# THE OREGON PLAN *for Salmon and Watersheds*

**2002 – 2005 Effectiveness Monitoring Report For the Western Oregon Stream Restoration Program**

**Report Number: OPSW-ODFW-2007-6**

**2002 – 2005 Effectiveness Monitoring for the Western Oregon Stream Restoration Program**

**Oregon Plan for Salmon and Watersheds**

**Annual Monitoring Report No. OPSW-ODFW-2007-6**

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## OBJECTIVES AND ACCOMPLISHMENTS

We monitored the effectiveness of instream restoration projects implemented by the Western Oregon Stream Restoration Program to assess whether the objectives of individual projects and the overall program were accomplished. Most instream projects either remove barriers to fish passage or add roughness and complexity to stream channels. We have elected to inventory habitat conditions before and after treatment to detect changes in stream conditions following the addition of large wood and/or boulders. The results of monitoring helps direct restoration biologists to modify treatment methods and locations to increase effectiveness of restoration projects and aid in the recovery of salmon and steelhead populations in western Oregon.

This document summarizes the results of three years of monitoring, and describes changes at a subset of sites monitored for up to three years. Monitoring occurred in coastal basins of western Oregon as well as the lower Columbia and Willamette River basins. Tasks included:

- Surveyed 99 sites in the summer and 86 sites in the winter before restoration treatment, and 106 sites in the summer and 84 sites in the winter after restoration treatment from 2002-2005.
- 54 of the sites had matching summer-winter pre-treatment and summer-winter post-treatment surveys.
- Nineteen sites were resurveyed 2-3 years following treatment.
- Monitored restoration treatments consisted primarily of large wood additions, but also included large boulder additions and culvert replacements
- Described status of the channel morphology, substrate compositions, instream wood, and riparian structure prior to and following treatment.
- Assessed the projects in terms of location relative to coho and steelhead distribution, and relative to the location of high intrinsic potential stream reaches (Burnett et al., 2007).
- Used the Habitat Limiting Factors Model (HLFM) version 7.0 (version 5.0 described in Nickelson et al., 1992, Nickelson 1998) and HabRate Model version 2.0 (Burke et al., 2001; updated with criteria for coho described in Anlauf and Jones 2007) to describe the quality of habitat for coho salmon before and after treatment.

## EXECUTIVE SUMMARY


Restoration projects were designed to restore ecological and hydrologic function of streams and to improve the productivity of streams for salmonids, particularly coho salmon. A total of 163 instream and riparian projects were completed by the Western Oregon Stream Restoration Program (WOSRP) on 178 miles (285 km) of stream during 2002, 2003 and 2004. The majority of projects were large wood placements (116), followed by stream fencing (20), fish passage (15), riparian planting (7) and boulder placement (2). Large wood placements accounted for 74 of the stream miles and fish passage another 76 miles. All the stream passage projects were coupled with large wood or boulder treatments. The sites were distributed primarily in coastal drainages north of Cape Blanco including the Umpqua, although some were implemented in tributaries to the lower Willamette and lower Columbia rivers, and near the coast in southern Oregon (Figure 1). All projects were implemented within the distribution of coho and/or steelhead.

Project effectiveness was assessed with three measures: 1) location within the distribution of coho or steelhead or in reaches of high intrinsic potential, 2) physical changes beneficial to stream function, and 3) physical changes beneficial to productivity of salmonids. We monitored a subset of WOSRP projects from 2002 through 2005. Restoration sites were surveyed in the summer and winter before and after treatment to assess changes in habitat. Most surveys were conducted within one year following treatment, but we also surveyed a selection of sites two to three years following treatment.

Restoration sites were all located within the distribution of coho and/or steelhead, or within the potential distribution assuming fish passage efforts were successful. More than half the projects were located in areas of high intrinsic potential.

The restoration activities were effective at improving overall habitat complexity and ecological conditions, although we did not observe a significant increase in quality of over-wintering habitat for juvenile coho salmon. Large wood pieces, volume and wood jams increased as a direct result of treatment. Some sites had high levels of wood loading, at greater than 30 $m^3$ large wood/100 m of stream. Amounts of wood observed in the winter and summer surveys following treatment were greater than that placed during restoration, which indicates some additional accumulation of large wood. It is unlikely, however, that large volumes of additional material will be recruited in the short-term, given the relatively young age and condition of most riparian areas. The fish habitat models did not demonstrate a large increase in habitat quality, in part because the amount of off-channel and slow water pool habitat did not increase significantly, although the treatments increased complexity of pool habitat.

# INTRODUCTION

Stream restoration has been a commonly employed tool of fish managers in the Pacific Northwest for decades, although monitoring the effect of the restoration rarely received equal support. The Western Oregon Stream Restoration Program, on the other hand, recognized the necessity to evaluate the effectiveness of the projects and provide feedback to practitioners and managers. We designed the monitoring strategy to quantify the effects of project treatments on stream habitat and to assess the overall impact on fish populations in western Oregon. In this report, we evaluate the site selection and assess changes observed in physical habitat using a pre-post survey design of restoration projects implemented from 2002-2004 in western Oregon.

## Background

Restoration practices have evolved in recent decades with the recognition that habitat restoration may be a key to recovery of native salmon and steelhead populations. The Oregon Coastal Salmon Restoration Initiative (1997) and Steelhead Supplement (1998), together referred to as the Oregon Plan for Salmon Watersheds (The Oregon Plan), were established to recover salmon and steelhead populations to a level of abundance that would not only prevent ESA listings, but provide societal and ecological benefits. The Oregon Plan established habitat restoration as a primary component of recovery. In addition, the Oregon Coast Coho Conservation Plan (Nicholas 2006) identified the need for marked improvement in freshwater habitat conditions throughout the range of coho salmon. The task is challenging because the watersheds and streams that support salmon and steelhead have been intensively modified during the past 150 years (Sedell and Luchesa 1982, Montgomery 2003). The productive capacity of the systems has been reduced, and the fish populations that they support have declined in abundance and distribution

Productive watersheds require complex, connected habitat across the continuum of fresh, estuarine, and marine environments to support salmonid species and their diverse life histories. Simplification of aquatic habitat in Oregon is reflected in elimination of stream, wetland and estuarine habitat, reduction of riparian buffers and structure, changes in channel morphology, loss of instream roughness, and changes in channel substrate composition (NMFS 1997). Simplification has been particularly detrimental to productivity of coho salmon in western Oregon. Of the 21 independent coho salmon populations in the Coastal Coho ESU, stream complexity was considered the primary limiting factor for thirteen of the populations, and the secondary limiting factor for the other eight (ODFW (2) 2005).

Habitat complexity is particularly important to survival of juvenile coho salmon during their first winter in freshwater, although steelhead also benefit from increased habitat complexity (Johnson et al., 2005). The Oregon coast experiences intense periods of rainfall from November through March. Streams quickly rise to bankfull, water velocity increases, and potential refugia become scarce. During the periods of high water, juvenile coho salmon seek low velocity refugia to prevent being washed downstream into undesirable habitats. Pools, and especially alcoves and beaver ponds, are favored habitat for overwintering coho salmon (Nickelson et al., 1992a). Historically, low velocity refugia were present in low gradient, lowland stream reaches with wide, active floodplains. Secondary channels, wetlands, abundant deep pools, and large wood accumulations provided low velocity, complex habitat. In the upper reaches and tributaries, large wood jams, beaver dam complexes, and small off-channel habitats provided ample opportunities for juvenile coho salmon to avoid excessive stream velocities during high rainfall events. The stream landscape varied from the upper watershed to the lower, but associations of channel features, large structural components (primarily wood), and small but numerous off-channel and slow water habitat units interacted to create high quality habitats for overwintering juvenile coho salmon.

Forest management, farming and grazing practices, and urbanization have resulted in a landscape scale decrease in the quality of aquatic habitat for juvenile salmon. Incision of streams reduced the amount of secondary channels and floodplain interactions, resulting in overall simplification of channel features. Large conifer trees that formerly fell or slid into streams have been removed from riparian areas and slopes, reducing the immediate and long term recruitment of large wood to the streams. Large wood in streams created large complex jams and tangential flows necessary to create and maintain off-channel habitat. Trapping of beavers led to a reduction in the amount of pool and in-channel slow water complex habitat. An increase in roads over time has created barriers to fish passage and increased the amount of fine sediment entering streams. Through the Oregon Plan, public and private interests work together to restore watersheds and fish populations through a combination of habitat protection and restoration. Regulatory and voluntary measures were enacted to reduce detrimental impacts of land management activities and to begin long-term restoration of stream systems. In the shorter term, active restoration of aquatic habitat is viewed as a critical component of recovery.

Active stream restoration can restore natural stream processes and improve instream habitat: e.g. planting riparian areas, fencing out livestock, adding salmon carcasses for nutrients, removing fish passage barriers, and improving stream complexity. Each restoration method is associated with a specific objective intended to increase survival of salmonids at a given life stage (large wood placement - increase instream complexity), increase potential distribution of fish (culvert replacement - improve passage), or restore ecological or hydrologic processes (riparian planting or fencing - stable banks; salmon carcass placement-food base productivity). Consideration of channel morphology and hydrology, and fish life history requirements during the site selection process will help determine the overall success of the restoration projects.

The Coastal Landscape Analysis and Modeling Study (Burnett et al., 2007) developed maps that depict streams that historically were potentially the most productive rearing habitat for coho salmon and steelhead. Stream reaches were categorized based on geomorphic and hydrologic features to determine a range of intrinsic potential. Streams at the upper end of this range are referred to as having high intrinsic potential (Burnett et al, 2007) for winter rearing of juvenile coho salmon (CWHIP) (Nicholas 2006).

These maps identify stream reaches in which restoration would most benefit juvenile coho salmon and steelhead. Site selection is tempered by actual or potential distribution of fish, and by additional environmental constraints such as temperature or flow. Regardless, the HIP maps provide an initial indication as to whether site selection met objectives outlined for each restoration project. At the individual site level, consideration is given to stream gradient, size, and quality of instream habitat. In general, instream restoration efforts are directed at sites that have sufficient pool habitat, but are structurally simple (lacking large wood, undercut banks, or off-channel habitats).

Several studies have illustrated the benefits of adding large structural elements to increase stream complexity, and large wood structures to increase pool habitat, stream complexity, and abundance of juvenile salmon (House and Boehne 1985 and 1986, Crispin et al., 1993, Cederholm et al., 1997, Roni and Quinn 2001). Nickelson et al., (1992b) documented an increase in survival of juvenile coho salmon when dammed pools and backwaters were created. The pools and backwater habitat immediately increased overwintering habitat, although this habitat degraded over time as constructed backwater pools filled in and the large wood that was alder-dominated degraded (Steve Johnson, pers comm.). Solazzi et al. (2000) reported that winter smolt survival increased when large wood was placed into two streams, compared to nearby reference streams. Johnson et al. (2005) noted improved coho and steelhead freshwater survival when they compared a stream treated with large wood with a reference stream. Roni et al. (2006) found that utilizing boulder weirs in bedrock and incised channels can effectively increase juvenile coho and trout summer abundance. Pollock et al. (2004) found that juvenile coho populations were substantially depressed when compared to historic levels in a Washington stream, primarily due to the loss of beaver ponds. However, beaver (*Castor Canadensis*) may favor habitat structures for dam building, depending on placement (MacCracken and Lebovitz 2005), with the resulting beaver ponds providing excellent winter rearing habitat (Nickelson 1998, ODFW (4) 2005).

Detectable changes in habitat may take two to five years, but a biological response could take 10-50 years (Roni et al., 2003). The time frame in which detectable physical results (e.g., channel form, channel units, wood retention and distribution, and substrate composition) are expected will vary depending on many factors, including stream flows, geology, restoration design, and other conditions. Good site selection coupled with appropriate restoration treatments targeted at stream processes or specific life history requirements of a species has the highest potential to produce beneficial results over the long term.

The Oregon Coast Coho Conservation Plan (Nicholas 2006) recognizes that an improvement in aquatic habitat conditions will be necessary to meet the coho abundance and productivity goals of the plan. To assist in tracking progress toward achieving recovery goals, the conservation plan provides specific targets for the smolt productive capacity of each of the 21 independent coho populations covered by the plan. While habitat restoration, as conducted by the Western Oregon Stream Restoration Program, is not expected to be the sole contributor to achieving the habitat targets specified in the Oregon Coast Coho Conservation Plan, it will undoubtedly have an important role.

## Western Oregon Stream Restoration Program

The Western Oregon Stream Restoration Program (WOSRP) in cooperation with private and corporate landowners selected sites and implemented projects consistent with criteria described in Thom et al. (2001). The program currently employs eight restoration biologists, located in Tillamook, Newport, Charleston, Gold Beach, Roseburg, and Clackamas, and coordinated by a project manager in Salem. A biologist located in Corvallis coordinates and reports monitoring results for the restoration projects, before and after treatment. Typically, restoration projects were implemented at sites with medium channel width (5-25m), low gradient (0-3%), moderate to high amount of pool habitat (35-50%), and low structural complexity (wood or boulders). The majority of treatments had large wood placed in a series of complex jams over varying stream lengths. Several projects utilized boulders, either in conjunction with, or in place of wood. Boulders used with large wood projects helped anchor and stabilize wood structures. Boulders used without large wood were placed randomly, usually in bedrock-dominated reaches where there was a need to accumulate gravels and raise the bottom of the stream channel. They were placed in such a way as to avoid blocking fish passage but to entrap wood and smaller substrate. Typically, projects that involved only boulders were utilized when a landowner was willing to allow stream enhancement activities but was resistant to placing large wood into a stream, commonly because of downstream structures such as culverts or bridges, or when the stream was severely incised with limited opportunity to anchor large wood. Rather than not completing any project in a given area, boulders were used to provide some instream enhancement. In many cases, large wood will be added in the future when a gravel/cobble substrate has accumulated over the existing bedrock. Fish passage projects open restricted habitats for juvenile and/or adult salmonids, and riparian planting and fencing improve riparian vegetation and bank structure. The length of treatment varied on a site-by-site basis. Culvert or dam removal projects may be very short, as little as 20 meters, although the treatment affects many kilometers of previously inaccessible habitat. Large wood treatments may extend over several miles. Project implementation occurred in western Oregon coastal basins, lower Columbia River basins, and Willamette River basins.

## Objectives

We assessed the potential effectiveness of the projects by considering site location and project type relative to species distribution and limiting factors, and by changes in stream habitat following treatment. We determined the proportion of sites selected within high intrinsic potential streams for steelhead or coho salmon, and by measuring changes in instream habitat characteristics one year and two to three years following treatment. We measured changes in instream habitat characteristics following treatment in two ways: 1) measured individual characteristics such as large wood and amount, size, and complexity of pool and beaver habitat, and 2) as combination of variables modeled as the capacity of habitat for juvenile coho salmon using the Habitat Limiting Factors Model Version 7.0 (version 5.0 described by Nickelson et al., 1992, Nickelson 1998) and as the quality of habitat for salmonids using HabRate Version 2.0 (Burke et al., 2001; updated with criteria for coho described by Anlauf and Jones 2007).

Projects were monitored during summer low flow conditions and winter high flow. We selected habitat variables that are sensitive to change, biologically relevant to different life stages and species of fish, and quantifiable with sufficient precision to detect change (Larsen et al., 2004; ODFW (2) 2005; Anlauf and Jones 2007). Our Oregon Plan survey program (Anlauf and Jones 2007) also incorporates a 10% resurvey effort in order to separate sources of variation in the field measurements: site, year, interaction, and residual (such as crew error).

This report discusses changes in habitat conditions of restoration projects completed by WOSRP biologists that were implemented in 2002, 2003 and 2004 (see also Jacobsen and Thom 2001; Jacobsen and Jones 2003). The projects were monitored prior to treatment to obtain baseline information and then one year post-treatment. In addition, a set of sites that were treated between 2001 and 2003 were monitored two to three years post-treatment to observe multi-year trends.

## METHODS

WORSP biologists implement approximately 40-50 restoration projects each year. The number and distribution vary annually by region, but are located in Willamette, Lower Columbia, and coastal drainages (Figure 1). We receive information from each biologist on the location, type, and extent of each project prior to treatment (Table 1). Of the potential projects, we selected up to fifteen sites annually in each geographic area for effectiveness monitoring (Lacy and Thom 2000) for a total of approximately 40 sites (Figure 2). This represents approximately 80% of the planned or completed instream work. While the sites were not randomly selected, the majority of projects including the extensive treatments were surveyed. The selected sites met minimum criteria of having fish passage improvements or the placement of at least two instream structures within a 500-meter segment of stream, although we preferentially selected sites that had more extensive treatment or affected more stream length. Sites were monitored the first year after restoration, and again one, and sometimes two or three years after treatment.

The large wood pieces placed in streams were a minimum of 1.5 times the active channel width and 25.4 cm (10 inches) in diameter. The average and median number of wood pieces placed in the treatments was 35 and 30 per kilometer respectively, or approximately 3 pieces per 100 m.

### Field Surveys

Each site received a pre-winter and a pre-summer evaluation to establish baseline conditions immediately preceding restoration treatment (Figure 2, Tables 2 and 3). Sites were treated in the summer or fall, post-treatment winter and post-treatment summer surveys were completed within the year immediately following treatment, and a subset again two to three years after treatment. For example, pre-treatment surveys were conducted during the winter of 2002 and the summer of 2002. Sites were then treated in the late summer or fall of 2002, and post-treatment surveys were conducted in the winter of 2003 and the summer of 2003.

The methods used to conduct physical habitat surveys were modified from the ODFW Aquatic Inventories protocols (Moore et al., 2007). Modifications to the survey methods included:

- Survey segments were typically 500 m for years 2001–03, and the entire length of treatment in years thereafter (range: 250-2400 m).
- All habitat unit lengths and widths were measured to avoid bias in estimations over short survey lengths.
- Wood diameter and length were estimated prior to 2004 and measured thereafter.
- Riparian transects were conducted in at three locations spaced at equal intervals throughout the survey. For sites longer than 1200 m, additional riparian transects were taken.
- Winter surveys did not assess stream shading, quantity of large boulders, undercut banks, erosion, or riparian conditions because these attributes were assumed similar to conditions during the summer surveys.

