Interim Activities for Monitoring Impacts Associated with Hatchery Programs in the Willamette Basin, USACE funding: 2007

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Task Order: NWPOD-07-FH-02

January 2008

Introduction

The National Marine Fisheries Service (NMFS) has listed spring Chinook salmon (*Oncorhynchus tshawytscha*) in the Upper Willamette River Evolutionarily Significant Unit (ESU) as threatened under the Endangered Species Act (ESA; 64 FRN 14308; 64 FRN 14517). Associated with this listing, any actions taken or funded by a federal agency must be evaluated to assess whether these actions are likely to jeopardize the continued existence of threatened and endangered species, or result in the destruction or impairment of critical habitat. Several fish hatcheries operate within the ESU and may impact wild populations of listed species. Although all of the artificial propagation programs that potentially affect listed salmonids in the Upper Willamette River ESUs are operated by the Oregon Department of Fish and Wildlife (ODFW), 90% of the funding for these operations comes from the U.S. Army Corps of Engineers (COE or the Corps).

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). The objective of this project is to evaluate the potential effects of hatchery programs on naturally spawning populations of spring Chinook within the Upper Willamette River ESU. The project employs three types of activities to achieve this goal: sampling of returns to hatcheries, monitoring of adult migration through the use video observations, and monitoring natural production through spawning ground surveys.

ODFW submits this report in fulfillment of Task Order NWPOD-07-FH-02. This report covers activities of the June 2007–May 2008 period that were implemented by ODFW on behalf of the Corps to assist with meeting the requirements of the reasonable and prudent alternatives and measures prescribed in the Biological Opinion of July 2000 that has since expired. The Corps has been in consultation with NMFS on operation of the hatchery program and will continue to monitor associated impacts until a new Biological Opinion is issued. The primary tasks covered in the reporting period were to continue monitoring activities initiated under the expired Biological Opinion as detailed below:

<u>Task 1.2</u> Monitor straying of hatchery fish on natural spawning grounds in the North Santiam, South Santiam, McKenzie, and Middle Fork Willamette Rivers to determine the distribution, abundance and proportion of hatchery and natural-origin fish spawning: conduct spawning ground surveys; estimate pre-spawning mortality; estimate the percentage of hatchery-origin spawners using otolith analysis; monitor fin-clipped and unclipped fish passing Leaburg Dam.

<u>Task 2.1</u> Monitor fin-clipped and unclipped fish entering hatcheries and collection facilities (i.e., record number, origin, length, weight, date of return); determine origin using otolith analysis; collect tissue samples for genetic analysis.

Approach

Spring Chinook Passage

The fish ladder at Leaburg Dam has a viewing station with a video camera in place. The species and mark status of all fish that passed the ladders were recorded.

Spawning Ground Surveys

Foot and boat surveys were conducted to make visual counts of spawners, redds, and to collect biological information including origin of spawners using fin clips and analysis of otoliths; and to evaluate pre-spawning mortality.

Hatchery Broodstocks

Hatcheries conventionally include some naturally produced spring Chinook in their broodstock, however, naturally produced fish in the broodstock should constitute no more than 10% of wild fish that spawn naturally. Data were collected on all spring Chinook spawned at hatcheries in the upper Willamette to determine their origin.

Spring Chinook Passage

Leaburg Dam, McKenzie River

Passage of spring Chinook through the fishways at Leaburg Dam was monitored by video. Results are presented in Table 1. Roughly 17% of the Chinook passing Leaburg Dam consisted of fin-clipped hatchery fish, which is similar to 2005 (17%), but lower than 2003 (38%), 2004 (47%), and 2006 (30%).

Table 1. Spring Chinook counted at Leaburg Dam, McKenzie River, 2007.

Month	Unclipped Adults	Fin-clipped Adults	Unclipped Jacks	Fin-clipped Jacks	Total
Apr	30	1	0	0	31
May	1,209	67	0	0	1,276
June	963	166	0	0	1,129
Jul	427	98	1	0	526
Aug	54	33	1	0	88
Sep	67	189	0	1	257
Oct	7	4	0	0	11
Season	**2,757**	**558**	**2**	**1**	**3,318**

Chinook began appearing at Leaburg Dam in April of 2007, with peak passage of unclipped fish occurring in late-May and a smaller peak in mid-June (Figure 1). Peak timing of fin-clipped fish past Leaburg Dam was similar to unclipped fish, although less pronounced. However, in addition to the late-May and mid-June peaks, a third peak occurred in mid-September and the greatest numbers of fin-clipped Chinook were observed at Leaburg Dam in September.

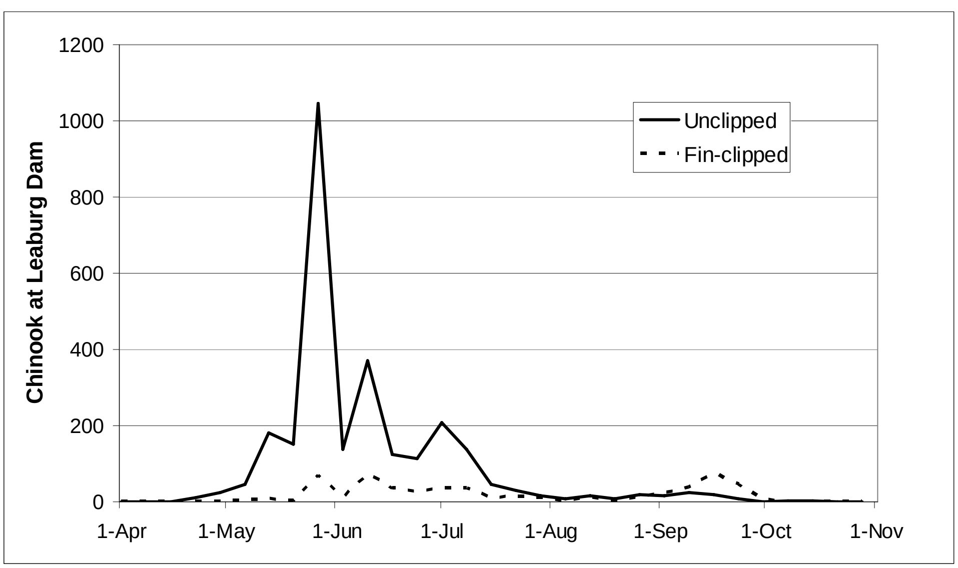

Figure 1. Chinook run-timing at Leaburg Dam, 2007.

