THE OREGON PLAN *for Salmon and Watersheds*

Oregon Coast Coho Habitat Assessment 1998-2003

Report Number: OPSW-ODFW-2005-5

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Executive Summary

In 1997 the Oregon Coastal Restoration Initiative (OCSRI 1997) identified the quality of stream habitat as a potential factor influencing the decline of coho salmon (*Oncorhynchus kisutch*) in Oregon coastal streams. In 1998 the Oregon Department of Fish and Wildlife (ODFW) implemented a monitoring program that utilizes a random, spatially balanced survey design to provide statistically rigorous information on the status and trend of habitat conditions in Oregon coastal streams. At the same time, ODFW implemented a monitoring program designed to provide information on the effectiveness of habitat restoration projects.

In this report, the status and trend of instream physical habitat conditions in the Oregon Coastal coho ESU are assessed from ten variables collected by the ODFW habitat monitoring program from 1998-2003. Habitat conditions are described at the scale of the ESU, four monitoring areas within the ESU, and by four land use categories (agriculture, urban, private forest, and public forest). The condition of habitat is compared among monitoring areas or land use categories. In addition, the habitat condition at random survey sites is compared to that at sites with minimal human disturbance (i.e. reference sites). Finally, the condition of instream physical habitat at habitat restoration sites before and after habitat restoration is evaluated.

The range of values for each habitat variable is extensive and is influenced by geomorphic setting, and the natural and anthropogenic history of each stream. As a result, our ability to detect trends in habitat from 1998 through 2003 is minimal. However, sensitivity analyses indicate that 15 years of data (eight years from the time of this writing) will greatly improve our ability to detect habitat changes.

Our analysis of the current status of instream physical habitat suggests that, relative to reference conditions, streams in the Oregon Coastal coho ESU have higher levels of fine sediment and lower levels of large wood. Compared to other monitoring areas in the ESU, the Umpqua has the poorest habitat quality, ranking poorest in 9 out of 10 physical habitat variables. Although habitat conditions differ by land use category, it is difficult to isolate the effects of watershed position, geomorphology from human induced habitat conditions.

In an attempt to address habitat deficiencies, a total of 451 miles of instream habitat restoration was conducted in the ESU from 1997-2003. Monitoring of a subset of these restoration sites by ODFW indicates that restoration is improving stream complexity by the addition of large wood. However, compared to reference sites, "restored" streams are deficient in total wood volume and have excessive fine sediment. The long-term response of streams to restoration is still being evaluated.

Introduction

In November 2003, the State of Oregon began a comprehensive review of coho and their habitat in NOAA Fisheries' Oregon Coastal Coho Evolutionary Significant Unit (ESU). The purpose of the review is threefold: 1) provide an analysis of the current status and trend in coho populations, their habitat, and related threats; 2) provide NOAA Fisheries with information it requires to determine whether formalized conservation efforts within the ESU justify not listing coho under the Endangered Species Act as outlined in their Policy for Evaluation of Conservation Efforts; and 3) provide information to state agencies, watershed councils, and others participating in the Oregon Plan for Salmon and Watersheds (OPSW) so they may assess the success of their OPSW programs and modify them where necessary to better achieve their objectives (i.e. adaptive management). This report describes the current status and trend of instream physical habitat for coho in the ESU as well as summarizes and evaluates instream habitat restoration activities conducted from 1997-2003.

Geomorphology, Land use, and Quality of Instream Physical Habitat to Survival of Coho

Coho spawn in moderate gradient (1-5%), small to medium size (4-20 m wide) streams in Oregon's coastal drainages from October through February. To protect newly fertilized eggs from predation and mortality associated with displacement by high winter stream flows, spawning female coho seek gravel that is large enough to provide protection to their offspring, yet small enough for them to successfully dig a spawning bed, deposit their fertilized eggs, and cover the eggs with gravel. A coho female needs approximately 2.8 m^2 of gravel that is 1.3 to 10.2 cm in diameter to successfully spawn (Reiser and Bjornn 1979).

Fertilized eggs remain in the gravel for up to four months, depending on water temperature, before they hatch. The newly hatched alevins remain in the gravel for up to one month as they absorb their yolk sacs and emerge from the spawning gravel as fry. For successful egg to fry survival, fertilized eggs and alevins require oxygen rich water. Fine sediment can reduce the flow of oxygenated water in the spawning gravel and decrease egg to parr survival rates (Tagart 1984) or physically prevent fry from emerging from the spawning bed (Lotspeich and Everest 1981, Lisle 1989).

After emergence in the spring, coho fry typically remain in freshwater for a full year before migrating to the ocean as smolts. During their year in freshwater, young coho prefer pool habitat over faster water habitats (Nickelson et al. 1992a). Edge cover and backwater habitats are particularly important to the survival of fry in the spring, but less so as they grow and move into larger pools during the summer. The distribution of juvenile coho extends beyond that of the adults' spawning range, limited primarily by the availability of pool habitat, food resources, and acceptable water quality. In the winter, juvenile coho prefer complex pool habitat which has low velocity refugia from high winter stream flows. This habitat is often found in the form of off-channel alcoves, dam pools, and beaver ponds (Nickelson 1992b). Large wood is an important structural component contributing to the complexity of these preferred habitats (Sedell 1984). Juvenile coho may extend their distribution downstream in the winter to habitat areas previously limited by high water temperature, including tidally influenced wetlands. Complex off-channel habitats along these large stream reaches may also be important in to overwintering juvenile coho.

Access to suitable habitat influences both the survival and distribution of juvenile and adult coho. For example, human caused or natural barriers can prevent juveniles from moving upstream to avoid increasing water temperatures in the summer. At the same time, barriers to adult migration reduce the amount of available spawning habitat, and subsequently juvenile rearing opportunities.

Coho historically used habitats distributed throughout a drainage, moving between different stream reaches as needed to maximize growth and survival at each life stage. Lower gradient streams flowing through wide, unconstrained valleys were particularly productive for coho (Lichatowich 1989). However, past land management activities have had a significant impact on the distribution and quality of instream physical habitat for coho. Removal of riparian buffers, poorly constructed roads, and other poor watershed management practices can increase fine sediment loads and degrade spawning gravel (Hartman et al. 1996). Splash damming conducted in the 19th and 20th century as a way to transport logs resulted in many coastal streams being simplified and scoured to bedrock (Sedell and Luchesa 1981), thereby reducing spawning and rearing habitat. Past logging, agricultural, and urbanization practices frequently resulted in channel destabilization, straightening and entrenchment, thereby reducing the ability of streams to meander and create complex, off-channel habitat (IMST 2002). These practices also have contributed to reduced large wood in coastal streams, resulting in a reduction in habitat complexity (IMST 2002). In addition, misguided efforts to remove log jams considered barriers to fish passage removed large wood from fish-bearing streams (IMST 1999, 2002). Each of these anthropogenic activities, sometimes exacerbated by natural flood and fire events, reduced the quality of habitat for each life stage of coho.

Methods for Determining Current Status and Trend of Instream Physical Habitat

Scope and Data Sources for Status and Trend Analysis

In 1997, the National Marine Fisheries Service and the State of Oregon identified simplified channel morphology, lack of instream roughness, and substrate changes as "factors for decline" related to instream physical habitat condition that potentially reduce or limit coho populations in the ESU (OCSRI 1997). Since 1998, as part of its contribution to the Oregon Plan for Salmon and Watersheds (OPSW), the Oregon Department of Fish and Wildlife (ODFW) has conducted a monitoring program designed to provide unbiased, statistically rigorous data on instream physical habitat condition, riparian condition, and geomorphic characteristics of streams within the Oregon Coastal coho ESU. In this report, the status and trend of habitat conditions in the ESU are based on ten variables related to the quality of instream physical habitat for coho (Table 1). Data are from surveys conducted from 1998-2003. Habitat conditions are described at the scale of the Oregon Coastal coho ESU and for each of the four monitoring areas within the ESU (Figure 1). Sites are also post-stratified and analyzed by land use category.

Status and Trend Survey Design and Methods

ODFW habitat surveys are designed to assess habitat in all "wadeable" streams within the distribution of coho in the ESU. Specifically, the sample frame is derived from 1st through 3rd order coho bearing streams depicted on a 1:100,000 scale digital hydrography layer developed by the USGS. Streams above dams that block adult coho passage are removed from the selection frame. A random tessellation stratified (RTS) design (Stevens 2002) is used to select potential sample sites from the candidate stream reaches in each monitoring area. The RTS selection protocol results in a pool of random, spatially balanced sites across the landscape, thereby reducing potential site selection bias. The selection protocol incorporated a panel design in which 25% of the sites were surveyed annually, 25% every three years, and 25% every nine years to improve trend detection.

Habitat surveys are conducted as described by Moore et al. (1997) with the modification that survey lengths are restricted to 1,000 m per site and all habitat unit lengths and widths are measured rather than estimated. Roughly 10 percent of the sites per year in each monitoring area are resampled by a separate two-person crew to measure variation within season and between crews. Using this methodology, a total of unique 353 sites were surveyed in the ESU from 1998-2003 (Figure 2).

Reference Site Selection

To assess the impact that human activities have had on habitat conditions in the ESU, we compare conditions found at random survey sites to those with a low impact from human activities (i.e. reference sites). Reference sites were selected from all habitat surveys conducted by ODFW in the ESU using a process outlined in Thom et al. (2001). Sites were initially selected based on land use and riparian classifications generally associated with low human impact (e.g. wilderness or roadless area, late successional or mature forest conditions). We further screened candidate reference sites by eliminating those in watersheds with non-ridge top roads. The final list of 124 reference sites (Figure 3) was similar to random sites in gradient, geology, and stream size (Table 2).

Site Weighting

A preliminary analysis of random survey data indicated differences in habitat quality by land use. In theory, the RTS site selection process should provide a list of candidate sample sites that are representative of land use. However, due to a higher rate of access denial to private lands compared to public lands (Table 3), there is a bias in our "random" survey data because land use types are not represented in proportion to their occurrence (Figure 4). To reduce this bias, we re-apportion site weights based on land use through the following steps: 1) site land use is stratified into one of five categories using a GIS coverage developed by Dent et al. 2004; 2) the number of coho stream miles within each ownership class and monitoring area is determined by overlaying a 1:100k digital coho distribution layer (http://rainbow.dfw.state.or.us/nrimp/information/fishdistdata.htm) on the land use coverage; 3) the number of sites sampled within each land use class is totaled for each monitoring area; 4) the final site weight is determined by dividing the number of sites within each land use class into the number of stream miles for that class. The primary assumption we make when weights are adjusted is that the sampled sites are representative of the non-sampled sites. However, there is no way to test the validity of this assumption.

Status and Trend Analytical Methods

S-PLUS 6.1 (Insightful Corporation) programs written by the U.S.E.P.A. were used to determine weighted values for the mean, median, and percentiles. More information on these S-Plus programs may be obtained at: (http://www.epa.gov/nheerl/arm/analysispages/techinfoanalysis.htm)

To compare stream conditions at the random sites to conditions at reference sites, we combine all years of random surveys according to spatial scale or land use category. Sites with multiple years of survey data are averaged to provide one estimate per site. We use T-tests (Snedecor and Cochran 1980) to compare differences between the weighted means of the spatial scale or land use categories to those of the reference sites. Differences in means are considered significant if P-values are ≤ 0.05. To compare the quality of habitat within monitoring areas or land uses, we use a nonparametric analysis that ranks the condition of a particular parameter for coho relative to other monitoring areas or land uses.

We use simple linear regression analysis (Neter and Wasserman 1974) to test for significant ($P \leq 0.05$) trends in the weighted yearly median values of each instream habitat variable for the ESU, monitoring area and land use categories. Land use categories are grouped into agriculture, public forested and private forested to maintain a sufficient sample size for the analysis. We did not conduct trend analysis for urban sites because of inadequate sample sizes. We use the computer program SigmaStat (SPSS Incorporated) to test the probability (i.e. power) that trend analyses correctly reject the null hypothesis of no trend in the survey data. We also use the computer program TREND (Gerrodette 1993) to calculate the amount of change in each variable that our sample design can detect ($\alpha = 0.05$; $\beta = 0.80$) with 10 or 15 years of sampling.

Scope and Data Sources for Assessment of Habitat Restoration Activities

Information on the location, type, and extent of instream habitat work was obtained from the Oregon Watershed Enhancement Board (OWEB) habitat restoration database and a habitat restoration database maintained jointly by the U.S. Forest Service (USFS) and Bureau of Land Management (BLM). While all federal restoration work is reported in the joint USFS-BLM database, only restoration work that receives OWEB funds has to be reported to the OWEB database. However, voluntary reporting by state and federal agencies, private forest owners, and other private land owners conducting restoration work suggests that the OWEB database contains most, if not all of the restoration work conducted in the ESU since 1997 that is not reported in the federal restoration database.

Comprehensive monitoring of the effectiveness of all the restoration projects reported in the state and federal restoration databases is lacking. However, since 1998 ODFW has monitored the habitat characteristics of a subset of restoration projects conducted by its habitat restoration biologists. More information on design of this monitoring program may be found in Jacobsen and Thom (2001) and Jacobsen and Jones (2003). For this report, the characteristics of 72 sites in western Oregon before and after habitat restoration are summarized and compared to conditions at the reference sites described earlier. Thirteen of the seventy-two sites are not within the distribution of coho, but the geomorphic characteristics of the sites are comparable to streams within coho distribution.

Results

Channel Morphology

Relative to other monitoring areas in the ESU, the Umpqua ranks the lowest or is tied for lowest condition in all four channel morphology variables (Table 4). The Mid-South Coast ranks highest in pools and deep pools, ties the Mid-Coast for highest rank in slackwater pools, and ties the Umpqua for lowest rank in secondary channels. The Mid-Coast also ties the Umpqua for lowest rank in deep pool occurrence. The North Coast ranks highest in secondary channel abundance.

Compared to other land uses, streams flowing through agricultural lands have more pool, deep pool, and slackwater habitat, but the least amount of secondary channels (Table 5). This situation is reversed on public forested lands which also tie urban lands for lowest amount of deep pools.

Box and whisker plots showing weighted means, standard error of the means, medians, and 25^{th} and 75^{th} percentiles the four channel morphology variables for reference and random sites are shown in Figures 5-8. The results of t-tests for differences in the weighted means of channel morphology variables at random sites and those at reference sites are shown in Table 6. The percent of pools is significantly higher than reference conditions for the ESU as a whole, the Mid-Coast and Mid-South Coast monitoring areas, and in stream reaches flowing through agriculture, private forest, and urban land uses. The percent of secondary channel area is significantly lower for the ESU as a whole, the Umpqua monitoring area, and streams flowing through private forests. Although similarly low mean values for percent secondary channel area are found in the Mid-Coast and Mid-South Coast monitoring areas and in streams flowing through agriculture and urban lands, high variability in this parameter results in a low statistical power to detect differences from reference conditions. The percent of slackwater pools is only significantly different (higher) from reference for streams flowing through agricultural lands. The number of deep pools/km is statistically significantly lower for the ESU as a whole, the Mid-Coast monitoring area, and public forested streams. Although similarly low mean values for deep pools are found in the North Coast and Umpqua monitoring areas, and streams flowing through private forest and urban lands, as high variability in data collected from these areas results in a low statistical power to detect differences from the amount of deep pools at reference sites.

Graphs of yearly channel morphology conditions are shown in Figures 9-12. With the exception of declining trends in percent secondary channel in the North Coast and slackwater pools in the Umpqua, no trends are observed in any of the channel morphology variables. Although the declining trends in secondary channel in the North Coast and slackwater pools in the Umpqua are statistically significant, we believe that they are most likely spurious results reflecting our small trend sample size and do not represent an actual change in these two parameters.

The results of sensitivity analyses on the channel morphology trend data are shown in Table 7. With the amount of variability observed in the current dataset, over a 15 monitoring period (eight years from the time of this writing) we will be able to detect a 6% or less change in the percentage of pools for all spatial extents and land use categories except the Mid-South Coast (17%) and agriculture (12%). With the exception of secondary channels in the North Coast and deep pools in the Mid-Coast our ability to detect changes in the other channel morphology variables is minimal because the relatively rare occurrence of secondary channel, slackwater pool, and deep pool habitats results in high sample variability.

Instream Roughness

Relative to other monitoring areas in the ESU, the Umpqua ranks the lowest condition in all three instream roughness variables (Table 8). The North coast ranks the highest for pieces and volume of wood and the Mid-Coast ranks highest for key pieces. Compared to other land uses, streams flowing through agricultural lands have the lowest levels of wood pieces and volume and are equal to urban streams for lowest levels of key pieces (Table 9). This situation is reversed on public forested lands which also tie urban lands for lowest amount of deep pools.

Box and whisker plots showing weighted means, standard error of the means, medians, and 25th and 75th percentiles of the three instream roughness variables at reference and random sites are shown in Figures 13-15. The results of t-tests for differences in the weighted means of instream roughness variables at random sites and those at reference sites are shown in Table 10. With the exception of the number of large wood pieces in the North Coast, there are significantly lower levels of all instream roughness variables for all spatial scales and land use categories compared to reference conditions.

There are no significant trends in any of the instream roughness variables (Figures 16-18). Results of sensitivity analyses on the instream roughness trend data are shown in Table 11. With the amount of variability observed in the current dataset, in 8 years from the time of this writing (15 years overall) we will be able to detect a 10% or less change in the number of pieces of large wood for all spatial extents and land uses except the Mid-Coast and agriculture. We will be able to detect a 10% or less change in wood volume for all spatial extents and land uses except the Mid-South, Umpqua, and agriculture. Our ability to detect a 10% or less change in key wood pieces is limited to private forested streams. As with some of the channel morphology parameters, our ability to detect changes in some instream roughness variables is minimal because the relatively rare occurrence of large wood in many coastal streams results in high sample variability.

Substrate

Relative to other monitoring areas in the ESU the Umpqua has lower levels of gravel, higher levels of bedrock, and lower levels of fine sediment in riffles (Table 12). The North Coast and Mid-South Coast have the lowest levels of bedrock. Relative to other land uses, streams flowing through agricultural lands have the highest levels of fine sediment in riffles and the lowest levels of bedrock (Table 13). Public forest streams have the lowest levels of fine sediment in riffles, lowest amount of gravel in riffles, and tie private forest streams for highest levels of bedrock.

Box and whisker plots showing weighted means, standard error of the means, medians, and 25th and 75th percentiles of the three substrate variables at reference and random sites are shown in Figures 19-21. The results of t-tests for differences in the weighted means of substrate variables at random sites and those at reference sites are shown in Table 14. Except for streams in the Umpqua and on public forest land, all spatial scales and land use categories have significantly higher levels of fine sediment in riffles compared to reference sites. Conversely, Umpqua and public forested streams are the only areas with significantly lower levels of gravel in riffles compared to reference sites. North Coast streams have significantly less bedrock, and Umpqua and public forested streams have significantly more bedrock than reference conditions.

Graphs of yearly substrate conditions are shown in Figures 22-24. Although significant increasing trends are indicated for percent fines in riffles in the Mid-South Coast, bedrock in the North Coast and ESU as a whole, and gravel in the North Coast, as with channel morphology variables, we believe that they are most likely spurious results reflecting our small trend sample size and do not represent an actual change in these two parameters.

The results of sensitivity analyses on substrate variables are shown in Table 15. With the amount of variability observed in the current dataset, 15 years of monitoring substrate will enable us to detect a 7% or less change in gravel for all spatial extents and land use categories, for fine sediment in the ESU as a whole, and private and public forested streams, and for bedrock in the ESU and Mid-Coast monitoring areas.

Instream Habitat Restoration

From 1997-2003 a total of 451 miles of instream habitat restoration were reported in the ESU. Channel morphology was addressed in 447 miles, instream roughness in 439 miles, lack of spawning gravel in 216 miles, and excessive fine sediment in 32 miles of stream. The Mid-Coast monitoring area had the most miles of instream restoration (175), followed by the Umpqua (134), Mid-South (68), and North Coast (58). The most miles of instream restoration work occurred in 2002, and the fewest miles in 2003 (Figure 26).

The results of the surveys at 72 restoration sites (Figure 25) are presented in Figure 27. Information from reference sites is also presented for comparison. T-tests (Table 16) indicate that large wood has increased significantly relative to pre-treatment conditions, although wood volume is still lower than at reference sites. Within one year of treatment, the amount of pools or sediment has not changed significantly. The restoration sites have more pools, though fewer deep pools, lower volume of large wood, and more fine sediment compared to the reference sites.

Discussion

Streams within the coho ESU are pool rich, but structurally simple. The amount of pool habitat is high within all monitoring areas in the ESU, although the amount of slow water and off-channel habitat is limited. Compared to conditions in streams with minimal human disturbance, amounts of large wood are low in all monitoring areas. In addition, amounts of fine sediment are higher than reference conditions in three of the four monitoring areas. The lack of large wood and relatively high amount of fine sediment was evident across all land use types. The only exception was that the levels of fine sediment were comparable to reference conditions on public land.

Geology of a stream basin sets the template for stream channel morphology and habitat features. The majority of streams that support coho (~ 75%) are in regions of sandstone lithology (ODFW unpublished data). Streams underlain by sandstone lithology tend to be lower gradient and have wider valley floors that provide more opportunity for the stream to meander and have more complex secondary and off-channel habitats. Coastal streams in volcanic regions are higher gradient and are constrained by narrow valleys. Instream habitat features, especially channel morphology and substrates, reflect each of these geologic origins.