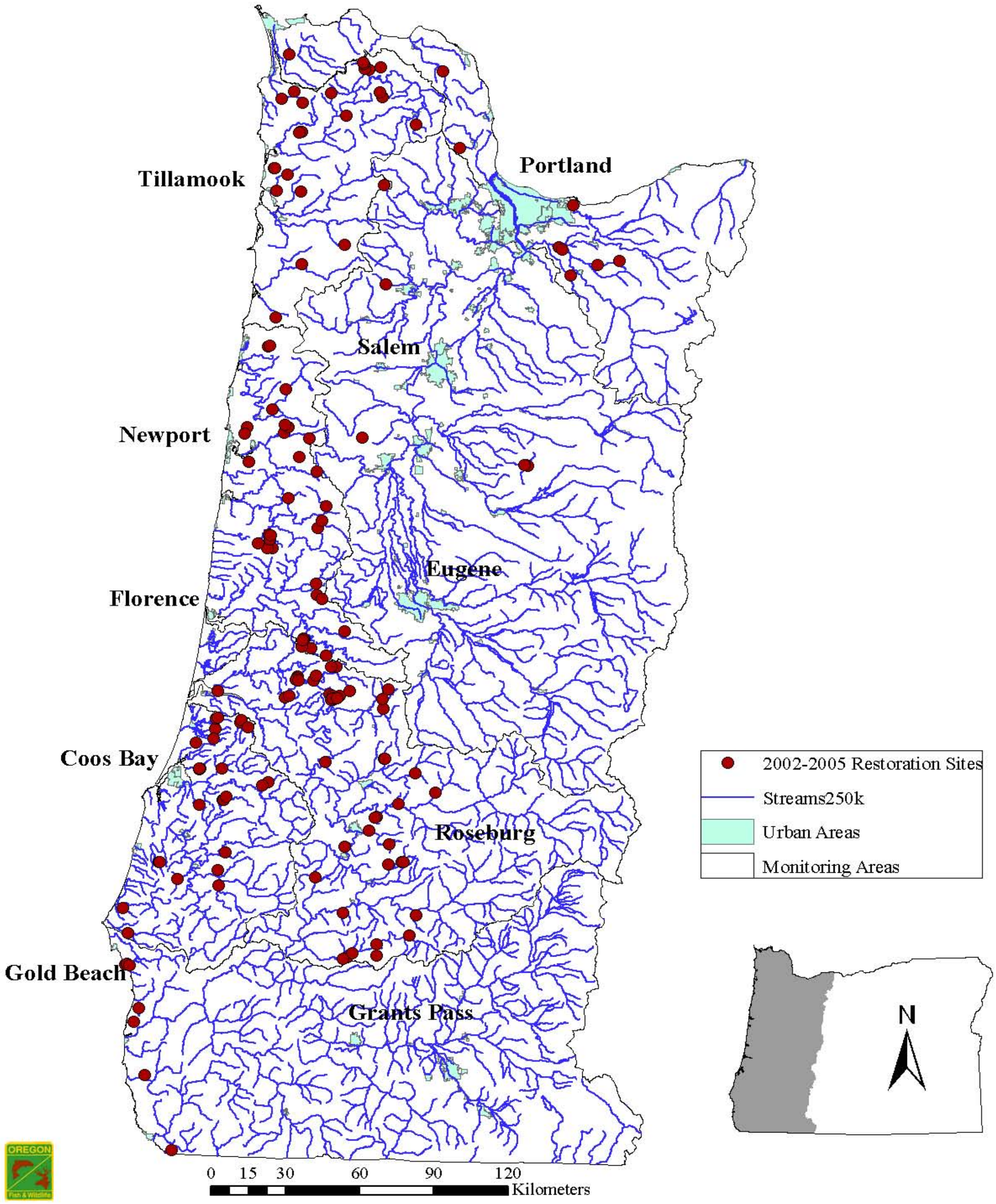



Figure 1. Restoration projects implemented by Western Oregon Stream Restoration Program biologists in western Oregon from 2002-2004.

Table 1. All Western Oregon Stream Restoration Program projects by area and project type. 2002-2004.

| | Project Types | | Large wood | | Boulders | | Fish Passage | | Stream Fencing | | Riparian Planting | | Misc. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | number of sites | treated miles | number of sites | treated miles | number of sites | miles opened | number of sites | treated miles | number of sites | treated miles | number of sites |
| North Coast | | | | | | | | | | | | | |
| | 2002 | | 8 | 2.76 | | | * | 0.60 | | | * | 0.10 | |
| | 2003 | | 8 | 2.20 | | | 1 | 0.10 | | | * | 0.80 | 1 |
| | 2004 | | 11 | 4.05 | | | | | | | | | |
| Mid Coast | | | | | | | | | | | | | |
| | 2002 | | 13 | 17.85 | * | | * | 4.00 | * | 3.08 | 2 | 1.00 | |
| | 2003 | | 8 | 4.80 | | | * | 7.83 | | | 1 | 0.30 | |
| | 2004 | | 13 | 5.83 | | | 1 | 3.18 | | | * | 0.87 | |
| Mid-South Coast | | | | | | | | | | | | | |
| | 2002 | | 5 | 2.00 | * | | 2 | 1.25 | 1 | 0.23 | * | | * |
| | 2003 | | 5 | 1.55 | | | | | | | * | 0.60 | |
| | 2004 | | 5 | 1.54 | | | * | 0.70 | | | | | 1 |
| Umpqua | | | | | | | | | | | | | |
| | 2002 | | 9 | 9.35 | * | | 1 | 5.00 | 12 | 10.80 | | | |
| | 2003 | | 3 | 1.70 | 2 | 2.00 | * | 5.05 | 5 | 3.11 | | | 1 |
| | 2004 | | 4 | 6.25 | * | | 5 | 10.00 | | | * | 1.75 | |
| South Coast | | | | | | | | | | | | | |
| | 2002 | | 4 | 1.00 | | | 1 | 1.20 | | | 1 | 0.20 | |
| | 2003 | | 4 | 0.80 | * | | 1 | 0.25 | | | * | | * |
| | 2004 | | 2 | 0.50 | | | 1 | 6.00 | | | | | |
| Lower Willamette | | | | | | | | | | | | | |
| | 2002 | | 5 | 6.60 | | | * | 4.50 | 1 | 0.50 | | | |
| | 2003 | | 1 | 0.25 | | | * | 1.20 | | | 1 | 0.04 | |
| | 2004 | | 5 | 2.75 | * | | 2 | 24.80 | | | 2 | 2.30 | |
| Upper Willamette | | | | | | | | | | | | | |
| | 2002 | | 1 | 1.50 | | | | | 1 | 0.28 | | | |
| | 2003 | | 1 | 0.68 | | | | | | | | | |
| | 2004 | | 1 | 0.25 | * | | | | | | | | |
| Total ------------------ | **Projects** | 163 | 116 | | 2 | | 15 | | 20 | | 7 | | 3 |
| ------------------ | **Miles** | 177.83 | | 74.21 | | 2.00 | | 75.66 | | 18.00 | | 7.96 | |

*sites include more than one treatment type (ie: large wood and fish passage). These sites are only counted once, as the dominant treatment type.

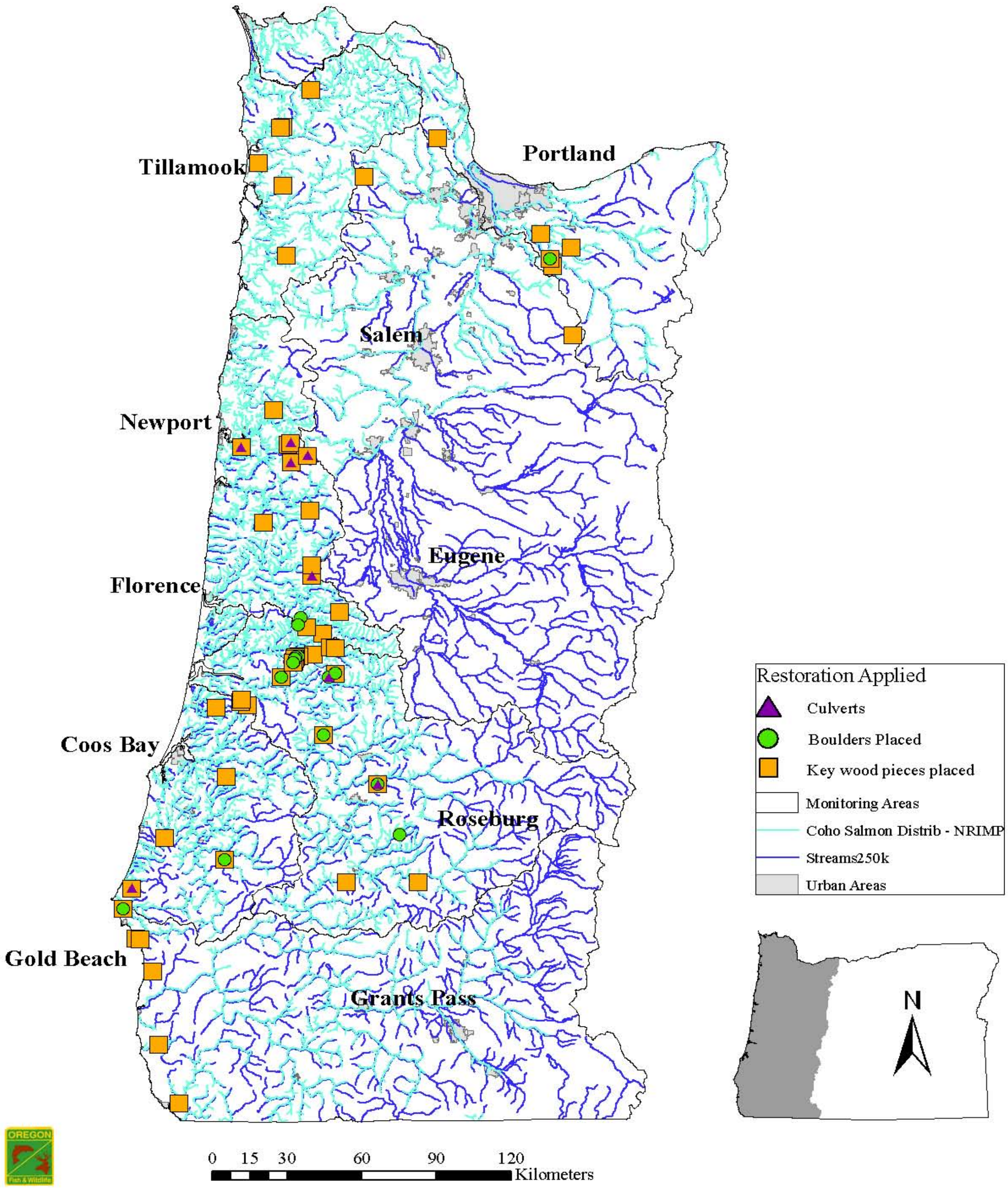



Figure 2. Restoration sites selected for monitoring before and after treatment.

Table 2. Monitored projects, year of treatment/resurvey, kilometers treated and treatment applied for projects monitored one year following treatment. Key Piece in this table is equal to 1.5 times active channel width and minimum 25.4 cm diameter.

| Stream | Basin | Site No. | Year | Active Channel Width (m) | Kilometers Treated | Key Pieces* Wood Placed | Boulders Placed | Culvert Stream km Opened |
|---|---|---|---|---|---|---|---|---|
| | | | **2002/2003** | | | | | |
| Bear Creek | Coquille | 1 | | 9.9 | 1.0 | 29 | | |
| Big Creek | Smith | 2 | | 7.6 | 4.0 | 150 | 200 | |
| Bummer Creek | Alsea | 3 | | 6.6 | 1.2 | 18 | | |
| Catching Creek | South Umpqua | 4 | | 4.9 | 1.6 | 66 | | |
| Cedar Creek | Elk | 5 | | 1.5 | 0.2 | 4 | 5 | |
| Clabber Creek | Smith | 6 | | 4.3 | 0.8 | 36 | | |
| Clover Creek | North Umpqua | 7 | | 5.2 | 1.6 | 73 | 12 | 1.6 |
| Crab Creek | Alsea | 8 | | 9.1 | 7.3 | 165 | | |
| Deep Creek | Pistol | 9 | | 7.9 | 0.4 | 12 | | |
| Devils Lake Fork | Wilson | 10 | | 4.6 | 0.4 | 20 | | |
| Esmond Creek (Lower) | Siuslaw | 11 | | 13.1 | 1.6 | | 455 | |
| Esmond Creek (Middle) | Siuslaw | 12 | | 10.0 | 1.6 | | 740 | |
| Foster Creek | Clackamas | 13 | | 4.6 | 0.8 | 24 | | |
| Knife Creek (Lower) | Millicoma | 14 | | 7.6 | 0.5 | 9 | | |
| Knife Creek (Upper) | Millicoma | 15 | | 7.6 | 0.5 | 9 | | |
| Myrtle Creek | Coquille | 16 | | 21.3 | 0.2 | 8 | 60 | |
| North Fork Eagle Creek | Clackamas | 17 | | 12.2 | 5.6 | 58 | | |
| Oxbow Creek | Siuslaw | 18 | | 5.9 | 1.6 | 68 | | |
| Panther Creek | Smith | 19 | | 7.6 | 2.4 | 84 | | |
| Pea Creek | Euchre | 20 | | 5.2 | 0.5 | 7 | | |
| Swanson Creek | Floras | 21 | | 4.6 | 0.8 | 24 | | 3.2 |
| Weatherley Creek | Umpqua | 22 | | 7.6 | 1.6 | 50 | 171 | |
| | | | **2003/2004** | | | | | |
| Barn Gulch | Tenmile Lake | 1 | | 3.0 | 0.3 | 36 | | |
| Bays Creek | Nestucca | 2 | | 7.6 | 0.6 | 18 | | |
| Big Tom Folley Creek | Umpqua | 3 | | 12.2 | 1.6 | | 500 | 8.1 |
| Brush Creek (Site A) | Ocean | 4 | | 6.7 | 0.4 | 9 | | |
| Brush Creek (Site B) | Ocean | 5 | | 6.7 | 0.4 | 9 | | |
| Dietz Creek | Kilchis | 6 | | 4.9 | 0.3 | 12 | | |
| Esmond Creek (Upper) | Siuslaw | 7 | | 7.2 | | 47 | | |
| Gods Valley Creek | Nehalem | 8 | | 6.1 | 1.3 | 40 | | 0.2 |
| Gourlay Creek | Scappoose | 9 | | 5.5 | 0.4 | 48 | | |
| Jack Creek | Chetco | 10 | | 7.6 | 0.2 | 2 | | |
| Miller Creek | Siuslaw | 11 | | 6.7 | 1.2 | 20 | | 2.0 |
| Slide Creek | South Umpqua | 12 | | 5.5 | 1.6 | | 218 | |
| Stouts Creek | South Umpqua | 13 | | 6.7 | 1.6 | 50 | | |
| Wapiti Creek | Coquille | 14 | | 3.2 | 0.5 | 24 | | |
| Wolf Creek Tributary | Yaquina | 15 | | 4.3 | 0.8 | 63 | | 1.7 |
| Wright Creek | Yaquina | 16 | | 4.5 | 1.6 | 67 | | 0.8 |
| | | | **2004/2005** | | | | | |
| Big Creek | Umpqua | 1 | | 7.7 | 4.0 | 40 | 435 | |
| Big Creek Tributary A | Umpqua | 2 | | 5.1 | 0.8 | 90 | 56 | |
| Big Creek Tributary B | Umpqua | 3 | | 5.0 | 0.8 | 20 | 46 | |
| Big Creek Tributary C | Umpqua | 4 | | 4.6 | 0.8 | 70 | 60 | |
| Big Tom Folley Creek | Umpqua | 5 | | 9.6 | 2.4 | 60 | 811 | |
| Clear Creek #1 | Clackamas | 6 | | 18.1 | 1.6 | 8 | | |
| Clear Creek #2 | Clackamas | 7 | | 18.4 | 0.8 | 6 | 75 | |
| Eames Creek | Siuslaw | 8 | | 6.1 | 1.9 | 79 | | |
| East Humbug Creek | Nehalem | 9 | | 11.7 | 1.2 | 30 | | |
| Foley Creek | Nehalem | 10 | | 6.0 | 1.2 | 35 | | |
| Gods Valley Creek | Nehalem | 11 | | 6.3 | 0.6 | 25 | | |
| Long Prairie Creek | Siletz | 12 | | 6.7 | 1.6 | 49 | | |
| Lost Creek | Molalla | 13 | | 14.1 | 0.3 | 15 | | |
| Lost Creek | Umpqua | 14 | | 8.5 | 1.6 | 69 | 103 | |
| Nelson Creek | Siuslaw | 15 | | 8.1 | 1.2 | 25 | | |
| Sugarbowl Creek | Yaquina | 16 | | 3.1 | 0.4 | 15 | | 1.6 |

Table 3. Monitored projects, year of treatment/resurvey, kilometers treated and treatment applied for projects monitored two or three years following treatment. Key Piece in this table is equal to 1.5 times active channel width and minimum 25.4 cm diameter.

| Stream | Basin | Site No. | Year | Active Channel Width (m) | Kilometers Treated | Key Pieces* Wood Placed | Boulders Placed | Culvert Stream km Opened |
|---|---|---|---|---|---|---|---|---|
| | | | **2001-03/2003-05** | | | | | |
| Big Creek | Smith | 1 | 2002/04 | 7.6 | 4.0 | 150 | 200 | |
| Brush Creek Site A | Ocean | 2 | 2003/05 | 6.7 | 0.4 | 9 | | |
| Brush Creek Site B | Ocean | 3 | 2003/05 | 6.7 | 0.4 | 9 | | |
| Bummer Creek | Alsea | 4 | 2002/04 | 6.6 | 1.2 | 18 | | |
| Catching Creek | South Umpqua | 5 | 2002/04 | 4.9 | 1.6 | 66 | | |
| Deep Creek | Pistol | 6 | 2002/04 | 7.9 | 0.4 | 12 | | |
| Esmond Creek (Lower) | Siuslaw | 7 | 2002/04 | 13.1 | 1.60 | | 455 | |
| Esmond Creek (Middle) | Siuslaw | 8 | 2002/04 | 10 | 1.60 | | 740 | |
| Feagles Creek | Yaquina | 9 | 2001/04 | 5.3 | 1.30 | 23 | | 4.8 |
| Knife Creek (Lower) | Millicoma | 10 | 2002/04 | 7.6 | 0.50 | 9 | | |
| Knife Creek (Upper) | Millicoma | 11 | 2002/04 | 7.6 | 0.50 | 9 | | |
| Miller Creek | Siuslaw | 12 | 2003/05 | 6.7 | 1.20 | 20 | | 2 |
| Myrtle Creek | Coquille | 13 | 2002/04 | 21.3 | 0.20 | 8 | 60 | |
| Oxbow Creek | Siuslaw | 14 | 2002/04 | 5.9 | 1.60 | 68 | | |
| Salmonberry Creek | Smith | 15 | 2001/03 | 5.5 | 1.10 | 43 | | |
| Weatherley Creek | Umpqua | 16 | 2002/04 | 7.6 | 1.60 | 50 | 171 | |
| West Fork Millicoma R. | Millicoma | 17 | 2003/05 | 7.5 | 1.10 | 29 | | |
| Wolf Creek | Yaquina | 18 | 2001/04 | 4.3 | 1.60 | 63 | | |
| Wright Creek | Yaquina | 19 | 2003/05 | 4.5 | 1.60 | 67 | | 0.8 |

## Analysis

The locations of the projects were compared to the known distribution of salmonid species and to the distribution of high intrinsic potential habitat for steelhead and coho salmon. We listed each project as within or outside each distribution. We compared the location of restoration sites relative to the distribution of salmonid species by overlaying site location with fish distributions on 1:100,000 digitized map layers. The placement of sites within stream reaches of potential high productivity was estimated by overlaying the sites on digitized maps of high intrinsic potential for coho salmon and steelhead (Burnett et al., 2007). High intrinsic potential was mapped within the coastal coho ESU (Sixes River north to the Necanicum River), although the upper Umpqua was excluded.

Changes in physical habitat features following restoration were evaluated with a pre- and post-treatment experimental design. The analysis emphasized changes in type, size, depth, and complexity of pools, substrate, and distribution and amounts of large wood (Table 4). We also compared habitat conditions at the restoration sites to conditions at randomly-selected sites that were surveyed as part of habitat monitoring in coastal basins under the coast-wide Oregon Plan for Salmon and Watersheds (OPSW) (Anlauf and Jones 2007) and to reference sites (Rodgers et al., 2005). Randomly-selected and reference sites used in the comparison had similar channel width, gradient, and morphology as the treated stream reaches, but did not contain habitat structures. These Oregon Plan surveys represented the range of natural stream conditions in coastal basins. The reference reaches were selected from ODFW Aquatic Inventory data from 1990 to 2003 and broadly represent the range of potential conditions in undisturbed, low gradient streams.

