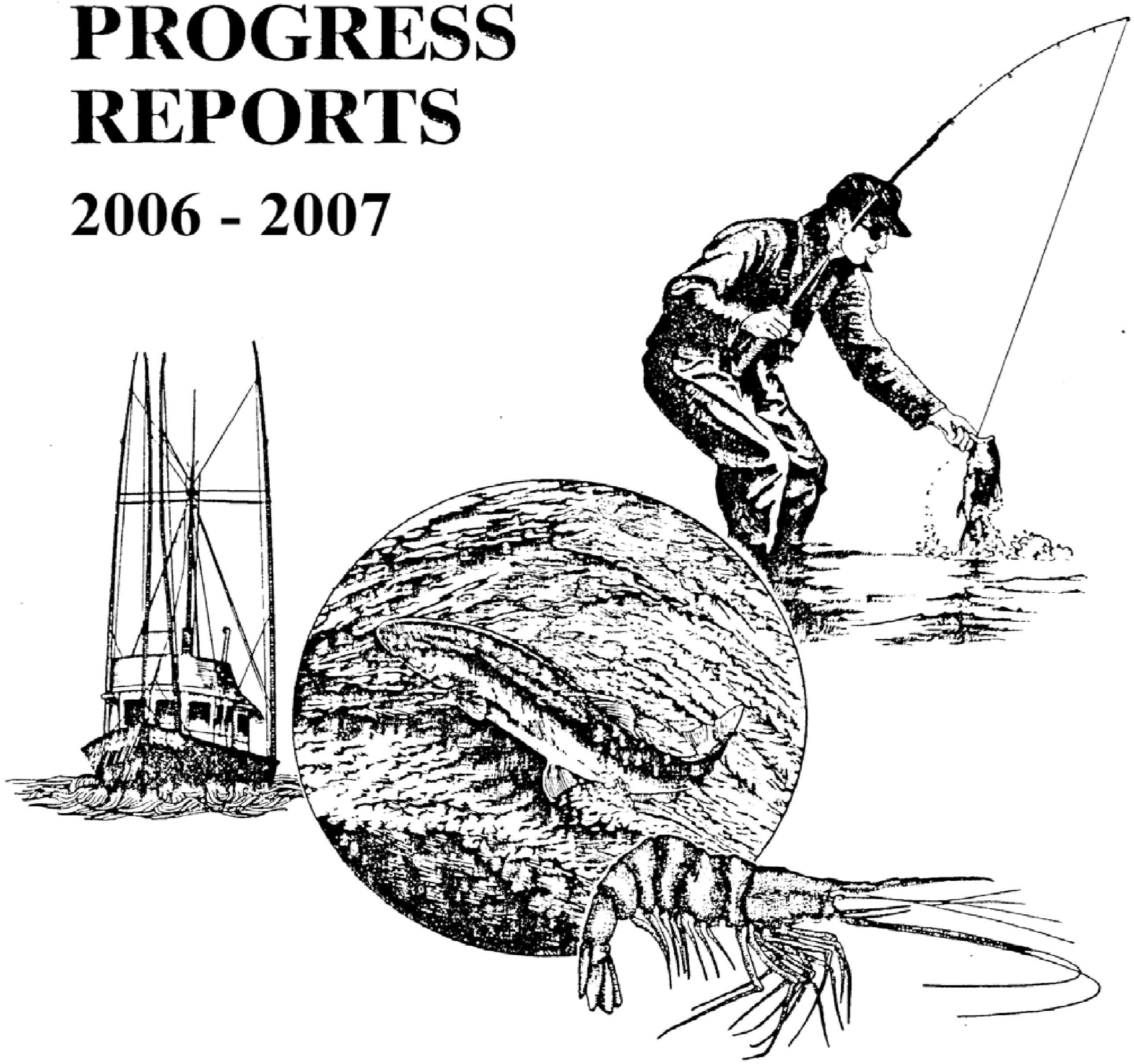
PROGRESS REPORTS

2006 - 2007



FISH DIVISION

Oregon Department of Fish and Wildlife

Spring Chinook in the Willamette and Sandy Basins

ANNUAL PROGRESS REPORT

FISH RESEARCH PROJECT
OREGON

\PROJECT TITLE: Spring Chinook Salmon in the Willamette and Sandy Rivers

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CONTENTS

KEY FINDINGS

1. The number of wild spring Chinook salmon in 2006 and 2007 in the three basins where we can estimate adult runs using otolith analysis was:
    - 2,189 and 2,735 (McKenzie upstream of Leaburg Dam), 40% and 35% lower than 2001–2005;
    - 798 and 1,178 (Clackamas above North Fork Dam), 68% and 53% lower than 2002–2005;
    - 1,209 and 1,304 (Sandy above Marmot Dam), 12% and 5% lower than 2002–2005.

2. The percentage of wild spring Chinook incorporated into hatchery broodstocks was higher in 2006 and 2007 than in previous years, and 100 or more wild fish were spawned at all hatcheries in at least one of the years:
    - 10% and 8% (McKenzie) compared to 2%;
    - 36% and 29% (North Santiam) compared to 2%;
    - 12% and 10% (South Santiam) compared to 5%;
    - 3% and 10% (Willamette) compared to 1%.

3. During a 42-day volitional fall release at McKenzie Hatchery, only a third of the fish emigrated from the hatchery pond and took longer to migrate to Willamette Falls than did fish in the standard release group. Within the volitional period, the highest level of migration occurred during a dark phase of the moon.

4. Many of the juvenile spring Chinook tagged in late spring and early summer migrate past Willamette Falls and into the lower Columbia River estuary as subyearlings, especially those tagged in the lower Santiam River and in the Willamette River downstream of the Santiam. A higher percentage of juvenile fish tagged in late June and July rear through the summer in the Willamette River or lower reaches of the large eastside tributaries and emigrate in fall-winter and the following spring, especially fish tagged in the McKenzie and North and South Santiam rivers.

5. The percentage of adult spring Chinook with an age-0 life history (subyearling) was lower for the 2000 brood year returns than the 1998–1999 and 2001 brood years, and was higher in the North and South Santiam than in other basins:
    - 2% (McKenzie) compared to an average of 21%;
    - 16% (South Santiam) compared to an average of 75%;
    - 9% (North Santiam) compared to an average of 45%;
    - 4% (Clackamas) compared to an average of 22%;
    - 5% (Sandy) compared to an average of 13%.

6. Pre-spawning mortality of adult spring Chinook was lowest in 2006 than any other year since we began surveys in 2001. Pre-spawning mortality remained low in 2007 in the McKenzie (upstream of Leaburg Dam), South Santiam, Clackamas, and Sandy rivers. Pre-spawning mortality was significantly higher downstream of dams than upstream.

INTRODUCTION

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

The Oregon Fish and Wildlife Commission adopted the Native Fish Conservation Policy (ODFW 2003a) and the Hatchery Management Policy (ODFW 2003b) in part to reduce adverse impacts of hatchery programs on wild native stocks. The Native Fish Conservation Policy recognizes that naturally produced native fish are the foundation for long-term sustainability of native species and hatchery programs, and the fisheries they support. Possible risks of artificial propagation programs have been well documented. Hazards include disease transfer, competition for food and spawning sites, increased predation, increased incidental mortality from harvest, loss of genetic variability, genetic drift, and domestication (Steward and Bjornn 1990; Hard et al. 1992; Cuenco et al. 1993; Busack and Currens 1995; NRC 1996; and Waples 1999). Hatcheries can also play a positive role for wild salmonids by bolstering populations, especially those on the verge of extirpation, by providing a genetic reserve as well as providing opportunities for nutrient enrichment of streams (Steward and Bjornn 1990; Cuenco et al. 1993).

In the past, hatchery programs and fish passage issues were the focus of spring Chinook salmon management in the Willamette and Sandy basins. Limited information was collected on the genetic structure among basin populations, on abundance and distribution of natural spawning, on rearing and migrating of juvenile salmon, 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 shown in **APPENDIX A**.

We conducted work in the main-stem Willamette River above Willamette Falls, and in the Middle Fork Willamette, McKenzie, North Santiam, South Santiam, Clackamas, and Sandy rivers in 2006 and 2007. 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 tasks that were worked on in late 2005 through early fall 2007.

TASK 1.2 – THE PROPORTION OF WILD FISH IN SPAWNING POPULATIONS

Restoration under the Endangered Species Act and the implementation of ODFW's Native Fish Conservation Policy require information on hatchery and wild fish in spawning populations. Partly in response to this need, but also to implement a selective fishery, all hatchery spring Chinook salmon in the Willamette basin were marked with adipose fin clips beginning with the 1997 brood. To help separate hatchery fish without fin clips from wild fish, otoliths were thermally marked on all hatchery spring Chinook released in the Willamette basin beginning with the 1997 brood year.

Methods

Juveniles

All hatchery spring Chinook salmon from the 2005 and 2006 brood were released in the Willamette and Sandy basins with thermal marks in their otoliths (Table 1). Thermal marks were induced by placing incubating eggs or hatched fry on water that was colder or warmer than ambient incubation water. Water temperature was decreased from ambient temperature using a chiller (McKenzie), or was increased using a heating unit (North Santiam) or well water (Willamette). Reference samples were collected at the hatcheries and analyzed for mark quality at the otolith laboratory operated by Washington Department of Fish and Wildlife (WDFW). Reference samples from the 2005 brood showed good quality marks that should be identifiable in returning adults. Results for the 2006 brood will be reported in the 2008 report, but no problems are anticipated because temperature differentials and marking cycles were similar to the 2005 brood.

Table 1. Data on thermal marking of spring Chinook salmon in Willamette River hatcheries and collection of reference samples, 2005 and 2006 brood years. Reference samples consisted of 40–50 fry (35–50 mm) from each egg take.

Stock	Egg takes	Treatment (hrs on/off)	Temperature differential (°C) [a]	Cycles[b]	Comments
			2005 Brood Year		
McKenzie	4	Chilled (24/72)	4.6–7.7	8[c]	--
North Santiam	4	Heated (48/48)	7.6–9.3	10	--
Willamette	4	Heated (48/48)	11.2–13.2	6	--
South Santiam	3	Heated (48/48)	11.0–13.1	6	Marked at Willamette H.
Clackamas	2	Heated (48/48)	13.0–14.0	6	Marked at Willamette H.
Sandy	3	Heated (48/48)	12.5–13.1	6	Marked at Willamette H.
			2006 Brood Year		
McKenzie	4	Chilled (24/72)	5.4–6.4	8[d]	--
North Santiam	4	Heated (48/48)	9.2–9.3	10	--
Willamette	3	Heated (48/48)	12.3–12.9	6	--
South Santiam	3	Heated (48/48)	11.7–12.8	6	Marked at Willamette H.
Clackamas	3	Heated (48/48)	12.4–12.8	6	Marked at Willamette H.
Sandy	3	Heated (48/48)	12.3–12.8	6	Marked at Willamette H.

[a] *Average difference between heated or chilled treatment and ambient incubation temperature.*
[b] *Number of treatment cycles for hatched fry, except where noted.*
[c] *4–5 cycles were administered to eggs and 3–4 cycles to hatched fry.*
[d] 3–*5 cycles were administered to eggs and 3–6 cycles to hatched fry.*

Adults

We collected otoliths from adult Chinook salmon on spawning grounds and at hatcheries in most of the major tributaries in the Willamette and Sandy basins in 2006 and 2007. Otoliths were removed from unclipped carcasses and placed into individually numbered vials.

We estimated the proportion of naturally produced ("wild") fish on spawning grounds in the Willamette basin from otoliths collected in 2006 and 2007 (Table 2). Wild fish were determined by absence of a fin clip and absence of an induced thermal mark in the otoliths. The distribution of redds among survey areas was used to weight the number of unclipped carcasses in each area based on differences in distribution of redds and carcasses reported previously (Firman et al. 2005). We then used results of otolith analysis to estimate the number of wild fish that would have spawned within a survey area.

Table 2. Otoliths collected in 2006 and 2007 from unclipped adult spring Chinook in the Willamette and Sandy River basins that were analyzed for presence of thermal marks.

Location	Number
2006	
McKenzie River	207
McKenzie Hatchery	146
North Santiam River	71
Minto Pond (North Santiam)	209
South Santiam River	57
South Santiam Hatchery	152
Middle Fork Willamette River	12
Willamette Hatchery	100
Fall Creek	32
Clackamas River	130
Sandy River	213
Sandy River broodstock	73
2007	
McKenzie River	332
McKenzie Hatchery	132
North Santiam River	57
Minto Pond (North Santiam)	171
South Santiam River	76
South Santiam Hatchery	97
Middle Fork Willamette River	11
Willamette Hatchery	228
Fall Creek	4
Clackamas River	147
Sandy River	216
Sandy River broodstock	48

Results

Composition and Size of Run

The percentage of wild spring Chinook recovered on spawning grounds in 2006 and 2007 was highest in the McKenzie, Clackamas, and Sandy rivers, and lowest in the Middle Fork Willamette and South and North Santiam rivers (Table 3). The percentage of carcasses that were wild increased in all basins in 2005–2007 over that in previous years. Data for Middle Fork Willamette were not available in 2006 because numbers of fin-clipped carcasses were incomplete. The percentage of unclipped fish that were of hatchery origin in 2006 and 2007 was lowest in the McKenzie River (< 2%), and was lower than in previous years in the North Santiam, Middle Fork Willamette, and Sandy rivers (Table 3).

As in previous years, the highest estimated number of wild fish in 2006 and 2007 occurred in the McKenzie River (Table 4). Estimates for the North Santiam were not available because fish traps at Bennett Dam were not operated in 2006 or 2007. The river with the highest percentage of wild fish in 2006 and 2007 was the Sandy with ≥ 90% followed by the McKenzie (Table 4). Analysis of fin-clipped to unclipped fish in the McKenzie River suggested that the proportion of fin-clipped fish estimated from carcass recovery was a more accurate measure of hatchery fish in the spawning population upstream of the dam than that estimated from counts of fin-clipped fish at Leaburg Dam (Schroeder et al. 2005). Therefore, we used the ratio of fin-clipped to unclipped carcasses recovered upstream of Leaburg Dam as a correction factor for the number of fin-clipped fish counted at the dam. McKenzie Hatchery is a short distance downstream of the dam (3 km) and fin-clipped hatchery fish have been observed to fall back over the dam, thereby inflating the count of clipped fish passing the dam. Resultant estimates of the percentage of wild fish in the McKenzie River upstream of Leaburg Dam were higher than those previously reported, which did not account for bias in counts of fin-clipped fish (Table 4).

Table 3. Composition of spring Chinook salmon in the Willamette and Sandy basins based on carcasses recovered, and presence or absence of thermal marks in otoliths. Weighted for distribution of redds among survey areas within a watershed (except Middle Fork Willamette).

River (section), run year	Fin-clipped	Unclipped[a] Hatchery	Wild	Percent wild[b]
McKenzie (above Leaburg Dam)				
2002	140	78 (15)	454	68 (62)
2003	131	60 (15)	333	64 (62)
2004	134	26 (8)	316	66 (60)
2005	32	15 (6)	251	84 (84)
2006	32	4 (2)	247	87 (83)
2007	68	3 (1)	352	83 (83)
North Santiam (Minto–Bennett dams[c])				
2002	230	44 (49)	45	14 (13)
2003	855	89 (77)	27	3 (4)
2004	321	21 (27)	56	14 (15)
2005	163	25 (24)	80	30 (30)
2006	109	12 (17)	59	33 (32)
2007	136	7 (14)	42	23 (25)
South Santiam (Foster–Waterloo)				
2002	1,604	37 (14)	224	12 (12)
2003	970	31 (17)	151	13 (13)
2004	838	30 (26)	85	9 (9)
2005	467	12 (9)	128	21 (20)
2006	243	9 (15)	50	17 (16)
2007	302	6 (8)	70	19 (19)
Middle Fork Willamette (Dexter–Jasper[d])				
2002	228	91 (85)	16	(5)
2003	62	48 (92)	4	(4)
2004	120	32 (59)	22	(13)
2005	37	10 (50)	10	(18)
2007	21	2 (18)	9	(28)
Clackamas (above North Fork Dam)				
2002	d	31 (31)	70	69 (59)
2003	5[e]	40 (22)	145	76 (79)
2004	40[e,f]	24 (10)	224	78 (71)
2005	35[e,f]	57 (27)	151	62 (58)
2006	8[e,f]	14 (17)	67	75 (76)
2007	2[e,f]	32 (28)	84	71 (69)
Sandy (above Marmot Dam)				
2002	3[e]	26 (18)	121	81 (81)
2003	9[e]	14 (12)	106	82 (80)
2004	2[e]	8 (4)	207	95 (95)
2005	0[e]	41 (16)	220	84 (85)
2006	9[e]	24 (10)	207	86 (86)
2007[g]	2[e]	15 (8)	186	92 (91)

[a] *Number in parentheses is percentage of unclipped fish that had a thermal mark (unclipped hatchery fish).*
[b] *Percentage not weighted for redd distribution is in parentheses.*
[c] *Including Little North Fork Santiam.*
[d] *Including Fall Creek, except 2007. Data on clipped fish in spawning population were incomplete for 2006.*
[e] *Fish were sorted at the dams and all or most of fin-clipped fish were removed.*
[f] *Includes 38 unclipped carcasses with coded wire tags (double-index release) in 2004, 35 in 2005, 7 in 2006, 2 in 2007.*
[g] *Marmot Dam was removed in 2007, fish ladder was operational to July 18; fish weir was operated until October 19.*

Table 4. Estimated number of wild and hatchery adult spring Chinook salmon in the McKenzie, North Santiam, Clackamas, and Sandy rivers upstream of dams. Estimated from counts at the dams and from presence of induced thermal marks in otoliths of unclipped carcasses recovered on spawning grounds. Numbers at dams were from video counts (McKenzie), daily trap counts (Clackamas and Sandy), and expanded trap counts (North Santiam, from 4 d/wk counts). **Traps on the North Santiam were not operated in 2006 or 2007**.