The characteristics of streams within each land use category are related in part to geographic position within a drainage network. Public forest and private industrial forest lands tend to be in the upper portions of drainages, whereas private non-industrial and agricultural lands are usually located lower in the drainage network. We believe that the higher percent of pools and number of deep pools in agricultural streams is most likely a result of stream size and gradient. We also believe that the low amounts of large wood in agricultural and urban streams relative to public and private forested streams are due primarily to land use activities and not watershed position because streams flowing through the agricultural and urban lands tend to be depositional reaches. These conclusions are similar to those of Wing and Skaugset (2002).

Our analysis indicates no consistent trend in instream habitat conditions in ESU streams from 1998 to 2003. These results are consistent with a study by Thom and Jones (1999) who assessed change in habitat from 1993-1999 for all Oregon coastal streams.

Although our ability to detect significant trends is minimized by the low statistical power of our analyses, we believe that short of catastrophic habitat changes (which have not occurred) we would not expect to see significant changes in habitat variables over the short time span we have been monitoring habitat with our random surveys. Even following the February 1996 flood, instream habitat features did not change in a unidirectional fashion across the North Coast (Moore and Jones 1997). Channel modifications did occur in some streams because of debris torrents and high water, but positive and negative effects were observed on instream features. We expect that habitat change will occur on a longer time scale as large trees are recruited into riparian areas and upland areas continue to stabilize.

Restoration projects are designed to be a bridge between current conditions and long-term watershed and stream recovery. Although monitoring of a subsample of restoration projects shows improvements in all measures of large wood, when compared to reference conditions, "restored" stream reaches are still in worse condition for deep pools, fine sediment, and volume of large wood. More time may be needed to allow restored reaches to trap more wood and scour deeper pools.

Across the ESU as a whole, we are unable to detect an overall improvement in levels of large wood due to restoration efforts. The number of restored stream miles (451) relative to the number of miles in our habitat sampling universe (5,553) and our relatively small yearly sample sizes contribute to our inability to detect a trend signal from habitat restoration, even though site specific monitoring of a subsample of restoration sites show significant increases in large wood.

Although we cannot detect an ESU-wide signal from habitat restoration, we do believe that the effects of restoration at the local or stream level can be significant. For example, studies by Nickelson (1992b) demonstrate effectiveness of improving habitat for juvenile coho at the reach level, and Johnson et al. (2005) describes the positive impact that a large wood enhancement project can have on the freshwater survival of coho.

It is important to emphasize that our finding of low levels of large wood and high levels of fine sediment relative to reference conditions does not mean that there is not adequate habitat to insure the viability of coho populations in the Oregon Coastal coho ESU. The recent coho population viability analysis conducted by ODFW (Chilcote et al. 2005) concludes that the ESU is supported by sufficient habitat to be sustainable through future periods of ocean, drought, and flood conditions similar or slightly more adverse than those experienced in the 1980s and 1990s. Rather, this report points out where future habitat enhancement and protection efforts should focus to assist with full recovery of coho populations in the ESU. It is our belief that two main areas of focus should be on increasing large wood levels and decreasing fine sediment.

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Table 1. Definition of habitat survey parameters evaluated for this report.

Decline Factor	Parameter	Definition
Channel morphology	% Pools	% Channel area represented by pool habitat
Channel morphology	% Secondary Channel	% Total channel area represented by secondary channels
Channel morphology	% Slackwater Pools	% Primary channel area represented by slackwater pool habitat (beaver pond, backwater, alcoves, isolated pools).
Channel morphology	Deep Pools/km	Pools > 1m deep per kilometer of primary channel
Substrate	% fines in riffles	Visual estimate of substrate composed of <2mm diameter particles
Substrate	% gravel in riffles	Visual estimate of substrate composed of 2-64mm diameter particles
Substrate	% bedrock in stream	Visual estimate of substrate composed of solid bedrock
Instream roughness	Pieces LWD/100m	# pieces of wood $\geq$ 0.15m diameter X 3m length per 100 meters primary stream length
Instream roughness	Volume LWD/100m	Volume (m^3) of wood $\geq$ 0.15m diameter X 3m length per 100 meters primary stream length
Instream roughness	Key Pieces LWD/100m	# pieces of wood $\geq$ 60 cm diameter & $\geq$ 12 meters long per 100 meters primary stream length

Table 2. Comparison of geomorphic characteristics and land use of random and reference sites.

Attribute	Random Sites	Reference Sites
Number of Sites	353	124
Total Distance (km)	353	162
Mean Active Channel Width (m)	9.9	9.3
Median Active Channel Width (m)	7.4	7.3
Mean % Gradient	2.7	2.8
Median % Gradient	1.8	2.3
Ownership	Private Forest 43% Public Forest 39% Agriculture 12% Urban 4% Other 2%	Public Forest 88% Private Forest 11% Other 1%
Geology	Sedimentary 71% Mixed 18% Volcanic 12%	Sedimentary 72% Volcanic 21% Mixed 7%

Table 3. Total number of candidate sites and percentage of sites not sampled within four land use categories in the Oregon Coastal coho ESU, 1998-2003.

Landuse	Number of Candidate Sites	Percentage Not Sampled			
		Access Denied[1]	Crew Error[2]	Cover Error[3]	Total
Agriculture	180	24%	6%	10%	39%
Private Forested	577	8%	4%	11%	23%
Public Forested	568	0%	4%	9%	13%
Urban	38	26%	3%	11%	39%

[1]Access to sites denied by landowners
[2]Sampling crews surveyed wrong location or could not locate sites
[3]An error in the digital site selection process that results in sites not located on actual streams

Table 4. Relative rankings of the four monitoring areas for channel morphology condition (1 = best condition, 4 = worst condition). Numbers in parentheses are the median value for that parameter.

Monitoring Area	% Pools	% Secondary Channel	% Slackwater Pools	Deep Pools/km
North Coast	3 (33.3)	1 (2.6)	2 (0.9)	2 (1.4)
Mid-Coast	2 (38.4)	2 (1.6)	1 (1.0)	3 (1.0)
Mid-South	1 (48.5)	3 (1.3)	1 (1.0)	1 (1.7)
Umpqua	4 (33.1)	3 (1.3)	3 (0.5)	3 (1.0)

Table 5. Relative rankings of the four land use categories for channel morphology condition (1 = best condition, 4 = worst condition). Numbers in parentheses are the median value for that parameter.

Land use Category	% Pools	% Secondary Channel	% Slackwater Pools	Deep Pools/km
Agriculture	1 (60.1)	4 (0.9)	1 (1.3)	1(1.8)
Private Forest	3 (35.9)	2 (1.4)	3 (0.8)	2 (1.0)
Public Forest	4 (31.1)	1 (2.5)	4 (0.6)	3 (0.9)
Urban	2 (56.6)	3 (1.3)	2 (1.2)	3 (0.9)

Table 6. Results of t-tests for differences between the weighted means of channel morphology variables at random survey sites and means from reference sites. Gray shaded cells indicate P-values ≤ 0.05.

Spatial Scale or Landuse Category	Percent Pools			Percent Secondary Channel			Percent Slackwater Pools			Deep Pools/km		
	D[1]	P-value	Power[2]	D[1]	P-value	Power[2]	D[1]	P-value	Power[2]	D[1]	P-value	Power[2]
ESU	6.6	0.005	0.750	-1.4	0.017	0.578	1.6	0.457	0.050	-0.7	0.040	0.419
North Coast	4.2	0.076	0.295	0.4	0.690	0.050	3.0	0.142	0.177	-0.6	0.168	0.147
Mid-Coast	8.1	0.001	0.932	-1.6	0.073	0.302	1.8	0.342	0.050	-1.1	0.002	0.842
Mid-South	11.0	0.001	0.961	-1.7	0.142	0.176	3.3	0.112	0.221	-0.1	0.885	0.050
Umpqua	4.1	0.169	0.146	-2.4	0.047	0.392	-0.7	0.779	0.050	-0.8	0.078	0.290
Agriculture	19.2	0.001	1.000	-2.3	0.107	0.229	6.1	0.049	0.383	-0.4	0.437	0.050
Private Forest	7.2	0.002	0.856	-1.6	0.039	0.426	1.6	0.392	0.050	-0.7	0.075	0.297
Public Forest	-2.0	0.347	0.050	-0.5	0.541	0.050	-0.1	0.943	0.050	-0.8	0.019	0.564
Urban	16.0	0.001	0.942	-1.8	0.472	0.050	-1.5	0.595	0.050	-1.0	0.197	0.121

[1]Difference from reference condition
[2]For $\alpha = 0.05$

Table 7. Median channel morphology values collected in 1998, coefficient of variation, and minimum rate of change that ODFW habitat monitoring program will be able to detect with 10 and 15 years of sampling.

Spatial Scale or Landuse Category	Habitat Variable	1998 Median Value	Coefficient of Variation	Minimum Detectable Annual Rate of Change[1]	
				10 Years	15 Years
ESU	% Pools	32.8	0.179	9%	4%
North Coast	% Pools	24.1	0.136	6%	3%
Mid-Coast	% Pools	35.5	0.217	12%	6%
Mid-South Coast	% Pools	21.6	0.403	52%	17%
Umpqua	% Pools	50.5	0.132	6%	3%
Agriculture	% Pools	66.4	0.340	30%	12%
Private Forested	% Pools	30.0	0.183	9%	4%
Public Forested	% Pools	27.9	0.238	14%	6%
ESU	% Secondary Channel	1.28	0.450	90%	22%
North Coast	% Secondary Channel	4.31	0.271	18%	8%
Private Forested	% Secondary Channel	1.58	0.334	29%	11%
Mid-Coast	% Secondary Channel	2.45	0.758	_[2]	_[2]
Mid-South Coast	% Secondary Channel	0.73	1.151	_[2]	_[2]
Umpqua	% Secondary Channel	0.12	1.031	_[2]	_[2]
Public Forested	% Secondary Channel	1.47	0.450	90%	22%
Agriculture	% Secondary Channel	0.14	1.158	_[2]	_[2]
ESU	% Slackwater Pools	0.96	0.771	_[2]	_[2]
North Coast	% Slackwater Pools	1.06	0.763	_[2]	_[2]
Mid-Coast	% Slackwater Pools	1.43	0.878	_[2]	_[2]
Mid-South Coast	% Slackwater Pools	0.00	1.240	_[2]	_[2]
Agriculture	% Slackwater Pools	2.86	1.435	_[2]	_[2]
Umpqua	% Slackwater Pools	1.90	0.492	199%	30%
Private Forested	% Slackwater Pools	0.78	0.792	_[2]	_[2]
Public Forested	% Slackwater Pools	0.66	1.193	_[2]	_[2]
ESU	Deep Pools/km	0.91	0.686	_[2]	_[2]
Mid-Coast	Deep Pools/km	0.93	0.079	3%	2%
Mid-South Coast	Deep Pools/km	0.00	1.055	_[2]	_[2]
Umpqua	Deep Pools/km	1.82	0.829	_[2]	_[2]
Agriculture	Deep Pools/km	1.82	0.819	_[2]	_[2]
North Coast	Deep Pools/km	0.99	0.363	36%	13%
Private Forested	Deep Pools/km	0.88	0.320	26%	10%
Public Forested	Deep Pools/km	0.90	0.704	_[2]	_[2]

[1]Minimum detectable rate of change with an 80% detection probability and a 5% probability of incorrectly asserting a trend.
[2]The variability of the habitat parameter is too great to be able to detect any rate change for this time period

Table 8. Relative rankings of the four monitoring areas for instream roughness condition (1 = best condition, 4 = worst condition). Numbers in parentheses are the median value for that parameter.

Monitoring Area	Key Pieces LWD/100m	Pieces LWD/100m	Volume LWD/100m
North Coast	2 (0.3)	1 (14)	1 (15)
Mid-Coast	1 (0.5)	2 (11)	1 (15)
Mid-South	3 (0.2)	3 (8)	2 (9)
Umpqua	4 (0.1)	4 (6)	3 (5)

Table 9. Relative rankings of the four landuse categories for instream roughness condition (1 = best condition, 4 = worst condition). Numbers in parentheses are the median value for that parameter.

Monitoring Area	Key Pieces LWD/100m	Pieces LWD/100m	Volume LWD/100m
Agriculture	3 (0.0)	4 (3)	4 (2)
Private Forest	2 (0.3)	2 (11)	2 (13)
Public Forest	1 (0.6)	1 (12)	1 (17)
Urban	3 (0.0)	3 (4)	3 (4)

Table 10. Results of t-tests for differences between the weighted means of instream roughness variables at random survey sites and means from reference sites. Gray shaded cells indicate P-values < 0.05.

Spatial Scale or Landuse Category	Key Pieces LWD/100m			Pieces LWD/100m			Volume LWD/100m		
	D[1]	P-value	Power[2]	D[1]	P-value	Power[2]	D[1]	P-value	Power[2]
ESU	-1.4	0.001	1.000	-7.1	0.001	1.000	-28.3	0.001	1.000
North Coast	-1.1	0.001	0.998	-2.4	0.227	0.098	-19.9	0.001	1.000
Mid-Coast	-1.3	0.001	1.000	-6.3	0.001	0.936	-26.4	0.001	1.000
Mid-South	-1.7	0.001	1.000	-7.9	0.001	0.959	-31.9	0.001	1.000
Umpqua	-1.7	0.001	1.000	-10.8	0.001	0.997	-34.1	0.001	1.000
Agriculture	-2.0	0.001	1.000	-13.6	0.001	1.000	-40.2	0.001	1.000
Private Forest	-1.5	0.001	1.000	-5.4	0.001	0.917	-27.9	0.001	1.000
Public Forest	-1.0	0.001	1.000	-4.6	0.006	0.748	-20.2	0.001	1.000
Urban	-1.9	0.001	0.991	-11.5	0.014	0.619	-37.5	0.001	0.992

[1]Difference from reference condition
[2]For $\alpha = 0.05$

Table 11. Median instream roughness values collected in 1998, coefficient of variation, and minimum rate of change that ODFW habitat monitoring program will be able to detect with 10 and 15 years of sampling.

Spatial Scale or Landuse Category	Habitat Variable	1998 Median Value	Coefficient of Variation	Minimum Detectable Annual Rate of Change[1]	
				10 Years	15 Years
ESU	Key Pieces LWD/100m	0.14	0.39	47%	16%
North Coast	Key Pieces LWD/100m	0.35	0.42	65%	19%
Mid-Coast	Key Pieces LWD/100m	0.13	0.52	784%	37%
Mid-South Coast	Key Pieces LWD/100m	0.12	0.93	_[2]	_[2]
Umpqua	Key Pieces LWD/100m	0.12	1.29	_[2]	_[2]
Agriculture	Key Pieces LWD/100m	0.00	2.72	_[2]	_[2]
Private Forest	Key Pieces LWD/100m	0.16	0.24	14%	6%
Public Forest	Key Pieces LWD/100m	0.52	0.52	528%	36%
ESU	Pieces LWD/100m	10.5	0.14	6%	3%
North Coast	Pieces LWD/100m	13.0	0.14	7%	3%
Mid-Coast	Pieces LWD/100m	8.49	0.27	18%	8%
Mid-South Coast	Pieces LWD/100m	8.68	0.41	56%	17%
Umpqua	Pieces LWD/100m	7.39	0.30	22%	9%
Agriculture	Pieces LWD/100m	4.36	0.35	32%	12%
Private Forest	Pieces LWD/100m	9.59	0.20	11%	5%
Public Forest	Pieces LWD/100m	11.3	0.21	12%	5%
ESU	Volume LWD/100m	9.63	0.09	4%	2%
North Coast	Volume LWD/100m	15.8	0.28	20%	8%
Mid-Coast	Volume LWD/100m	8.13	0.25	15%	7%
Mid-South Coast	Volume LWD/100m	8.28	0.42	60%	18%
Umpqua	Volume LWD/100m	8.81	0.60	_[2]	90%
Agriculture	Volume LWD/100m	6.22	0.66	_[2]	974%
Private Forest	Volume LWD/100m	10.2	0.12	5%	2%
Public Forest	Volume LWD/100m	15.9	0.14	6%	3%

[1]Minimum detectable rate of change with an 80% detection probability and a 5% probability of incorrectly asserting a trend.
[2]The variability of the habitat parameter is too great to be able to detect any rate change for this time period

Table 12. Relative rankings of the four monitoring areas for substrate condition (1 = best condition, 4 = worst condition). Numbers in parentheses are the median value for that parameter.

Monitoring Area	% fines in riffles	% gravel in riffles	% bedrock in stream
North Coast	3 (18)	3 (34)	1 (3)
Mid-Coast	2 (15)	2 (43)	2 (7)
Mid-South	3 (18)	1 (45)	1 (3)
Umpqua	1 (14)	4 (28)	3 (9)

Table 13. Relative rankings of the four land use categories for substrate condition (1 = best condition, 4 = worst condition). Numbers in parentheses are the median value for that parameter.

Monitoring Area	% fines in riffles	% gravel in riffles	% bedrock in stream
Agriculture	3 (23)	3 (40)	1 (1)
Private Forest	2 (15)	2 (42)	3 (8)
Public Forest	1 (14)	4 (33)	3 (8)
Urban	2 (15)	1 (43)	2 (2)

Table 14. Results of t-tests for differences between the weighted means of substrate variables at random survey sites and means from reference sites. Gray shaded cells indicate P-values < 0.05.

Spatial Scale or Landuse Category	Percent Fines in Riffles			Percent Gravel in Riffles			Percent Bedrock		
	D[1]	P-value	Power[2]	D[1]	P-value	Power[2]	D[1]	P-value	Power[2]
ESU	5.8	0.002	0.850	-1.5	0.457	0.050	2.4	0.204	0.115
North Coast	9.2	0.001	0.994	-3.7	0.086	0.271	-3.2	0.029	0.488
Mid-Coast	4.8	0.008	0.705	3.6	0.088	0.265	2.2	0.234	0.093
Mid-South	10.5	0.001	0.999	2.6	0.303	0.054	-0.5	0.826	0.050
Umpqua	2.0	0.348	0.050	-7.4	0.007	0.727	8.6	0.001	0.916
Agriculture	16.4	0.001	1.000	1.4	0.661	0.050	-3.9	0.063	0.334
Private Forest	4.8	0.003	0.820	-0.3	0.898	0.050	3.7	0.081	0.282
Public Forest	0.6	0.683	0.050	-5.3	0.008	0.693	5.6	0.007	0.718
Urban	9.2	0.012	0.639	4.2	0.324	0.050	-2.9	0.385	0.050

[1]Difference from reference condition
[2]For $\alpha = 0.05$

Table 15. Median substrate values collected in 1998, coefficient of variation, and minimum rate of change that ODFW habitat monitoring program will be able to detect with 10 and 15 years of sampling.

Spatial Scale or Landuse Category	Habitat Variable	1998 Median Value	Coefficient of Variation	Minimum Detectable Annual Rate of Change[1]	
				10 Years	15 Years
ESU	% fines in riffles	20.3	0.182	9%	4%
North Coast	% fines in riffles	29.3	0.373	39%	14%
Mid-Coast	% fines in riffles	19.5	0.386	44%	15%
Mid-South Coast	% fines in riffles	11.4	0.399	50%	16%
Umpqua	% fines in riffles	22.3	0.532	_[2]	41%
Agriculture	% fines in riffles	23.0	0.416	59%	18%
Private Forest	% fines in riffles	15.8	0.146	7%	3%
Public Forest	% fines in riffles	19.1	0.251	16%	7%
ESU	% gravel in riffles	32.1	0.127	6%	3%
North Coast	% gravel in riffles	29.5	0.126	6%	3%
Mid-Coast	% gravel in riffles	39.1	0.131	6%	3%
Mid-South Coast	% gravel in riffles	29.6	0.251	16%	7%
Umpqua	% gravel in riffles	36.4	0.262	17%	7%
Agriculture	% gravel in riffles	36.0	0.251	16%	7%
Private Forest	% gravel in riffles	30.5	0.176	9%	4%
Public Forest	% gravel in riffles	30.5	0.193	10%	5%
ESU	% bedrock in stream	2.29	0.256	16%	7%
North Coast	% bedrock in stream	0.39	0.427	67%	19%
Mid-Coast	% bedrock in stream	9.06	0.195	10%	5%
Mid-South Coast	% bedrock in stream	4.04	1.284	_[2]	_[2]
Umpqua	% bedrock in stream	1.75	0.507	329%	33%
Agriculture	% bedrock in stream	0.00	1.290	_[2]	_[2]
Private Forest	% bedrock in stream	5.85	0.453	94%	23%
Public Forest	% bedrock in stream	3.65	0.444	83%	21%

[1]Minimum detectable rate of change with an 80% detection probability and a 5% probability of incorrectly asserting a trend.
[2]The variability of the habitat parameter is too great to be able to detect any rate change for this time period

Table 16. Results of t-tests comparing instream habitat conditions at reference sites to those at habitat restoration sites pre- and post treatment. Gray shaded cells indicate P-values < 0.05.

