STUDY 2: REHABILITATION OF WILD SALMONIDS THROUGH HABITAT IMPROVEMENT

INTRODUCTION

Over the last 30 years, the use of stream habitat “improvement” or “restoration” techniques by land managers have become common and are now an accepted management technique in the Pacific Northwest (Hall and Baker 1982: Reeves and Roelofs 1982). Various types of habitat restoration techniques aimed at increasing rearing density of salmonids have been tried in Oregon coastal streams. These techniques have included placing structures made of wood, boulder, or concrete across the stream channel, excavating off-channel alcoves, and placing wood and boulders in various configurations into small coastal streams.

To adequately plan and implement effective stream restoration, managers must understand the habitat requirements of the species of interest, the type of habitat that is in the shortest supply, and what technique to use to create the habitat that is needed. Unfortunately, in the few instances where habitat improvements have been evaluated in Pacific Northwest streams, most have relied on fish population data collected only during summer months (Olsen et al. 1984; House and Boehne 1985, 1986; Petrosky and Holubetz 1986; Shirvell 1990). Only occasionally have researchers considered the value of constructed habitat during the winter (Peterson 1985: Everest et al. 1986: Cederholm et al. 1988). In our research (Nickelson et al. 1992a) we have shown that juvenile coho salmon (*Oncorhynchus kisutch*) use different types of habitat at different times of the year, and have suggested that the availability of winter habitat may limit coho salmon smolt production in many Oregon coastal streams. In such streams, habitat restoration projects that do not create good winter habitat will fail to increase the production of coho salmon smolts.

Our approach to studying the effectiveness of instream restoration projects at increasing freshwater production of juvenile salmonids was twofold. First, we elected to complete an extensive sampling program on many Oregon coastal streams to evaluate the effectiveness of existing instream restoration projects. The purposes of this sampling were to: (1) examine the types of rearing habitat created by various habitat improvement techniques; (2) compare the relative effectiveness of the habitat created by these techniques to support juvenile coho salmon during the summer and winter, and; (3) compare the density of juvenile coho salmon in constructed habitats with that of juvenile coho salmon in natural habitats of the same type. This work was published in Nickelson et al. (1992b). The second phase of our research was to complete an intensive sampling effort on a few streams before and after restoration work to determine if the habitat modifications resulted in significant changes in total smolt production. A portion of this work has been submitted for publication.

PHASE 1: Extensive Evaluation of Previously Constructed Habitat

METHODS

Our approach was to sample different types of previously constructed habitat over a broad range of streams to determine: (1) the average density of juvenile coho salmon associated with each type of habitat, and; (2) the extent to which the density varied seasonally. Because we intended that our density estimates reflect the average potential of different types of constructed habitat to support juvenile coho salmon in Oregon coastal streams, we eliminated from our analysis those streams that we judged were underseeded [i.e. those streams having an average summer rearing density of juvenile coho salmon of less than 1.0 fish/m^2 in natural pools (see Nickelson et al. 1992a)].

Between 1986 and 1989, we sampled pools constructed by the U.S. Bureau of Land Management, the USDA Forest Service, and the Oregon Department of Fish and Wildlife in 21 coastal streams. Most of the pools we sampled were created by the construction of structures placed across the full width of the stream channel; the most common technique employed in coastal Oregon streams. Materials used for the construction of these structures included rock-filled gabions (wire baskets), logs or timbers, boulders, a combination of logs and boulders, or concrete. Full-width structures were arranged perpendicular to the channel, diagonal to the channel, or in a downstream “V”. A second category of habitat restoration that we sampled was constructed alcoves, quiet water areas or ponds excavated into the streambank. We also sampled pools created by a variety of log deflectors, and blasting in bedrock. Sampling took place during the summer low-flow period (August-mid October) and during winter following a bank-full flow event (December-mid February). We classified each constructed pool according to type: plunge pool, dammed pool, scour pool, or alcove. Typically, pools created upstream of full-width structures were classified as dammed pools whereas those located downstream of the structure were classified as plunge pools.

We estimated the population size of juvenile coho salmon in each pool by blocking off the pool with seines and conducting a mark-recapture estimate (Chapman 1951) using electrofishing equipment and seines. We estimated the wetted surface area and calculated the density of juvenile coho salmon for each pool. We also estimated the maximum depth, substrate type, percent undercut bank, and amount of wood associated with each pool.

We limited our analysis to constructed alcoves and to dammed pools and plunge pools associated with full-width structures (construction materials combined) because these were the most common and were the only habitats constructed in more than one stream. We used the analysis of variance (ANOVA) to compare the average density among types of constructed pools during the summer. We were unable to make similar comparisons among types of constructed pools during the winter because the variances among the pool types were heterogeneous and large variance was paired with small sample size despite a natural logarithm transformation (see Day and Quinn 1989). To determine whether juvenile coho salmon used constructed pools to the same extent that they used natural pools during summer and winter, we made comparisons with data collected for purposes of describing juvenile coho salmon habitat use (Nickelson et al. 1992a).

We noted that pools associated with constructed structures tended to lack the quality of cover in natural pools of the same type. We therefore designed an experiment to test whether the placement of bundles of small trees (brush bundles) in constructed pools would increase the winter carrying capacity of those pools for juvenile coho salmon. The experiment consisted of (1) sampling pools created by full-width structures during the summer and winter using the methods described above, (2) cabling bundles of two or three small (3-12 m in length) conifer or alder trees (brush bundles) to the streambank of a subset of the pools following a second summer's sampling and (3) sampling during the winter following the brush placement. We sampled 24 pools treated with brush bundles and 17 control pools located in 7 streams. Twenty of the pools were classified as plunge pools and 21 were classified as dammed pools. Sixteen of the pools were created by rock gabions, nine by log sills, eight by boulder berms, six by concrete sills, and two by combination boulder and log berms.

The data from all streams was pooled. Separate comparisons were made for dammed pools, plunge pools, and total pools. Comparisons between treatment and controls were made by analysis of covariance (ANCOVA) (Snedecor and Cochran 1967) using pretreatment densities as the covariate. Comparisons were also made of the mean winter density and mean percentage of the summer population remaining during the winter.