Table 4. Definition of habitat survey parameters evaluated for this report.

| Parameter | Definition |
|---|---|
| % Pools | % Channel area represented by pool habitat |
| % Secondary Channel | % Total channel area represented by secondary channels |
| % Slackwater Pools | % Primary channel area represented by slackwater pool habitat (beaver pond, backwater, alcoves, isolated pools). |
| Deep Pools/km | Pools > 1m deep per kilometer of primary channel |
| % fines | Visual estimate of substrate composed of <2mm diameter particles in low gradient riffles |
| % gravel | Visual estimate of substrate composed of 2-64mm diameter particles in low gradient riffles |
| Pieces LWD/100m | # pieces of wood ≥ 0.15m diameter X 3m length per 100 meters primary stream length |
| Volume LWD/100m | Volume ($m^3$) of wood ≥ 0.15m diameter X 3m length per 100 meters primary stream length |
| Key Pieces LWD/100m | # pieces of wood ≥ 60 cm diameter & ≥ 12 meters long per 100 meters primary stream length |
| Wood Jams | Number of wood accumulations that had more than 4 pieces of LWD |

We compared the pre- and post- data sets and the random reaches from the OPSW. The random reaches were used as baseline conditions for comparison with the treated sites. In addition, reference reaches were used to represent streams in unmanaged watersheds. All pre- and post-treatment sites were used for the descriptive analysis to provide an overall display of WOSRP restoration projects (pre-treatment summer n=99, winter n=86; post-treatment summer n=106, winter n=84). Cumulative frequency diagrams for pre- and post-treatment habitat conditions in the summer and winter at restoration sites, at reference sites, and random sites are shown in Appendix C.

Statistical comparisons were conducted only with sites that had matching pre- and post-treatment surveys (n=54). We evaluated the distribution of data to check for normalcy prior to statistical tests of the sites that had pre- and post-treatment data (n=54). It was found to be slightly skewed. As a result, we used both paired t-tests (for the pairwise comparisons) and a Wilcoxon test to examine the data for significant change from pre- to post-treatment. Box and whisker plots were also used to compare the range and median of data between pre- and post-treatment. Fifty-four sites were monitored one year following treatment, and nineteen sites were also monitored at least two or three years after treatment.

## Overall Habitat Assessment

In this report, we combined habitat attributes to provide an integrated assessment of instream habitat to describe changes in ecological stream function or improvement in stream conditions relative to fish habitat requirements by life stage.   We use the following definitions:

*High ecological function*: those reaches that display a combination of habitat features beneficial to the ecological functions of a stream as defined by Thom et al (2000).  Criteria used to define high ecological function were: pool area greater than 35% of channel area, the presence of slackwater pools or secondary channels, wood volume greater than 20 $m^3$ per 100 m of stream channel, and the presence of at least one key piece of woody debris per 100 m of stream length. These criteria target lower gradient, mid-network, moderate size streams. The number of sites with high ecological function was summarized by channel type. The major channel type divisions were: wide valley floor (greater than 2.5 times the active channel width) and narrow valley floor (less than or equal to 2.5 times the active channel width).  The wide valley floor channels were subdivided into: unconstrained reaches (flood prone width greater than 2.5 times the active channel width and terrace height less than flood prone height); potentially unconstrained reaches (flood prone width less than 2.5 times the active channel width and terrace height less than 125% of the flood prone height); and deeply incised reaches (terrace height more than 125% of the flood prone height).

*Salmonid habitat quality*: the quality of reaches rated as 1 (poor), 2 (fair), or 3 (good) by the HabRate fish habitat model ((Burke et al., 2001) using parameters for coho salmon (Anlauf and Jones 2007).  HabRate assesses stream conditions relative to spawning and emergence, summer rearing, and winter rearing life stages for coho salmon and steelhead. HabRate emphasizes a combination of pool amount and type, channel morphology, wood complexity, and depth.

*High quality winter habitat for juvenile coho salmon*: those reaches that have a winter carrying capacity higher than 1850 parr per kilometer (Nicholas 2006) or higher than 0.30 parr per square meter (Nickelson 1998).  Parr capacity was estimated with the Habitat Limiting Factors Model version 7.0 (version 5.0 described in Nickelson et al 1992a, Nickelson 1998).  HLFM Version 7.0 emphasizes the amount and type of pools, particularly the amount of beaver and alcove pools, but also recognizes benefit for large wood in pools.

# RESULTS

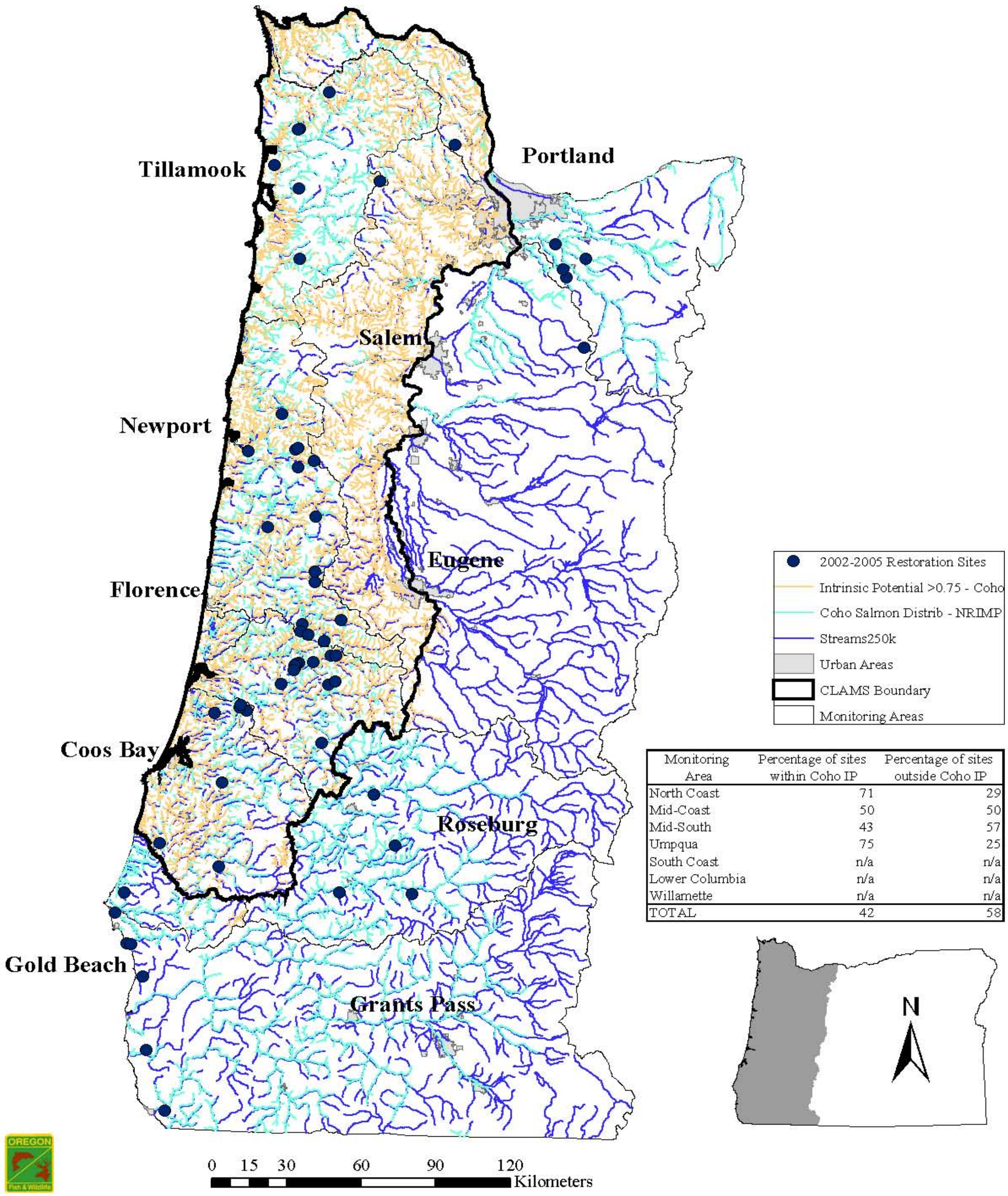
A total of 163 instream and riparian projects were completed by WOSRP in 178 miles (285 km) of stream in western Oregon during 2002 - 04 (Figure 1, Table 1). The majority of projects were large wood placements (116), followed by stream fencing (20), fish passage (15), riparian planting (7) and boulder placement (2). Large wood placements accounted for 74 of the stream miles and fish passage an additional 76 miles. Stream passage projects were coupled with large wood treatments. In this report, we describe the findings from monitoring 54 of the projects during the summer and winter prior to and following the implementation of the treatments, and 15 projects after two or three years.

## Site Selection of Projects

We monitored a subset of WOSRP projects (54 pre- and post-treatment) from 2002 through 2005. All sites were located within the distribution of coho and/or steelhead, or within the potential distribution assuming fish passage efforts were successful. Up to three treatments were applied; key wood pieces were placed, boulders were positioned, and culverts were improved or replaced. Eight restoration sites targeted culvert improvement projects, most in the mid-coast streams. The passage projects (that we monitored) increased access to 0.2 to 8.1 km of stream per project, with an average and median of 2.4 and 1.7 km respectively (Table 2). Sixteen of the sites had boulders placed; the majority of those sites were located in the Umpqua monitoring area. Key pieces of wood were placed in 50 of the 54 sites. Twelve sites had both key wood pieces and boulder treatments. One site had both boulder and culvert treatments. Seven sites had both key wood pieces and culvert project treatments. Clover Creek in the North Umpqua had all three treatments.

Restoration sites were placed in wide valley floor, low gradient (<3%) reaches of streams. Stream size at the restoration sites ranged from 1.5 to 21.5 m active channel width, with a median of 6.5 m (Table 2). The majority of wood treatment projects (43% to 75% depending on monitoring area) were implemented within the high intrinsic potential reaches (Figure 3). Four of six of the passage projects were in reaches with high intrinsic potential. The other two projects were outside of the mapped distribution of intrinsic potential. Each passage project opened up 0.2-8 km of stream for a total of 19 kilometers.

Restoration reaches prior to treatment were generally rich in pool habitat, but had low amounts of large wood debris (Appendix C). On average, restoration sites had twice the amount of pool habitat than at randomly selected sites in Oregon coastal basins; the median value of pool habitat in all coast streams was 20 percent compared to 40 percent prior to treatment at restoration sites. In contrast, the amount of large wood prior to treatment at restoration sites was significantly less than at most Oregon Plan sites. The restoration sites also had more pool area and substantially less wood than reference sites as well. The amount of gravels and fine particles in the substrate (by percent of




| Monitoring Area | Percentage of sites within Coho IP | Percentage of sites outside Coho IP |
|---|---|---|
| North Coast | 71 | 29 |
| Mid-Coast | 50 | 50 |
| Mid-South | 43 | 57 |
| Umpqua | 75 | 25 |
| South Coast | n/a | n/a |
| Lower Columbia | n/a | n/a |
| Willamette | n/a | n/a |
| TOTAL | 42 | 58 |

Figure 3. Sites mapped relative to coho salmon distribution and high intrinsic potential. High intrinsic potential was not mapped in south coast, lower Columbia or Willamette monitoring areas. See publication at http://oregonstate.edu/Dept/ODFW/freshwater/inventory/rest_reports.htm to view larger image of map.

surface area) were similar between restoration and Oregon Plan sites, although the reference sites had lower amounts of fine particles in the substrate.

## Post-Treatment Condition One Year after Implementation

As expected for wood placement projects, the quantity of large woody debris increased immediately following restoration. Resurveys in the summer one year after treatment indicated that the number of pieces of large wood increased by an average of five pieces per 100 m (range: -17 to 25), with 50% of the sites increasing by at least five pieces per 100 m. Similarly, the volume of large woody debris increased by an average of 11 $m^3$/100 m (range: -11 to 55), with 50% of the sites increasing by at least 11 $m^3$/100 m (Appendix C). The number of key pieces (0.6m dbh x 12m length) of wood increased by an average of 1 piece per 100 m (range: -1 to 8), with 50% of the sites increasing by at least 0.4 pieces per 100 m, and the number of large wood jams increased by an average of four jams per km (range: -13 to 19), with 50% increasing by at least four jams per km. In the winter surveys six months after treatment, the quantity of large woody debris was higher than prior to the restoration (Appendix C). The number of pieces of large wood increased by an average of eight pieces per 100 m (range: 10.5 to 33), with 50% of the sites increasing by at least eight pieces per 100 m. Similarly, the volume of large woody debris increased by an average of 16 $m^3$/100 m (range: -8 to 59), with 50% of the sites increasing by at least 19 $m^3$/100 m. The number of key pieces of wood increased by an average of 1.5 pieces per 100 m (range: -1 to 9), with 50% of the sites increasing by at least one piece per 100 m, and the number of large wood jams increased by an average of 6.5 jams per km (range: -6 to 20), with 50% increasing by at least six jams per km.

Statistically significant increases ($p<0.05$) were noted for large wood pieces, large wood volume, key pieces and wood jams for both summer and winter surveys one year following treatment (Table 5). In almost all cases, the post-treatment conditions were higher than the pre-treatment conditions for number of pieces, volume, number of key pieces, and number of wood jams, with many sites meeting the desirable conditions for high quality habitat according to ODFW Aquatic Inventories Benchmarks (Rodgers et al., 2005). Although wood volume and key pieces at the restoration sites (post-treatment) were commonly higher than the OPSW random sites, they were not nearly as high as the reference sites.

Table 5. Results of paired t-tests and Wilcoxon test comparing pre- and post-treatment data for sites resurveyed one year following treatment (n=54). Significant differences indicated by asterisks (two-tailed $p\leq0.05$).

| | **Summer** | | | T-Test | Wilcoxon | **Winter** | | | T-Test | Wilcoxon |
|---|---|---|---|---|---|---|---|---|---|---|
| | Pre-Tx | Post-Tx | Difference | P-Value | P-Value | Pre-Tx | Post-Tx | Difference | P-Value | P-Value |
| Pool Area | 1609.3 | 1642.8 | 33.5 | 0.671 | 0.857 | 1863.5 | 1821.3 | -42.1 | 0.075 | 0.145 |
| Deep Pools / km | 1.8 | 1.7 | -0.1 | 0.778 | 0.775 | 5.5 | 5.4 | -0.1 | 0.648 | 0.392 |
| Slackwater Pool Area | 89.7 | 79.4 | -10.3 | 0.756 | 1.000 | 91.5 | 100.3 | 8.9 | 0.887 | 0.337 |
| % Riffle Fines | 19.2 | 19.6 | 0.5 | 0.834 | 0.827 | 17.6 | 19.6 | 2.1 | 0.346 | 0.337 |
| % Riffle Gravel | 42.7 | 44.4 | 1.7 | 0.349 | 0.226 | 45.2 | 46.9 | 1.7 | 0.696 | 0.840 |
| Wood Pieces / 100m | 10.8 | 16.0 | 5.2 | 0.000 | 0.000 * | 11.3 | 19.5 | 8.2 | 0.000 | 0.000 * |
| Wood Volume / 100m | 10.4 | 21.9 | 11.4 | 0.000 | 0.000 * | 11.0 | 27.4 | 16.4 | 0.000 | 0.000 * |
| Key Wood Pieces / 100m | 0.4 | 1.1 | 0.7 | 0.000 | 0.000 * | 0.5 | 2.0 | 1.5 | 0.000 | 0.000 * |
| Wood Jams / km | 4.3 | 8.1 | 3.9 | 0.000 | 0.000 * | 3.9 | 10.4 | 6.5 | 0.000 | 0.000 * |
| Secondary Channel Area | 128.6 | 139.6 | 11.1 | 0.7739 | 0.777 | 71.4 | 86.4 | 15.0 | 0.1197 | 0.1059 |

The effect of the restoration activities on the number, type, and amount of pools was variable. The average amount of pool area was essentially unchanged across all sites. The pool area increased 34 $m^2$ increase (range: -1689 to 1517) in summer, and 42 $m^2$ increase (range: -3565 to 3762) in winter. In the summer, the average number of deep pools decreased following restoration by an average of 0.1 deep pools/km (range: -6 to 5). In the winter, the average number of deep pools stayed the same (range: -15 to 15). There were no significant changes in either pool area (summer p=0.671, winter p=0.075) or number of deep pools (summer p=0.778, winter p=0.648) (Table 5).

Pool area and the number of deep pools were similar at the pre- and post-treatment sites and the OPSW random sites for the 2002-05 data sets, although the restoration sites had more deep pools in the winter than the OPSW random sites (Appendix C). There was no overall change in the number of deep pools between the pre- and post-treatment surveys. Pool area observed during the summer was slightly higher in both the pre- and post-treatment sites than the random or reference sites.

The changes in percent gravel and fines at the restoration projects were variable (Appendices A and B). There were no significant changes for either percent of fines in riffle (summer p=0.834, winter p=0.346) or percent gravel in riffle (summer p=0.349, winter p=0.696) (Table 5). There were no differences observed in percent riffle fines and riffle gravel between random, reference, pre- and post-treatment sites sampled during summer and winter (Appendix C).

The quantity of secondary and slow water pool habitat did not increase significantly in the summer or winter post-treatment surveys (p>0.05) even though the overall amount of secondary channel area increased pre- to post-treatment in summer and winter (Table 5).

## Post-Treatment Conditions Two or More Years after Implementation

The habitat response measured at least two years post-treatment varied among the sites. The number of large wood pieces increased in the summer by an average of seven pieces per 100 m (range: -11 to 19) (Appendix C), with 50% of the sites increasing by at least eight pieces per 100 m. The volume of large wood increased by an average of 17 $m^3$/100 m (range: 2 to 46), with 50% of the sites increasing by at least 16 $m^3$/100 m and all of the sites increasing by at least 2 $m^3$/100 m. Key pieces of wood increased by an average of 0.9 pieces per 100 m (range: -0.6 to 3.5), with 50% of the sites increasing by at least 0.8 pieces per 100 m, while large wood jams increased by an average of five jams per km (range: -13 to 17), with 50% of the sites increasing by at least five jams per km. The winter sites had more robust trends in levels of large wood. The number of large wood pieces increased by an average of eleven pieces per 100 m (range: -3 to 24) (Appendix C), with 50% of the sites increasing by at least 12 pieces per 100 m. The volume of large wood increased by an average of 20 $m^3$/100 m (range: -7 to 53), with 50% of the sites increasing by at least 18 $m^3$/100 m. Key pieces of wood increased by an average of 1.8 pieces per 100 m (range: -0.4 to 6.8), with 50% of the sites increasing by at least 1.6 pieces per 100 m, while large wood jams increased by an average of six jams per km (range: -8 to 18), with 50% of the sites increasing by at least five jams per km. Statistically significant increases were noted for large wood pieces, large wood volume, key pieces and wood jams for both summer and winter ($p<0.05$), (Table 6).

