 178 redds, 78 carcasses, and 116 live chinook below the dam. Analysis of scales collected from carcasses indicated that 47% were spring chinook (41% of females and 58% of males), and the remainder were fall chinook (Table 11). As expected, the percentage of spring chinook in the lower Clackamas was highest in the uppermost section and declined downstream (Table 11). Based on the percentage of spring chinook females, we estimated there were approximately 48 spring chinook redds in the lower river (Table 12), for a density of 2.1 redds/mi compared to a density of 6.0 redds/mi in the upper basin.

Table 11. Overlap of spring and fall chinook salmon in the Clackamas River below River Mill Dam based on scale patterns from recovered carcasses, 1998.

Section	Number of carcasses: Fall chinook	Number of carcasses: Spring chinook	Percent spring chinook
River Mill Dam – Barton Park	12	19	61
Barton Park – Carver	5	3	38
Carver – mouth	9	1	10

Table 12. Summary of spawning surveys for spring chinook salmon in the Clackamas River below River Mill Dam, 1998.

Survey section	Length (mi.)	Counts[a]: Live fish	Counts[a]: Carcasses[b]	Counts[a]: Redds	Redds/mi
River Mill Dam – Barton Park	9.8	34	30	31	3.2
Barton Park – Carver	5.5	3	4	3	0.5
Carver – mouth	8.0	5	2	14	1.8
Total	23.3	42	17	48	2.1

[a] *The proportion of spring chinook was based on analysis of scales collected from carcasses.*
[b] *Includes carcasses that were seen but not sampled.*

Aerial Redd Counts

Redds were counted from a helicopter provided by Portland General Electric Company. The 1998 survey was conducted October 5. Redds were counted from the topmost section of the Clackamas River downstream to North Fork Reservoir. We also counted redds in the Collawash River from the topmost section downstream to the confluence with the Clackamas River.

Redd counts in the aerial survey were compared to counts in ground surveys (foot or boat). Comparisons of the redd counts between the two survey methods were made for the two week period prior to the aerial survey (September 21-October 9), and for the season total prior to the aerial survey. Ground surveys in the two weeks before the aerial count encompassed the peak period of spawning in the Clackamas and Collawash rivers.

The aerial redd count was 66% lower (range -60% to -71%) than the count of redds in ground surveys during the previous two weeks (Table 13). Additionally, the aerial count was 77% lower (range -74% to -78%) than the count of redds in ground surveys during the spawning season prior to the aerial count (Table 13). In 1996 our aerial redd count was also lower than the ground survey counts, although we counted a higher percentage of the ground survey redds during the aerial survey in 1996 than in 1998 (Figure 7). Aerial surveys in both years were conducted by the same person and under full sun. However, the 1998 survey was later in the day than the 1996 survey, which decreased visibility because many stretches of the river were in shadows.

Although aerial surveys are less labor intensive than ground surveys, factors such as speed of flight and limited visibility (riparian vegetation, reflected light, low angle of the sun during autumn) reduce the surveyor's ability to accurately count redds. Although we have just two years of data, the results indicate that aerial surveys are not a reliable method for accurately enumerating spring chinook redds in the upper Clackamas River Basin.

Spawning Ground Surveys in the Upper Sandy River Basin

We surveyed 43 miles of stream in the Sandy River Basin above Marmot Dam in 1998, and counted 744 redds (Table 14). As in the previous two years, Salmon River and Still Creek were the primary spawning areas (Figure 8). Collectively, these streams accounted for 93% of the total redds and 94% of the total carcasses.

The 1998 redd count in the upper Sandy Basin was similar to 1997 and was 31% higher than in 1996. We recovered 175 carcasses in 1998, compared to 120 and 491 carcasses in 1997 and 1996, respectively. In 1997 and 1998, we did not sample all of the carcasses seen in order to survey more spawning areas.

Table 13. Comparison of spring chinook salmon redds counted from a helicopter with those counted in ground surveys (by foot or boat) for two time periods prior to the helicopter count, upper Clackamas River Basin, 1998.

Survey section	Helicopter survey (Oct 5)	Ground surveys Two weeks (21 Sep-4 Oct)	Ground surveys Total (1 Sep-4 Oct)
Clackamas River:			
Above Collawash River	29	73	132
Collawash – Cripple Cr.	20	61	84
Cripple Cr. – North Fork Reservoir	12	42	55
Collawash River	8	25	31
Total	69	201	302

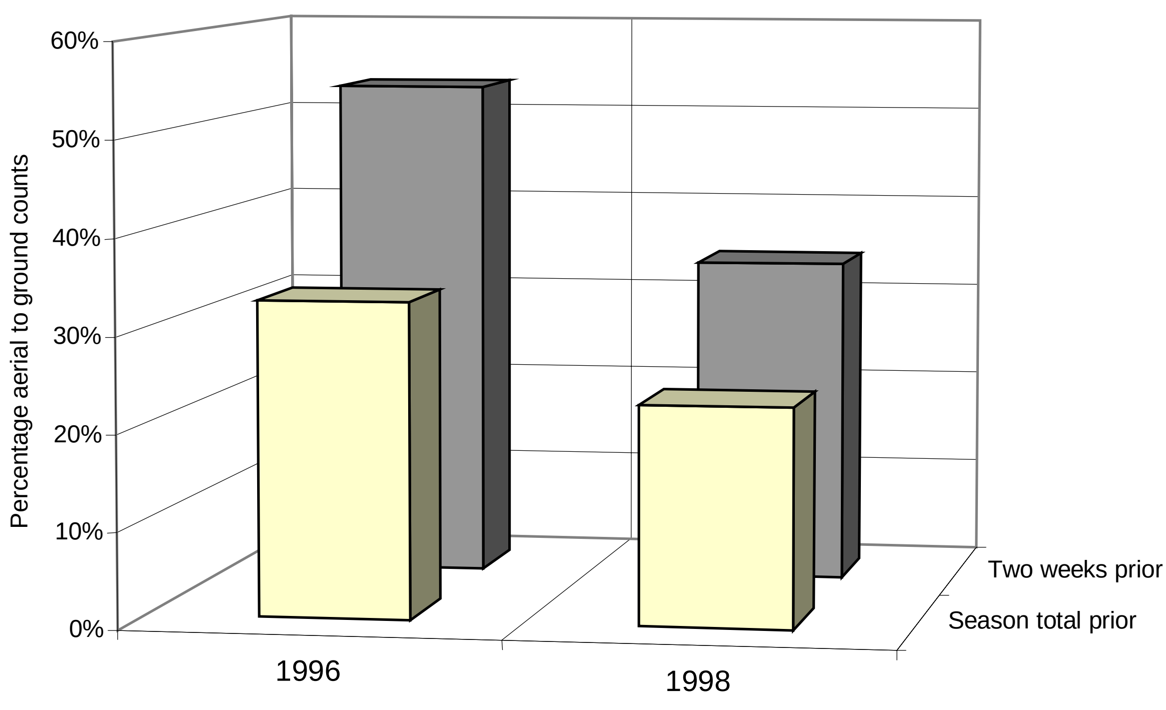

Figure 7. Percentage of spring chinook salmon redds counted during an aerial survey that had been counted in ground surveys (foot or boat), in the upper Clackamas River Basin, 1996 and 1998. Aerial counts were compared to ground counts for two time periods prior to the aerial survey (two weeks and season total).

Table 14. Summary of spawning surveys for spring chinook salmon in the Sandy River above Marmot Dam, 1998. Data for shorter survey sections are shown in **APPENDIX C**.

Survey section	Length (mi.)	Counts: Live fish	Counts: Carcasses[a]	Counts: Redds	1998 redds/ mile	1997 redds/ mile	1996 redds/ mile
Salmon River:							
Final Falls - Forest Rd 2618	3.2	303	84	213	66.6	57.8	39.7
Forest Rd 2618 - Bridge Street	3.6	125	27	55	15.3	12.2	19.7
Bridge Street - Highway 26	6.2	567	272	324	52.3	45.2	41.5
Highway 26 - mouth	0.6	8	7	9	15.0	b	b
Tributaries[c]	3.0	0	0	2	0.7	2.5	--
Zigzag River:							
Devil Canyon Creek - mouth	5.5	2	9	10	1.8	13.6	--
Still Creek: Forest Rd 2612 - mouth	5.3	74	23	92	17.4	21.5	12.3
Camp Creek: Laurel Hill - mouth	4.0	9	4	9	2.3	3.0	3.0[d]
Other Zigzag tributaries[e]	4.8	0	0	0	0.0	0.0	0.0
Clear Creek: Powerline - mouth	1.4	1	0	0	0.0	0.0	2.0[f]
Clear Fork: Barrier - mouth	0.6	11	13	17	28.3	5.0	6.0[g]
Lost Creek: Lost Creek Campground - mouth	4.5	9	2	13	2.9	0.8	4.8[h]
Total	42.7	1109	441	744	17.0	17.0	18.8

[a] *Includes carcasses that were not sampled.*
[b] *This section was not surveyed in 1997 and was surveyed once in 1996 with the Bridge St.-Highway 26 section.*
[c] *Cheeney and Boulder creeks were surveyed in 1997 and 1998, and an additional unnamed creek was surveyed in 1997.*
[d] *This section was 2.0 miles shorter in 1996.*
[e] *Devil Canyon, Henry, Lady creeks were surveyed 1996-98; Muddy Fork Creek was surveyed in 1997 and 1998.*
[f] *This section was 0.9 miles shorter in 1996.*
[g] *This section was 0.9 miles longer in 1996.*
[h] *This section was 2.5 miles shorter in 1996.*

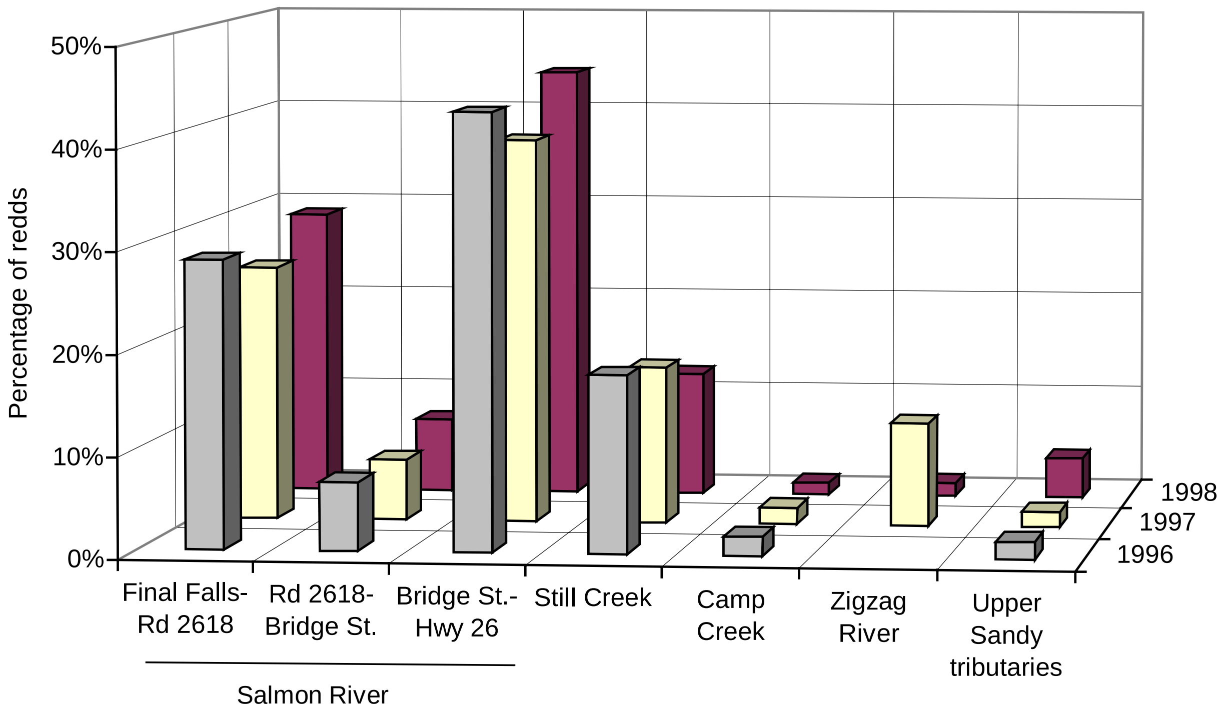

Figure 8. Geographical distribution of spawning for spring chinook salmon in the Sandy River Basin upstream of Marmot Dam, 1996-98.

The general distribution of redds in the upper basin was similar in 1996-98, although shifts of relative contribution between sections occurred (Figure 8). Redds in survey areas that we added in 1997 accounted for just 2% of the 1998 total compared to 11% of the total in 1997, primarily because spawning decreased in the Zigzag River. The density of redds in the lower Zigzag River was 87% lower in 1998 than in 1997 (Table 14 and Figure 8). A large landslide occurred in the upper Zigzag River in July 1998. Consequently, the visibility was impaired during much of the spawning season and a large quantity of silt was observed in the substrate of the river. These factors may have affected our ability to see redds and may have caused a decrease in use of the Zigzag by spawning salmon. The density of redds in Clear Fork Creek (an upper Sandy tributary) was five times higher in 1998 than the average density in 1996 and 1997 (Table 14 and Figure 8).