Variable	Pre- vs Post-Treatment			Post-Treatment vs Reference		
	D[1]	P-value	Power[2]	D[3]	P-value	Power[2]
% Pools	2.6	0.485	0.05	10.1	<0.01	0.96
% Secondary Channel	0.6	0.698	0.05	0.4	0.72	0.05
% Slackwater Pools	-0.8	0.671	0.05	-0.7	0.77	0.05
Deep Pools/km	0.6	0.364	0.05	-1.4	<0.01	0.85
Key Pieces LWD/100m	-1.2	0.001	0.99	-0.2	0.44	0.05
Pieces LWD/100m	-6.4	0.001	1.00	-0.2	0.92	0.05
Volume LWD/100m	-16.6	0.001	1.00	-14.2	<0.01	0.86
% bedrock in stream	-0.2	0.939	0.05	1.5	0.55	0.05
% fines in riffles	-1.3	0.464	0.05	3.2	0.05	0.39
% gravel in riffles	-0.4	0.913	0.05	4.0	0.12	0.20

[1]Pre-treatment mean minus post-treatment mean
[2]For $\alpha = 0.05$
[3]Post-treatment mean minus reference condition mean

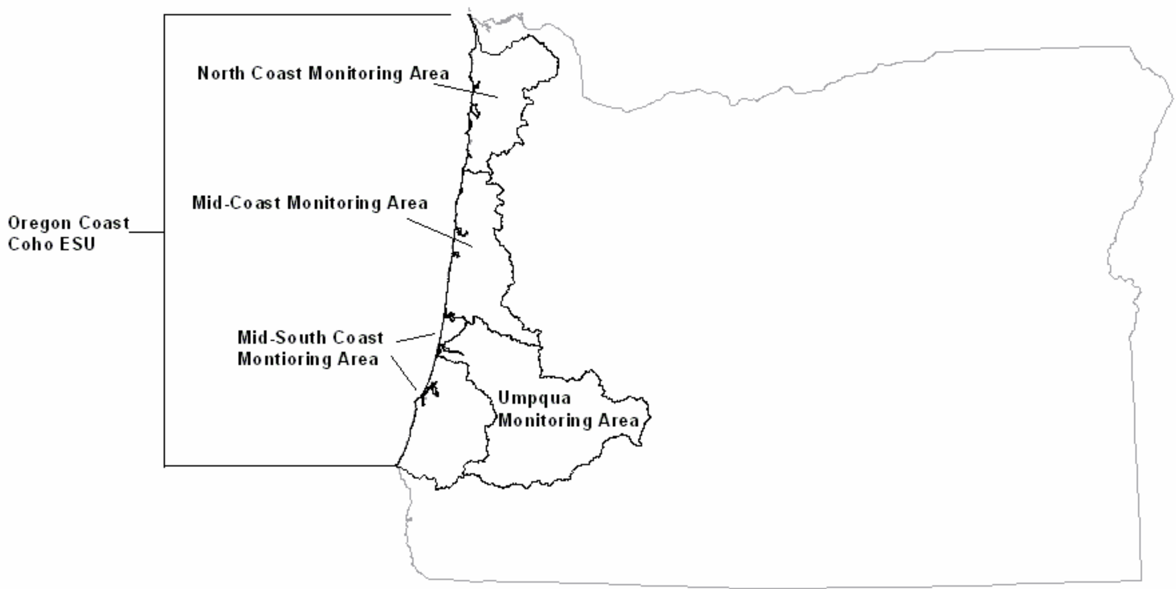

Figure 1. Location of four monitoring areas in the Oregon Coastal coho ESU. A GIS coverage of these monitoring areas my be obtained at: http://nrimp.dfw.state.or.us/OregonPlan/default.aspx?page=130

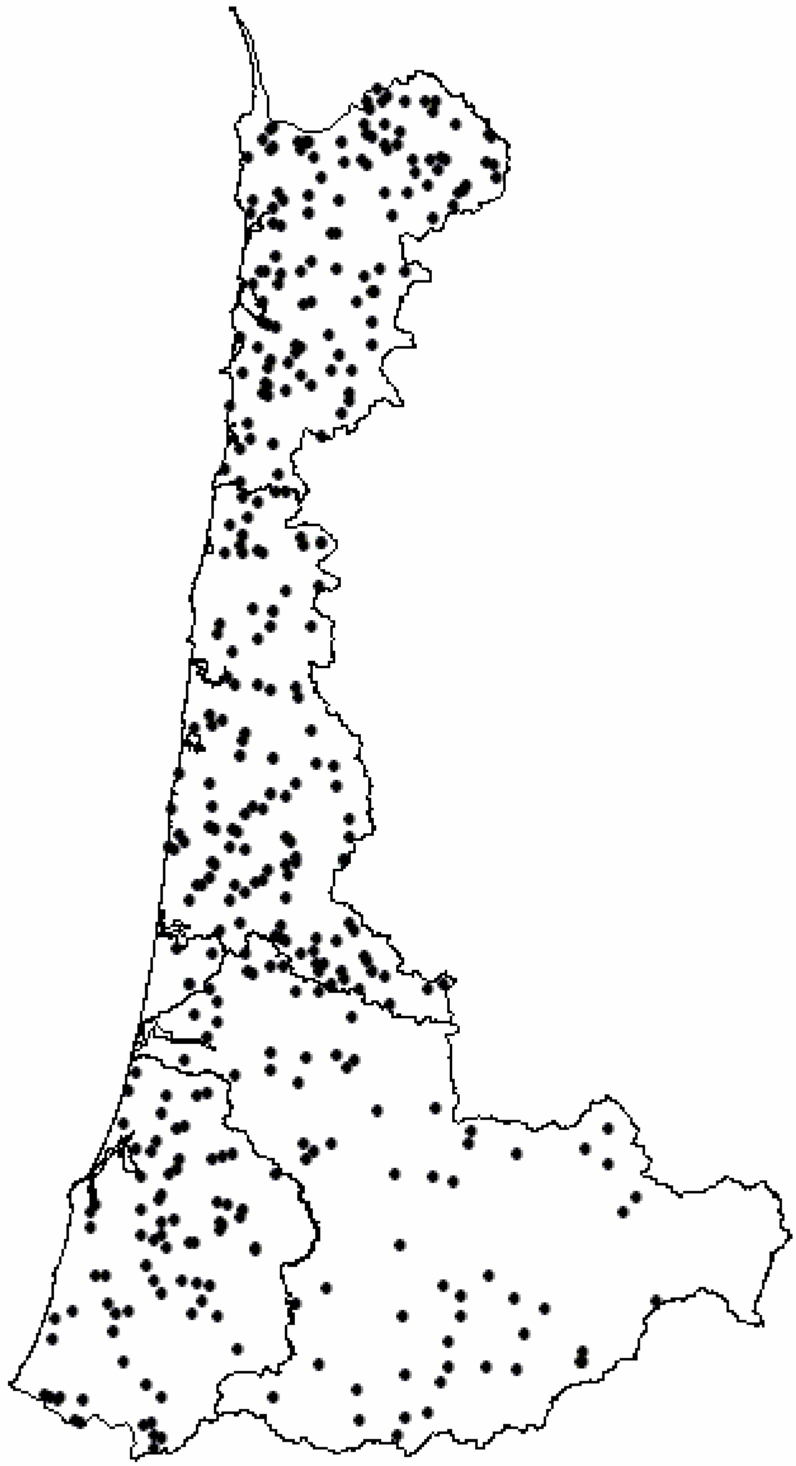

Figure 2. Location of 353 random sites surveyed from 1998-2003. (Go to http://nrimp.dfw.state.or.us/OregonPlan/default.aspx?page=130 for random site data).

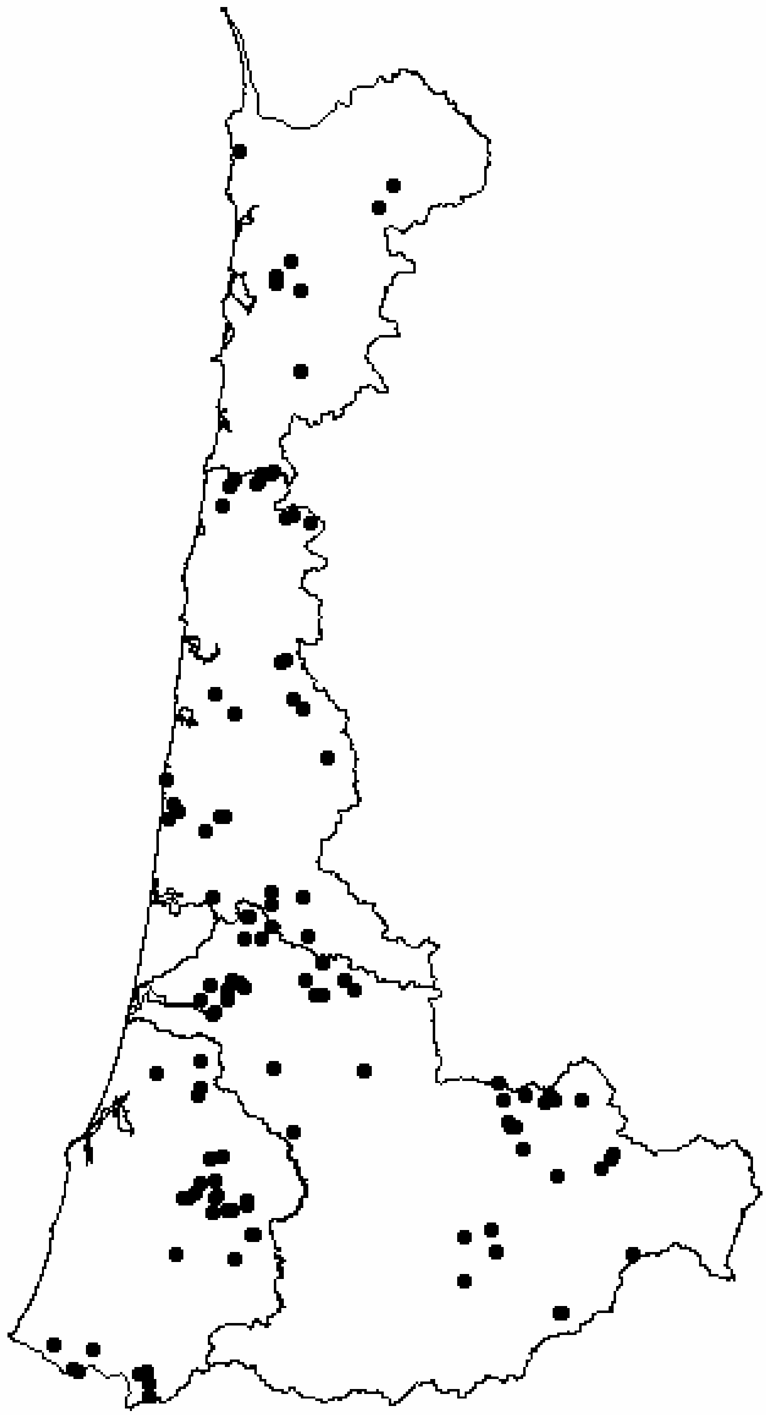

Figure 3. Location of 124 reference sites. (Go to http://nrimp.dfw.state.or.us/OregonPlan/default.aspx?page=130 for reference site data).

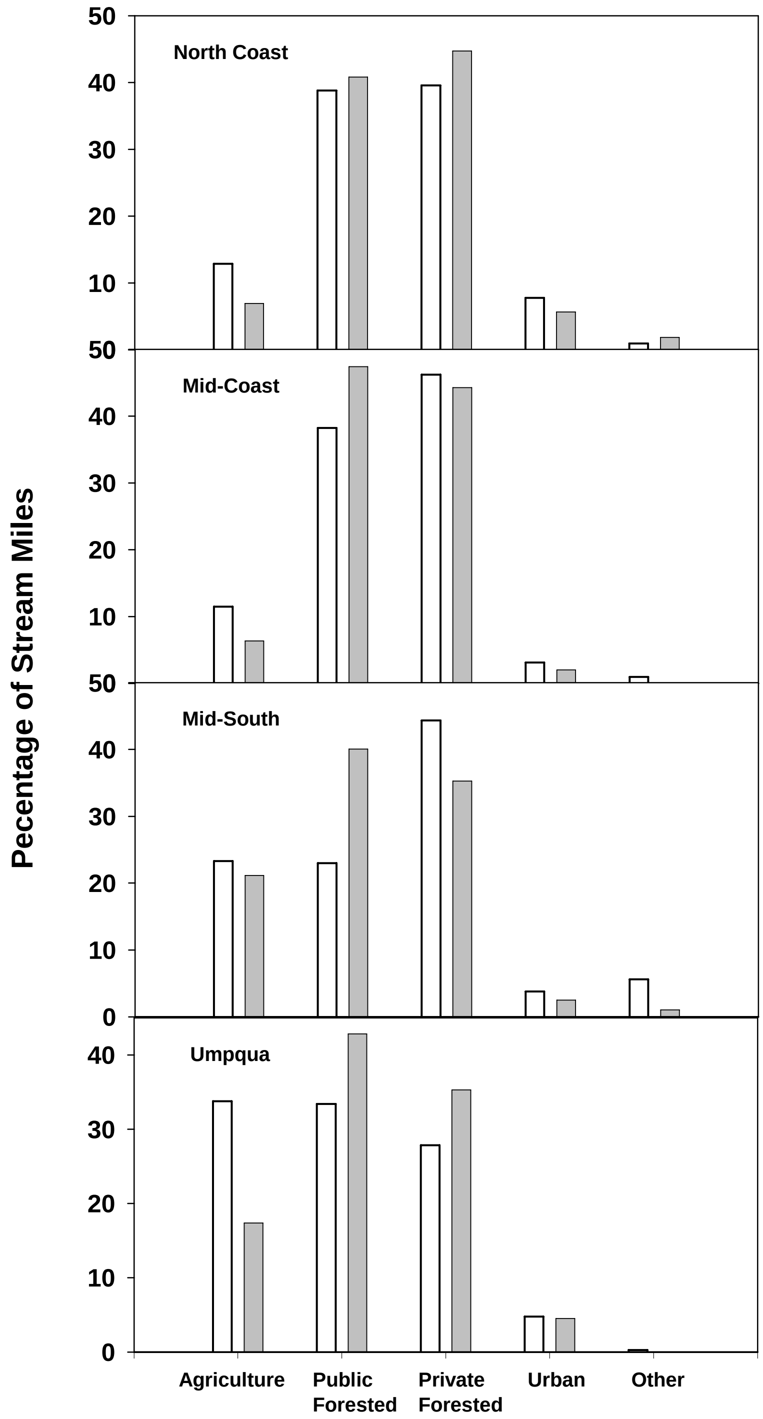

Figure 4. Comparison of land occurrence along coho bearing streams (white bars) and land use represented in un-weighted, raw survey data (grey bars) for each monitoring area. (Go to http://nrimp.dfw.state.or.us/OregonPlan/default.aspx?page=130 for detailed information on land use).

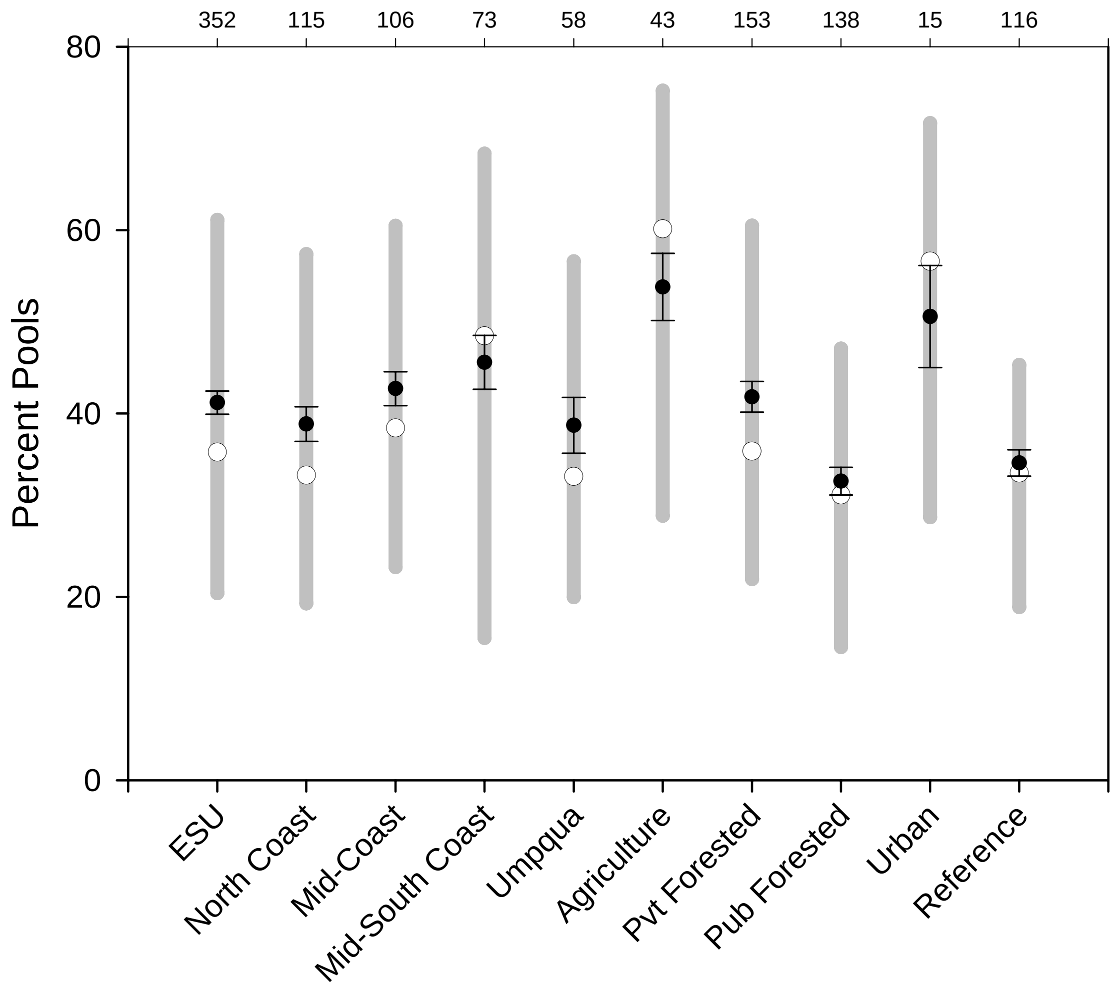

Figure 5. The percentage of pools at reference sites and for random surveys conducted at the ESU, monitoring area, and land use scales from 1998-2003. (black circles = means; white circles = medians; thick gray bars = 25th and 75th percentiles; black lines = standard error of the mean). Sample sizes are along the top x-axis. Data are available at: http://nrimp.dfw.state.or.us/OregonPlan/default.aspx?page=130

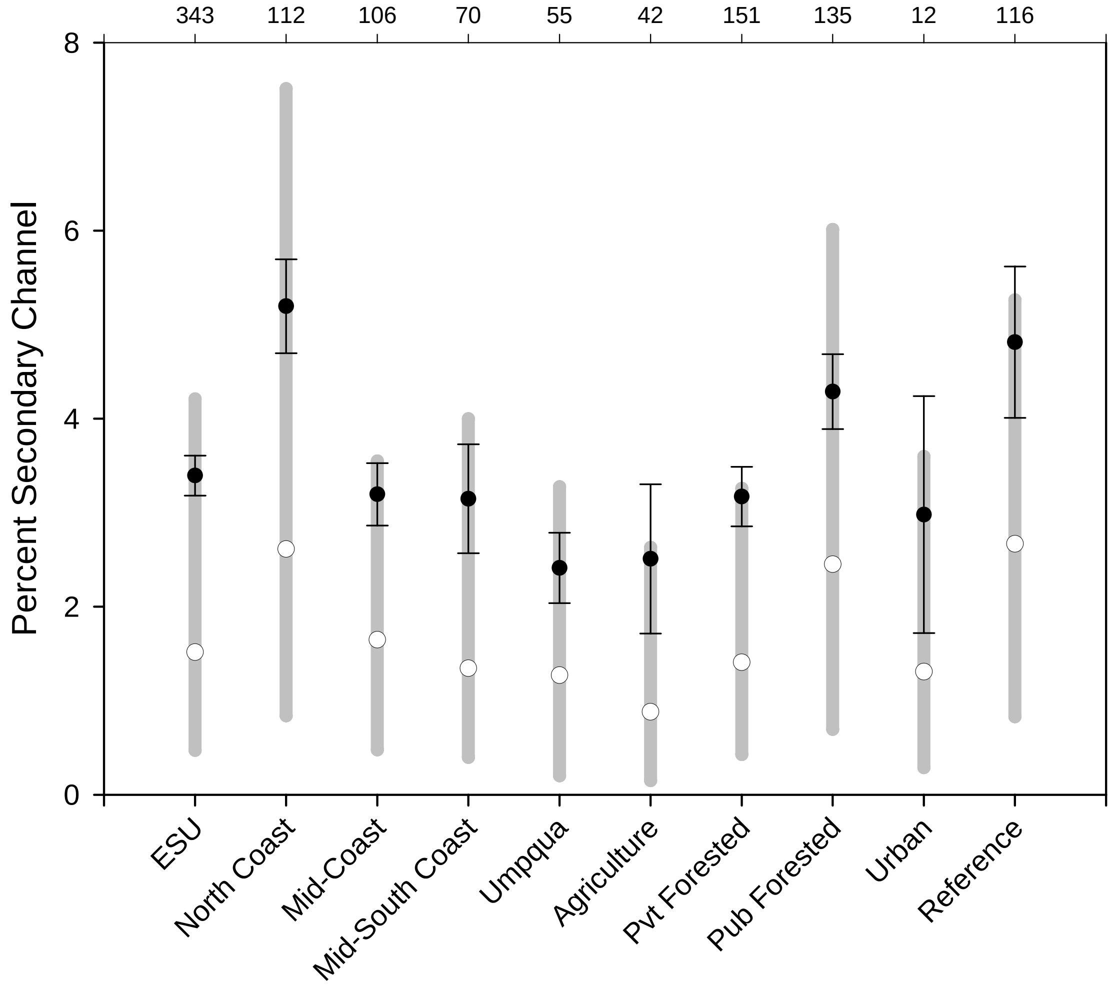

Figure 6. The percentage of secondary channel at reference sites and for random surveys conducted at the ESU, monitoring area, and land use scales from 1998-2003. (black circles = means; white circles = medians; thick gray bars = 25th and 75th percentiles; black lines = standard error of the mean). Sample sizes are along the top x-axis. Data are available at: http://nrimp.dfw.state.or.us/OregonPlan/default.aspx?page=130

