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Northwest Forest Plan– The First 20Years (1994-2013)

Watershed Condition Status and Trend

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Abstract

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We used two data sets to evaluate stream and upslope/riparian condition for sixth-field watersheds in each aquatic province within the Northwest Forest Plan (NWFP) area. The stream evaluation was based on stream sampling data collected from 2002 to the 2013 (214 watersheds) as part of an eight year repeating (rotating) sample design. We are currently halfway through our second rotation of stream sampling, and have repeated 110 watersheds since the second rotation began in 2009. The analysis presented in this report uses roughly half the number of watersheds as was originally intended by the sample design since re-visitation will not be completed until 2017. In the meantime, we compare the first rotation of visits (2002-2009) to the first four years of the second rotation (2010-2013) giving us a general idea of current patterns. To evaluate stream condition we used a reference condition nearest neighbor statistical approach to calculate the stream physical habitat scores based on substrate, wood, and pool metrics for each watershed. Macroinvertebrates and water temperature were analyzed separately from physical habitat and provide additional assessment of overall watershed condition. Scores for both stream and upslope/riparian conditions were normalized to fall between 0 (poor) and 100 (good).

For both rotations, more than 65 percent of the stream scores fell between 40 and 60 and relatively few (2 percent) were less than 20; no watershed scored above 80 during the second rotation and only 12 percent during the first. For watersheds with scores under 20, the pool score component of the physical habitat was often the most influential factor. We detected improving status trends in both aquatic macroinvertebrates scores and water temperature. No trend was detected in the overall stream physical habitat condition across the Northwest Forest plan area. This result is consistent with expectations based on the Aquatic Conservation Strategy (ACS) (FEMAT 1993), as detection of changes in stream watershed conditions were not expected for several decades. Completing the current and future rotations will inform these trends.

Upslope/riparian conditions were evaluated for federal lands in all 1,974 sixth-field watersheds in the NWFP area with at least 5 percent federal ownership. The assessment was based on factors affecting five major aquatic processes: sediment production and delivery (mass wasting), wood production and delivery, riparian habitat, hydrologic processes (specifically peak flows), and fish passage. Impacts were based on mapped data, including road metrics from U.S. Forest Service and Bureau of Land Management geographic information system road layers and vegetation metrics derived from satellite imagery.

Upslope/riparian condition scores were calculated for 1993 and 2012, and the difference between these scores was used to represent trend. In 2012, 26 percent of the overall watershed area received scores above 80, 68 percent scored between 40 and 80, and only 6 percent scored below 40. Less than 1 percent of the area scored below 20 in both 1993 and 2012 status assessments. Since 1993, scores in 16 percent of the NWFP area increased by more than 5 percent while only 7 percent declined by a similar magnitude. Though at the plan level the mean score changed little (+1), there were broad scale moderate gains due to vegetation growth and larger but more concentrated gains due to road decommissioning. These gains, which occurred predominantly in the areas most heavily managed prior to the NWFP, were largely offset by high score declines due to large fires, particularly in reserve areas.

Keywords: Effectiveness monitoring, status and trend monitoring, aquatic ecosystems, riparian ecosystems, watersheds, decision-support models, Northwest Forest Plan, aquatic conservation strategy, Pacific Northwest.

Preface

The effectiveness monitoring program plan for the Northwest Forest Plan (NWFP) was approved by an Intergovernmental Advisory Committee in 1995 to meet the requirements for tracking status and trend of watershed condition, late successional old growth, population and habitats of northern spotted owls and marbled murrelets, social and economic conditions, and tribal relationships. Monitoring is conducted in 1- to 5- or 8-year intervals depending on the program. Monitoring results for the first 10 (Gallo et al. 2005) and 15 (Lanigan et al. 2012) years were documented in a series of general technical reports available online at http://www.fs.fed.us/pnw/publications/gtrs.shtml. This report covers the first 20 years of the plan.

Summary

The watershed monitoring module (also known as the Aquatic and Riparian Effectiveness Monitoring Program or AREMP) determines if the Northwest Forest Plan's (NWFP) aquatic conservation strategy is achieving the goals of maintaining and restoring the condition of watersheds. The NWFP area being evaluated includes USDA Forest Service (FS), USDI Bureau of Land Management (BLM), and USDI National Park Service (NPS) lands. Only the federal portion of sixth-field watersheds was included when determining watershed condition status and trend because federal agency land managers have no jurisdiction over nonfederal lands. Overall results are also broken down by the NWFP land use management allocations and by key versus nonkey watershed designations.