Table 6. Results of paired t-tests comparing pre- and post-treatment data resurveyed two or three years following treatment (n=19). Significant differences indicated by asterisks (two-tailed $p \leq 0.05$).

| | **Summer** | | | T-Test | Wilcoxon | **Winter** | | | T-Test | Wilcoxon |
|---|---|---|---|---|---|---|---|---|---|---|
| | Pre-Tx | Post-Tx | Difference | P-Value | P-Value | Pre-Tx | Post-Tx | Difference | P-Value | P-Value |
| Pool Area | 1411.9 | 1271.1 | -140.8 | 0.345 | 0.954 | 1157.3 | 1352.3 | 195.0 | 0.249 | 0.283 |
| Deep Pools / km | 1.6 | 1.2 | -0.4 | 0.352 | 1.000 | 5.2 | 4.0 | -1.2 | 0.257 | 0.527 |
| % Riffle Fines | 13.8 | 16.0 | 2.2 | 0.426 | 0.650 | 17.5 | 15.5 | -2.0 | 0.584 | 0.501 |
| % Riffle Gravel | 41.9 | 38.3 | -3.7 | 0.272 | 0.569 | 47.1 | 51.1 | 4.0 | 0.422 | 0.549 |
| Wood Pieces / 100 m | 11.1 | 18.2 | 7.1 | 0.001 | 0.015 * | 11.7 | 22.4 | 10.7 | 0.000 | 0.001 * |
| Wood Volume / 100 m | 9.9 | 26.6 | 16.7 | 0.000 | 0.000 * | 9.0 | 29.3 | 20.3 | 0.000 | 0.000 * |
| Key Wood Pieces / 100 m.0031 | 0.4 | 1.3 | 0.9 | 0.003 | 0.009 * | 0.2 | 2.1 | 1.9 | 0.000 | 0.000 * |
| Wood Jams / km | 4.9 | 10.5 | 5.6 | 0.001 | 0.002 * | 5.3 | 11.4 | 6.1 | 0.001 | 0.001 * |
| Slackwater Pool Area | 128.2 | 27.2 | -101.0 | 0.172 | 0.724 | 28.3 | 71.7 | 43.4 | 0.004 | 0.013 * |
| Secondary Channel Area | 129.1 | 174.2 | 45.1 | 0.253 | 0.465 | 91.6 | 165.8 | 74.2 | 0.063 | 0.101 |

In the summer, pool area showed little response at most sites and decreased by an average of 11% (range: -56 to 78) (Appendix C). Two of the 40 sites saw a 70% increase in pool area. In the winter, pool area increased by an average of 15% (range: -44 to 195) with 50% of the sites experiencing an increase of at least 32%. The change in the number of deep pools was variable, but decreased overall. In the summer, deep pools decreased by an average of 0.4 deep pools/km (range: -5 to 2), with 42% of the sites exhibiting no change and 37% of the sites showing a decrease. In the winter, deep pools decreased by an average of 1.2 deep pools/km (range: -9 to 7) with 47% of the sites showing a decrease. However, 21% of the sites had an increase of at least two deep pools/km. There were no significant changes for either pool area (summer p=0.972, winter p=0.241) or deep pools (summer p=0.583, winter p=0.476) (Table 6). Slackwater pool area showed a significant increase in the winter (p=0.022).

The percentage of fines and gravel in riffles also showed little change. In the summer, the percentage of fines increased an average of 2% (range: -25 to 27) and the percentage of gravel decreased an average of 4% (range: -33 to 21). In the winter, fines decreased an average of 2% (range: -41 to 35), while gravel increased an average of 4% (range: -37 to 42) (Figure 7). There were no significant changes for either riffle fines (summer p=0.436, winter p=0.371) or riffle gravel (summer p=0.695, winter p=0.537) (Table 6).

Wood levels observed in the pre-treatment streams for the summer and winter data sets were lower than wood levels from the OPSW random sites and the reference sites (Appendix C). As with the one year post-treatment data, in almost all cases the post-treatment conditions were higher than the pre-treatment for number of pieces, volume, key pieces and wood jams, with many sites meeting the desirable conditions for high quality habitat according to ODFW Aquatic Inventories Benchmarks. Fifty percent of the pre-treatment surveys had wood volume of less than 10 $m^3$/100 m while 50% of the post-treatment surveys had at least 25$m^3$/100 m of wood volume. Seventy-five percent of the pre-treatment surveys had less than one key piece per 100 m of channel length, while 75% of the post-treatment streams had at least two key pieces per 100 m of channel length. Half of the post-treatment sites had eight or more wood jams compared to less than three jams in 50% of the pre-treatment sites in both summer and winter. In most cases the wood volume and key pieces were higher than the OPSW random sites, but not nearly as high as the reference sites. The restoration treatment had a significant affect on the number, size, and aggregation of large wood in the restoration sites (Table 6).

Pool area and the number of deep pools were similar at the pre- and post-treatment sites, the OPSW random sites, and the reference sites for the 2001-05 data set, although the restoration sites had more pool area in the summer than the reference sites. There was no overall change in the number of deep pools between the pre- and post-treatment surveys. There were also no differences observed in percent riffle fines and percent riffle gravel between random, reference, pre- and post-treatment sites sampled during summer and winter.

Thirteen sites were surveyed in successive years: one year following restoration and two or three years following restoration. There were no significant differences at $P \leq 0.05$ between the two post-treatment periods (paired T-test and Wilcoxon; n=11), even though the mean values of large wood variables increased between the survey periods (Tables 5 and 6).

## Overall Aquatic Habitat

### Ecological Function

Only three of the seventy 2002-04 restoration sites had high function summer habitat prior to treatment while 21 met the high function standards following treatment. Five of the 60 restoration sites had high function winter habitat prior to treatment while 19 met the high function standards after treatment (Table 7). More high function sites were observed in wide than narrow valley floor sites. Most of the sites did not meet both the large wood and pool requirements for designation as high function habitat.

In the 2001-05 dataset, none of the 19 sites had high function habitat prior to treatment (Table 8). Six summer sites and ten winter sites had high function habitat two to three years following treatment. In the summer surveys, these high function sites were located in wide valley floor sites, while in the winter surveys, seven sites were in wide valleys and three were located in narrow valley floors.

### Salmonid Habitat Quality

The HabRate scores showed little overall change from pre-treatment conditions in the 54 paired sites (Figure 3). Scores indicated habitat was of fair quality prior to treatment with fair (rating =2) quality for spawning gravel, summer rearing habitat, and fair to good (rating = 3) winter habitat. However, 15 sites showed increased overall quality for winter rearing while 7 decreased. Thirty-two sites stayed remained unchanged. Only 2 of 54 sites had a rating of poor (1) following restoration.

Table 7. Number of restored reaches with high function habitat based on channel type and instream habitat one year following restoration.

| | Wide Valley Floor | | | Narrow Valley |
|---|---|---|---|---|
| **Summer Pre Treatment** | Unconstrained | Potentially Unconstrained | Deeply Incised | Constrained By Hillslopes |
| High Function | 0 | 0 | 3 | 0 |
| Moderate-Low Function | 3 | 9 | 47 | 8 |
| Total Number | 3 | 9 | 50 | 8 |

| | Wide Valley Floor | | | Narrow Valley |
|---|---|---|---|---|
| **Summer Post Treatment** | Unconstrained | Potentially Unconstrained | Deeply Incised | Constrained By Hillslopes |
| High Function | 1 | 2 | 18 | 0 |
| Moderate-Low Function | 4 | 2 | 36 | 7 |
| Total Number | 5 | 4 | 54 | 7 |

| | Wide Valley Floor | | | Narrow Valley |
|---|---|---|---|---|
| **Winter Pre Treatment** | Unconstrained | Potentially Unconstrained | Deeply Incised | Constrained By Hillslopes |
| High Function | 0 | 1 | 4 | 0 |
| Moderate-Low Function | 5 | 5 | 38 | 7 |
| Total Number | 5 | 6 | 42 | 7 |

| | Wide Valley Floor | | | Narrow Valley |
|---|---|---|---|---|
| **Winter Post Treatment** | Unconstrained | Potentially Unconstrained | Deeply Incised | Constrained By Hillslopes |
| High Function | 2 | 1 | 15 | 1 |
| Moderate-Low Function | 1 | 9 | 26 | 5 |
| Total Number | 3 | 10 | 41 | 6 |

Table 8. Number of restored reaches with high function habitat based on channel type and instream habitat two or three years following restoration.

| Summer Pre Treatment | Wide Valley Floor<br>Unconstrained | Potentially Unconstrained | Deeply Incised | Narrow Valley<br>Constrained By Hillslopes |
|---|---|---|---|---|
| High Function | 0 | 0 | 0 | 0 |
| Moderate-Low Function | 1 | 4 | 10 | 4 |
| Total Number | 1 | 4 | 10 | 4 |

| Summer Post Treatment | Wide Valley Floor<br>Unconstrained | Potentially Unconstrained | Deeply Incised | Narrow Valley<br>Constrained By Hillslopes |
|---|---|---|---|---|
| High Function | 0 | 1 | 5 | 0 |
| Moderate-Low Function | 2 | 0 | 9 | 2 |
| Total Number | 2 | 1 | 14 | 2 |

| Winter Pre Treatment | Wide Valley Floor<br>Unconstrained | Potentially Unconstrained | Deeply Incised | Narrow Valley<br>Constrained By Hillslopes |
|---|---|---|---|---|
| High Function | 0 | 0 | 0 | 0 |
| Moderate-Low Function | 0 | 3 | 10 | 6 |
| Total Number | 0 | 3 | 10 | 6 |

| Winter Post Treatment | Wide Valley Floor<br>Unconstrained | Potentially Unconstrained | Deeply Incised | Narrow Valley<br>Constrained By Hillslopes |
|---|---|---|---|---|
| High Function | 1 | 1 | 5 | 3 |
| Moderate-Low Function | 0 | 2 | 5 | 2 |
| Total Number | 1 | 3 | 10 | 5 |

Two to three years following treatment, approximately 52 – 60% of the sites evaluated showed little change in habitat quality between the pre-treatment survey and the post-treatment survey. 26% of the spawning/emergence habitats, 28% of the summer rearing habitats, and 12% of winter rearing habitats improved in quality. 18% of the spawning/emergence habitats, 19% of the summer rearing habitats, and 28% of the winter rearing habitats declined in quality.

We examined the habitat components of the HabRate model scores that comprised the input for the overall rating by life stage: substrate, gradient, amount and complexity of pools and sheltered pools, and structural elements. The individual components remained essentially constant from pre- to post-treatment and from summer to winter flow conditions. However, ratings for large wood increased significantly from pre- to post-treatment which increased the pool complexity ranks, but the amount of sheltered pools remained low. The result is that the overall scores increased slightly for the quality of overwinter habitat for 0+ juvenile coho.

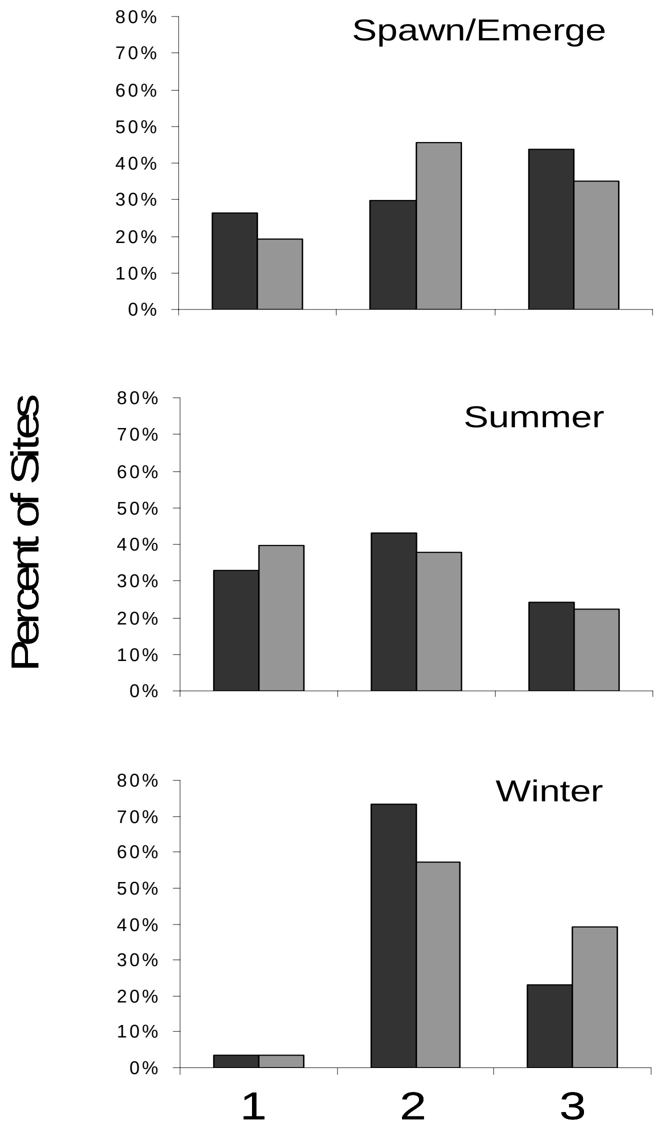



Figure 4. Rating of habitat quality at restoration projects one-year following treatment according to the HabRate model for spawn and emergence, summer rearing, and winter rearing conditions for coho salmon. The black bar represents pre-treatment conditions and the gray bar represents post-treatment conditions. A rating of 1=poor, 2=fair, and 3=good.

**High Quality Winter Habitat for Juvenile Coho Salmon**

Habitat capacity (parr per km) and quality (parr per $m^2$) for over-wintering juvenile coho predicted by HLFM version 7.0 did not show an overall change (Figure 5). Approximately half of the sites increased slightly and half decreased. The sites were primarily of moderate quality (0.12 to 0.30 parr per $m^2$), and low to moderate capacity (less than 1850 parr per km). The amount of total pool habitat or the beaver dam and alcove habitat did not change following treatment, although the amount of large wood in lateral scour, plunge, and dam pools did increase on average.

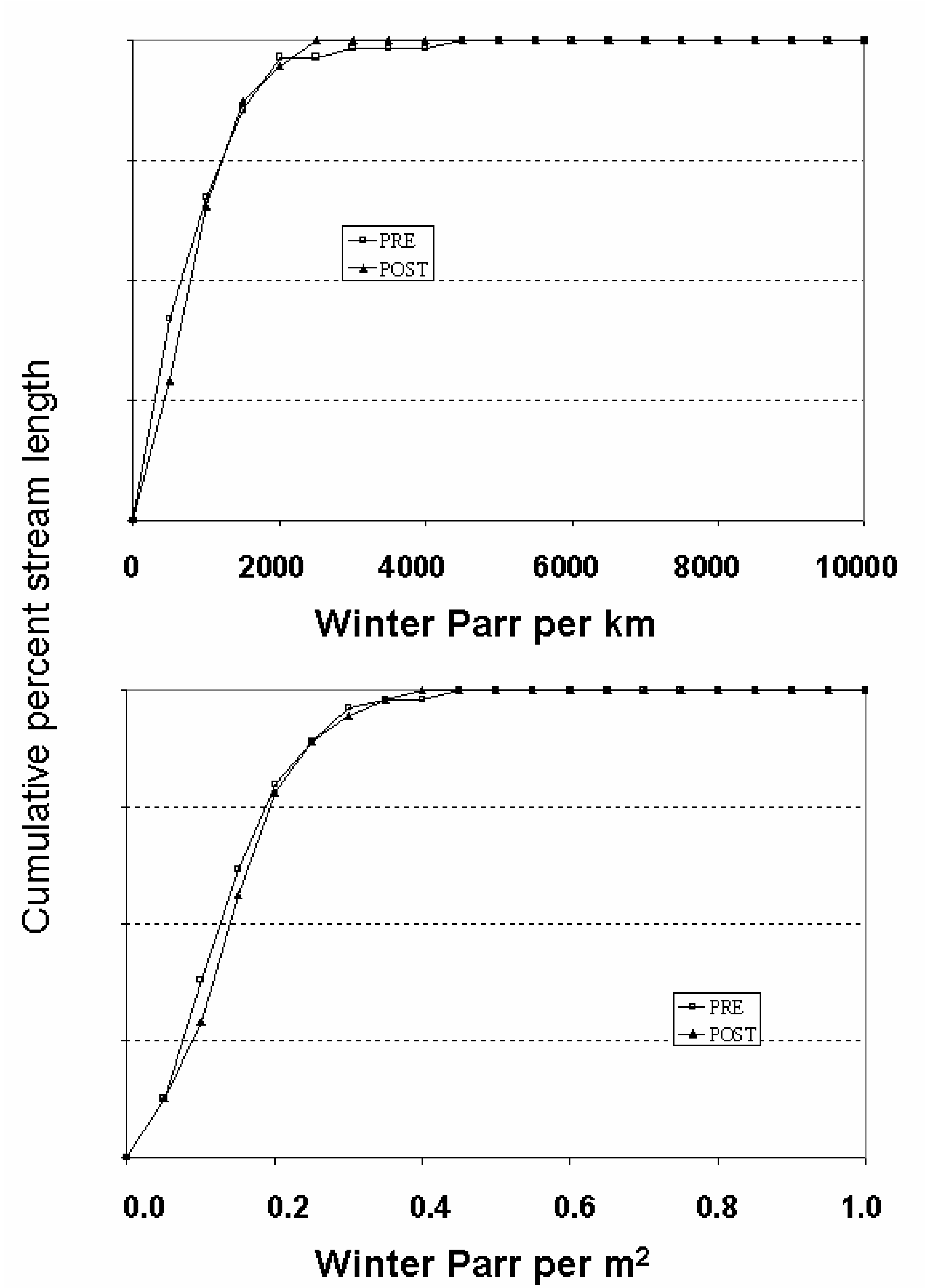



Figure 5. Cumulative distribution frequencies of habitat capacity (parr/km) and quality (parr/m2) as estimated by HLFM 7.0.

## DISCUSSION

The restoration treatments were designed to improve the habitat complexity and ecological function of streams, and increase the amount and quality of rearing habitat for salmonids in western Oregon streams. Most of the projects were located within the distribution of coho salmon in coastal streams (and other salmonids in the lower Columbia and Willamette), and implemented in low gradient, moderate size streams. The number of kilometers treated was low relative to the number of kilometers inhabited by coho salmon in coastal drainages. However, the project biologists were selecting appropriate sites and treatment methods.

A map of intrinsic potential for winter rearing of juvenile coho is now available for all coastal and lower Columbia River drainages (Burnett et al., 2007). Reaches and streams identified as high intrinsic potential provide a landscape-scale tool for filtering the selection of restoration sites that are designed to improve the habitat quality for juvenile coho during the winter. Even without the availability of the maps in the past, the habitat biologists followed the selection procedures and many of the sites fell within the reaches identified as high intrinsic potential.

Surveys were conducted during the winter and summer at each restoration site to assess habitat characteristics during different flow regimes. Habitat characteristics recorded by the surveyors were partially dependent on the flow characteristics at the time of survey. In particular, the depth, complexity, and pool types and number were frequently different during winter base flows compared to summer low flow. Increased flows during the winter affect the dynamics of each project by moving wood into or out of the project area, creating jams, scouring pools, and redistributing substrate. River discharges during the period 2002-05 were average, with no dramatic peak stream flows in the north, and a moderately high peak discharge in the Umpqua basin in 2004 (USGS 2006). Winter flows are the primary factor affecting dramatic change in stream habitat, the collection of wood jams, scour of pools, accumulation of large substrate, and creation of secondary and off-channel habitat. Although change of stream habitat through time is typically slow and encompasses years to decades, very high winter stream flow pulses can speed this process.

We incorporated protocol modifications starting in January 2004 that included increasing the length of surveys and measuring the length and diameter of all large wood. Formerly, all wood dimensions were estimated, but with some degree of variability between survey crews. We felt that it was necessary to have more precise information since wood is integral to restoration treatments and changes in stream morphology. This will allow us to better detect the movement and recruitment of wood from or to the restoration structures. We also modified the length of stream sections monitored so they include the entire treatment area. Formerly, we were monitoring a standardized 500 meter segment. We felt that we may have missed changes that occurred outside the discrete segments of the treated reach. We now survey the entire segment to be treated plus an additional 50 meters downstream and upstream to ensure we encompass all areas that might be affected by restoration activities. Measuring wood and monitoring longer stream segments will restrict the total number of sites that we can monitor. However, it will provide more precise data.

The restoration activities were effective at increasing access to additional habitat, improving overall habitat complexity and improving the over-wintering habitat for juvenile coho salmon. Six sites had culverts replaced, opening up nearly 20 kilometers of stream habitat to anadromous fish use. The removal of these culvert barriers was beneficial to coho as well as other anadromous and resident fish species, as all age classes of fishes can freely migrate within as well as outside the affected stream. The availability of maps of intrinsic potential will assist habitat biologists to select passage projects that will restore habitat with the highest potential to improve fish populations.