Chinook Spawning Surveys

We surveyed most of the major tributaries in the Willamette Basin upstream of Willamette Falls in 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 determine the proportion of hatchery fish on spawning grounds. Otoliths were also collected from carcasses without fin clips to sort out unclipped hatchery fish from those produced naturally (*see* **Otolith Sampling** below). 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. We collected the snouts of fish that had a tag, which were then put into plastic bags along with a unique identification number.

Spawning Ground Surveys

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 2), and was higher than the 2004–2006 average (17.7 redds/mi), but was lower than in 2003 (55.5 redds/mi). Of the carcasses we recovered in the North Santiam in 2007, 71% had fin clips (Table 3), similar to the 2004–2006 average (75%).

Table 2. Summary of spawning surveys for spring Chinook salmon in the North Santiam River, 2007, and comparison to redd densities in 1996–2006. Spawning in areas downstream of Stayton may include some fall Chinook.

Survey section	Length (mi)	Counts		Redds/mi											
		Carcass	Redd	2007	2006	2005	2004	2003	2002	2001	2000	1999	1998	1997	1996
Minto–Fishermen's Bend	10.0	130	323	32.3	14.8	20.6	17.7	55.5	16.2	17.9	23.0	15.6	11.8	8.5	7.8
Fishermen's Bend–Mehama	6.5	34	72	11.1	4.9	3.1	2.8	6.5	9.4	5.7	5.8	3.1	4.3	2.5	3.5
Mehama–Stayton Is.	7.0	7	15	2.1	3.1	2.0	12.6	4.7	6.1	10.0	**a**	--	0.6	0.9	1.0
Stayton Is.–Stayton	3.3	0	20	6.1	3.9	7.3	7.9	3.6	3.0	6.7	**a**	--	10.0	3.6	2.0
Stayton–Greens Bridge	13.7	2	--	--	0.4	0.3	0.2	0.1	0.4	0.1	--	0.0	0.4	1.1	0.1
Greens Br.–mouth	3.0	--	--	--	--	0.0	0.0	1.7	4.7	--	--	--	4.7	9.7	--
Little North Santiam	14.4[b]	14	64	4.4[c]	2.0[d]	3.6[e]	3.0[f]	1.8[g]	1.8[h]	1.1	1.3	1.0	2.2	0.6	0.0

[a] *Data was recorded for Mehama–Stayton and density was 0.9 redds/mi.*
[b] *17.0 miles were surveyed in 1996–2006.*
[c] *195 unclipped adult spring Chinook were released in August (16th, 22nd, 29th) and September (17th, 18th, 24th, 27th).*
[d] *130 unclipped adult spring Chinook were released on June 21 and July (7th, 26th).*
[e] *329 unclipped adult spring Chinook were released on July 27, August 30, and September (2nd, 6th, 9th, 12th).*
[f] *377 unclipped adult spring Chinook were released on July 9, August (19th, 27th), and September (9th).*
[g] *268 unclipped adult spring Chinook were released in June (25th), July (9th,15th,22nd), August (25th), and September (2nd, 4th).*
[h] *400 unclipped adult spring Chinook were released in August (20th, 30th), and September (5th, 6th).*

Table 3. Composition of naturally spawning spring Chinook salmon from carcasses recovered in the North Santiam River upstream of Stayton Island, 2007.

Section	Unclipped	Fin-clipped
Minto–Fishermen's Bend	27	103
Fishermen's Bend–Mehama	10	24
Mehama–Stayton Island	3	4
Little North Fork Santiam	14	0
Total	54	131

The McKenzie River was regularly surveyed July 31–October 23 to recover carcasses and count redds. Active redd building began in early September, with the first redd observed on September 4th, 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 of 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 2). The percentage of redds counted in the main stem upstream of Forest Glen decreased in 2007 (20%) compared to 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 4).

