THE OREGON PLAN *for Salmon and Watersheds*





OREGON Fish & Wildlife

Salmonid Life-Cycle Monitoring Project, 2001

REPORT NUMBER: OPSW-ODFW-2002-2

SALMONID LIFE-CYCLE MONITORING PROJECT 2001

Oregon Plan for Salmon and Watersheds

Monitoring Report No. OPSW-ODFW-2002-2

March 2, 2002

Mario F. Solazzi
Steven L. Johnson
Bruce Miller
Tim Dalton

Coastal Salmonid Inventory Project
Western Oregon Research and Monitoring Program
Oregon Department of Fish and Wildlife
28655 Highway 34
Corvallis, OR 97333

Funds provided in part by:
Oregon Department of Fish and Wildlife
Sport Fish and Wildlife Restoration Program administered by the U.S. Fish and Wildlife Service F-171-R
Bureau of Land Management Salem and Coos Bay Districts
Oregon Plan for Salmon and Watersheds
Tillamook Bay National Estuary Program
Oregon Department of Forestry

Citation: Solazzi, M.F., S.L. Johnson, B. Miller, T. Dalton 2002. Salmonid Life-Cycle Monitoring Project 2001 Monitoring Program Report Number OPSW-ODFW-2002-2, Oregon Department of Fish and Wildlife, Portland, Oregon.

Table of Contents

List of Figures.

List of Tables

PART I. SMOLT AND ADULT MONITORING

Introduction

In 1998, as part of the Oregon Plan for Salmon and Watersheds, the Oregon Department of Fish and Wildlife (ODFW) began monitoring survival and downstream migration of salmonid fishes (*Oncorhynchus spp*.) in coastal basins. As a part of this program the Salmonid Life-cycle Monitoring project developed three objectives: 1) estimate abundance of adult salmonids and downstream migrating juvenile salmonids, 2) estimate marine and freshwater survival rates for coho salmon (*Oncorhynchus kisutch)* and 3) evaluate effects of habitat modification on the abundance of juvenile salmonids in Cummins and Tenmile Creeks.

This report summarizes data collected on downstream migration of juvenile salmonids during the spring of 2001, as well as the adult return data from the winter of 2000-01. We also summarize the results from the Cummins and Tenmile Creeks habitat modification project that began in 1991. We include a brief description of the preliminary results from sampling in Winchester Creek and South Slough (Coos Bay).

During 2000 we estimated abundance of adult salmonids at eight locations: N. Fork Scappoose Creek (Lower Columbia), North Fork Nehalem River, Mill Creek (Siletz Basin), Mill Creek (Yaquina Basin), Cascade Creek (Alsea Basin), West Fork Smith River, Fall Creek (Coos Basin) and Winchester Creek (South Slough, Coos Bay). At these locations, we were able to monitor both the downstream migrants (smolts) and returning adults. We also operated smolt traps at six other locations to monitor downstream migration. We were not able to monitor the numbers of returning adults at these additional sites due to the lack of adult capture facilities. These sites are the same as reported in Solazzi et al (2001).

Methods for Estimating Abundance of Migrating Juvenile Salmonids

Rotary screw traps or rotating incline-plane traps were used to capture downstream-migrating juvenile salmonids. Traps generally began fishing in early March and fished continuously until catches diminished to low levels (or low streamflows precluded further operation of the traps), usually by mid June. The traps were normally checked and cleared of fish and debris once a day, although, to ensure fish safety, visits were more frequent during storm events and periods of high debris. Fish were anesthetized with MS-222 and enumerated by species, size class, age, and development (smoltification) class as indicated by visible brightness.

Each species was classified by age or size group. Coho salmon *(O. kisutch)* were identified as fry (age 0+) or smolts (age 1+). All chum salmon (*O. keta*) captured were fry (age 0+). Chinook salmon (*O. tshawytscha*), also age 0+, were identified as fry that migrated soon after emergence (<60 mm fork-length) and fingerlings that remained to rear until ≥60 mm. Trout species were classified into size classes that roughly correspond to age classes, the largest class for each species containing smolts, the smaller classes parr. Fry (<60 mm) were not differentiated to the species level. Additional size classes were 60-89, 90-119 and ≥120 mm for steelhead (*O. mykiss*), and 60-89, 90-119, 120-159 and ≥160 mm for cutthroat trout (*O. clarki*). Sea-run trout migrate to sea at various ages according to individual smoltification maturity, steelhead usually at ages 1+ or 2+, cutthroat at 2+, 3+, and 4+; however, both can migrate at any age.

To calibrate the efficiency of the traps and to estimate total outmigration, each day up to 25 fish of each species and size class were marked with a small clip on their caudal fin then released upstream of the traps for recapture. Marked fish were released at dusk from a floating timer-actuated release device (Miller et al. 2000). Recaptured marked fish were likewise enumerated by species and size class, and estimates of total outmigrants were made by expanding trap catches using the following equations:

$$N = n_i / E_i,$$
and
$$E_i = r_i / m_i,$$

where N = total estimated outmigrants, n_i = number of fish captured, E_i = estimated trap efficiency, r_i = number of recaptured marked fish, and m_i = number of marked fish released. Values used in these estimates were usually weekly totals. However, when recaptures were infrequent, weeks were pooled. Weekly estimates were summed to estimate total outmigrants for the season. Population estimates were not calculated if less than five marked fish of a particular species and size class were recaptured.

A bootstrap procedure was used to determine the variance and 95% confidence interval for each population estimate (Thedinga et al 1994). An estimate of the population bias was also obtained from the bootstrap procedure. A negative bias indicates that the true population size is likely to be underestimated, while a positive bias indicates that the true population size is likely to be overestimated. The percentage value referred to in the **Estimates of Population Size** section of this report is the percentage of times that the bootstrap procedure calculated a larger (or smaller) population size compared to the population estimate that we calculated. All variance estimates were based on 1000 iterations of the bootstrap procedure. The protocols described above were followed at each trap site.

The average length at the time of peak migration was calculated for each species. Peak migration was determined by selecting the week when the maximum numbers of migrants were estimated to have passed the trap. For coho salmon and steelhead trout smolts, the average lengths that we report are for fish >60mm and >120mm respectively. For cutthroat trout the average length that we report is for all cutthroat captured during the peak week and is not restricted by size class.

Results and Discussion

Estimates of Population Size

Populations of coho salmon smolts were generally higher during the spring of 2001 than previously observed since monitoring began in 1998 (Figure 1). For the four years of sampling, the 95% confidence interval for coho salmon smolts averaged ±15% of the population estimate and had an average bias of –0.7%. Coho salmon fry abundance during 2001 was also the highest observed at all sites since monitoring began except for Bales Creek and the Little North Fork Wilson River (Figure 2). The confidence interval for four years averaged ±34% of the population estimate and had an average bias of –2.7%. Chinook salmon fry abundance in 2001 was variable with some stations having higher abundance than observed during 2000 and some with lower abundance (Figure 3). The confidence intervals for chinook salmon fry (four years) averaged ±14% of the population estimate and had an average bias of -0.77%. Steelhead smolt populations tended to be higher in 2001 than in any other year since monitoring began with the exception of the North Fork Nehalem and Cummins Creek, which were the second highest on record (Figure 4). The steelhead smolt confidence intervals averaged ±21% of the population estimates and had an average bias of –1.1%. Cutthroat trout smolt populations were variable, with some stations having the highest abundance observed and some having the lowest (Figure 5).

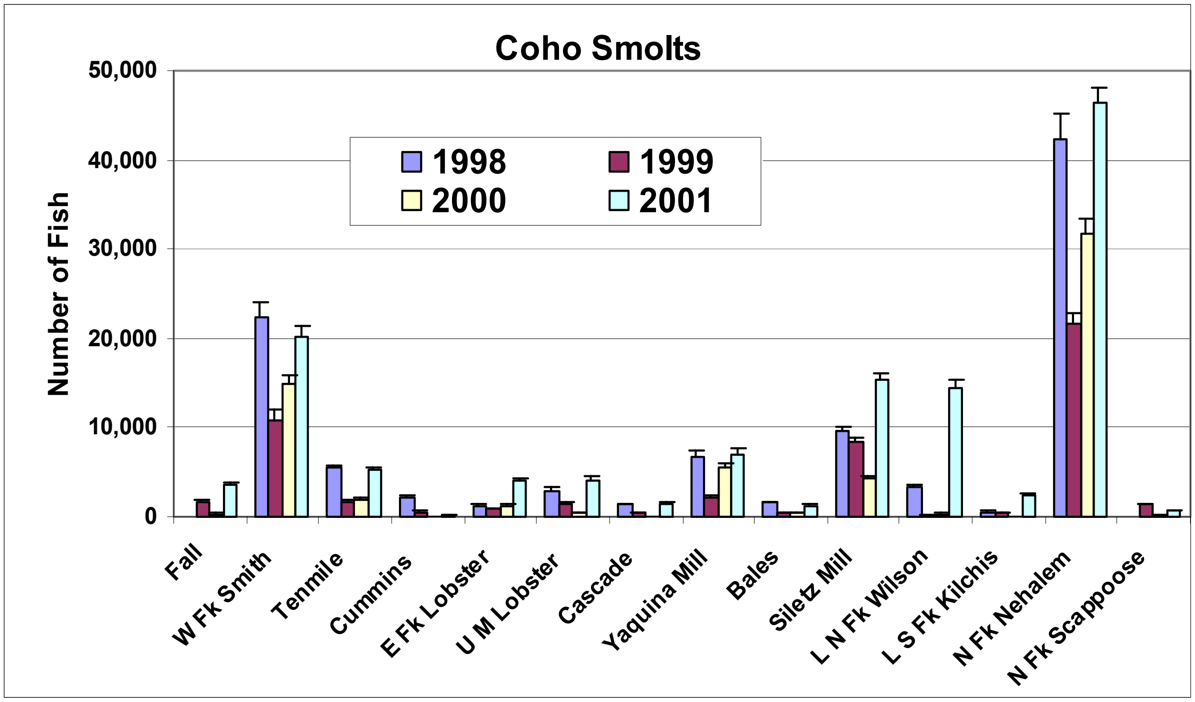

Figure 1. Population estimates and 95% confidence intervals for coho salmon smolts at 14 life cycle monitoring sites, 1998–2001.