Large wood pieces, volume and wood jams increased as a direct result of treatment. Amounts of wood observed in the winter and summer surveys following treatment were greater than that placed during restoration, which indicates additional accumulation of large wood. Winter flows have and will affect the condition and configuration of wood in the stream channel, and should bring additional large and small pieces to accumulate behind the placed structures. However, most sites still fell below benchmark levels of 30 $m^3$ large wood /100 m stream channel (Rodgers, et al. 2005). Based on previous studies (Jacobsen and Jones 2003), sites that depended on riparian recruitment actually lost wood volume while gaining smaller wood pieces over the long term, suggesting that as wood moved through the system, only smaller alder species were being accumulated. Therefore, higher loading of reaches at the outset may ensure not only the intended treatment goals are reached but also help longer-term retention of large wood.

Pool area and the number of deep pools changed at many sites, although overall, the changes were not significant. However, individual sites realized significant gains in pool habitat, with 20% of the sites gaining at least 50% in area in the summer and 25% of the sites doing the same in the winter. One summer and two winter sites had pool area grow by over 150%. The number of deep pools decreased in the summer, but that may be a reflection of low stream flows at the time of survey, especially since deep pools increased as a group in the winter. It may also be that pools have to get much deeper in the summer to be considered deep (at least 1.0 m deep), while in the winter, when flows are higher, only a slightly deeper scour may achieve this standard. Reference sites had the most deep pools (75% of the reference stream channel had at least four deep pools vs. only two in the treated segments) when compared to pre- and post-treatment and OPSW sites. The addition of large wood, particularly in jams, should help scour deeper pools at sites in alluvial streams. Streams incised to bedrock will likely not experience additional scour.

Gravel and fines did not change dramatically on average although some sites illustrated large variation. This may be due to a number of factors. Precision of substrate estimations is low, and the large changes may be an artifact of measurement error. Some basins may have good sources of sediment inputs while others may not. Perhaps an earth movement upstream of a treatment provided a large influx of gravels in some locations. Overall, sediment redistribution takes time and it is not surprising that large changes were not evident. Substantial alteration will occur from large scale flood events, many years of winter flows, or a delivery mechanism such as a landslide.

Sites two to three years after treatment showed a greater increase in large wood attributes and in pool habitat as compared to sites one year post-treatment. Large wood pieces, volume and jams all increased, and the key pieces were similar. Pool area decreased slightly in the summer but was much higher in the winter after two to three years. Deep pools and riffle substrate changed little in both the short and longer term sites. However, the differences in matched sites (n=13) were not significant at $p \leq 0.05$ for any variables.

These data suggest that stream attributes may improve with time, but that we are unable to demonstrate a significant difference with these data. A larger sample size, or several winters or high flow events may be necessary for the restoration treatments to be more effective. It may require monitoring sites five to ten years following restoration. The restoration sites had significantly higher wood than random sites, but still less than reference sites. This suggests that restoration is effective at increasing stream complexity, but also that streams need to be managed so that wood can naturally recruit to the systems. The restoration sites represent a small portion of the coho distribution which reinforces the notion that a combination of continued restoration and protecting the conditions that allow for natural recruitment is important to recovery of stream systems.

## Ecological Function

We defined ecological function as habitat that meets four criteria in combination: sufficient pool area, wood volume, key wood pieces, and secondary and off-channel habitat (Thom et al., 2000). While very few sites had high ecological function prior to restoration, 30% did after treatment, and 50% of the winter sites that were surveyed two or three years post-treatment met these criteria. In fact, 20% of the sites that did not have high quality habitat after treatment were missing only one of the required attributes. In most cases the deficiency was an insufficient amount of large wood volume or number of key pieces. Although this is not unexpected as natural recruitment is planned as part of the restoration process, reasonable efforts should be made to ensure both the number of key wood pieces and wood volume is sufficiently high when treatments are applied. Our implicit assumption is that conditions more similar to reference conditions (pools, large wood – structural complexity, unconstrained stream with secondary channels and off-channel habitats) are beneficial to productivity of juvenile salmonids. In addition, the passage projects will increase connectivity among local subpopulations and increase the amount of spawning and rearing habitat.

## Salmonid Habitat Quality

HabRate scores did not increase much because the habitat was already in fair condition with an abundance of pools. However, the increase in the number of sites with ratings of 3 (good) reflects the effect of large wood treatment and additional wood recruitment. Results of watershed scale restoration in Tenmile Creek in Oregon (Johnson et al., 2005) indicated that the freshwater survival of coho and steelhead increased following wood treatment whereas survival of fish in an adjacent reference stream did not. The assumption was that the increase in stream complexity provided refugia during high winter flows.  The WOSRP restoration treatments, though on a smaller scale, may be increasing the survival of juvenile salmonids that reside or migrate through the reach.

### High Quality Winter Habitat for Juvenile Coho Salmon

HLFM Version 7.0 did not indicate an overall improvement in either habitat capacity or quality following restoration.  The restoration sites were selected in reaches that already had a high amount of pool habitat, and the treatments involved large wood placement rather than building off-channel ponds.  Over time the wood jams may create more off-channel habitat, and provide an anchor for beavers to build ponds in larger streams.  Monitoring sites at 5 and 10-year intervals will be important for comparing changes in habitat capacity for over-wintering juvenile coho, and understanding why particular sites increased in capacity while others did not.

### Progress Toward Recovery Plan Goals

Findings of the restoration monitoring indicate progress towards increasing ecological function of low gradient streams and increasing complexity and suitability of habitat for juvenile salmonids.  However, the restoration does not yet indicate progress in increasing habitat capacity.  The Oregon Coast Coho Conservation Plan (Nicholas 2006) specifies habitat targets expressed in terms of winter habitat capacity for each coho population along the Oregon Coast, as estimated by HLFM Ver 7.0.  For each of the 18 non-lake coho populations in the Oregon Coast ESU, the Plan specifies how many kilometers of stream habitat need to be able to support at least 1,850 juvenile coho parr per km during the winter in order to sustain populations during periods of poor ocean conditions. Currently, less than 10% of the restoration sites meet this goal. The wood placement projects may not be able to meet these goals alone, but in combination with increased effort on improving streams in the lower portions of the watersheds, the restoration projects may become an important component of recovery.

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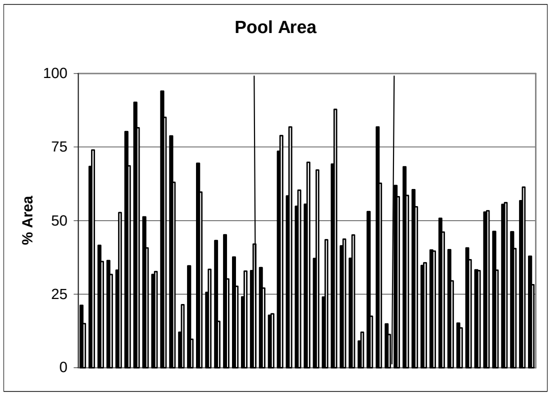
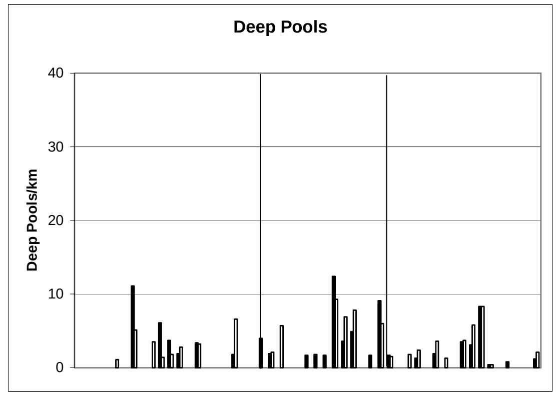
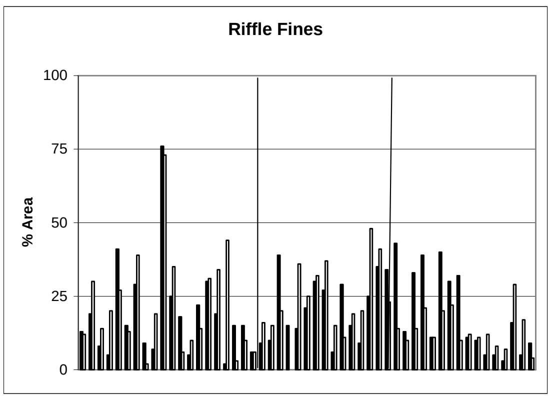
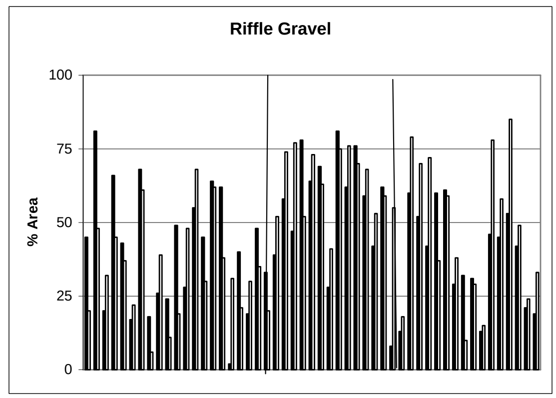
Appendix A-1. Summer comparisons of individual sites pre- and post-treatment. 2002-2005 (n=54). Sites identified in Table 2.

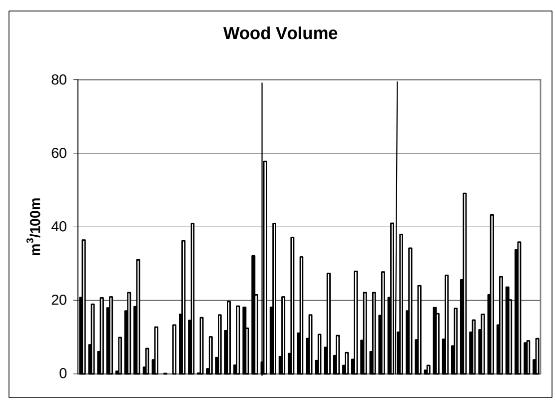


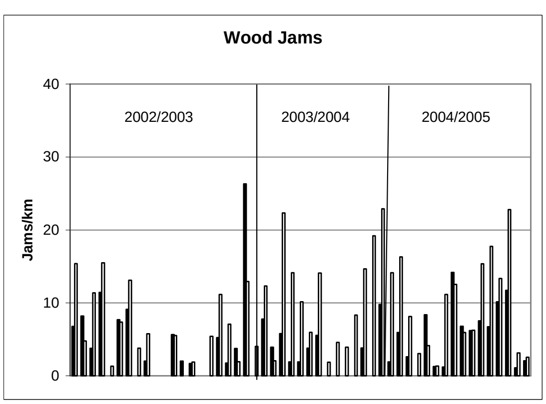



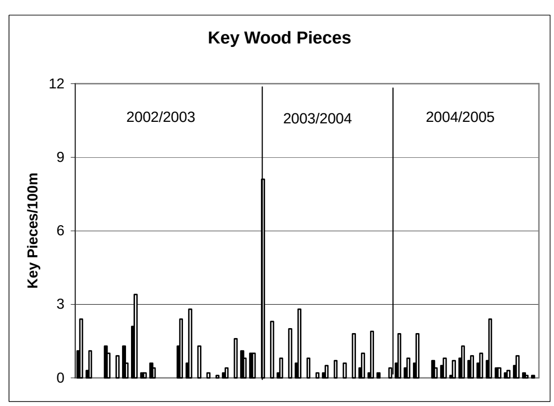



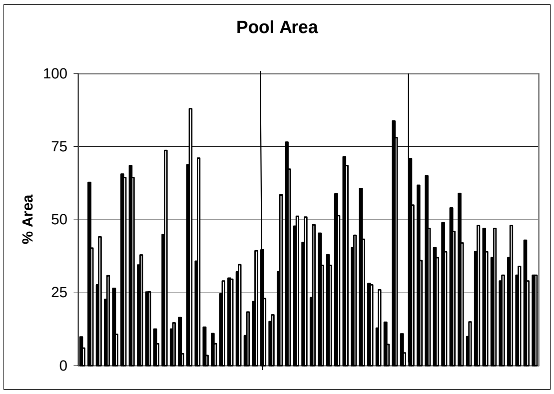


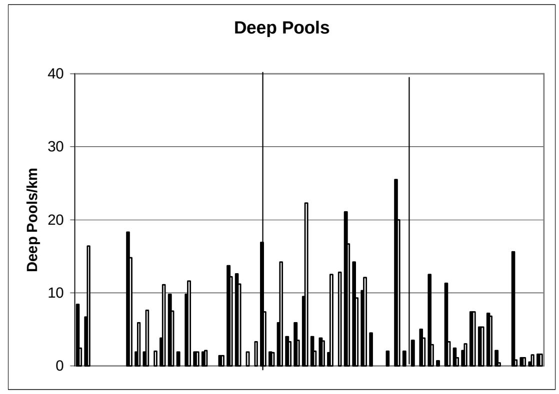


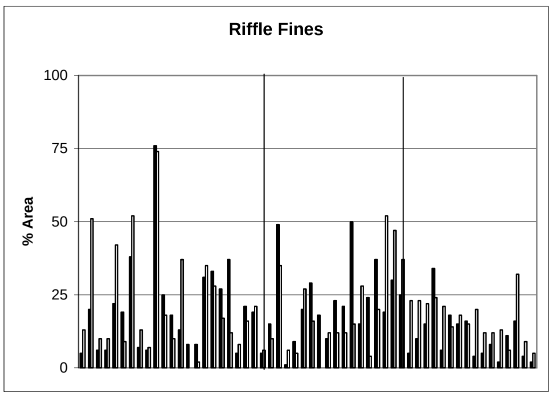



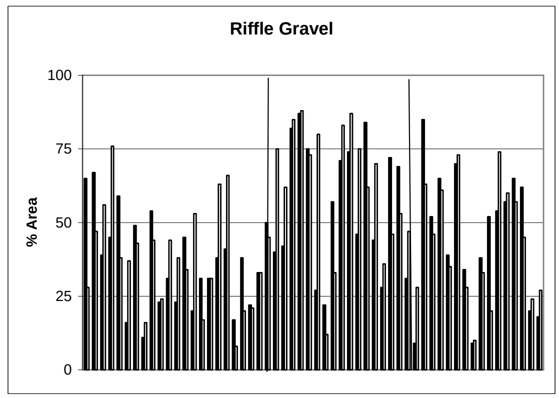



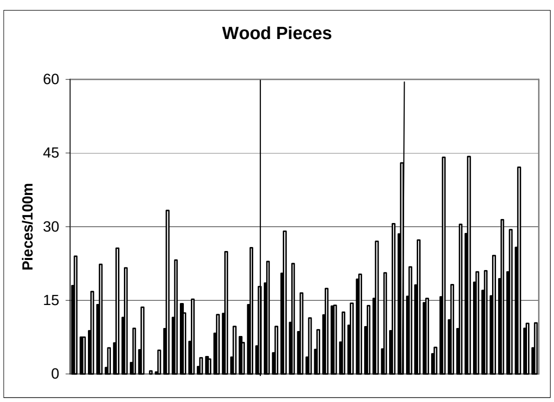
Appendix A-2. Winter comparisons of individual sites pre- and post-treatment. 2002-2005 (n=54). Sites identified in Table 2.