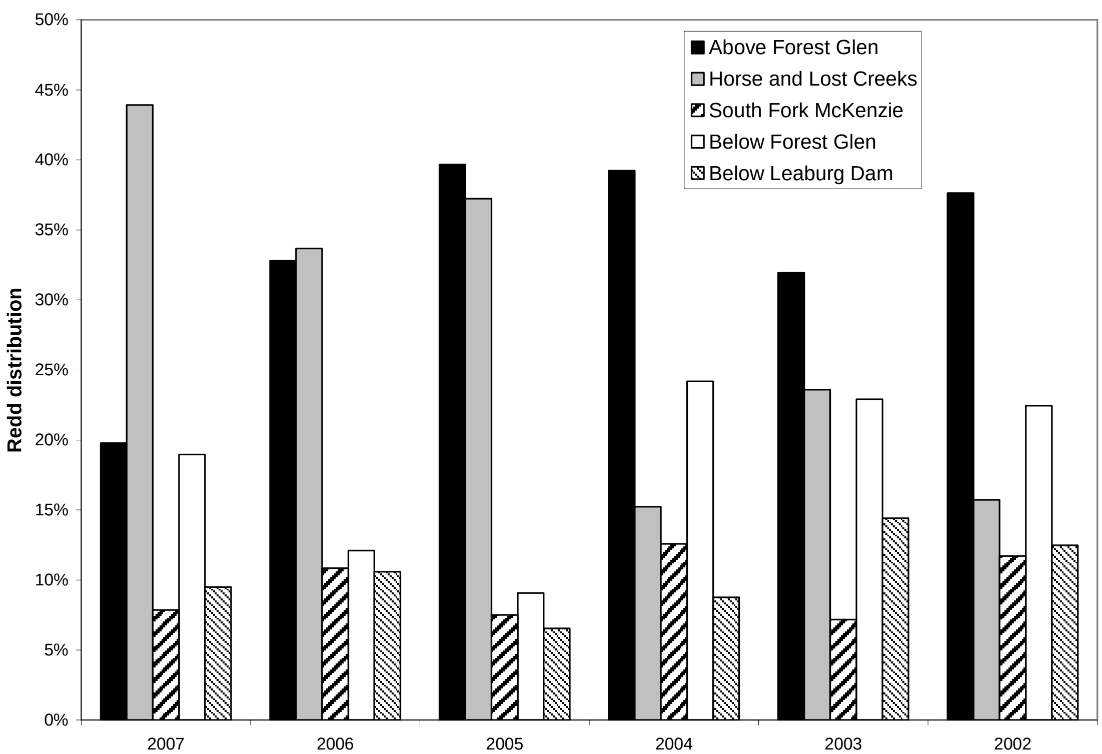

Figure 2. Distribution of spring Chinook salmon redds in the McKenzie River basin, 2002–2007.

Table 4. Summary of Chinook salmon spawning surveys in the McKenzie River, 2007, and comparison to redd densities (redds/mi, except redds/100 ft for spawning channel) in 1996–1998 and 2000–2006.

				Redds/mi[a]										
Survey section	Length (mi)	Carcass	Redds	2007	2006	2005	2004	2003	2002	2001	2000	1998	1997	1996
McKenzie River:														
Spawning channel	0.1	33	36	6.8	13.8	12.8	18.6	7.2	15.4	--	--	--	1.0	2.6
Olallie–McKenzie Trail	10.3	52	107	10.4	14.1	31.1	22.1	24.7	16.3	17.7	5.6	--	11.4	7.0
McKenzie Trail–Hamlin	9.9	31	59	6.0	1.8	4.2	9.4	4.0	5.2	4.9	1.6	--	--	2.1
Hamlin–S. Fork McKenzie	0.3	7	28	93.3	6.6	--	--	10.0	36.7	--	--	--	--	--
South Fork–Forest Glen	2.4	23	64	26.7	10.8	12.1	12.1	19.2	16.7	0.8	2.1	--	--	0.8
Forest Glen–Rosboro Br.	5.7	58	174	30.5	6.7	3.7	36.1	26.8	14.9	13.2	5.8	--	--	6.1
Rosboro Br.–Ben and Kay	6.5	30	108	16.6	8.9	12.5	10.3	7.4	16.2	6.3	3.2	--	--	4.9
Ben and Kay–Leaburg Lake	5.9	--	--	--	--	0.3	--	12.0	2.9	3.2	--	--	--	1.8
South Fork McKenzie:														
Cougar Dam–Road 19 Br.	2.3	19	38	16.5	23.9	22.2	49.1	31.7	36.5	--	--	--	--	--
Road 19 bridge–mouth	2.1	48	79	37.6	14.8	16.7	13.8	5.7	11.4	8.1	7.6	--	--	2.9
Horse Creek:														
Pothole Cr.–Separation Cr.	2.8	25	63	22.5	9.3	5.4	5.4	18.6	--	--	--	--	--	--
Separation Cr.–mouth	10.7	78	356	33.3	16.1	19.2	10.3	13.6	12.1	7.4	--	--	--	5.3
Lost Creek:														
Spring–Limberlost	2.8	11	100	35.7	3.2	15.4	6.4	9.3	--	--	--	--	--	--
Limberlost–Hwy 126[b]	2.0	11	134	53.6	30.0	78.5	13.5	21.0	--	--	--	--	--	--
Hwy 126–mouth[b]	0.5	--	--	--	0.0	14.0	4.0	30.0	32.0	--	--	--	--	--
McKenzie River:														
Leaburg Dam–Leaburg Landing[c]	6.0	52	141	23.5	12.0	12.5	16.5	28.5	19.2	12.3	--	15.3	19.8	10.3

[a] *Except redds/100 ft for spawning channel.*
[b] *Limberlost–Hwy 126 and Hwy 126–mouth sections were combined in 2007.*
[c] *Additional caracases 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 5) 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 5. 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

Other rivers that were regularly surveyed in 2007 (Table 6) 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.

With the exception of the South Santiam upstream of Lebanon, the estimated pre-spawning mortality of spring Chinook salmon in the Willamette basin was higher in 2007 than in 2006 (Table 7), but generally was lower than in 2002–2005. Pre-spawning mortality was particularly low in 2006 compared to other years. 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.

Table 6. Summary of Chinook salmon spawning surveys in the Middle Fork Willamette and South Santiam basins, 2007, and comparison to redd densities in 1998, and 2002–2006.