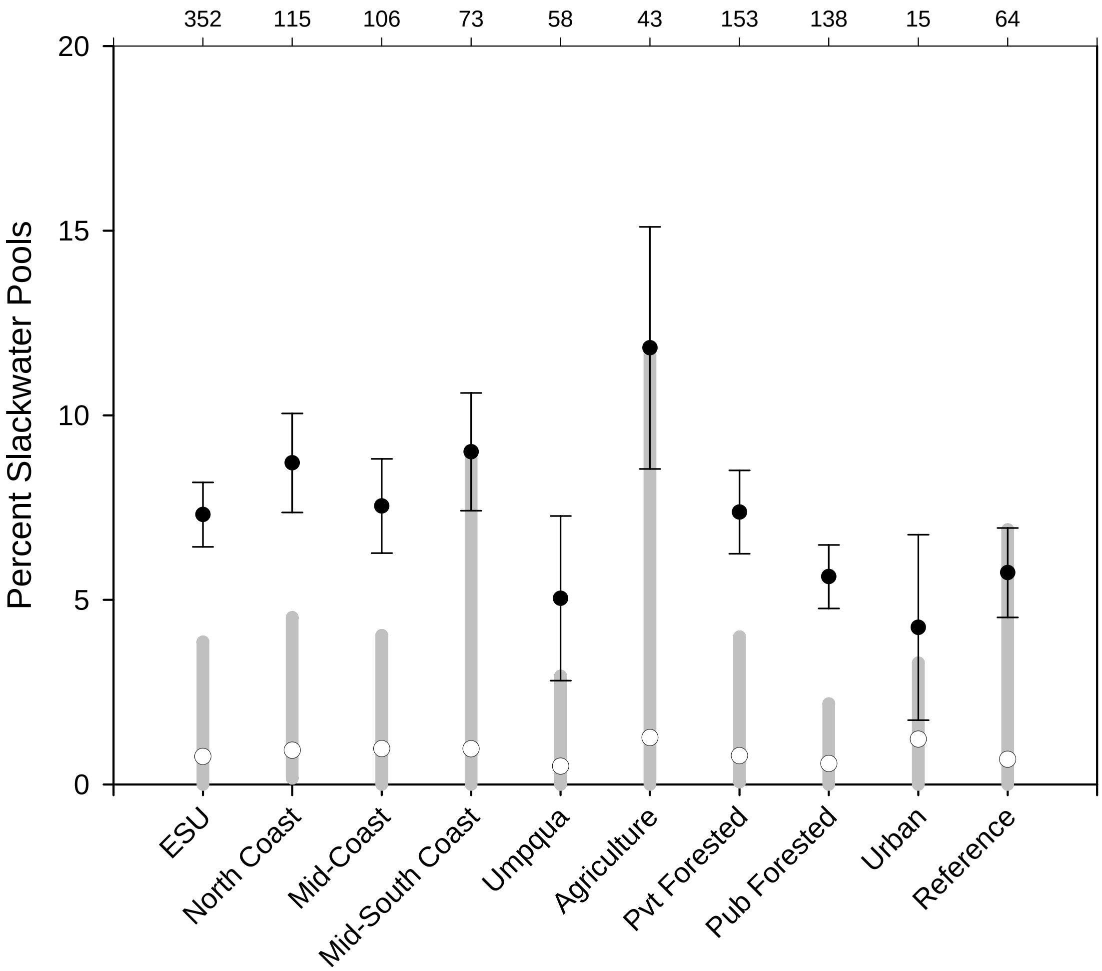

Figure 7. The percentage of slackwater pools at reference sites and for random surveys conducted at the ESU, monitoring area, and land use scales from 1998-2003. (black circles = means; white circles = medians; thick gray bars = 25th and 75th percentiles; black lines = standard error of the mean). Sample sizes are along the top x-axis. Data are available at: http://nrimp.dfw.state.or.us/OregonPlan/default.aspx?page=130

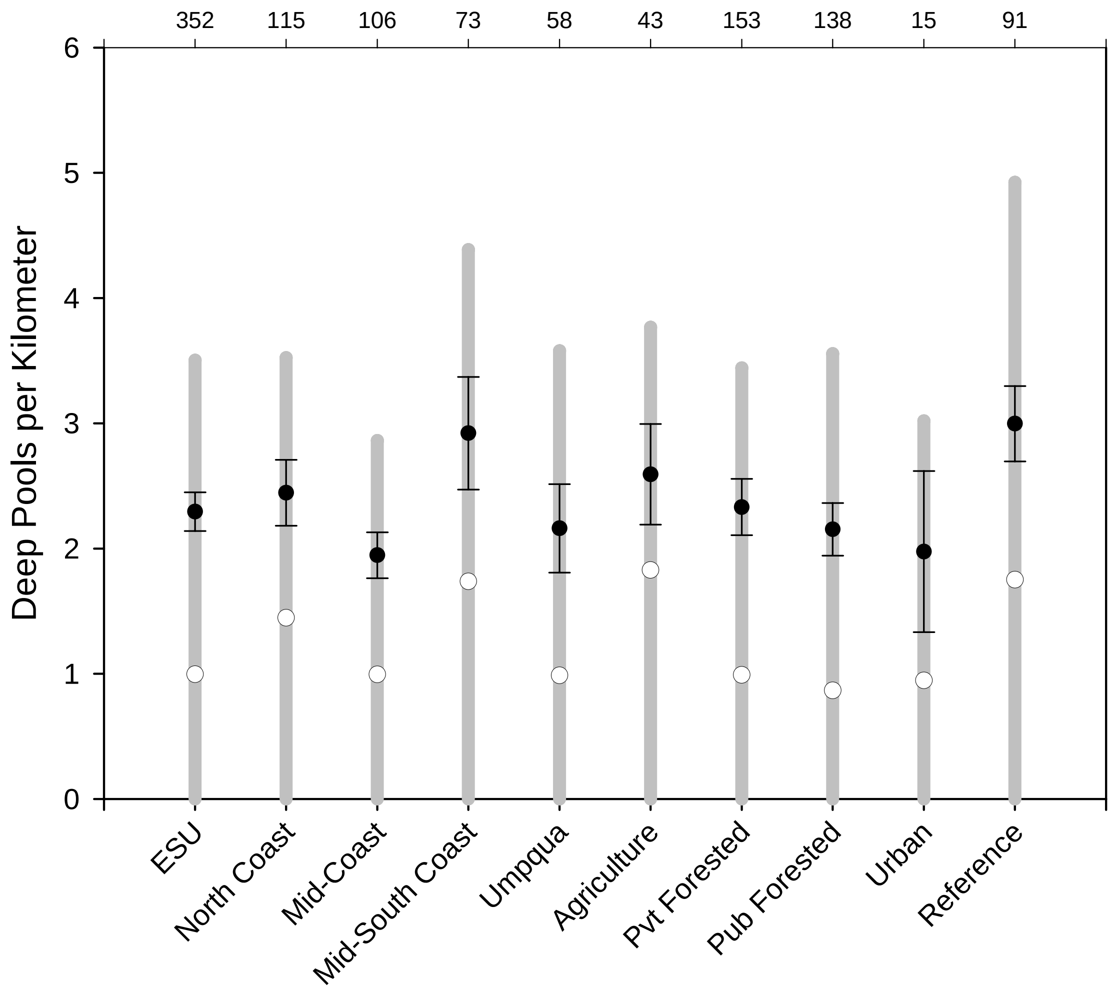

Figure 8. The number of deep (> 1m) pools/km at reference sites and for random surveys conducted at the ESU, monitoring area, and land use scales from 1998-2003. (black circles = means; white circles = medians; thick gray bars = 25th and 75th percentiles; black lines = standard error of the mean). Sample sizes are along the top x-axis. Data are available at: http://nrimp.dfw.state.or.us/OregonPlan/default.aspx?page=130

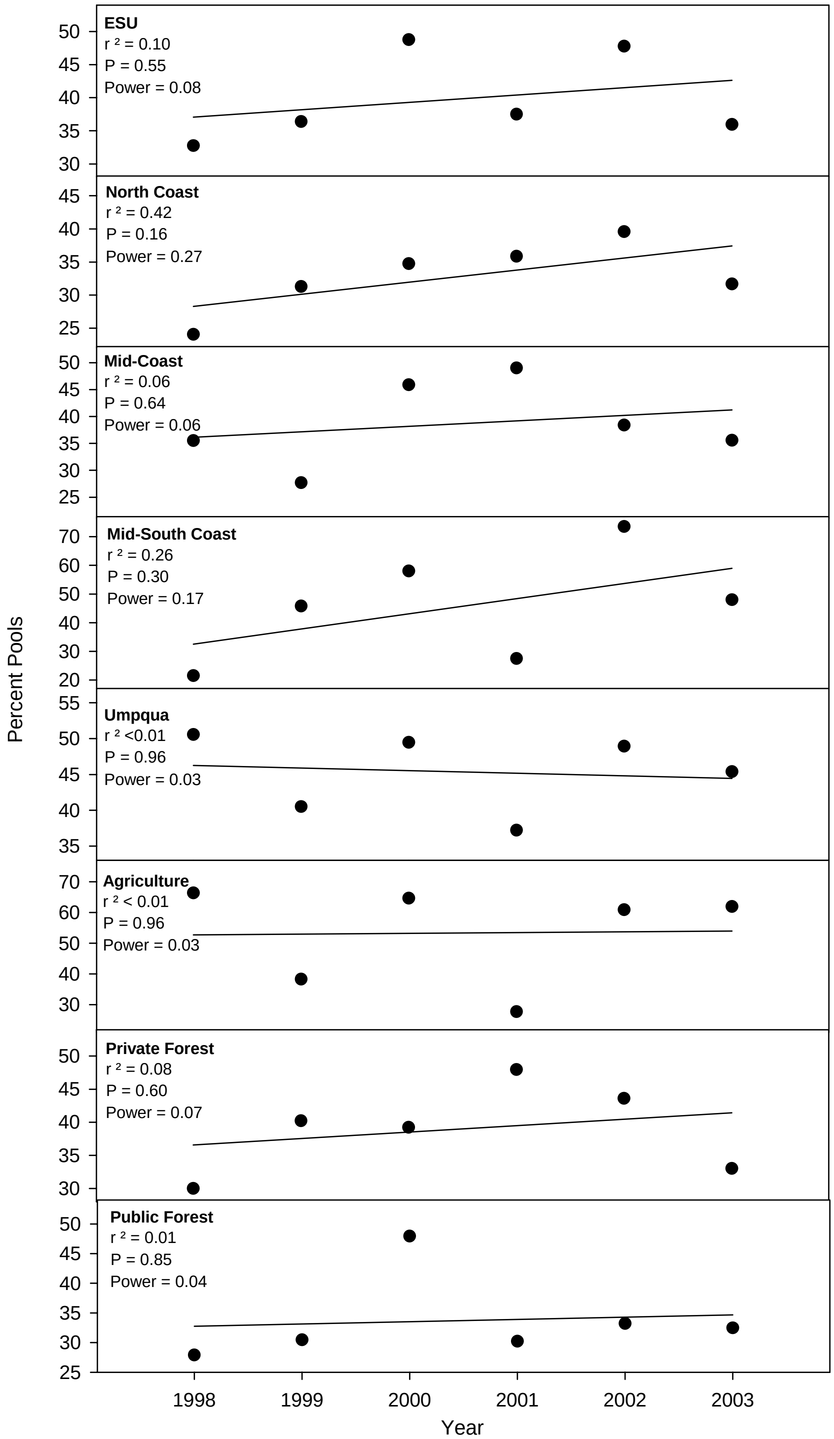

Figure 9. Yearly median values of the percent of pools at the ESU, monitoring area, and land use scale. Go to: http://nrimp.dfw.state.or.us/OregonPlan/default.aspx?page=130 for yearly median values.

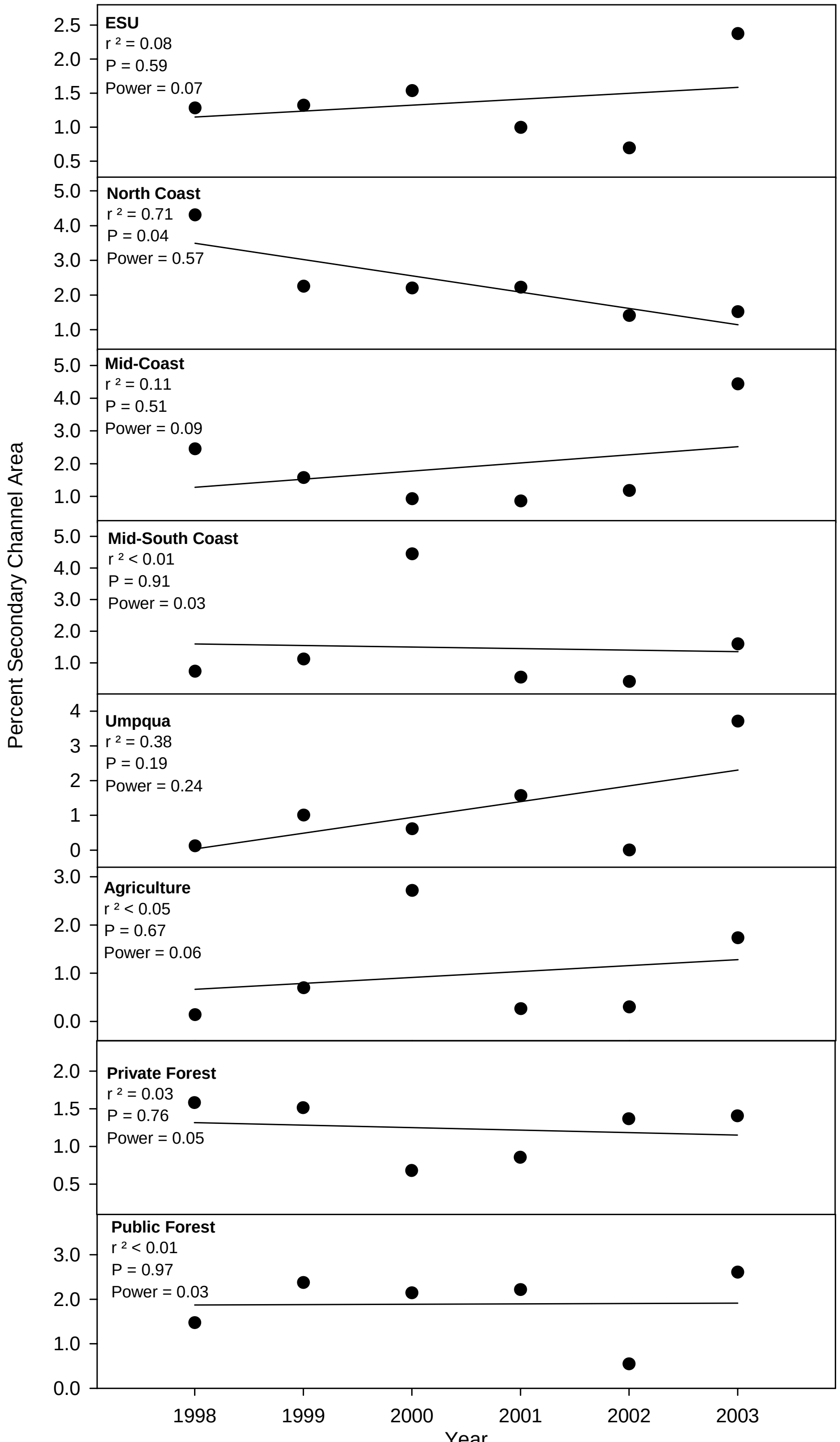

Figure 10. Yearly median values of the percent secondary channel area at the ESU, monitoring area, and land use scale. Go to: http://nrimp.dfw.state.or.us/OregonPlan/default.aspx?page=130 for yearly median values.

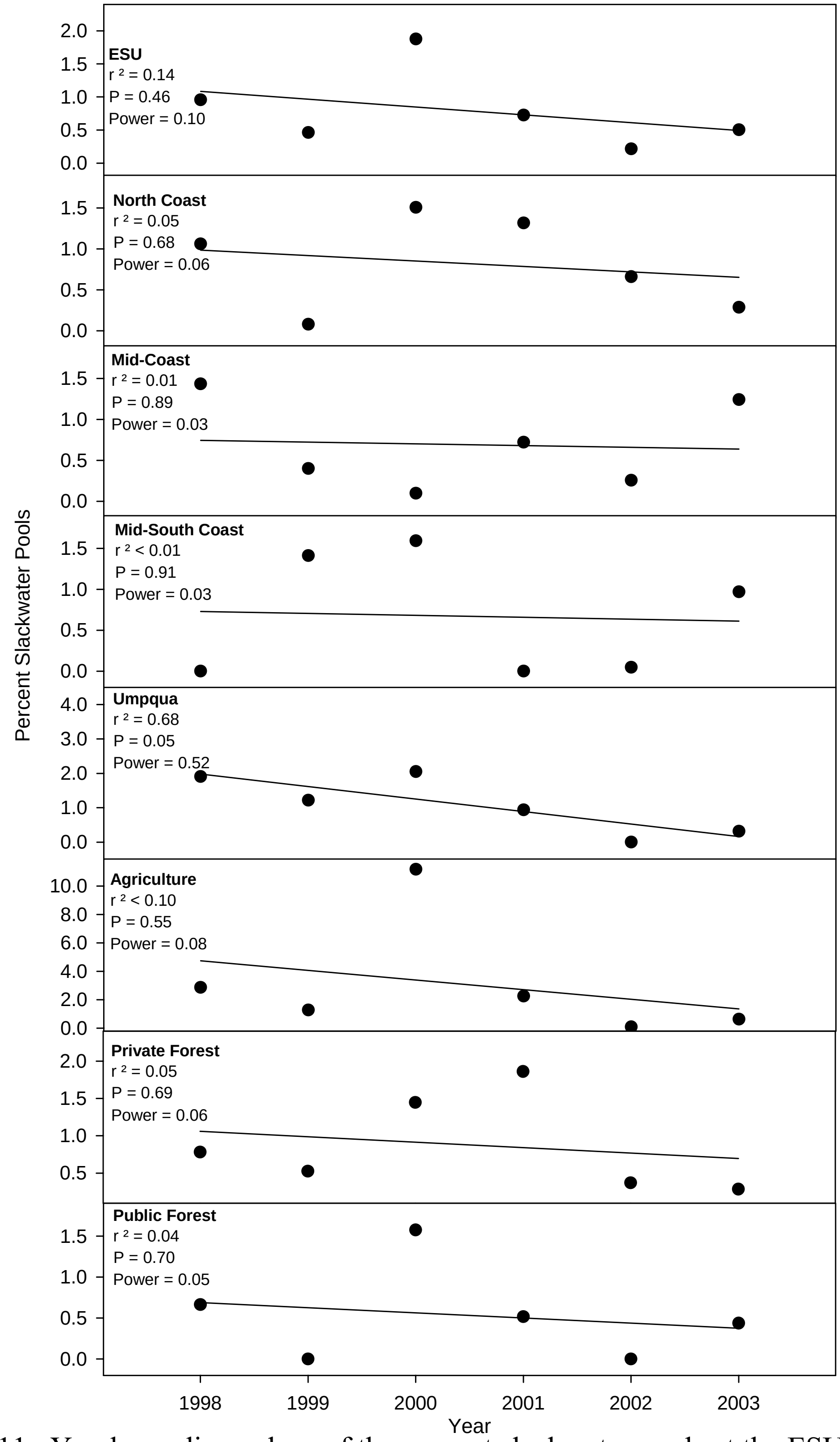

Figure 11. Yearly median values of the percent slackwater pools at the ESU, monitoring area, and land use scale. Go to: http://nrimp.dfw.state.or.us/OregonPlan/default.aspx?page=130 for yearly median values.