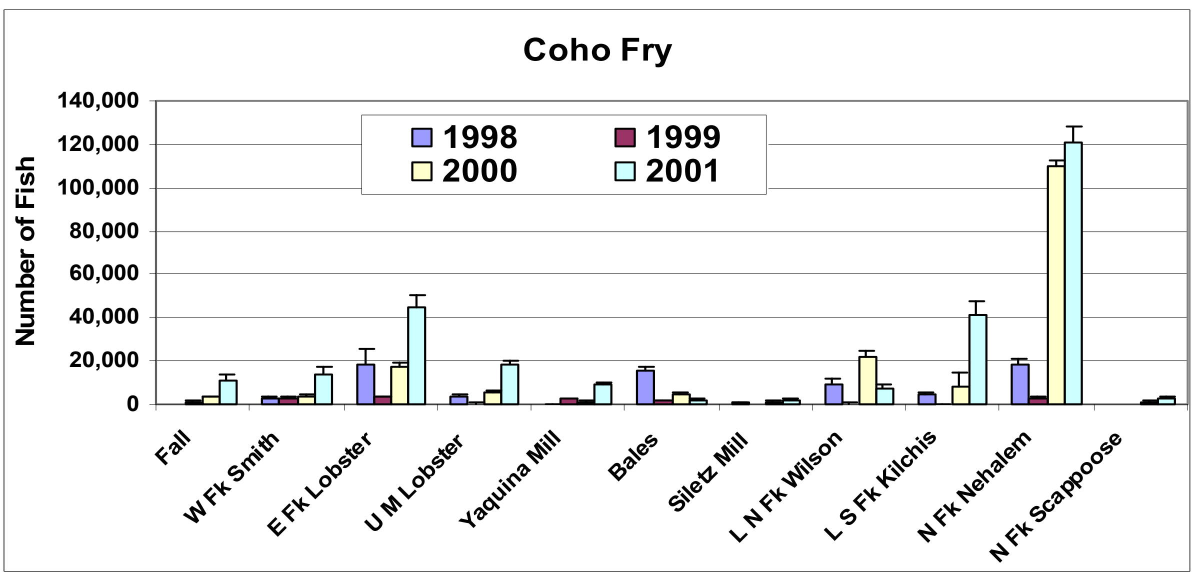

Figure 2. Population estimates and 95% confidence intervals for coho salmon fry at 11 life cycle monitoring sites, 1998-2001.

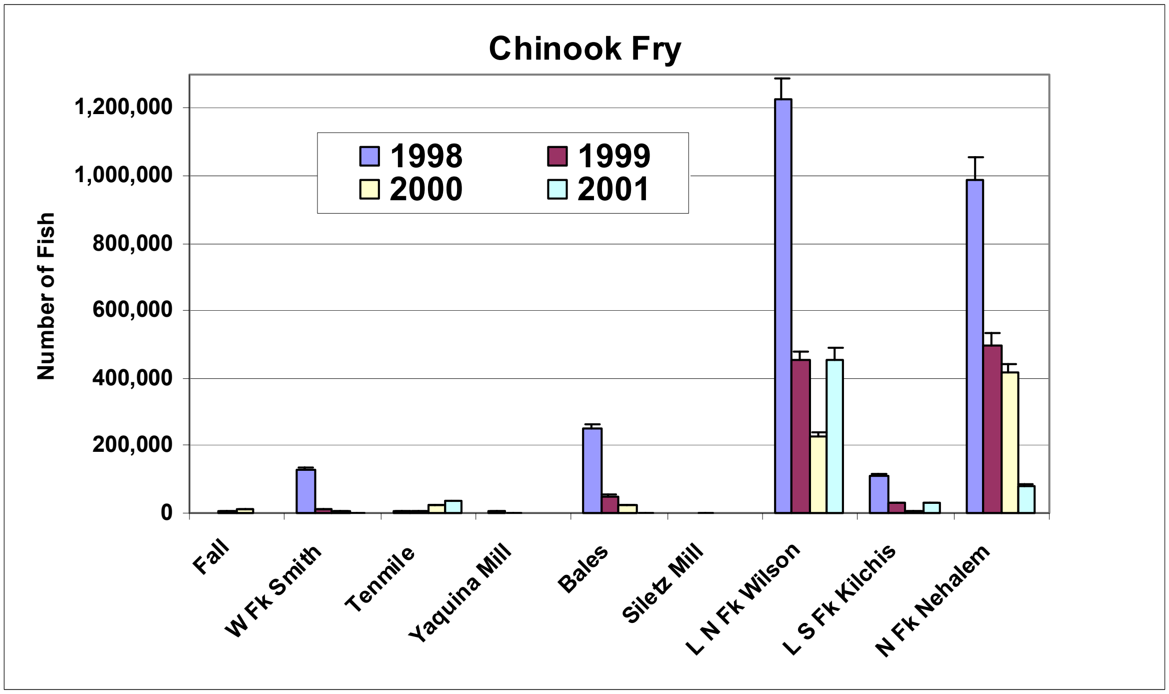

Figure 3. Population estimates and 95% confidence intervals for chinook salmon fry at 9 life cycle monitoring sites, 1998-2001.

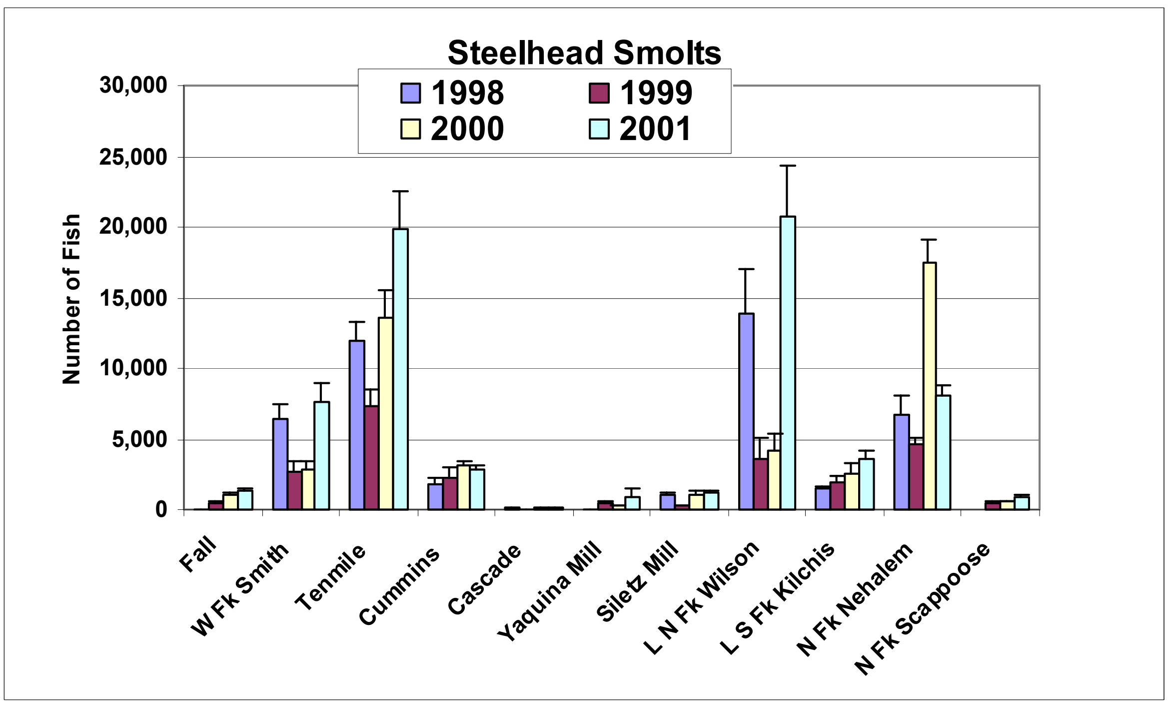

Figure 4. Population estimates and 95% confidence intervals for steelhead smolts at 11 life-cycle monitoring sites, 1998-2001.

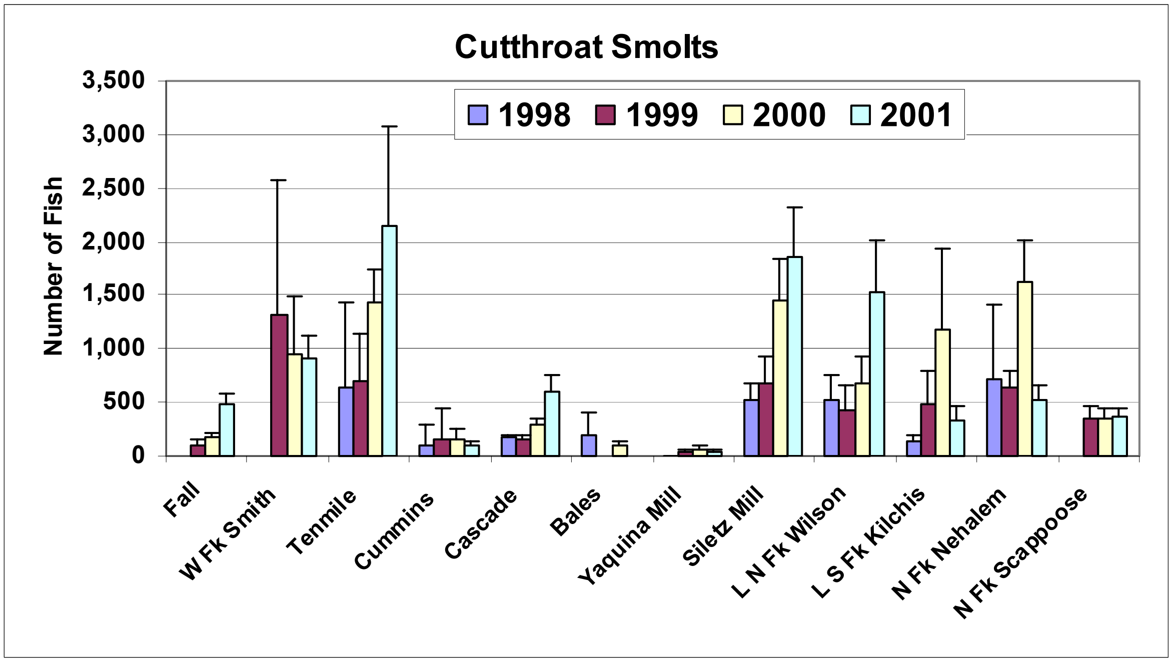

Figure 5. Population estimates and 95% confidence intervals for cutthroat trout smolts at 12 life-cycle monitoring sites, 1998-2001.