River, section	Length (mi)	Carcasses	Redds	Redds/mi 2007	2006	2005	2004	2003	2002	1998
Middle Fork Willamette										
Dexter–Jasper	9.0	32	9	1.0	12.3	1.0	1.0	1.5	7.1	1.1
Fall Creek (above reservoir)	16.3	3[a]	28	1.7	13.3	8.1	12.9	6.1	12.9	--
South Santiam										
Foster–Pleasant Valley	4.5	343	418	92.9	102.9	112.7	75.1	132.0	194.4	36.0
Pleasant Valley–Waterloo	10.5	35	65	6.2	4.4	2.2	3.3	1.5	1.8	1.8
Lebanon–mouth	20.0	--	--	--	1.0	--	0.2	1.0	3.4	2.9

[a] *Clipped carcasses were not counted in 2007.*

Table 7. Estimates of the percent pre-spawning mortality of Chinook salmon in the Willamette Basin, based on recovery of female carcasses, 2001–2007. **Only for areas and years with ≥ 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 peak 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 (July 10)
McKenzie above Leaburg	11 (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)
N Santiam above Bennett	75 (Aug 14)	50 (Aug 1)	64 (Jun 27)	75 (Jun 17)	46 (Jul 13)	16 (Jul 27)	41 (Jul 3)
N 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)		
S Santiam above Lebanon		25 (Aug 6)	28 (Jul 14)	71 (Jul 20)	31 (Jul 18)	12 (Jul 26)	8 (Jul 16)

Although estimated pre-spawning mortality was higher for unclipped fish than for clipped fish in the upper McKenzie, North and South Santiam rivers in 2007 (Table 8), the difference between these two groups over several years (Figure 3a) was not significant ($P > 0.05$). However, the estimated pre-spawning mortality was significantly higher ($P < 0.05$) downstream of dams than upstream in the McKenzie and North Santiam rivers (Figure 3b).

Table 8. Pre-spawning mortality (percentage in parentheses) of fin-clipped and unclipped spring Chinook carcasses based on recovery of female carcasses recovered, 2007.

	Not spawned		Spawned	
River	clipped	not clipped	clipped	not clipped
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

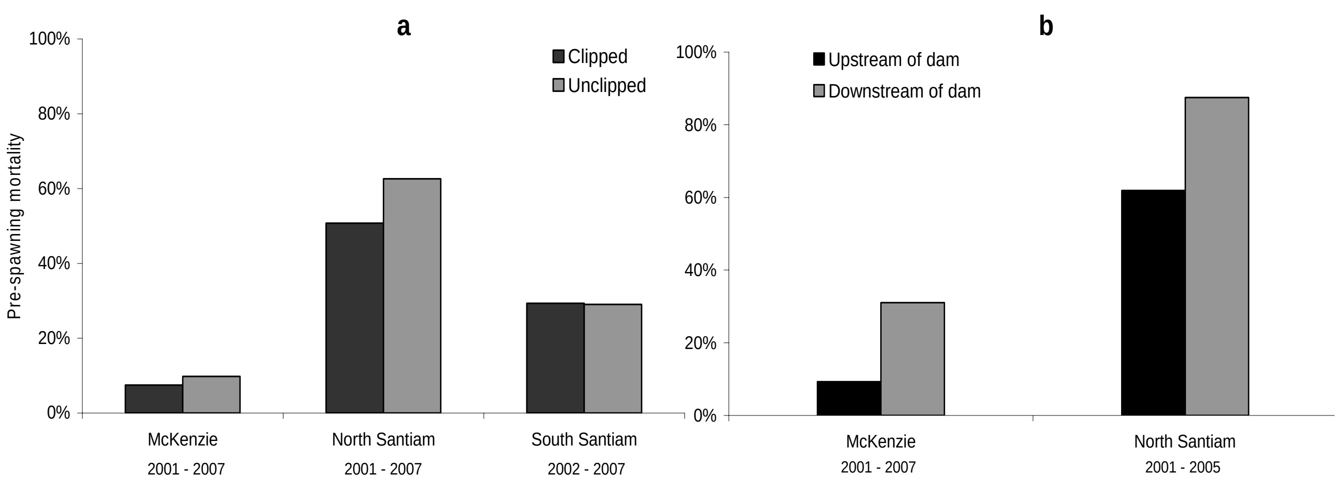

Figure 3. Average pre-spawning mortality based on recoveries of female carcasses for **(a)** clipped and unclipped adult Chinook salmon in the McKenzie, North and South Santiam rivers, and **(b)** upstream and downstream of dams in the McKenzie and North Santiam rivers.

Efforts to Re-Establish Populations

In an effort to increase natural production, 193 unclipped adult spring Chinook collected at Minto Pond were outplanted into the Little North Fork Santiam River on seven dates (August 16–September 27). 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 9) 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 or outplanted from Minto.

Surplus fin-clipped Chinook collected at Minto Pond were outplanted into the North Santiam and Breitenbush rivers upstream of Detroit Dam (Table 9; *also* Table 19). Fish were released on six dates (August 22–September 24) into the Breitenbush River at Cleator Bend (rm 12), and into the 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 (Table 9), 70 were downstream of the release site. Peak redd counts were in the third week of September.

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). 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 9). Releases in the South Santiam occurred later than releases in the upper North Santiam. 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 outplanted there.

Table 9. 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
LNFk Santiam	193	64	3.0	4.6
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, or 20 redds counted in one survey.

Otolith Sampling

Restoration of spring Chinook salmon 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. In response to this need and to implement a selective fishery, all hatchery spring Chinook salmon in the Willamette basin, beginning with the 1997 brood, were marked with adipose fin clips. Although the intention is to externally mark all juvenile hatchery fish, some are missed during marking. To help separate returning hatchery fish without fin clips from wild fish, otoliths have been thermally marked on all hatchery spring Chinook released into the Willamette basin beginning with the 1997 brood year.

Methods

We collected otoliths from adult spring Chinook without fin clips on spawning grounds and at hatcheries in most of the major tributaries in the Willamette Basin in 2006 and 2007. Otoliths were removed from carcasses without fin clips 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 10). Wild fish were determined by absence of a fin clip and absence of an induced thermal mark in the otoliths. We previously documented a significant difference between the distribution of redds and the distribution of carcasses recovered among survey areas within some watersheds (Firman et al. 2005). Therefore, we used the distribution of redds among survey areas to weight the number of unclipped carcasses in each area. We then used results of otolith analysis to estimate the number of wild fish that would have spawned within a survey area. We reasoned that variability in counting redds among survey areas was less than that in finding and recovering carcasses because spring Chinook redds are in relatively shallow water and their visibility is less dependent on stream characteristics such as stream size or survey method (boat versus foot) than that of recovering carcasses.