RESULTS AND DISCUSSION

Mean densities of juvenile coho salmon varied among constructed habitats and among seasons (Figure 1). We found no significant difference in mean density of juvenile coho salmon among types of constructed pools during the summer (ANOVA, $p = 0.31$). The mean density in the constructed pools during the summer was similar to that which we found for natural pools (ANOVA, $p=0.93$). Our data suggest (although we were unable to test them statistically) that constructed alcoves support much greater densities of juvenile coho salmon during winter than do either constructed plunge or dammed pools (Figure 1). The mean density of juvenile coho salmon in constructed plunge pools and alcoves during the winter was similar to the density in natural plunge pools and

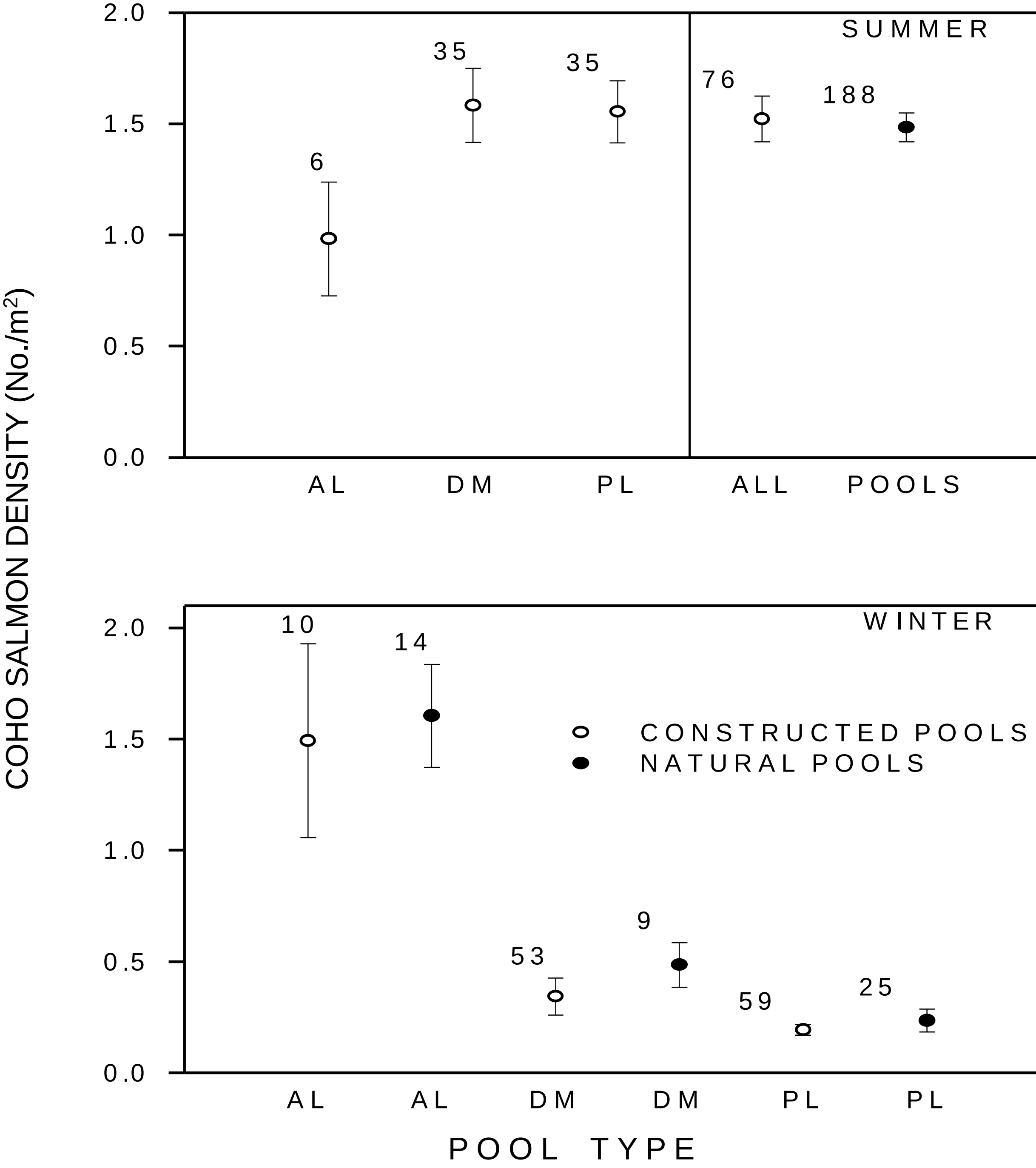

Figure 1. Mean and standard error for density of juvenile coho salmon in constructed and natural pools during summer and winter. AL = alcove; DM = dammed pool; PL = plunge pool (after Nickelson et al. 1992b).

alcoves, respectively (ANOVA, *p*=0.98 and *p*=0.80). However, the mean density of juvenile coho salmon in constructed dammed pools during the winter was significantly less than the mean density in natural dammed pools (ANOVA , *p*=0.04).

Results of the brush bundle experiment showed a significant increase in winter rearing densities when the constructed pools were filled with small trees to increase pool complexity. After adjusting for differences in density of coho salmon during the pretreatment year between pools with and without brush, mean density of coho salmon in pools with brush was significantly greater than those without (ANOVA on transformed data, *p*=0.01, Figure 2). However, these differences occurred in dammed pools (ANOVA on transformed data, *p*=0.02, Figure 2) but not in plunge pools (ANOVA on transformed data, *p*=0.33, Figure 2). The addition of brush increased the mean density of coho salmon in the constructed dammed pools during the winter to a level not significantly different from that of natural dammed pools (ANOVA on transformed data, *p*=0.96).