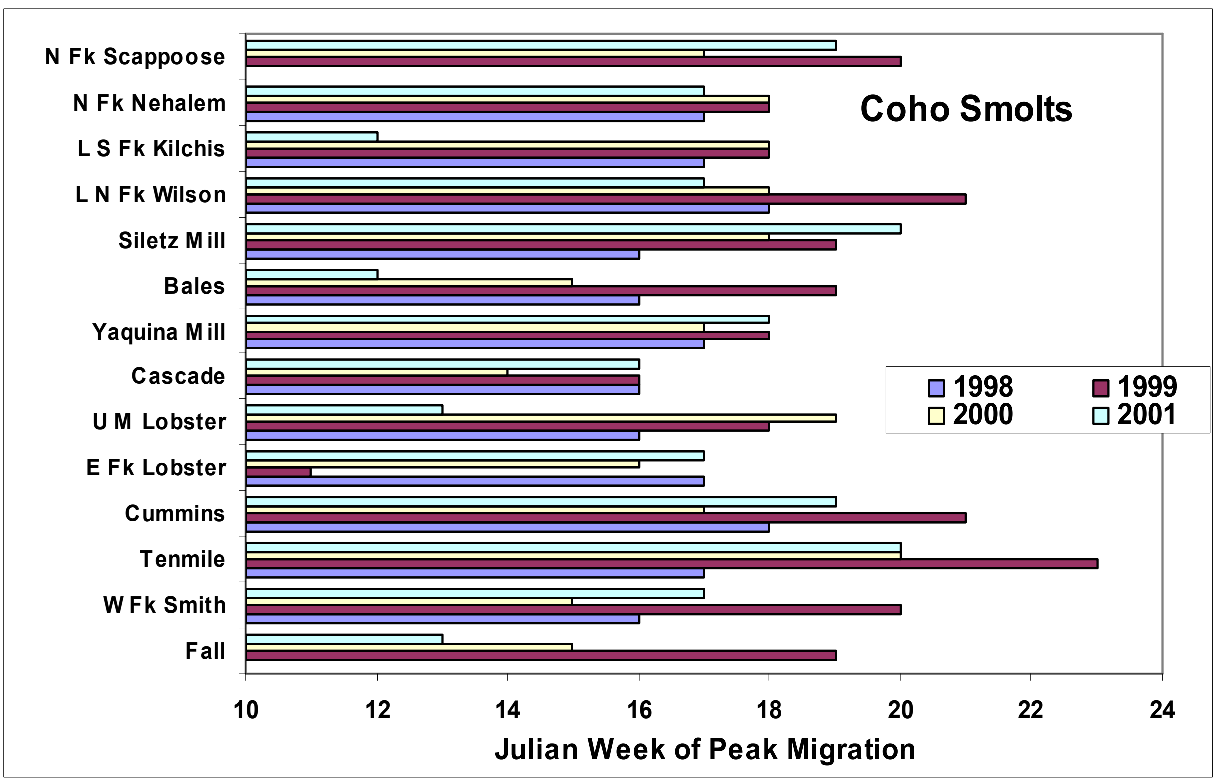

Figure 6. Julian week of peak migration of coho salmon smolts at 14 life-cycle monitoring sites, 1998-2001.

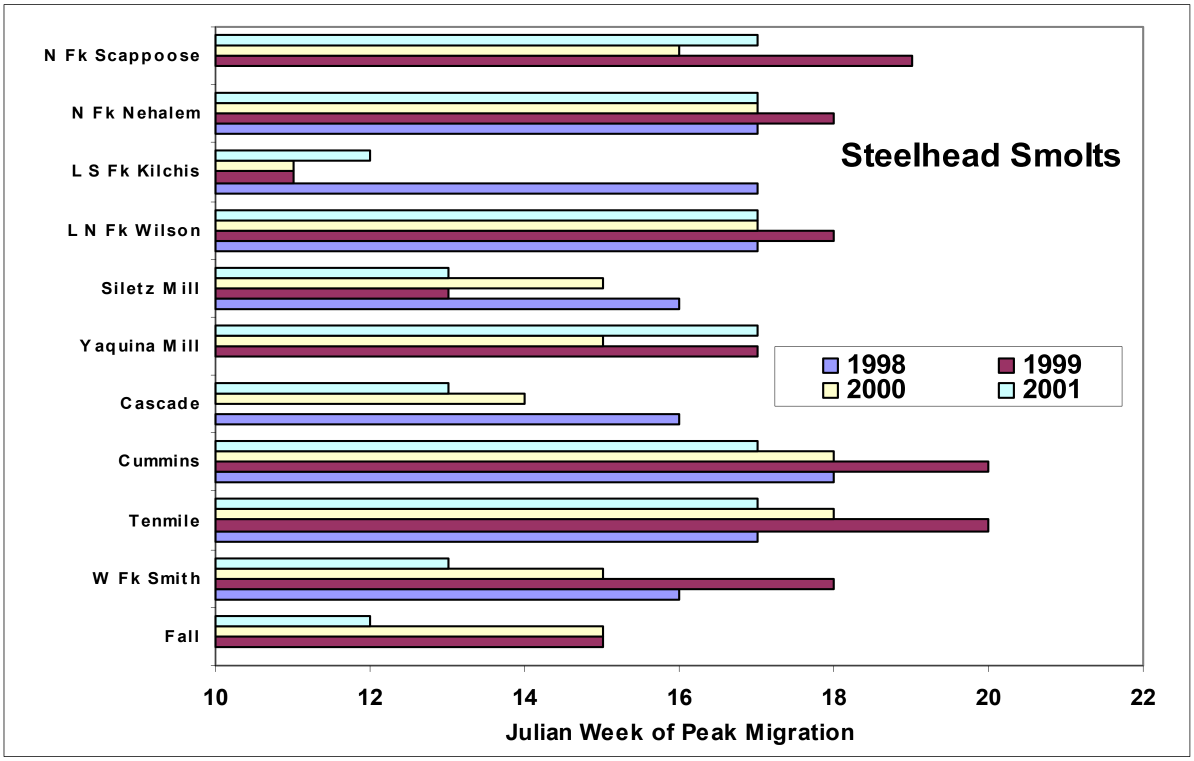

Figure 7. Julian week of peak migration of steelhead smolts at 11 life-cycle monitoring sites, 1998-2001.

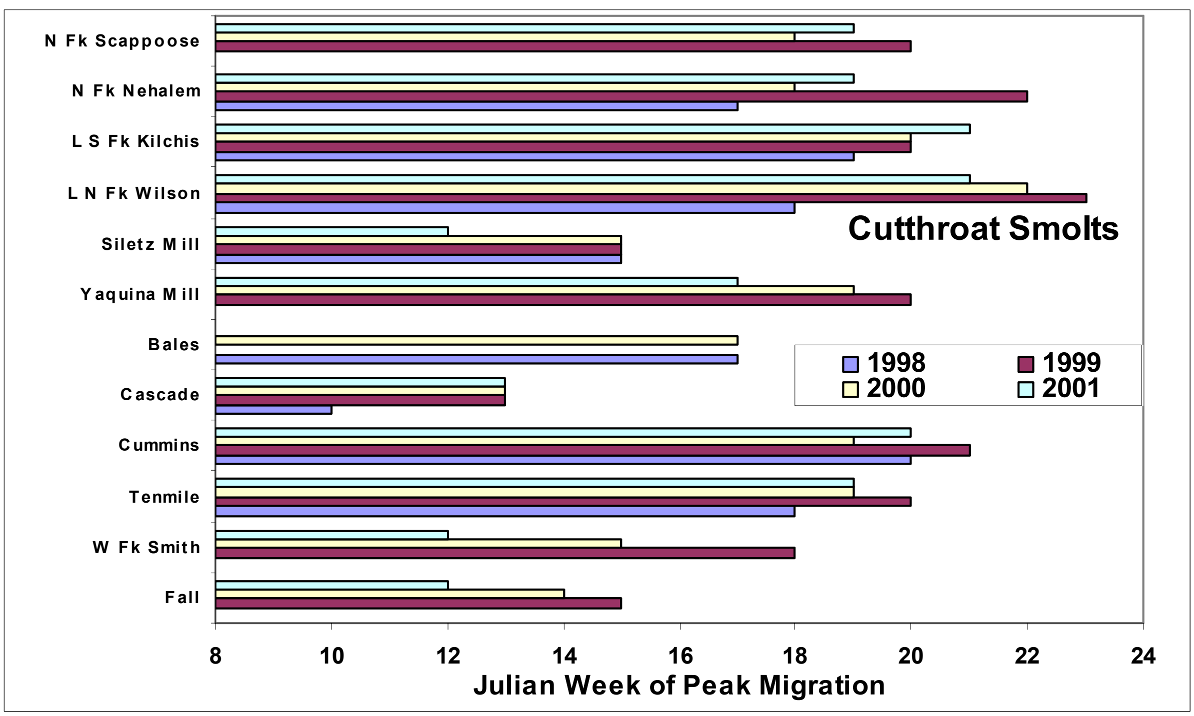

Figure 8. Julian week of peak migration of cutthroat trout smolts at 12 life-cycle monitoring sites, 1998-2001.

The average confidence interval was ±52% of the population estimate and the bias averaged –4.8%.

Timing of Downstream Migration

Peak migration timing for juvenile coho salmon, steelhead, and cutthroat trout smolts (1998-2001) is summarized in Figures 6-8. The migration peak of coho salmon smolts in 2001 was the earliest on record at four locations (Kilchis, Bales, Upper Lobster and Fall Creeks). No significant trends were observed for either steelhead or cutthroat trout smolts (Figures 7 and 8).

Average Size of Downstream Migrants

Coho salmon smolts from Yaquina Mill Creek continued to be larger at the time of peak migration than smolts from the other sites monitored except N. Fk. Scappoose Creek (Figure 9). This was due in part to their use of a reservoir (located above the trap site) for rearing, resulting in faster growth and a larger average length at peak migration. The increased length of coho salmon smolts from Cascade Creek during 2000 was probably a consequence of the extremely low rearing density during the previous summer as the increase in average length was not observed during the spring of 2001, when densities were similar to those observed during 1998.

North Fork Scappoose Creek coho salmon smolts continued to be larger than those found in coastal basins, as reported last year (Solazzi et al 2000). The low abundance and rearing density of this population could be a significant factor contributing to their larger size at peak migration. Rearing densities (smolts/m) were generally the lowest in the N. Fk. Scappoose compared to the other locations monitored. This size difference between the Scappoose smolts (Columbia Basin) and coastal smolts may also be a demonstration of the specific genetic adaptations of each stock to optimize size and timing of migration. Further monitoring of these populations may provide the information necessary to determine the degree to which each of these factors may be contributing to the observed size difference.

The coho salmon smolts in Lobster Creek, from both the East Fork and Upper Mainstem, continued to migrate at a smaller average size than was observed in other coastal streams. This was due in part to the location of the traps in the upper section of the drainage basin, where juvenile coho salmon smolts had further to migrate than those at the other sites that we monitor.

The steelhead smolts from Yaquina Mill Creek continued to be slightly larger than observed at the other monitoring locations (Figure 10). This was probably related to the fish's use of the reservoir for rearing before migrating downstream. The average lengths of steelhead smolts at the time of peak migration were similar between years within locations. Most of the steelhead populations that we monitor average about 150mm fork-length at the time of peak migration.

Cutthroat trout continued to be larger at peak migration in Yaquina Mill Creek than in the other locations monitored, except for Tenmile Creek (Figure 11). The large average length of cutthroat trout smolts from Tenmile Creek may be due to differences in life history and movement of this group of fish that we do not observe in the other populations that we monitor. A lower proportion of the fluvial type cutthroat trout in lower Tenmile Creek than in the other streams, because of the proximity of the trap to the ocean, may tend to shift the average length to a larger size.

Density of Downstream Migrants

The numbers of smolts produced per meter of stream length in each year are summarized in Figures 12-14. The average density of coho salmon smolts ranged from a high of 0.44 smolts/meter in 2001 to a low of 0.13 smolts/meter in 2000. Average density of steelhead smolts ranged from 0.11 smolts/meter in 1999 to 0.29 smolts/meter in 2001. Density of cutthroat trout smolts averaged 0.02 smolts/meter during 1998 and 1999 and increased to 0.04 smolts/meter during 2001.