Based on surveys in core sections, peak spawning in the upper Sandy Basin occurred from mid-September to early October, during the fourth and fifth survey cycles (Table 15). Seventy-four percent of the spawning took place during this time. However, the percentage of redds counted during this period varied among the individual sections from 45% in Still Creek to 84% in the uppermost Salmon River section (Table 15). The timing of spawning by two-week periods was more protracted in 1997 and 1998 than in 1996 (Figure 9). We extended surveys until October 29 in 1998 because we counted almost 50 fresh chinook redds during the last 1997 surveys (October 22-23). However, we counted just 18 redds from October 19 through October 29 in 1998.

Table 15. Redd counts of spring chinook salmon by survey cycle in core sections of the upper Sandy River Basin, 1998. Only redds not previously counted were included in each survey period.

Survey section	Survey cycles: Aug 24-31	Sep 2-9	Sep 10-16	Sep 17-23	Sep 24-Oct 1	Oct 2-9	Oct 10-19	Oct 20-29
Salmon River:								
Final Falls - Road 2618	0	0	32	90	88	3	0	--
Road 2618 - Bridge Street	--	0	1	34	9	11	0	0
Bridge St. - Hwy 26	--	7	27	154	88	30	16	2
Still Creek	--	0	12	18	23	29	7	3
Total	0	7	72	296	208	73	23	5

The ratio of the adult count over Marmot Dam (one week prior to the last survey minus harvest) to the redd count was 3.3:1 in 1998, and the 1996-98 average was 3.9:1 (**APPENDIX C**). We accounted for 61% of the fish passing Marmot Dam, compared to an average of 48% in the previous two years (Figure 10). These estimates assume that each redd we counted was made by two spawners and that the sex ratio was 1:1. The estimated harvest of spring chinook above the dam was from punch card data (**APPENDIX C**). The most likely explanations for the unaccounted fish are pre-spawning mortality and spawning occurring in areas not surveyed, particularly the mainstem Sandy River above Marmot Dam. We were unable to conduct extensive surveys of the Sandy River because of poor visibility during spring chinook spawning season. However, the quantity and quality of suitable spawning areas for spring chinook in many sections of the mainstem Sandy is reduced because of large amounts of glacial sediment (suspended and deposited) and high gradient.

Comparison of Spawn Timing among Basins

Spring chinook salmon began spawning about the first week of September and ended by mid October in the Clackamas, Sandy, and North Santiam rivers in 1998. No spawning was observed in the Clackamas in late August as occurred in 1997. Spawning activity started out the slowest in the Sandy and the fastest in the North Santiam (Figure 11). Although spawning was generally completed by mid October,

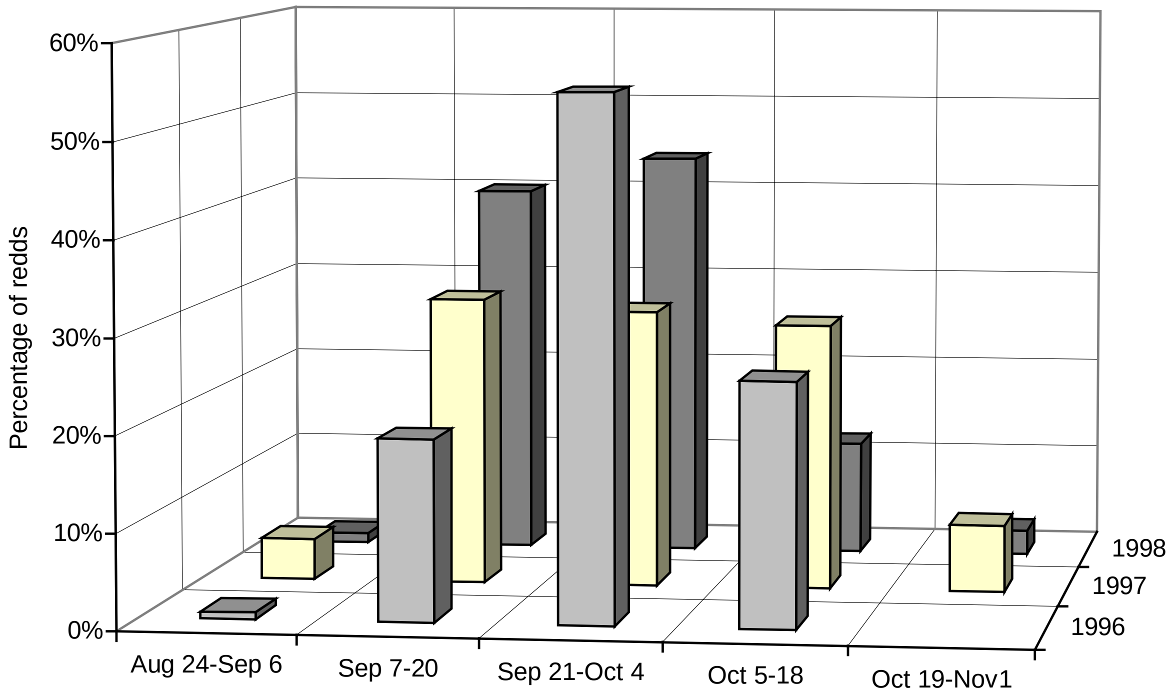

Figure 9. Timing of spring chinook salmon spawning in the Sandy River upstream of Marmot Dam, 1996-98.

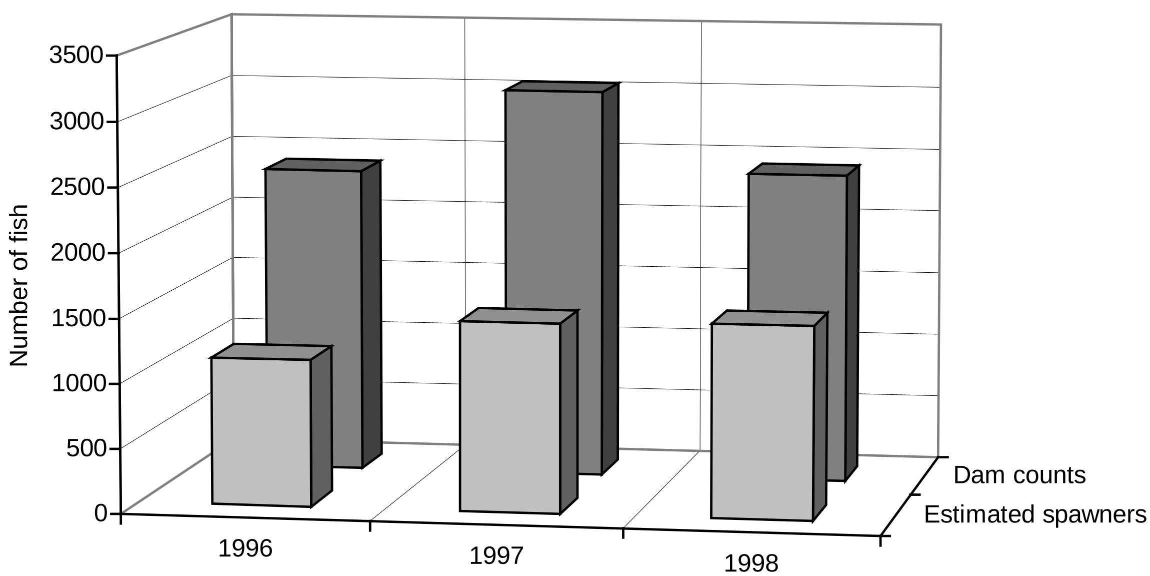

Figure 10. Comparison of spring chinook salmon passing over Marmot Dam on the Sandy River and the estimated number of spawners above the dam, 1996-98. Dam counts are the total adult fish past the dam up to one week before the last spawning survey minus the estimated harvest above the dam. Spawners are estimated from redd counts assuming a 1:1 sex ratio and two fish per redd.

a few new redds were observed in the Clackamas and Sandy rivers on the last surveys in late October. In general, the progression of spawning was more similar among the three basins in 1998 than in either 1997 or 1996. The mid-point of spawning within each basin varied from only 4 to 7 days over the 3 years that basins were surveyed (Table 16).

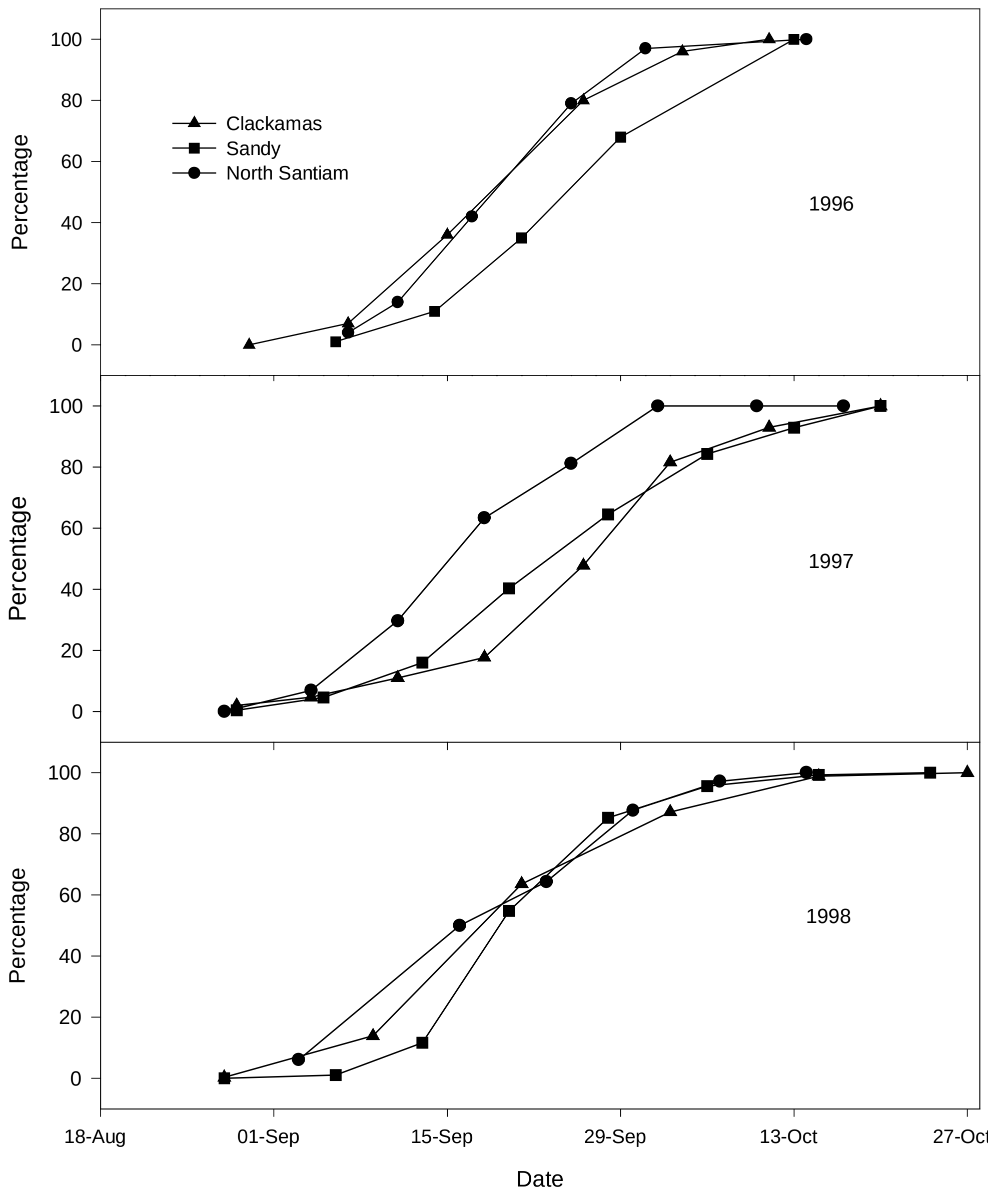

Figure 11. The progression of spawning of spring chinook salmon in the Clackamas, Sandy, and North Santiam rivers, 1996-98. Data points represent the cumulative distribution of new redds observed and are plotted by the midpoint of the survey week.

Table 16. Date when 50% of the redds were observed in the Clackamas, Sandy, and North Santiam rivers, 1996-98.