The construction of full-width structures, the most common habitat restoration technique employed in Oregon coastal streams at the time of the study, resulted in the creation of habitat suitable for rearing of juvenile coho salmon during summer. Constructed alcoves also provided habitat during summer. During summer, coho salmon prefer pool habitat regardless of type (Nickelson et al. 1992a), and we found the density of juvenile coho salmon in constructed pools during the summer to be similar to that of natural pools. However, Nickelson et al. (1992a) suggested that given adequate spawners and adequate water quality, winter habitat may limit production of coho salmon in many Oregon coastal streams. With a few exceptions, (i.e. some deep dammed pools), the constructed full-width structures in this study did not provide good overwinter habitat. Throughout their range, juvenile coho salmon prefer low velocity areas for overwintering (Tschaplinski and Hartman 1983; Hartman and Brown 1987; Cederholm et al. 1988; Shirvell 1990; Nickelson et al. 1992a). It was not surprising then to observe low densities of juvenile coho salmon in constructed plunge pools during the winter, just as we had observed low densities of juvenile coho in natural plunge pools during the winter (Nickelson et al. 1992a). We found the mean density of juvenile coho salmon in constructed dammed pools above full-width structures was less than we observed in natural dammed pools (Figure 1). There was a wide range of rearing densities in the constructed dammed pools however. Six of the constructed dammed pools had a winter density greater than 1.0 fish /m^2, but the remaining 47 constructed dammed pools had a winter rearing density of less than 0.5 fish/m^2. The few constructed dammed pools that supported the high density of coho salmon in the winter were significantly deeper than those with low densities of coho salmon. Because the area above a full-width structure is a natural deposition area (Reeves and Roelofs 1982), many dammed pools will become shallow through time. Our results suggest that constructed dam pools should contain scour logs or boulders to maintain depth in a portion of the pool if it is to be used for winter rearing. By adding bundles of small trees to constructed dammed pools, we were able to increase the density of coho salmon in the pools during the winter,

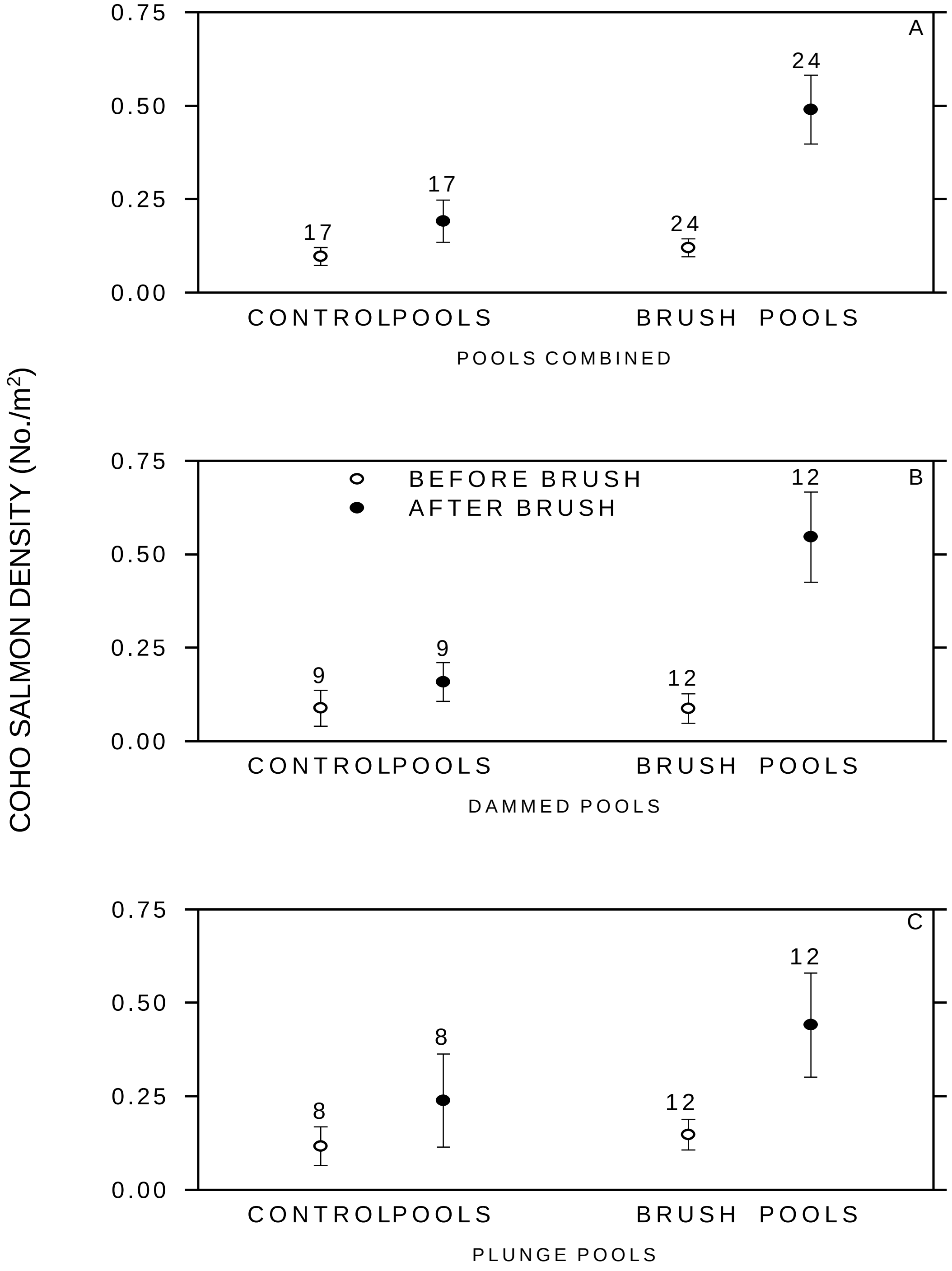

Figure. 2. Mean and standard error for winter density of juvenile coho salmon in constructed pools in the years before and after the addition of brush. The comparisons are between control pools, which received no brush, and brush pools, to which brush was added in the second year, for (A) all pools combined, (B) dammed pools, and (C) plunge pools. (after Nickelson et al. 1992b).