Abundance of Returning Adult Salmonids

North Fork Scappoose Creek

Adult salmonids were trapped in a fish ladder located at Bonnie Falls. The fish ladder provides passage around a waterfall that is considered a complete barrier to upstream migration of adult salmon and steelhead. The trap began operation in mid September 2000 and was fished continuously through June 2001. All fish entering the trap were examined for marks, identified as male or female, measured for fork length, given a lower caudal mark, then released upstream from the trap. The caudal mark was used to determine if any fish had fallen back over the falls and re-entered the trap. The numbers of each species captured at this facility are summarized in Tables 1-3.

Table 1. Number of coho salmon captured at eight life-cycle monitoring sites for the 2000-2001 run year.

	At Trap					
	Wild			Hatchery		
Location	Males	Females	Jacks	Males	Females	Jacks
Scappoose	38	19	14	0	0	1
N. Nehalem	127	147	17	31	24	21
Siletz Mill	117	119	12	2	1	0
Yaquina Mill	24	40	258	0	0	0
Cascade	34	11	10	0	0	0
W. Smith	55	46	25	--	--	--
Fall	28	9	21	0	0	0
Winchester	2	3	73	0	0	1

Table 2. Population estimates for coho salmon at eight life-cycle monitoring sites for the 2000-2001 run year.

	Estimated coho salmon spawners above trap site					
	Wild			Hatchery		
Location	Males	Females	Jacks	Males	Females	Jacks
N. Scappoose	38	19	14	0	0	1
N. Nehalem	284	328	--	48	61	--
Siletz Mill	127	130	35	--	--	--
Yaquina Mill	24	40	258	0	0	0
Cascade	34	11	10	0	0	0
W. Fk. Smith	294	241	--	--	--	--
Fall	28	9	21	0	0	0
Winchester	2	3	--	0	0	0

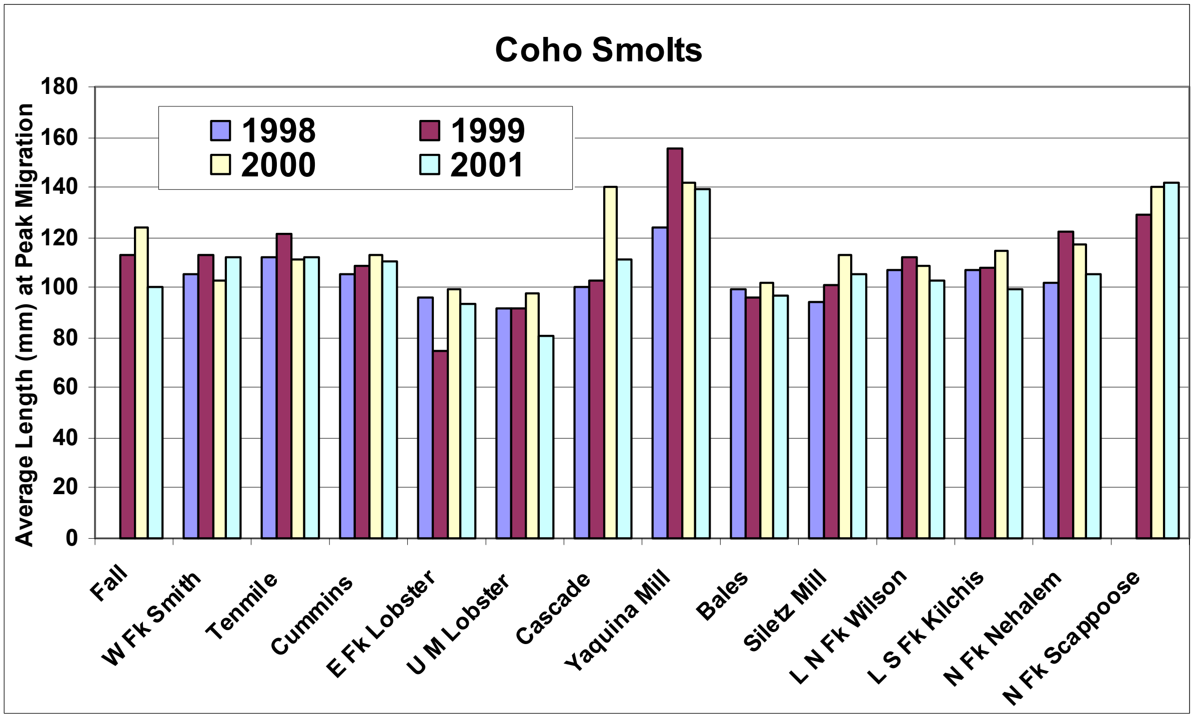

Figure 9. Average length at peak migration of coho salmon smolts at 14 life-cycle monitoring sites, 1998-2001.

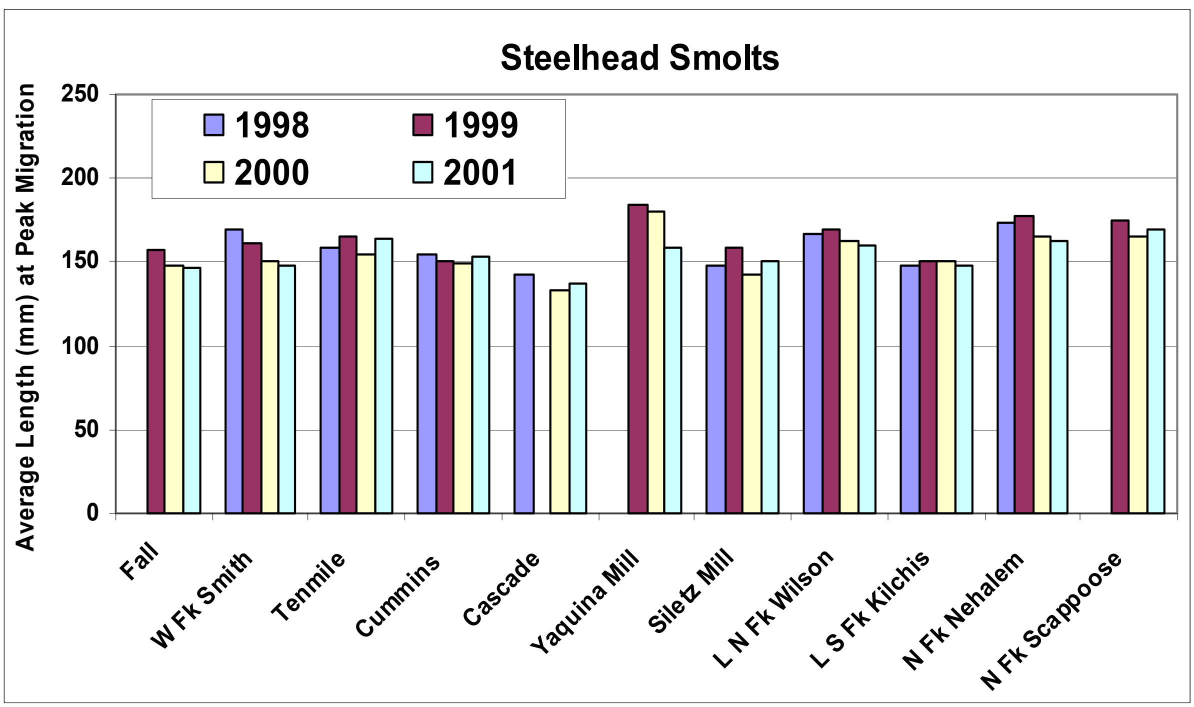

Figure 10. Average length at peak migration of steelhead smolts at 11 life-cycle monitoring sites, 1998-2001.

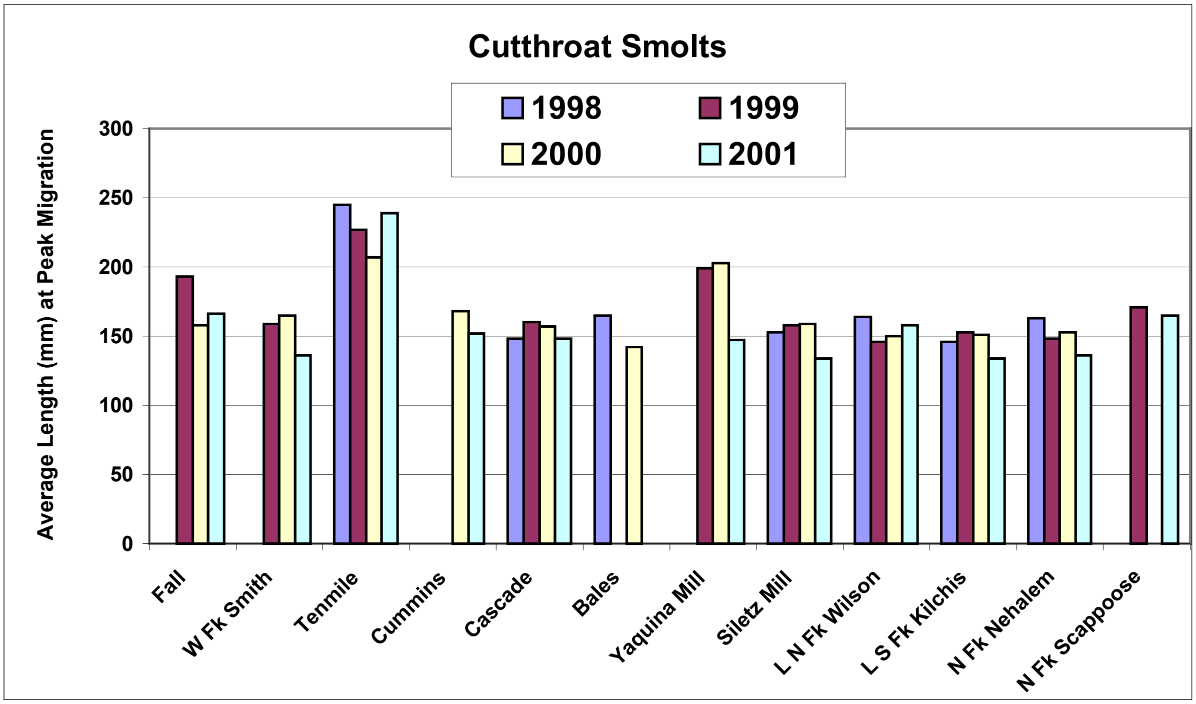

Figure 11. Average length at peak migration of cutthroat trout smolts at 12 life-cycle monitoring sites, 1998-2001.