Table 10. 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	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	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

The percentage of wild spring Chinook in 2006 and 2007 was highest in the McKenzie River and much lower in the other basins, similar to that in other years (Table 11). The percentage of carcasses that were wild increased in all basins in 2005–2007 over that in previous years. Data for the Middle Fork Willamette were not available in 2006 and did not include Fall Creek in 2007 because numbers on clipped carcasses were incomplete or not collected. The percentage of unclipped fish that were of hatchery origin was lowest in the McKenzie River in 2006–2007 ($\leq$ 2%), and generally was lower than in previous years in all basins.

Table 11. Composition of spring Chinook salmon in the Willamette Basin based on carcasses recovered. Weighted for distribution of redds among survey areas within a watershed (except Middle Fork Willamette).

River (section), run year	Fin-clipped	Unclipped[a]		Percent wild[b]
		Hatchery	Wild	
McKenzie (upstream of Leaburg Dam)				
2001	62	53 (17)	263	70 (69)
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])				
2001	385	43 (43)	56	12 (6)
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 Fk 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)

[a] *The proportion of hatchery and wild fish was determined by presence or absence of thermal marks in otoliths. 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.*

As in previous years, the highest estimated number of wild fish in 2006 and 2007 occurred in the McKenzie River (Table 12). 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 (> 80%) was the McKenzie (Table 12). Analysis of fin-clipped to unclipped fish in the McKenzie River suggested that the proportion 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 12).

Table 12. Estimated number of wild and hatchery adult spring Chinook salmon in the McKenzie and North Santiam rivers upstream of dams. Estimated from counts at the dams and from presence of induced thermal marks in otoliths of non fin-clipped carcasses recovered on spawning grounds. Numbers at dams were from video counts (McKenzie), and expanded trap counts (North Santiam, from 4 d/wk counts). **Traps on the North Santiam were not operated in 2006 and 2007**.

Run year	Dam count		Unclipped with thermal marks (%)[b]	Estimated number		
	Unclipped	Fin-clipped[a]		Wild	Hatchery[a]	Percent wild[a]
			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			
2000[b]	1,045	1,241	90.7[c]	97	2,189	4
2001	388	6,398	43.4	220	6,566	3
2002	1,233	6,407	51.0[d]	604	7,036	8
2003	1,262	11,570	78.5[d]	271	12,561	2
2004	1,510	12,021	67.6[d]	489	13,042	4
2005	924	3,958	27.8[d]	667	4,215	14

[a] *The dam counts 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] *Escapement at Bennett dams was likely underestimated (*see *Schroeder et al. 2001).*
[d] *Weighted average of adjusted spawning ground samples and samples from Minto Pond.*

Hatchery Broodstocks

Disposition

Information about the disposition of adult spring Chinook was compiled from the upper Willamette Basin hatcheries for 2005–2007 (Tables 13–15). The total number of Chinook may include fish handled more than once because of factors such as recycling. Willamette Hatchery data include fish collected the Dexter facility and taken to the hatchery for spawning and fish directly outplanted. The tables below include those fish under Willamette Hatchery. Some Chinook have been collected at Leaburg Dam and either held at McKenzie Hatchery for broodstock (unclipped fish), or outplanted (fin-clipped fish), and these are noted in the tables. Surplus hatchery fish (fin-clipped) were outplanted into historic habitats, and unclipped fish were outplanted into accessible habitats, primarily from Minto Pond into the Little North Fork Santiam (Tables 16–18).

Table 13. Disposition of fin-clipped and unclipped spring Chinook entering hatcheries and collection facilities, 2005. Unspawned includes mortalities, green fish, excess fish (including those killed to recovery coded wire tags), and females culled for BKD.

Hatchery	Disposition	Clipped Adults	Unclipped Adults	Total Adults	Clipped Jacks	Unclipped Jacks	Total Chinook	% Unclipped
Marion Forks	Spawned	470	34	504	0	0	504	6.75
	Outplanted	615	343	958	15	0	973	35.25
	Recycled	104	0	104	4	0	108	0.00
	Unspawned	219	8	227	0	0	227	3.52
	Total	***1,408***	***385***	***1,793***	***19***	***0***	***1,812***	***21.25***
S. Santiam	Spawned	909	90	999	71	0	1,070	8.41
	Outplanted	571	867	1,438	0	0	1,438	60.29
	Recycled	1,078	0	1,078	41	0	1,119	0.00
	Unspawned	339	18	357	8	0	365	4.93
	Food Share	7	1	8	0	0	8	12.50
	Total	***2,904***	***976***	***3,880***	***120***	***0***	***4,000***	***24.40***
Willamette	Spawned[a]	1,492	43	1,535	0	0	1,535	2.80
	Outplanted	2,023	5	2,028	227	0	2,255	0.22
	Unspawned[a]	1,067	31	1,098	0	0	1,098	2.80
	Food Share	1,217	0	1,217	243	0	1,460	0.00
	Total	***5,799***	***79***	***5,878***	***470***	***0***	***6,348***	***1.24***
McKenzie	Spawned	1,022	60	1,082	0	0	1,082	5.55
	Outplanted	998	0	998[b]	14	0	1,012	0.00
	Unspawned	408	6	414	23	0	437	1.37
	Food Share	86	0	86	3	0	89	0.00
	Tribes	666	0	666	3	0	669	0.00
	Total	***3,180***	***66***	***3,246***	***43***	***0***	***3,289***	***2.01***

[a] *Spawned fish that were not clipped based on the number of otoliths collected (including fish with partial fin clips); Unspawned fish that were not clipped was from the percentage of unclipped fish in the spawned group.*
[b] *Includes 33 fin-clipped fish trapped at Leaburg Dam and released into Mohawk River.*

Table 14. Disposition of fin-clipped and unclipped spring Chinook entering hatcheries and collection facilities, 2006. Unspawned includes mortalities, green fish, excess fish (including those killed to recovery coded wire tags), and females culled for BKD.