We evaluated stream and upslope/riparian condition for each aquatic province within the NWFP. The stream evaluation was based on stream data (e.g., substrate, pieces of large wood, percentage of pool tail fines, water temperature, and macroinvertebrates) sampled from 2002 to 2013 (214 watersheds) as part of a repeating (i.e., rotation) sample design. We are currently halfway through our second rotation of stream sampling, and have repeated 110 watersheds since the second rotation began in 2009. This analysis uses roughly half the number of watersheds as was originally intended by the sample design since re-visitation will not be completed until 2017. In the meantime, comparing the first rotation of visits (2002-2009) to the first four years of the second rotation (2010-2013) as well as estimating the yearly trend in status scores gives a general idea of current patterns. We used a reference condition nearest neighbor statistical approach to calculate the physical habitat scores for each watershed. Macroinvertebrates and water temperature were analyzed separate from physical habitat and provide additional assessment of overall watershed condition. Scores for both the stream and upslope/riparian assessments were normalized to fall between 0 (poor) and 100 (good) (Al-Chokhachy et al. 2011).

For both rotations, more than 65 percent of the stream scores fell between 40 and 60 and relatively few (2 percent) were less than 20; no watershed scored above 80 during the second rotation and only 12 percent during the first. For watersheds with scores under 20, the pool score component of the physical habitat was often the most influential factor.

We detected improving trends in the yearly status scores for aquatic macroinvertebrates and in yearly seven day average water temperatures. Future sampling will reveal whether this increase in aquatic invertebrate assemblages and reduction in mean watershed temperatures

persists. No trend was detected in the overall physical habitat stream condition across the Northwest Forest plan area. This is consistent with expectations based on the Aquatic Conservation Strategy (ACS) (FEMAT 1993), as detection of changes in stream watershed condition were not expected for several decades. Completing the current and future rotations based on our current sampling design will inform these trends. Since the second rotation is not scheduled to be completed until 2017, any rotational trend results should be considered preliminary as we have not achieved design sample size.

Upslope/riparian conditions were evaluated for federal lands in all 1,974 sixth-field watersheds in the NWFP area with at least 5 percent federal ownership. The assessment was based on factors affecting five major aquatic processes: sediment production and delivery (mass wasting), wood production and delivery, riparian habitat, hydrologic processes (specifically peak flows), and fish passage. The status of each process was estimated based on impacts of road densities and vegetation conditions derived from mapped data, including road metrics from U.S. Forest Service and Bureau of Land Management geographic information system road layers and vegetation metrics derived from satellite imagery.

In 2012, 26 percent of watersheds scored above 80, 68 percent scored between 40 and 80, and only 6 percent scored below 40. Less than 1 percent of the area scored below 20 in 1993 and 2012 status assessments. Since 1993, scores in 16 percent of the NWFP area increased by more than 5 percent while only 7 percent declined by a similar magnitude. Though at the plan level the mean score changed little (+1), an increase in scores was especially noticeable as a shift from scores in the low to mid-range (15-50) to the higher range (60-90). There were broad-scale moderate gains due to vegetation growth and larger but more concentrated gains due to road decommissioning. These gains, which occurred predominantly in the areas most heavily managed prior to the NWFP, were largely offset by high score declines due to large fires, particularly in reserve areas.

In terms of the land use allocations set by the NWFP, upslope/riparian condition scores were highest for Congressionally reserved (CR) areas (mean = 75,74, standard deviation (sd) = 18,18 for 1993 and 2012, respectively), followed by late-successional reserves (LSR) (mean = 66, 68, sd = 20, 19) and matrix lands (mean = 62, 65, sd = 19, 19). Changes in mean scores over the 20-year period were slight, with CR showing a very slight decline (mean = -1, sd = 7), while LSR and matrix lands had small increases (+2, +3, sd = 8, 6). Scores for key watersheds, designated for their current or potential capacity to provide high-quality habitat or refuge for aquatic- and riparian-dependent species, differed little from nonkey watersheds (key mean = 68,68, sd = 20,19 versus nonkey mean = 67, 69, sd = 20, 19).