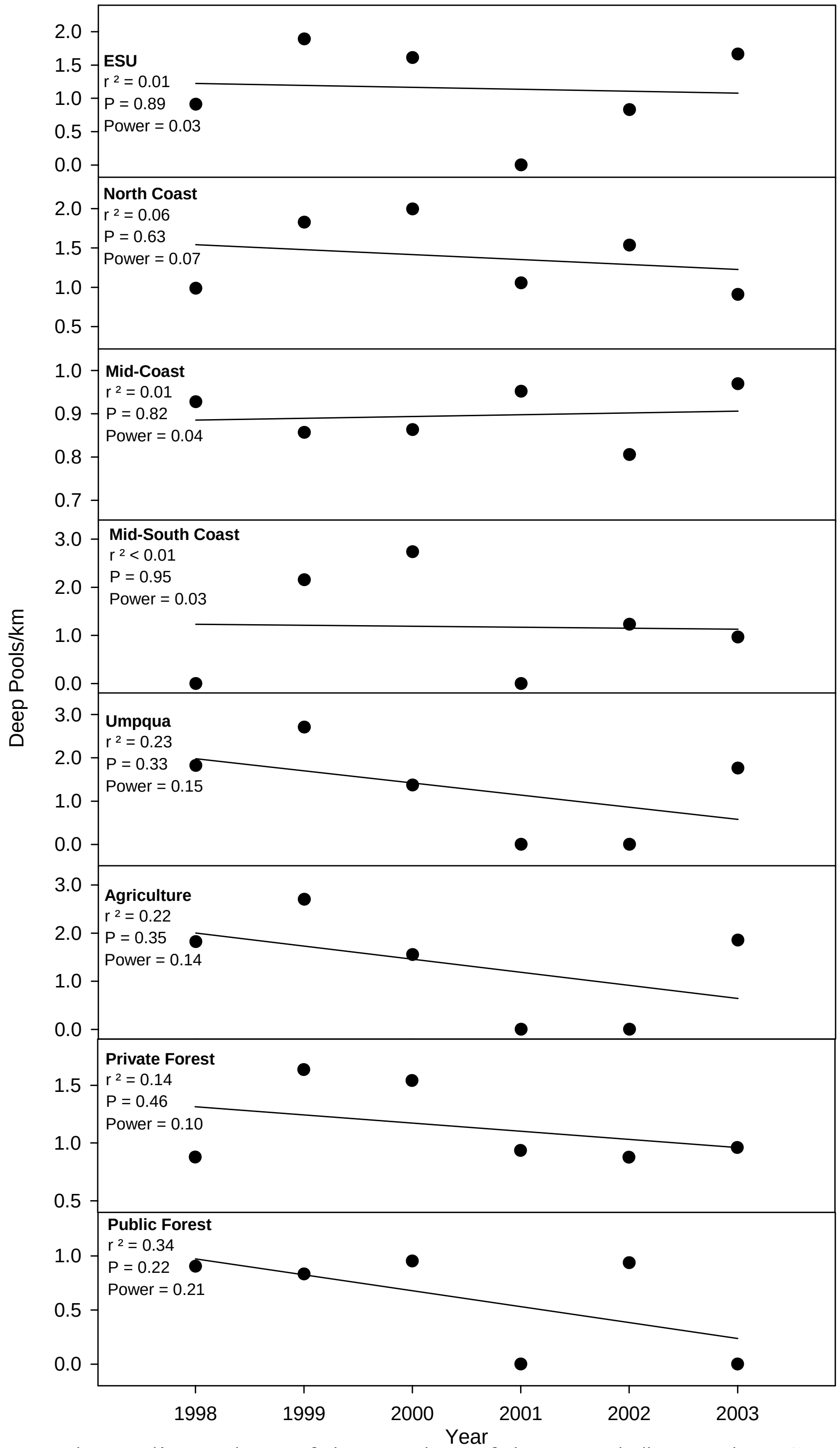

Figure 12. Yearly median values of the number of deep pools/km at the ESU, monitoring area, and land use scale. Go to: http://nrimp.dfw.state.or.us/OregonPlan/default.aspx?page=130 for yearly median values.

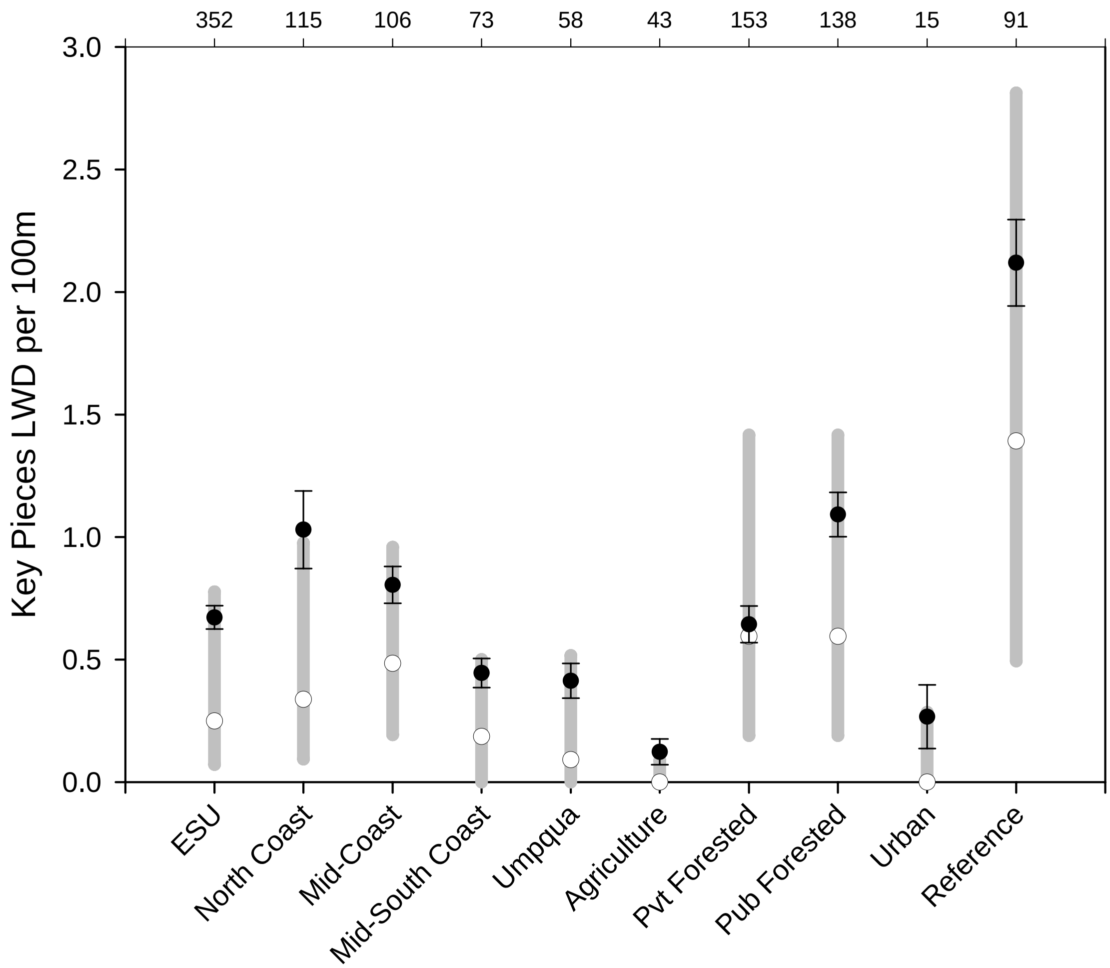

Figure 13. The number of key pieces of wood at reference sites and for random surveys conducted at the ESU, monitoring area, and land use scales from 1998-2003. (black circles = means; white circles = medians; thick gray bars = 25th and 75th percentiles; black lines = standard error of the mean). Sample sizes are along the top x-axis. Data are available at: http://nrimp.dfw.state.or.us/OregonPlan/default.aspx?page=130

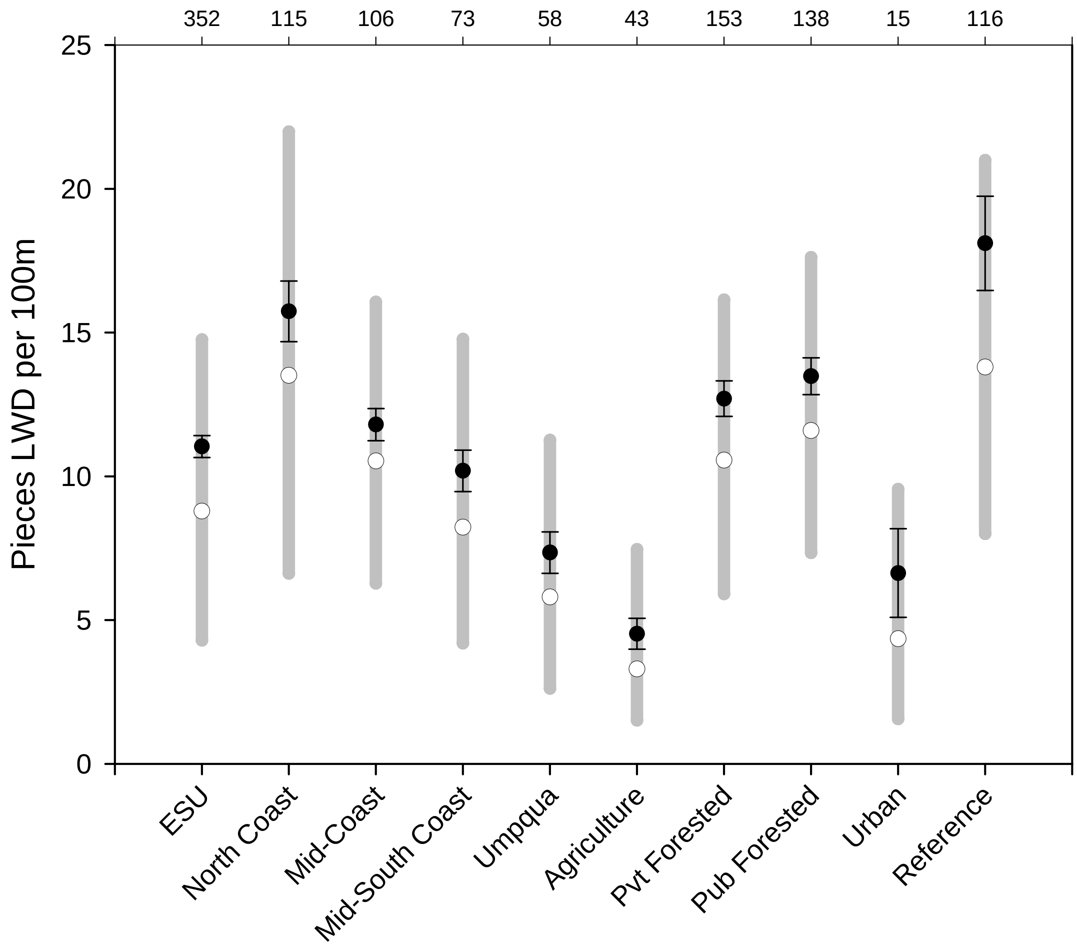

Figure 14. The number of pieces of wood at reference sites and for random surveys conducted at the ESU, monitoring area, and land use scales from 1998-2003. (black circles = means; white circles = medians; thick gray bars = 25th and 75th percentiles; black lines = standard error of the mean). Sample sizes are along the top x-axis. Data are available at: http://nrimp.dfw.state.or.us/OregonPlan/default.aspx?page=130

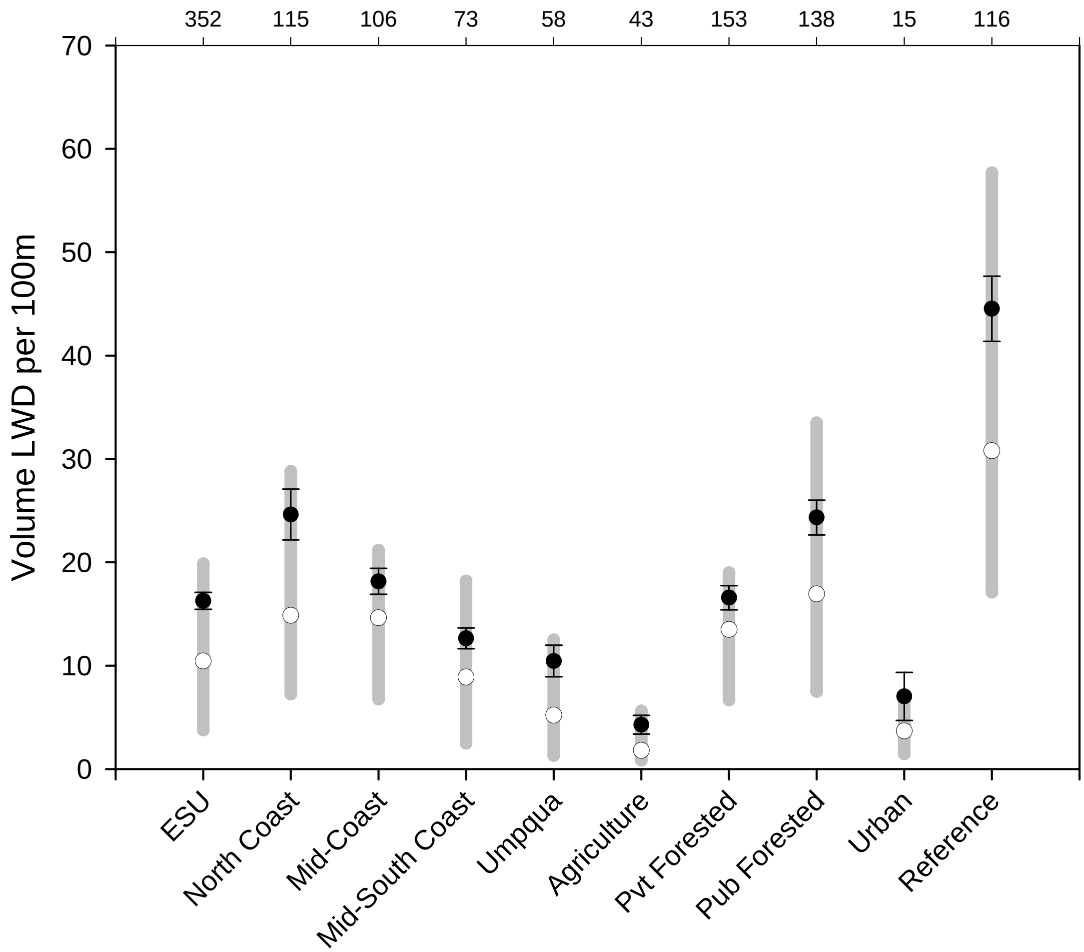

Figure 15. The volume of wood at reference sites and for random surveys conducted at the ESU, monitoring area, and land use scales from 1998-2003. (black circles = means; white circles = medians; thick gray bars = 25th and 75th percentiles; black lines = standard error of the mean). Sample sizes are along the top x-axis. Data are available at: http://nrimp.dfw.state.or.us/OregonPlan/default.aspx?page=130

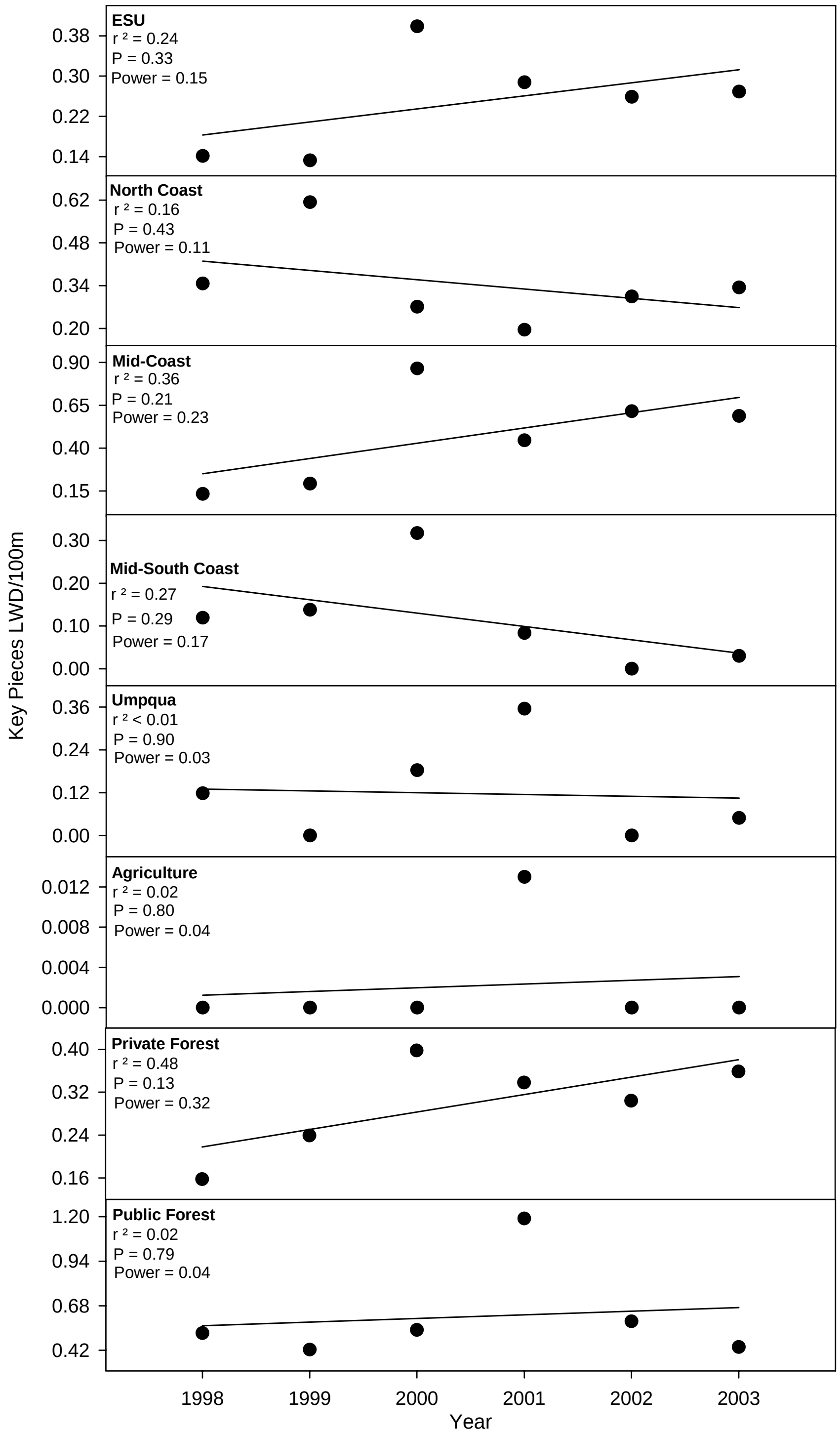

Figure 16. Yearly median values of the number of key pieces of large wood/100m of stream channel at the ESU, monitoring area, and land use scale. Go to: http://nrimp.dfw.state.or.us/OregonPlan/default.aspx?page=130 for yearly median values.

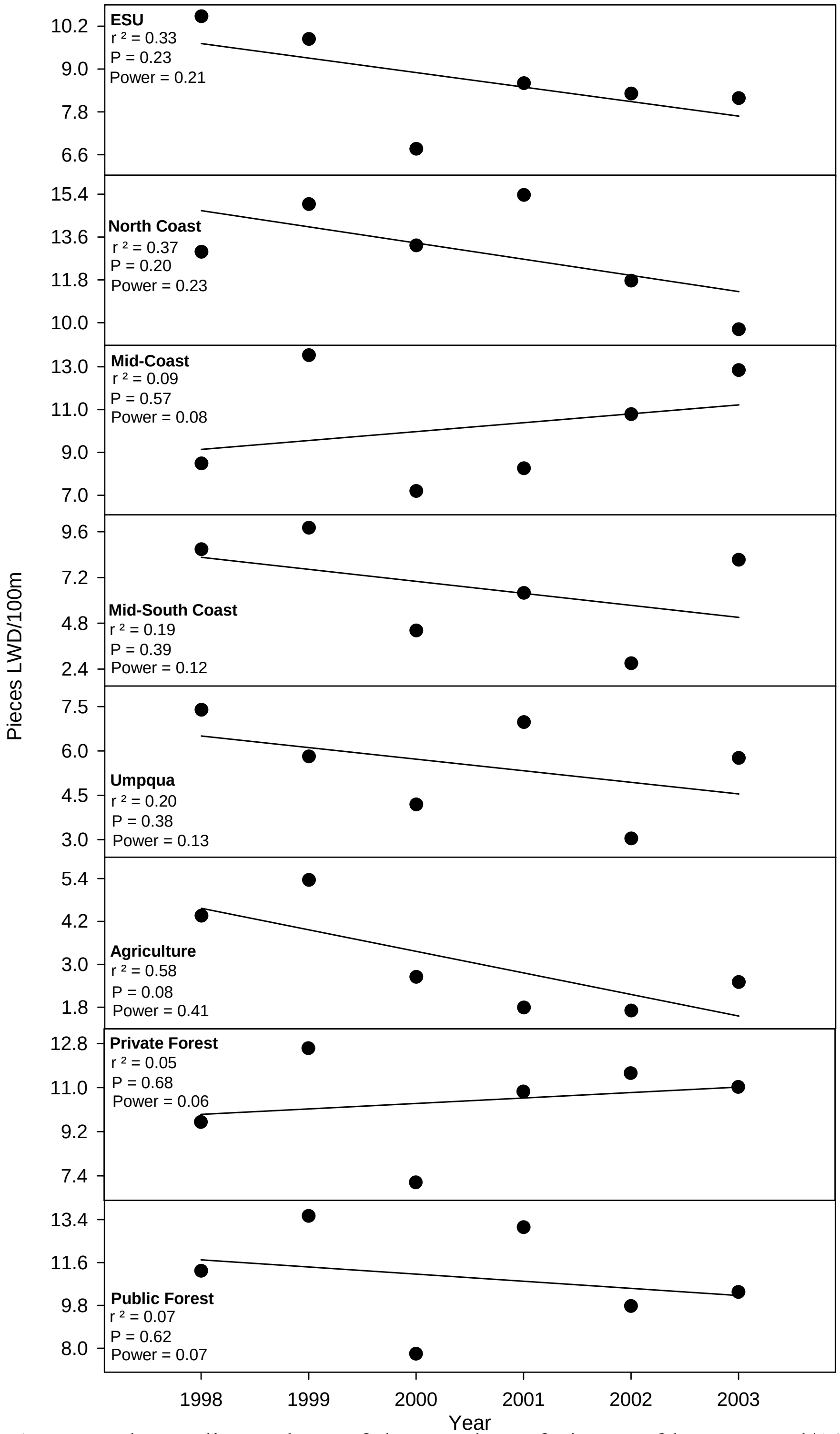

Figure 17. Yearly median values of the number of pieces of large wood/100m of stream channel at the ESU, monitoring area, and land use scale. Go to: http://nrimp.dfw.state.or.us/OregonPlan/default.aspx?page=130 for yearly median values.