Basin	Date of 50% spawning		
	1996	1997	1998
Clackamas	19-Sep	26-Sep	21-Sep
Sandy	25-Sep	23-Sep	20-Sep
North Santiam	19-Sep	15-Sep	15-Sep

Other Chinook Spawning Areas

In addition to surveys in the Clackamas River below River Mill Dam, we also surveyed sections of other rivers in 1998 for spring chinook salmon that were not surveyed in previous years. These additional areas were surveyed once during or just after peak spawning time, which was based on surveys in previous years of nearby areas. Redds were counted but not flagged. Scales were collected from a subset of carcasses to help separate chinook salmon into spring and fall race. The snout was collected from carcasses with a missing adipose fin.

McKenzie River

ODFW District personnel surveyed the McKenzie River between Leaburg Dam and Leaburg Landing (RM 29) on four different dates. A total of 92 redds were observed and 94 spring chinook carcasses recovered. We surveyed sections of the McKenzie River from Leaburg Landing to the mouth on September 25, September 28, and October 8. Only 21 redds were observed, all above Hendricks Bridge (RM 20). A helicopter survey, conducted on September 28, confirmed that no spring chinook spawned in the McKenzie River below Hendricks Bridge. The area above Leaburg Dam was not surveyed in 1998.

Almost half of the spring chinook returning to the McKenzie River enter McKenzie Hatchery (RM 32.5). What natural spawning occurs below Leaburg Dam is confined to the area near the dam. Eugene Water and Electric Board operates a video recorder in the fish ladder at Leaburg Dam (RM 35). Counts taken at Leaburg Dam recorded 1,874 spring chinook through October 31 in 1998. McKenzie Hatchery attracts and traps spring chinook at their facility by using the hatchery outfall. In 1998 the hatchery collected 1,690 adults, 999 of which were used for broodstock, 377 were outplanted above Trailbridge and Cougar dams, and 156 were outplanted in the Mohawk River (RM 9.8) above Marcola. No spring chinook were released back into the McKenzie River.

Middle Fork Willamette River

The Middle Fork Willamette River was surveyed from Dexter Dam to its confluence with the Coast Fork Willamette (RM 187) on September 23. Only 10 redds were observed, all above Jasper (RM 195). All of the 41 chinook carcasses examined were assumed to be spring chinook and appeared to have died before spawning.

Willamette Hatchery collects spring chinook salmon at a trap at Dexter Dam (RM 204), the upstream barrier to migrating chinook. In 1998, 8,891 chinook were trapped. A total of 2,697 chinook were retained for broodstock, 4,128 were killed and provided to treaty tribes, and about 2,000 were outplanted to spawning areas above Fall Creek Dam (565), above Hills Creek Dam (1,225), and into Mosby Creek in the Coast Fork Willamette (191). No chinook were released back into the Middle Fork Willamette below Dexter Dam.

Despite having substantial numbers of spring chinook salmon returning to the Middle Fork Willamette, few use the area below the dam for natural spawning. High water temperatures may prevent spring chinook from holding in the river until they are ready to spawn. In addition, submergent vegetation covers much of the substrate near the dam, which may make the area unsuitable for spawning.

Mainstem Willamette River

We surveyed the mainstem Willamette River from Island Park (RM 185), near the confluence of the Coast Fork Willamette and Middle Fork Willamette (RM 187) down to Harrisburg (RM 161) on October 1 and October 8. There is an extensive island and braided channel network in the Willamette from the mouth of the McKenzie (RM 175) to Harrisburg. Two chinook redds were observed approximately 4 miles below the mouth of the McKenzie River. No carcasses were found. The mainstem Willamette River does not appear to be extensively used by spring chinook.

South Santiam River

The entire South Santiam River below Foster Dam (RM 38) was surveyed in mid September except for a 2.2 mile section from Waterloo Park to Lebanon Dam, which has no spawning habitat. Sections from Foster Dam, which blocks passage into the upper South Santiam River, to Waterloo Park (RM 23) and from Lebanon Dam (RM 21) to Sandersons Bridge (RM 8) were surveyed on September 17. The remainder of the river from Sandersons Bridge to the mouth was surveyed on September 25.

Analysis of scales from 54 chinook salmon carcasses above Waterloo Park showed 87% were spring chinook and the remaining 13% were fall chinook (Table 17). A total of 181 redds were counted in this section, most near Foster Dam. Of the 15 carcasses sampled below Sandersons Bridge, 7% were spring chinook and 93% were fall chinook (Table 17). A total of 80 redds were counted in this section. It appears that spring chinook and fall chinook are spatially separated in the South Santiam River similar to what we have observed in the North Santiam River.

Although a large proportion of the spring chinook salmon that return to the South Santiam River enter the trap at Foster Dam, we estimated that 163 redds from the dam to the mouth were made by spring chinook salmon in 1998. The density of spring chinook redds in the upper section from Foster Dam to Waterloo was 10.5 redds/mi only slightly lower than that from Minto to Fisherman's Bend in the North Santiam River (11.8 redds/mi).

Table 17. Overlap of spring and fall chinook salmon in the South Santiam River and in the main stem Santiam below the confluence with the north and south forks based on fish scale patterns from recovered carcasses, 1998.

Section	Number of carcasses		Percent spring chinook
	Fall chinook	Spring chinook	
South Santiam:			
Foster - Waterloo	7	47	87
Lebanon Dam – mouth	14	1	7
Mainstem Santiam:			
Confluence of North and South Santiam - mouth	11	0	0

It is unknown how many of the chinook salmon spawning below Foster Dam are hatchery chinook. In 1998, 3,782 adult spring chinook salmon and 62 jacks returned to the trap at Foster Dam. Most of the fish were retained for broodstock while 55 were externally tagged and released into the South Santiam River below Foster Dam to provide for angler catch. Some of those recycled fish re-entered the Foster trap, some were caught by anglers, and some remained in the river to spawn naturally. No chinook were recycled downriver for fishery purposes after August 28. Beginning in September, spring chinook on hand at the hatchery were used for broodstock (930), outplanted to spawning areas above the dam (699), outplanted to spawning tributaries below the dam [Crabtree Creek (40), Thomas Creek (107)], and outplanted into other Willamette tributaries [Abiqua Creek (100), Calapooia River (316)]. An additional 1,171 chinook were killed and provided to treaty tribes.

Mainstem Santiam River

We surveyed sections of the mainstem Santiam from the confluence of the North and South Santiam rivers (RM 11.7) to the confluence with the Willamette River above Buena Vista (RM108) on September 24, September 25, October 1, and October 7. A total of 49 redds were counted. Scales from 11 chinook salmon carcasses indicated that none of the fish were spring chinook (Table 17). This area appears to be used for spawning only by fall chinook salmon.

Coded Wire Tag Recoveries

Only coded wire tags collected in the McKenzie River in 1998 were decoded by the time this report was written (Table 18). At Leaburg Dam, all of the stray spring chinook sampled were South Santiam and Willamette stocks. On spawning grounds below Leaburg Dam, most strays were South Santiam and Clackamas stocks. The Clackamas stock (1994 brood) was reared in McKenzie Hatchery and released into the lower Willamette River as part of a study to evaluate the use of net pens to acclimate spring chinook salmon. Tags from fish with adipose clips recovered in 1998 spawning ground surveys in the North Santiam (7), South Santiam (10), Middle Fork Willamette (2), Clackamas (2), and Sandy (3) rivers have not yet been decoded.

TASK 2.1-- MORTALITY IN A CATCH AND RELEASE FISHERY

Freshwater sport fisheries account for much of the harvest mortality of Willamette River spring chinook salmon. From 1989 through 1993 freshwater harvest of Willamette spring chinook accounted for about 70% of the total harvest in ocean and freshwater fisheries (Bennett 1994). Freshwater sport fisherman took 55% of the total catch and the Columbia River gill-net fishery accounted for another 15% of the catch (Bennett 1994). Sport catch is underestimated because it does not include fisheries in the upper mainstem Willamette or in tributaries above Willamette Falls (Bennett 1994). Harvest rates on 4 and 5 year-old fish in the lower Willamette River sport fishery average about 28% each year (Foster 1997).

The sport fishery on Willamette spring chinook salmon is largely driven by hatchery programs that release 5-8 million juveniles annually into the Willamette Basin. The intense sport fishery supported by large hatchery programs poses a risk of overharvest of wild spring chinook salmon. To reduce this risk, we evaluated the feasibility of a catch and release fishery that would allow anglers to keep marked hatchery fish but require them to release unmarked wild fish. This evaluation estimated the hooking mortality managers can expect on spring chinook salmon that are caught and released in the lower Willamette sport fishery. We also compared our hooking mortality study to the general sport fishery in the lower Willamette River.

Table 18. Coded wire tag information from fish marked with adipose fin clips and recovered at Leaburg Dam and in spawning surveys below the dam in the McKenzie River, 1998. PSC = Pacific Salmon Commission.

Recovery location, tag code	Number observed	Brood year	Release site	Rearing hatchery	Stock	Treatment
McKenzie River at Leaburg Dam:						
70240	1	92	McKenzie	McKenzie	McKenzie	Normal growth
70428	1	92	McKenzie	Marion Forks	McKenzie	
70343	1	93	Youngs Bay	Klatskanine	Willamette	
70444	2	93	McKenzie	McKenzie	McKenzie	Net pen control, PSC indicator
70830	1	93	Lower Willamette	McKenzie	McKenzie	Net pen
70831	1	93	Lower Willamette	McKenzie	McKenzie	Direct release
70835	1	93	Lower Willamette	McKenzie	McKenzie	Net pen
70836	1	93	Lower Willamette	McKenzie	McKenzie	Net pen
70850	1	93	McKenzie	McKenzie	McKenzie	Net pen control, PSC indicator
70445	2	94	McKenzie	McKenzie	McKenzie	
70857	2	94	S. Santiam	S. Santiam	S. Santiam	
70858	2	94	S. Santiam	S. Santiam	S. Santiam	
70860	1	94	McKenzie	McKenzie	McKenzie	Net pen control
71153	1	94	S. Santiam	Willamette	S. Santiam	Waterloo release
71237	1	94	Lower Columbia	McKenzie	S. Santiam	Blind Slough release
76328	1	92	Middle Fork Willamette	Willamette	Willamette	Oxygen study
91715	1	95	Lower Willamette	Willamette	Willamette	
McKenzie River below Leaburg Dam:						
70428	1	92	McKenzie	Marion Forks	McKenzie	
70444	1	93	McKenzie	McKenzie	McKenzie	Net pen control, PSC indicator
70830	2	93	Lower Willamette	McKenzie	McKenzie	Net pen
70831	1	93	Lower Willamette	McKenzie	McKenzie	Direct release
70835	2	93	Lower Willamette	McKenzie	McKenzie	Net pen
70850	1	93	McKenzie	McKenzie	McKenzie	Net pen control, PST indicator
70445	1	94	McKenzie	McKenzie	McKenzie	
70860	1	94	McKenzie	McKenzie	McKenzie	Net pen control
71048	1	94	Lower Willamette	McKenzie	Clackamas early	Direct release
71050	1	94	Clackamette Cove	McKenzie	Clackamas early	Direct release
71120	1	94	Youngs Bay	McKenzie	Clackamas early	
71237	1	94	Lower Columbia	McKenzie	S. Santiam	Blind Slough release
71045	2	94	Lower Willamette	McKenzie	Clackamas early	Net pen
70858	1	94	S. Santiam	S. Santiam	S. Santiam	

Hooking Mortality Study

Methods

We tagged adult spring chinook salmon at Willamette Falls (RM 27) on the Willamette River for 13 days from April 27 through May 12, 1998 to evaluate hooking mortality (Table 19). The area at Willamette Falls was chosen because fish tend to concentrate in the horseshoe-shaped falls before finding one of four fishway entrances to resume migration above the falls (Figure 12. This concentration enabled us to sample large numbers of fish with several types of sport fishing gear. The nearby fishway also allowed us to capture control groups with a trap located in one arm of the fishway ("cul-de-sac" arm) (Figure 12). We generally fished above the deadline located at the entrance to the horseshoe, an area closed to public boating and fishing. Willamette Falls is generally impassable to fish during spring flows except through the fishway.

Our tagging design consisted of treatment groups caught on typical sport fishing gear and control groups caught in a trap located in the cul-de-sac arm of the fishway (Table 19). We divided the experiment into two parts because we were uncertain how handling might affect behavior of control groups. One part compared treatment and control groups released into the river ("river releases") (Table 19). The other part compared treatment and control groups released into the fishway ("fishway releases") (Table 19). River releases were composed of fish caught on lures (spinners, plugs, etc.), fish caught on bait (prawns and spinner-prawn combination), and a control group removed from the fishway and lowered back into the river. Fishway releases were composed of fish caught on lures, and hoisted into the fishway, and a control group trapped and released into the fishway. A weir installed in the lower end of the cul-de-sac arm prevented tagged fish released into the fishway from immediately dropping downstream into the river below the falls. The weir did not impede upstream migration.