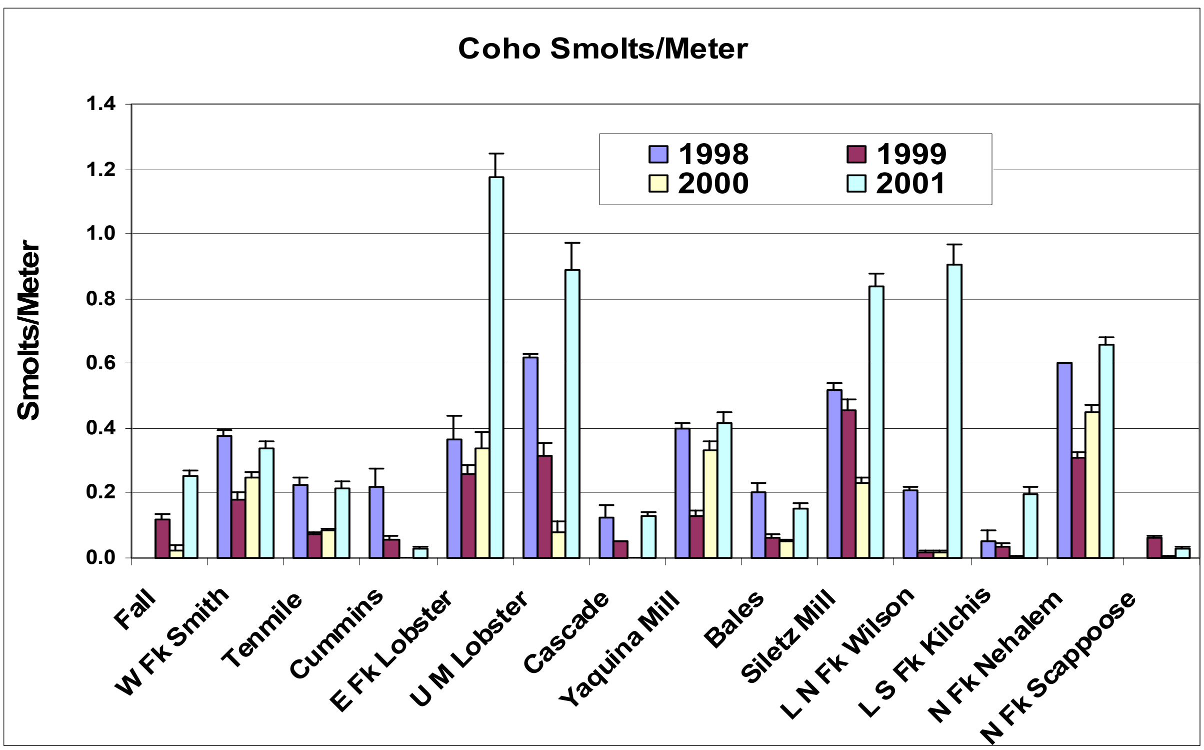

Figure 12. Coho salmon smolts produced per meter of stream length at 14 life-cycle monitoring sites, 1998-2001.

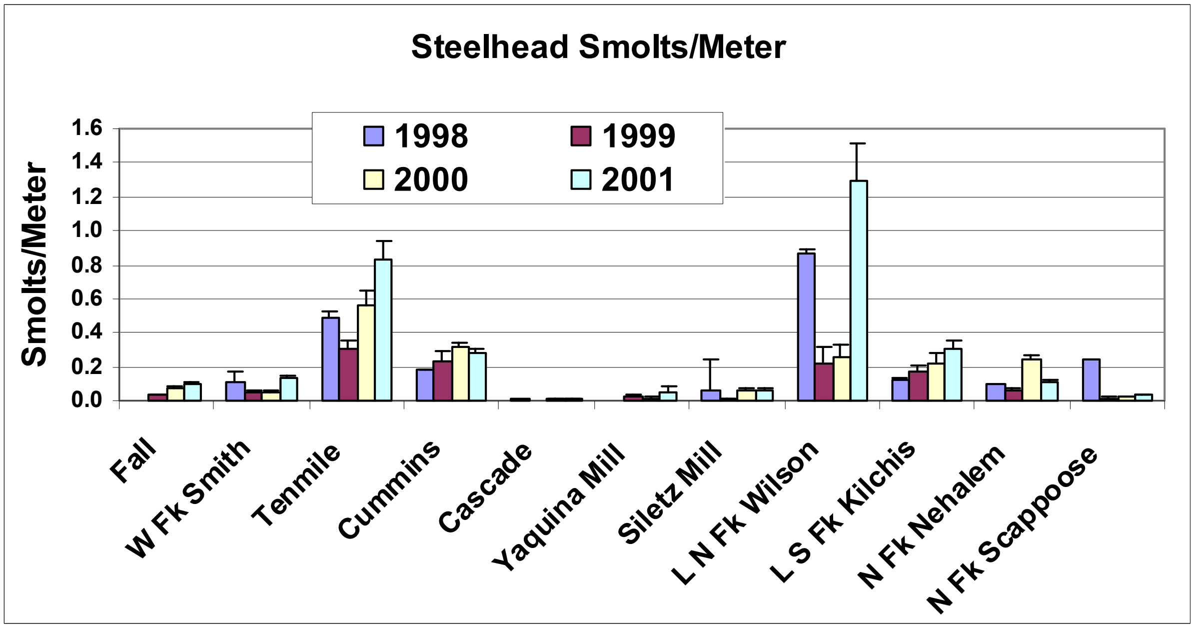

Figure 13. Steelhead smolts produced per meter of stream length at 11 life-cycle monitoring sites, 1998-2001.

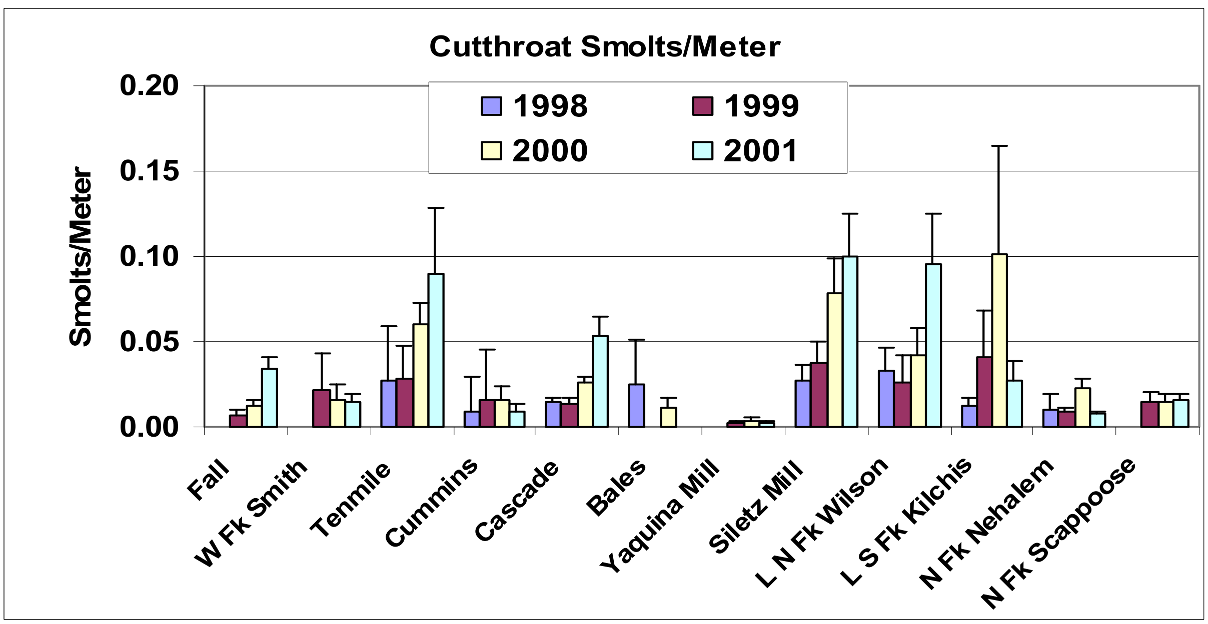

Figure 14. Cutthroat trout smolts produced per meter of stream length at 12 life-cycle monitoring sites, 1998-2001.

Table 3. Population estimates of chinook, steelhead and cutthroat at eight monitoring sites for the 2000-2001 run year. Estimates do not include jacks.

Location	Chinook	Steelhead	Cutthroat[a]
N. Scappoose	0	12	82
N. Nehalem	138	515	--
Siletz Mill	1	--	4
Yaquina Mill	2	31	6
Cascade	0	36	8
W. Fk. Smith	26[b]	307	--
Fall	0	37	--
Winchester	3	0	--

[a]The cutthroat trout number represents the number of fish captured and is incomplete because the bar spacing in the traps allows cutthroat trout to pass.
[B]Number of fish captured at the trap.

North Fork Nehalem River

Mature salmonids returning to spawn (coho and chinook salmon, as well as steelhead) were trapped and tagged in the fish ladder that provides passage around Waterhouse Falls, a partial barrier to upstream migration. The trap began operation on October 2, 2000 and was operated through June 5, 2001. Fish were inspected for marks, identified to species, sex and origin (hatchery or wild), and fork-length was measured. Coho salmon <51 cm and chinook salmon <61 cm were designated jacks. Wild fish were implanted with one or two floy tags (tag color varying by species) near the base of the dorsal fin, given a small punch in the left operculum, and passed upstream. Hatchery reared coho salmon were killed, whereas hatchery reared steelhead were floy tagged and then transported downstream to provide additional fishery opportunities.

Hatchery reared and wild coho salmon were caught in the Waterhouse Falls ladder trap until December 3 and January 5, respectively, but both were mostly trapped in October with the highest numbers caught in the first half of that month. A large storm occurred just before the trap began operating, substantially raising river flows and attracting many fish upstream; the season's greatest daily catch occurred the first day of trapping, which was the last day of this three day high flow event. Thus, it is likely that significant numbers of fish migrated past Waterhouse Falls before we began trapping, particularly hatchery reared fish, which usually migrate in the largest numbers earliest in the fall. That this was the case was suggested by catches in the fish trap at the Nehalem hatchery, approximately 1.6 km downstream of Waterhouse Falls, which was operating throughout this event. To adjust for this, we estimated hatchery reared fish numbers by their relative abundance compared to wild fish in upriver locations (i.e., among carcasses found on spawner surveys or fish trapped in a ladder located about 6.5 km upstream of Waterhouse Falls). In previous years we had estimated hatchery fish numbers by their abundance compared to wild fish trapped at Waterhouse Falls.

The upstream ladder trap, located above the confluence of Fall Creek, operated from October 6 to June 5. Tagged wild fish caught in this trap or found as carcasses on spawner surveys were pooled as mark recoveries. Their proportion among all wild fish sampled by these methods was used to estimate trapping efficiency at the Waterhouse Falls ladder, and thus to expand the catch data into a wild fish population estimate using an adjusted Petersen Mark-Recapture methodology:

$$N = ((M + 1) (C + 1)) / (R + 1)$$

where:

M = 274, the number of wild adult coho salmon marked with floy tag(s).
C = 88, the number of wild adult coho salmon captured in the upstream ladder or found as carcasses on spawner surveys.
R = 39, the number of wild adult coho salmon marked with floy tag(s) captured in the upstream ladder or found as carcasses on spawner surveys.