presumably by decreasing water velocities at high stream flows and providing cover at low stream flows. However, we could detect no effect of adding brush bundles to constructed plunge pools. This may be because plunge pools, by nature, are turbulent, and the brush bundles failed to reduce turbulence and velocity at high stream flows. Most constructed alcoves did provide winter habitat for juvenile coho salmon. We found the density of juvenile coho salmon in constructed alcoves in the winter to be greater than that in constructed dammed pools and plunge pools, and similar to that observed in natural alcoves (Nickelson et al. 1992a). While most of the constructed alcoves supported a high density of juvenile coho salmon, a few supported almost no fish at all. The large variation in density can partially be explained by the variability in the characteristics of the stream channel accessing the alcove. When the access channel had adequate depth and flow and the entrance to the channel was open, we found the density of juvenile coho salmon to be higher than when the channel was shallow, partially obstructed with debris or sediment, or had low or diffuse flow into the mainstem.

PHASE 2: Intensive Evaluation of Salmonid Smolt Production Before and After Habitat Restoration

INTRODUCTION

We designed and implemented 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 of this study have been submitted for publication.

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.

STUDY AREA DESCRIPTION

Upper Mainstem Lobster Creek and East Creek were chosen as study streams in the Alsea/Nestucca Winter Habitat study. These streams are low to moderate in gradient and consist primarily of sandstone, typical of many Oregon coastal streams where juvenile coho salmon rear during the freshwater portion of their life history. Tenmile Creek was chosen as the treatment stream in the

Tenmile Creek Watershed Restoration Study. Tenmile Creek and its reference stream, Cummins Creek, consist primarily of basalt. While these streams have populations of coho salmon, they also produce significant numbers of steelhead and cutthroat trout. Physical characteristics of the six study streams are given in Table 1.

Table 1. Physical characteristics of the six study streams.

Stream	Basin Area (km^2)	Stream Length (km)	Mean summer wetted width (m)	Average gradient (%)
Alsea Basin:				
E.F. Lobster Cr.	14.2	3.5	3.5	4.0
U.M. Lobster Cr.	12.4	4.7	3.2	2.6
Nestucca Basin				
Moon Cr.	13.2	3.8	3.6	1.8
East Cr.	17.5	5.0	4.0	2.4
Tenmile Cr.	60.7	24.0	8.5	1.7
Cummins Cr.	24.6	10.0	6.6	2.9

DESCRIPTION OF HABITAT MODIFICATIONS

Alsea/Nestucca Winter Habitat Study

The habitat modification was completed during the summer of 1990 in East Creek (Nestucca basin) and during the summer of 1991 in Upper Mainstem Lobster Creek (Alsea basin). Work on both streams was funded and constructed by the U.S. Bureau of Land Management (BLM) in consultation with the Oregon Department of Fish and Wildlife. The total cost was about $80,000. A track hoe was used to place full spanning logs into the stream channel (to create large dam pools) and to excavate off-channel rearing ponds (alcoves). Erosion cloth and chain link fence were attached to the upstream side of most full spanning logs to reduce undercutting. Most of the large logs were anchored to the substrate with rebar. Large wood was added to each dam pool to act as scour agents. Rootwads and smaller trees were added to increase habitat complexity within the pools.

Sites for alcove construction were selected by using natural springs or seeps whenever possible. Full spanning logs were generally placed immediately below the mouth of the alcove to insure that water flooded the entrance. We created 23 dam pools and 8 alcoves in Upper Mainstem Lobster Creek throughout a 3.2 kilometer reach. Twenty-nine dam pools and 13 alcoves were constructed in East Creek throughout a 2.4 kilometer reach.

Tenmile Creek Watershed Restoration Study

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 each of the six study streams during August and September of each year, we completed physical habitat surveys. We used the methods described by Hankin and Reeves (1988) to estimate the amount of available habitat, as described by Nickelson et al. (1992a). Surface area for each habitat unit in each stream was visually estimated, and every tenth unit was measured to calibrate the visual estimates. In addition, we classified the substrate in each habitat unit by visually estimating the percentage of each category of substrate present. Substrate composition was 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 measured the maximum depth of each pool, and estimated the surface area of undercut bank, the percent canopy, and the wood complexity for each habitat unit.

Twice during the pre-restoration period and twice during the post-restoration period, 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.

Estimating Population Size

Estimates were 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) estimated the mean number of fish per pool by snorkeling every third pool, (2) adjusted 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) multiplied this adjusted mean by the total number of pools in the stream (Hankin and Reeves 1988). Snorkel estimates were impractical in habitat with shallow depths. Therefore, we estimated 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 estimated 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 were 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 was 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 continued 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 was required before discontinuing the sampling effort. For the mark-recapture estimates, we attempted to retrieve 50% of the marked fish released.

In the Alsea/Nestucca Winter Habitat Study, we generally sampled 10 pools, 10 glides and 10 riffles and rapids in each stream. In the Tenmile Creek Watershed Restoration Study, both the treatment stream (Tenmile Creek) and the reference stream (Cummins Creek) covered more stream miles. We therefore divided the Tenmile Creek basin into 6 stream reaches, and the Cummins Creek basin into 3 stream reaches. We made separate estimates of the number of juvenile salmonids rearing in each reach during the summer. We generally sampled 5 pools, 10 glides, and 10 riffles in each stream reach.

Estimating the Number of Downstream Migrants

Alsea/Nestucca Winter Habitat Study

We estimated the number of downstream-migrating coho salmon ($\geq$70 mm), steelhead ($\geq$90 mm), and cutthroat trout ($\geq$90 mm) in each stream, each spring for 8 years based on numbers of juvenile salmonids captured by modified incline plane traps (McLemore et al. 1989). Sampling began by the first week in March and continued until we no longer captured any fish, usually by 1 June. Traps generally operated 24 hours per day and were monitored daily. Captured fish were removed daily from the trap and anesthetized with buffered MS-222. We measured up to 25 juvenile coho salmon to the nearest mm fork length each week.