Run year	Dam count		Unclipped with thermal marks (%)[b]	Estimated number		
	Unclipped	Fin-clipped[a]		Wild	Hatchery[a]	Percent wild
			McKenzie			
2001	3,433	780 (869)	16.1	2,880	1,333	68 (67)
2002	4,223	1,352 (1,864)	14.7	3,602	1,973	65 (59)
2003	5,784	2,298 (3,543)	15.3	4,899	3,183	61 (53)
2004	4,788	2,417 (4,246)	7.7	4,419	2,816	61 (49)
2005	2,579	377 (515)	5.6	2,435	521	82 (79)
2006	2,225	410 (945)	1.6	2,189	445	83 (69)
2007	2,757	510 (558)	0.8	2,735	532	84 (83)
			North Santiam			
2001	388	6,398	43.4	220	6,566	3
2002	1,233	6,407	51.0[c]	604	7,036	8
2003	1,262	11,570	78.5[c]	271	12,561	2
2004	1,510	12,021	67.6[c]	489	13,042	4
2005	924	3,958	27.8[c]	667	4,215	14
			Clackamas			
2002	2,171	**d**	30.7	1,505	666	69
2003	3,364	**d**	21.6	2,637	727	78
2004	5,176	**d**	21.7[e]	4,053	1,123[e]	78
2005	2,882	**d**	37.9[e]	1,790	1,092[e]	62
2006	1,049	**d**	23.9[e]	798	251[e]	76
2007	1,655	**d**	28.8[e]	1,178	477[e]	71
			Sandy			
2002	1,159	**d**	17.7	954	205	82
2003	969	**d**	11.7	856	113	88
2004	2,491	**d**	3.7	2,399	92	96
2005	1,541	**d**	15.7	1,299	242	84
2006	1,349	**d**	10.4	1,209	140	90
2007[f]	1,410	**f**	7.5	1,304	106	92

[a] *The dam count of fin-clipped fish in the McKenzie River is adjusted by the ratio of fin-clipped to unclipped carcasses recovered upstream of the dam to account for fallback at the dam. The unadjusted dam counts and the estimate of percent wild based on the unadjusted counts are in parentheses.*

[b] *Adjusted by distribution of redds among survey areas.*

[c] *Weighted average of adjusted spawning ground samples and samples from Minto Pond.*

[d] *Fish were sorted at North Fork (Clackamas) and Marmot (Sandy) traps and only unclipped fish were allowed to pass.*

[e] *Includes unclipped fish with coded wire tag (double-index release).*

[f] *Marmot Dam was removed in 2007. Fin-clipped fish were sorted at the fish ladder to July 18 and later at a picket weir downstream of the dam site during dam removal until October 19 when the coffer dam was breached.*

Stray Hatchery Fish

Few coded wire tags were recovered from spring Chinook on the spawning grounds in 2005 and 2006 (Table 5), making it difficult to estimate the percentage of stray hatchery fish in river basins. McKenzie stock fish that were released in the Lower Columbia, Willamette, and Clackamas basins in 2001–2004 as part of a netpen and direct release evaluation (Schroeder et al. 2005) accounted for most of the strays in returns from the 1996–1999 brood releases. In 2006, the number of strays in the McKenzie basin (1 of 8 tags recovered) and South Santiam basin (0 of 18 tags recovered) decreased following the final return of those experimental fish. The percentage of stray hatchery fish in the North Santiam was higher than other basins in 2006 (5 of 8 tags recovered), and was composed primarily of South Santiam releases into Molalla (3) or South Santiam (1).

We examined how the percentage of wild fish in the McKenzie and North Santiam basins would be affected if stray hatchery fish were removed from the spawning populations. Estimates of hatchery fish were based on counts at the dams and on otolith analysis of unclipped carcasses recovered on spawning grounds. If stray hatchery fish had been removed in the North Santiam basin in 2001–2004, the percentage of wild fish in the basin would have been unchanged (Table 6) because the percentage of strays in the hatchery component was relatively low (2–18%) and the number of hatchery fish was high compared to the number of wild fish. If stray hatchery fish had been removed in the McKenzie basin, the percentage of wild fish would have increased an average of about 5% (Table 6) because the percentage of stray hatchery fish (3–35%) was generally higher than the North Santiam in a hatchery component that was smaller. However, releases of McKenzie hatchery fish into the lower Clackamas and Willamette rivers as part of a netpen acclimation experiment averaged 60% of the stray hatchery fish in the McKenzie in 2001–2004. Therefore, if strays from these releases alone had not been present in 2001–2004, the percentage of hatchery fish would have decreased and the percentage of wild fish would have increased an average of 3%.

Table 5. Numbers of spring Chinook salmon returns that were composed of hatchery fish released within the basin (local) or released in other basins, 2002–2006, determined by coded wire tags in carcasses on spawning grounds. The sample size was expanded (in parentheses) for the percentage of each release group that was tagged.

		Origin of release								
River, run year	n	Local	Netpen[a]	Lower Willamette[a]	Molalla[b]	North Santiam	South Santiam	McKenzie	Youngs Bay[c]	Clackamas
McKenzie										
2002	95 (263)	93 (254)	1 (8)	1 (1)	0	0	0		0	0
2003	16 (81)	8 (53)	1 (1)	7 (7)	0	1 (20)	0		0	0
2004	19 (79)	9 (63)	2 (2)	7 (7)	0	0	1 (7)		0	0
2005	3 (29)	2 (22)	0	0	0	0	1 (7)		0	0
2006	8 (80)	7 (76)	0	0	1 (4)	0	0		0	0
North Santiam										
2002	80 (217)	76 (213)	0	1 (1)	3 (3)		0	0	0	0
2003	46 (634)	29 (594)	2 (2)	8 (8)	4 (11)		1 (11)	1 (7)	1 (1)	0
2004	28 (228)	10 (188)	1 (1)	9 (9)	5 (12)		3 (18)	0	0	0
2005	7 (114)	1 (10)	0	5 (98)	0		1 (6)	0	0	0
2006	8 (54)	3 (32)	1 (6)	0	3 (10)		1 (6)	0	0	0
South Santiam										
2002	310 (1,111)	302 (1,103)	0	8 (8)	0	0		0	0	0
2003	97 (640)	53 (468)	12 (133)	27 (27)	4 (11)	0		0	1 (1)	0
2004	121 (605)	91 (572)	5 (5)	23 (23)	2 (5)	0		0	0	0
2005	50 (299)	45 (281)	0	1 (1)	2 (5)	0		1 (11)	1 (1)	0
2006	18 (107)	18 (107)	0	0	0	0		0	0	0
M Fk Willamette										
2002	356 (1,736)	355 (1,735)	0	1 (1)	0	0	0	0	0	0
2003	1 (19)	1 (19)	0	0	0	0	0	0	0	0
2004	5 (38)	5 (38)	0	0	0	0	0	0	0	0
2005	3 (22)	3 (22)	0	0	0	0	0	0	0	0
Molalla										
2002	22 (57)	22 (57)	0	0		0	0	0	0	0
2003	5 (14)	5 (14)	0	0		0	0	0	0	0
2004	2 (3)	1 (2)	0	1 (1)		0	0	0	0	0
2005	4 (9)	4 (9)	0	0		0	0	0	0	0

[a] *McKenzie stock acclimated or directly released into the lower Clackamas (netpen) or into the lower Willamette.*
[b] *South Santiam and McKenzie stocks.*
[c] *Middle Fork Willamette stock released into netpens near mouth of Columbia River.*

Table 6. Composition of wild and hatchery adult spring Chinook in the McKenzie and North Santiam basins upstream of Leaburg and Bennett dams, respectively, using two scenarios: (1) with stray hatchery fish and (2) assuming successful removal of all strays. Hatchery fish estimates are from counts of Chinook at the dams and from presence of induced thermal marks in otoliths of unclipped carcasses recovered on spawning grounds. Stray hatchery fish estimates are from coded wire tag recoveries, expanded by the percent of release that was tagged. **Only years where >10 tags were recovered are included.**

	Estimated number			Percent wild	
River, run year	Wild	Hatchery with strays	Hatchery without strays	with strays	without strays
McKenzie					
2001	2,880	1,333	1,241	68	71
2002	3,602	1,973	2,400	65	65
2003	4,899	3,183	2,897	61	71
2004	4,419	2,816	3,687	61	66
North Santiam					
2001	220	6,566	6,127	3	3
2002	604	7,036	6,906	8	8
2003	271	12,561	11,769	2	2
2004	489	13,042	10,754	4	4

TASK 1.3 – DISTRIBUTION AND ABUNDANCE OF NATURAL SPAWNERS

Methods

We surveyed most of the major spawning tributaries in the Willamette and Sandy basins in 2006 and 2007 by boat and on foot to count spring Chinook salmon carcasses and redds. We counted redds during peak times of spawning based on data from surveys conducted in past years. Carcasses were examined for adipose fin clips to help determine the proportion of hatchery fish on spawning grounds. In addition, otoliths were collected from carcasses without fin clips to separate unclipped hatchery fish from naturally produced fish. We used hand-held electronic tag detectors manufactured by Northwest Marine Technology, Inc. to determine if carcasses with adipose fin clips had a coded wire tag, and in the McKenzie and Clackamas rivers to determine if unclipped carcasses had a tag (double-index release group). We collected the snouts of fish with a tag, which were then put into plastic bags along with a unique identification number. We estimated pre-spawning mortality of adult spring Chinook using the proportion of recovered female carcasses that died prior to spawning. Because survey intensity varies among rivers and between years, and because recovery of carcasses is generally more difficult later in the season when all carcasses would be successful spawners, pre-spawning estimates should be viewed in relative terms (e.g., high, medium, low) rather than as absolute estimates.

Redd Counts

Redd densities and carcasses recovered were generally greater in 2007 than in 2006, except in the Middle Fork Willamette and Sandy rivers (Table 8). Detailed data for previous years (1996–2005) are in Schroeder et al. 2005.

Table 8. Summary of spawning surveys for spring Chinook salmon in the Willamette and Sandy basins, 2006 and 2007, and comparisons to redd densities in 2002–2005. Data are for regularly surveyed areas and do not include areas upstream of dams where surplus hatchery fish have been outplanted. Carcass numbers include fish that were processed but presence or absence of a fin clip could not be determined.

	2007 Counts		2006 Counts		Redds/mi[a]					
Basin, section	carcass	redds	carcass	redds	2007	2006	2005	2004	2003	2002
McKenzie										
above Leaburg Dam	426	1,346	283	709	23.0	12.1	16.7	17.7	15.8	14.2
below Leaburg Dam	52	141	31	72	23.5	12.0	12.5	16.5	28.5	19.2
North Santiam										
above Bennett Dam	185	474	181	236	12.5	5.8	7.4	8.2	7.3	7.5
below Bennett Dam	2	20	3	18	6.1	1.1	1.4	1.5	1.0	1.5
South Santiam										
above Lebanon Dam	378	483	302	509	32.2	33.9	35.3	24.9	40.7	59.6
below Lebanon Dam	0	--	1	19	--	1.1	--	0.2	1.0	3.4
Middle Fork Willamette										
Dexter–Jasper	32	9	20	111	1.0	12.3	1.0	1.0	1.6	7.1
Fall Creek	3	28	39	217	1.7	13.3	8.1	12.9	6.1	12.9
Clackamas										
above North Fork Dam	136	495	89	321	8.8	6.5	10.7	18.6	6.2	6.7
Sandy										
above Marmot Dam	227	271	240	427	10.9	17.2	17.6	28.6	7.1	10.4

[a] *Distance surveyed may vary between years.*

The North Santiam River was regularly surveyed July 3–October 16 to recover carcasses and count redds. Redd construction was first observed on September 5 and peak spawning occurred in early October. The redd density in 2007 was highest in the section immediately downstream of Minto dam (Table 9), and was higher than the 2004–2006 average (17.7 redds/mi), but was lower than in 2003 (55.5 redds/mi).

Table 9. Summary of spawning surveys for Chinook salmon in the North Santiam River, 2006 and 2007. Spawning in areas downstream of Stayton may include some fall Chinook.

Survey section	Length (mi)	2007 Carcass	2007 Redd	2006 Carcass	2006 Redd	Redds/mi 2007	Redds/mi 2006
Minto–Fishermen's Bend	10.0	130	323	114	148	32.3	14.8
Fishermen's Bend–Mehama	6.5	34	72	35	32	11.1	4.9
Mehama–Stayton Is.	7.0	7	15	15	22	2.1	3.1
Stayton Is.–Stayton	3.3	0	20	3	13	6.1	3.9
Stayton–Greens Bridge	13.7	2	--	0	5	--	0.4
Greens Br.–mouth	3.0	--	--	--	--	--	--
Little North Santiam	14.4[a]	14	64	17	34	4.4[a, b]	2.0[c]

[a] *17.0 miles were surveyed in 2006.*
[b] *195 unclipped adult spring Chinook were released in August (16th, 22nd, 29th) and September (17th, 18th, 24th, 27th).*
[c] *130 unclipped adult spring Chinook were released on June 21 and July 7 and 26.*

The McKenzie River was regularly surveyed July 31–October 23 in 2007 to recover carcasses and count redds. Active redd building began in early September, with the first redd observed on September 4, similar to previous years. Peak spawning occurred in late September to early October. The total number of redds was higher in 2007 (1,487) than in the three previous years. This was largely because the number of redds counted in Horse (419) and Lost (234) creeks increased in 2007 and accounted for 44% of redds in the McKenzie basin, compared to 34% in 2006 (Figure 1). The percentage of redds counted in the main stem upstream of Forest Glen decreased in 2007 (20%) from that in 2006 (33%), whereas the percentage of redds downstream of Forest Glen increased from 12% in 2006 to 19% in 2007. Redd densities increased in 2007 compared to 2006 in all survey sections except the McKenzie River upstream of McKenzie Trail and in the upper reach of the South Fork McKenzie downstream of the dam (Table 10).

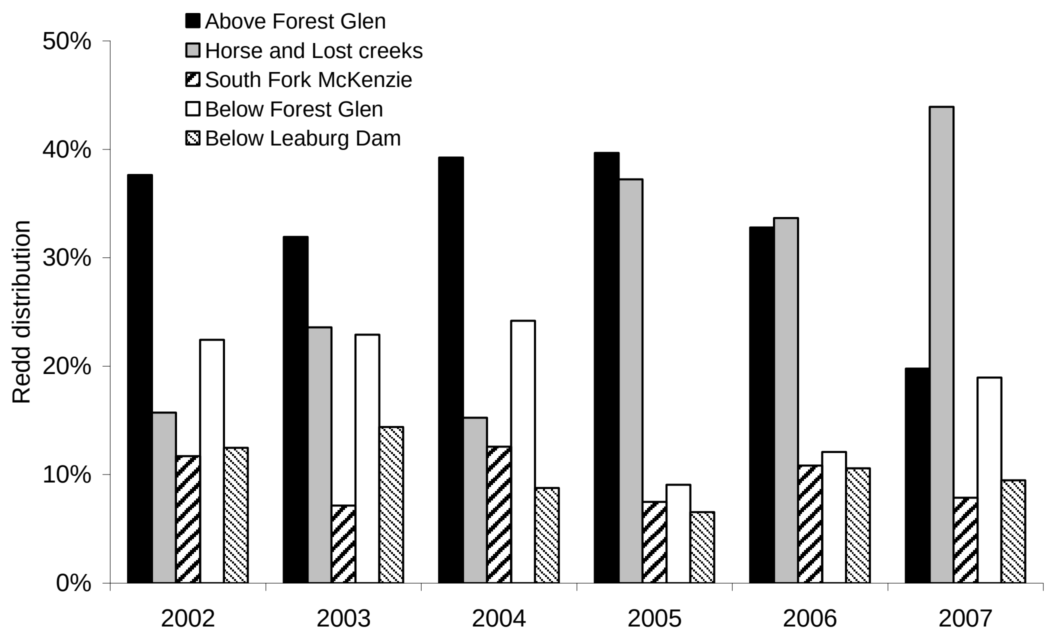

Figure 1. Distribution of spring Chinook redds in the McKenzie River basin, 2002–2007.

Table 10. Summary of spring Chinook spawning surveys in the McKenzie River, 2006 and 2007.

	Length	2007		2006		Redds/mi[a]	
Survey section	(mi)	Carcass	Redds	Carcass	Redds	2007	2006
McKenzie River:							
Spawning channel	0.1	33	36	27	69	6.8	13.8
Olallie–McKenzie Trail	10.3	52	107	13	145	10.4	14.1
McKenzie Trail–Hamlin	9.9	31	59	2	18	6.0	1.8
Hamlin–S. Fork McKenzie	0.3	7	28	0	2	93.3	6.6
South Fork–Forest Glen	2.4	23	64	5	26	26.7	10.8
Forest Glen–Rosboro Br.	5.7	58	174	34	38	30.5	6.7
Rosboro Br.–Ben and Kay	6.5	30	108	18	58	16.6	8.9
Ben and Kay–Leaburg Lake	5.9	--	--	--	--	--	--
South Fork McKenzie:							
Cougar Dam–Road 19 Br.	2.3	19	38	60	55	16.5	23.9
Road 19 bridge–mouth	2.1	48	79	51	31	37.6	14.8
Horse Creek:							
Pothole Cr.–Separation Cr.	2.8	25	63	8	26	22.5	9.3
Separation Cr.–mouth	10.7	78	356	56	172	33.3	16.1
Lost Creek:							
Spring–Limberlost	2.8	11	100	3	9	35.7	3.2
Limberlost–Hwy 126[b]	2.0	11	134	5	60	53.6[b]	30.0
Hwy 126–mouth[b]	0.5	--	--	1	0	--	0.0
McKenzie River:							
Leaburg Dam–Leaburg Landing[c]	6.0	52	141	31	72	23.5	12.0

[a] *Except redds/100 ft for spawning channel.*
[b] *Limberlost–Hwy 126 and Hwy 126–mouth sections were combined in 2007.*
[c] *Additional carcasses were recovered downstream of Leaburg Landing (3 in 2007; 3 in 2006); no redds were counted in 2007 and 12 redds were counted in 2006.*

The percentage of fin-clipped carcasses upstream of Leaburg Dam (Table 11) was similar in 2007 (16%) to that in 2005 (13%) and 2006 (15%), but was lower than in 2003 (28%) and 2004 (34%). Conversely, a higher percentage of carcasses downstream of Leaburg Dam were fin-clipped in 2007 (76%) than in 2005 (53%) and 2006 (52%).

Table 11**.** Composition of naturally spawning spring Chinook salmon from carcasses recovered in the McKenzie River, 2007.