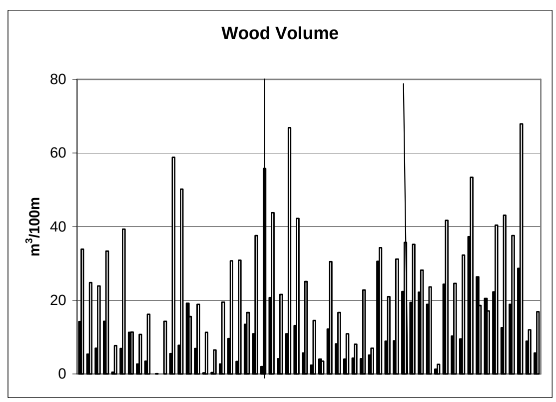


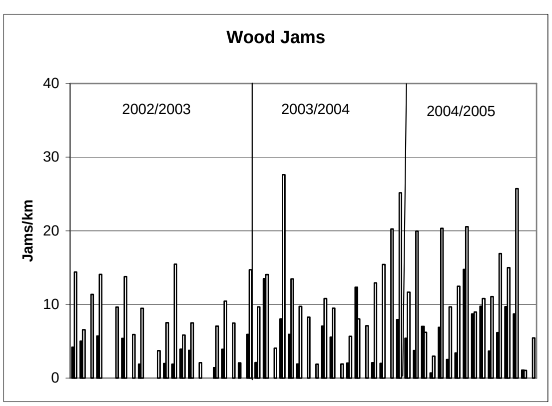



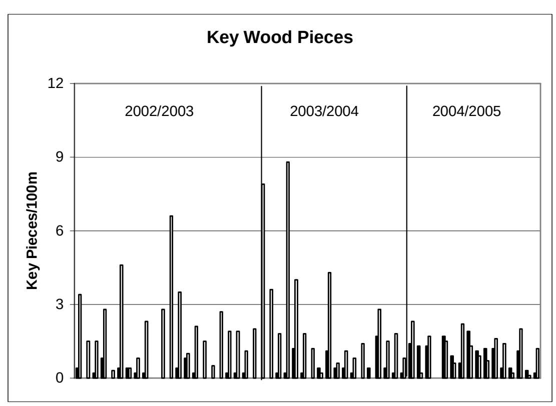



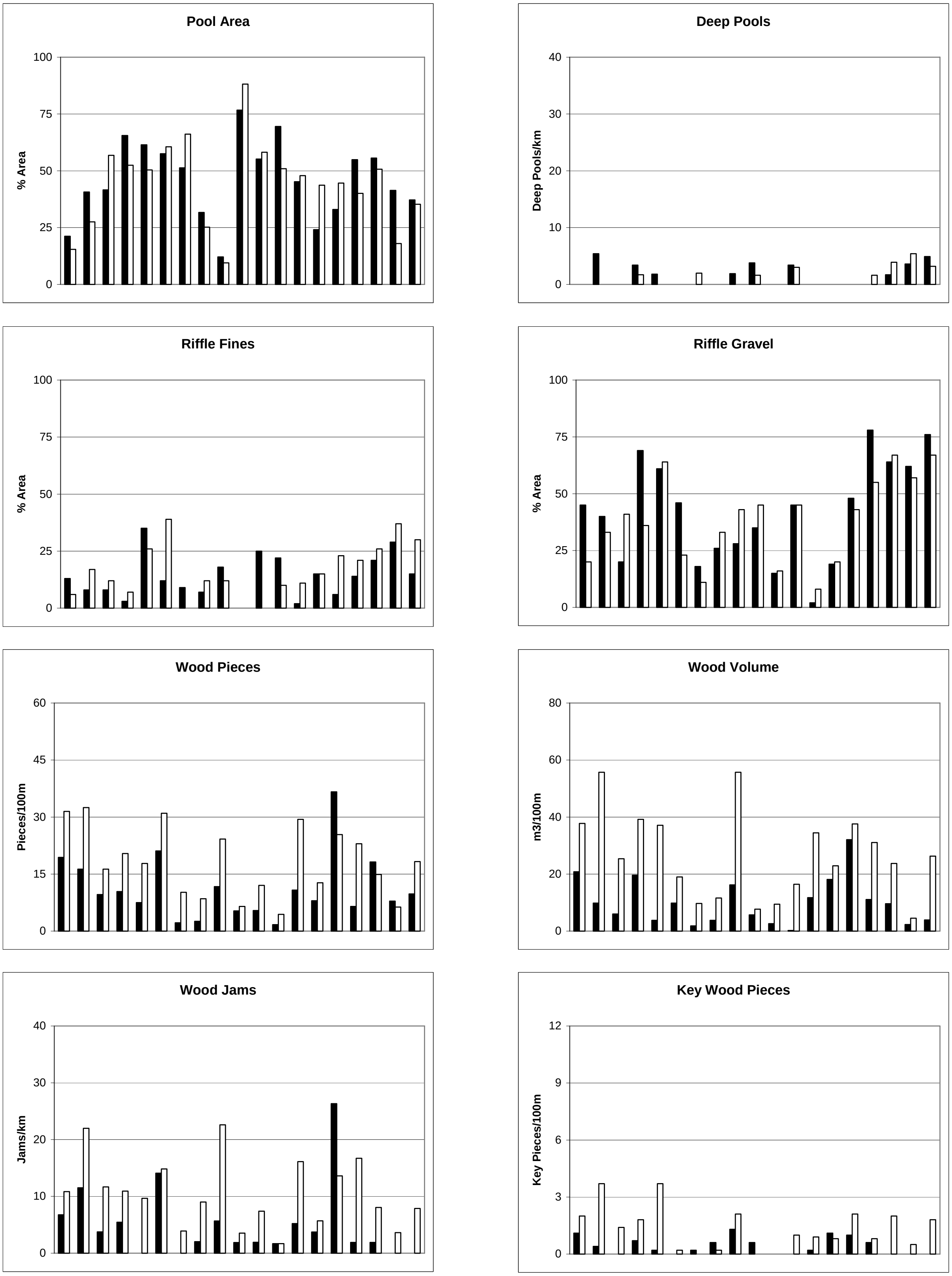



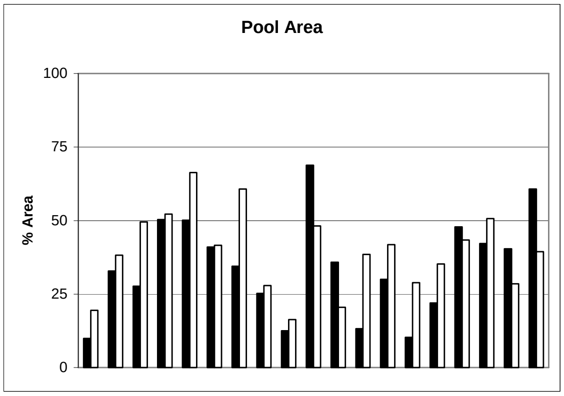



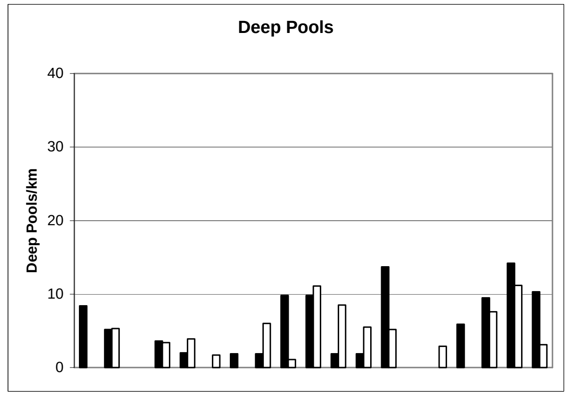



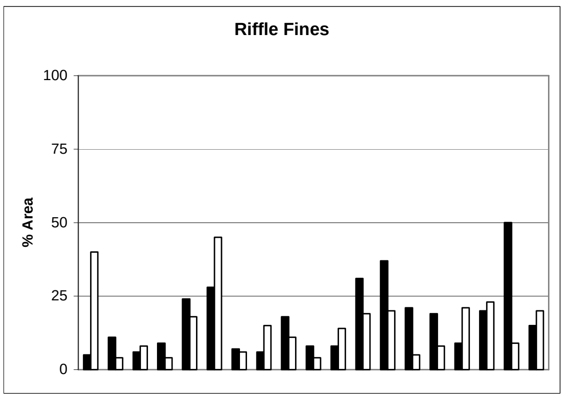
Appendix A-3. Summer comparisons of individual sites after at least two years post-treatment. 2001-2005 (n=19). Sites identified in Table 3.

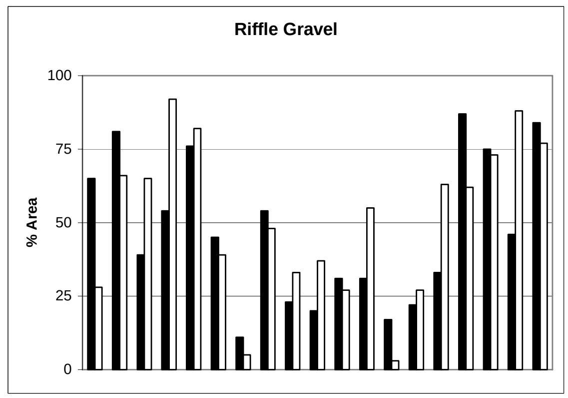


Appendix A-4. Winter comparisons of individual sites after two-three years post-treatment (n=19). Sites identified in Table 3.

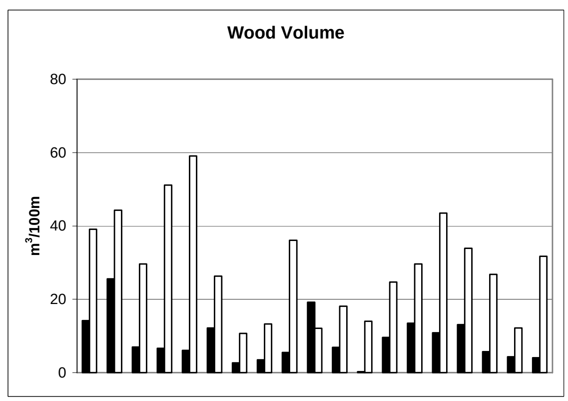


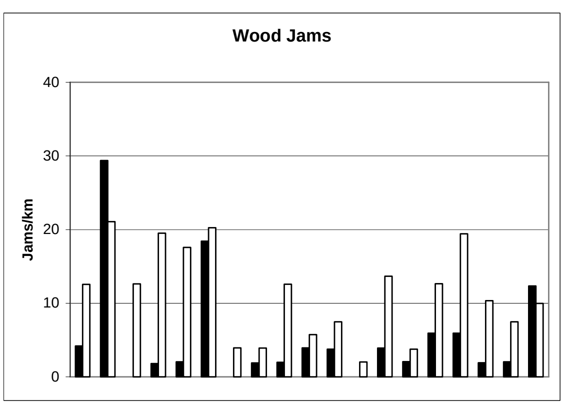



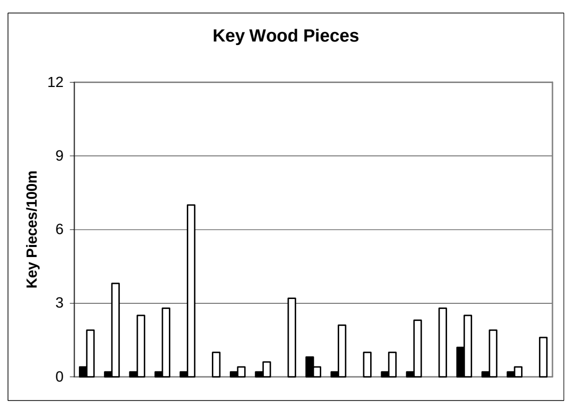



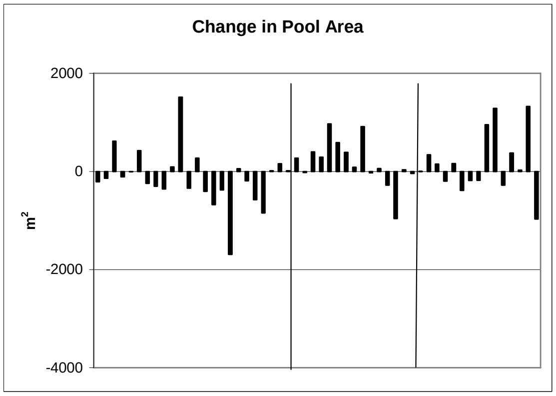


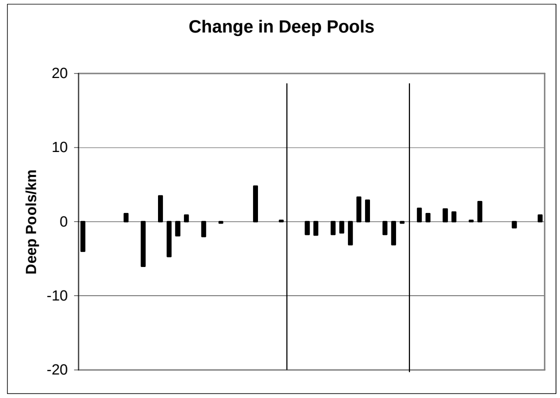


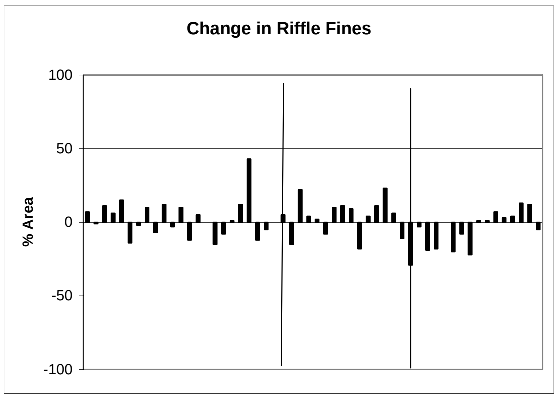



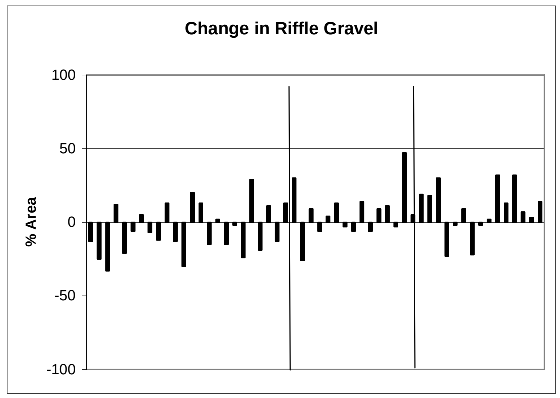



Appendix B-1. Summer comparisons of change at individual sites one year after treatment (n=54). Sites identified in Table 2.

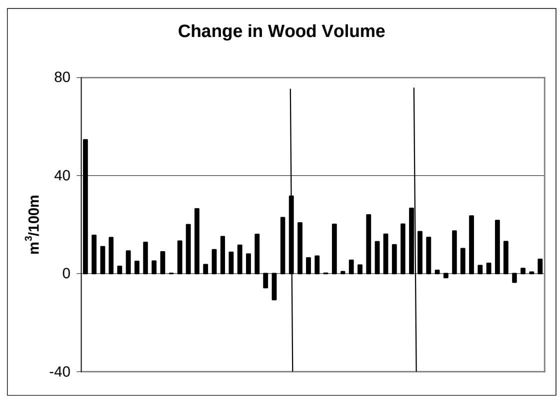


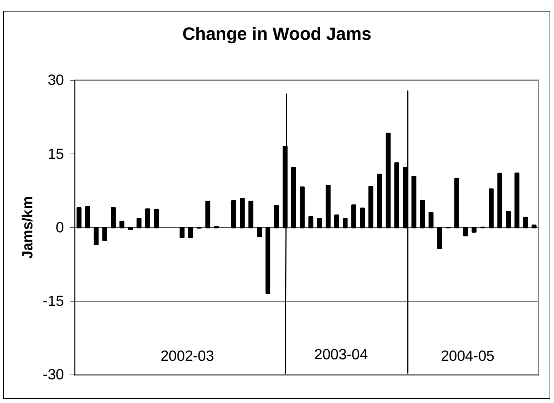



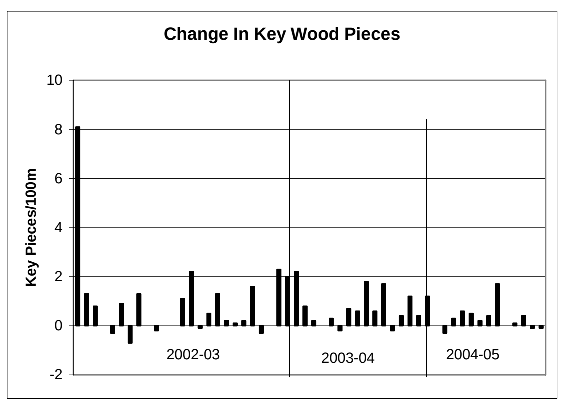



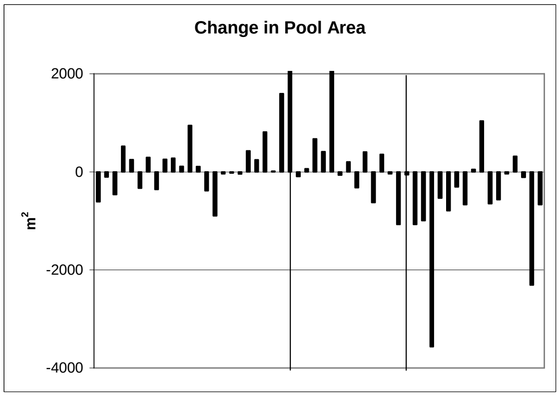


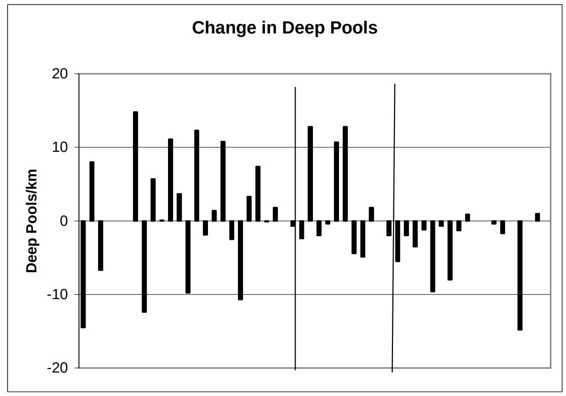


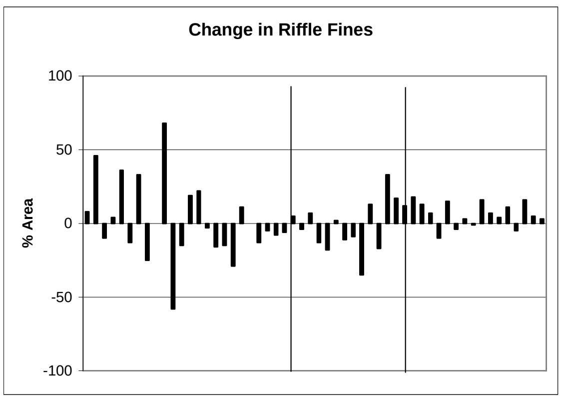



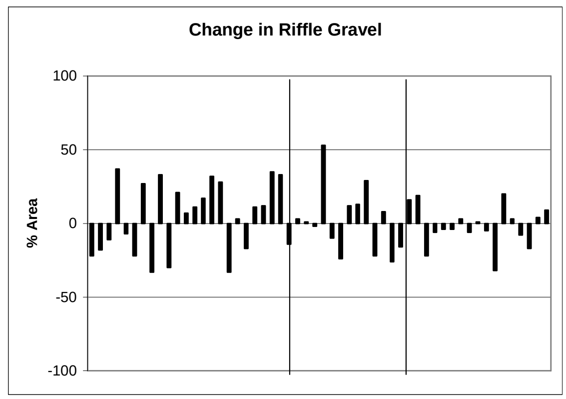



Appendix B-2. Winter comparisons of change at individual sites one year after treatment (n=54). Sites identified in Table 2.

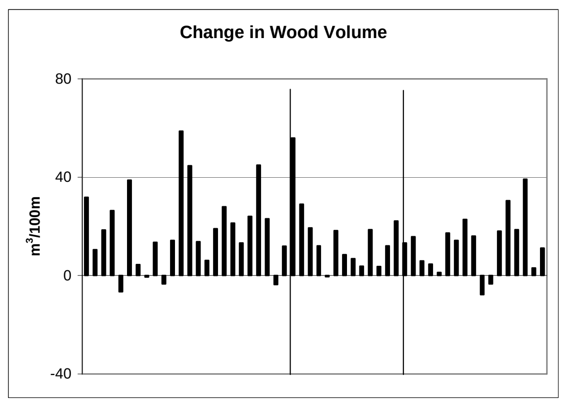


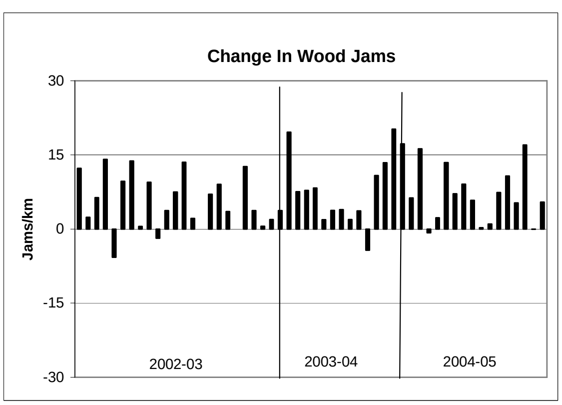



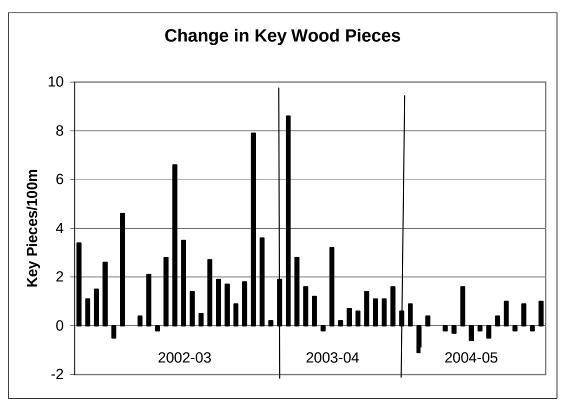



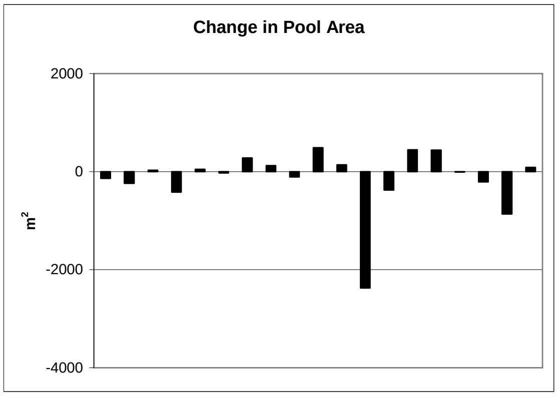


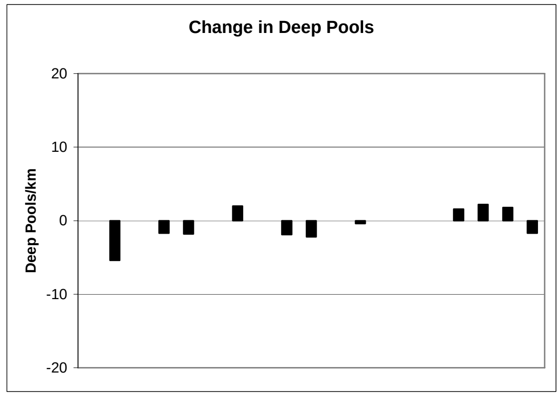


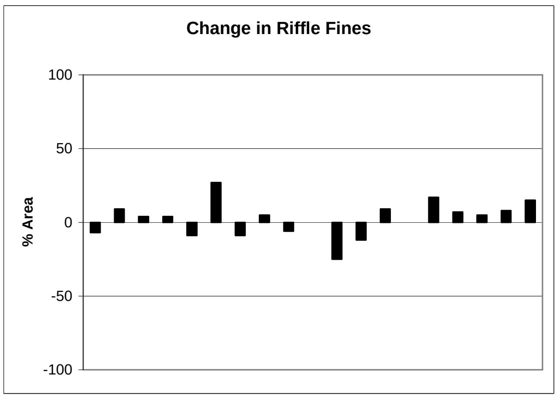



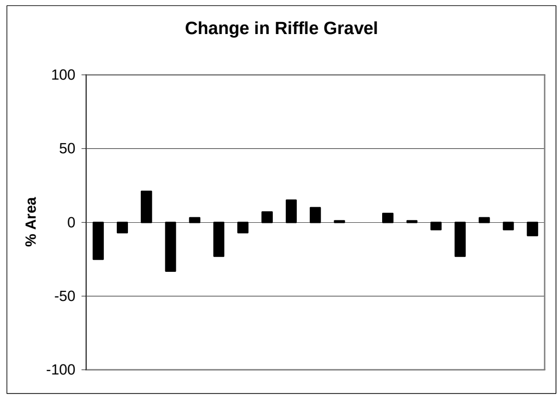



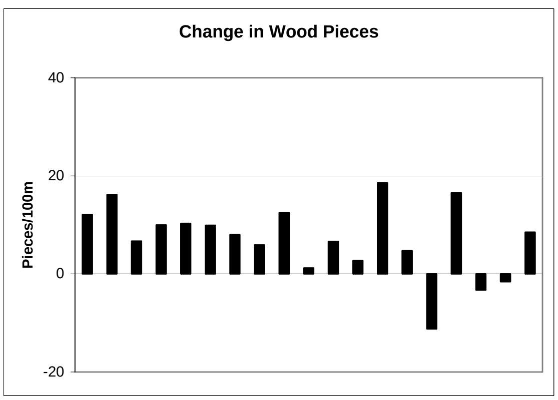
Appendix B-3. Summer comparisons of change at individual sites two-three years after treatment (n=19). Sites identified in Table 3.