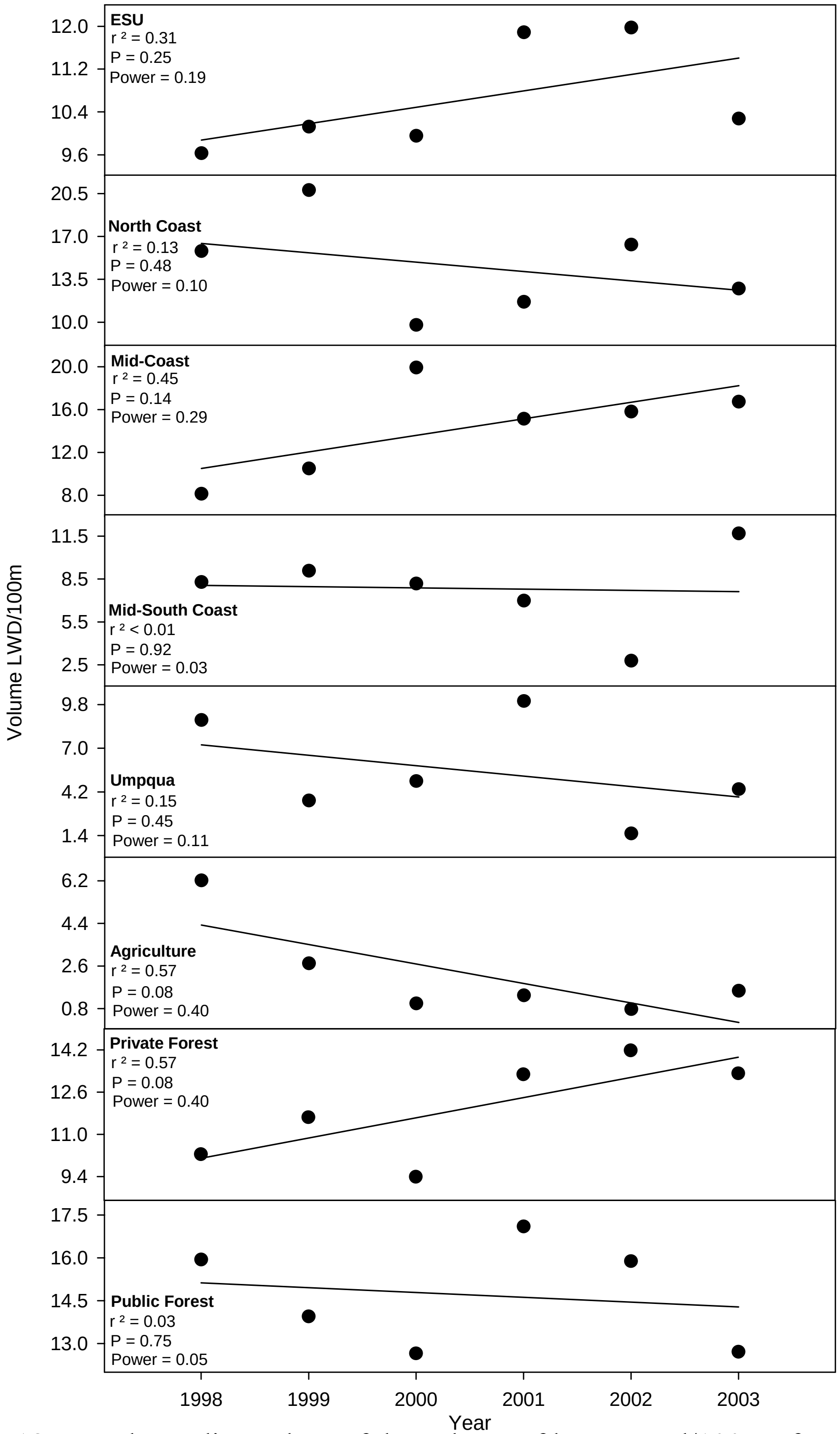

Figure 18. Yearly median values of the volume of large wood/100m of stream channel at the ESU, monitoring area, and land use scale. Go to: http://nrimp.dfw.state.or.us/OregonPlan/default.aspx?page=130 for yearly median values.

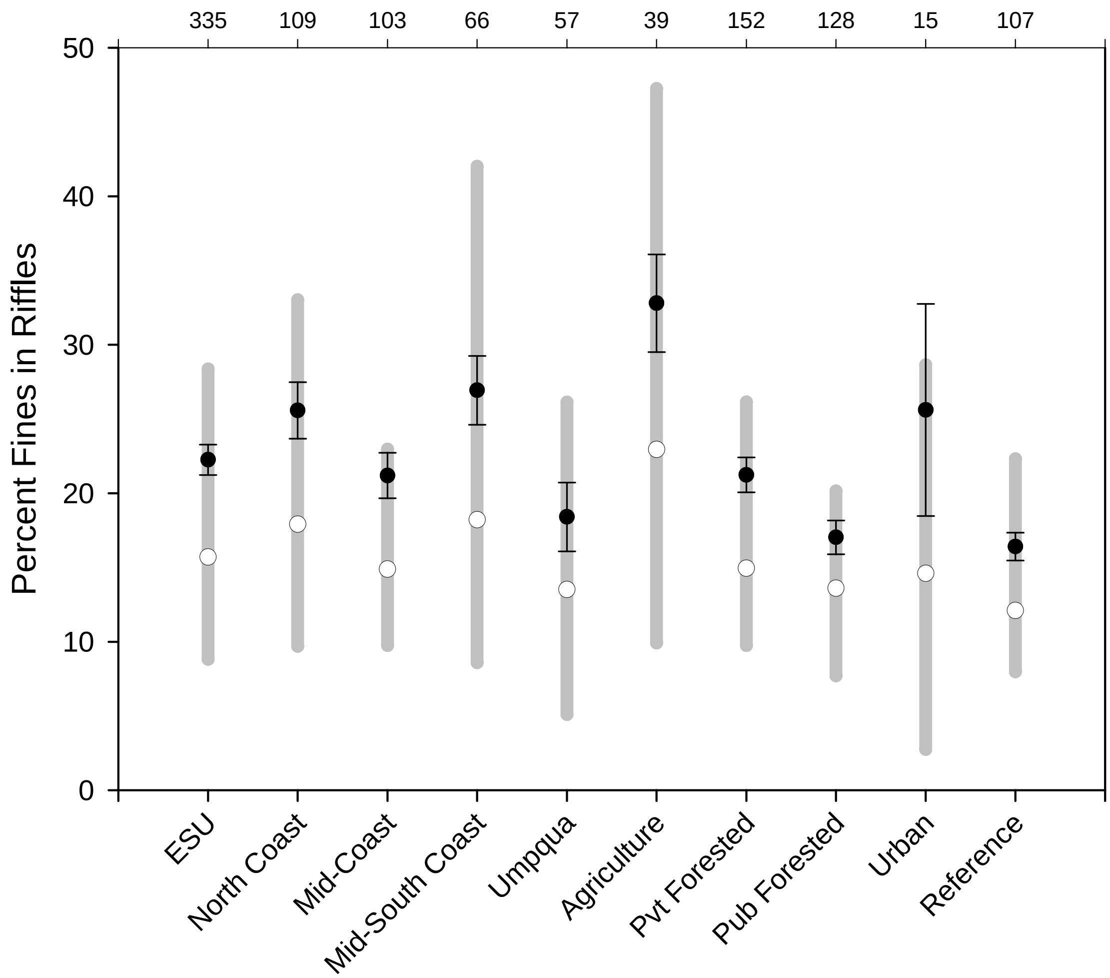

Figure 19. The percent of fine sediment in riffles at reference sites and for random surveys conducted at the ESU, monitoring area, and land use scales from 1998-2003. (black circles = means; white circles = medians; thick gray bars = 25th and 75th percentiles; black lines = standard error of the mean). Sample sizes are along the top x-axis. Data are available at: http://nrimp.dfw.state.or.us/OregonPlan/default.aspx?page=130

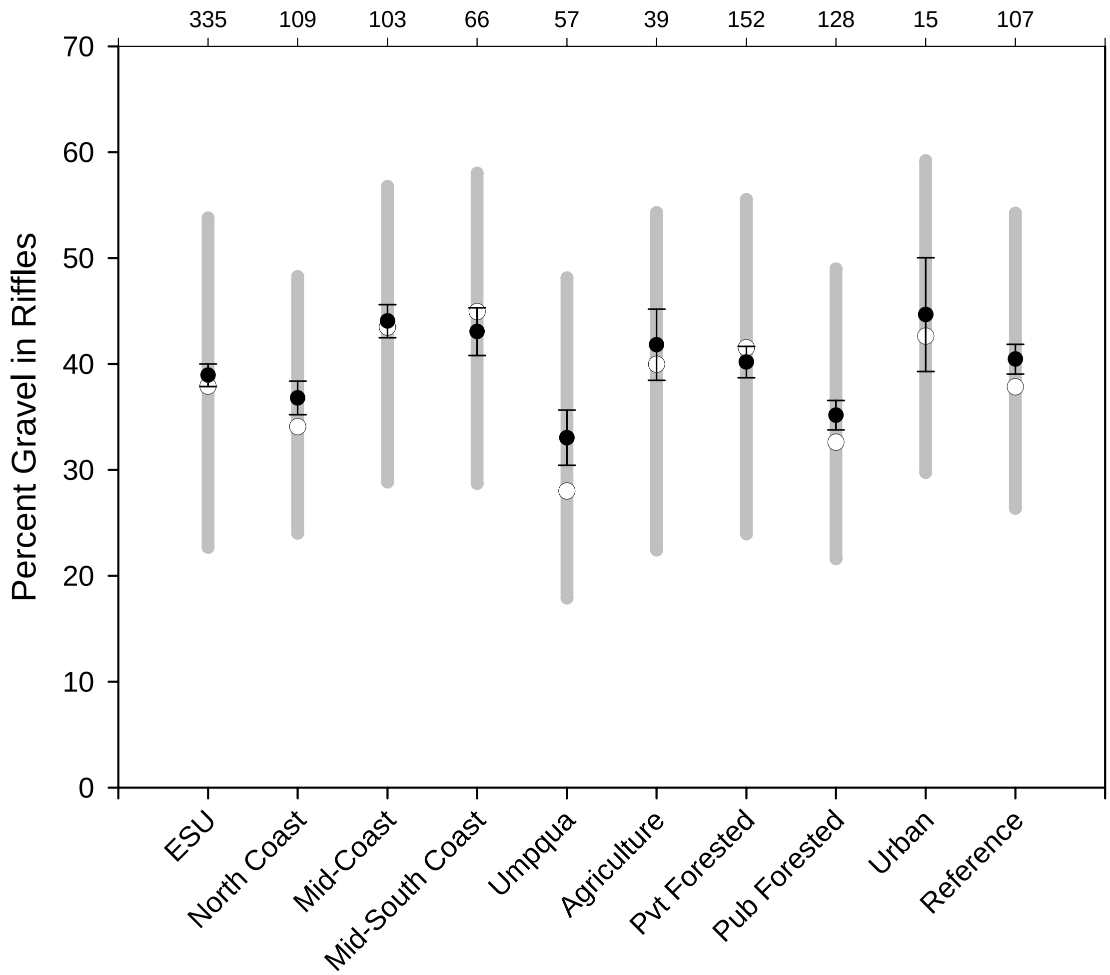

Figure 20. The percent of gravel in riffles at reference sites and for random surveys conducted at the ESU, monitoring area, and land use scales from 1998-2003. (black circles = means; white circles = medians; thick gray bars = 25th and 75th percentiles; black lines = standard error of the mean). Sample sizes are along the top x-axis. Data are available at: http://nrimp.dfw.state.or.us/OregonPlan/default.aspx?page=130

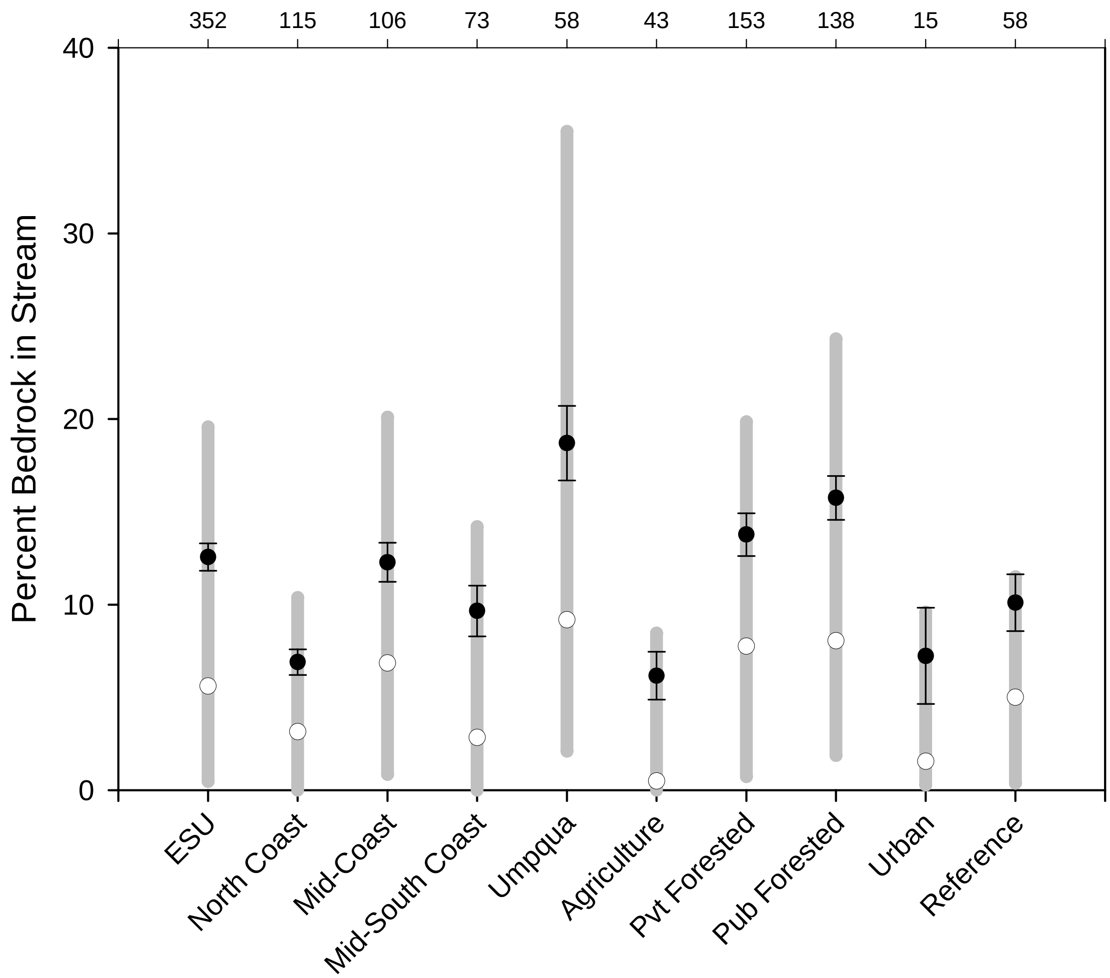

Figure 21. The percent of bedrock at reference sites and for random surveys conducted at the ESU, monitoring area, and land use scales from 1998-2003. (black circles = means; white circles = medians; thick gray bars = 25th and 75th percentiles; black lines = standard error of the mean). Sample sizes are along the top x-axis. Data are available at: http://nrimp.dfw.state.or.us/OregonPlan/default.aspx?page=130

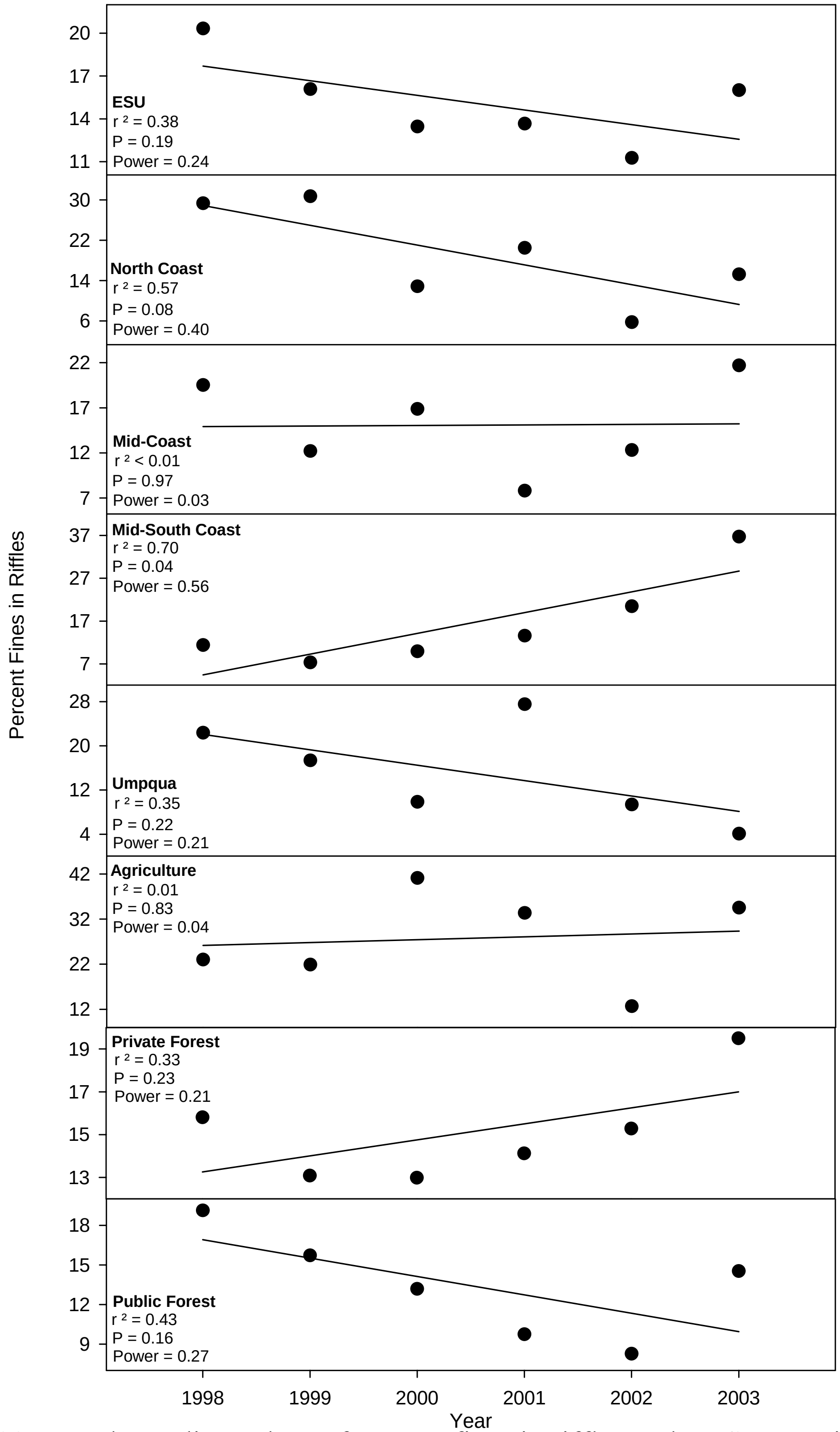

Figure 22. Yearly median values of percent fines in riffles at the ESU, monitoring area, and land use scale. Go to: http://nrimp.dfw.state.or.us/OregonPlan/default.aspx?page=130 for yearly median values.