Hatchery	Disposition	Clipped Adults	Unclipped Adults	Total Adults	Clipped Jacks	Unclipped Jacks	Total Chinook	% Unclipped
Marion Forks	Spawned	335	209	544	0	0	544	38.42
	Outplanted	2,458	273	2,731	0	0	2,731	10.00
	Recycled	54	0	54	0	0	54	0.00
	Unspawned	241	1	242	0	0	242	0.04
	Tribes	65	0	65	0	0	65	0.00
	Total	***3,153***	***483***	***3,636***	***0***	***0***	***3,636***	***13.28***
S. Santiam	Spawned	957	183	1,140	0	0	1,140	16.05
	Outplanted	1,293	75	1,368	0	0	1,368	5.48
	Recycled	1,626	0	1,626	0	0	1,626	0.00
	Unspawned	79	6	85	12	0	97	6.19
	Food Share	8	3	11	0	0	11	27.27
	Total	***3,963***	***267***	***4,230***	***12***	***0***	***4,242***	**6.29**
Willamette	Spawned[a]	1,608	100	1,708	0	0	1,708	5.85
	Outplanted	2,085	1	2,086	10	0	2,096	0.05
	Unspawned[a]	604	31	635	1	0	636	4.87
	Food Share	773	0	773	15	0	788	0.00
	Tribes	391	0	391	10	0	401	0.00
	Total	***5,461***	***132***	***5,593***	***36***	***0***	***5,629***	**2.34**
McKenzie	Spawned	845	146[b]	991	0	0	991	14.73
	Outplanted	1,387	0	1,387	12	0	1,399	0.00
	Unspawned	135	31[b]	166	1	0	167	18.56
	Food Share	188	0	188	4	0	192	0.00
	Tribes	368	0	368	1	0	369	0.00
	Total	***2,923***	***177***	***3,100***	***18***	***0***	***3,118***	***5.68***

[a] *Spawned fish that were not clipped based on the number of otoliths collected (including fish with partial fin clips); Unspawned fish that were not clipped was from the percentage of unclipped fish in the spawned group.*

[b] *Includes 92 unclipped fish trapped at Leaburg Dam and brought to hatchery.*

Table 15. Disposition of fin-clipped and unclipped spring Chinook entering hatcheries and collection facilities, 2007. Unspawned includes mortalities, green fish, excess fish (including those killed to recovery coded wire tags), and females culled for BKD.

Hatchery	Disposition	Clipped Adults	Unclipped Adults	Total Adults	Clipped Jacks	Unclipped Jacks	Total Chinook	% Unclipped
Marion Forks	Spawned	375	175	550	5	0	555	31.53
	Outplanted	967	193	1,160	27	2	1,189	16.40
	Recycled	32	0	32	0	0	32	0.00
	Unspawned	205	0	205	8	0	213	0.00
	Total	***1,579***	***368***	***1,947***	***40***	***2***	***1,989***	***18.50***
S. Santiam	Spawned	783	102	885	13	0	898	11.36
	Outplanted	385	18	403	0	0	403	4.47
	Recycled	43	3	46	26	0	72	4.17
	Unspawned	75	8	83	0	0	83	9.64
	Total	***1,286***	***131***	***1,417***	***39***	***0***	***1,456***	***9.00***
Willamette	Spawned[a]	1364	228	1,592	0	0	1,592	14.32
	Outplanted	831	1	832	14	0	846	0.12
	Unspawned[a]	673	103	776	0	0	776	13.27
	Food Share	493	0	493	13	0	506	0.00
	Total	***3,361***	***332***	***3,693***	***27***	***0***	***3,720***	***8.92***
McKenzie	Spawned	891	129 [b]	1,020	0	0	1,020	12.65
	Outplanted	1,054	17	1,071	12	0	1,083	1.57
	Unspawned	258	15 [b]	273	0	2	275	5.45
	Food Share	152	0	152	0	0	152	0.00
	Total	***2,355***	***161***	***2,516***	***12***	***2***	***2,530***	***6.36***

[a] *Spawned fish that were not clipped based on the number of otoliths collected (including fish with partial fin clips); Unspawned fish that were not clipped was from the percentage of unclipped fish in the spawned group.*

[b] *Includes 139 unclipped fish trapped at Leaburg Dam and brought to hatchery.*

Table 16. Outplants of spring Chinook captured in hatcheries and collection facilities, 2005.

Hatchery	Release Location	Clipped Adult	Unclipped Adult	Clipped Jack	Unclipped Jack	Total Chinook	% Unclipped
Marion Forks	N. Santiam above Detroit	513	0	15	0	528	0.00
	Breitenbush River	86	0	0	0	86	0.00
	Above Minto Dam	16	14	0	0	30	46.67
	Little N. Fork Santiam	0	329	0	0	329	100.00
	Total	***615***	***343***	***15***	***0***	***973***	***35.25***
S. Santiam	S. Santiam above Foster	936	0	0	0	936	0.00
	Wiley Creek	166	0	0	0	166	0.00
	Thomas Creek	193	0	0	0	193	0.00
	Crabtree Creek	143	0	0	0	143	0.00
	Total	***1,438***	***0***	***0***	***0***	***1,438***	**0.00**
Willamette	Salt Creek	405	0	0	0	405	0.00
	N Fk Mid Fk Willamette	798	0	0	0	798	0.00
	Mid Fk Willamette	1,052	0	0	0	1,052	0.00
	Total	***2,255***	***0***	***0***	***0***	***2,255***	**0.00**
McKenzie	S Fk McKenzie above Cougar	849	0	14	0	863	0.00
	Above Trail Bridge Reservoir	116	0	0	0	116	0.00
	Mohawk R	33	0	0	0	33	0.00
	Total	***998***	***0***	***14***	***0***	***1,012***	**0.00**

Table 17. Outplants of spring Chinook captured in hatcheries and collection facilities, 2006.