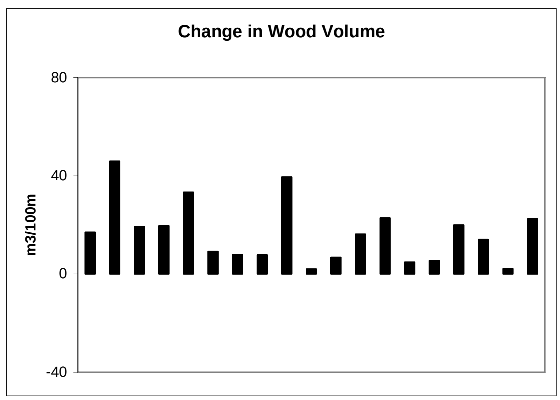


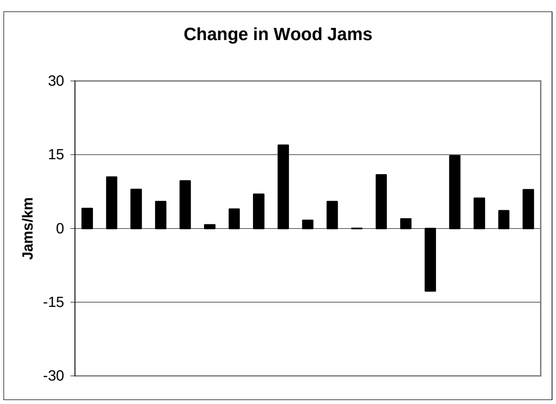



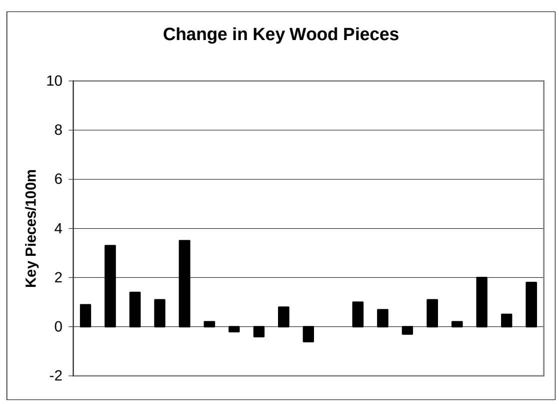



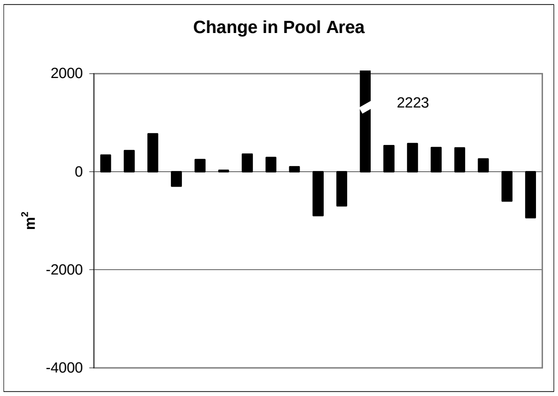



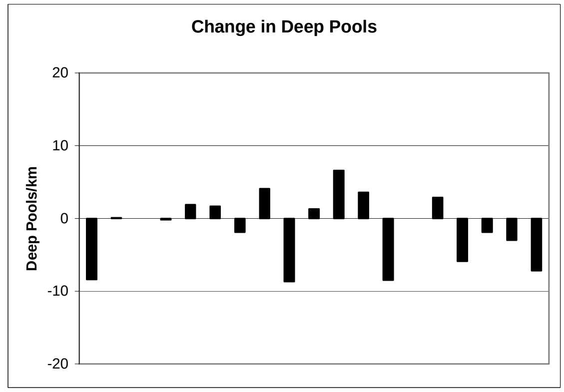



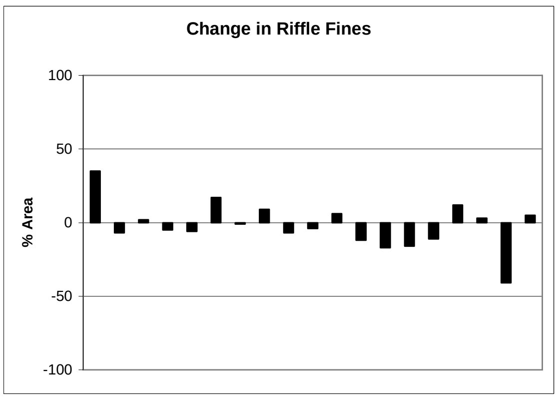



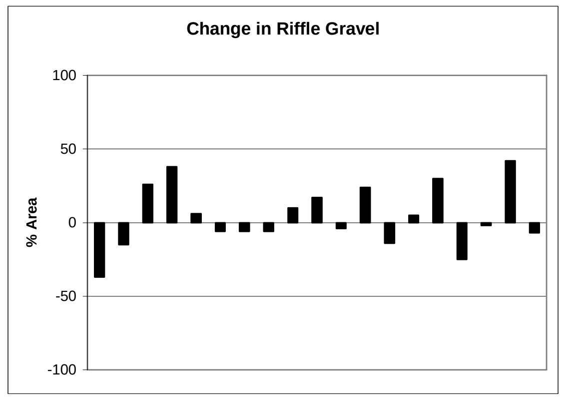



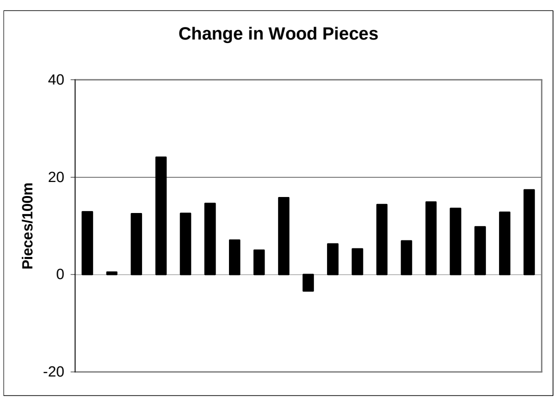
Appendix B-4. Winter comparisons of change at individual sites two to three years after treatment (n=19). Sites identified in Table 3.

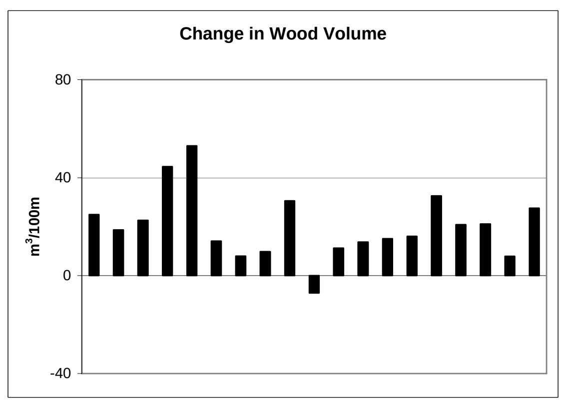


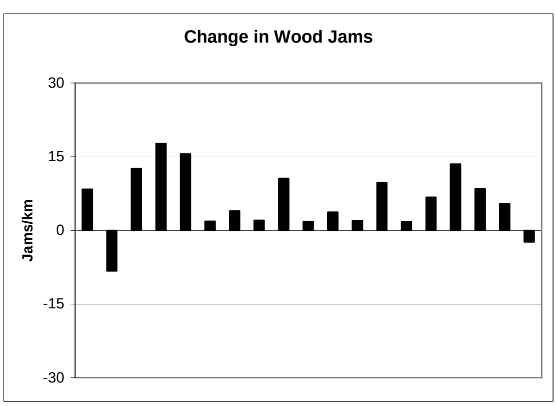



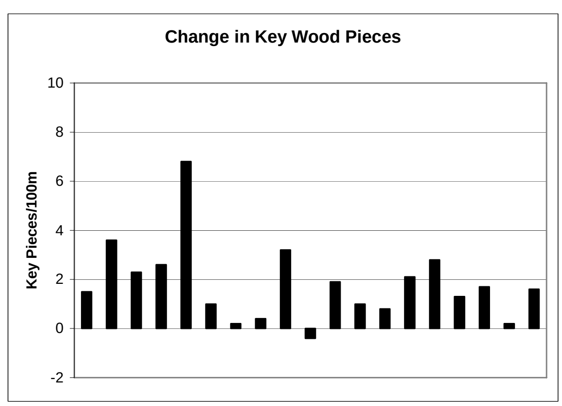



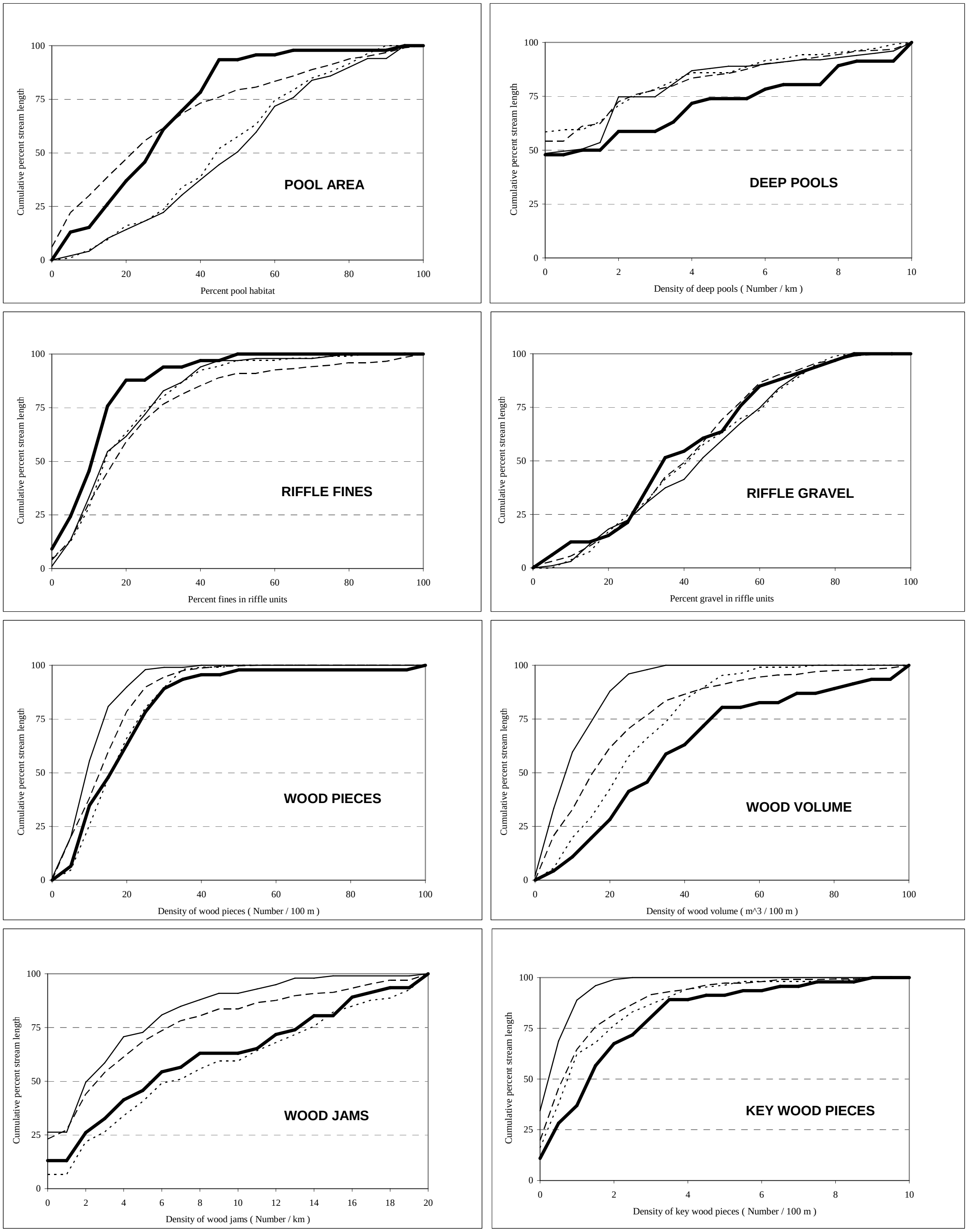



Appendix C-1. Summer characterization of pre-treatment, post-treatment (one year), reference sites and random sites.