Section	Unclipped	Fin-clipped
McKenzie spawning channel	28	5
Olallie–Forest Glen	101	9
Forest Glen–Leaburg Lake	52	36
S Fork McKenzie	56	11
Horse Creek	103	0
Lost Creek	17	5
Total upstream of Leaburg Dam	357	66
Downstream of Leaburg Dam	13	42

The Clackamas River upstream of River Mill Dam was regularly surveyed August 21–October 29 in 2007. The section downstream of River Mill Dam was regularly surveyed July 24–October 17. We started surveys in this section early to assess pre-spawning mortality of fish in the lower river. Active redd building began in early September, with the first redd observed on September 4. As in previous years, peak spawning occurred in early to mid-October. Total redds counted in the basin were higher in 2007 than 2006, as were redd densities in most sections (Table 12). However, both redd densities and carcasses recovered in the section below River Mill Dam declined from 2006 to 2007.

Regular surveys were conducted in the Sandy River basin from August 23–October 25 in 2007. As in other basins, active redd building began in early September. The first redd was observed on September 10 with peak spawning occurring in early October. In general, total redd counts were similar in 2006 and 2007 in most sections, with the exception of Still Creek, which decreased from 117 redds in 2006 to 28 redds in 2007 (Table 13).

Table 12. Summary of spawning surveys for spring Chinook salmon in the Clackamas River basin, 2006 and 2007.

Survey section	Length (mi)	2007 Carcass	2007 Redd	2006 Carcass	2006 Redd	Redds/mi 2007	Redds/mi 2006
Clackamas River:							
Sisi Creek–Forest Rd 4650	9.1	35	145	11	78	15.9	8.6
Forest Rd 4650–Collawash R.	8.0	3	37	6	29	4.6	3.6
Collawash R–Cripple Cr.	8.5	27	112	10	61	13.2	7.2
Cripple Cr.–South Fork	14.5	27	82	41	106	5.7	14.5
. South Fork–Reservoir	1.0	18	26	5	7	26.0	7.0
South Fork Clackamas:							
Falls–mouth	0.6	6	24	0	4	40.0	6.7
Collawash River:							
Forest Rd 63–Hot Sprs. Fork	2.0	0	0	--	--	0.0	--
Hot Sprs. Fork–mouth	4.5	16	49	16	22	10.9	4.9
Fish Creek:							
Forest Rd 5430–mouth	4.5	0	0	**a**	**a**	0.0	**a**
Roaring River:							
Falls–mouth	2.0	4	20	0	4	10.0	2.0
Above Falls	1.5	--	--	0	10	--	1.5
North Fork Clackamas:							
Mouth area	0.2	0	0	0	**b**	0.0	**b**
Below Faraday Dam:							
Free-flowing stretch	1.5	4	2	3	**b**	1.3	**b**
Below River Mill Dam:[c]							
McIver–Barton	9.5	38[d]	76[d]	363[e]	169[e]	8.0	17.8
Barton–mouth	13.5	3	7	2	**b**	0.5	**b**

[a] *Redd survey not conducted until October 25 after first high water. No redds were found this late in the season.*

[b] *Redds were not counted in 2006: no surveys in North Fork or Barton–mouth; low flow in South Fork; flow too high below Faraday.*

[c] *Some fall Chinook salmon could spawn in this area.*

[d] *1 additional carcass and 4 additional redds were in the 0.3 mi River Mill Dam—McIver section.*

[e] *8 additional carcasses and 12 additional redds were in the 0.3 mi River Mill Dam–McIver section.*

Table 13. Summary of spawning surveys for spring Chinook salmon in the Sandy River basin, 2006 and 2007.

Section	Length	2007		2006		Redds/mi	
	(mi)	Carcass	Redd	Carcass	Redd	2007	2006
Salmon River:							
Final Falls–Forest Rd 2618	3.2	79	79	71	139	24.7	43.4
Forest Rd 2618-ArrahWanna	5.4	72	54	32	45	10.0	8.3
ArrahWanna-Mouth	4.4	49	58	53	67	13.2	13.4
Still Creek:							
Cool Creek– mouth	3.3	1	28	28	117	8.5	35.5
Zigzag River:							
Camp Creek– mouth	4.0	22	40	52	43	10.0	10.8
Lost Creek:							
Riley Campground–mouth	2.0	2	9	4	9	4.5	4.5
Camp Creek:							
Campground–mouth	2.0	0	0	0	5	0.0	2.5
Clear Fork Creek:							
Barrier–mouth	0.6	--	--	--	--	--	--
Clear Creek:							
E. Barlow Rd–mouth	0.5	2	3	0	2	6.0	4.0
Sandy River:							
Marmot Dam–Revenue Br.	6.2	--	--	9	51		8.2
Dodge Park–Oxbow Park	7.5	--	--	1	49		6.5

Other rivers that were regularly surveyed in 2007 (Table 14) were South Santiam (July 16–October 24) and Middle Fork Willamette (July 10–October 23). Active redd building began in early September in the South Santiam, with peak counts observed in early October and slightly fewer redds counted in 2007 than in 2006. No redds were counted in the Middle Fork Willamette until September 19 and only 9 redds were counted downstream of Dexter Dam, which was much lower than in 2006 (111) but similar to 2003–2005.

Table 14. Summary of Chinook salmon spawning surveys in the Middle Fork Willamette and South Santiam basins, 2006 and 2007.

River, section	Length	2007		2006		Redds/mi	
	(mi)	Carcasses	Redds	Carcasses	Redds	2007	2006
Middle Fork Willamette							
Dexter–Jasper	9.0	32	9	20	111[a]	1.0	12.3
Fall Creek (above reservoir)	16.3	3[a]	28	39[a]	217	1.7	13.3
South Santiam							
Foster–Pleasant Valley	4.5	343	418	259	463	92.9	102.9
Pleasant Valley–Waterloo	10.5	35	65	43	46	6.2	4.4
Lebanon–mouth	20.0	--	--	1	19	--	1.0

[a] *234 redds were counted in a survey by Corps of Engineers biologists including 73 in two small side channels.*
[a] *Clipped carcasses were not counted in 2006 or 2007.*

Pre-spawning Mortality

Although the estimated pre-spawning mortality of spring Chinook was higher for unclipped fish than for fin-clipped fish in the upper McKenzie, North and South Santiam rivers in 2007 (Table 15), the difference between these two groups over several years (Figure 2) was not significant ($P > 0.05$). Estimated pre-spawning mortality was significantly higher ($P < 0.05$) downstream of dams than upstream in the McKenzie, North Santiam, Clackamas, and Sandy rivers (Figure 3). Estimated pre-spawning mortality of spring Chinook salmon in the Willamette basin was higher in 2007 than in 2006, except in the South Santiam, lower Clackamas, and Sandy rivers (Table 16), but generally was lower than in 2002–2005. Pre-spawning mortality was particularly low in 2006 compared to other years. Additional data are in **APPENDIX B**.

Table 15**.** Pre-spawning mortality (percentage in parentheses) of fin-clipped and unclipped spring Chinook based on recovery of female carcasses recovered, 2007.

	Not spawned		Spawned	
River	clipped	unclipped	clipped	unclipped
McKenzie above Leaburg	1 (2%)	13 (6%)	45	215
McKenzie below Leaburg	12 (41%)	1 (17%)	17	5
North Santiam above Bennett	39 (38%)	14 (56%)	64	11
South Santiam above Lebanon	17 (8%)	4 (12%)	205	29
Middle Fork Willamette	14 (100%)	6 (86%)	0	1
Clackamas below Faraday	9 (56%)	8 (89%)	7	1

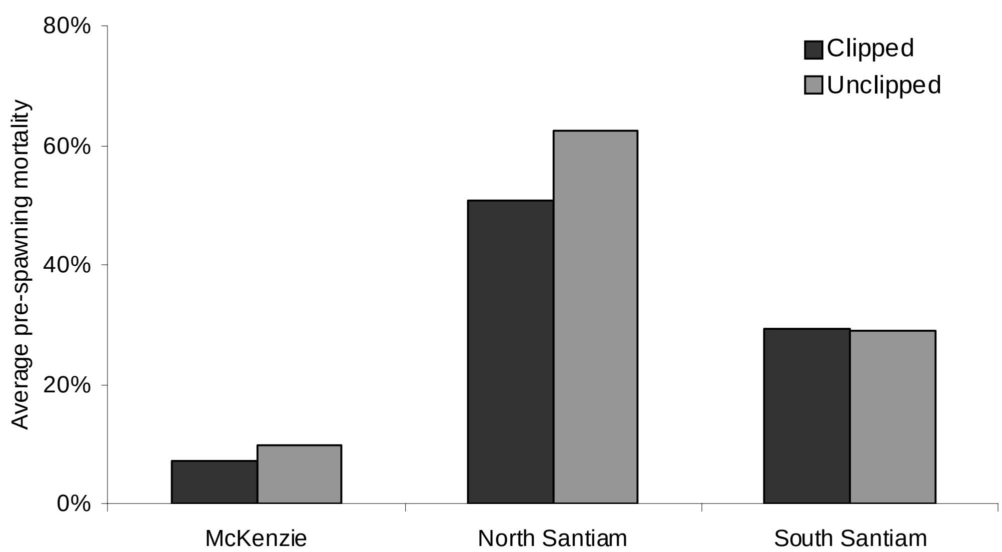

Figure 2. Average estimated pre-spawning mortality of clipped and unclipped adult Chinook salmon in the McKenzie (upstream of Leaburg Dam), North Santiam (upstream of Bennett Dam), and South Santiam rivers, based on recoveries of female carcasses.

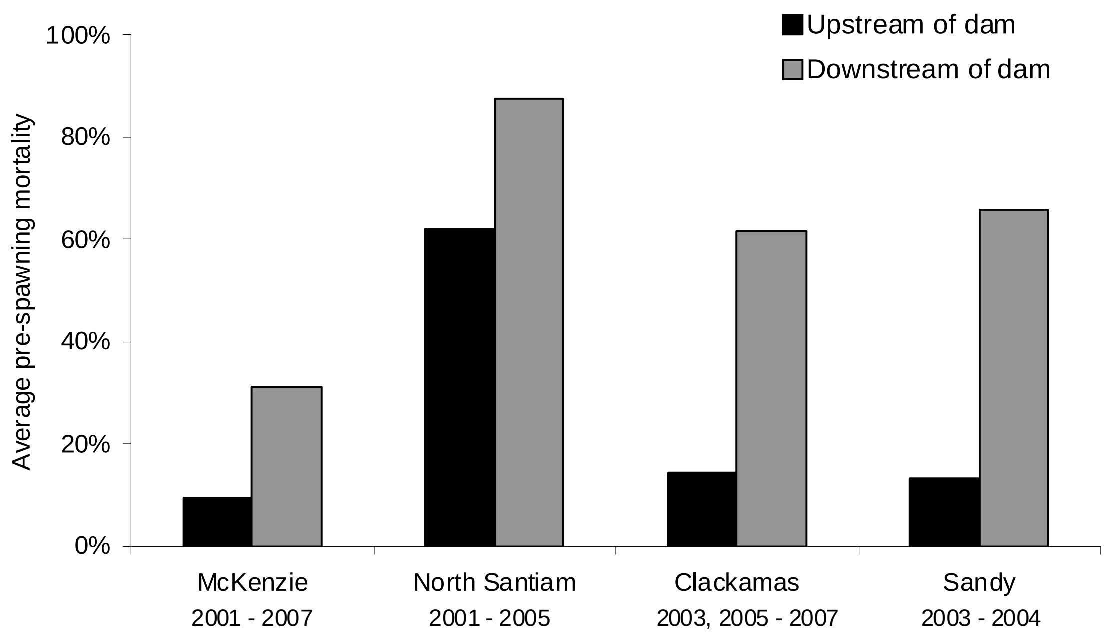

Figure 3. Average estimated pre-spawning mortality of adult Chinook salmon upstream and downstream of dams in the Willamette and Sandy basins, based on recoveries of female carcasses.

TASK 3.1 – EVALUATION OF HATCHERY CHINOOK RELEASED DOWNSTREAM OF WILLAMETTE FALLS.

Studies in the 1970s 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. However, straying also increased. We conducted a study with eight brood years (1992–1999) to determine if acclimation in net pens prior to release could increase sport harvest of hatchery fish returning to the lower Willamette River. Preliminary results were reported in Schroeder et al. 2005 with the following conclusions: 1) direct smolt releases into the lower Willamette River (Multnomah Channel) generally did not increase sport catch; 2) sport catch of fish acclimated in net pens in the fall was equal to or higher than the control group in three of four releases; 3) fish released into the lower Willamette River tended to stray into the Clackamas and most other spawning tributaries, and direct river releases strayed more than the acclimated releases; 4) based on hatchery recoveries, fish released into Clackamette Cove returned mainly to the Clackamas River, and was higher than for fish released directly into the lower Clackamas River; 5) for groups released into the Clackamas River in spring, those acclimated in Clackamas Cove appeared to contribute more to sport fisheries as adults in the Willamette and Clackamas rivers than groups released directly into the Cove or into the Clackamas River, although returns from the 1998–1999 broods showed slightly higher catch of the direct river releases. On average, all releases in the Clackamas River contributed more to the sport fishery than did returns from control groups released at McKenzie Hatchery. Compilation of final returns will be presented in a separate report.

Table 16. Estimates of the percent pre-spawning mortality of Chinook salmon in the Willamette and Sandy River basins, based on recovery of female fish carcasses, 2001–2007. **Only for areas and years with $\geq$ 10 recoveries**. Date of first survey is included in parenthesis. Data in boldface indicate surveys began late or ended prior to the end of the peaking spawning time.

River	2001	2002	2003	2004	2005	2006	2007
Fall Creek above dam		67 (Aug 28)		**45 (Aug 10)**		**0 (Sep 18)**	
Middle Fork Willamette		84 (Aug 7)	**100 (Jul 15)**	**99 (Aug 24)**	94 (Jul 29)	**6 (Oct 2)**	95 (Jul 10)
McKenzie above Leaburg	7 (Aug 21)	5 (Aug 15)	16 (Aug 11)	11 (Aug 19)	16 (Aug 10)	**1 (Sep 12)**	5 (Aug 15)
McKenzie below Leaburg	**17 (Sep 17)**	16 (Aug 26)	52 (Aug 7)	60 (Aug 18)	29 (Aug 23)	5 (Sep 5)	37 (Jul 31)
North Santiam above Bennett	75 (Aug 14)	50 (Aug 1)	64 (Jun 27)	75 (Jun 17)	46 (Jul 13)	16 (Jul 27)	41 (Jul 3)
North Santiam below Bennett	91 (Aug 16)	79 (Aug 1)	**99 (Jun 18)**	94 (Jun 17)	74 (Jul 12)		
Little North Santiam			81 (Jul 10)		36 (Aug 31)		
South Santiam above Lebanon		25 (Aug 6)	28 (Jul 14)	71 (Jul 20)	31 (Jul 18)	12 (Jul 26)	8 (Jul 16)
Clackamas above North Fork		**0 (Sep 17)**	22 (Aug 20)	8 (Aug 19)	26 (Aug 22)	5 (Aug 17)	4 (Aug 21)
Clackamas below Faraday				71 (Aug 2)	55 (Sep 8)		
Clackamas below River Mill		**57 (Sep 11)**	73 (Jul 24)	**98 (Jul 23)**	85 (Aug 4)	23 (Jul 28)	65 (Jul 24)
Sandy above Marmot		**0 (Sep 11)**	16 (Aug 19)	10 (Sep 1)	10 (Aug 23)	6 (Aug 24)	4 (Aug 23)
Sandy below Marmot			**67 (Sep 24)**	**65 (Sep 28)**			
Bull Run						11 (Aug 31)	

TASK 3.2 – MIGRATION OF HATCHERY CHINOOK RELEASED IN THE FALL

We tagged hatchery spring Chinook with PIT tags at McKenzie Hatchery in 2005 to assess the effect of release strategies on migration out of hatchery ponds and to Willamette Falls. Fish in the control group (n = 489) were tagged on October 12 and were released in a standard manner—allowed to volitionally leave the pond over 7 days with the remaining fish forced out after this. The experimental group (n = 848) was tagged October 4 and was allowed to volitionally leave the pond over 42 days via two subsurface exit pipes (7 in. diameter) mounted at the downstream end of the raceway. We used PIT tag antennas and readers (Destron-Fearing® FS2001F) to record the exact date and time fish left the hatchery pond. During the 42 days, the water level in the pond was held constant. After the volitional period, the water level in the pond was lowered over two days and on the third day all remaining fish were forced out. Migration timing in the McKenzie and Willamette rivers was determined with a PIT tag detector at Willamette Falls 293 km (182 mi) downstream (*see* Tasks 4.1 and 4.3).

Based on observations by hatchery personnel, about half of the fish in the control group left the pond in the first two nights after screens were removed on November 7th. In contrast, only 5% of the test group left the first two nights, but screens for this group were removed about a month earlier than for the control group. By November 9, about 30% of the test group (n = 242) had volitionally migrated from the pond, which represented most of the fish that eventually migrated through the end of the 42-day period (n = 281) when water level in the pond was constant. Of the fish remaining, about 38% (n = 318) left over two days as the water level in the pond was lowered, and 30% (n = 249) were forced out. The two primary times when fish volitionally left the pond were shortly after the screens were pulled in early October (19%), and in early November (52%) during the new moon to first quarter lunar phase (Figure 4).

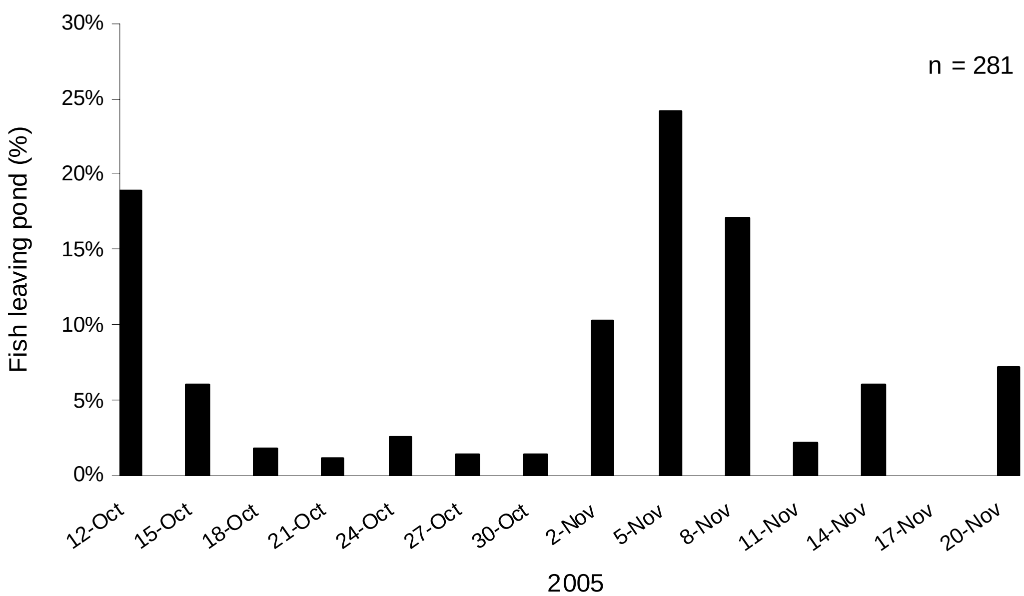

Figure 4. Emigration of juvenile hatchery Chinook that volitionally migrated from a hatchery pond at McKenzie Hatchery under stable water levels, October 10–November 20, 2005.