Up to 25 fish from each species were removed from the trap each day, given a caudal fin notch mark and released into an area of quiet water 50 to 100 m above the trap site. Marked fish were usually released just before sunset each evening. Weekly trap efficiency estimates were calculated by dividing the number of marked fish re-captured by the number of marked fish released each week.

The total number of unmarked fish captured was divided by the estimated trap efficiency to estimate the number of fish passing the trap site each week. Weekly estimates were summed to estimate the total number of fish passing the trap site each spring. We used a bootstrap method (Efron and Tibshirani 1986) to estimate the variance for each weekly population estimate for coho salmon. The variance from each week was summed to estimate the variance for the total number of migrants passing the trap site. Because of the low numbers of trout migrants captured, we did not attempt to calculate weekly variance estimates for these species. A population estimate for trout was calculated by dividing the total number of trout captured during the trapping season by the seasonal trap efficiency estimate.

A bootstrap method was then used to estimate the variance for the seasonal steelhead and cutthroat trout population estimates. Ninety-five percent confidence intervals were estimated for each species based on the variance estimates. An overwinter survival rate for coho salmon was calculated by dividing the estimate of the total number of coho salmon migrating past the trap site each season by the summer population estimate.

Tenmile Creek Watershed Restoration Study

Sampling protocols to determine the number of downstream migrants were the same in this study with the following exceptions. Estimates of steelhead trout migrants were made for the following size categories: 60-89mm, 90-119mm and ≥ 120mm. Only steelhead migrants in the ≥ 120mm size category showed physical characteristics associated with seaward migration (silvering, loss of condition) and were classified as steelhead smolts. Estimates of cutthroat trout migrants were made for the following size categories: 60-89mm, 90-119mm and 120-159mm, and ≥ 160mm. Only cutthroat migrants in the ≥ 160mm size category showed physical characteristics associated with seaward migration (silvering, loss of condition) and were classified as searun cutthroat smolts. Because Tenmile has a population of chinook salmon, we also estimate the number of downstream migrant chinook each spring and summer.

Downstream migrants are captured in rotating screw traps at the mouth of Tenmile Creek and Cummins Creek, as opposed to the modified incline plane traps used in the Alsea/Nestucca Winter Habitat Study. Trapping begins in early March in each stream. Trapping is discontinued in Cummins Creek in mid-June, when downstream migrants are no longer caught. Trapping continues in Tenmile Creek until late July in order to estimate chinook migrants out of the basin. Fish used in trap efficiency experiments are usually marked with a Panjet Marking Instrument rather than marked with a caudal notch.

Analysis

Alsea/Nestucca Winter Habitat Study

A two-way analysis of variance (ANOVA) was used to examine treatment effects on the coho salmon summer population estimate and overwinter survival rate, and on the number of downstream-migrant coho salmon, steelhead, and cutthroat trout produced. We did not compare overwinter survival rate or the summer population estimates for trout because both populations contained several different year classes. In the Alsea study streams, we compared the 1986-1989 brood year estimates for the pre- treatment period with the 1990-1993 brood year estimates for the post-treatment period. In the Nestucca study streams, we compared the 1986-1988 brood year estimates as pre-treatment with the 1989-1993 brood year estimates as the post-treatment period.

Tenmile Creek Watershed Restoration Study

A similar design and analysis will be completed for the Tenmile Creek Watershed Restoration Study when the post-restoration sampling is completed.

RESULTS AND DISCUSSION

Habitat Modification: Alsea/Nestucca Winter Habitat Study

In the Alsea/Nestucca Winter Habitat Study, the habitat modification project increased the amount of dammed pool and alcove surface area and decreased the amount of rapid, riffle and glide surface area in both treatment streams during winter (Fig. 3). Changes in habitat composition resulting from the modification project increased the amount of habitat available for winter rearing of juvenile salmonids by providing an increased amount of refuge area with low water velocities during high discharge events (dammed pools and alcoves). Alcoves located out of the main channel have slow velocities. The addition of large amounts of woody debris to the main channel dammed pools helped to reduce velocities in those habitats.