Using this methodology, the spawning escapement of wild adult coho salmon in the North Fork Nehalem River watershed upstream of Waterhouse Falls was estimated to be 612 adults (95% CI = ±103). The ratio between wild males and females caught in the Waterhouse Falls trap was used to estimate that 284 of these were males and 328 were females. The ratio between wild and hatchery reared adults caught in the upstream trap or found as carcasses was compared to the wild adult spawning escapement estimate upstream of Waterhouse Falls to estimate the total number of hatchery reared adults that had jumped Waterhouse Falls and migrated upstream. The numbers of these that were male and female were estimated by the male to female ratio among hatchery reared fish in the upstream trap and carcasses. Finally, the hatchery reared fish killed in the upstream trap were subtracted to yield estimates of the number of hatchery reared males (48) and females (61) that spawned upstream of Waterhouse Falls.

Chinook salmon (all wild) were trapped at Waterhouse Falls from October 2 until December 3, with few fish being caught before mid October. An estimate of adult chinook salmon spawners was made using the same methodology, where:

M = 50, the number of adult chinook salmon marked with floy tag(s).
C = 18, the number of adult chinook salmon captured in the upstream ladder or found as carcasses on spawner surveys.
R = 6, the number of adult chinook salmon marked with floy tag(s) captured in the upstream ladder or found as carcasses on spawner surveys.

The estimate for the spawning escapement of adult chinook salmon in the North Fork Nehalem watershed above Waterhouse Falls was 138 fish (95% CI = ±73). Using the ratio between males and females among ladder captures and carcass recoveries, we estimated that there were 118 males and 25 females. We believe that the low abundance of females may have been due to passage difficulties downstream associated with very low river levels that particularly inhibited the females from migrating far upriver.

Both wild and hatchery reared steelhead were first caught at Waterhouse Falls on November 28. Hatchery reared fish predominated through January, wild fish were prevalent in February and afterwards. The last hatchery reared and wild fish were captured on March 27 and May 9, respectively. In addition to those trapped in the upstream ladder, steelhead that had migrated upstream of Waterhouse Falls were captured in juvenile traps migrating back downstream in the spring. An estimate of adult steelhead spawners was made using the same methodology, where:

M = 189, the number of adult steelhead marked with floy tag(s).
C = 36, the number of adult steelhead captured in the upstream ladder or in juvenile traps.
R = 26, the number of adult steelhead marked with floy tag(s) captured in the upstream ladder or juvenile traps.

Using this methodology, the spawning escapement of wild adult steelhead in the North Fork Nehalem River watershed upstream of Waterhouse Falls was estimated to be 260 adults

(95% CI=±15). The ratio between wild males and females caught at Waterhouse falls was used to estimate that 125 of these were males and 135 were females. We estimated the numbers of male (98) and female (157) hatchery reared adults that jumped Waterhouse Falls to spawn upstream (those that entered the ladder were transported downstream and thus subtracted, as was one female that died in the upstream ladder) by assuming that the same proportion of both hatchery reared and wild steelhead jumped the falls, and that they occurred at the same male to female ratio as in the Waterhouse Falls ladder.

Siletz Mill Creek

Adult salmonids were trapped in a fish ladder near the mouth of Siletz Mill Creek (River Kilometer 0.4). The fish ladder provides passage around a small waterfall that is a partial barrier to adult salmon and steelhead upstream migration. The trap was fished continuously from mid-September 2000 through June 2001. All adult salmon, steelhead and cutthroat trout entering the trap were examined for marks, identified as male or female, and measured for fork length. All wild salmon and wild steelhead were given a Floy-tag on each side of the dorsal fin and released upstream. All hatchery coho were killed. If these fish were bright and in good condition, they were taken to local food share organizations, if dark, they were deposited below the trap in the stream. All hatchery steelhead captured in the trap were given a hole punch in the operculum and released below the falls.

The waterfall at Siletz Mill Creek is not a complete barrier to upstream migration at all river levels. Therefore, some fish may jump the falls rather than move through the fish ladder and into the trap where they can be counted. In order to estimate the total number of spawners, we conducted spawning fish surveys above the trap site to determine the proportion of tagged and untagged fish.

Ten adult coho salmon spawning surveys in the Siletz Mill Creek watershed were completed weekly from November 1, 2000 through January 31, 2001. The total length for all surveys combined was 14.3 km, and encompassed the best spawning areas within the watershed. Surveyors counted live and dead adult salmonids in each survey area to determine the tagged to untagged ratio of adult salmonids above the trap site.

Four steelhead spawning surveys in the Siletz Mill Creek watershed were completed biweekly from February 1, 2001 through April 15, 2001. The total length of these surveys combined was 7.5 km. Surveyors kept similar information on all dead and live steelhead as described above for coho salmon spawning surveys.

Table 1 summarizes the trap catch and Table 2 summarizes the population estimates at Siletz Mill Creek between October 2000 and June 2001. Two hundred and thirty six wild adult coho and 12 wild jack coho entered the trap during the winter of 2000-2001 (Table 1). Three hatchery adult coho were collected in the trap during the winter (Table 1). Two hundred and thirty six adult coho (117 males and 119 females) and 12 coho jacks were released above the trap. All of these fish were double Floy-tagged.

Thirteen wild steelhead adults (6 males and 7 females) were double-Floy-tagged and released above the trap. Twenty-two hatchery adult steelhead also entered the trap during the winter of 2000-2001. Hatchery fish accounted for 59% of the steelhead entering the watershed. Hatchery fish entered the trap in November and December and again in March. Steelhead entering the trap in November and December were adipose-clipped fish and were generally dark, indicating they had been in the river for some time. Presumably, these were mostly Siletz summer steelhead. Most of the hatchery fish entering the trap in the late winter and spring were adipose-left maxillary marked. These were Siletz winter steelhead originally released from the Palmer Creek acclimation ponds near Moonshine Park.

One hundred forty four live coho salmon were observed on spawning surveys. One hundred seventeen of these fish were observed well enough to determine if the fish was tagged.

Twelve coho salmon carcasses were found. Ninety two percent of the adult coho salmon observed were Floy-tagged, indicating they had been counted at the trap. Five live steelhead and one steelhead carcass were observed on the spawning surveys. Four of these fish were observed well enough to determine if the fish was tagged. Only one tagged steelhead was observed.

An estimate of the adult coho spawners was made using the adjusted Petersen Mark-Recapture methodology where:

M = 236, the number of adult coho marked with Floy-tags
C = 129, the number of adult coho observed for presence of Floy-tags on spawning surveys. This includes live and dead fish. Live fish that could not be observed well enough to determine if a Floy-tag was attached were excluded from this analysis.
R = 119, the number of marked live or dead fish observed during the spawning surveys.

The spawning escapement of adult coho in Siletz Mill Creek was estimated to be 257 fish (95% CI=$\pm$13 which included 127 males and 130 females (Table 2). Because few steelhead were Floy-tagged at the trap, and only one tagged fish were observed on steelhead spawning surveys, no population estimate for steelhead spawners could be made for the winter of 2000-2001.

Yaquina Mill Creek

The adult trap was installed in the fish ladder late September 2000, and fished through May 2001. All adult salmonids entering the trap were examined for marks, identified as male or female, and measured for fork length. All fish were given a hole punch in the left operculum to determine if fish were falling back down through the reservoir spillway and re-entering the ladder and trap. After processing, wild coho were placed in the reservoir and allowed to proceed upstream (Table 3). Hatchery coho (fin clipped fish) were killed. Bright fish in good condition were taken to a local food-share organization. Dark fish were placed in the stream below the fish ladder. Wild and hatchery steelhead were given a left operculum mark and placed in the reservoir and allowed to proceed upstream (Table 3).

A total of 64 wild coho adults and 258 wild coho jacks were captured in the Yaquina Mill Creek trap (Table 1). No hatchery coho were observed at the trap site in the winter of 2000-2001. A total of 64 wild coho adults (40 females and 24 males) and 252 coho jacks were placed above the trap and into the reservoir. Because the ladder is the only possible route into reservoir, this represents the total number of spawners.

Cascade Creek

The adult trap was installed in the fish ladder in late September 2000, and fished through May 2001. All adult salmonids entering the trap were examined for marks, identified as male or female, and measured for fork length. All fish were given a hole punch in the left operculum to determine if fish were falling back down the waterfall and re-entering the ladder and trap. All hatchery coho were killed. If these fish were bright and in good condition, they were taken to food share, if dark, they were deposited below the trap in the stream. All hatchery steelhead were given a hole-punch in the operculum and released below the falls to provide additional fishery opportunities.

Adult salmonids were trapped as they moved through a fish ladder near the mouth of Cascade Creek. The fish ladder provides passage for adult salmon and steelhead around a waterfall at river kilometer 0.15. The falls are believed to be a complete barrier to upstream migration, so the trap catch should represents the total spawners in the basin. A total of 45 wild coho adults and 10 coho jacks were captured in the Cascade Creek trap (Table 1). Forty five wild adult coho (11 females and 34 males) and 10 wild jack coho were placed above the trap.

West Fork Smith River

The adult trap was operated continuously from September 15, 2000 to May 26, 2001. During October and November, precipitation was below average and stream flows were very low. Few coho salmon or chinook salmon were able to reach or enter the adult trap until stream flows increased slightly in late November. Although fish could not ascend West Fork Smith River early in the migration period, many fish were observed holding in pools in the 1.5km reach below the adult trap.

During higher stream flows in December, accumulation of suspended leaves on the floating barrier weir at the adult trap caused the weir to submerge on two occasions that totaled four days. Most fish that were holding in pools below the trap were able to bypass the trap when the weir was submerged. After December, leaf accumulation on the weir was not a problem and the weir remained an effective barrier to fish passage. Beginning February 2, a small portion of the weir was intentionally submerged to allow downstream passage of post-spawned (kelt) winter steelhead. Although not a complete barrier when operated in this manner, the weir still functioned to trap most returning steelhead.

Run timing into the adult trap was strongly influenced by stream flow. Most chinook entered following the first freshet in late November. A few coho also entered the trap in late November, but most were trapped following a strong freshet in mid-December. Winter steelhead were trapped as early as December, but the peak in run timing occurred during a series of moderate freshets in March. Low to moderate stream flows during most of the spawning period permitted good survey conditions to observe live fish and note whether fish had lost one of two tags applied at the adult trap.

A total of 34 chinook salmon were trapped between October 23 and December 25, 2000, but 79 % of these fish were trapped during the five-day period November 27 to December 1. Only one female chinook salmon entered the trap. One live fish and three carcasses were observed on spawning surveys, but no yellow-tagged chinook salmon were recovered. Although it is likely that some chinook salmon bypassed the trap when the weir was submerged in December, the low incidence of live-fish observation and carcass recovery suggests that run size was small. No estimate of chinook spawners was made.