The detection rate of PIT-tagged fish at Willamette Falls was the same for the two release groups (Table 17). Within the test group, the detection rate of fish that volitionally left the pond was slightly higher than the fish that were forced out, but the difference was not significant ($P > 0.05$). Migration timing of fish to Willamette Falls was less than 4 days for control fish and almost 12 days for all test fish (Table 17), although the difference was not significant ($P = 0.19$) because of relatively small sample sizes and a high standard deviation in the test group caused by one fish that did not pass the falls until late March (119 days). Without this fish, travel time of the test group was significantly longer than the control group ($P = 0.02$). However, for the two groups with somewhat similar release strategies (control and forced test group), travel time was not significantly different with or without the fish that took 119 days to migrate. Within the test group the travel time of fish that were forced out was significantly shorter than the volitional migrants ($P = 0.01$), if the fish that took 119 days was excluded. Based on the length of the fish at the time they were tagged, the fish that volitionally migrated (average = 156 mm) were significantly larger ($P = 0.03$) than the fish that were forced out (average = 153 mm). However, the first migrants that left during the volitional period were significantly smaller ($P < 0.01$) at the time they were tagged than the last migrants or the migrants that left when the pond was lowered (Figure 5). In contrast, the fish that were forced out at the end of the test were generally the smaller fish at the time of tagging and were significantly smaller than those that left when the pond was lowered and than the volitional migrant group, with the exception of the first group of migrants (Figure 5).

In conclusion, only a third of the juvenile hatchery Chinook volitionally migrated from the hatchery pond during a 42-day period that began in early October, and took longer to migrate to Willamette Falls than did fish in the standard release group. The one period of time that large numbers of fish left the pond was during a dark phase of the moon. As might be expected, the fish that remained in the pond the longest generally were smaller at the time they were tagged, although within the volitional period, the first migrants were smaller.

Table 17. Detection rate, travel time, and fork length of two release groups of hatchery spring Chinook, October–November 2005, McKenzie Hatchery.

		Test		
	Control	All	Volitional	Forced
Number tagged (McKenzie Hatchery)	489	848	281	567
Number detected (Willamette Falls)	15	26	10	16
Detection rate (%)	3.1	3.1	3.6	2.8
Travel time (days)				
All detections	3.9	11.7	9.3	13.3
Range	2–24	3–119	3–14	4–119
Without 119 d fish	3.9	7.4	9.3	6.2

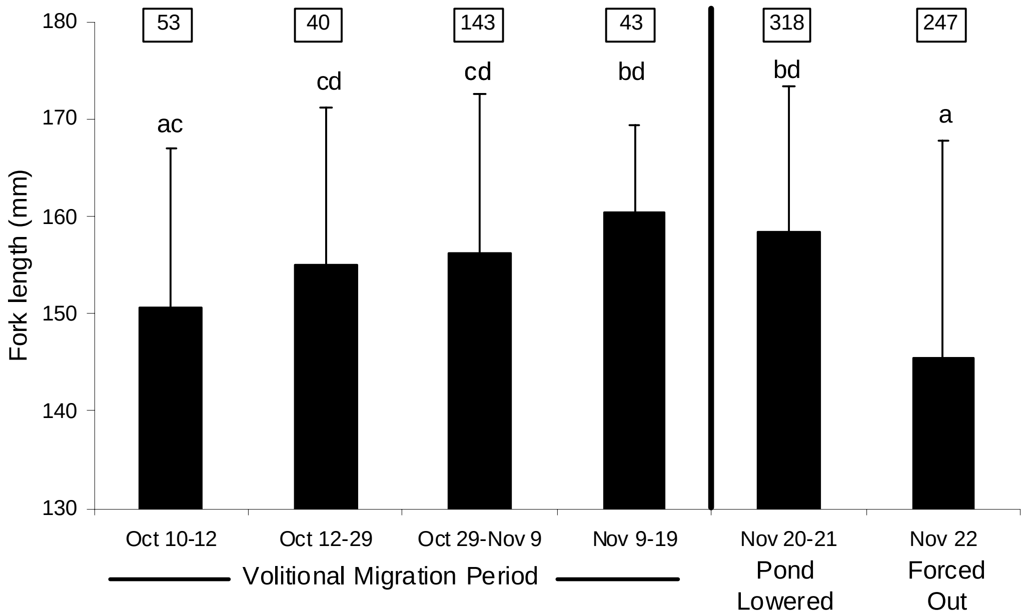

Figure 5. Mean fork length (+ SD) at the time of tagging (October 4) of juvenile spring Chinook that migrated from a hatchery pond during several time periods of a test release from McKenzie Hatchery, 2005. Columns with no letters in common are significantly different ($P < 0.01$). Numbers above bars are sample sizes (some tagged fish were not measured).

The detection rate of the 2005 fall releases from McKenzie Hatchery was lower than in previous years (Table 18). Detection rate in the fall is dependent on flow in late November and early December when most of the fall hatchery fish usually migrate past Willamette Falls. Detections of fish in December during relatively low flow represented 42% and 26% of the combined November and December detections in 2000 and 2002, respectively. The flow in 2005 was 65% higher in November and 10% higher in December than in previous years, and included a high flow period of almost 50,000 cfs in early December. With the exception of hatchery Chinook released in fall 2000, an average of 85% of the fall release migrated downstream past Willamette Falls within the first month of release (Table 18). The more protracted migration of the fall 2000 release may have been because of low flow in the Willamette River (Schroeder et al. 2001).

Table 18. Number of PIT tags detected by month from fall releases of hatchery Chinook from McKenzie Hatchery, 2000–2005.

		Number detected							
Year	Release date	Nov	Dec	Jan	Feb	Mar	Apr	May	Detection rate
2000	Nov 8	52	38	1	4	16	6		11.7
2001	Nov 7	89				1	3	1	9.4
2002	Nov 6	111	39				2		15.3
2004	Nov 1	60	4	4	1	1			6.7
2005	Nov 9	15							3.1
2005	Oct 11–Nov 23	36	4			1			3.1

TASK 3.4 – INCORPORATING WILD FISH INTO HATCHERY BROODSTOCKS

Otoliths were collected in 2006 and 2007 from unclipped spring Chinook spawned at Willamette basin hatcheries to determine the number and percentage of wild fish incorporated into the broodstocks. The percentage of wild fish in the unclipped portion of the broodstock was higher in 2006 and 2007 than in previous years at all hatcheries, and 100 or more were spawned at all hatcheries in at least one of the years (Table 19). The percentage of unclipped hatchery fish at most hatcheries decreased in 2006–2007, and was lowest at Minto (6%) in 2006. We recorded 33 fish with partial fin clips at Willamette Hatchery in 2006, of which otolith analysis indicated that 32 were of hatchery origin. Excluding these fish from the "unclipped" group would decrease the percentage of unclipped hatchery fish from 55% to 34%.

TASK 3.5 – OVERLAP IN SPAWNING OF FALL AND SPRING CHINOOK

We collected 30 tissue samples from adult Chinook salmon on the Clackamas River below River Mill Dam in mid October 2006 for DNA microsatellite analysis. Mid October is a time period where there is potential overlap of spring and fall Chinook spawning in the same area. Samples have been stored in alcohol until funding is available for analysis. Only spring Chinook were detected in limited samples collected in previous years from the lower Clackamas River (Schroeder et al 2005).

Table 19. Hatchery and wild composition of spring Chinook salmon that were spawned at Willamette basin hatcheries, based on the presence or absence of thermal marks in otoliths, 2002–2007. Run of wild fish is estimated from dam counts and does not include wild fish downstream of Leaburg (McKenzie) and Bennett (North Santiam) dams.

	Unclipped[a]		Fin-clipped	Percent wild—	
River, year	Wild	Hatchery	hatchery	in broodstock	of run
McKenzie					
2002	13	101	933	1.2	0.4
2003	14	42	953	1.4	0.3
2004	24	105	880	2.4	0.5
2005[b]	20	40	1,022	1.8	0.8
2006	100	46	845	10.1	4.6
2007[c]	81	48	891	7.9	3.0
North Santiam (Minto)					
2002	4	7	671	0.6	0.7
2003	2	17	599	0.3	0.7
2004	12	13	541	2.1	2.4
2005[b]	18	16	470	3.6	2.7
2006	197	12	335	36.2	***d***
2007[c]	158	17	375	28.7	***d***
South Santiam					
2002	26	19	1,174	2.1	
2003	25	23	1,048	2.3	
2004	78	16	905	7.8	
2005[b]	71	19	999	6.5	
2006[e]	137	46	957	12.0	
2007[c]	89	13	783	10.1	
Willamette					
2002	5	53	1,602	0.3	
2003	5	59	1,465	0.3	
2004	16	28	1,807	0.9	
2005	19	24	1,497	1.2	
2006	45	55	1,608	2.6	
2007	161	67	1,364	10.1	

[a] *Includes fish with partial or questionable fin-clips.*
[b] *Otoliths were analyzed for 53 fish at McKenzie (of which 18 were wild); 21 at North Santiam (11 wild); and 63 at South Santiam (50 wild).*
[c] *Otoliths were analyzed for 128 fish at McKenzie (of which 84 were wild, but 4 were not spawned); 171 fish at North Santiam (154 wild), and 97at South Santiam (85 wild).*
[d] *Bennett Dam trap on the North Santiam was not operated in 2006 and 2007.*
[e] *Otoliths were collected on 152 unclipped fish, of which 114 were wild and 38 were of hatchery origin.*

TASKS 4.1 AND 4.3 – MIGRATION TIMING, LIFE HISTORIES, AND HABITAT USE OF JUVENILES

Migration Timing and Life Histories—Seining and PIT Tags

Methods

We used PIT tags to monitor migration of juvenile spring Chinook salmon in the McKenzie, Willamette, and Santiam rivers. Age 0 Chinook salmon representative of the fry migrants were seined and tagged in the lower McKenzie and upper Willamette rivers in June and July because fry are too small to tag when they migrate past Leaburg Dam in February–April. We sampled these fish in the lower McKenzie and upper Willamette rivers downstream of the major spawning areas. In addition, we seined in sections of the Willamette River from Harrisburg to Newburg and in the Santiam River basin. We also captured and tagged fish at the Leaburg bypass flume in fall 2005 and spring 2006.

Migrating juvenile Chinook salmon were scanned with a tag detector (Destron-Fearing® FS1001) at Willamette Falls in the bypass of the T. J. Sullivan hydroelectric plant operated by Portland General Electric Company (PGE). Only a portion of the juvenile salmon migrating past Willamette Falls uses the bypass system (Royer et al. 2001). Tags also were detected and reported by the NOAA Fisheries during their juvenile salmonid studies in the Columbia River estuary (Ledgerwood et al. 2004). Additional methods are in Schroeder et al. (2003).

An adult PIT tag detection system was installed in the Willamette Falls fishway in the spring of 2006 to identify the contribution to adult returns of different juvenile life histories and of the juvenile fish from different watersheds in the basin. The system consists of four antennas at both the entrance and exit of the count window pool with Destron-Fearing® FS1001 transceivers. All adult salmon migrating upstream of Willamette Falls must pass through the fishway.

Migration

We tagged 9,732 wild spring Chinook salmon in the McKenzie, Willamette, and Santiam rivers in May–July 2006 and 11,253 in May–July 2007 (Table 20). We also tagged 3,272 fall migrants and 626 spring yearling migrants of the 2004 brood year at the Leaburg Canal bypass, and 3,084 fall migrants and 737 spring yearling migrants of the 2005 brood year. Beach seining catch rate (fish/seine haul) varied among rivers and between years (Table 21). Although catch rate probably reflects relative abundance to some degree, other factors such as river conditions also affect the catch. In addition, the number of fish tagged in any given year or river is reflective of effort and river conditions. For example, the increased number of fish tagged in the middle Willamette (Newberg–Santiam confluence) in 2007 was primarily because river conditions were favorable to seining in this section early in the sample season when juvenile Chinook are in high abundance prior to migrating out of the Willamette. Additional data are in **APPENDIX C**, and tables of all fish caught by basin are in **APPENDIX D**.

Table 20. Number of wild spring Chinook salmon (age 0) that were seined, PIT-tagged, and released in the McKenzie River below Hendricks Bridge (rkm 34, rm 21), in the Willamette River above and below the Santiam River, and in the Santiam River watershed, 2002 (June–July), 2003 (late May–mid July), 2004 (mid May–mid July), 2005 (mid May–mid July), 2006 (late May–late July), and 2007 (mid May–late July).

River	2002	2003	2004	2005	2006	2007
McKenzie	1,848	1,949	1,337	1,972	1,596	1,967
Upper Willamette	1,606	1,868	1,511	2,785	1,766	2,071
Middle Willamette	225	733	377	547	593	1,976
Santiam[a]	487	193	239	400	1,516	1,828
North Santiam		966	258	187	1,725	1,429
South Santiam		330	146	--	2,536	1,982
Total	4,166	6,039	3,868	5,891	9,732	11,253

[a] *From confluence of North and South Santiam to mouth.*

Table 21. Catch rate with a beach seine (fish/seine set) of juvenile Chinook salmon in the Willamette, McKenzie, and Santiam rivers, 2000–2007.

	Willamette River				Santiam River		
Dates	Newburg–Santiam R.	Santiam R.–Harrisburg	Harrisburg–McKenzie R.	McKenzie River	North	South	Mouth to confluence
Jul 25–Sep 11, 2000		3.8	4.1	5.3			
Jul 2–Aug 9, 2001		1.4	6.1	10.9			
Jun 19–Jul 31, 2002	3.4	11.0	16.6	22.0			10.2
May 21–Jul 28, 2003	37.5	21.1	20.2	59.6	33.0	21.1	67.3
May 19–Jul 22, 2004	6.5	19.4	16.1	23.6	11.5	6.5	11.3
May 25–July 28,2005	10.8	17.1	29.7	21.3	10.6	0.8	12.6
May 25–July 28, 2006	15.6	9.9	9.8	9.1	12.5	16.7	16.7
May 15–July 23, 2007	22.6	10.6	12.8	14.7	11.2	17.2	28.7

Most of the detections of PIT-tagged juvenile Chinook occurred at Willamette Falls (Tables 22–23). A generalized model of migration based on our investigations and those of other biologists indicate that diverse migratory life histories are present in the Willamette Basin spring Chinook (Figure 6), and that juvenile Chinook use multiple habitats for rearing, including the main stem of the Willamette River and non-natal tributaries (Schroeder et al. 2005).

Table 22. Detection at the PGE Sullivan Plant at Willamette Falls of juvenile wild and hatchery spring Chinook salmon given PIT tags and released in May 2005–March 2006 (brood year 2004). Numbers in parenthesis are the number of fish tagged.

	U. Willamette R. & McKenzie R.	M. Willamette R. & Santiam R.	Leaburg Bypass		McKenzie Hatchery		
	May 26-Jul 28, 2005 (4,752)	May 25-Jul 13, 2005 (1,134)	Oct 21-Dec16, 2005 (3,273)	Feb 9-Mar 31, 2006 (626)	Oct 10-Nov 23, 2005 (1,346)	Feb 6, 2006 (983)	Mar 9, 2006 (998)
Month tag detected:							
May	3	1	--	--	--	--	--
June	72	73	--	--	--	--	--
July	4	0	--	--	--	--	--
August	0	0	--	--	--	--	--
September	0	0	--	--	--	--	--
October	0	0	0	--	7	--	--
November	2	0	7	--	29	--	--
December	1	0	8	--	4	--	--
January	0	0	0	--	0	--	--
February	1	0	1	0	0	13	--
March	1	0	15	2	1	18	21
April	0	0	17	9	0	6	14
May	0	0	2	40	0	1	0
June[a]	0	0	0	1	0	0	0
Detection rate at Willamette Falls (%)	2.2	7.3	1.5	8.1	3.0	3.8	3.6
95% CI	1.8-2.6	5.8-8.8	1.1-1.9	6.0-10.3	2.1-3.9	2.6-5.0	2.5-4.8
Mean length (mm) at time of tagging for—							
Fish released	81.9	93.6	106.3	99.8	153.2	142.6	159.9
Fish detected	88.2	96.2	107.0	100.4	162.6	134.7	149.9

[a] *PGE Sullivan Plant shut down June 9, 2006*.

Table 23. Detection at the PGE Sullivan Plant at Willamette Falls of juvenile wild spring Chinook salmon given PIT tags and released in May 2006–March 2007 (brood year 2005). Numbers in parenthesis are the number of fish tagged.

	U. Willamette R. & McKenzie R.	M. Willamette R. & Santiam R.	Leaburg Bypass	
	May 15-Jul 21, 2006 (3,362)	May 23-Jul 13, 2006 (6,370)	Nov 2-Dec 3, 2006 (3,084)	Jan 21-Mar 23, 2007 (737)
Month tag detected[a]:				
May	0	4	--	--
June[a]	12	32	--	--
July[a]	--	--	--	--
August[a]	--	--	--	--
September[a]	--	--	--	--
October[a]	--	--	--	--
November[a]	0	0	0	--
December	0	0	1	--
January	0	0	0	0
February	0	0	0	0
March	1	2	4	0
April	0	0	18	11
May	0	1	6	21
June	0	0	0	0
Detection rate at Willamette Falls (%)	0.4	0.6	0.9	4.3
95% CI	0.2-0.6	0.4-0.8	0.6-1.3	2.9-5.8
Mean length (mm) at time of tagging for—				
Fish released	90.2	89.5	110.0	98.8
Fish detected	102.6	100.0	104.4	100.9

[a] *PGE Sullivan Plant shut down June 9–November 8, 2006*.