Habitat Modification: Tenmile Creek Watershed Restoration Study

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

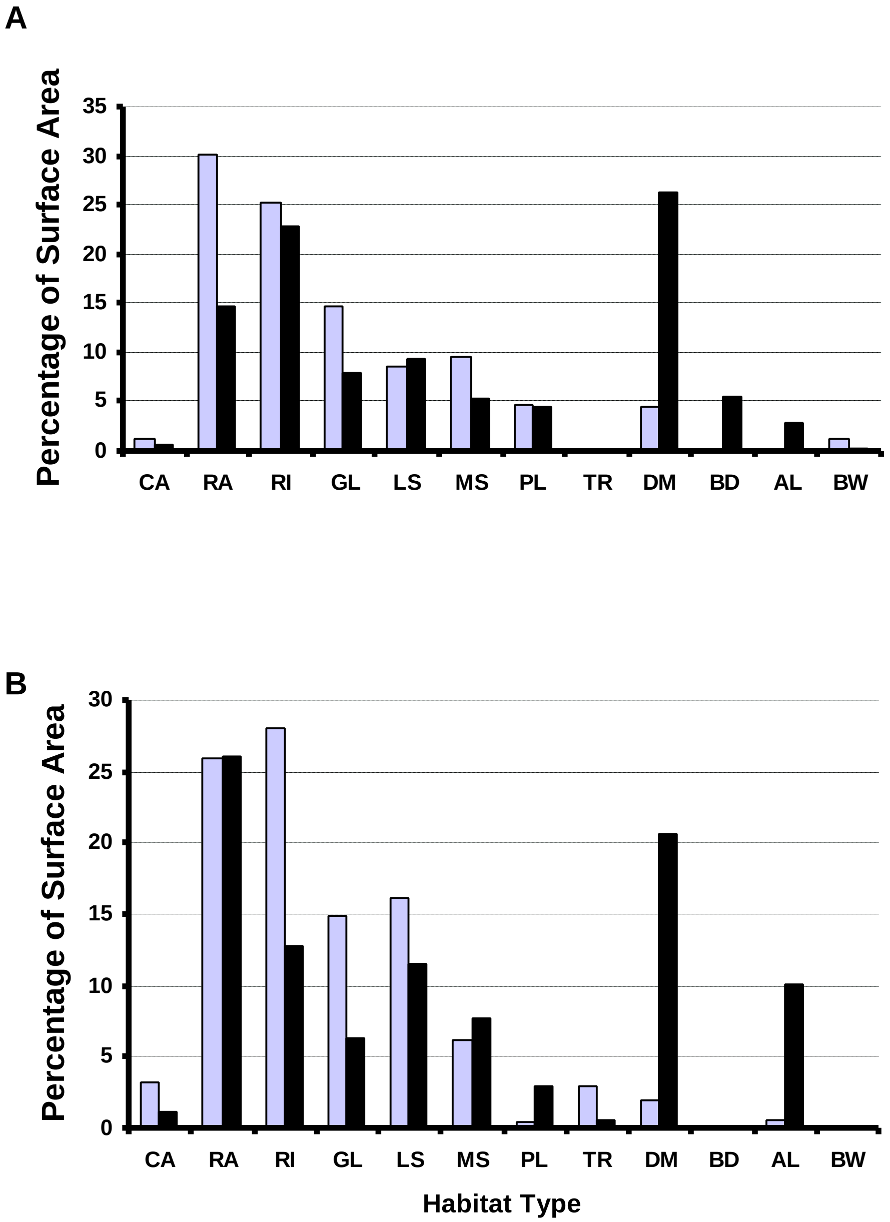

Figure 3. Percentage of surface area by habitat type during winter for the treatment streams, pre- (light bars) and post-treatment (dark bars). (A) Alsea treatment stream; (B) Nestucca treatment stream. Habitat types are arranged from fastest to slowest water velocities. CA = cascade; RA = rapid; RI = riffle; GL = Glide; LS = lateral scour pool; MS = mid-channel scour pool; PL = plunge pool; TR = trench pool; DM = dammed pool; BD = beaver pond; AL = alcove; BW = backwater pool.

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% and 18% in post-restoration surveys completed during the summers of 1997 and 1998. 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 physical habitat changes resulting from the restoration work will be completed as more years of post restoration data are collected.

FISH POPULATIONS

Alsea/Nestucca Winter Habitat Study

Summer population size of juvenile coho salmon did not change significantly in either Upper Lobster Creek (*p*=0.24) or East Creek (*p*=0.44) treatment stream during the post-treatment period compared to the pre-treatment period (Table 2). However, the number of age 1+ coho salmon smolts migrating downstream each spring during the post-treatment period did increase compared to the pre-treatment period in both Upper Lobster Creek (*p*=0.006) and East Creek (*p*=0.012) treatment streams. The overwinter survival rate increased about three-fold in the treatment streams during the post-treatment period compared to the pre-treatment period. The overwinter survival rate for coho salmon was highest the first year after habitat modification (50% in Upper Lobster Creek and 52% in East Creek), and in the remaining post-treatment years averaged approximately 35% in both streams, remaining fairly constant through the conclusion of the experiment (Table 2). Overwinter survival did not change significantly in the reference streams (E. F. Lobster Creek *p*= 0.58; Moon Creek *p*=0.21).

Average fork length of coho salmon migrants was not different between the pre-treatment and post-treatment periods in either Upper Lobster Creek (*p*=0.44) or East Creek (*p*=0.33) treatment streams. The average fork length of coho salmon in both streams was greatest the first year after the habitat modification work was completed (Table 2). This was at first thought to be related to increased food availability caused by the physical disturbance of the streambed and surrounding vegetation during the construction phase of the project. However, upon further review, it appears that the large size in the year of habitat modification was probably the result of improved growth associated with low summer density. Average length of coho migrants in the four study streams was related to density of parr the previous summer (*p*<0.001).

The average number of downstream migrant steelhead greater than 90mm increased significantly in both treatment streams (Upper Lobster Creek *p*= 0.007; East Creek *p*=0.02) during the post-treatment period compared to the pre-treatment period (Table 3). Changes in average number of steelhead migrants in the reference streams were not significant (E. F. Lobster Creek *p*= 0.61; Moon Creek *p*=0.46).

Table 2. Population parameters for coho salmon in the Alsea and Nestucca study streams. Data shown in bold type represent the post-treatment years.