The spatial distribution of watershed scores showed some noticeable patterns. The highest scores (>80) were found in the central Olympic Peninsula (Olympic National Park), the north central Cascades and scattered along the Cascades in Oregon and Washington, often corresponding to designated wilderness areas. Other high-scoring areas occur in the Siuslaw National Forest, in the northeast and southwest areas of the Rogue River-Siskiyou National Forest, and in scattered wilderness areas in the Klamath mountain range in northern California. Low scores (<40) were seen in the southern Olympic region, and along the eastern flank of the Oregon Coast range and western flanks of the Cascade Range in Oregon and Washington. However, these lower-scoring areas also showed the most consistent, moderate upward trend in scores over the Plan area. Growth in vegetation and decommissioning of roads made considerable positive impact on the upslope/riparian condition scores in these areas.

Contents

Chapter 1: Introduction

In 1994, the Northwest Forest Plan (NWFP) Record of Decision amended 19 national forest and 7 Bureau of Land Management (BLM) resource plans within the range of the northern spotted owl (*Strix occidentalis caurina*) (USDA and USDI 1994). The NWFP put in place a new approach to federal land management. Key components of the Plan included a new set of land use allocations—late-successional reserves, matrix lands, riparian reserves, adaptive management areas, and key watersheds. The NWFP standards and guidelines provided direction regarding how these land use allocations were to be managed. In addition, the NWFP put in place a variety of strategies and processes to be implemented. These included adaptive management, an Aquatic Conservation Strategy (ACS), late-successional reserve and watershed assessments, a survey and manage program, an interagency executive organization, social and economic mitigation initiatives, and monitoring.

The monitoring component of the plan provides a means to address the effectiveness of these strategies and compliance with forest management laws and policy. Monitoring is essential and required:

> Monitoring is an essential component of the selected alternative. It ensures that management actions meet the prescribed standards and guidelines and that they comply with applicable laws and policies. Monitoring will provide information to determine if the standards and guidelines are being followed, verify if they are achieving the desired results, and determine if underlying assumptions are sound. [USDA and USDI 1994]

Judge Dwyer reinforced the importance of monitoring in his 1994 decision declaring the NWFP legally acceptable: “Monitoring is central to the [NWFP’s] validity. If it is not funded, or not done for any reason, the plan will have to be reconsidered” (Dwyer 1994).

An interagency effectiveness monitoring framework was implemented to meet requirements for tracking status and trend for watershed condition, late and old forests, social and economic conditions, tribal relationships, and population and habitat for marbled murrelets (*Brachyramphus marmoratus*), and northern spotted owls. The aquatic and riparian effectiveness monitoring program (AREMP) was developed to implement the effectiveness monitoring component of the NWFP Aquatic Conservation Strategy (ACS). Periodic analysis and interpretation of monitoring data is essential to completing the adaptive management cycle. This important step was described in the overall monitoring strategy (Mulder et al. 1999) and approved by the Regional Interagency Executive Committee. Beginning in 2005, monitoring reports have been published at 5-year intervals and made available at http://www.reo.gov/monitoring/.

The Aquatic and Riparian Effectiveness Monitoring Program (AREMP) assesses the status and trend of watersheds at the sixth-field hydrological units (HUs) scale. AREMP employs two different methodologies to evaluate condition. The upslope/riparian condition program component uses geographic information system (GIS) data to evaluate all watersheds with at least 5 percent of area within a watershed on federal land within the Northwest Forest Plan (NWFP), and the stream condition component is based on monitoring stream attributes within randomly selected watersheds with a minimum of 25 percent federal ownership along the 1:100,000 stream layer.

This "20-year report" evaluates status and changes in condition under the NWFP aquatic conservation strategy during years 1993–2013. Although this report is intended to evaluate 20 years of data, we are only able to achieve a full 20 year analysis for the upslope/riparian portion of the program where data were available since the NWFP inception. The stream condition monitoring program began in 2002 and is currently on an eight year rotation to visit approximately 214 randomly selected watersheds. The first rotation was completed in 2009; we are currently in the second rotation and are about halfway through repeating these watersheds.