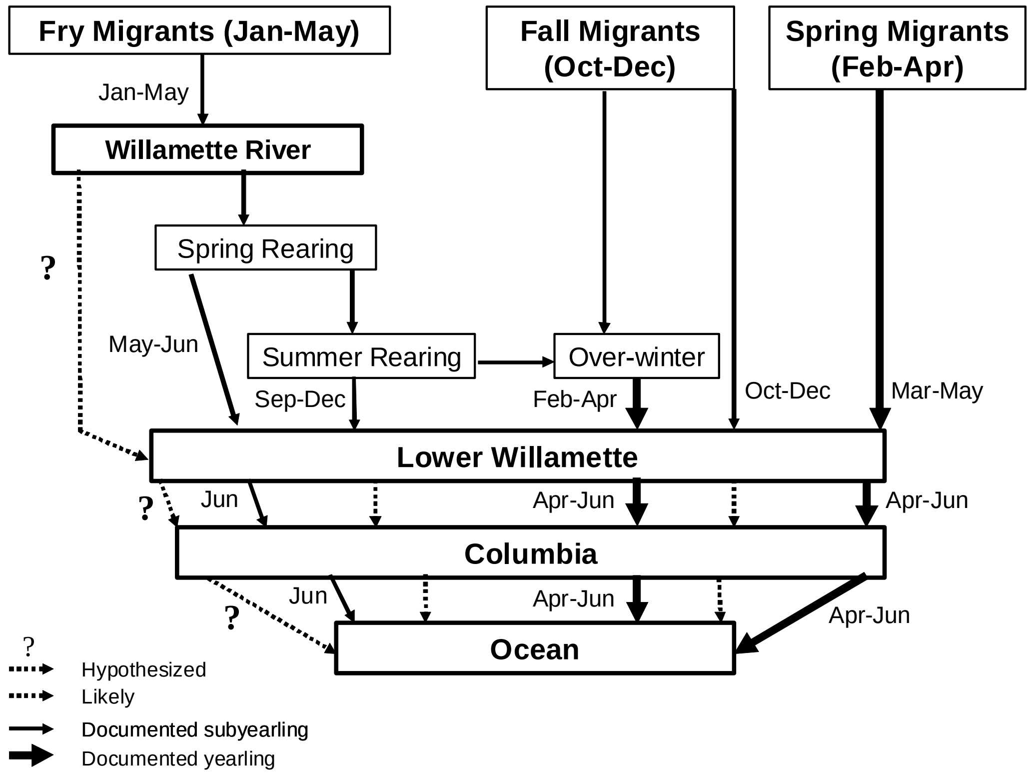

Figure 6. Schematic representation of the migratory and rearing diversity in Willamette Basin spring Chinook salmon. Starting point at the top of the diagram is based on observed peaks of migration from upper McKenzie River spawning areas determined by trapping at the Leaburg Dam juvenile bypass.

Juvenile Chinook that are seined and tagged in late spring and early summer in the lower reaches of tributaries and in the main stem of the Willamette likely represent a combination of fry that migrate early from spawning areas to rear, and fish that rear closer to spawning areas and emigrate in spring in response to a stimulus such as energetic demands. A portion of these fish emigrate from the Willamette Basin as subyearlings and are detected at Willamette Falls. The proportion of fish tagged in late spring and summer that are detected at the falls varies by year and is likely influenced by several factors including river conditions affecting growth that might stimulate emigration, river conditions such as flow that affect detection efficiency at the falls, and the time of year and location where fish are tagged. In general, a larger proportion of Chinook tagged in the middle Willamette and Santiam rivers are detected at Willamette Falls in the first few months following tagging than fish tagged in the upper Willamette and McKenzie rivers (Table 24). The time of year fish are tagged can influence detection of fish at the falls (number detected and when detected). For example, the detection rate of fish tagged and released before mid June was higher than for fish released later (Figure 7). During years when the Sullivan Plant was operated all summer, most detections of subyearling migrants were prior to mid July. Few fish migrate after mid July because water temperature becomes high in the Willamette River (Figure 8). Sampling generally has occurred earlier in the Santiam and middle Willamette rivers than elsewhere because fish are large enough to tag, and has occurred in late June or July in the McKenzie River to avoid handling fish that are too small to tag (< 65 mm).

Table 24. Detection rate (%) of juvenile Chinook salmon PIT-tagged and released in the Willamette Basin in late spring and early summer and detected at Willamette Falls during the same summer, 2002–2007.

	Tag Year					
	2002	2003	2004[a]	2005	2006[a]	2007
M. Willamette	1.3 (225)	4.5 (733)	2.6 (342)	9.1 (547)	(0)	9.1 (1,976)
Santiam	2.7 (487)	11.4 (193)	7.6 (224)	6.0 (400)	3.8 (861)	9.1 (1,828)
N Santiam	--	11.6 (966)	(0)	0 (187)	(0)	6.7 (1,429)
S Santiam	--	9.4 (330)	1.8 (56)	--	0.3 (1,002)	2.5 (1,982)
U. Willamette	0.1 (1,606)	1.6 (1,868)	4.9 (452)	2.8 (2,785)	2.8 (429)	2.9 (2,030)
McKenzie	0.1 (1,848)	0.3 (1,949)	1.1 (270)	0 (1,967)	(0)	0 (1,967)

[a] *Sullivan Plant was shut down for the summer June 14, 2004 and June 9, 2006. Number of fish tagged for these years are those released prior to the shut down with enough migration time to reach the falls.*

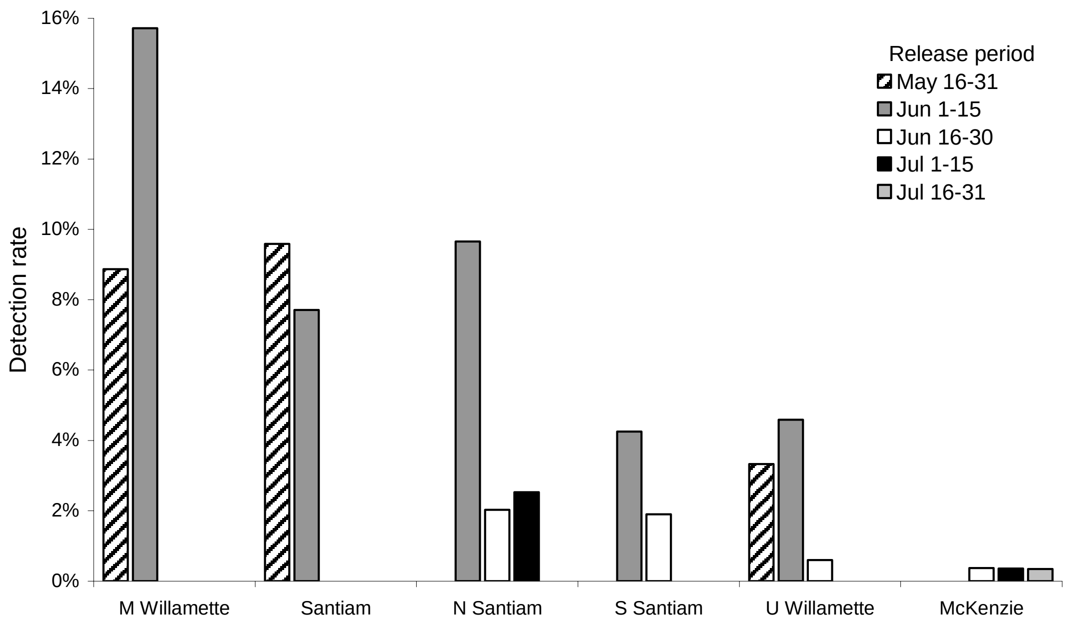

Figure 7. Detection rate at Willamette Falls of juvenile spring Chinook salmon that were PIT-tagged in six areas of the Willamette Basin, by two-week release periods in 2007.

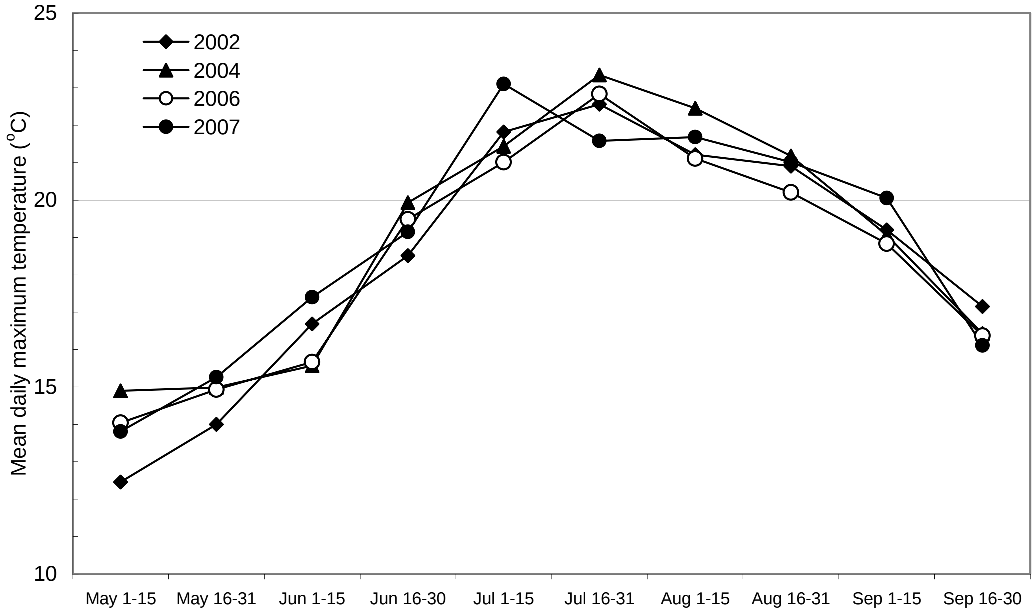

Figure 8. Patterns of the May 1–Sep 30 mean daily maximum water temperature (°C) by two-week periods in the Willamette River downstream of Salem (rkm 130) from 2002–2007 data.

Detections of fish tagged in spring and summer in most areas generally were highest in summer (Figure 9). However, the pattern of seasonal emigration from the Willamette River was affected by the time of year we sampled and the location where fish were tagged. Although the detections of fish tagged in the McKenzie River are small, about half occurred in summer when most of the tagging was completed before mid June, whereas when fish were tagged in late June and July, no fish were detected at the falls in the summer (Figure 9). In 2007, almost all of the detections of fish tagged in the upper Willamette occurred before mid July and no fish were detected the following spring. The fish were tagged primarily in early June to early July, and almost half of the fish were tagged downstream of Harrisburg. In contrast, most of the juvenile fish in 2000 were tagged in late July and August, primarily upstream of Harrisburg, and the few detections of these fish were in fall and the following spring. The effect of time of tagging on detections at the falls was also observed for fish tagged in the Santiam River, with more detections occurring later in 2002 when fish were tagged in mid June to early July than in 2007 when most fish were tagged from late May to mid June. We applied correction factors to the detections at the falls to account for reduced efficiencies at high flow, which were based on the percentage of flow diverted into the PGE Sullivan Plant and the percentage of time the PIT tag detector was operational. Although we are uncertain if these factors accurately represent the efficiency of the detector and consequently the seasonal migration patterns, the data in 2000–2007 span various flow conditions, including some years with low flow in winter and early spring (and presumably higher detection efficiencies at the falls). In addition, the average detection of fall migrants tagged in the McKenzie River at the Leaburg bypass indicates the detection of fish can be relatively high during fall-winter and spring (Figure 9). These data suggest that juvenile fish tagged in late spring and early summer tend be fish that are actively emigrating from the Willamette River as subyearlings, whereas fish tagged later in the summer probably rear through summer in the Willamette River or lower reaches of tributaries and emigrate in fall-winter and the following spring.

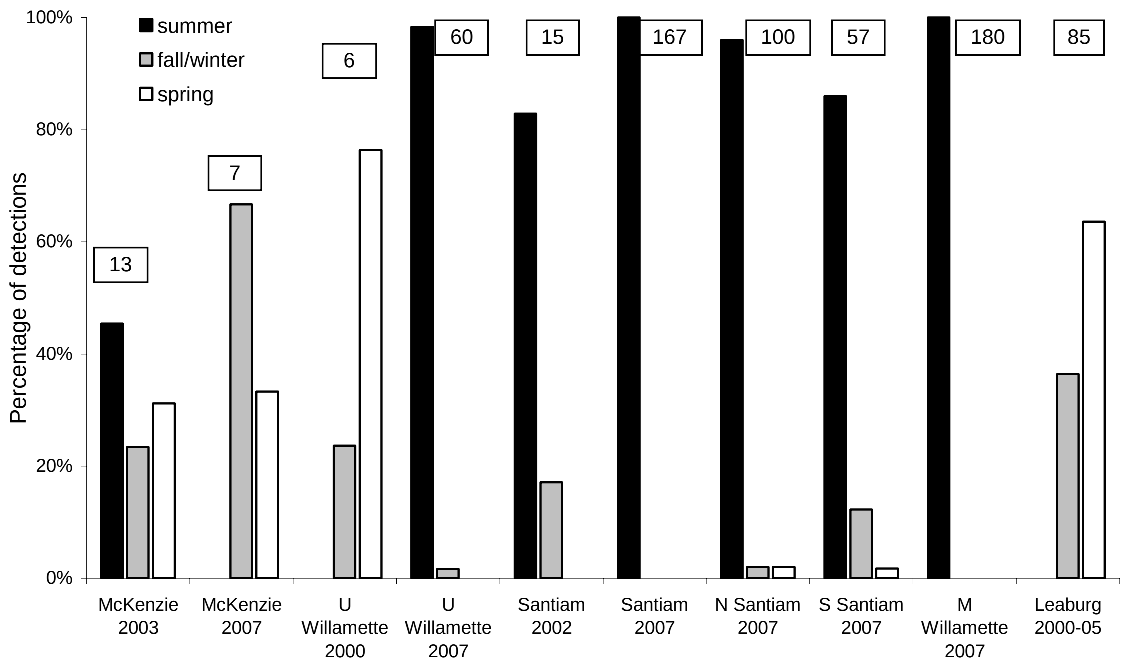

Figure 9. Seasonal migration pattern of subyearling spring Chinook tagged in the Willamette Basin in late spring and summer and detected at the PGE Sullivan Plant. Migration of McKenzie River fall migrants tagged at Leaburg bypass is presented for comparison. Number of fish detected (in boxes) was expanded for percentage of flow entering the bypass and percentage of time the PIT tag detector was operable.

A portion of the subyearling Chinook that emigrated from the Willamette River were detected in the Columbia River estuary (Figure 10). Based on efficiency estimates calculated as a percentage of all tags detected at Bonneville Dam that were detected in the trawl sampler (3%, unpublished data, R.D. Ledgerwood, NMFS), the expanded detection rate of subyearling Chinook was highest for fish tagged in the Santiam (average of 28%) and middle Willamette rivers (average of 13%). The average detection rate of fish tagged in the Willamette upstream of the Santiam confluence (10%) was slightly lower than for fish tagged in the middle Willamette, and the detection rate of fish tagged in the North and South Santiam rivers was relatively low (average of 3–4%). Subyearling Chinook tagged and released in the McKenzie River were not detected in the trawl sampler in 2004 –2007 within the same year they were tagged, although some of these fish were detected at Willamette Falls in summer 2004 and 2005. A couple of juvenile Chinook tagged in the McKenzie River as subyearlings were detected in the trawl sampler a year after they tagged and released. The trawl sampler was operated on a limited schedule in the fall of 2006 and one Chinook tagged in July in the upper Willamette was detected in late October. The pattern of migration for subyearling Chinook from trawl detections was similar to that observed at Willamette Falls: high summer emigration of fish tagged in the Willamette and Santiam rivers and low emigration from the McKenzie and North and South Santiam rivers (Figures 9 and 10).

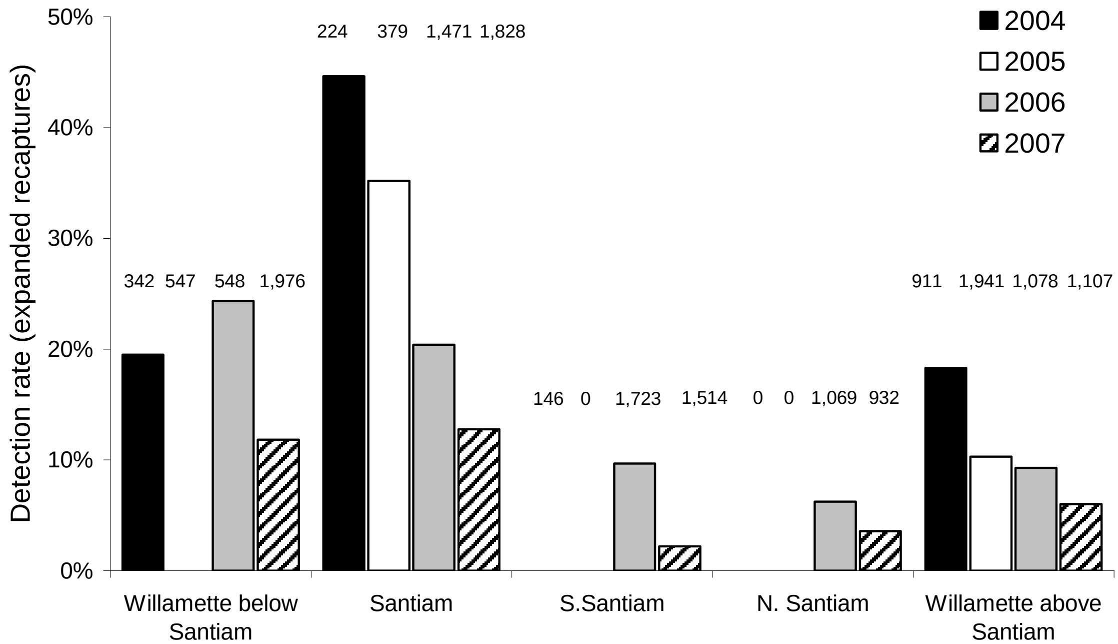

Figure 10. Detection rate in the lower Columbia River trawl sampler of subyearling Chinook tagged and released in the Willamette Basin upstream of Willamette Falls in late spring and summer 2004–2007. Numbers of fish tagged are above bars and include only fish that were released during the time the trawl was operated. Numbers of recaptured fish were expanded by the estimated trawl detection rate of 3%.