Fish were played and netted in a normal manner. The net and fish were then lifted into a 50-gallon tank in the center of the boat. One biologist removed hooks, noting hook location, and took the fish out of the net. Hooks were not removed from fish caught on bait and hooked in the gill arches, esophagus, or stomach. Our rationale was that most anglers would accept cutting off a hook in a deeply hooked fish if it improved the chances that a fish would survive, but would not accept cutting off a favorite or expensive lure. Fish that were foul hooked and those with obvious infections or open wounds unrelated to hooking were immediately released untagged. Because the fish were not anesthetized, we placed them headfirst into a round, rubber boot mounted in the bottom of the tank while we tagged them. The fish were generally very calm once their head was inside the darkened boot. The fish was then tagged, swabbed with iodine at the tag insertion point to reduce infection, and released. Processing time after hooks and net were removed averaged 1.03 min (n = 108). We recorded the tag number, time of day, specific gear type (spinner, prawn, etc), hook type (single or treble), hook size, hook location (jaw, gill arches, etc), degree of bleeding (none or slight, moderate, or severe) and fork length to the nearest 1.0 cm. Sex could not be determined by external observation and was not recorded.

Table 19. Temperature, streamflow, and number of fish tagged on each day spring chinook salmon were sampled at Willamette Falls, 1998.

Date	Temperature range (°F)[a]	Streamflow (thousands of cfs)[b]	River releases			Fishway releases	
			Lures	Bait	Control	Lures	Control
Apr 27	55.2 - 55.2	17.0	3	0	0	1	5
29	56.6 - 58.0	14.5	24	0	18	0	5
30	58.0 - 60.2	13.9	64	0	38	0	0
May 1	60.2 - 62.2	13.6	18	18	39	0	0
3	62.2 - 63.6	13.6	0	18	0	0	0
4	62.8 - 62.8	14.6	1	19	0	0	30
5	62.2 - 62.8	13.9	0	43	5	0	30
6	61.4 - 62.2	13.9	0	24	5	21	7
7	60.8 - 61.4	13.4	0	0	0	40	13
8	60.8 - 61.4	13.0	0	0	0	38	6
9	60.2 - 60.2	12.7	0	0	0	25	0
11	57.4 - 56.6	12.6	12	26	0	0	16
12	55.2 - 53.8	12.0	15	2	0	0	9

[a] *Temperature readings were taken at 7:30 am and 7:30 PM, the approximate start and end of a fishing day.*
[b] *Measured at the Salem gauge.*

A guide provided the boat and sport fishing gear for fish caught on hook and line. The guide determined the specific terminal gear that was most effective within the two general lure and bait categories (Table 20). Two different volunteers from the public fished on the boat each day. Two biologists on the boat processed the fish caught, recorded data, and fished when there was opportunity.

Each fish caught on lures and released into the fishway was processed while being transported a short distance by boat to a location under the fishway. The fish was removed from the processing tank, placed into a watertight, aluminum tube partially filled with water, and hoisted 30 ft to the fishway. The fish was then released into a recovery trough suspended in the fishway. Once recovered, the fish was allowed to swim into the fishway.

Control groups were caught in a trap located in the cul-de-sac arm of the Willamette Falls fishway (Figure 12). The trap was equipped with a small viewing window and gates operated by air-pressured valves, which allowed us to shunt chinook salmon into the trap or pass them up the fishway if they were already tagged or injured. A Denil fish ladder (Clay 1995) with about 1 cfs of flow was used to attract fish into a 12

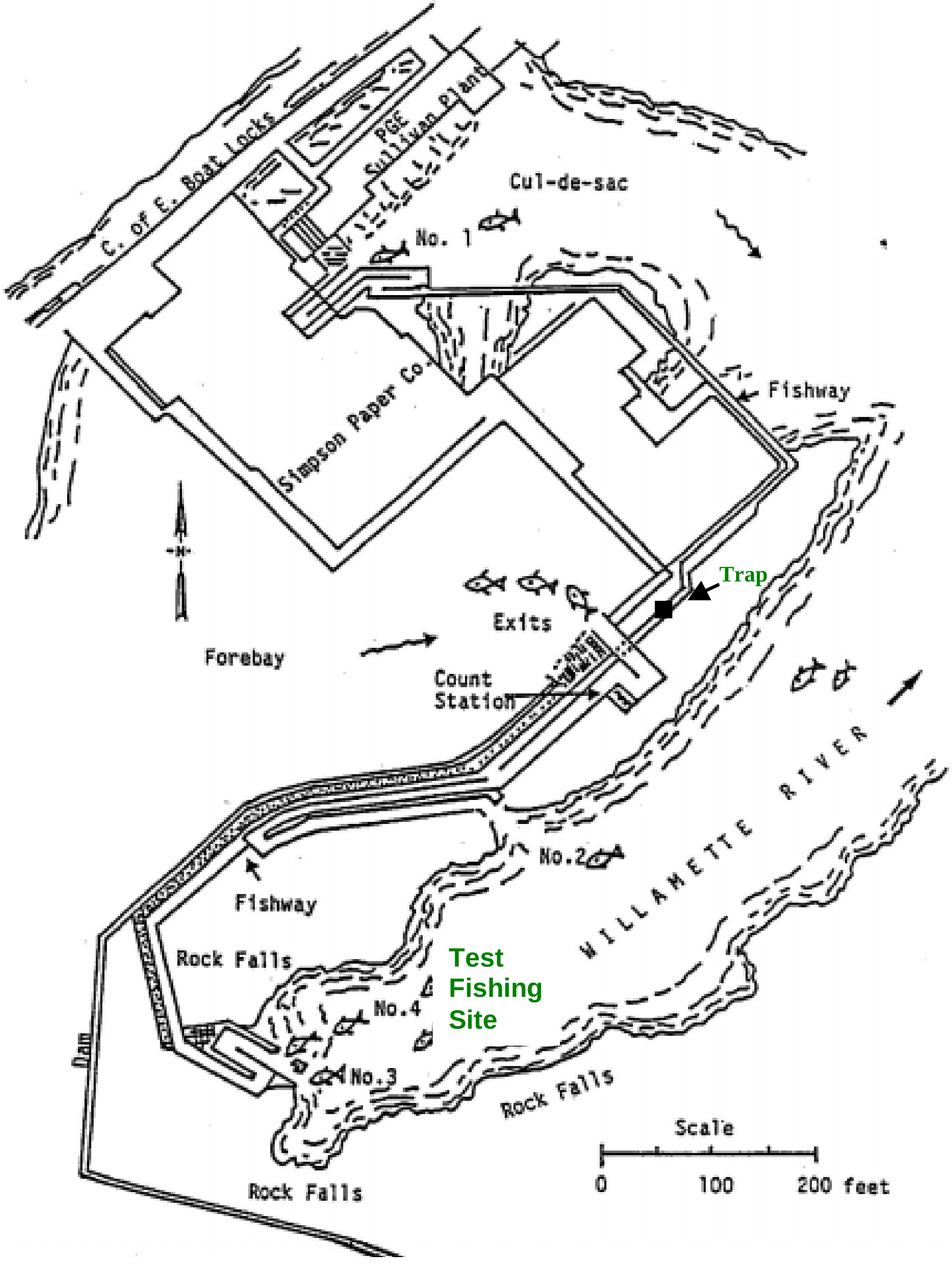

Figure 12. Map of Willamette Falls [after Foster (1997)].

Table 20. Number of fish hooked on various types of terminal tackle.

Terminal gear	Hook Type	Hook Number	Hook Size	Number of fish
Lures[a]:				
Spinner	Treble	1	2/0	148
Diving Plug	Treble	2	5,5	24
	Treble	2	5,3	73
Wobbler	Treble	1	2	17
Bait:				
Prawn-spinner	Single	1	4/0	32
	Single	1	5/0	4
	Single	2	4/0,4/0	16
	Single	2	5/0,3/0	93
Prawn	Single	1	4/0	4
	Single	2	5/0,3/0	1

[a] *Includes river and fishway releases combined.*

ft long x 2 ft deep wooden trough on top of the fishway. The trough was partitioned into three compartments with slide gates. The first 8 ft of the trough was 2 ft wide and the last 4 ft was 1 ft wide. The narrow end of the trough was fitted with a V-shaped, metal insert, which was open-ended and had slightly smaller dimensions than the last compartment. The metal insert, with a black rubber hood attached at the head end, was used to handle the un-anesthetized fish.

Once in the wooden trough, a single fish was gently herded into the V-shaped insert and the gate was closed. The head of the fish was put under the rubber hood, which calmed the fish for processing. Control fish were measured and tagged in the same way as those caught by hook and line. The metal insert was then lifted without handling the fish and the fish either slid through a PVC tube directly into a recovery trough suspended in the fishway (fishway releases) or into an aluminum tube partially filled with water (river releases). River releases were transported in the aluminum tube by hand truck about 120 ft along the top of the fishway and lowered 30 ft into a 6 ft diameter, circular recovery tank. After recovering, fish were able to swim into the river through a hole cut in the side of the tank.

The same three biologists did all the tagging to ensure similar numbers of fish in each group were tagged by each biologist. This eliminated any bias in recovery frequencies among groups due to differences in tagging technique. We tagged all fish at the base of the dorsal fin with T-anchor tags (heavy duty monofilament, Floy® FD-94) that were individually numbered and included an ODFW telephone number. To assess tag loss we also tagged each fish with a filament, T-anchor tag (Floy® FD-67F) color coded for each of the five experimental groups (Table 21). Water temperature during tagging was monitored with a temperature probe (Onset® HoboTemp) placed in the fishway (Table 19).

Tagged salmon were recovered at hatcheries, in fishway traps, and in fisheries. A fish was considered a survivor if it was recovered in any of these locations. Biologists processed fish at hatcheries and at traps and noted tag number and filament color. Information on fish caught in sport fisheries was collected from anglers who called the telephone number printed on the numbered tag. No creel surveys were conducted to actively collect tag information from anglers, although signs requesting tag returns were posted at boat ramps on several rivers.

Table 21. Five groups of spring chinook salmon tagged at Willamette Falls, spring 1998, to evaluate hooking mortality.

Release location, group	Filament tag color	Number tagged
River releases:		
Lures	Yellow	137
Bait	Red	150
Control	Green	105
Fishway releases:		
Lures	Brown	125
Control	Blue	121

Results and Discussion

Hooking mortality was higher for fish caught on lures than for fish caught on bait. Mortality averaged 22.8% for two groups of chinook salmon caught on lures and released (Table 22). In contrast, mortality was 9.6% for chinook salmon caught on bait and released (Table 22). Although both rates are higher than the overall rate reported for chinook salmon fisheries in the Kenai River in Alaska (7.6%) (Bendock and Alexandersdottir 1993), they must be put into the context of the overall potential effect on spring chinook salmon runs in the Willamette River. Based on fishery survey data collected in 1998, only 17% of anglers in the Willamette River below the falls used lures, whereas, 83% used bait (*see* **Comparison of Hooking Mortality Study with the**

Lower River Fishery, page 40). Anglers harvested a mean of 28% of the spring chinook salmon run entering the Willamette River below Willamette Falls in normal fishing seasons from 1970 through 1995 (Foster 1997). Assuming that catch rates of lures and bait are the same and that mortality rates in our experiment are representative of the mortality that would be observed in the sport fishery below the falls, mortality of wild spring chinook in a catch and release fishery in the Willamette River would be about 3% of the run into the river.

Table 22. Hooking mortality of adult spring chinook salmon caught on lures and on bait and released at Willamette Falls, April 29-May 12, 1998.

Group	Number tagged	Number recovered	Percent recovered	Percent mortality
		River Releases		
Lure	137	50	36.5	30.3
Bait	150	71	47.3	9.6
Control	105	55	52.4	--
		Fishway Releases		
Lure	125	42[a]	33.6	15.3
Control	121	48[a]	39.7	--

[a] *Recoveries in the fishery in the Middle Fork Willamette were excluded.*

Hooking mortality was estimated by using all recovery data (**APPENDIX D**) with the exception of recoveries of the two fishway release groups in the fishery in the Middle Fork Willamette. These data were excluded because the proportions of recoveries in the Middle Fork fishery were significantly different ($P < 0.01$, Fisher Exact test) than the proportions that were recovered in the adjacent hatchery at Dexter. There were no significant differences in the proportion of recoveries in fisheries and hatcheries for river release groups or for fishway groups in other rivers. We assumed recoveries in hatcheries and at traps represented the relative abundance of the different tag groups because the distribution of tag recoveries from hatcheries and traps was not significantly different ($P = 0.62$, χ^2 test) from that of the total recovery of chinook salmon above the falls (Figure 13). Figure 13 indicates that all tag groups were uniformly distributed among the major sub-basin populations of spring chinook salmon above the falls.