Overview of the Aquatic Conservation Strategy

The aquatic conservation strategy (ACS) is a comprehensive, region-wide strategy designed to maintain, restore, and protect those processes and landforms that create good ecological conditions in watersheds, such as high-quality habitat for aquatic and riparian organisms and good water quality (FEMAT 1993; USDA and USDI 1994). The strategy contains nine objectives that describe general characteristics of functional aquatic and riparian ecosystems that are intended to maintain and restore good habitat (see Reeves et al. 2004). This approach was intended to prevent further degradation of aquatic ecosystems and restore habitat over broad landscapes, as opposed to focusing on individual projects or species. Aquatic and riparian organisms evolved in a dynamic environment influenced by natural disturbance. The authors of the strategy believed that stewardship of aquatic resources is most likely to protect biological diversity and productivity when land use activities do not substantially alter the natural disturbance regime to which organisms are adapted. Therefore, the strategy used several tactics to try to maintain the natural disturbance regime in watersheds. The strategy also includes standards and guidelines that apply to management activities in riparian reserves and key watersheds. The four components of the strategy were intended to work in concert to maintain and restore the health of aquatic and riparian ecosystems:

- Watershed analysis—used to characterize watersheds and provide a basis (context) for making management decisions.
- Riparian reserves—used to enhance habitat for riparian-dependent organisms, to provide good water quality dispersal corridors for terrestrial species, and connectivity within watersheds.
- Key watersheds—provide high-quality habitat or refuge for aquatic- and riparian-dependent species, or would be able to after restoration.
- Watershed restoration—designed to recover degraded habitat and maintain existing good conditions.

Although late-successional reserves are not listed among the components of the strategy, they provide increased protection for aquatic and riparian ecosystems. Late-successional reserves contain areas of high-quality stream habitat that serve as refuge for aquatic and riparian organisms and as source areas from which organisms may move to recolonize formerly degraded areas (USDA and USDI 1994).

Monitoring was included in the strategy to achieve three goals: ensure that management actions follow the standards and guidelines and comply with applicable laws and policies (implementation monitoring), determine the effectiveness of management practices at multiple spatial scales ranging from individual watersheds to the entire NWFP area (effectiveness monitoring), and determine whether the assumptions underlying the strategy are sound (validation monitoring) (ROD 1994 – section B-32). The first goal was accomplished through the implementation monitoring program (Baker et al. 2005). The aquatic and riparian effectiveness monitoring program (AREMP) was developed to reach the effectiveness monitoring goal.

Effectiveness Monitoring Questions

The AREMP is charged with answering questions about the effectiveness of the aquatic conservation strategy in achieving its goal of maintaining and improving the condition of watersheds in the NWFP area (Reeves et al. 2004). This report focuses on responding to two questions, the answers to which provide insight for evaluating the success of the aquatic conservation strategy:

1. What is the status and trend of stream conditions?
2. What is the status and trend of upslope/riparian watershed conditions?

Chapter 2: Methods

Each of the two principal monitoring questions is answered using somewhat different data sources and methods. Due to updates in information and data sources, as well as improvements in analytical techniques, the results in this report are not directly comparable to previous reports. The comparisons to earlier years, in this report, use consistent and updated methodology throughout all time periods and represent the most current information available as of 2013. We first describe the common elements of the program, study area and the conceptual models before moving onto sections providing more details on study designs, data sources, and analytical procedures for the two principal monitoring questions.

Overview of the Aquatic and Riparian Effectiveness Monitoring Program

The AREMP is responsible for the effectiveness monitoring component of the ACS. Its purpose is to assess the effectiveness of the NWFP by periodically determining the status of watershed condition and using this information to track trends in the condition of watersheds through time. Watershed condition refers to a combination of aquatic, riparian, and upslope characteristics within 6th field hydrological units (HU). Hydrological units are based on U.S. Geological survey classification of river systems defined using topography and classified into smaller, relatively uniformly sized subunits using a combination of drainage basin or distinct hydrological features (Seaber et al 1987). Sixth-field HUs are small units (10,000-40,000 acres) and thought to have less internal variation and, thus, allow us to more easily detect changes than larger 5th field units (Reeves et al 2004). HUs are commonly used as a framework for water-resource and related planning and are the basis for defining watersheds in the ACS (Seaber et al. 1987, Reeves et al. 2004). “True watersheds” are defined as topographic surfaces where water drains to a specific point and vary extensively in scale (Omernik et al. 2011). While we acknowledge that hydrological units and “true watersheds” are not always synonymous, the 6th field HU provides a discrete unit used as the basis for AREMP monitoring design. These were the smallest consistently delineated unit available at the time and have undergone minor boundary modifications since the ROD was signed. These 6th field HUs, henceforth called watersheds, serve as discrete units used in these analyses which can be aggregated at multiple spatial scales to make assessments of condition.