Average migration rates of subyearling Chinook salmon to Willamette Falls and the lower Columbia River ranged from 9 km/d to over 30 km/d (Tables 25–26). Of the fish that migrated past Willamette Falls, subyearling Chinook tagged in the Santiam and upper Willamette generally had the highest rate of migration (Table 25). In the years when the detector at Willamette Falls was operated through the summer, migration rates of subyearling Chinook tagged in the Willamette and Santiam rivers were higher in 2003 and 2005 than in 2007. Although flow was generally lower in 2007, than in 2003 or 2005, and could affect rates of migration, the fish were also tagged earlier in the spring in 2007 at a smaller size that might have been beneath a migratory threshold. The migration rate of yearling smolts was generally lower than that of subyearling or fall migrants (Tables 25–26). Several individual fish were detected both at Willamette Falls and in the Lower Columbia trawl in the same year. Although the sample size is small, subyearling Chinook migrated from their release site to Willamette Falls at a higher rate than yearling smolts, but yearling smolts migrated at a higher rate from Willamette Falls to the Lower Columbia (Figure 11)

Table 25. Average migration rate (km/d) of juvenile spring Chinook that were PIT-tagged and released in the Willamette Basin upstream of Willamette Falls, and detected at the PGE Sullivan Plant at the falls (number detected in parentheses), 2002–2007. Detected within the same year except fall migrants tagged at Leaburg, which were detected the following spring.

	Tag Year					
Group, area	2002	2003	2004[a]	2005	2006[a]	2007
Subyearling (seining)						
Willamette below Santiam	13 (3)	13 (34)	11 (9)	14 (60)		9 (180)
Santiam	16 (13)	18 (22)	22 (17)	24 (24)	18 (33)	13 (167)
North Santiam		13 (112)				10 (96)
South Santiam		13 (31)	16 (1)		29 (3)	12 (49)
Willamette above Santiam	15 (1)	20 (29)	21 (22)	17 (69)	31 (12)	15 (59)
McKenzie	18 (1)	15 (6)	14 (3)			
Yearling (bypass trap)						
Leaburg, fall migrant in fall	0	**b**	19 (11)	25 (15)	18 (1)	30 (10)
Leaburg, fall migrant in spring	3 (15)	**b**	3 (117)	2 (35)	2 (31)	2 (32)
Leaburg, spring smolt	7 (86)	16 (16)	**b**	13 (64)	6 (52)	5 (30)

[a] *Sullivan Plant was shut down for the summer June 14, 2004 and June 9, 2006.*
[b] *Leaburg bypass trap was not run in fall 2003 or spring 2004 because of construction.*

Table 26. Migration rate (km/d) of juvenile spring Chinook that were PIT-tagged and released in the Willamette Basin upstream of Willamette Falls, and detected in the Lower Columbia River trawl sampler (number detected in parentheses), 2004–2007. Fish were tagged in late spring and early summer except in the McKenzie River at the Leaburg bypass sampler. Fish were detected in the same year except where noted.

	Tag Year				
Group, area	2003	2004	2005	2006	2007
Subyearling (seining)					
Willamette below Santiam		15 (2)		16 (4)	14 (6)
Santiam		23 (3)	21 (4)	16 (9)	16 (2)
North Santiam				17 (2)	11 (1)
South Santiam				17 (5)	11 (1)
Willamette above Santiam		22 (5)	16 (6)	19 (4)	21 (2)
McKenzie[a]	1 (1)			1 (1)	
Yearling (bypass trap)					
McKenzie – Leaburg fall migrant[a]			3 (1)	3 (5)	
McKenzie – Leaburg spring smolt				6 (6)	6 (2)

[a] *Fish was detected in the following year; 2006 and 2007 for fish tagged at Leaburg in the fall, and 2004 and 2007 for fish tagged in the McKenzie River in the summer.*

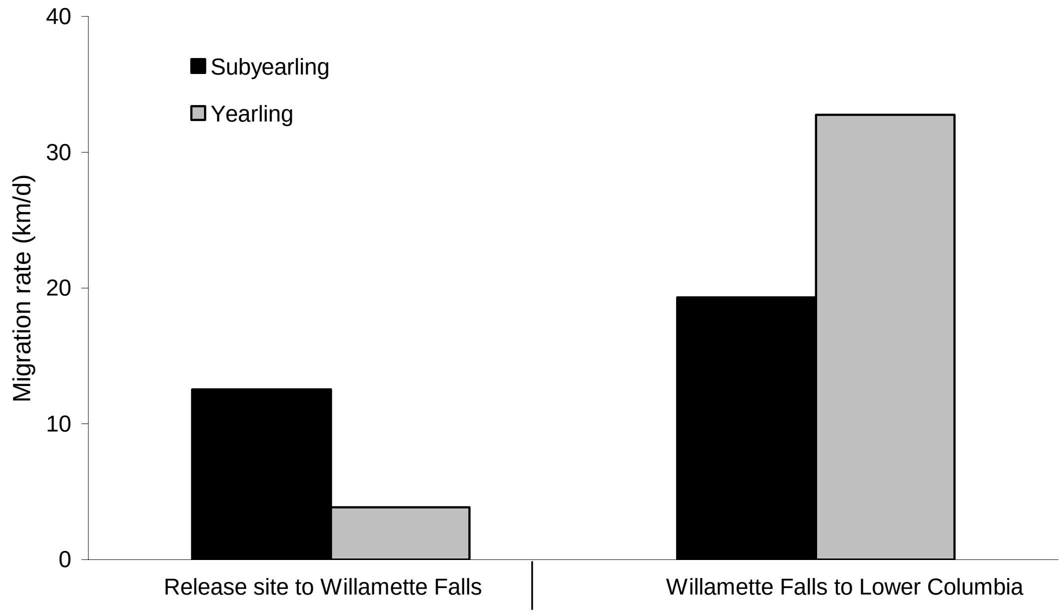

Figure 11. Migration rate (km/d) of subyearling (n = 7) and yearling (n = 3) Chinook salmon that were PIT-tagged and released in the Willamette Basin and detected both at Willamette Falls and in the lower Columbia River in the same year, 2004–2007.

Although many of the juvenile Chinook captured and tagged during spring and summer sampling emigrated from the Willamette River and tributaries, in-river recaptures of tagged fish suggested more restricted movement (Figure 12). However, these data represent only a partial view of the migratory behavior of subyearling Chinook and are likely composed primarily of the fish that rear in the Willamette Basin through summer. The number of recaptured fish represented a small percentage of the number of fish that were tagged, and fewer fish were recaptured by seining during the summer than were detected migrating past Willamette Falls (Table 27), with the exception of large numbers of fish recaptured at a single site in the McKenzie River in 2007. Because seining effort within the basin is not evenly distributed (temporally or spatially), data from recaptured fish is influenced by several factors: (1) sampling does not occur frequently enough in all areas to recapture active migrants given their migration rate (*see* Table 25); (2) sampling generally occurs earlier in downstream areas than in areas upstream thus limiting the ability to detect fish migrating into and through downstream areas (long-distance migrants); and (3) over 70% of the fish that were recaptured by seining in 2007 were tagged after June 15 and fish tagged after mid June (generally in upstream areas) were detected at a lower rate at Willamette Falls than fish tagged earlier (*see* Figure 7).

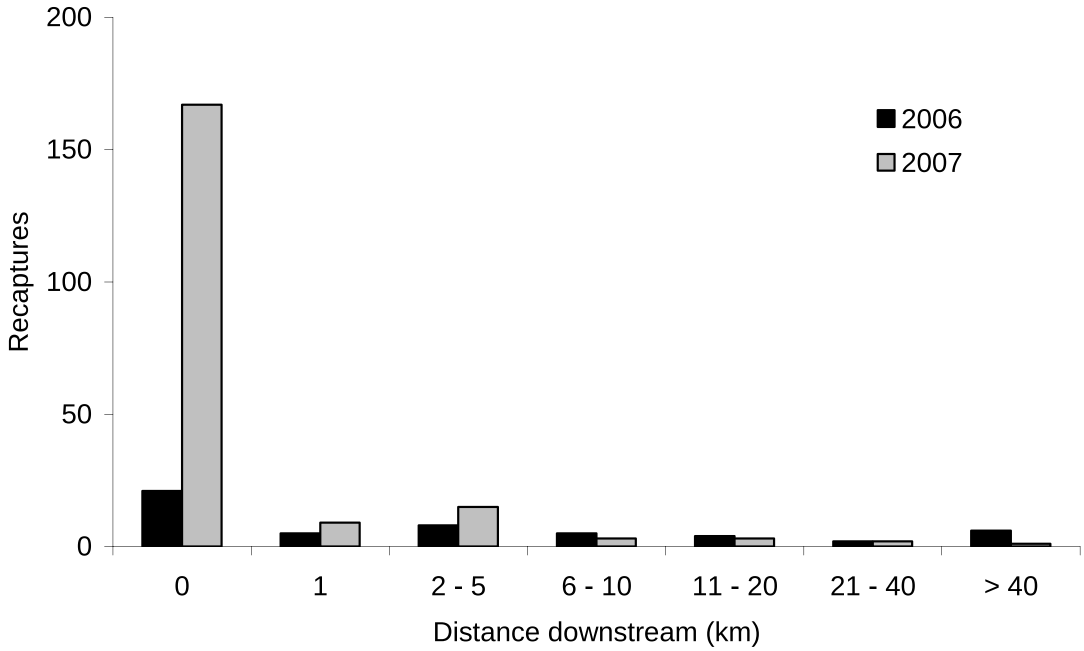

Figure 12. Distance between tagging and subsequent recapture site for juvenile Chinook seined in the summer of 2006 and 2007 in the Willamette River basin. Does not include one fish that was recaptured 2 km upstream from tagging location.

Table 27. Number of juvenile Chinook salmon that were tagged in the Willamette Basin and number of tagged fish that were recaptured by seining within the basin 5 days or more after initial release or detected at Willamette Falls.

Year, location	Tagged	Tag dates (% tagged after Jun 15)	Recaptured	Detected[a]
2007				
M Willamette	1,976	May 16–Jun 5 (0%)	12	180
Santiam	1,828	May 23–Jun 13 (0%)	6	167
N Santiam	1,429	Jun 4–Jul 12 (35%)	21	96
S Santiam	1,982	Jun 11–Jul 2 (54%)	17	49
U Willamette	2,030	May 15–Jul 18 (45%)	25	59
McKenzie	1,967	Jun 18–Jul 26 (100%)	119	0
2006				
M Willamette	593	Jun 13–26 (1%)	1	**a**
Santiam	1,516	May 25–Jun 27 (3%)	11	**a**
N Santiam	1,725	Jun 8–Jul 12 (38%)	9	**a**
S Santiam	2,536	May 30–Jul 13 (4%)	18	**a**
U Willamette	1,766	May 24–Jul 14 (50%)	7	**a**
McKenzie	1,596	Jun 6–Jul 21 (95%)	5	**a**

[a] *Same summer; incomplete data in 2006 because PGE Sullivan Plant was shut down June 9.*

During the fall, the reservoir behind Cougar Dam on the South Fork of the McKenzie River is lowered to its flood conservation pool level. This reduction in water level stimulates the emigration of juvenile Chinook from the reservoir. Juvenile Chinook were captured in two rotary screw traps below Cougar Dam in the winter of 2005–2006 and injected with PIT tags before their release. The average length of these 69 fish was 159 mm. We recaptured five fish at Leaburg Dam, 47 km downstream, with one fish arriving in less than one day (62 km/d) and four arrived two days later (24 km/d). We detected four additional tagged fish from this group at Willamette Falls, 343 km downstream. One was detected less than six days later (63 km/d), one was detected about 16 days later (22 km/d), and the other two were detected in March and April (3 and 6 km/d).

Summer Rearing Growth Rates

Growth rate of age-0 Chinook was estimated in 2006 and 2007 for PIT-tagged fish that were recaptured at least five days after being released (Table 28). Average growth rate for all areas combined was significantly greater ($P = 0.01$) in 2006 (0.52 mm/d) than in 2007 (0.36 mm/d). In general, growth rates were lowest in the McKenzie and upper Willamette and highest in the Santiam. In 2006, the average growth rate of fish in the McKenzie and upper Willamette was significantly smaller ($P < 0.05$) than that in the North Santiam and Santiam (Table 28). The average growth rate in 2007 of fish in the McKenzie and upper Willamette was significantly smaller ($P < 0.01$) than growth in the middle Willamette, and growth rate of McKenzie fish also was smaller than that in the Santiam (Table 28).

Table 28. Growth rate (mm/d) of PIT-tagged juvenile Chinook (age 0) recaptured $\geq$ 5 days after tagging in the Willamette River and its tributaries, 2006 (June–July) and 2007 (May–July).

	Recaptures[a]			Growth rate (mm/d)		
Year, river	n	Days	FL	Average	Minimum	Maximum
2006						
McKenzie	5	13	92.6	0.20	0.08	0.47
North Santiam	8	16	84.9	0.65	0.28	1.08
South Santiam	18	15	80.3	0.48	0.14	1.07
Santiam	10	13	80.5	0.85	0.38	2.43
Upper Willamette	8	8	95.2	0.13	0.00	0.41
2007						
McKenzie	11	17	81.3	0.17	0.00	0.45
North Santiam	17	17	90.4	0.35	0.00	0.63
South Santiam	14	14	86.1	0.36	0.00	0.77
Santiam	6	13	82.5	0.52	0.00	0.89
Upper Willamette	20	16	79.6	0.28	0.00	0.48
Middle Willamette	11	13	87.6	0.62	0.20	1.29

[a] *Average days between release and recapture, and average fork length at time of release.*

Size of juvenile Chinook captured by beach seine has generally been smallest in the McKenzie and upper Willamette rivers and largest in the middle Willamette (Table 29). The size of Chinook in the McKenzie and upper Willamette rivers was significantly smaller ($P < 0.01$) on average in 2002–2005 than elsewhere, with the exception of upper Willamette and South Santiam in 2003 (Table 29). However, in 2006 and 2007 the average size of fish in the upper Willamette was significantly greater ($P < 0.01$) than that in the Santiam basin. Juvenile Chinook in the middle Willamette were significantly larger ($P < 0.01$) than fish captured elsewhere with the exception of the Santiam in 2002 and the North Santiam in 2005.

Table 29. Mean fork length of wild spring Chinook salmon (age 0) captured by beach seine in the McKenzie River below Hendricks Bridge (rkm 34, rm 21), in the Willamette River upstream and downstream of the Santiam River, and in the Santiam Basin, 2002–2007.

	Mean fork length (mm)					
River	2002	2003	2004	2005	2006	2007
McKenzie	84.8	78.4	80.0	79.5	83.9	81.3
Upper Willamette	83.3	85.2	84.4	83.6	95.9	89.0
South Santiam		86.2	92.1		86.9	83.1
North Santiam		90.7	91.8	100.5	88.1	87.8
Santiam[a]	90.3	90.1	89.7	86.2	91.4	87.5
Middle Willamette	90.6	94.9	95.8	96.7	99.9	92.1

[a] *From confluence of North and South Santiam to mouth.*

Returning Adult Chinook with PIT Tags

An adult PIT tag detection system was installed in the fishway at Willamette Falls in the spring of 2006. The system consists of four antennas to cover each submerged orifice of the entrance and exit of the fishway pool where the fish counting window is located. In April 2006, we tested the new system by PIT-tagging hatchery adult spring Chinook that were captured in a fish trap about 50 m downstream of the antennas. PIT-tagged fish were detected multiple times on individual antenna and individual fish were often detected on all four of the antennas. The median time from release to first detection was about 5 h (range 2 h–33 d). Most fish moved directly from the downstream entrance to the upstream exit of the pool, although many stayed in the pool for several hours and were detected several times as they swam past the antennas.

Nine PIT-tagged adults were detected at the Willamette Falls Fishway in 2006. Five of these detections were wild fish tagged as juveniles at the Leaburg bypass trap in fall of 2002 and spring of 2003. The other four fish were tagged at McKenzie Hatchery in fall of 2002 and spring of 2003 and 2004. In 2007, eight PIT-tagged adults were detected at Willamette Falls. Two were wild spring Chinook tagged during the fall (2002 and 2004) at the Leaburg bypass trap, five were hatchery fish released in early spring (2004 and 2005) at McKenzie Hatchery, and one was from a PGE test release of Chinook in the forebay of the Sullivan hydroelectric plant at Willamette Falls. In addition, two wild Chinook tagged as subyearlings in 2005 in the upper Willamette and Santiam rivers were detected at Bonneville Dam on the Columbia River.

Life History—Scales

Otolith marking of all hatchery spring Chinook released in the Willamette and Sandy basins offered an opportunity to collect scales from known wild spring Chinook adults. Scales and otoliths were collected from unclipped adult Chinook recovered in spawning areas. We used otoliths to identify and exclude scales collected from unclipped hatchery fish. Scales were analyzed to determine the freshwater age of smolts and the total age of adults. Below are preliminary results for the 2001–2004 adult returns. Additional data are in **APPENDIX C**.

The percentage of returning adult spring Chinook that had an age-0 (subyearling) life history was higher in the North and South Santiam rivers than in the other basins (Figure 13). Spring Chinook in these rivers spawn lower in the watershed than they did historically because access to the upper watersheds is blocked by dams. Emergence timing and growth of juvenile fish would be affected by water temperature, which is higher in the lower watershed than in the upper watershed during incubation, emergence, and early rearing. However, release of water from the dams also elevates water temperature. Therefore, spring Chinook would emerge earlier in the North and South Santiam rivers than in rivers where access to the upper watershed remains, and a greater percentage of those that survive would likely reach a threshold size to trigger an age-0 migration. The percentage of spring Chinook with a subyearling life history was very low in returns of adults from the 2000 brood year (Figure 13). We have not yet analyzed potential effects of water temperature or flow on the incidence of subyearling life history in returning adults, but changes in flow and temperature regimes caused by hydroelectric operations can alter life history patterns (Connor et al. 2005; Williams et al. 2008).