Hatchery	Release Location	Clipped Adult	Unclipped Adult	Clipped Jack	Unclipped Jack	Total Chinook	% Unclipped
Marion Forks	N. Santiam above Detroit	1,123	0	0	0	1,123	0.00
	Breitenbush River	720	0	0	0	720	0.00
	Above Minto Dam	615	143	0	0	758	18.87
	Little N. Fork Santiam	0	130	0	0	130	100.00
	Total	***2,458***	***273***	***0***	***0***	***2,731***	***10.00***
S. Santiam	S. Santiam above Foster	857	75	0	0	932	8.05
	Thomas Cr	256	0	0	0	256	0.00
	Crabtree Cr	180	0	0	0	180	0.00
	Total	***1,293***	***75***	***0***	***0***	***1,368***	***5.48***
Willamette	Salt Creek	381	0	0	0	381	0.00
	N Fk Mid Fk Willamette	821	0	6	0	827	0.00
	Mid Fk Willamette	691	0	3	0	694	0.00
	Above Hills Cr Reservoir	75	0	0	0	75	0.00
	Mosby Creek	117	1	1	0	119	0.84
	Total	***2,085***	***1***	***10***	***0***	***2,096***	**0.05**
McKenzie	S Fk McKenzie above Cougar	1,008	0	10	0	1,018	0.00
	Above Trail Bridge Reservoir	114	0	2	0	116	0.00
	Mohawk R	265	0	0	0	265	0.00
	Total	***1,507***	***0***	***14***	***0***	***1,521***	***0.00***

Table 18. Outplants of spring Chinook captured in hatcheries and collection facilities, 2007.

Hatchery	Release Location	Clipped Adult	Unclipped Adult	Clipped Jack	Unclipped Jack	Total Chinook	% Unclipped
Marion Forks	N. Santiam above Detroit	564	0	10	0	574	0.00
	Breitenbush River	403	0	17	0	420	0.00
	Little N. Fork Santiam	0	193	0	2	195	100.00
	Total	***967***	***193***	***27***	***2***	***1,189***	***16.23***
S. Santiam	S. Santiam above Foster	385	18	0	0	403	0.00
Willamette	Salt Creek	72	0	0	0	72	0.00
	N Fk Mid Fk Willamette	555	0	0	0	555	0.00
	Mid Fk Willamette	176	0	0	0	176	0.00
	Mosby Creek	43	0	0	0	43	0.00
	Total	***846***	***0***	***0***	***0***	***846***	***0.00***
McKenzie	S Fk McKenzie above Cougar	735	0	8	0	743	0.00
	Above Trail Bridge Reservoir	128	0	4	0	132	0.00
	Mohawk R	191	0	0	0	191	0.00
	McKenzie R above Leaburg	0	17	0	0	17	100.00
	Total	***1,054***	***17***	***12***	***0***	***1,083***	***1.57***

Broodstock Biometrics

Lengths were measured on 3,712 adult spring Chinook in 2007, and ranged between 40 and 120 cm (Table 19). Mean lengths among hatcheries were compared using a Kruskal-Wallis One-Way ANOVA on ranks followed by Dunn's pairwise multiple comparison method. Mean fork length was significantly different among all hatcheries except between Marion Forks and South Santiam hatcheries ($p < 0.05$ for all comparisons). The composite mean fork length was greatest at South Santiam hatchery (84.0 cm) and least at Willamette hatchery (79.8 cm; Table 19 and Figure 4). Mean lengths of fin-clipped and unclipped Chinook at each hatchery were also significantly different (Mann-Whitney Rank Sum Test, $p< 0.05$), but the pattern was not consistent among hatcheries. Fin-clipped Chinook were larger than unclipped Chinook at Marion Forks and South Santiam hatcheries, whereas unclipped Chinook were larger than fin-clipped Chinook at McKenzie and Willamette hatcheries.

Table 19. Fork length (cm) statistics of Chinook at Upper Willamette hatcheries, 2007.

Hatchery	Mark	Measured	Minimum	Maximum	Mean
McKenzie	Unclipped	122	49	105	84.9
McKenzie	Fin-clipped	983	48	105	80.3
Marion Forks	Unclipped	158	60	99	81.7
Marion Forks	Fin-clipped	539	53	107	83.6
S. Santiam	Unclipped	96	53	105	80.8
S. Santiam	Fin-clipped	696	40	106	84.4
Willamette	Unclipped	225	46	120	84.4
Willamette	Fin-clipped	883	46	99	78.6
McKenzie	All	1,115	48	105	80.8
Marion Fks	All	697	53	107	83.2
S. Santiam	All	792	40	106	84.0
Willamette	All	1,108	46	120	79.8