Stream	Brood Year	Adult Spawners	Summer Population	95% CI	Spring Migrants	95% CI	Mean Length	SE	Over-winter Survival
E. F. Lobster Cr.	1986	159			1,178	149	83.1	0.83	
(Reference)	1987	90	11,462	11,650	2,691	271	82.0	0.85	0.23
	1988	302	13,694	9,319	2,554	223	80.3	0.72	0.19
	1989	154	19,278	11,536	1,975	130	81.1	0.68	0.10
	1990	32	9,964	4,693	**2,291**	**154**	**83.0**	**0.67**	**0.23**
	1991	21	**7,716**	**3,126**	**1,983**	**226**	**87.9**	**0.61**	**0.26**
	1992	272	**15,842**	**5,739**	**3,117**	**214**	**82.0**	**0.66**	**0.20**
	1993	20	**6,432**	**3,036**	**757**	**105**	**89.0**	**0.70**	**0.12**
Pre-Treatment Average			13,600		2,100		81.6		0.17
Post-Treatment Average			**9,997**		**2,037**		**85.5**		**0.20**
U. M. Lobster Cr.	1986	31			1,337	212	88.0	0.76	
(Treatment)	1987	32	10,667	8,386	832	253	85.7	0.91	0.08
	1988	22	6,406	4,144	904	96	89.3	0.80	0.14
	1989	40	18,161	8,061	2,925	141	79.7	0.59	0.16
	1990	9	7,633	4,182	**3,800**	**190**	**94.0**	**0.78**	**0.50**
	1991	11	**8,819**	**3,682**	**2,607**	**177**	**89.4**	**0.51**	**0.30**
	1992	284	**23,012**	**9,672**	**8,663**	**364**	**82.0**	**0.64**	**0.38**
	1993	47	**15,486**	**6,482**	**5,459**	**283**	**88.0**	**0.67**	**0.35**
Pre-Treatment Average			10,717		1,500		85.7		0.13
Post-Treatment Average			**15,772**		**5,132**		**88.4**		**0.38**
Moon Cr.	1986				343	205	101.6	0.99	
(Reference)	1987		3,627	2,267	908	204	92.4	0.94	0.25
	1988	23	4,215	3,440	553	108	100.5	0.80	0.13
	1989	7	1,635	906	**396**	**118**	**95.7**	**0.83**	**0.24**
	1990	4	**455**	**607**	**35**	**49**	**107.9**	**1.78**	**0.08**
	1991	5	**1,616**	**1,313**	**184**	**99**	**97.7**	**1.43**	**0.11**
	1992	11	**2,763**	**1,356**	**146**	**85**	**99.0**	**1.34**	**0.05**
	1993	14	**1,048**	**827**	**27**	**43**	**109.0**	**1.85**	**0.03**
Pre-Treatment Average			3,159		601		98.2		0.19
Post-Treatment Average			**1,471**		**158**		**101.9**		**0.10**
East Cr.	1986				752	147	107.9	0.79	
(Treatment)	1987		7,929	5,249	722	165	97.0	0.98	0.09
	1988	42	9,376	5,179	1,210	323	95.3	0.80	0.13
	1989	15	2,883	1,931	**1,485**	**182**	**121.1**	**0.71**	**0.52**
	1990	1	**2,648**	**1,733**	**1,090**	**253**	**110.7**	**0.79**	**0.41**
	1991	23	**7,406**	**3,397**	**2,504**	**299**	**97.8**	**0.68**	**0.34**
	1992	20	**7,078**	**3,493**	**2,520**	**299**	**100.0**	**1.64**	**0.36**
	1993	9	**4,613**	**2,003**	**1,456**	**213**	**104.0**	**0.75**	**0.32**
Pre-Treatment Average			6,729		895		100.1		0.11
Post-Treatment Average			**5,436**		**1,811**		**106.7**		**0.39**

Table 3. Population parameters for steelhead in the Alsea and Nestucca study streams. Data shown in bold type represent the post-treatment years.

Stream	Brood Year	Summer Population	95% CI	Spring Migrants	95% CI	Mean Length	SE	Sample Size
E. F. Lobster Cr.	1986			49	73	109	5.0	13
(Reference)	1987	530	522	3	-	91	0.0	1
	1988	792	792	41	59	111	4.3	9
	1989	474	804	55	80	102	3.5	10
	1990	543	277	**46**	**35**	**107**	**4.7**	**22**
	1991	**363**	**348**	**148**	**116**	**104**	**1.7**	**38**
	1992	**672**	**372**	**24**	**32**	**110**	**3.4**	**13**
	1993	**468**	**360**	**25**	**38**	**99**	**2.8**	**11**
Pre-Treatment Average		585		37		103		
Post-Treatment Average		**501**		**61**		**105**		
U. M. Lobster Cr.	1986			9	5	88	0.8	4
(Treatment)	1987	437	573	0	-	0	0.0	0
	1988	248	480	20	16	101	3.1	5
	1989	766	838	42	65	116	3.7	13
	1990	235	452	**274**	**172**	**110**	**1.7**	**65**
	1991	**216**	**301**	**245**	**386**	**116**	**3.3**	**35**
	1992	**148**	**123**	**114**	**67**	**113**	**3.3**	**42**
	1993	**150**	**220**	**38**	**59**	**119**	**5.2**	**10**
Pre-Treatment Average		422		18		102		
Post-Treatment Average		**171**		**168**		**115**		
Moon Cr.	1986			109	142	109	6.8	13
(Reference)	1987	805	753	211	271	100	1.8	39
	1988	709	1,047	313	441	110	4.2	25
	1989	1,227	645	**20**	**21**	**93**	**0.8**	**5**
	1990	**826**	**620**	**310**	**229**	**106**	**2.4**	**62**
	1991	**539**	**382**	**138**	**223**	**101**	**2.7**	**25**
	1992	**1,788**	**1,064**	**121**	**184**	**98**	**1.6**	**23**
	1993	**1,338**	**645**	**72**	**112**	**103**	**0.5**	**16**
Pre-Treatment Average		914		211		106		
Post-Treatment Average		**1,123**		**132**		**100**		
East Cr.	1986			95	157	111	5.2	18
(Treatment)	1987	930	1,376	55	76	110	7.6	10
	1988	1,130	1,184	63	37	107	7.7	7
	1989	867	753	**453**	**820**	**121**	**3.4**	**42**
	1990	**1,147**	**1,062**	**536**	**269**	**110**	**2.0**	**103**
	1991	**1,382**	**535**	**484**	**833**	**109**	**2.3**	**45**
	1992	**2,250**	**1,080**	**121**	**23**	**101**	**1.8**	**32**
	1993	**921**	**492**	**126**	**177**	**116**	**4.7**	**28**
Pre-Treatment Average		976		71		109		
Post-Treatment Average		**1,425**		**344**		**111**		

Table 4. Population parameters for cutthroat and age 0+ trout in the Alsea and Nestucca study streams. Data shown in bold type represent the post-treatment years.