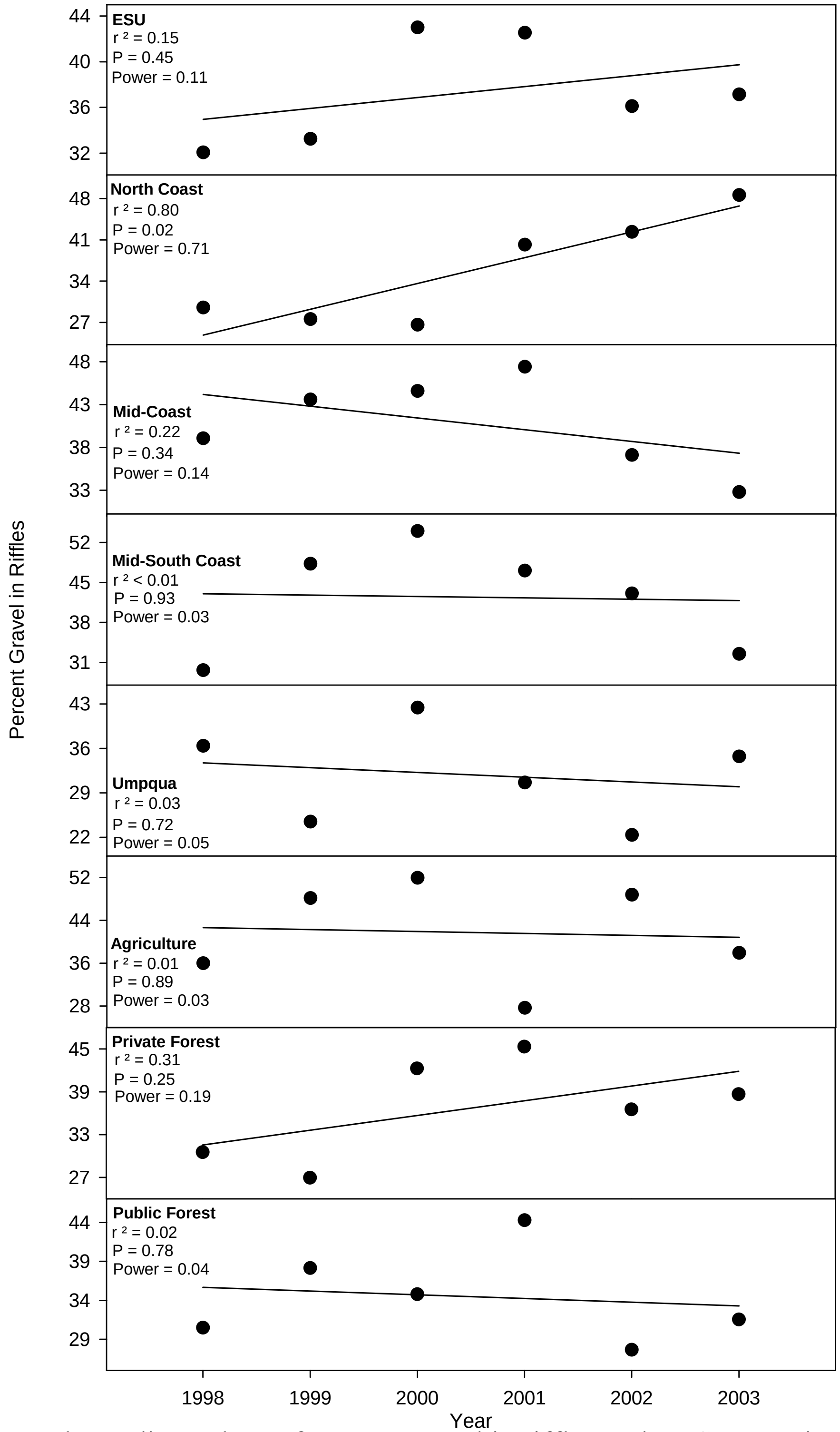

Figure 23. Yearly median values of percent gravel in riffles at the ESU, monitoring area, and land use scale. Go to: http://nrimp.dfw.state.or.us/OregonPlan/default.aspx?page=130 for yearly median values.

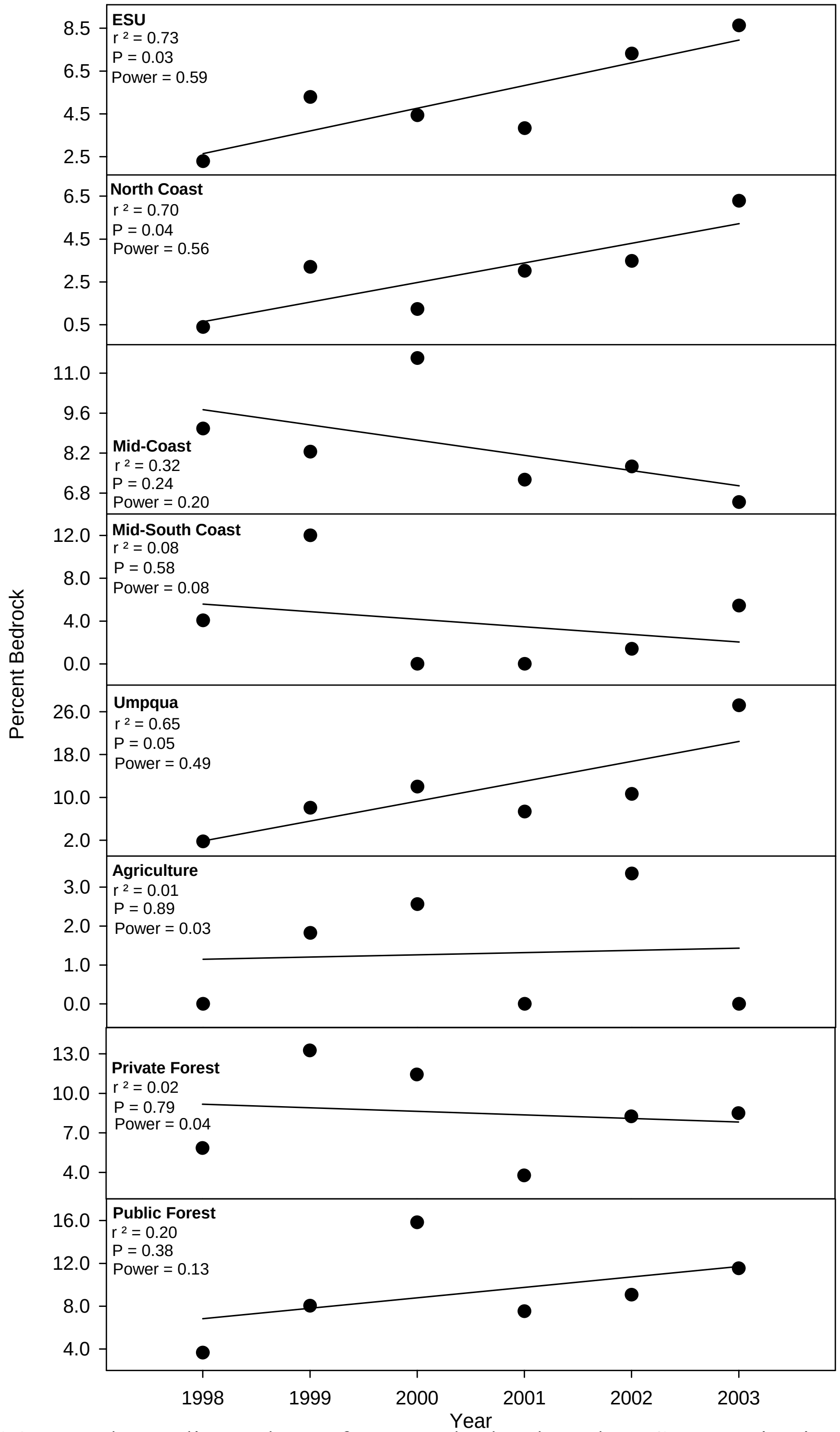

Figure 24. Yearly median values of percent bedrock at the ESU, monitoring area, and land use scale. Go to: http://nrimp.dfw.state.or.us/OregonPlan/default.aspx?page=130 for yearly median values.

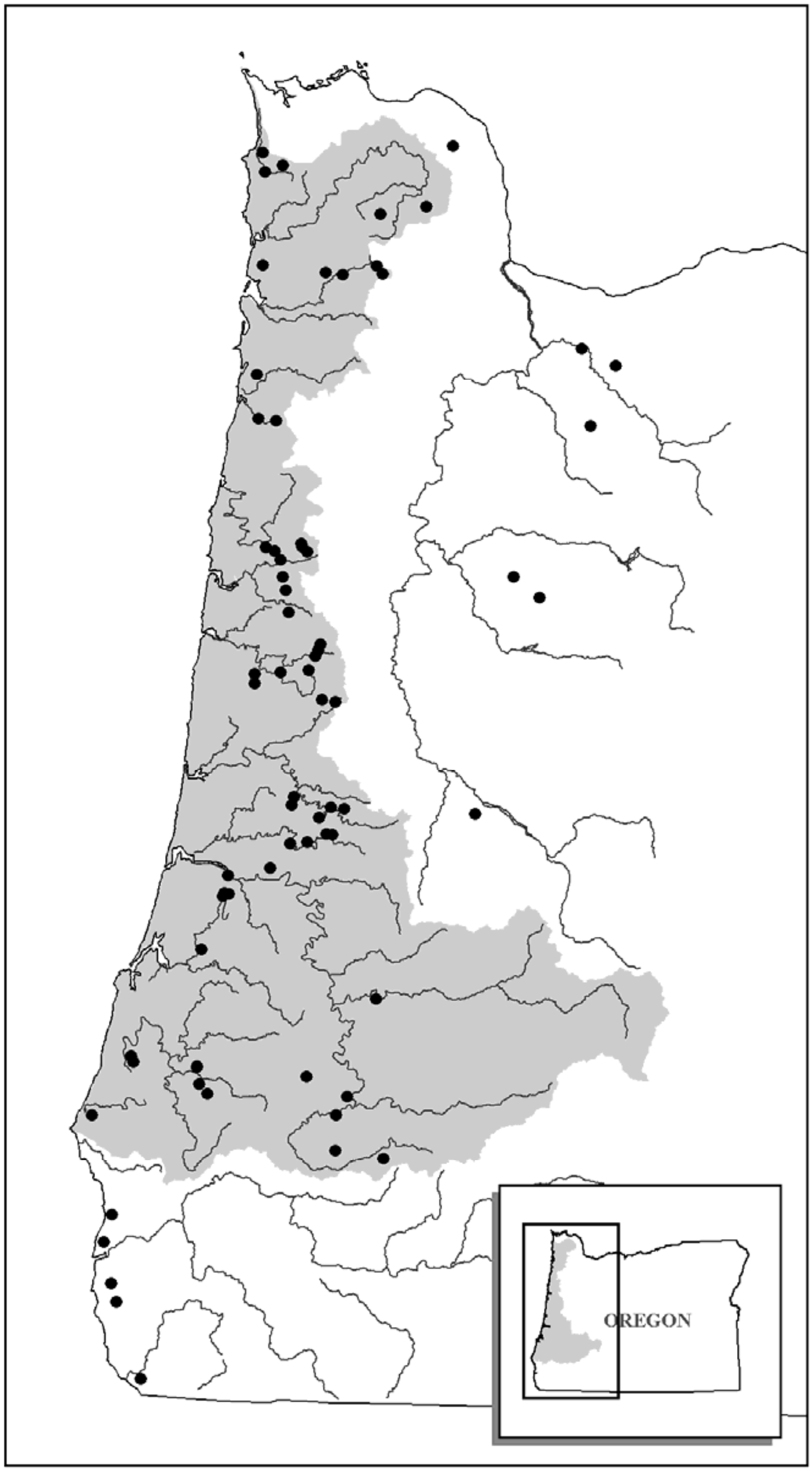

Figure 25. Location of restoration sites monitored before and after treatment. Geographic coordinates and habitat characteristics of the sites may be obtained at:
http://nrimp.dfw.state.or.us/OregonPlan/default.aspx?page=130

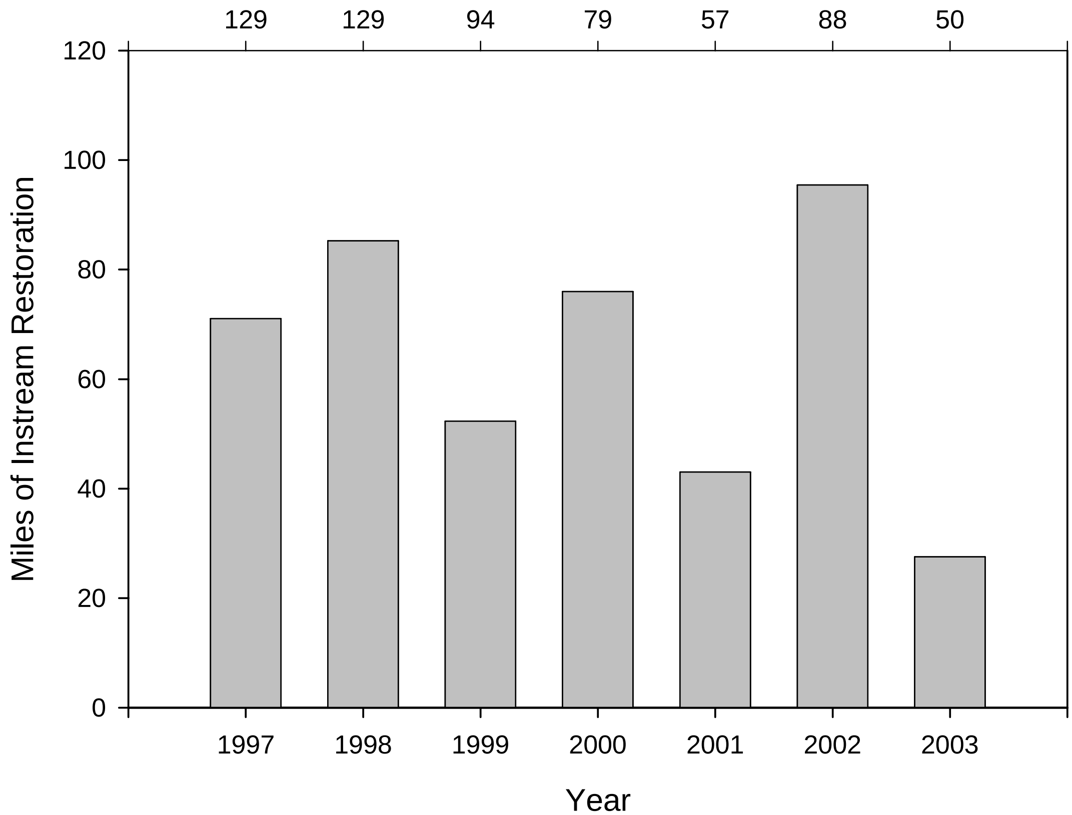

Figure 26. Miles of instream habitat restoration conducted each year in the Oregon Coastal coho ESU. Numbers along top x-axis are the number of projects.

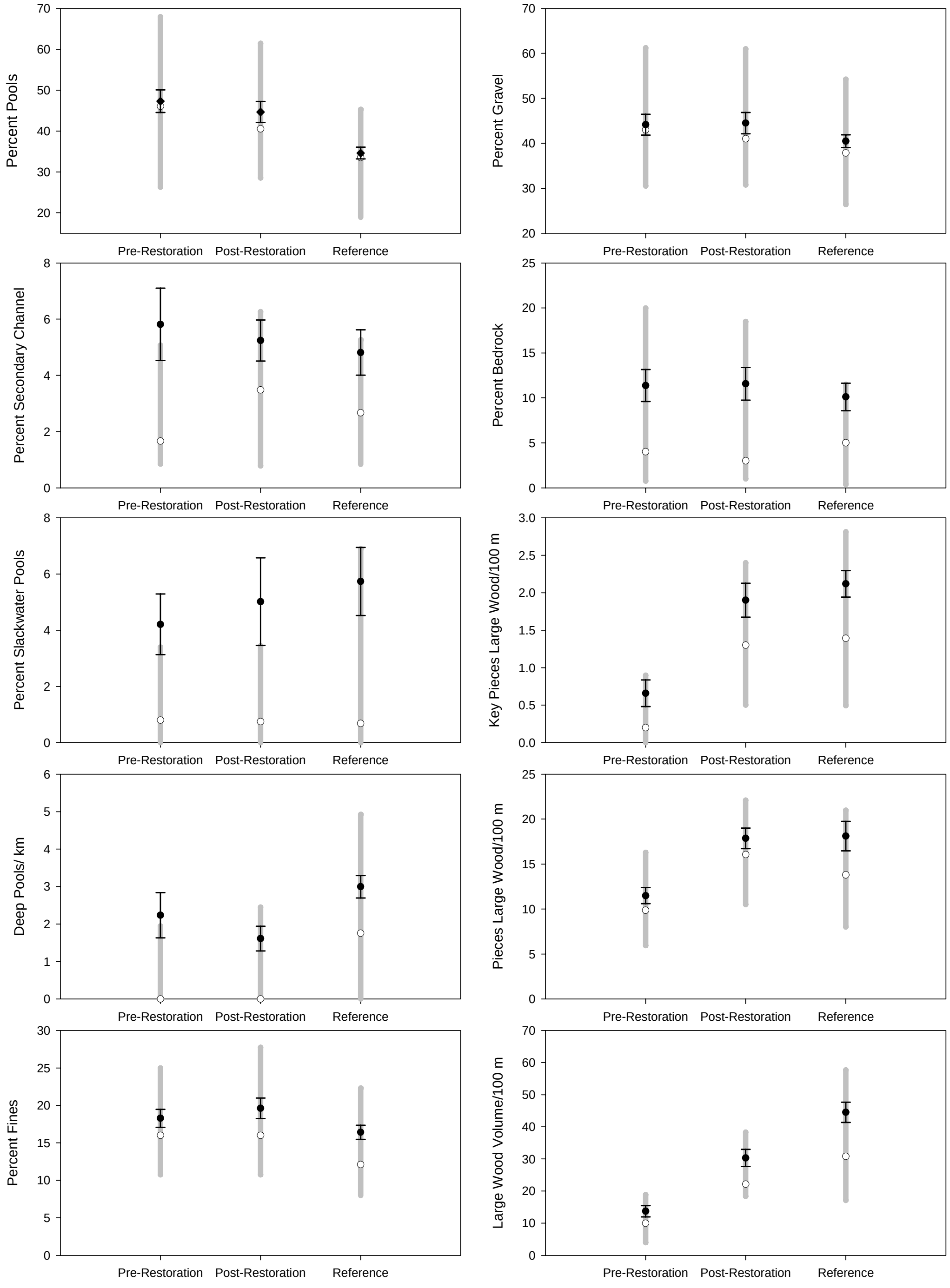

Figure 27. Pre- and post- habitat restoration conditions at 72 restoration sites and at reference sites surveyed by ODFW. (black circles = means; white circles = medians; thick gray bars = 25th and 75th percentiles; black lines = standard error of the mean).(Go to http://nrimp.dfw.state.or.us/OregonPlan/default.aspx?page=130 for a table of means, medians, and percentiles).

Chapter 2: Spatial Distribution and Relative Seasonal Capacity of Instream Habitat for Juvenile Coho Salmon in the Oregon Coastal Coho ESU

Executive Summary

Summer habitat smolt potential was calculated for all available habitat and then reduced proportionally to reflect potential summer water temperature limitations identified at the Monitoring Area scale by ODEQ (Part 4(B) Water Quality Report). Winter habitat smolt potential was calculated for all available habitat and for only high quality habitat. Calculation of the smolt potential from high quality habitat was conducted because modeling conducted by Nickelson and Lawson (1998) demonstrate that during periods of prolonged poor ocean survival, coho populations will tend to persist only in areas with high quality winter habitat.

During periods of good ocean survival, the temperature limited summer smolt capacity for the ESU as a whole is approximately 1.7 times higher than total winter smolt capacity. When only the smolt production capacity of high quality winter habitat is considered (i.e. those areas where populations will persist during poor ocean conditions) the temperature limited summer smolt capacity is over 6 times higher than winter capacity.

This analysis suggests that winter habitat (i.e. stream complexity) is a higher priority for restoring coho populations across the ESU than water quality. This analysis also demonstrates that during periods of good ocean conditions, the Umpqua populations may be limited by summer rearing capacity (i.e. water quality).

Introduction

Persistence of coho salmon populations in coastal drainages during periods of poor ocean conditions is dependent on the distribution and carrying capacity of freshwater habitat. Coho salmon are sensitive to the quality of habitat during each life stage and seasonal effects on survival are propagated through subsequent life stages (Nickelson et al. 1992). In this chapter, we use measures of habitat quality and quantity to determine overall carrying capacity of freshwater habitat at two juvenile coho life stages: 1) fry through summer parr; and 2) over-winter parr to smolt. From this information we identify life stages at which habitat may limit the coho smolt production capacity for the coho salmon populations considered independent by NOAA Fisheries Technical Recovery Team.

Methods for determining carrying capacity of streams in the Oregon Coastal ESU

Data Source

Streams within the Oregon Coastal ESU were surveyed from 1990 through 2003 in all but two of the independent coho salmon population units (Siltcoos Lake and Tahkenitch Lake). Habitat surveys were conducted in 1,898 reaches of selected streams during the summers of 1990–2003. More information about these "basin" surveys may be found at http://oregonstate.edu/dept/ODFW/freshwater/inventory/basinwid.html. Surveys were also conducted at 352 randomly selected sites during the summers of 1998-2003. A subset of 218 of the randomly selected sites were resurveyed during the following winter. More information about these random surveys may be found in chapter 1 of this report. From both types of surveys we collected information on attributes relevant to determining the potential quality and carrying capacity of aquatic habitat for different life stages of coho salmon: stream substrate (fine sediment, gravel, and cobble), habitat unit type (scour, beaver, and off channel pools), cover (large wood, undercut banks), and channel morphology (secondary channels, gradient).