A total of 126 coho salmon were trapped between November 2, 2000 and February 6, 2001, but most (79 %) were trapped during the nine-day period December 14 to 22. Coho spawners were found in all five major tributaries and all survey reaches (five) on the mainstem, but highest counts occurred in Beaver Creek and in reaches of the mainstem downstream from Crane Creek and upstream from Gold Creek. A population estimate of adult coho salmon spawners (>510mm fork length) was made based on number of yellow-tagged live fish observed on spawning surveys plus those recovered as carcasses. A modified Peterson estimate was made using the formula:

$$N = \frac{(M(1-p^2) + 1)(C+1)}{(R + 1)}$$

where:

N = estimated population above the West Fork Smith trap

M = (99) the number of adult fish yellow-tagged and passed above the trap

C = (502) the number of fish observed (live counts + carcass recoveries) for tags

R = (93) the number of fish observed with yellow tags

p^2 = the probability that a fish lost both yellow tags before being observed

The probability that a fish lost one of the two tags implanted was estimated by the formula:

$$p = n_1 / (2n_2 + n_1)$$

where:

n_1 = (6) the number of fish observed with one yellow tag

n_2 = (87) the number of fish observed with two tags

Using this method, a total of 535 (95% CI= $\pm$277) coho salmon spawned in the West Fork Smith River during the 2000-2001 run year. This estimate includes 241 females, based on the sex ratio of fish that entered the adult trap. Using this estimate of total spawners, trap efficiency for coho salmon was 0.19.

Winter Steelhead entered the trap between December 22, 2000 and May 20, 2001, but most (71.0%) were trapped during the 15 day period March 15 to 29. Steelhead spawners were found in all five major tributaries and all survey reaches (nine) on the mainstem, but highest counts occurred in Gold Creek and in reaches of the mainstem upstream from Moore Creek and upstream from Gold Creek. An estimate of steelhead spawners was made using the same method, where:

M = (269) the number of fish yellow-tagged and passed above the trap

C = (181) the number of fish observed (live counts + carcass recoveries) for tags

R = (158) the number of fish observed with yellow tags (including four fish for which number of tags could not be discerned)

n_1 = (23) the number of fish observed with one yellow tag

n_2 = (131) the number of fish observed with two tags

Using these data, the estimated number of steelhead spawners was 307 (95% CI= $\pm$18). Based on the sex ratio of steelhead trapped at the West Fork Smith trap, 162 females were calculated to have spawned above the trap. Using this estimate of total escapement, trap efficiency for steelhead was 0.88.

Fall Creek

The adult fish trap in Fall Creek began operation during October 2000, but returning coho salmon could not reach the fish ladder and enter the trap until stream flows increased in mid-December. In addition, once stream flow increased, the lower falls (below the fish ladder) became a partial barrier to migration. High stream flows during the previous winter had altered the stream bed and hydrology at the lower falls, and these changes made it difficult for fish to find and negotiate the by-pass channel around the falls. As a result, it was estimated that at least half of the coho salmon that returned to Fall Creek were unable to ascend the lower falls and reach the fish ladder. Following the first freshet event in mid-December, modifications to the stream channel were made to increase flow to the by-pass at the lower falls. These modifications allowed a portion of returning coho spawners to reach and ascend the fish ladder.

A total of 58 coho salmon were trapped in the adult trap during the 11-day period December 15 to 25, 2000. Most of these fish were adult males or jacks; only nine females were trapped.

A total of 37 winter steelhead were trapped in Fall Creek between December 26, 2000 and March 26, 2001. Three male winter steelhead were Ad-LV clipped. These hatchery fish were likely from releases made at the acclimation pond in Big Creek, 12 miles downstream from Fall Creek on the Coos River.

Winchester Creek

The Winchester Creek adult trap was operated continuously from October 1, 2000 to January 14, 2001. A total of 78 coho were trapped, implanted with two Floy tags, and released above the trap. Additionally, one adipose-clipped coho jack was trapped but not passed above the trap, and one jack was trapped and released from the juvenile out-migrant trap (100m below the adult trap) on February 23, 2001. Most fish trapped were male jack coho (1998 brood year); only three females were trapped. Age of larger jacks (510 – 515 mm) was confirmed by scale analysis. Two tagged jacks subsequently swam downstream and were recaptured in the trap, indicating the adult weir was not a total barrier to jacks and that some fish may have passed above the trap uncounted.

Three female chinook salmon were tagged and inadvertently passed above the trap. One male (jack) chinook was not passed. Chinook salmon have not historically used Winchester Creek for spawning and these fish were likely strays from Coos River.

Most coho salmon were trapped during the four-day period December 14-17 that corresponded with the first freshet event. Except for the short interval of higher stream flow in mid-December, low precipitation and very low stream flows were the predominant conditions throughout the trapping period. Because of low stream flows, the trap remained a barrier to all adult fish and the number trapped is equivalent to spawner escapement.

Three spawning surveys were conducted in West Fork Winchester Creek between early December and mid-January, and one survey was conducted on Middle Fork Winchester Creek in late December. One redd was observed in the West Fork, but no live fish or carcasses were observed on any survey. No age-0 fry were observed during spring 2001, either in the West Fork (sampled by electrofishing) or at the downstream migrant trap in lower Winchester Creek, but sampling conducted in fall 2001 in the West Fork did show presence of juvenile coho in low densities.

PART II. DETERMINE FRESHWATER AND MARINE SURVIVAL RATES FOR COHO SALMON

Introduction

The purpose of estimating the freshwater and marine survival rates for coho salmon in Oregon coastal streams is to develop a database of survival information that can be used to monitor the status and trends in population abundance. In addition, this type of information will be useful to determine if any future changes in the status of coho salmon populations are being affected by freshwater or marine environmental conditions. When we refer to freshwater survival rate we include only that part of the life history between egg deposition and arrival at the trap site. This often does not include subsequent residence time in freshwater during migration. Marine survival rate therefore, includes the remaining time in freshwater and estuarine survival.

Methods

To calculate the freshwater survival rate for coho salmon, we estimated the number of eggs placed in redds by the females that spawned in 1999-00. We estimated the fecundity of each female above the N. Fk. Nehalem, Siletz Mill Creek, Yaquina Mill Creek, Cascade Creek, and W. Fk. Smith traps using the following equation where:

Number of eggs = 7.9556 (fork length in mm) -2854.07.

This relationship between length of female coho salmon and fecundity was developed from hatchery fish returning to Fall Creek Hatchery in the Alsea basin (Johnson 1983). Freshwater survival rate for each brood was calculated by dividing the estimated number of smolts produced by the number of eggs that were estimated to be deposited by their parents. To calculate the marine survival rate for coho salmon, the estimated number of adults returning in year t is divided by the estimated smolt abundance in year t-2.

Results and Discussion

Summary statistics used to calculate marine and freshwater survival for coho salmon are shown in Table 4. Freshwater survival rate has ranged from a high of 12.7% for the 1999 brood coho salmon in Winchester Creek to a low of 0.1% for the 1998 brood in Cascade Creek. Marine survival rate has ranged from a high of 10% for the 1995 brood in Yaquina Mill Creek to a low of 0.2% for the 1997 brood in Winchester Creek.

Table 4. The freshwater and marine survival for coho salmon at eight life-cycle monitoring sites.

Stream	Brood Year	Female Spawners	Egg Deposition	Smolts Produced	Returning Adults Male	Returning Adults Female	FW Survival (%)	Marine Survival (%)
Scappoose	1997			1,453	24	17		2.8
	1998			134				
	1999	6	15,892	659			4.1	
	2000	17	44,071					
NF Nehalem	1996			42,427	374	363		1.7
	1997			21,702	284	328		2.8
	1998	447	1,179,267	31,776			2.7	
	1999	568	1,623,341	46,375			2.9	
	2000	389	1,089,021					
Siletz Mill	1995			8,110	30	25		0.7
	1996			9,547	64	83		1.5
	1997	48	95,945	8,409	127	130	8.8	3.1
	1998	25	52,716	4,311			8.2	
	1999	83	204,416	15,475			7.6	
	2000	130	330,551					
Yaquina Mill	1995			1,381	58	80		10.0
	1996			6,698	49	43		1.4
	1997	42	101,674	2,225	24	40	2.2	2.9
	1998	77	206,935	5,599			2.7	
	1999	43	116,500	7,026			6.0	
	2000	40	105,800					
Cascade	1996			1,404	4	5		0.6
	1997	17	37,321	557	34	11	1.5	8.1
	1998	5	10,104	13			0.1	
	1999	5	14,927	1,485			10.0	
	2000	11	28,471					
WF Smith	1996			22,412	160	104		1.2
	1997			10,866	295	243		5.0
	1998			14,663				
	1999	104	291,955	20,091			6.9	
	2000	241	642,747					
Fall	1997			1,681	26	9		2.1
	1998			333				
	1999	11	28,556	3,506			12.3	
	2000	9						
Winchester	1997			2,208				0.2
	1998			3,129				
	1999	14	36,121	4,600			12.7	
	2000	3	8,344					

PART III. TENMILE CREEK WATERSHED RESTORATION STUDY

Introduction

This objective initially involved two separate studies. Both studies combined a treatment and reference stream approach with a pre- and post-project evaluation. The first study (Alsea/Nestucca Winter Habitat Study) involved two treatment streams and two reference streams and was designed to examine the effects of increasing winter habitat on the production of downstream migrant salmonids, particularly coho salmon. This study involved two streams in the Alsea basin, East Fork Lobster Creek and Upper Mainstem Lobster Creek, and two streams in the Nestucca basin, East Creek and Moon Creek, as paired study sites. This study began in 1988 and continued for 8 years. Results are summarized in (Solazzi et al. 1998 and Solazzi et al. 2000).

A second study (Tenmile Watershed Restoration Study) was initiated in 1991 on Tenmile Creek and Cummins Creek, both ocean tributary streams on the central Oregon coast. This study was designed to examine the effects of watershed restoration activities (including the addition of large wood into the stream channel) on the production of downstream migrant salmonids, particularly steelhead and cutthroat trout. Most of the restoration activities in the Tenmile Creek study took place in 1996, and the post-restoration sampling is ongoing. An update of data collected in 2000-2001 is presented here.

Study Area Description

Tenmile Creek was chosen as the treatment stream in the Tenmile Creek Watershed Restoration Study with Cummins Creek as its reference. While these streams have populations of coho salmon, they also produce significant numbers of steelhead and cutthroat trout. Tenmile Creek also has a viable population of chinook salmon. Physical characteristics of the study streams are given in Table 5.

Table 5. Physical characteristics of the two study streams.