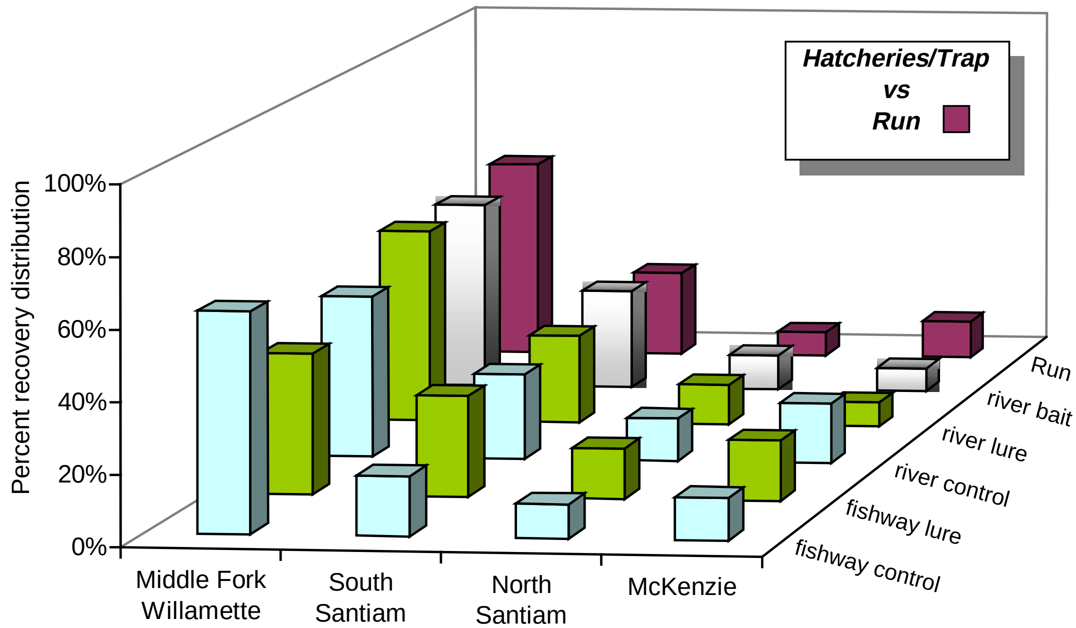

Figure 13. Distribution of spring chinook salmon tag recoveries in hatcheries and fishway traps above Willamette Falls for five hooking mortality study groups. The recovery distribution of the general spring chinook salmon run in the upper Willamette River excluding tagged fish is plotted in the back row of the graph.

The time from initial tagging at the falls until recovery averaged 68 days and ranged from 6 to 158 days. Ninety-six percent of the recoveries occurred above Willamette Falls (**APPENDIX D**). Because hatchery spring chinook salmon compose a high percentage of the fish that migrate through the Willamette River, most of the fish (71%) were recovered at four large hatchery facilities above the falls. Only 10 tags were recovered in areas below the falls with the Clackamas River accounting for six of those. In addition, 10% of the tags were recovered at traps in fishways in the North Santiam and in the McKenzie rivers. Returns from anglers accounted for 16% of the recoveries.

Tag loss was low, especially for numbered tags. Out of 220 fish examined, 1% had lost the numbered tag, whereas 6% of the filament tags were lost. Tag loss only included fish examined by biologists at hatcheries or in traps in fishways. In the future we will use just a single numbered tag because tag loss was so low.

About 46% of the general spring chinook salmon run over Willamette Falls in 1998 were accounted for in hatcheries and traps where our tagged fish were recovered. In contrast, recovery of our two control groups was 35% and 39% at these same locations. The lower recovery frequencies of our control groups relative to the general run suggest some background mortality of our experimental groups due to handling. However, all our experimental groups were tagged downstream of the counting station in the Willamette Falls fishway. Some mortality occurs as fish attempt to find entrances to the fishway (Foster 1997). In addition, there was some indication that passage mortality in the cul-de-sac arm, where two of our experimental groups were released, was higher than that in other arms of the fishway.

The recovery frequencies of the two experimental groups released into the fishway at Willamette Falls were lower than those of comparable groups released into the river (Table 22). We had expected opposite results because fishway releases did not have to find the fishway entrances to migrate above the falls. The difference suggests a problem with passage in the cul-de-sac arm of the ladder although possible mechanisms for this difference are unknown. The cul-de-sac arm of the ladder is thought to provide about 20% of the total annual passage at Willamette Falls (Personal communication, Craig Foster, ODFW, Clackamas).

We compared the recovery frequency of fish hooked in the jaw with that of fish hooked in the gill arches and in the tongue (Table 23). The tongue, gill arches, and eyes were considered "vital" hooking locations in a hooking mortality study of chinook salmon in the Kenai River, Alaska (Bendock and Alexandersdottir 1993). Mongillo (1984) considered the tongue, gill arches, eye, and esophagus "critical" anatomical sites. In our study, we combined recoveries of adult chinook salmon caught with lures and with bait to compare relative survival of fish hooked in the jaw, tongue, and gill arches. We found that recovery of fish hooked in the tongue was not significantly different ($P = 0.56$, χ^2 test) from that of fish hooked in the jaw (Table 23). In contrast, fish hooked in gill arches suffered significantly higher mortality ($P < 0.05$, χ^2 test) than those hooked in either the tongue or the jaw (Table 23). We concluded that the tongue was not a critical hook location for spring chinook salmon in the Willamette River. Combined sample sizes were too small to evaluate relative survival of fish hooked in the eye or in the esophagus/stomach. In the absence of data to the contrary, we considered the eye and esophagus (including the stomach) critical hooking locations (Mongillo 1984, Bendock and Alexandersdottir 1993).

Table 23. Recovery of adult spring chinook salmon hooked in the jaw, in the tongue, and in the gill arches.

	Jaw	Tongue	Gill arches
Percentage recovered	44	36	11
Number recovered	148	9	4

The difference in mortality between chinook salmon caught on lures and those caught on bait was due in part to differences in the anatomical hooking location and the severity of bleeding. Thirteen percent of the fish caught on lures were hooked in a "critical" location (gill arches, eye, or esophagus) compared to 10% of the fish caught on bait (Table 24). In addition, of the fish hooked in critical locations, 64% of those caught on lures and 33% of those caught on bait were judged to be bleeding severely at release (Table 25). Consequently, the recovery frequency of critically hooked fish was only 12% of those caught on lures and 27% of those caught on bait (Table 26). Injury of fish deeply hooked on bait was probably less severe because the line was cut and the hook was not removed. Lures were removed regardless of where the fish was hooked.

The most common critical hook location for lures and bait was the gill arches (Table 24). Fish hooked in gill arches also suffered more trauma than those hooked in other locations. Sixty-eight percent of the fish hooked in gill arches were severely bleeding at release (Table 25). In contrast, none of the fish hooked in the jaw were severely bleeding when released (Table 25). Although sample sizes were small, the removal of lures from gill arches resulted in 72% of the fish bleeding severely compared to 50% for bait where the line was cut and the hook left in place. The low recovery (11%) of fish hooked in gill arches (lure and bait-caught groups combined) (Table 23) was likely associated with the high percentage of severe bleeding. However, not all of these fish died. Of the four fish that were recovered after being hooked in gill arches, all were severely bleeding at release and all were recovered above Willamette Falls.

Table 24. Anatomical hook location on adult spring chinook salmon that were caught, tagged, and released at Willamette Falls, April 29-May 12, 1998.

	Lures[a]		Bait	
Hook location	Number	Percentage	Number	Percentage
Jaw	207	80	128	86
Tongue	19	7	6	4
Gill arch	29	11	8	5
Eye	4	2	2	1
Esophagus-stomach	0	0	5	3
Unknown	3	--	1	--

[a] *Combines groups released into the river and into the fishway.*

Table 25. Severity of bleeding by hook location at the time fish were caught and tagged.

Degree of bleeding	Jaw	Tongue	Gill arches	Eye	Esophagus -stomach
			Lures [a]		
None-slight	202	14	4	2	0
Moderate	5	3	4	2	0
Severe	0	2	21	0	0
			Bait		
None-slight	124	4	3	1	4
Moderate	4	2	1	1	0
Severe	0	0	4	0	1

[a] *Combines groups released into the river and into the fishway.*

Differences in the incidence and severity of injury of critical hooked fish explained some but not all of the difference in mortality between fish caught on lures and those caught on bait. Recovery frequencies also differed between lure-caught and bait-caught fish hooked in non-critical locations (jaw and tongue). Fish hooked in non-critical locations, primarily the jaw, were recovered at frequencies of 41% and 50% for lures and bait, respectively (Table 26). This difference may be because of the increased time that it took to remove treble hooks from fish caught with lures. Although we did not record the elapsed time, it was usually easier and faster to remove single hooks than treble hooks from fish. Single hooks were used when fishing bait whereas treble hooks were used with lures (Table 20). When two single or two treble hooks were used, the fish was usually hooked with only one hook.

Comparison of the Hooking Mortality Study to the Lower River Fishery

In addition to the hooking mortality study, we conducted a tackle survey of spring chinook salmon anglers in the Willamette River below Willamette Falls in 1998. The purpose of the survey was to identify the types of terminal gear used and the anatomical hook location of fish caught in the general sport fishery for comparison with our hooking mortality study at Willamette Falls. These survey data will also be used in the future to design hooking mortality studies that better represent the spring chinook salmon fishery in the lower Willamette River.

Table 26. Recovery by hook location of adult spring chinook salmon that were caught, tagged, and released at Willamette Falls, April 29-May 12, 1998.

Hook location	Lures[a]			Bait		
	Number tagged	Number recovered	Percentage recovered	Number tagged	Number recovered	Percentage recovered
Jaw	207	84	41	128	64	50
Tongue	19	8	42	6	1	17
Gill arches	29	3	10	8	1	12
Eye	4	1	25	2	1	50
Esophagus-stomach	0	--	--	5	2	40

[a] *Combines groups released into the river and into the fishway.*

Methods

The terminal gear survey in 1998 was an additional component to ODFW's standard, annual creel survey of spring chinook salmon anglers in the lower Willamette River (Foster 1997). Because of low run predictions, the 1998 angling season for Willamette spring chinook salmon was generally restricted to 2 days each week beginning March 9 and extending through April 8 when the season closed. The season reopened on May 10 because a revised forecast indicated that the spring chinook run was higher than earlier predicted. The gear survey was conducted on 9 days when the fishery was open during the restricted period (March 9-April 8). About 60% of the total 1998 catch of spring chinook salmon in the Willamette River occurred during this period. In a normal year the spring chinook salmon season generally begins in March and runs continuously into June.

Data on angler effort, catch of chinook salmon, terminal gear, and anatomical hook location were collected in three sections of the river during the restricted season. The upper section extended from the deadline at Willamette Falls (RM 27) downstream to the railroad bridge below Lake Oswego (RM 20). The mid section extended from the railroad bridge (RM 20) downstream to the St. John's Bridge in Portland (RM 7). The lowermost section extended from the St. John's Bridge (RM 7) to the mouth of the Willamette (RM 0) and included Multnomah Channel (a 22 mile channel that enters the Columbia River downstream from the mouth of the Willamette River).

Anglers were asked to identify the specific terminal gear used during their fishing trip and the relative proportion of the time that each gear type was used. Angling hours were then apportioned by the specific type of terminal gear. Baits used in combination with spinner blades or other lure-type attractors were included in the bait category. If spring chinook salmon were caught, the specific tackle used to catch the fish and the anatomical hook location was recorded. Creel clerks examined the fish and confirmed the anatomical hook location. Only those fish whose hook locations could be verified by the creel clerk were used in assessing hook location. Estimates of catch and effort, were expanded for the time period of the gear survey (unpublished data, Craig Foster, ODFW). These estimates were prorated by the proportion of each gear type observed during the gear survey to estimate catch and effort by gear type in the lower Willamette River. Data on anatomical hook location were based only on fish observed by a creel clerk.

Catch Distribution and Gear Types

Distribution of catch differed among sections in the lower Willamette River (Figure 14). In 1998 about 60% of the spring chinook salmon were caught in the upper section near Willamette Falls (where we conducted our hooking mortality study), whereas about 20% of the salmon were caught in each of the lower sections (Figure 14) (Craig Foster, ODFW, unpublished data). However, the fishing season in 1998 was considerably shorter than in a normal year because of a low run. In normal years, the lowermost section from St. John's Bridge to the mouth accounts for over half of the total catch in the lower Willamette River (Figure 14). The shortened season in 1998 reduced the proportion of the catch that normally occurs in the lowermost section below Portland and increased the proportion of the catch that normally occurs near Willamette Falls (Figure 14).

Based on the 1998 survey, bait was used about 83% of the time in the spring chinook salmon fishery below Willamette Falls. The use of bait varied little across sections, ranging from a low of 77% in the section near Willamette Falls, to a high of 92% in the mid section from Lake Oswego to St. John's Bridge. However, the use of specific baits differed substantially among the three sections of the river (Table 27). Prawns were a big component of the bait used in the fishery near Willamette Falls (79%), but a minor component in the section below Portland (4%). Anglers primarily used herring and anchovies in the lowermost section below St. John's Bridge (95%), but rarely used them in the upper section near Willamette Falls (5%).