Summer Habitat Capacity (parr/mile)

Estimates of summer capacity were developed following procedures outlined in the Habitat Limiting Factors Model (HLFM) described by Nickelson (1998). The model associates each habitat type with a specific seasonal density of coho salmon, which is multiplied by the surface area of each habitat unit and summed for each site or reach surveyed. We applied an updated version of the model which reduces by 66% the carrying capacity of all habitat types except beaver ponds and alcoves for streams larger than 12 meters active channel width. To reduce the potential bias associated with a non-proportional representation of land uses in the survey data, we adjusted each site weight by dividing the number of miles within a land use category in each population unit by the number of sites or reaches surveyed within that land use category. The carrying capacity for stream habitat within each population unit was then estimated using the following equation:

$$\text{Population Unit Capacity} = \sum_{1}^{n}(site * weight)$$

Where:
n= sites within population unit
weight = $miles_{LU}$ / n_{LU}
LU = land use category within a population unit

Winter Habitat Capacity (parr/mile)

To estimate winter habitat conditions at sites surveyed only in the summer, we developed a predictive model based on the relationship between summer and winter habitat conditions at the 218 sites surveyed both seasons. To develop the model we first used HLFM to estimate the number of parr supported at each of the 218 sites in the summer and winter. We then used estimated summer parr capacity and selected habitat parameters in a multiple regression (Neter and Wasserman 1974) to select explain the variation in estimated winter parr capacity. The final model we developed explains 79% of the variability in winter parr capacity. The predictive model is:

Winter Parr/km = 0.19 x (Summer Parr/km) + 14.51 x (Active Channel Width) + 10.47 x (% of Alcoves and Beaver Ponds) – 1

We estimated the winter carrying capacity of each population unit by summing the predicted estimates of each surveyed site multiplied by site weight adjusted by land use as described in the summer habitat capacity section.

Winter Habitat Quality (parr/m^2)

Modeling conducted by Nickelson and Lawson (1998) demonstrates that during periods of prolonged poor ocean survival (i.e. $\leq$ 3%), coho populations will be more likely to persist in areas with high quality winter habitat. Based on expected life cycle survival, a population at full seeding requires winter habitat with a quality sufficient to support a rearing density of > 0.3 juveniles/m^2 when marine survival is 3% for the population to replace itself (i.e. two spawners produce two adults) (Tom Nickelson, ODFW, personal communication).

The identification of high quality habitat within each population unit was determined using the HLFM model described earlier and the model HabRate (Burke et al. 2001) modified to accommodate Oregon Coast coho (Table 3 in Anlauf and Jones 2007). HabRate is a habitat based model designed to estimate the potential for smolt production based on a review of literature on the critical habitat needs for coho. HabRate's basic design is to assign a rating of high, medium, and low to the condition of each stream survey variable for each stream rearing life stage. Variable scores are combined to provide a rating for each life stage at the micro- and mesoscale. For instance, substrate ratings for fines, gravel and cobble, are combined to create an overall rating for substrate. Similarly habitat unit level information such as pools, depth, large boulders, and large wood are combined into an overall rating for habitat complexity. These overall ratings are then combined to create a single rating for that life stage.

We choose to use both the HLFM and HabRate models to estimate habitat quality because we believe they capture two different components of high quality habitat. The HLFM model does a good job of capturing channel morphology related aspects of winter habitat quality but does not include habitat complexity (e.g. amount of large wood). The HabRate model incorporates habitat complexity into habitat rankings but downplays the importance of channel morphology (e.g. off-channel habitat and beaver ponds).

The number of miles of high quality habitat within each population unit was determined using the site weight expansion factor as was done for carrying capacity estimates. Carrying capacity was estimated for each high quality site (identified by either the HLFM or HabRate model), and expanded to represent the miles of high quality habitat within a population unit.

Summer to winter smolt capacity comparisons

We compared the carrying capacity of habitat during the summer rearing period and the winter rearing period to assess the limiting season (or life stage) for juvenile coho salmon in each population unit. We then summed the total carrying capacity during summer and winter within each population unit and applied a density independent survival factor obtained from Nickelson (1998) to calculate total smolt potential (72% survival from summer juvenile to smolt out-migrant, and 90% survival from winter juvenile to smolt out-migrant).

The Oregon Department of Environmental Quality's assessment of water quality conditions in the Oregon Coast ESU (Part 4(B) Water Quality Report) found that a significant amount stream reaches available in the ESU exceed water temperature standards (54% at the ESU scale; 31% in the North Coast; 54% in the Mid-Coast; 44% in the Mid-South Coast; and 77% in the Umpqua). To assess the potential impact of water temperature limitations on summer habitat capacity, we reduced the total potential summer smolt production capacity of each population unit by the percentage ODEQ found for the monitoring area in which the population unit is embedded.

The smolt production capacity of currently available winter habitat was estimated in two ways. The first was a measure of total potential capacity of winter habitat in each population unit. This represents the potential production of smolts based on all available winter habitat during periods of good ocean survival (i.e. >3%). The second approach uses only the smolt production capacity from high quality winter habitat. This represents the potential production of smolts from habitat where populations are expected to persist during periods of poor ocean survival (i.e. ≤ 3%).

Lakes

Special considerations were made when calculating habitat capacity and quality from the lakes in the Oregon Coastal coho ESU. For summer and winter habitat capacity (i.e. total parr and parr/mile), only free flowing stream reaches were considered. Since no stream habitat survey data are available for the Siltcoos and Tahkenitch Lake systems, we were unable to calculate parr capacity for these two population units. For winter habitat quality, all stream miles accessible to coho above lakes were given a high habitat quality ranking under the assumption that fish from these areas migrate to the lakes where they would experience high overwinter survival rates. We did not calculate an estimate of smolt production capacity for lake systems due to a lack of quantitative information on the carrying capacities of the lakes.

Results and Discussion

Summer parr capacity ranged from 1,985 parr/mile in the South Umpqua to 8,991 parr/mile in the Yaquina (Table 1). The overall average for the ESU was 5,358 parr/mile. Total capacity of summer habitat at the population level ranged from 239,675 parr in Beaver Creek to 4,574,850 parr in the Nehalem (Table 1). Winter habitat parr capacity ranged from 616 parr/mile in the South Umpqua to 2,199 parr/mile in the Coos, and totaled from 60,727 in Beaver Creek to 1,159,863 in the Nehalem (Table 1).

The location of high quality winter habitat sites is shown in Figure 1. The amount of high quality winter habitat varies dramatically by population, ranging from 0% in the Sixes to 74% in the Siltcoos (Table 2). The total amount of high quality winter habitat is estimated to comprise approximately 14% of freshwater habitat available to juvenile coho across the ESU. This value is less than the 22% estimate of high quality habitat that Nickelson (1998) reported for the Oregon Coast in 1998. We believe that four factors influence the difference between these two estimates: 1) differences in the equations used to convert summer habitat to winter habitat capacity; 2) potential bias because the habitat surveys available for use in the Nickelson (1998) analysis were basin surveys conducted primarily on forested streams, 3) the earlier analysis also used data from USDA Forest Service surveys which the current analysis did not include, and; 4) the addition of random surveys and weighting by land use in the current analysis.

It is important to remember that our estimate of the amount of high quality habitat is based on a 3% marine survival rate. Because the relationship between marine survival rate and habitat quality needed for population equilibrium (i.e. replacement) is curvilinear, the numerical definition of high quality habitat (i.e. fish/m^2) changes with marine survival (Figure 2). Further, due to density dependant compensation effects on freshwater survival rates, the numerical definition of high quality habitat for a given marine survival rate changes with population seeding level. As a result, there is no single correct answer for the amount of high quality habitat available to coho in the Oregon Coastal coho ESU. Our estimates of the amount of high quality habitat should be viewed as an index which will be most useful to future analyses of habitat trend.

Table 3 shows the seasonal estimated number of smolts for each population unit. Assuming no water temperature limitations, the summer smolt capacity for the ESU as a whole is over three times more than that of the winter habitat capacity. Further, all population units have substantially more summer habitat capacity to produce smolts compared to winter habitat capacity when potential summer temperature limitations are not included. When ODEQ's estimates of water temperature limitations are incorporated into the summer smolt capacity estimates, all population units except those in the Umpqua still have substantially more summer habitat smolt production capacity than winter capacity (Table 3). When only the winter smolt production potential of high quality habitat is considered, summer habitat smolt production potential without temperature limitations is 12 times that of winter habitat potential, and over six times that of winter potential even with assumed temperature limitations. Thus it appears that with the exception of areas in the Umpqua during good ocean conditions, the smolt production capacity of most population units is limited by stream complexity rather than water temperature.

A caveat pertaining to our conclusions regarding seasonal habitat bottlenecks is that our analysis does not consider the spatial juxtaposition of winter and summer habitat. If winter habitat and summer habitat are sufficiently separated such that fish cannot move between them, habitat connectivity and/or proximity may limit smolt production regardless of the amount of high quality winter habitat. In addition, if areas of high winter habitat quality are areas with summer temperature limitations, and these high quality winter habitat areas are not accessible by fish residing during the summer in non-temperature limited reaches, it is possible that summer habitat conditions could limit smolt production, again regardless of the amount of high quality winter habitat. While our analysis does address this issue to some degree by evaluating habitat limitations at the population unit scale rather than just at the ESU scale, we currently lack the ability to incorporate finer scale spatial patterns of seasonal habitat capacity into our analysis.

Finally, we believe that our estimates of the amount of quality winter habitat are most likely underestimates. Our analysis is based primarily on habitat surveys conducted in wadeable stream reaches and thus may not adequately inventory the amount of high quality winter habitat available in areas such as off-channel habitat along non-wadeable stream reaches and tidal wetlands. In the future, more Oregon Plan monitoring resources will be devoted to identifying and monitoring the habitat quality in these areas.

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Table 1. Estimated capacity of summer and winter rearing habitat within the Oregon Coastal coho ESU to rear juvenile coho parr.

Population Unit	Summer		Winter	
	Parr/mile	Total Parr	Parr/mile	Total Parr
Necanicum	4,116	292,253	1,025	72,776
Nehalem	6,879	4,574,850	1,744	1,159,863
Nestucca	5,018	1,023,726	1,259	256,859
Tillamook	6,444	2,351,923	1,601	584,255
Alsea	6,864	2,594,599	1,574	594,971
Beaver	6,658	239,675	1,687	60,727
Salmon	5,297	291,354	1,385	76,200
Siletz	4,931	1,237,796	1,263	316,952
Siuslaw	6,208	4,711,605	1,483	1,125,592
Yaquina	8,991	2,211,868	2,158	530,765
Coos	6,854	2,823,902	2,199	906,025
Coquille	5,347	2,892,838	1,269	686,575
Floras	5,801	413,620	1,283	91,495
Siltcoos	NA[1]	NA[1]	NA[1]	NA[1]
Sixes	7,776	471,869	1,818	110,308
Tahkenitch	NA[1]	NA[1]	NA[1]	NA[1]
Tenmile[2]	8,109	637,264	2,106	165,480
Lower Umpqua	6,168	3,300,142	1,499	802,229
Midddle Umpqua	3,366	1,760,354	848	443,521
North Umpqua	2,768	492,620	711	126,471
South Umpqua	1,985	1,470,649	616	456,353
ESU	5,358	33,792,907	1,358	8,567,416

[1]Estimates not available not available.
[2]For stream segments only - does not include lake capacity.

Table 2. The amount of high quality winter habitat for juvenile coho in the Oregon Coastal coho ESU.

Population Unit	Total Miles Available To Juvenile Coho	% High Quality Habitat	Miles of High Quality Habitat
Necanicum	71	5%	3
Nehalem	665	14%	95
Nestucca	204	5%	11
Tillamook	365	3%	11
Alsea	378	12%	46
Beaver	36	49%	18
Salmon	55	4%	2
Siletz	251	11%	27
Siuslaw	759	22%	168
Yaquina	246	23%	57
Coos	412	21%	85
Coquille	541	13%	72
Floras	71	18%	13
Siltcoos	88	74%	65
Sixes	61	0%	0
Tahkenitch	48	69%	33
Tenmile	79	61%	48
Lower Umpqua	535	11%	61
Middle Umpqua	523	7%	35
North Umpqua	178	6%	10
South Umpqua	741	3%	20
ESU	6307	14%	879

Table 3. Relative coho smolt production capacity of summer and winter habitat in streams in the Oregon Coastal coho ESU.

Population Unit	Summer Smolt Capacity With No Temperature Limitation	Summer Smolt Capacity With Temperature Limitation	Winter Smolt Capacity Based on Total Available Habitat	Winter Smolt Capacity Based on High Quality Habitat	Ratio of Summer Smolt Capacity Relative to Total Winter Capacity With No Summer Temperature Limitation	Ratio of Summer Smolt Capacity Relative to High Quality Winter Habitat Capacity With No Summer Temperature Limitation	Ratio of Summer Smolt Capacity Relative to Total Winter Capacity With Summer Temperature Limitation	Ratio of Summer Smolt Capacity Relative to High Quality Winter Habitat Capacity With Summer Temperature Limitation
Necanicum	210,422	145,191	65,498	12,844	3.2	16.4	2.2	11.3
Nehalem	3,293,892	2,272,785	1,043,877	244,570	3.2	13.5	2.2	9.3
Nestucca	737,083	508,587	231,173	22,070	3.2	33.4	2.2	23.0
Tillamook	1,693,385	1,168,435	525,830	45,741	3.2	37.0	2.2	25.5
Alsea	1,868,111	859,331	535,474	108,784	3.5	17.2	1.6	7.9
Beaver	172,566	79,380	54,654	40,604	3.2	4.2	1.5	2.0
Salmon	209,775	96,496	68,580	9,068	3.1	23.1	1.4	10.6
Siletz	891,213	409,958	285,257	89,182	3.1	10.0	1.4	4.6
Siuslaw	3,392,355	1,560,483	1,013,033	327,643	3.3	10.4	1.5	4.8
Yaquina	1,592,545	732,571	477,688	225,182	3.3	7.1	1.5	3.3
Coos	2,033,210	1,138,597	815,422	467,636	2.5	4.3	1.4	2.4
Coquille	2,082,844	1,166,392	617,918	129,569	3.4	16.1	1.9	9.0
Floras	297,806	166,772	82,346	0	3.6	-[1]	2.0	-[1]
Siltcoos	NA[2]	NA[2]	NA[2]	NA[2]	NA[2]	NA[2]	NA[2]	NA[2]
Sixes	339,746	190,258	99,277	0	3.4	-[1]	1.9	-[1]
Tahkenitch	NA[2]	NA[2]	NA[2]	NA[2]	NA[2]	NA[2]	NA[2]	NA[2]
Tenmile	NA[2]	NA[2]	NA[2]	NA[2]	NA[2]	NA[2]	NA[2]	NA[2]
Lower Umpqua	2,376,102	546,504	722,006	137,878	3.3	17.2	0.8	4.0
Middle Umpqua	1,267,455	291,515	**638,670**[3]	105,591	3.2	12.0	0.0	2.8
North Umpqua	354,686	81,578	**182,119**[3]	16,131	3.1	22.0	0.0	5.1
South Umpqua	1,058,867	243,539	**657,148**[3]	50,051	2.6	21.2	0.0	4.9
ESU	**23,872,063**[3]	**12,890,914**[3]	**8,115,969**[3]	2,032,543	3.2	117.4	1.6	63.4

[1]No high quality habitat available.
[2]Estimates for lake population units not available.

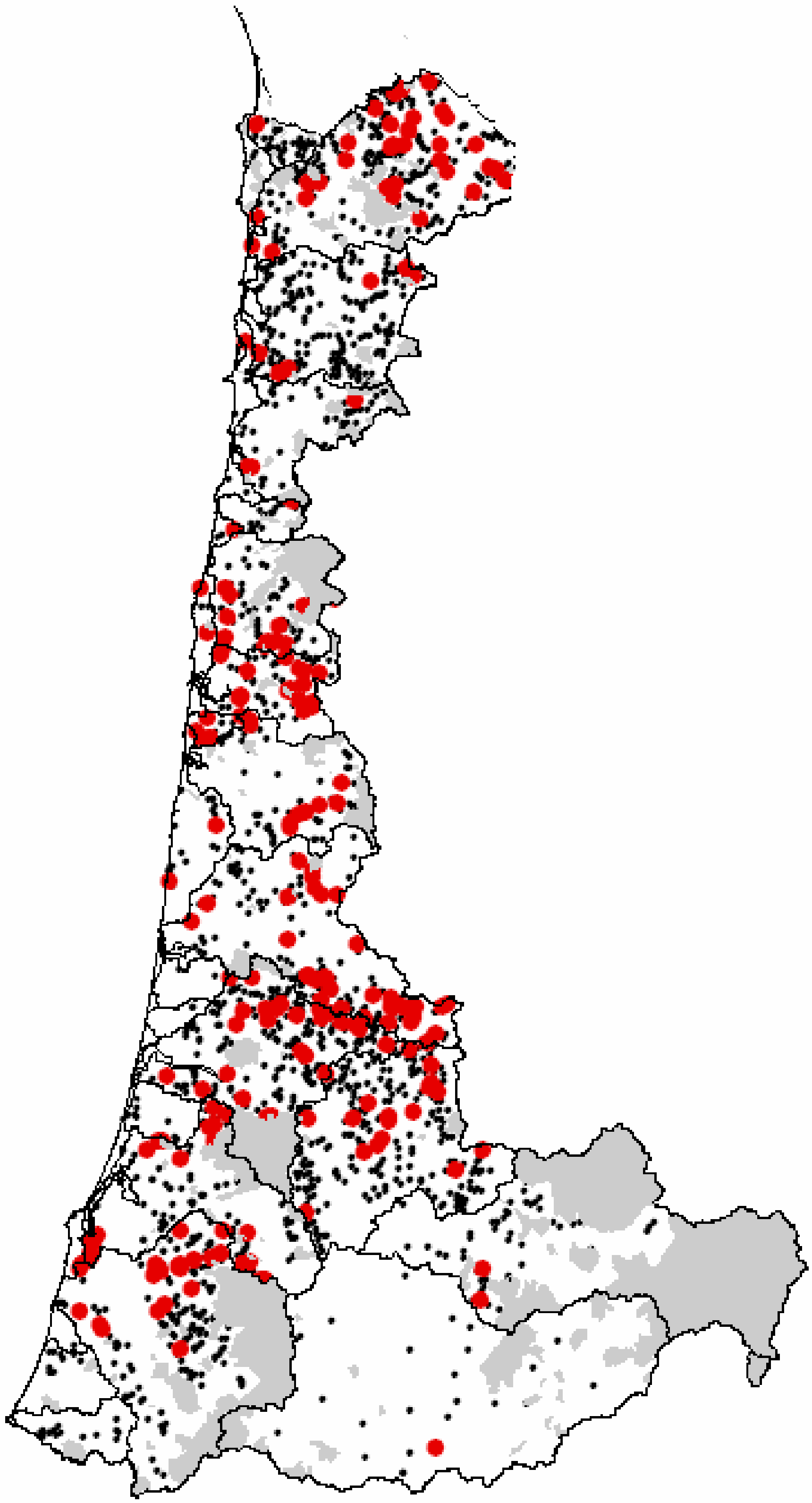

Figure 1. Location of high quality habitat sites for overwintering coho in the Oregon Coastal coho ESU (large dots). The smaller black dots indicate other sites surveyed for habitat quality. Gray areas are inaccessible to coho.

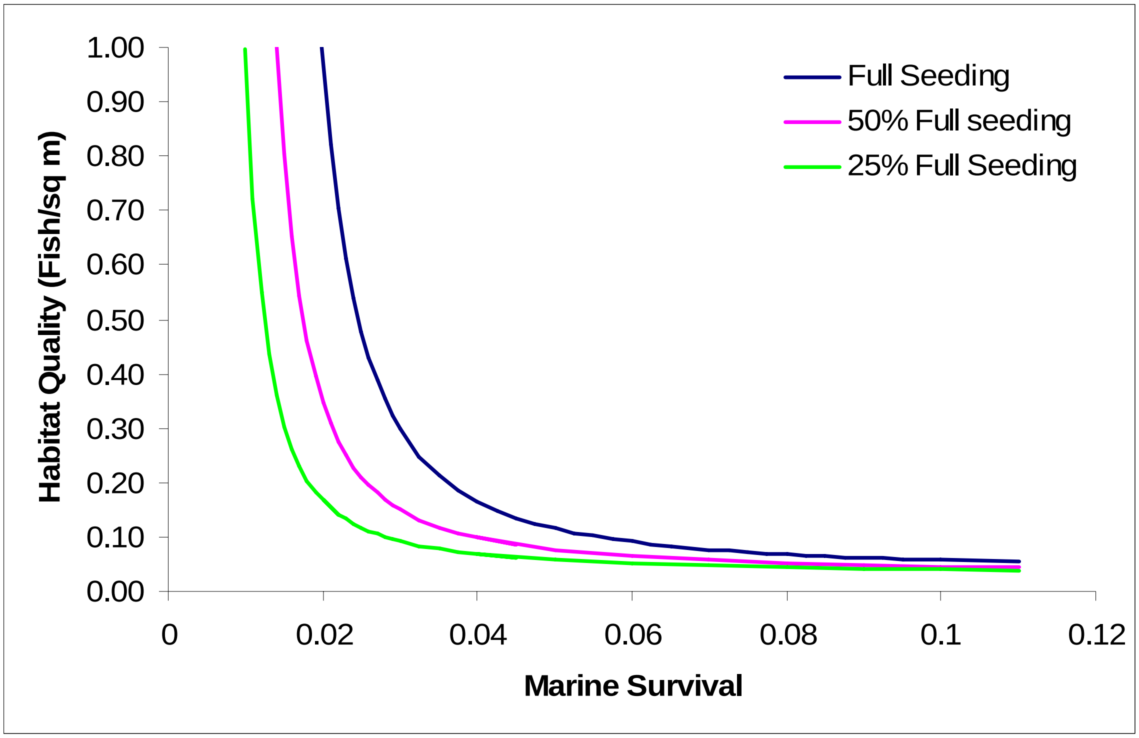

Figure 2. Relationship between the quality of winter habitat (fish/m^2) where populations will replace themselves and marine survival, for three levels of seeding of summer habitat.