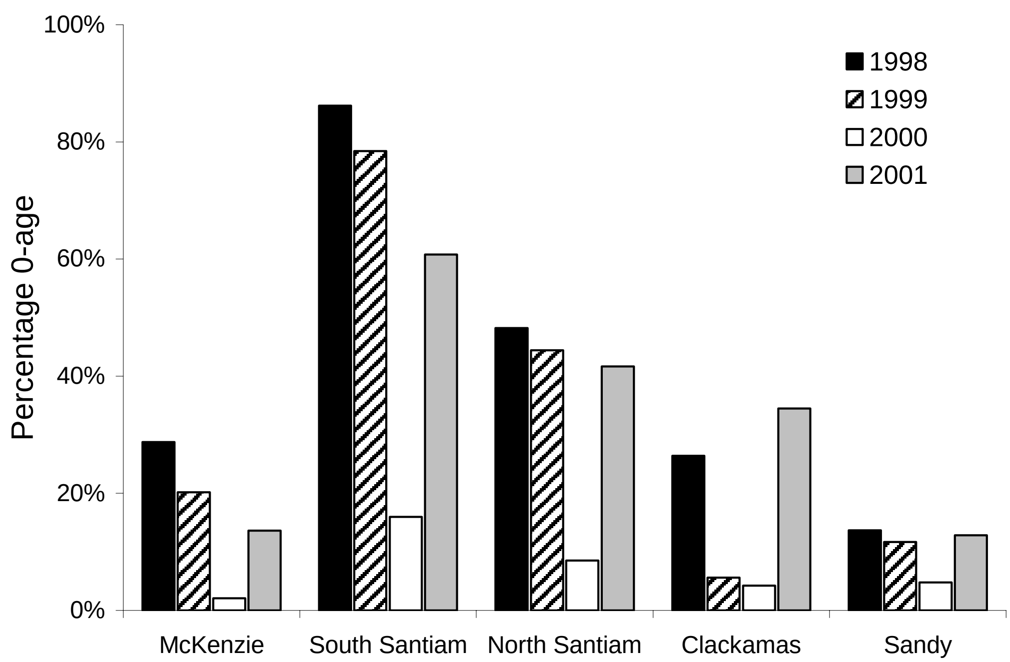

Figure 13. Percentage of wild adult spring Chinook recovered in spawning areas of the Willamette and Sandy basins that had an age-0 life history, 1998–2001 brood years. The 2001 brood year does not include age 6 returns. Wild origin of fish was determined by absence of induced thermal marks in otoliths.

Wild spring Chinook in the Willamette and Sandy basins primarily returned as age 4 and age 5 fish although there was substantial variation among individual basins (Table 30). The average age composition in the McKenzie Basin was predominantly age 5, whereas on average these older fish composed a much smaller percentage of the run in returns to the South Santiam River. The percentage of age 6 fish was higher in the Clackamas and Sandy basins than in the other basins (Table 30).

Table 30. Average age composition (%) of returning wild adult spring Chinook, 2001–2006 run years.

River (run years)	Age 3	Age 4	Age 5	Age 6	Age 7	Average n
McKenzie (2001–2006)	0.5	26.7	70.8	2.0	0.0	221
South Santiam (2002–2006)	1.3	59.2	38.1	1.4	0.0	112
North Santiam (2001–2006)	4.8	48.6	44.6	2.4	0.0	45
Clackamas (2002–2006)	0.0	37.9	58.8	3.1	0.3	110
Sandy (2002–2006)	0.6	39.9	54.9	4.6	0.0	150

With the exception of returns in 2004, the age composition of wild fish in the McKenzie and Sandy basins was similar between years, and age 5 fish tended to be the predominant age at return (Figure 14). These basins have a high percentage of wild fish (*see* Table 4), a low percentage of adults with a subyearling life history (Figure 13), and access to much of their historic spawning and rearing areas. The pattern of age composition among return years was generally similar for wild spring Chinook in the North and South Santiam rivers, with the exception of the 2003 return year, and age 4 fish generally composed a higher percentage of the return (Figure 15). Wild fish spring Chinook are a relatively small component of the returns in these basins and are composed of a high percentage of adults with a subyearling life history. Size of juvenile salmon is an important factor in age at maturity (Morita et al. 2005; Scheuerell 2005), and generally fish that are larger return from the ocean earlier (Scheuerell 2005). Because access to historic spawning and early rearing areas in the Santiam Basin is blocked by dams, juvenile Chinook in this basin have a less complex suite of available rearing habitat than fish in the McKenzie and Sandy basins, especially rearing areas with cold water.

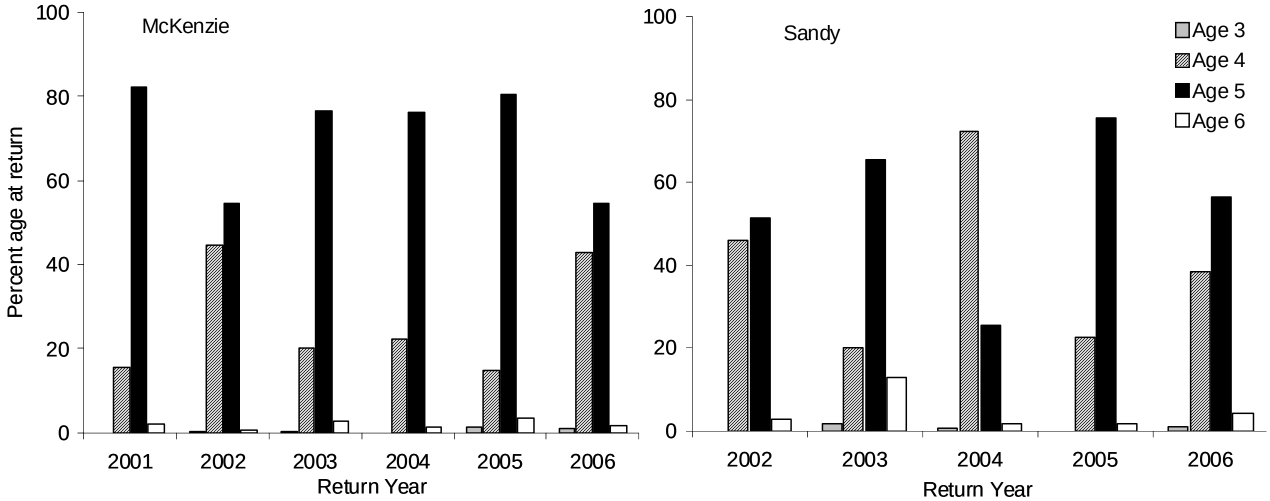

Figure 14. Age composition of returning wild adult spring Chinook salmon in the McKenzie (2001–2006) and Sandy (2002–2006) basins.

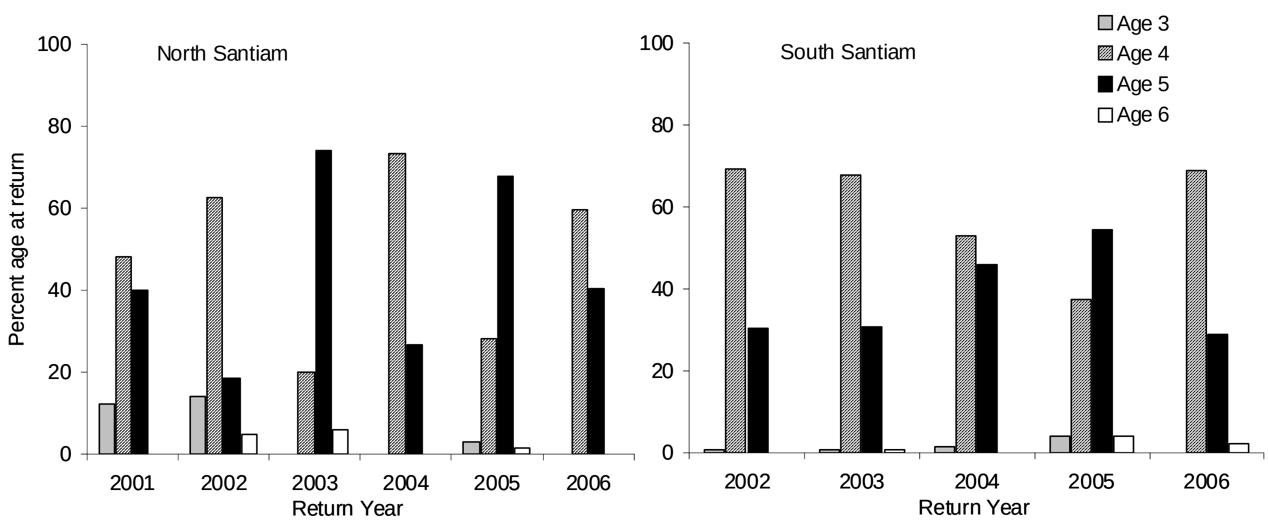

Figure 15. Age composition of returning wild adult spring Chinook salmon in the North (2001–2006) and South Santiam (2002–2006)basins.

Habitat Use—Floodplain

We have been monitoring catch of juvenile spring Chinook in a Willamette River floodplain drainage channel located on the Kenagy farm near Albany (rkm 188; rm 117) since spring 2004. History and details of the trapping facilities are described in Schroeder et al. (2005). Catch of species by year is in **APPENDIX D**.

The drainage channel was inundated with water for 56 days in late 2005 and early 2006 (Figure 16). We caught four juvenile Chinook in a two way trap located near the confluence of the drainage with the Willamette River. We also captured two additional fish by dipnet at a road crossing further upstream.

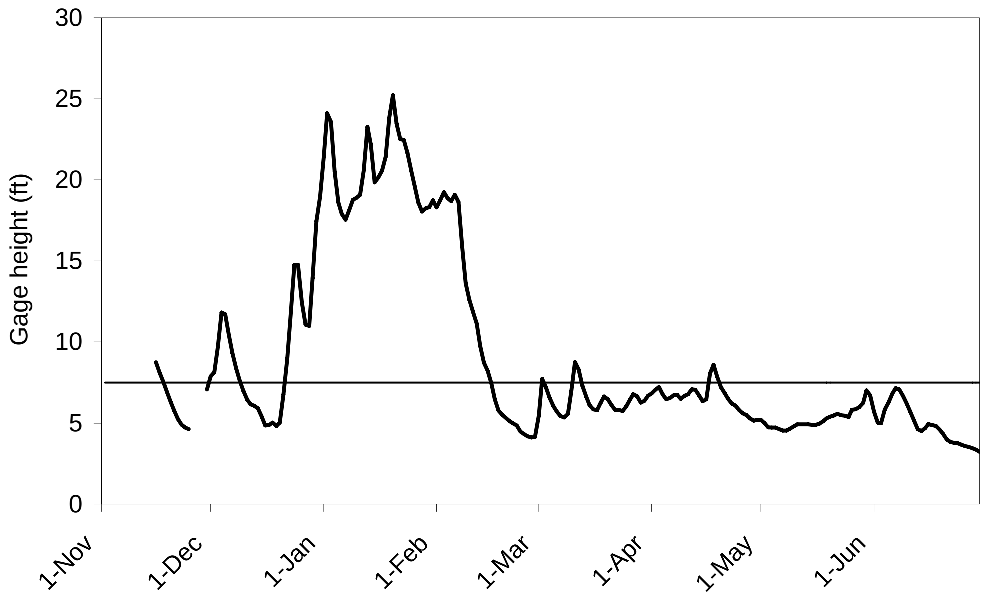

Figure 16. Gauge height of the Willamette River at Albany (USGS), November 2005–June 2006. Kenagy farm drainage channel is flooded by the Willamette River at gauge heights > 7.5 ft, shown by the solid horizontal line.

The Kenagy farm drainage channel began flooding in early November 2006, and was inundated for 70 days (Figure 17). We sampled fewer Chinook in 2007 than in other years when the drainage channel was inundated with water consistently ≥ 50 d (Table 31). Only two Chinook were captured at the trap in 2007, an unclipped fish on 18 January and a hatchery fish on 20 February, both in the outmigrant trap box. We did not sample in the pond area and upper bridge crossing in 2007, where we had found juvenile Chinook in previous years. The capture of Chinook has been limited at the trap site in the drainage channel, and we have been unable to examine when and at what size fish migrate into the off-channel area, or the relationships to river stage and water temperature. Future work will occur in other areas and we will use other techniques to investigate winter use of floodplains by juvenile spring Chinook.

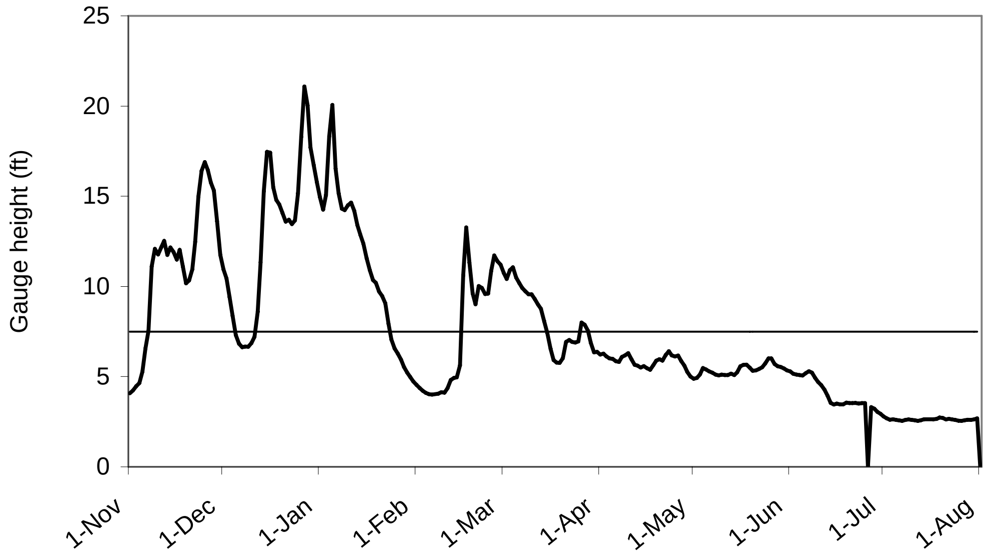

Figure 17. Gauge height of the Willamette River at Albany, November 2006–July 2007. Kenagy farm drainage channels are flooded by the Willamette River at gauge heights > 7.5 ft, shown by the solid horizontal line.

Table 31. Days between 15 December and 1 April that the Willamette River at the Albany gauge exceeded 7.5 ft and inundated the drainage channel at the Kenagy Farm, and the number of migrant juvenile Chinook captured in the Kenagy floodplain.

Year	Days inundated	Number caught
2004	71	63[a]
2005	15	0
2006	59	6
2007	70	2

[a] *7 were caught in a lower trap at a similar location where a trap was fished in 2005–2007, and 56 were caught in an upper trap. An additional 47 fish were seined in a pond between the two traps; 35 were netted in the concrete culvert upstream of the upper trap, and 4 were electrofished in a culvert upstream of the lower trap.*

TASK 5.3 – EFFORTS TO RE-ESTABLISH POPULATIONS

In an effort to increase natural production, the U.S. Army Corps of Engineers and ODFW have reintroduced spring Chinook salmon into quality habitat downstream of dams in the Little North Fork Santiam River and into historical habitat upstream of dams in the Willamette Basin. Access to historical spawning habitat has been identified as a limiting factor for natural production of spring Chinook salmon in the Willamette basin. We evaluated the success of the outplant program in the North and South Santiam basins by conducting spawning surveys to count redds and collect carcasses.

Little North Fork Santiam

Unclipped spring Chinook (195) collected at Minto Pond were outplanted into the Little North Fork Santiam River on seven dates (August 16–September 27) in 2007. All fish were externally marked with a red Floy® tag, and were released into a deep pool at the Narrows (rm 8) where survival has been good in previous years. Fewer Chinook were outplanted in 2007 and 2006 (130) than in 2004–2005 (350) because more unclipped fish have been retained for spawning at the hatchery to increase the percentage of wild fish incorporated into the broodstock. Seven sections (14.4 mi) of stream upstream and downstream of the release site were surveyed on five dates. The number of redds counted in the Little North Fork in 2007 (Table 33) was similar to that in 2005 (61), and was higher than in 2006 (34) and 2004 (51), and 70% of the redds were upstream of the release site. Of the 14 salmon carcasses recovered in the Little North Fork, 7 were tagged (outplanted from Minto).

Upper North Santiam above Detroit Dam

Surplus fin-clipped Chinook collected at Minto Pond were outplanted into the North Santiam and Breitenbush rivers upstream of Detroit Dam (Table 32). Fish were released on six dates (August 22–September 24) into the Breitenbush River at Cleator Bend (rm 12), and into the main stem of the North Santiam River at Coopers Ridge Road (rm 62) and at Parish Lake Road (rm 81). We counted 70 redds in the main stem of the North Santiam 7 mi upstream of the main release site at Coopers Ridge Road and in Horn and Marion creeks on five dates (September 11–October 16). All surveys were upstream of rm 69 because the river morphology downstream made surveys too difficult. Most redds were between Pamelia (rm 69) and Minto (rm 72) creeks (23), and in Marion (18) and Horn (14) creeks, both of which enter the North Santiam between rm 73 and 74. Peak redd counts were in mid-October. No redds were counted between Bugaboo Creek and Parish Lake Road. ODFW District personnel conducted one survey in the Parrish Lake Road area shortly after fish were outplanted and counted 20 redds.

Nine sections of the Breitenbush River were surveyed on four dates (September 6–October 3) from the head of the reservoir (rm 4) to just upstream of the confluence of the North and South forks (rm 14). Of the 92 redds counted, 70 were downstream of the release site. Peak redd counts were in the third week of September.

Table 32. Summary of adult spring Chinook outplanted in 2007. Includes only those basins where spawning surveys were conducted to assess the success of the outplant program.

Section	Adults outplanted	Redds	Adults/redd	Redds/mi
L. North Fork Santiam	195	64	3.0	4.4
Upper North Santiam[a]	514	70	7.3	10.1
Breitenbush	403	94	4.3	7.4
Upper South Santiam	385	211	1.8	26.0

[a] Does not include 50 adults released at Parish Lake Road and 20 redds that were counted on one survey.

Upper South Santiam River above Foster Dam

Unclipped spring Chinook from South Santiam Hatchery were outplanted into the upper South Santiam River at Gordon Road (rm 54) on four dates (September 7–October 3) in 2007. The river was surveyed from Moose Creek (rm 52) to Little Boulder Creek (rm 52) on four dates (September 12–October 11). Of the 211 redds counted (Table 9), 191 were located upstream of the release site within 2.3 mi.

Outplanting success was highest in the South Santiam River, where the percentage of successful spawners was very high, and was lowest in the upper North Santiam (Table 32). Releases in the South Santiam (September 7–October 3) occurred later than releases in the upper North Santiam (August 29–September 25). About half (255) of the fish released at Coopers Ridge Road in the North Santiam were released on August 29, relatively early in the season. Later releases to the South Santiam may account for the greater spawning success of fish.