The specific types of bait used in the general fishery also differed substantially from those used in our study. The prawn-spinner combination that accounted for 97% of the fish caught on bait in our hooking mortality experiment, only accounted for 8% of the spring chinook salmon harvested on bait in the general fishery in the lower Willamette River.

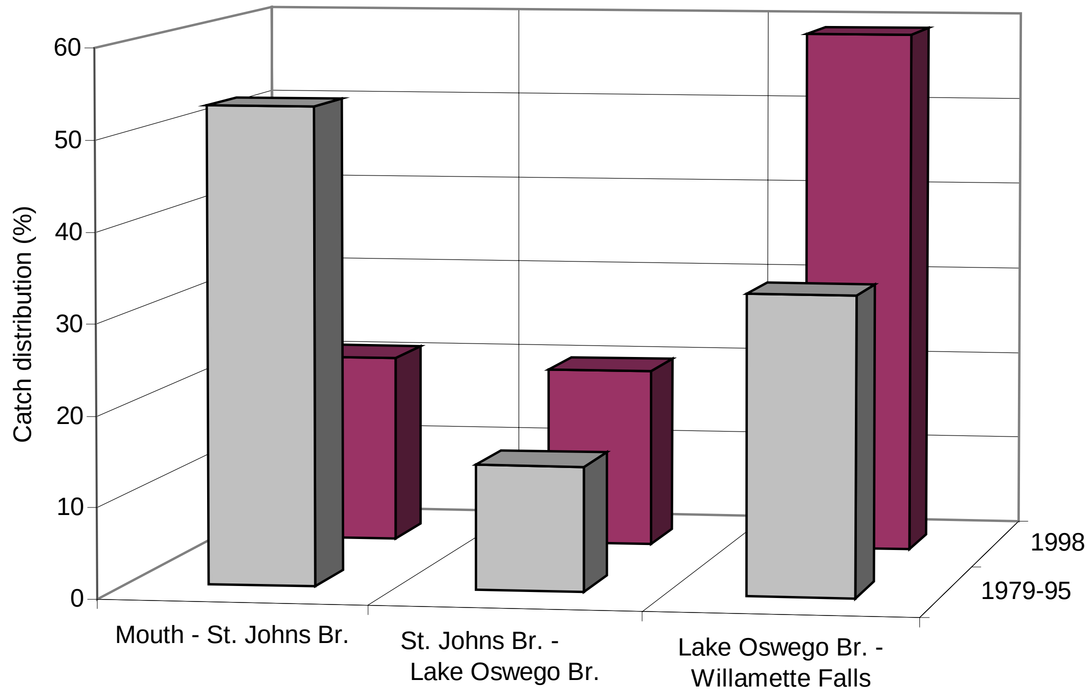

Figure 14. Distribution of the catch of adult spring chinook salmon in three sections of the Willamette River below Willamette Falls, 1979-95 (Foster 1997) and 1998 (Craig Foster, ODFW, unpublished data). The angling season in 1998 (also 1996 and 1997) was shorter than that in 1979-95 because of a low run.

Salmon anglers used lures 17% of the time in the lower Willamette River fishery in 1998. The types of lures used differed somewhat among the three sections of the lower river (Table 27). Spinners were the predominant lure used in the two upper sections above St. John's Bridge (57% and 46%), whereas plugs were the predominant lures used in the lowermost section below St. John's Bridge (50%). Spinners composed about 40% of the lures used below St. John's Bridge.

Overall, spinners were the most common lure used by salmon anglers below Willamette Falls (Table 27), accounting for 50% of the total hours that lures were used. Spinners also accounted for most of the catch on lures (49%). Plugs (mainly Flatfish/Kwikfish) accounted for 36% of the effort and 18% of the catch in the fishery. Of the fish caught with lures in our hooking mortality study at Willamette Falls, 56% were caught with spinners and 37% were caught with plugs (mainly Wiggle Warts).

The 1998 creel survey showed that gear types used by chinook salmon anglers varied among the three sections of the lower river. The survey also showed that the distribution of effort and of catch during the shortened season differed among sections from that in a normal fishing season. Because of these two factors, the survey in 1998 may not represent the overall relative use of different gear types that would occur in a normal lower river fishery.

Table 27. The percentage of time anglers used different gear types in each of three sections of the lower Willamette River, March 9-April 8, 1998. Baits used with a lure attractor are included under the bait category. Percentages may not add to 100% due to rounding errors. Data on specific gear types is in **APPENDIX D**.

	River section		
Gear types	Mouth to St. John's Bridge[a]	St. John's Bridge to Lake Oswego	Lake Oswego to Willamette Falls
		BAIT	
Fish (e.g. herring)	95	65	5
Eggs	0	0	15
Prawns	4	36	79
		LURES	
Plugs[b]	50	38	25
Spinners	41	46	57
Wobblers, spoons	6	9	16
Other[c]	2	7	2

[a] *Includes Multnomah Channel.*
[b] *Flatfish, Wiggle Warts, etc.*
[c] *Includes Spin Glo and rubber squid.*

Anatomical Hooking Location

The anatomical hooking location of spring chinook salmon caught in the lower Willamette River fishery varied with gear type. Of the 252 spring chinook salmon examined by creel clerks during the lower river survey, most were hooked in the jaw (78%), similar to what we observed in the hooking mortality study (82%). Sixteen percent of the fish caught on bait in the sport fishery were hooked in critical locations (gill arches, eye, esophagus, and stomach), compared to 10% in our hooking mortality study. No fish caught with lures were hooked in critical locations in the sport fishery, whereas 13% of the fish caught on lures in our hooking mortality study were hooked in a critical site. These differences may result in our hooking mortality study underestimating mortality of fish caught and released on bait and overestimating mortality of fish caught and released on lures.

The difference in the percentage of fish hooked in critical locations with bait between the general sport fishery and our hooking mortality study was due to differences in the use of specific baits. We predominantly used a prawn-spinner combination in the hooking mortality study, whereas herring and prawns (without lure-type attractors) were predominantly used in the sport fishery. Anglers who fished with herring hooked only 2% of the fish in a critical location (Table 28). However, anglers who used prawns alone hooked 42% of the fish in a critical site (Table 28). The addition of a spinner to the prawn reduced the percentage of critical hooking in the general fishery from 42% to 6% (Table 28) similar to the 10% observed in our hooking mortality study. The physical size of the prawn-spinner combination may keep the bait from being taken deep into critical areas.

We do not know why there were no critically-hooked fish caught on lures in the general fishery when 13% of the fish caught on lures in the hooking mortality study were hooked in a critical site. Spinners were the predominant lure used in both cases. The difference may merely reflect the low sample size in the general creel survey because only 23 fish were checked that had been caught on spinners. In contrast, 148 fish were caught and released on spinners in the hooking mortality study. The difference could also be due to differences in the construction or size of the spinners, or the fish's response to a lure fished in fast, turbulent water that characterizes the horseshoe area of Willamette Falls.

TASK 2.2-- MORTALITY FROM FIN MARKING HATCHERY FISH

Mortality from externally marking hatchery spring chinook salmon is another aspect of determining the feasibility of a catch and release fishery in the lower Willamette River because hatchery fish would need to be marked for anglers to distinguish them from unmarked wild fish. In 1998 the second (1996 brood) of three broods of spring chinook salmon, marked by removing either a ventral fin or a maxillary bone, was released to determine survival to adult return. We also released groups with a combination ventral or maxillary clip and coded wire tag from McKenzie Hatchery to evaluate regeneration of the ventral fin and maxillary bone (Table 29). All groups were released in early spring from McKenzie, Marion Forks, and Clackamas hatcheries (Table 29). Coded wire tagged fish released at the same time at each hatchery served as controls. These fish will begin to return as age 4 adults in 2000.

The ability of markers to remove either a ventral fin or a maxillary bone was examined at the time smolts were released from Marion Forks and McKenzie hatcheries (Table 30). Fish at Clackamas hatchery were not checked because of the difficulty sampling their large rearing pond. However, Clackamas fish are marked at Marion Forks Hatchery prior to being transferred to Clackamas Hatchery. Quality checks of Marion Forks fish were assumed to be representative of Clackamas fish because both are marked by the same personnel during the same time period.

Table 28. Anatomical hook locations by gear type for spring chinook salmon caught by anglers in the Willamette River below Willamette Falls, March 9-April 8, 1998. Only hook locations verified by an ODFW creel clerk are included.

Gear type	Jaw	Tongue	Gill arch	Esophagus/ stomach	Total
Bait:					
Anchovy/spinner	1	0	0	0	1
Eggs	3	0	0	0	3
Eggs/shrimp	1	1	0	1	3
Herring	85	16	0	2	103
Herring/flasher	6	1	0	0	7
Herring/Spin Glo	1	0	0	0	1
Herring/spinner	3	0	0	0	3
Prawn	27	4	10	12	53
Prawn/spinner	16	0	1	0	17
Shrimp	4	0	1	5	10
Shrimp/spinner	0	0	0	1	1
Bait total	147	22	12	21	202
Lure:					
Alvin	2	0	0	0	2
Flatfish	3	0	0	0	3
Kwikfish	5	0	0	0	5
Kwikfish/flasher	1	0	0	0	1
Rubber squid	1	0	0	0	1
Spin Glo	1	0	0	0	1
Spinner	22	1	0	0	23
Spoons	2	0	0	0	2
Wiggle Wart	2	0	0	0	2
Wobbler	10	0	0		10
Lure total	49	1	0	0	50

Table 29. Groups of spring chinook salmon (1995 and 1996 broods) released as smolts into the McKenzie, North Santiam and Clackamas rivers in 1997 to evaluate effects of removing a ventral fin or a maxillary bone on survival to adult.

Hatchery	Mark	Number	Size at release (fish/lb)	Release date
		1995 Brood		
McKenzie	LV	29,632	8.7	Mar 6, 1997
	LM	29,624	8.7	Mar 6, 1997
	AD+CWT	97,148	8.7	Mar 6, 1997
Marion Forks (North Santiam R.)	RV	30,204	15.3	Mar 3-4, 1997
	RM	30,125	13.0	Mar 3-4, 1997
	AD+CWT	33,195	12.9	Mar 4, 1997
Clackamas	LV	26,692	13.6	Mar 31, 1997
	LM	26,526	13.6	Mar 31, 1997
	AD+CWT	29,211	13.6	Mar 31, 1997
		1996 Brood		
McKenzie	RV	32,537	9.3	Mar 5, 1998
	RM	37,723	9.2	Mar 5, 1998
	RVAD+CWT	28,383	8.5	Mar 5, 1998
	RMAD+CWT	29,620	8.5	Mar 5, 1998
	AD+CWT	224,474	9.0	Mar 5, 1998
Marion Forks (North Santiam R.)	LV	30,111	15.7	Mar 2-3, 1998
	LM	30,175	16.0	Mar 2-3, 1998
	AD+CWT	652,585	14.3	Mar 2-3, 1998
Clackamas	RV	29,279	13.9	Mar 18, 1998
	RM	30,438	13.9	Mar 18, 1998
	AD+CWT	31,007	13.9	Mar 18, 1998

Table 30. Quality of ventral and maxillary marks on 1996 brood spring chinook salmon at Marion Forks (North Santiam River) and McKenzie hatcheries at time of release in 1998.

Hatchery, clip quality	Ventral clip	Maxillary clip
Marion Forks	**(LV)**	**(LM)**
Completely clipped	91%	99%
75%-50% clipped	6%	<1%
Less than 50% clipped	3%	<1%
Sample size	163	145
McKenzie	**(RV)**	**(RM)**
Completely clipped	100%	98%
75%-50% clipped	0%	2%
Less than 50% clipped	0%	0%
Sample size	61	66
McKenzie	**(RVAD+CWT)**	**(RMAD+CWT)**
Completely clipped	63%	93%
75%-50% clipped	24%	2%
Less than 50% clipped	13%	5%
Sample size	62	58

TASK 2.3-- EVALUATION OF NET PENS IN THE LOWER WILLAMETTE RIVER

In the 1970's, studies by Smith et al. (1985) found that trucking juvenile spring chinook salmon below Willamette Falls at Oregon City increased angler catch in the Clackamas and lower Willamette rivers by improving survival to adult. Straying also increased. However, Specker and Schreck (1980) found that trucking smolts caused severe stress that tended to reduce survival compared to fish not trucked. Johnson et al. (1990) and Seiler (1989) suggested that stress from trucking could be reduced and survival increased by acclimating juveniles at a site for several weeks prior to release. Acclimation at lower river release sites may increase angler harvest by improving survival of juveniles and by delaying migration to upriver areas.