Stream	Basin area (km2)	Stream length (km)	Mean summer wetted width (m)	Average gradient (%)
Tenmile Cr.	60.7	24.0	8.5	1.7
Cummins Cr.	24.6	10.0	6.6	2.9

Description of Habitat Modification

Watershed restoration work in the Tenmile basin began in the summer of 1996 as a cooperative project with the US Forest Service (Siuslaw Forest) and local landowners. The U.S. Forest Service decommissioned approximately 12 miles of roads in the watershed, removing culverts and fill to decrease future landslides. Riparian areas were planted with approximately two thousand young conifer trees along approximately 1.6 km of stream. Other streamside riparian areas dominated by hardwood were thinned to increase the growth of existing conifers in the understory. In October of 1996, 240 large conifer trees were transported to the stream channel by helicopter. About 200 of the trees (length of 30 – 35 m, 75 cm butt diameter) were felled on adjacent ridges and placed within the stream channel with limbs attached. The remaining trees were removed from two debris torrent deposits on the road running adjacent to Tenmile Creek. These trees often had rootwads attached, but were generally shorter in length (15 – 20 m) than the felled trees. The trees were placed at 35 different sites throughout reach 3

(133 trees) and the upper portion of reach 2 in the mainstem of Tenmile Creek. Most sites consisted of 3 to 8 large trees placed together to produce accumulations of large wood. Most sites were located in areas near the upper or lower entrances of old side channels, or in natural bends in the stream where large debris would logically accumulate. Trees were not cabled or attached, and no attempt was made to create specific types of habitat (i.e. dam pools) as in the Alsea/Nestucca Winter Habitat Study.

Methods

Summer and Winter Habitat Surveys

In both study streams during August and September of each year, we complete physical habitat surveys. We use the methods described by Hankin and Reeves (1988) to estimate the amount of available habitat (Nickelson et al. 1992). Surface area for each habitat unit in each stream is visually estimated, and every tenth unit is measured to calibrate the visual estimates. In addition, we classify the substrate in each habitat unit by visually estimating the percentage of each category of substrate present. Substrate composition is separated into the following categories: clay (extremely fine sediment that is tightly packed), silt (fine sediment often containing a large proportion of organic material that when disturbed will become suspended in the water column); sand (<0.2 cm); gravel (particles between 0.2 and 6 cm. in diameter); cobble (6 to 25 cm.); small boulders (26 to 100 cm.); large boulders (>100 cm); and bedrock. We also measure the maximum depth of each pool, and estimate the surface area of undercut bank, the percent canopy, and the wood complexity for each habitat unit.

Twice during the pre-restoration period (1991-92, and 1993-94) and once during the post- restoration period (1996-97), we completed winter habitat surveys to determine the amount of winter habitat available for rearing in each stream. These surveys were completed in December and January during moderate winter flow conditions. Another winter habitat survey is planned for the winter of 2000-01.

Estimating Population Size

Estimates are made of the number of young-of-the-year coho salmon, young-of-the-year trout (steelhead and cutthroat combined), age 1+ steelhead trout, and age 1+ cutthroat trout rearing in each stream above the trap sites each year. To estimate the number of fish rearing in the pools, we (1) estimate the mean number of fish per pool by snorkeling every third pool, (2) adjust the mean fish per pool estimate by a calibration factor derived from electrofishing population estimates in a subset of the snorkeled pools, and then (3) multiply this adjusted mean by the total number of pools in the stream (Hankin and Reeves 1988). Snorkel estimates are impractical in habitat with shallow depths. Therefore, we estimate the mean density of fish for a subset of glide, riffle, and rapid habitats by electrofishing. For each habitat type, we then multiplied this mean density by the surface area of this habitat type in the entire stream reach above the trap (Hankin 1984).

We estimate the population size for each species and size group of juvenile salmonid in each sample unit by using either a mark-recapture estimate (Chapman 1951) or a removal estimate with two or more passes (Seber and LeCren 1967). Mark-recapture estimates are generally used in pool habitat that was characterized by high levels of wood complexity or presented special sampling problems where removal estimation methods have been shown to be less accurate (Rodgers et al. 1992). Every habitat unit is blocked by seines on both ends and sampled for juvenile salmonids using 1000-volt D.C. backpack electrofishers. Specific criteria for sampling intensity were established to control the size of the confidence interval derived from the population estimate and to prevent exposing the fish to unnecessary repeated electrofishing. When using the removal method, we continue to sample until we achieved a 50% reduction in the number of fish captured on the previous pass, if the catch on the first pass was fewer than

10 fish. If the catch on the first pass was greater than or equal to 10 fish, then a 66% reduction is required before discontinuing the sampling effort. For the mark-recapture estimates, we attempt to retrieve 50% of the marked fish released.

We divided the Tenmile Creek basin into 6 stream reaches, and the Cummins Creek basin into 3 stream reaches. We make separate estimates of the number of juvenile salmonids rearing in each reach during the summer. We generally sample 5 pools, 10 glides, and 10 riffles in each stream reach.

Estimating the Number of Downstream Migrants

We estimate the number of downstream-migrating juvenile coho salmon, steelhead, cutthroat trout, and chinook salmon in Tenmile and Cummins Creeks each spring using the methods described in the "**Methods for Estimating Abundance of Migrating Juvenile Salmonids**" section of this report.

Results and Discussion

Habitat Modification

In the Tenmile Creek Watershed Restoration Study, the number of key pieces of large wood increased from 21 pieces in reach 3 in pre-restoration surveys to over 150 in the initial post-restoration survey. As a result, the percent of summer pool surface area in reach 3 with high wood complexity increased from an average of 6% in pre-restoration surveys to 12%, 18%, 15%, and 12% in post-restoration surveys completed during the summers of 1997-2000. To date, the total number of pools, the surface area of pools, and the substrate composition have not changed significantly in reach 3 as a whole.

Observations of habitat immediately in the vicinity of selected sites does suggest substrate changes are occurring near the wood accumulations. More detailed analysis of the physical habitat changes that resulted from the restoration work will be completed as more years of post restoration data are collected.

Estimating Fish Populations

Estimates of fish populations in the post- restoration phase of this project are not complete. Results of summer population estimates and spring migrant estimates observed to date are given for both Tenmile and Cummins Creeks in Tables 6 and 7.

Table 6. Summer population estimates of juvenile salmonids in Tenmile and Cummins Creeks during the Tenmile Creek Restoration Study, 1991-2000. Summer population surveys were not done in 2001.

Stream	Year of summer Sampling	Coho Salmon	Cutthroat Trout ≥90mm	Steelhead ≥90mm	0+ trout
Cummins Cr.	1991	1,292	1,177	2,306	6,467
	1992	1,316	1,591	3,010	8,104
	1993	1,079	1,274	2,946	4,646
	1994	1,015	1,281	2,255	7,998
	1995	913	1,502	3,689	9,383
	1996	1,074	1,545	5,002	8,625
	1997	1,646	2,417	4,798	17,927
	1998	863	2,524	7,171	11,132
	1999	0	2,702	5,472	16,717
	2000	209	1,890	6.272	14,156
Tenmile Cr.	1991	8,003	4,023	16,613	79,958
	1992	7,799	3,503	16,324	66,226
	1993	30,663	3,231	18,417	70,664
	1994	3,294	2,540	12,180	54,865
	1995	4,369	2,822	12,818	69,391
	1996	3,783	4,256	19,784	63,193
	1997	4,410	2,412	13,491	59,710
	1998	2,105	2,957	12,204	60,903
	1999	1,198	4,203	11,258	74,337
	2000	4,580	4,409	16,179	72,430

Table 7. Estimates of salmonid smolt production in Tenmile and Cummins Creeks during the Tenmile Creek Restoration Study, 1992-2001.

Stream	Year of spring sampling	Coho salmon smolts	Cutthroat Trout smolts ≥160mm	Steelhead Smolts ≥120mm	Chinook
Cummins Cr.	1992	1,024	36	766	0
	1993	741	35	1,375	0
	1994	1,336	64	1,287	0
	1995	1,065	30	1,274	0
	1996	424	88	2,300	0
	1997	730	127	2,438	0
	1998	2,215	94	1,816	0
	1999	584	162	2,311	0
	2000	7	160	3,206	3,353
	2001	306	89	2,863	0
Tenmile Cr.	1992	5,338	244	5,686	587[a]
	1993	5,229	187	7,876	386[a]
	1994	9,266	123	4,953	583[a]
	1995	1,679	182	2,200	1,013[a]
	1996	2,182	117	4,538	2,821[b]
	1997	2,975	523	7,184	4,120[b]
	1998	5,462	644	11,869	4,841[b]
	1999	1,739	687	7,315	5,667[b]
	2000	1,998	1,434	13,641	21,777[b]
	2001	5,193	2,144	19,883	29,079[b]

[a] Trapping period March 1 - June 30
[b] Trapping period March 1 - August 15

ACKNOWLEDGEMENTS

We would like to thank the following organizations for providing information used in this report: ODFW Aquatic Inventory Project, CLAMS project (USFS), Salem and Coos districts of the BLM, and the Oregon Department of Forestry

REFERENCES

Chapman, D. G. 1951. Some properties of the hypergeometric distribution with applications to zoological sample census. Univ. Calif. Publ. Stat. 1:131-160.

Hankin, D.G. 1984. Multistage sampling designs in fisheries research: Applications in small streams. Can. J. Fish. Aquat. Sci. 41: 1575-1591.

Hankin, D.G., and Reeves, G.H. 1988. Estimating total fish abundance and total habitat area in small streams based on visual estimation methods. Can. J. Fish. Aquat. Sci. 45: 834-844.

Johnson, S. L. 1983. The effects of the 1983 El Nino on Oregon's coho (*Oncorhynchus kisutch*) and chinook (*O. tshawytscha*) salmon. Fish. Res. 6:105-123.

Nickelson, T.E., Rodgers, J.D., Johnson, S.L., and M.F. Solazzi. 1992. Seasonal changes in habitat use by juvenile coho salmon (*Oncorhynchus kisutch*) in Oregon coastal streams. Can. J. Fish. Aquat. Sci. 49:783-789.

Miller, B.A., Rodgers, J.D., and M.F. Solazzi. 2000. An automated device to release marked juvenile fish for measuring trap efficiency. N. Am. J. Fish. Manage. 20:284-287.

Rodgers, J. D., M. F. Solazzi, S. L. Johnson, and M. A. Buckman. 1992. A comparison of three population estimation techniques to estimate juvenile coho salmon populations in small streams. N. Am. J. Fish. Manage. 12:79-86.

Seber, G.A.F., and LeCren, E.D. 1967. Estimating population parameters from catches large relative to the population. J. Anim. Ecol. 36:631-643.

Solazzi, M.F., T.E. Nickelson, S.L. Johnson and J.D. Rodgers. 1998. Final Report: Development and Evaluation of Techniques to Rehabilitate Oregon's Wild Salmonids. Oregon Department of Fish and Wildlife, Fish Research Project F-125-R, Annual Progress Report, Portland.

Solazzi, M.F., T.E. Nickelson, S.L. Johnson and J.D. Rodgers. 2000 Effects of increasing winter rearing habitat on abundance of salmonids in two coastal Oregon streams. Can. J. Fish. Aquat. Sci. 57:906-914.

Thedinga, J.F., M.L. Murphy, S.W. Johnson, J.M. Lorenz, and K.V. Koski. 1994. Determination of Salmonid Smolt Yield with Rotary-Screw Traps in the Situk River, Alaska, to Predict Effects of Glacial Flooding. N. Am. J. Fish. Manage. 14:837-851.