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APPENDIX A

Schematic of Willamette Spring Chinook Salmon Study Plan

STUDY PLAN OVERVIEW
(see proposal for details)

MANAGEMENT GOAL: A management strategy for spring chinook salmon in the Willamette and Sandy basins that (1) protects the genetic integrity of natural populations, and (2) maintains sport and commercial fisheries and the programs that support them.

To Achieve this Goal, R&D will Help Managers:

OBJ. 1

Determine the numerical status of existing natural populations and develop methods for monitoring that status. Determine if these populations belong to one or more gene conservation groups.

- **1.1.** Determine if Sandy and Clackamas ChS belong to the same gene conservation group as ChS above the falls
- **1.2.** Estimate the proportion of wild fish in spawning populations
- **1.3.** Develop annual indexes for monitoring natural spawner abundance of ChS
- **1.4.** Establish escapement goals for natural production in Willamette subbasins and in the Sandy

OBJ. 2

Decrease mortality of wild fish in fisheries by determining feasibility of catch and release sport fisheries and by exploring options for reducing mortality in commericial fisheries.

- **2.1.** Estimate sport angling mortality of caught and released fish
- **2.2.** Estimate mortality that would occur from finclipping hatchery fish so that anglers could tell hatchery from wild
- **2.3.** Evaluate other mass marking techniques so anglers can identify hatchery adults in sport fisheries
- **2.4.** Explore options with Salmon Program Mgr. and Columbia River Mgt for reducing mortality of wild fish in commericial fisheries

OBJ. 3

Reduce the risk that large hatchery programs pose for natural populations by developing ways of decreasing interactions between wild and hatchery in streams and by determining need for more wild fish in hatchery broodstocks

- **3.1.** Evaluate fishery contribution and straying from netpen releases below the falls
- **3.2.** Determine if hatchery fish released in the fall overwinter, potentially competing with wild ChS
- **3.3.** Explore options for trapping hatchery ChS above or near traditional fisheries but below wild spawning areas
- **3.4.** Determine need and look at ways of incorporating wild fish into hatchery broodstock
- **3.5.** Look at overlap of spawning between fall and ChS

OBJ. 4

Protect existing natural production areas by defining temporal and spatial use patterns by life stages of ChS and identify the habitat/environmental attributes conducive to that use.

- **4.1.** Document distribution of spawning and rearing, timing of emergence and migration in basins used by ChS
- **4.2.** Identify ChS habitat & environmental attributes
- **4.3.** Identify life histories and the habitat/environment critical to maintaining them

OBJ. 5

Increase natural production by improving habitat in existing production areas and by re-establishing populations where they were found historically.

- **5.1.** Identify opportunities to re-establish populations and to improve habitat
- **5.2.** Estimate the potential of Willamette/Sandy (post-dam) to produce wild ChS
- **5.3.** Evaluate current efforts to re-establish ChS (S. Santiam above dams, Thomas, Crabtree, and Calapooia)

APPENDIX B

Distribution of Spawners and Pre-spawning Mortality

Appendix Table B-1. Distribution of spring Chinook redds in five sections of the McKenzie River basin, 2002–2007.

Section	2002	2003	2004	2005	2006	2007
Above Forest Glen	347	379	443	455	260	294
Horse and Lost creeks	145	280	172	427	267	653
South Fork McKenzie	108	85	142	86	86	117
Below Forest Glen	207	272	273	104	96	282
Below Leaburg Dam	115	171	99	75	84	141

Appendix Table B-2. Spawning success of female spring Chinook salmon that were fin-clipped or not fin-clipped in the McKenzie (upstream of Leaburg Dam), North Santiam (upstream of Bennett Dam), and South Santiam rivers, 2001–2007.

	Fin-clipped		Not fin-clipped	
River, year	Spawned	Not spawned	Spawned	Not spawned
McKenzie				
2001	37	5	140	16
2002	100	4	274	17
2003	83	9	182	42
2004	95	14	172	19
2005	23	3	137	27
2006	28	0	146	2
2007	45	1	215	13
North Santiam				
2001	75	206	3	22
2002	72	74	21	20
2003	203	327	6	49
2004	55	154	8	34
2005	65	50	10	13
2006	58	10	30	7
2007	64	39	11	14
South Santiam				
2002	476	158	113	32
2003	404	168	69	12
2004	148	351	10	48
2005	207	90	37	19
2006	144	22	33	3
2007	205	17	29	4

Appendix Table B-3. Spawning success of female spring Chinook salmon upstream and downstream of dams in the McKenzie, North Santiam, Clackamas, and Sandy rivers.

	Upstream of dam		Downstream of dam	
River, year	Spawned	Not spawned	Spawned	Not spawned
McKenzie				
2001	177	21	15	3
2002	374	21	97	19
2003	265	51	22	24
2004	267	33	17	26
2005	160	30	12	5
2006	174	2	19	1
2007	260	14	22	13
North Santiam				
2001	78	228	1	10
2002	93	94	9	33
2003	209	376	1	154
2004	63	188	2	34
2005	75	63	9	26
Clackamas				
2003	75	21	34	92
2005	92	33	32	188
2006	37	2	167	51
2007	69	3	8	15
Sandy				
2003	37	7	5	10
2004	86	10	6	11

APPENDIX C

Migration and Life History of Juveniles

Appendix Table C-1. Detection at Willamette Falls of juvenile spring Chinook salmon that were PIT-tagged in six areas of the Willamette Basin, for two-week release periods in 2007.

River, release period	Tagged	Detected
Willamette below Santiam		
May 16–31	1,906	169
June 1–15	70	11
Santiam		
May 16–31	1,387	133
June 1–15	441	34
North Santiam		
June 1–15	932	90
June 16–30	394	8
July 1–15	79	2
South Santiam		
June 1–15	918	39
June 16–30	948	18
July 1–15	116	0
Willamette above Santiam		
May 16–31	60	2
June 1–15	1,047	48
June 16–30	503	3
July 1–15	103	0
McKenzie		
June 16–30	533	2
July 1–15	553	2
July 16–31	872	3

Appendix Table C-2. Detections in the lower Columbia River trawl sampler of subyearling Chinook PIT-tagged and released in the Willamette Basin upstream of Willamette Falls in late spring and summer 2004–2007. Numbers of fish tagged include only those released with enough time to migrate to the lower Columbia when the trawl was operated. Numbers of recaptured fish were expanded by the estimated trawl detection rate of 3%.

River, year	Tagged	Detected	Expanded
Willamette below Santiam			
2004	342	2	67
2005	547	0	0
2006	548	4	133
2007	1,976	7	233
Santiam			
2004	224	3	100
2005	379	4	133
2006	1,471	9	300
2007	1,828	7	233
South Santiam			
2004	146	0	0
2005	0	0	0
2006	1,723	5	167
2007	1,514	1	33
North Santiam			
2004	0	0	0
2005	0	0	0
2006	1,069	2	67
2007	932	1	33
Willamette above Santiam			
2004	911	5	167
2005	1,941	6	200
2006	1,078	3	100
2007	1,107	2	67

Appendix Table C-3. Percentage of wild adult Chinook with an age 0 life history that were recovered in spawning areas in the Willamette and Sandy basins. Sample size is in parentheses.

Basin	Brood year 1998	1999	2000	2001[a]
McKenzie	28.8 (344)	20.2 (223)	2.1 (192)	13.6 (132)
South Santiam	86.2 (174)	78.4 (139)	16.0 (100)	60.1 (51)
North Santiam	48.2 (56)	44.4 (27)	8.5 (82)	41.7 (36)
Clackamas	26.4 (106)	5.6 (125)	4.2 (188)	34.5 (58)
Sandy	13.7 (73)	11.7 (77)	4.8 (312)	12.8 (156)

[a] *Does not include 6 year old returns.*

Appendix Table C-4. Age composition by return year of wild adult spring Chinook salmon in the Willamette and Sandy basins from analysis of scales. Wild origin of fish was determined by absence of induced thermal marks in otoliths.

River, age	Return year 2001	2002	2003	2004	2005	2006
McKenzie						
3	0	1	1	0	2	2
4	22	154	50	49	26	84
5	116	188	192	167	141	107
6	3	2	7	3	6	3
North Santiam						
3	3	6	0	0	2	0
4	12	27	7	36	19	31
5	10	8	26	13	46	21
6	0	2	2	0	1	0
South Santiam						
3		1	1	1	4	0
4		132	97	44	37	31
5		58	44	38	54	13
6		0	1	0	4	1
Clackamas						
3		0	0	0	0	0
4		39	16	89	21	39
5		26	63	104	97	37
6		1	4	4	3	1
7		0	0	0	0	1
Sandy						
3		0	1	1	0	2
4		34	11	178	38	80
5		38	36	63	126	118
6		2	7	4	3	9

APPENDIX D

Capture of Fish Species in the Willamette Basin by Beach Seine and Traps

Appendix Table D-1. Fish species and numbers captured by beach seine in two sections of the Willamette River, May–July 2007. The middle Willamette extends from the Yamhill River upstream to the Santiam River. The upper Willamette extends from the Santiam River to the confluence of the Middle Fork and Coast Fork Willamette rivers. The number of seine hauls is in parentheses.

Species	Middle Willamette May 16–31 (78)	Middle Willamette June 5 (12)	Upper Willamette May 14–15 (14)	Upper Willamette June 4–21 (128)	Upper Willamette July 2–18 (55)
Chinook salmon (wild)	1,965	71	116	1,570	624
Rainbow trout	3	0	0	133	58
Cutthroat trout	0	0	6	300	165
Trout fry	0	0	0	9	13
Chinook salmon (hatchery smolt)	0	0	0	0	1
Steelhead (wild)	9	0	0	1	0
Steelhead (hatchery)	4	0	0	1	2
Summer steelhead (adult)	3	1	3	5	0
Mountain whitefish	132	1	8	180	118
Northern pikeminnow	70	6	1	36	158
Redside shiner	133	25	5	181	194
Largescale sucker	56	0	0	28	118
Dace	22	10	18	171	91
Sculpin	29	3	15	49	16
Chiselmouth	0	0	0	2	1
Peamouth	25	1	0	3	4
Three spine stickleback	0	0	0	1	0
Banded killifish	91	7	0	0	0
Smallmouth bass	4	0	0	1	0
Largemouth bass	9	0	0	0	0
Bluegill	1	0	0	1	0

Appendix Table D-2. Fish species and numbers captured by beach seine in the McKenzie and Middle Fork Willamette rivers, June and July 2007. The number of seine hauls is in parentheses.

	McKenzie		Middle Fork Willamette
Species	June 19–28 (54)	July 3–26 (99)	June 27 (12)
Chinook salmon (wild)	600	1,647	19
Rainbow trout	88	233	9
Cutthroat trout	71	198	11
Trout fry	1	61	0
Chinook salmon (hatchery smolt)	0	1	0
Steelhead (hatchery)	1	9	0
Chinook salmon (adult)	0	0	2
Summer steelhead (adult)	9	0	1
Mountain whitefish	2	6	0
Northern pikeminnow	0	1	1
Redside shiner	2	6	0
Dace	3	3	1
Sculpin	13	190	1
Peamouth	0	1	0
Three spine stickleback	0	65	0
Bluegill	0	0	1

Appendix Table D-3. Fish species and numbers captured by beach seine in the Santiam River basin, May–July 2007. The number of seine hauls is in parentheses.

Species	Santiam		North Santiam		South Santiam	
	May 23–29 (35)	June 12–13 (31)	June 4–26 (95)	July 5–12 (41)	June 11–26 (96)	July 2–3 (25)
Chinook salmon (wild)	1,439	438	1,403	126	1,956	122
Rainbow trout	14	72	375	133	97	4
Cutthroat trout	6	10	2	4	25	2
Trout fry	0	0	92	52	6	0
Chinook salmon (hatchery smolt)	0	0	1	0	5	0
Steelhead (wild)	9	1	1	0	5	0
Steelhead (hatchery)	0	0	18	0	2	0
Coho salmon (wild)	0	0	0	3	0	0
Chinook salmon (adult)	0	0	1	0	0	0
Summer steelhead (adult)	1	1	6	0	1	0
Mountain whitefish	1	52	87	11	33	0
Northern pikeminnow	109	84	22	36	2	1
Redside shiner	352	547	241	24	94	4
Largescale sucker	127	19	2	0	15	0
Dace	40	184	14	0	76	4
Sculpin	33	26	33	2	77	19
Peamouth	5	0	11	2	4	2
Three spine stickleback	0	0	2	1	0	1
Sand roller	0	0	0	0	1	0
Smallmouth bass	1	0	0	0	0	0
Yellow perch	1	0	0	0	0	2

Appendix Table D-4. Fish species and numbers captured by beach seine in two sections of the Willamette River above Willamette Falls, May–July 2006. The middle Willamette extends from the Yamhill River upstream to the Santiam River. The upper Willamette extends from the Santiam River to the confluence of the Middle Fork and Coast Fork Willamette rivers. The number of seine hauls is in parentheses.

	Middle Willamette	Upper Willamette		
Species	June 13–26 (39)	May 24–31 (43)	June 1–29 (120)	July 5–14 (36)
Chinook salmon (wild)	610	437	1,227	292
Rainbow trout	1	30	87	145
Cutthroat trout	0	95	279	178
Trout fry	0	2	0	0
Steelhead (hatchery)	2	0	7	0
Summer steelhead (adult)	0	6	1	0
Mountain whitefish	236	715	688	251
Northern pikeminnow	93	353	148	61
Redside shiner	369	588	784	158
Largescale sucker	182	202	229	3
Dace	21	37	190	56
Sculpin	6	3	31	2
Chiselmouth	1	5	20	0
Peamouth	87	2	1	0
Sand roller	0	2	3	0
Banded killifish	539	0	0	0
Smallmouth bass	5	1	0	0
Largemouth bass	1	0	0	0
Bluegill	0	1	0	0
Carp	0	1	0	0

Appendix Table D-5. Fish species and numbers caught by beach seine in the McKenzie and Santiam rivers, June and July 2006. The number of seine hauls is in parentheses.

	McKenzie		Santiam	
Species	June 6–22 (59)	July 5–21 (135)	May 25–26 (18)	June 7–27 (76)
Chinook salmon (wild)	502	1,267	892	676
Rainbow trout	42	399	36	61
Cutthroat trout	71	175	9	19
Trout fry	0	5	0	1
Chinook salmon (hatchery)	0	25	2	0
Steelhead (wild)	0	0	2	0
Steelhead (hatchery)	0	0	0	1
Coho salmon (wild)	0	0	2	4
Summer steelhead (adult)	0	0	4	2
Mountain whitefish	1	7	5	221
Northern pikeminnow	6	10	0	56
Redside shiner	31	183	4	217
Largescale sucker	1	0	6	154
Dace	7	11	31	140
Sculpin	6	19	22	33
Peamouth	0	2	0	8
Three spine stickleback	1	1	0	1

Appendix Table D-6. Fish species and numbers caught by beach seine in the North and South Santiam rivers, May–July 2006. The number of seine hauls is in parentheses.

	North Santiam		South Santiam		
Species	June 8–23 (88)	July 11–12 (57)	May 30–31 (21)	June 1–28 (110)	July 13 (29)
Chinook salmon (wild)	1,438	379	809	1,753	107
Rainbow trout	343	477	42	144	64
Cutthroat trout	5	9	7	70	45
Trout fry	9	180	0	4	2
Steelhead (wild)	0	0	1	1	0
Steelhead (hatchery)	0	0	0	1	0
Coho salmon (wild)	2	0	0	0	0
Summer steelhead (adult)	0	0	4	2	0
Mountain whitefish	10	13	17	53	0
Northern pikeminnow	26	2	14	14	0
Redside shiner	101	40	417	170	1
Largescale sucker	3	3	5	2	0
Dace	17	2	10	20	2
Sculpin	12	7	16	40	7
Peamouth	0	0	19	3	0
Three spine stickleback	12	0	0	0	0

Appendix table D-7. Catch of fish and amphibians in the Kenagy floodplain two-way trap, 8 November 2006 to 28 March 2007. Additional catches of non-salmonids occurred until ditch was dry in mid-June but were not counted.

Species	In-migrants	Out-migrants
Chinook salmon	0	2
Northern pikeminnow	2	3
Red side shiner	38	14
Largescale scale sucker	10	6
Dace	1	5
Sculpin	1	21
Bluegill	5	2
Black crappie	2	0
Warmouth	1	0
Yellow perch	0	34
Black bullhead	0	1
Red-legged frog	1	2

Appendix table D-8. Catch of fish and amphibians in the Kenagy floodplain two-way trap, 1 December 2005 to 8 June 2006.

Species	In-migrants	Out-migrants
Chinook salmon	2	2
Cutthroat trout	1	0
Northern pikeminnow	18	60
Red side shiner	37	367
Largescale scale sucker	15	21
Chiselmouth	5	0
Stickleback	3	3
Bluegill	9	32
Black crappie	3	41
Warmouth	0	1
Black bullhead	0	2
Largemouth bass	2	0
Mosquitofish	1	0
Goldfish	0	1
Red-legged frog	3	22
Unknown species pollywog	0	1

Appendix Table D-9. Catch of fish and amphibians in the Kenagy floodplain two-way trap, 8 December 2004 to 13 May 2005.

Species	In-migrants	Out-migrants
Northern pikeminnow	8	1
Red-side shiner	50	4
Largescale scale sucker	3	2
Sculpin	2	5
Chiselmouth	2	1
Peamouth	0	1
Bluegill	2	1
Black crappie	1	1
Yellow perch	1	3
Black bullhead	0	1
Red-legged frog	4	0

Appendix Table D-10. Catch of fish in the Kenagy floodplain one-way traps, 16 March to 18 May 2004.

Species	Upper site	Lower site
Chinook salmon[a]	56	7
Northern pikeminnow	8	11
Red-side shiner	52	88
Largescale scale sucker	5	16
Dace	0	3
Sculpin	0	4
Stickleback	57	14
Lamprey	0	1
Bluegill	35	2
Black crappie	1	0
Largemouth bass	1	0
Mosquitofish	2	5

[a] *An additional 86 juvenile non-migrant Chinook were captured in the floodplain channel or floodplain ponds by seine, dipnet, and electrofisher; other species captured during this sampling were not enumerated.*