1996 Brood Releases

A study was begun in 1992 to determine if acclimation prior to release could be used to increase harvest of hatchery spring chinook salmon in the lower Willamette River. McKenzie River stock was to be used because of concerns about straying of other stocks into the McKenzie, a stronghold for wild spring chinook salmon. The evaluation of straying was an important part of the study. Fish were acclimated in net pens and compared to fish trucked directly from the hatchery. Control groups were released into the McKenzie River from McKenzie Hatchery. The study was originally planned for 4 brood years. However, numerous problems led to modifications in study design beginning with the 1995 brood and an extension of the study for three additional years through 1998 brood releases. Lindsay et al. (1997) describe releases of experimental groups for 1992-95 broods (corrected release numbers for the 1995 brood are shown in **APPENDIX E** of this report). Table 31 shows study releases of 1996 brood spring chinook.

Adult Recovery of 1992 Brood Releases

The main objective of acclimating juveniles in net pens in the lower Willamette River was to increase the sport harvest of these fish when they returned. Adults from the first acclimated (1992 brood) releases were primarily recovered in 1996 and 1997 at age 4 and age 5, respectively. Recovery data were standardized for differences in the number of smolts released.

About eight times more control fish released at McKenzie Hatchery were caught in freshwater sport fisheries in the lower Willamette River than were either the acclimated or direct release groups (Table 32) ($P < 0.05$, ANOVA with arcsin square root transformed data and Student-Newman-Keuls pairwise multiple comparison methods). In addition, most of the adult returns from acclimated groups strayed to hatcheries other than McKenzie Hatchery where they originated (Table 32). The recovery of fish in Willamette River fisheries was low in 1996 and 1997 because the duration of the fishing season was shortened each year due to low runs. Sport harvest in freshwater over a full season may have yielded different results. Harvest in ocean fisheries suggested survival of acclimated groups was higher than freshwater recovery data indicated (Table 32). However, the difference between the recovery of control and acclimated groups in the ocean was not significant (Kruskal-Wallis ANOVA on ranks). The return of direct release groups was much lower than either acclimated or control groups (Table 32).

Table 31. Releases of spring chinook salmon into the lower Clackamas and Willamette rivers to evaluate acclimation in net pens, 1996 brood.

Stock	Tag code	Treatment	Location of release	Number AD+CWT	Size: Fish/lb	Size: Length (mm)	Days Accli-mated	Release date
McKenzie	092228[a]	Acclimate	Mult. Channel	30,368	7.9	172.0	21	11/6/97
McKenzie	092229[a]	Acclimate	Mult. Channel	30,916	7.8	170.8	21	11/6/97
McKenzie	092230[a]	Direct	Mult. Channel	30,273	7.4	170.7	--	11/6/97
McKenzie	092231[a]	Direct	Mult. Channel	31,359	8.3	170.7	--	11/6/97
Willamette[b]	092159[a]	Acclimate	River Place	26,180	9.7		20	11/4/97
Willamette[b]	092159[a]	Direct	Will. Park	26,121	8.5		--	11/4/97
McKenzie	092238	Acclimate	Clack. Cove	39,168	9.4	163.8	24	3/12/98
McKenzie	092239	Acclimate	Clack. Cove	39,106	10.3	165.9	24	3/12/98
McKenzie	092236	Direct	Clack. Cove	37,178	9.4	161.4	--	3/12/98
McKenzie	092237	Direct	Clack. Cove	36,825	9.5	156.6	--	3/12/98
McKenzie	092234	Direct	Clack. River	34,071	8.4	162.3	--	3/12/98
McKenzie	092235	Direct	Clack. River	36,118	8.6	159.3	--	3/12/98
McKenzie	092232	Direct	Mult. Channel	36,135	9.0	166.4	--	3/13/98
McKenzie	092233	Direct	Mult. Channel	30,798	8.5	159.7	--	3/13/98
McKenzie	092242	Control	McK. Hatch.	28,685	9.3	--	--	3/5/98
McKenzie	092243	Control	McK. Hatch.	28,391	9.3	--	--	3/5/98
McKenzie	092244	Control	McK. Hatch.	28,531	9.4	--	--	3/5/98
McKenzie	092248	Control	McK. Hatch.	56,907	9.4	--	--	3/5/98

[a] *Tag codes not in PSMFC database as of 12/31/98.*
[b] *These fish are not part of the net pen evaluation.*

Table 32. Coded wire tag recoveries (expanded) of experimental fish used to evaluate acclimation in net pens in the Willamette River, 1992 brood. Recoveries were adjusted to a standard 100,000 smolt release. Tag recoveries were obtained from coded wire tag data reports of the Pacific Marine Fisheries Commission's Regional Mark Processing Center, December 1998.

Recovery location	Control	Acclimated	Direct
Ocean			
Troll and net fisheries	12	20	0
Freshwater			
Columbia River gill net	1	0	0
Sport fisheries	25	3	0
Hatcheries			
Originating	183	10	5
Other	2	13	0
Leaburg Dam trap (Mckenzie River)	6	0	0
Spawning grounds (McKenzie River)	3	0	0
Other[a]	2	0	0

[a] *Includes dead fish found immediately below Willamette Falls, fish sampled in Willamette Falls fishway, and fish caught in treaty and test fisheries.*

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REFERENCES

Aebersold, P.B., G.A. Winans, D.J. Teel, G.B. Milner, and F.M. Utter. 1987. Manual for starch gel electrophoresis: a method for the detection of genetic variation. National Oceanic and Atmospheric Administration Technical Report, National Marine Fisheries Service 61, Seattle, Washington.

Bennett, D.E. 1994. 1994 Willamette River spring chinook salmon run, fisheries, and passage at Willamette Falls. Oregon Department of Fish and Wildlife, Portland.

Bendock, T. and M. Alexandersdottir. 1993. Hooking mortality of chinook salmon released in the Kenai River, Alaska. North American Journal of Fisheries Management. 13:540-549.

Bentzen, P., and J. Olsen, and J. Britt. 1998. Microsatellite DNA polymorphism in spring chinook (*Oncorhynchus tshawytscha*) from Clackamas Hatchery, the Upper Sandy River and the Bull Run River and it implications for population structure. University of Washington, Marine Molecular Biotechnoloty Laboratory, Final Report. Seattle.

Brothers, E.B. 1990. Otolith marking. American Fisheries Society Symposium 7:183-202.

Clay, C. H. 1995. Design of fishways and other fish facilities. CRC Press, Florida. 248 pp.

Foster, C.A. 1997. 1996 Willamette River spring chinook salmon run, fisheries, and passage at Willamette Falls. Oregon Department of Fish and Wildlife, Portland.

Grimes, J.T., R.B. Lindsay, K.R. Kenaston, K. Homolka, and R.K. Schroeder. 1996. Willamette spring chinook salmon. Oregon Department of Fish and Wildlife, Fish Research Project F-163-R-00, Annual Progress Report, Portland.

Grimm, J. J., and E. C. Volk. 1998. Evaluation of otolith thermal marks in spring chinook (*Oncorhynchus tshawytscha*): report to the Oregon Department of Fish and Wildlife. Unpublished report. Washington Department of Fish and Wildlife, Olympia.

Johnson, S.L., M.F. Solazzi, and T.E. Nickelson. 1990. Effects on survival and homing of trucked hatchery yearlying coho salmon to release sites. North American Journal of Fisheries Management 10:427-433.

Lindsay, R.B., K.R. Kenaston, R.K. Schroeder, J.T. Grimes, M. Wade, K. Homolka, and L. Borgerson. 1997. Spring chinook salmon in the Willamette and Sandy rivers. Oregon Department of Fish and Wildlife, Fish Research Report F-163-R-01, Annual Progress Report, Portland.

Mongillo, P. 1984. A summary of salmonid hooking mortality. Washington Department of Game. Unpublished draft report.

ODFW (Oregon Department of fish and Wildlife). 1988. McKenzie subbasin fish management plan. Oregon Department of Fish and Wildlife, Portland.

ODFW (Oregon Department of fish and Wildlife). 1992. Wild fish Management Policy. Oregon Department of Fish and Wildlife Administrative Rule No. 635-07-252 through 635-07-529, Portland.

ODFW (Oregon Department of fish and Wildlife). 1992a. Clackamas subbasin fish management plan. Oregon Department of Fish and Wildlife, Portland.

ODFW (Oregon Department of fish and Wildlife). 1992b. Santiam and Calapooia subbasins fish management plan. Oregon Department of Fish and Wildlife, Portland.

ODFW (Oregon Department of fish and Wildlife). 1996. Sandy subbasin fish management plan (draft). Oregon Department of Fish and Wildlife, Portland.

ODFW (Oregon Department of fish and Wildlife). 1998. The biological & technical justification for the Willamette River flow proposal of the Oregon Department of Fish and Wildlife (draft). Oregon Department of Fish and Wildlife, Portland.

Seiler, D. 1989. Differential survival of Grays Harbor basin anadromous salmonids: water quality implications. Canadian Special Publication of Fisheries and Aquatic Sciences 105: 123-135.

Smith, E.M., J.C. Zakel, and W.H. Day. 1985. Willamette River salmon studies. Oregon Department of Fish and Wildlife, Fish Research Projects F-102-R6 (as part of F-119-R) and DACW 57-74-C-0192, Annual Progress Report, Portland.

Specker, J.L. and C.B. Schreck. 1980. Stress responses to transportation and fitness for marine survival in coho salmon (Oncorhynchus kisutch) smolts. Canadian Journal of Fisheries and Aquatic Sciences 37: 765-769.

Utter, F., P. Aebersold, and G. Winans. 1987. Interpreting genetic variation detected by electrophoresis. Pages 21-45 in N. Ryman and F.W. Utter, editors. Population Genetics and Fishery Management. Washington Sea Grant, University of Washington Press, Seattle.

Volk, E.C., S.L. Schroder, and K.L. Fresh. 1990. Inducement of unique otolith banding patterns as a practical means to mass-mark juvenile Pacific salmon. American Fisheries Society Symposium 7:203-215.

APPENDIX A

Schematic of Willamette Spring Chinook Salmon Study Plan

APPENDIX B

Otoliths Collected from Adult Spring Chinook Salmon in Several Willamette River Tributaries, 1997 and 1998.

Stream	Location	Number	Comments
	1998		
North Santiam	Spawning ground	5	AD+CWT
	Minto pond	49	AD+CWT
McKenzie	Hatchery	183	AD+CWT
	Spawning ground[a]	94	AD+CWT (19) and unmarked (75)
Middle Fork Willamette	Hatchery	124	AD+CWT, random sample
	1997		
North Santiam	Creel survey	34	Every fish possible
	Spawning ground	134	Every fish possible
	Minto pond	148	Unmarked, every third fish
	Minto pond	45	AD+CWT
McKenzie	Hatchery	209	AD+CWT, over 86 cm
	Leaburg Dam[b]	26	AD+CWT
	Spawning ground	50	AD+CWT and unmarked
Middle Fork Willamette	Hatchery	117	AD+CWT, random sample

[a] *Below Leaburg Dam.*

[b] *These fish were taken to McKenzie Hatchery and spawned, otoliths were collected at the time of spawning.*

APPENDIX C

Spawning Surveys for Spring Chinook Salmon in the Willamette and Sandy Basins, 1998

Appendix Table C-1. Number of chinook redds and carcasses observed in the North Santiam River in 1998.

Survey section	Length (mi)	Number of surveys	Counts: Redds	Counts: Carcasses[a]
North Santiam:				
Minto - Fishermen's Bend	10.0	7	118	172
Fishermen's Bend - Mehama	6.5	9	28	79
Mehama - Power line	3.5	3	4	3
Powerline - Gerren Island	3.5	3	0	0
N. + South Channels - Stayton[b]	3.3	3	33	4
Stayton - Shellburn	5.5	2	0	0
Shellburn - Greens bridge	8.2	2	64	48
Greens bridge - mouth	3.0	1	14	1
Little North Santiam River:				
Elkhorn Bridge - Salmon Falls	1.0	2	2	0
Salmon Falls - Golf bridge	3.5	2	23	3
Golf bridge - Middle bridge	5.3	2	11	5
Middle bridge - Mouth	7.2	2	2	0

[a] *Includes carcasses that could not be reached to sample.*

[b] *The north channel was surveyed twice and two carcasses and 29 redds were counted. The south channel was surveyed three times and two carcasses and 4 redds were counted.*

Appendix Table C-2. Spawning surveys for spring chinook salmon in the Clackamas River above North Fork Dam, 1998.