	Cutthroat Trout								0+ Trout	
Stream	Brood Year	Summer Population	95% CI	Spring Migrants	95% CI	Mean Length	SE	Sample Size	Summer Population	95% CI
E. F. Lobster Cr.	1986			71	116	131	3.5	16		
(Reference)	1987	368	457	358	578	126	4.4	37	5,098	5,292
	1988	961	744	128	123	127	3.7	34	2,279	1,720
	1989	1,811	1,774	255	171	128	2.4	52	2,837	3,546
	1990	686	608	**246**	**104**	**128**	**3.0**	**73**	3,490	638
	1991	**1,255**	**1,391**	**583**	**192**	**128**	**2.1**	**146**	**3,096**	**1,091**
	1992	**2,793**	**1,732**	**738**	**289**	**121**	**2.2**	**135**	**2,298**	**1,200**
	1993	**998**	**556**	**224**	**387**	**121**	**4.0**	**34**	**2,278**	**842**
Pre-Treatment Average		957		203		128			3,426	
Post-Treatment Average		**1,682**		**448**		**125**			**2,557**	
U. M. Lobster Cr.	1986			118	386	136	4.3	21		
(Treatment)	1987	338	496	25	25	121	6.2	5	2,916	2,449
	1988	596	798	71	101	127	5.4	12	3,242	2,723
	1989	792	880	269	134	131	3.1	73	2,288	1,544
	1990	525	631	**719**	**174**	**135**	**1.9**	**193**	1,776	871
	1991	**1,268**	**1,218**	**382**	**143**	**141**	**3.0**	**87**	**2,951**	**1,420**
	1992	**3,337**	**2,209**	**579**	**138**	**132**	**2.4**	**176**	**1,327**	**710**
	1993	**729**	**1,033**	**606**	**200**	**119**	**5.2**	**10**	**2,562**	**1,505**
Pre-Treatment Average		563		121		128			2,556	
Post-Treatment Average		**1,778**		**572**		**132**			**2,280**	
Moon Cr.	1986			264	496	125	4.1	34		
(Reference)	1987	396	591	176	223	127	5.4	33	7,916	4,484
	1988	644	1,785	192	328	118	5.7	24	7,029	4,469
	1989	896	1,045	**20**	**21**	**109**	**11.5**	**5**	8,760	3,963
	1990	**485**	**1,213**	**170**	**209**	**142**	**6.3**	**34**	**7,508**	**2,645**
	1991	**395**	**254**	**289**	**396**	**129**	**5.1**	**24**	**9,398**	**2,905**
	1992	**872**	**681**	**81**	**75**	**97**	**6.0**	**18**	**8,538**	**2,851**
	1993	**585**	**592**	**42**	**41**	**107**	**9.6**	**10**	**7,209**	**1,735**
Pre-Treatment Average		645		211		123			7,902	
Post-Treatment Average		**584**		**120**		**117**			**8,163**	
East Cr.	1986			133	98	133	3.4	39		
(Treatment)	1987	1,369	1,796	72	124	132	5.2	16	8,137	5,258
	1988	704	835	121	119	146	7.1	11	5,249	4,026
	1989	903	681	**603**	**969**	**153**	**4.1**	**43**	3,227	1,333
	1990	**716**	**890**	**541**	**738**	**150**	**5.2**	**31**	**9,556**	**7,644**
	1991	**1,251**	**708**	**367**	**446**	**143**	**3.5**	**49**	**5,663**	**1,552**
	1992	**2,204**	**1,408**	**192**	**29**	**129**	**4.7**	**40**	**7,277**	**1,950**
	1993	**1,563**	**1,057**	**336**	**551**	**136**	**4.2**	**45**	**4,251**	**1,074**
Pre-Treatment Average		992		109		137			5,538	
Post-Treatment Average		**1,434**		**408**		**142**			**6,687**	

The average number of downstream migrant cutthroat trout larger than 90mm significantly increased in both treatment streams (Upper Lobster Creek *p*= 0.003; East Creek *p*=0.004) during the post-treatment period compared to the pre-treatment period (Table 4). Changes in the average number of cutthroat trout migrants in Moon Creek were not significant (*p*=0.31). However, average number of cutthroat trout migrants in E. F. Lobster Creek did increase (*p*=0.06), although only a doubling compared to a five-fold increase in the treatment stream (Table 4).

Although the habitat modification was designed to improve winter habitat for coho salmon, the increased slow-water habitat and stream complexity also benefited juvenile steelhead and cutthroat trout. Despite replacement of fast-water habitat, typically associated with trout fry during spring and summer (Hartman 1965) by pool habitat (Fig. 2), the summer populations of trout fry in the treatment streams did not change significantly (Upper Lobster Creek *p*= 0.69; East Creek *p*=0.42). However, upper age class steelhead and cutthroat trout migrant populations did increase. This suggests that winter habitat was limiting their abundance and that the habitat modifications increased the capacity of the streams to produce steelhead and cutthroat trout.

Tenmile Creek Watershed Restoration Study

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 5 and 6. Estimates of steelhead trout smolts and searun cutthroat trout smolts were higher in the spring of 1998 than any estimates made during the pre-restoration years. Additional years of sampling are needed to see if this trend continues.

Table 5. Summer population estimates of juvenile salmonids in Tenmile and Cummins Creeks during the Tenmile Creek Restoration Study, 1991-98. Post-restoration sampling will continue in future years.

Stream	Year of Summer Sampling	Coho Salmon	Cutthroat Trout ≥90mm	Steelhead ≥90mm	0+ Trout
Cummins Creek	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
Tenmile Creek	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

Table 6. Estimates of salmonid smolt production in Tenmile and Cummins Creeks during the Tenmile Creek Restoration Study, 1992-98. Post-restoration sampling will continue in future years.

Stream	Year of Spring Sampling	Coho Salmon Smolts	Cutthroat Trout Smolts ≥160mm	Steelhead Smolts ≥120mm	Chinook
Cummins Creek	1992	1,023	50	786	-
	1993	738	56	1,424	-
	1994	1,435	106	1,623	-
	1995	1,076	40	1,167	-
	1996	475	142	2,303	-
	1997	674	223	2,790	-
	1998	2,215	110	1,816	-
Tenmile Creek	1992	5,442	429	6,312	557 a
	1993	5,260	350	7,817	381 a
	1994	9,234	259	5,420	527 a
	1995	1,729	324	2,342	700 a
	1996	2,230	215	4,652	2,773 b
	1997	2,952	632	7,334	4,046 b
	1998	5,462	813	11,869	4,841 b

(a) Trapping period March 1- June 30
(b) Trapping period March 1 – August 15

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