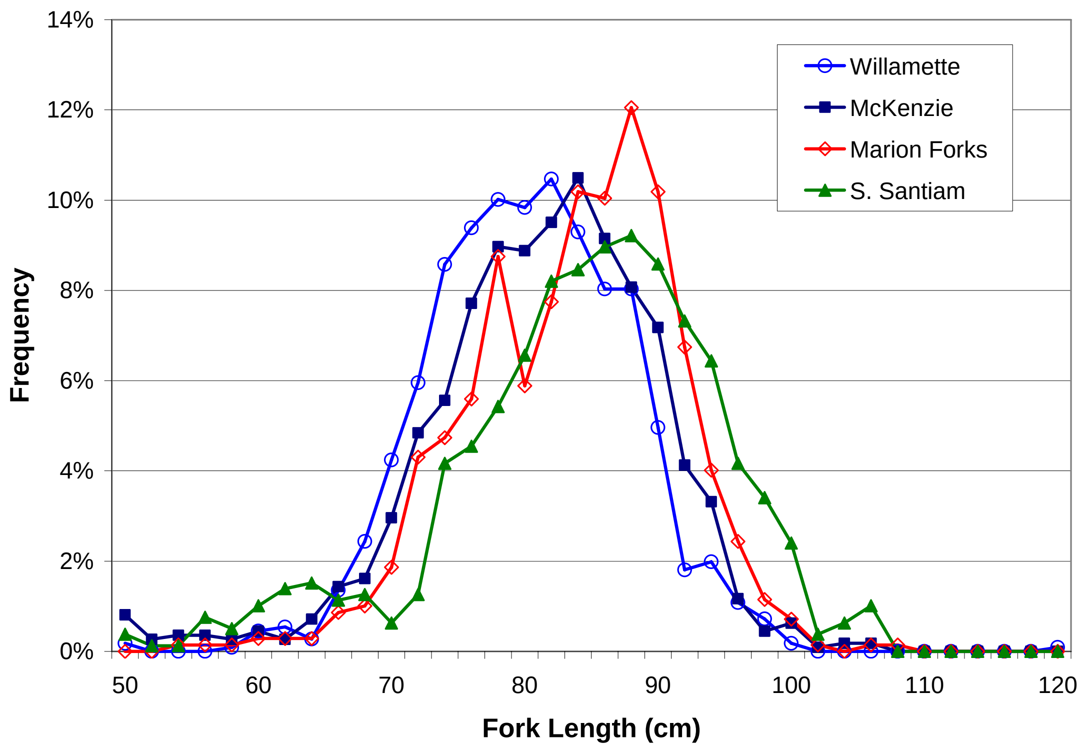

Figure 4. Length frequency distributions of hatchery broodstocks, 2007.

Number and Percentage of Natural-Origin Spring Chinook Taken for Broodstock

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 wild fish were spawned at all hatcheries in at least one of the years (Table 20). 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%.

Acknowledgements

Many individuals and groups helped with this study. We thank hatchery managers Brett Boyd, Greg Grenbemer, Kurt Kremers, Dan Peck, and their crews for collecting data on Chinook captured at their facilities and conducting the otolith marking of Chinook at their hatcheries. We also thank Kurt Kremers, McKenzie hatchery staff, and Mike Hogansen for providing count data for Chinook at Leaburg Dam. We thank Greg Taylor of the U.S. Army Corps of Engineers for providing spawning survey data for Fall Creek. We would like to recognize seasonal biologists Josh Boatner, Linda Campbell, Bart Debow, Ryan Emig, Ed Hughes, Ryan Jacobsen, David Jones, Jim Latshaw, Paul Olmsted, Matt Strickland, and Scott Young who collected much of the field data during spawning ground surveys. Finally, we would like to sincerely thank Brian Cannon who assisted with the supervision and training of all field crews and the collection of field data.

Table 20. Composition of spring Chinook salmon without fin clips 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 run of wild fish downstream of Leaburg and Bennett dams in the McKenzie and North Santiam rivers, respectively.

River, year	Unclipped[a] Wild	Unclipped[a] Hatchery	Fin-clipped hatchery	Percent wild— in broodstock	Percent wild— 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 97 at South Santiam (85 wild).*
[d] *Bennett Dam trap on the North Santiam was not operated in 2006.*
[e] *Otoliths were collected on 152 unclipped fish, of which 114 were wild and 38 were of hatchery origin.*

Literature Cited

Busack, C.A. and K.P. Currens. 1995. Genetic Risks and Hazards in Hatchery Operations: Fundamental Concepts and Issues. American Fisheries Society Symposium 15:71-80.

Cuenco, M.L., T.W.H. Backman, and P.R. Mundy. 1993. The use of supplementation to aid in natural stock restoration. In, Genetic Conservation of Salmonid Fisheries, J.G. Cloud and G.H. Thorgaard, eds. Plenum Press, New York.

Firman, J., M. Buckman, R. Schroeder, and K. Kenaston, M. Hogansen, B. Cannon. 2005. Work Completed for Compliance With the Biological Opinion for Hatchery Programs in the Willamette Basin, USACE funding: 2004. Oregon Department of Fish and Wildlife, Task Order: NWP-OP-FH-02-01, Salem.

Hard, J.J., R.P. Jones, M.R. Delarm, and R.S. Waples. 1992. Pacific salmon and artificial propagation under the Endangered Species Act. NOAA Tech. Memo. NMFS F/NWC-2, 56p.

NRC (National Research Council). 1996. Upstream: Salmon and Society in the Pacific Northwest. National Academy Press, Washington, D.C. 452 p.

Schroeder, R. K., K. R. Kenaston, and R. B. Lindsay. 2001. Spring Chinook salmon in the Willamette and Sandy rivers. Oregon Department of Fish and Wildlife, Fish Research Report F-163-R-06, Annual Progress Report, Portland.

Schroeder, R. K., K. R. Kenaston, and L.K. Krentz. 2005. Spring Chinook salmon in the Willamette and Sandy rivers: with 1996–2004 summaries. Oregon Department of Fish and Wildlife, Fish Research Report F-163-R-10, Annual Progress Report, Portland.

Steward, C.R. and T.C. Bjornn. 1990. Supplementation of salmon and steelhead stocks with hatchery fish: a synthesis of published literature. Tech, Rpt. 90-1. Idaho Cooperative Fish and Wildlife Research Unit. University of Idaho, Moscow, ID.

Waples, R.S. 1999. Dispelling some myths about hatcheries. Fisheries 24(2) 12-1.