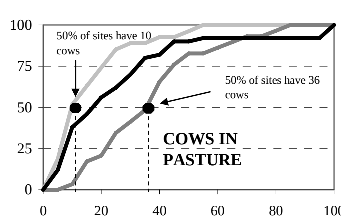

2002/2004 Pre-Treatment Sites

2002/2003 Random Sites

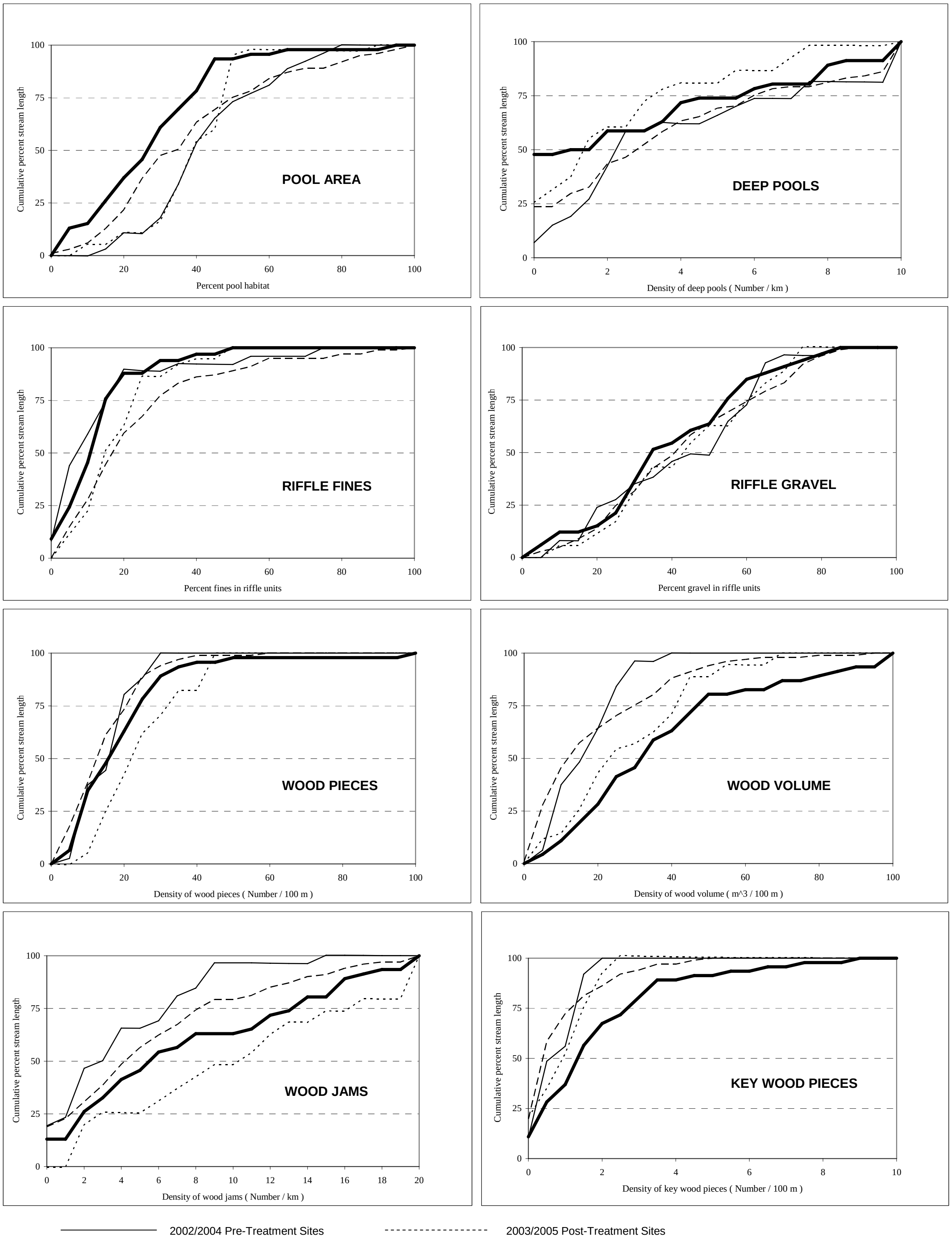
2003/2005 Post-Treatment Sites

2000 Reference Sites

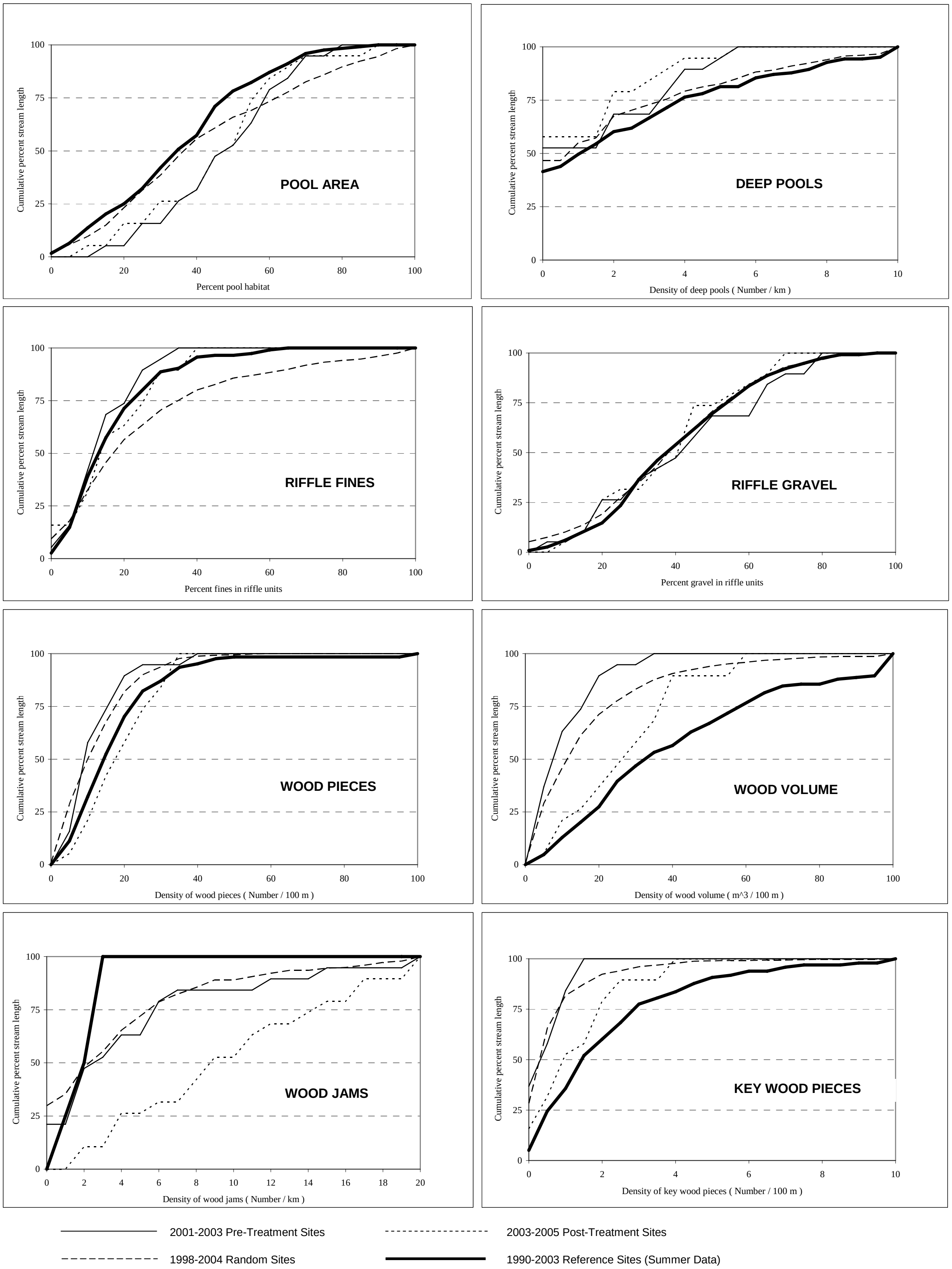
Example



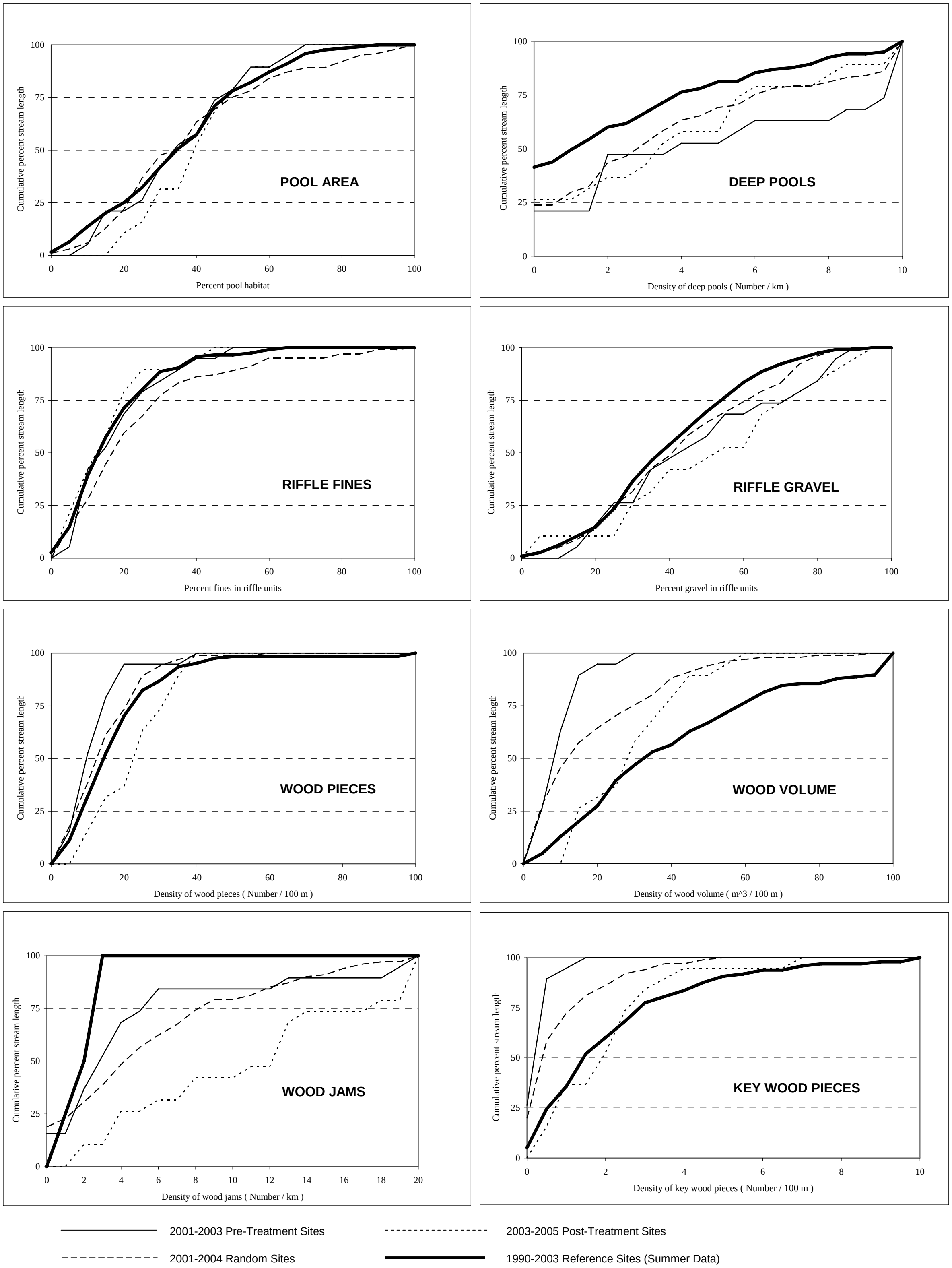
Appendix C-2. Winter characterization of pre-treatment, post-treatment (one year), reference sites and random sites.



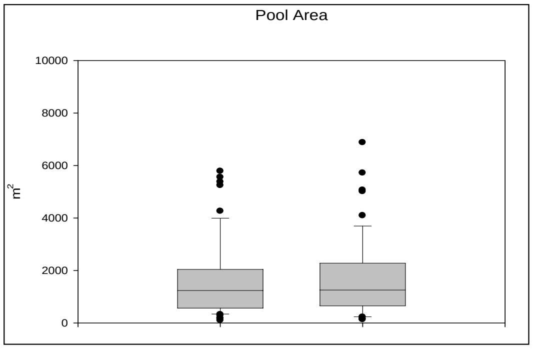
Appendix C-3. Summer characterization of pre-treatment, post-treatment (two to three years), reference sites and random site.

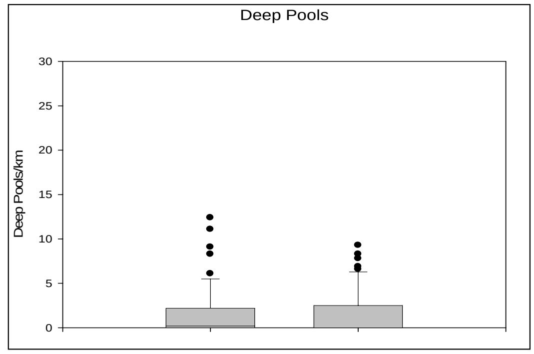


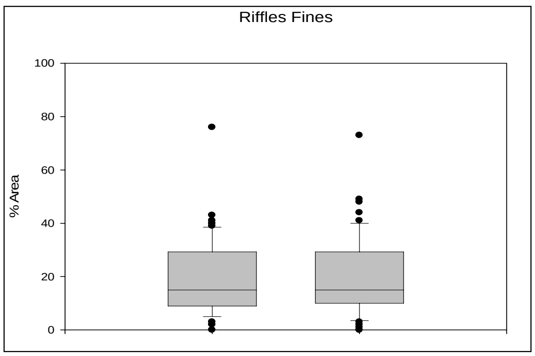
Appendix C-4. Winter characterization of pre-treatment, post-treatment (two to three years), reference sites and random sites.

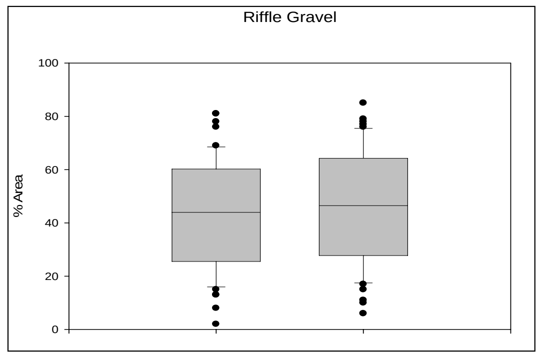


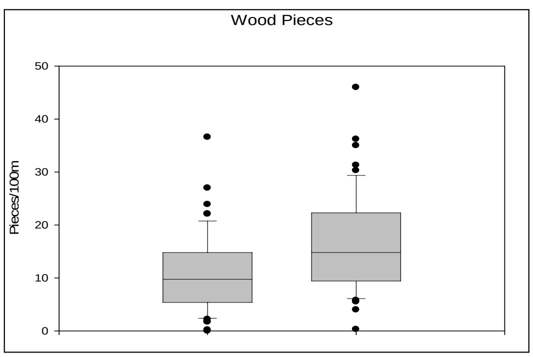
Appendix D-1. Summer characterization of pre-treatment and one year post-treatment.

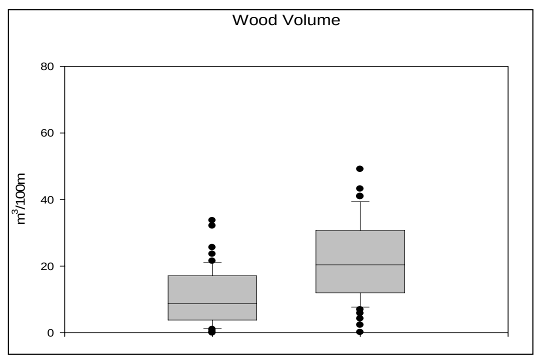


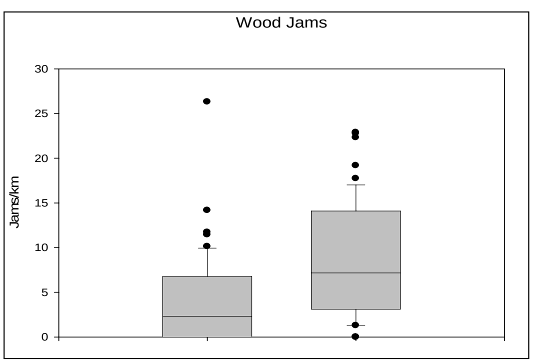



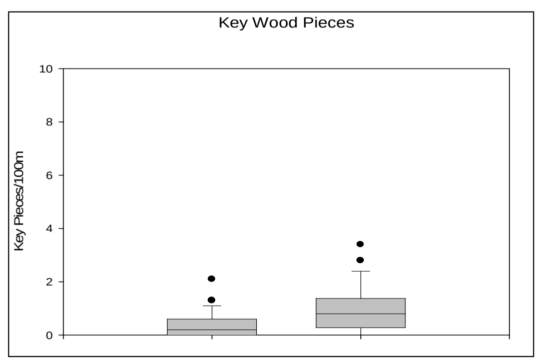



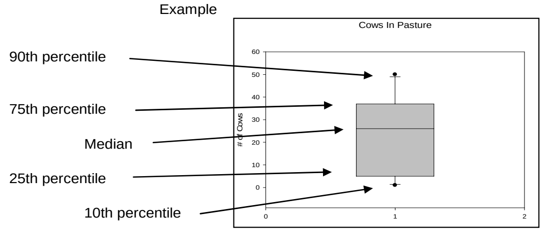



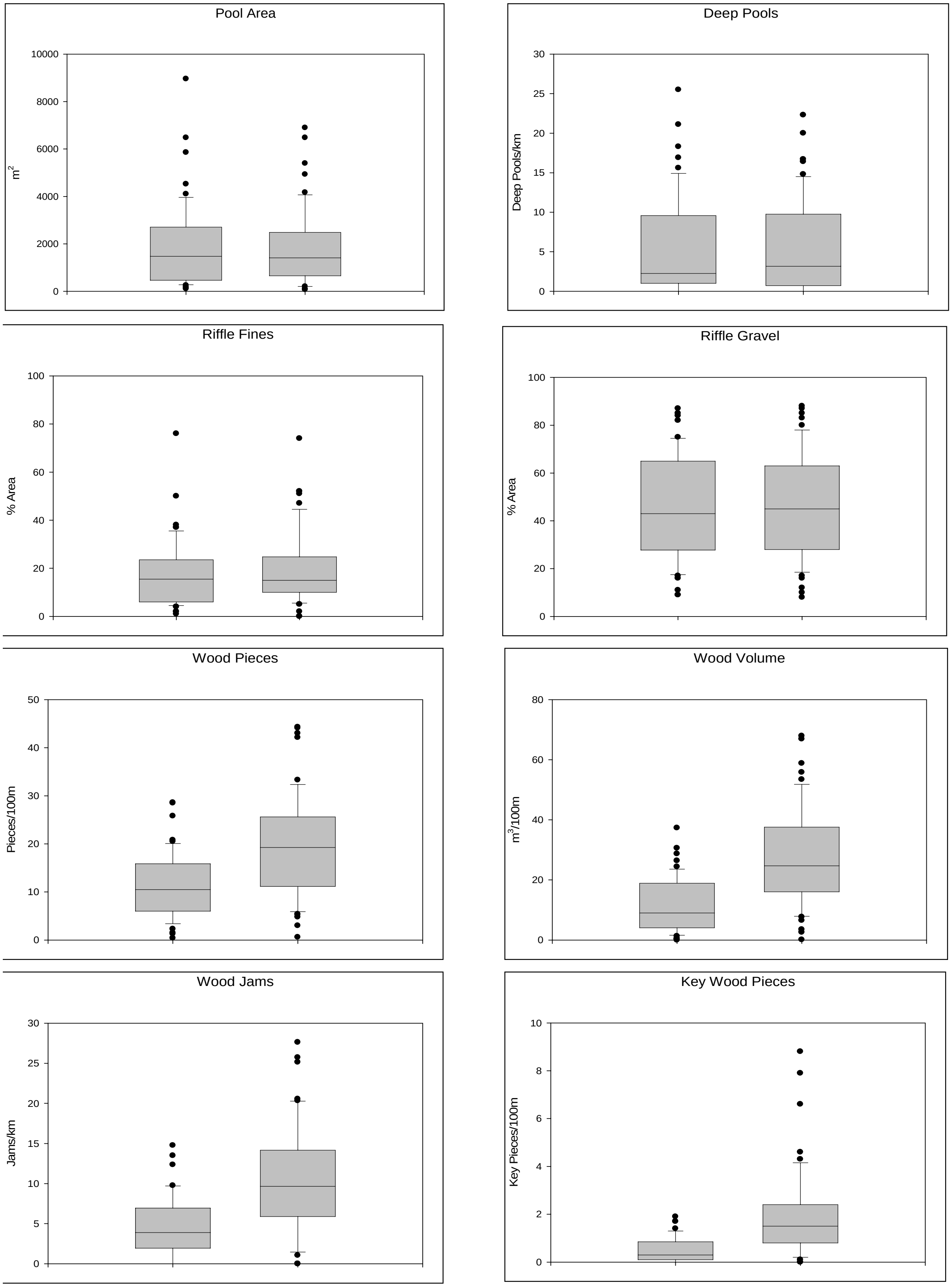



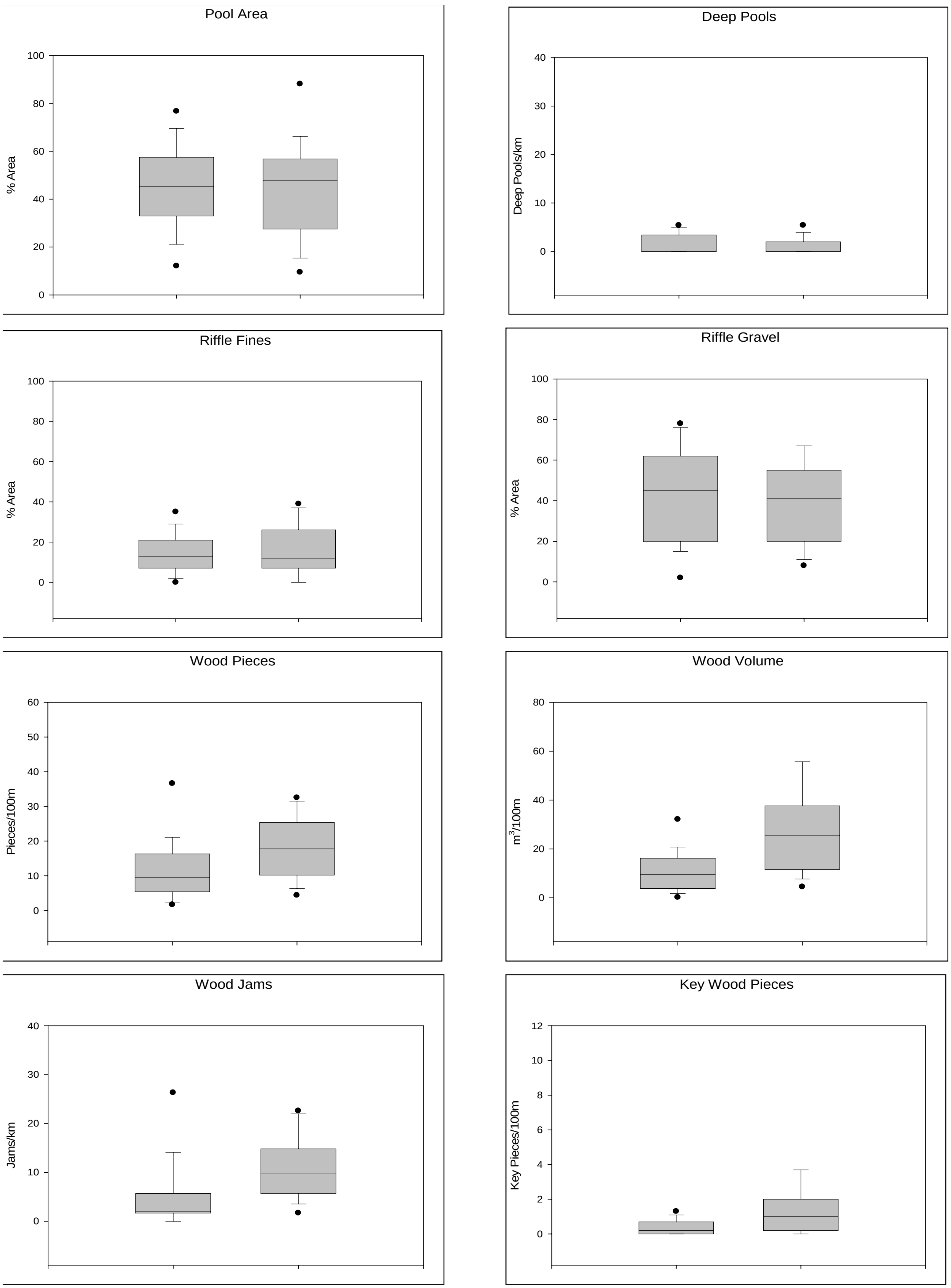

Example



Appendix D-2.  Winter characterization of pre-treatment and one year post-treatment.



Appendix D-3. Summer characterization of pre-treatment and two-three years post-treatment.



Appendix D-4. Winter characterization of pre-treatment and two-three years post-treatment.