Survey section	Length (mi.)	Number of surveys	Counts		
			Live fish	Carcasses[a]	Redds
Clackamas River:					
Sisi Creek – Pinhead Creek	5.8	3	12	2	10
Pinhead Creek – Forest Road 4650	3.3	8	86	12	77
Forest Road 4650 – Collawash River	8.0	7	110	12	56
Collawash River – Oak Grove Fork	3.8	5	102	25	48
Oak Grove Fork – Cripple Creek	4.7	6	88	21	49
Cripple Creek – Fish Creek	6.8	6	27	11	33
Fish Creek – South Fork Clackamas	7.7	6	59	23	43
South Fork Clackamas – North Fork Reservoir	1.0	3	12	3	7
Collawash River:					
2.0 miles upstream – Collawash Falls	2.0	1	0	0	0
Collawash Falls – Upper Forest Road 63	1.0	3	4	0	2
Upper Forest Road 63 – Hot Springs Fork	2.0	4	19	0	12
Hot Springs Fork – Mouth	4.5	5	23	6	29
Hot Springs Fork:					
Bagby Trail Bridge – Pegleg Falls	1.3	2	0	0	0
Pegleg Falls - Mouth	5.0	2	0	0	0
Pinhead Creek:					
Last Creek – mouth	1.0	1	0	0	0
Roaring River:					
Falls – mouth	2.0	4	5	0	3
Fish Creek:					
Silk Creek – mouth	4.7	4	1	0	8
South Fork Clackamas River:					
Falls – mouth	0.6	5	3	0	3
North Fork Clackamas River:					
Fall Creek – mouth	1.5	1	0	0	0

[a] *Includes carcasses that could not be reached to sample.*

Appendix Table C-3. Spawning surveys for spring chinook salmon in the Sandy River above Marmot Dam, 1998.

Survey section	Length (mi.)	Number of surveys	Counts		
			Live fish	Carcasses[a]	Redds
Salmon River:					
Final Falls – Rolling Riffle	1.5	7	199	52	102
Rolling Riffle – Forest Road 2618	1.7	7	104	32	111
Forest Road 2618 – Bridge Street	3.6	7	125	27	55
Bridge Street – start of USFS index area	1.1	7	115	50	84
USFS index area	0.2	7	49	17	26
End of index area – Arrah Wanna campground	0.5	7	37	30	15
Arrah Wanna campground – Highway 26	4.4	7	366	175	199
Highway 26 – mouth	0.6	3	8	7	9
Tributaries:					
Cheeney Creek	2.0	3	0	0	2
Boulder Creek	1.0	1	0	0	0
Zigzag River:					
Devil Canyon Creek – Camp Creek	1.5	1	0	0	0
Camp Creek – Still Creek	2.0	2	0	3	2
Still Creek - mouth	2.0	3	2	6	8
Still Creek:					
Forest Road 2612 – Cool Creek	2.0	2	0	0	0
Cool Creek – Forest Road 20	1.7	7	40	8	38
Forest Road 20 – smolt trap	1.3	6	33	12	51
Smolt trap – mouth	0.3	6	1	3	3
Camp Creek:					
Laurel Hill – campground	2.0	1	0	0	0
Campground – mouth	2.0	3	9	4	9
Other Zigzag tributaries:					
Lady Creek: 1.0 miles upstream – mouth	1.0	1	0	0	0
Henry Creek: East Henry Road – mouth	1.0	2	0	0	0
Devil Canyon Creek: Falls – mouth	0.8	1	0	0	0
Muddy Fork Creek: 2.0 miles upstream – mouth	2.0	1	0	0	0
Clear Creek:					
Powerline - mouth	1.4	2	1	0	0
Clear Fork:					
Barrier - mouth	0.6	3	11	13	17
Lost Creek:					
Lost Creek Campground – Riley Creek campground	2.5	1	0	0	0
Riley Creek campground – mouth	2.0	3	9	2	13

[a] *Includes carcasses that could not be reached to sample.*

Appendix Table C-4. Counts of adult spring chinook salmon at North Fork Dam and the relationship to successful spawners in the Clackamas River Basin above the dam, 1996-98.

Year	Counts			Fish/redd[c]
	North Fork Dam[a]	Total redds	Spawners[b]	
1996	824	182	364	4.53
1997	1261	376	752	3.35
1998	1382	380	760	3.64

[a] *Total up to one week prior to the last spawning survey.*
[b] *Estimated from redds using 1:1 sex ratio and two fish per redd.*
[c] *From dam counts.*

Appendix Table C-5. Counts of adult spring chinook salmon at Marmot Dam and the relationship to successful spawners in the Sandy River Basin above the dam, 1996-98.

Year	Counts				Fish:redd[d]
	Marmot Dam[a]	Harvest[b]	Total redds	Spawners[c]	
1996	2461	78	569	1138	4.19
1997	3277	233	731	1462	4.16
1998	2606	185	744	1488	3.25

[a] *Total up to one week prior to the last spawning survey.*
[b] *For Sandy River above dam. Estimated from punch card data: point estimate for 1996 (last point estimate available); and 1988-96 average exploitation rate of 7.1% (punch card estimate/ Marmot Dam count) for 1997 and 1998.*
[c] *Estimated from redds using 1:1 sex ratio and two fish per redd.*
[d] *From dam counts minus harvest.*

APPENDIX D

Hooking Mortality and Gear Survey Data Collected in the
Willamette River, Spring, 1998.

Appendix Table D-1. Recovery by location and method for hooking mortality experimental groups of adult spring chinook salmon tagged and released at Willamette Falls, 1998.

Location	Method	Fishway control	Fishway lure	River control	River lure	River bait	Total
Middle Fork Willamette	Fishery	0	5	3	3	5	16
	Hatchery	26	14	19	24	32	115
McKenzie	Hatchery	4	4	3	2	3	16
	Trap	1	2	4	1	1	9
	Spawning ground	0	0	0	0	1	1
South Santiam	Fishery	2	4	4	1	4	15
	Hatchery	7	10	10	11	17	55
North Santiam	Fishery	0	2	0	0	0	2
	Hatchery	1	1	2	1	1	6
	Trap	3	4	3	4	5	19
	Spawning ground	1	0	2	1	0	4
Santiam	Fishery	0	0	0	0	1	1
Mollala	Fishery	0	1	0	0	0	1
Willamette (above falls)	Fishery	0	0	1	0	0	1
Willamette (below falls)	Fishery	1	0	1	1	0	3
Clackamas	Fishery	0	0	2	1	0	3
	Hatchery	2	0	0	0	1	3
Columbia	Fishery	0	0	1	0	0	1
Total		48	47	55	50	71	271

Appendix Table D-2. Annual estimates of spring chinook salmon catch in the lower Willamette River by river section, 1979-98. Data from 1979-96 from Foster (1997).

	River section						
	Mouth to St. John's Bridge[a]		St. John's Bridge to Lake Oswego		Lake Oswego to Willamette Falls		
Year	catch	Percent	catch	percent	catch	Percent	Total
1979	8412	65	1915	15	2522	20	12849
1980	4552	65	1031	15	1411	20	6994
1981	7391	71	964	9	2125	20	10480
1982	9870	52	2834	15	6202	33	18906
1983	7593	55	1421	10	4814	35	13828
1984	7222	37	3275	17	8870	46	19367
1985	8130	52	2439	16	4971	32	15540
1986	8837	59	950	6	5214	35	15001
1987	11036	59	2352	12	5449	29	18837
1988	10377	42	3580	15	10687	43	24644
1989	15339	63	3252	13	5615	23	24206
1990	10897	47	3754	16	8324	36	22975
1991	13205	43	6111	20	11183	37	30499
1992	8168	60	1647	12	3693	27	13508
1993	7451	36	3683	18	9609	46	20743
1994	6039	53	1309	11	4110	36	11458
1995	6041	41	2226	15	6414	44	14681
1996	1342	22	968	16	3746	62	6056
1997	534	29	544	29	783	42	1861
1998	579	21	570	20	1649	59	2798

[a] *Includes Multnomah Channel.*

Appendix Table D-3. General gear type and success rate of spring chinook salmon anglers by river section on the lower Willamette River, March 9-April 8, 1998. Section 1 = Willamette Falls to Lake Oswego; section 2 = Lake Oswego to St. John's Bridge; section 3 = St. John's Bridge to the mouth (including Multnomah channel).

	River section		
	1	2	3
Chinook caught	629	550	494
Angler hours:			
Bait	17426	13351	19165
Lures	5124	1103	3872
Percent bait	77.3%	92.4%	83.2%
Success rate (hours/fish)	35.9	26.3	46.6

Appendix Table D-4. Catch rate (hours per fish) of spring chinook salmon for gear types that caught fish in the Willamette River below Willamette Falls, March 9-April 8, 1998.

Tackle	Angler hours	Catch[a]	Hours per fish
Herring/Spin Glo	20	3	6.5
Rubber squid	21	3	7.0
Kwikfish/flasher	30	3	10.1
Anchovy/spinner	80	7	11.4
Wobbler	676	58	11.7
Prawn/spinner	1765	111	15.9
Spoons	178	10	17.8
Shrimp/spinner	260	11	23.6
Spin Glo	194	7	27.7
Prawn	13297	426	31.2
Herring	22505	668	33.7
Alvin	206	6	34.3
Shrimp	4086	115	35.5
Kwikfish	911	25	36.5
Spinner	5038	123	41.0
Eggs	1096	20	54.8
Wiggle Wart	357	6	59.4
Flatfish	904	12	75.4
Eggs/shrimp	1646	20	82.3
Herring/flasher	3021	21	143.8
Herring/spinner	1814	9	201.6

[a] *An additional nine fish were caught on unknown tackle.*

Appendix Table D-5. Angler hours by river section for different lures used to fish spring chinook salmon, March 9-April 8, 1998. Section 1 = Willamette Falls to Lake Oswego; section 2 = Lake Oswego to St. John's Bridge; section 3 = St. John's Bridge to the mouth (including Multnomah channel).

Lure	River section 1	River section 2	River section 3
Alvin	49	22	135
Flatfish	0	0	904
Flatfish/herring	0	0	45
Flatfish/sardine	0	0	21
Hotshot	0	0	11
Kwikfish	153	131	627
Kwikfish/flasher	0	0	30
Lures (unknown)	44	79	0
Plugs (unknown)	1137	0	247
Rubber squid	0	0	21
Spin Glo	79	79	36
Spinner	2941	503	1594
Spoons	101	0	77
Wiggle Wart	0	289	68
Wobbler	621	0	55
Total	5124	1103	3872

Appendix Table D-6. Angler hours by river section for different baits used to fish spring chinook salmon, March 9-April 8, 1998. Section 1 = Willamette Falls to Lake Oswego; section 2 = Lake Oswego to St. John's Bridge; section 3 = St. John's Bridge to the mouth (including Multnomah channel).

Bait	River section		
	1	2	3
Anchovy	55	0	0
Anchovy/spinner	80	0	0
Cut plug	0	0	14
Eggs	1077	0	19
Eggs/shrimp	1646	0	0
Herring	789	7719	13997
Herring/flasher	0	487	2534
Herring/Spin Glo	0	0	20
Herring/spinner	0	140	1674
Herring/wobbler	0	0	24
Prawn	9036	3782	479
Prawn/spinner	1567	0	198
Sardine/spinner	0	0	34
Shrimp	3043	926	117
Shrimp/herring	0	228	0
Shrimp/spinner	133	70	57
Total	17426	13351	19165

APPENDIX E

Corrected Releases of Spring Chinook Salmon into the Lower Clackamas and Willamette Rivers to Evaluate Acclimation in Net Pens, 1995 Brood [a]

Stock	Tag code	Treatment	Location of release	Number Ad+CWT	Size: Fish/lb	Size: Length (mm)	Days Accli-mated	Release date
McKenzie	091758	Acclimate	Clack. Cove	29,049	8.0	167.8	22	11/8/96
McKenzie	091759	Acclimate	Clack. Cove	29,407	7.9	168.2	22	11/8/96
McKenzie	091756	Direct	Clack. Cove	29,610	7.1	174.0	--	11/8/96
McKenzie	091757	Direct	Clack. Cove	28,955	7.1	174.0	--	11/8/96
McKenzie	091754	Direct	Clack. River	33,415	7.0	172.0	--	11/8/96
McKenzie	091755	Direct	Clack. River	27,699	6.9	173.6	--	11/8/96
Willamette[b]	091715[c]	Acclimate	River Place	14,301	7.7	167.5	24	11/9/96
Willamette[b]	091715[c]	Direct	Will. Park	16,587	9.3	--	--	11/5/96
McKenzie	091801	Acclimate	Clack. Cove	30,529	9.5	158.1	21	3/13/97
McKenzie	091802	Acclimate	Clack. Cove	24,996	8.2	164.9	21	3/13/97
McKenzie	091760	Direct	Clack. Cove	30,170	9.1	165.5	--	3/13/97
McKenzie	091762	Direct	Clack. Cove	30,120	8.9	161.9	--	3/13/97
McKenzie	091761	Direct	Mult. Channel	28,380	10.1	156.0	--	3/13/97
McKenzie	091763	Direct	Mult. Channel	29,634	8.9	160.8	--	3/13/97
McKenzie	071258	Control	McK. Hatch.	29,143	8.7	167.7	--	3/6/97
McKenzie	091803	Control	McK. Hatch.	34,167	8.7	167.7	--	3/6/97
McKenzie	091804	Control	McK. Hatch.	33,838	8.7	167.7	--	3/6/97

[a] *Corrected Table 25 from Lindsay et al. 1997.*
[b] T*hese fish are not part of the net pen evaluation.*
[c] *Tag codes not in PSMFC database as of 12/31/98*