The original intent of the AREMP was to combine all these characteristics into a single watershed evaluation (Reeves et al. 2004), but the evaluation process has evolved to consider stream condition separately from upslope/riparian condition because of the different data sources and resulting sampling designs. Many GIS data sources are not updated yearly making yearly upslope condition assessments difficult since they often are temporally not in sync and, also computational intensive. Further, the upslope assessments are considered a census whereas the stream program relies on a statistical sample to extrapolate to the region. Stream condition is based on physical stream data (e.g., substrate, pieces of large wood, and pool tail fines), macroinvertebrates, and water temperature. Upslope/riparian condition is based on mapped data, e.g., road density and vegetation data.

Stream, and upslope /riparian condition, are determined by integrating multiple sources of information (Reeves et al. 2004).The results are assessed as a distribution of condition scores across the NWFP area. If the NWFP is effective, the distribution of conditions should either stay the same or improve over time (Reeves et al. 2004). Note that the authors of the ACS did not intend for each of the objectives to be monitored individually, nor did they expect that the objectives would be met in each watershed at all times (USDA and USDI 2003).

Evaluating the effectiveness of the ACS was based on measuring changes in the distribution of stream and upslope/riparian condition scores through time. The ACS does not describe the baseline condition of streams and watersheds, nor does it define a desired distribution. We infer that if the strategy has been effective in maintaining and improving the condition of watersheds, then the distribution of stream and upslope/riparian condition scores should shift in a direction that indicates improvement (Reeves et al. 2004).

Definition of Watershed Condition

The definition of watershed condition developed by the monitoring program was based on the goals of the NWFP aquatic conservation strategy and on guidance provided by the aquatic monitoring plan (Reeves et al. 2004). The NWFP was designed to account for the complex and dynamic nature of aquatic ecosystems resulting from the wide range of physical characteristics, natural disturbance events, and climatic features of the region (Benda et al. 1998, Naiman et al. 1992). Monitoring these dynamic watershed processes was accomplished by linking them to measurable physical attributes (e.g., vegetation structure, road density, water temperature). Reeves et al. (2004) initially identified 90 potential attributes that represent key functions and processes in watersheds. This number of attributes was reduced based on criteria established by Noon et al. (1999). The monitoring program further removed some attributes that were found not to produce useful or consistent information (Lanigan et al. 2007). The remaining attributes represent upslope, riparian, and stream processes.

The condition of a watershed was defined as "good" if it supports ecological integrity to the extent that key biotic and physical processes are sustained (Mulder et al. 1999; Naiman et al. 1992; Reeves et al. 2004). Many of the physical indicators were chosen for their relevance to native or desired fish species because of these species' roles in driving management policies (including the NWFP itself) and the availability of research related to their habitat needs. However, we attempted to assess indicators relative to the natural potential of the site to provide biotic habitat. A watershed that naturally was outside fish distributions (because of elevation or other natural conditions) but has little vegetation disturbance, few roads, good pools, and wood should be evaluated positively. If this watershed loses significant vegetation, even from natural causes (e.g., fire), then the condition rating will go down (it is below its potential).

This simplified view of condition is a consequence of the fact that indicators taken at one point in time are imperfect measures for dynamic temporal processes. Even a watershed with intact processes may not be in good condition in terms of providing quality fish habitat at any single assessment period. A fundamental principle underlying the monitoring program is that watersheds are naturally dynamic systems. Individual watersheds will cycle through conditions of high and low habitat quality, and not all watersheds can be expected to be in good condition at any one time (Naiman et al. 1992, Reeves et al. 1995, Roper et al. 1997). Therefore, the most important product of the monitoring program is the *overall distribution* of individual watershed ratings in the NWFP area. Implementing the ACS should result in an overall distribution of watershed condition scores that improves over time since it is assumed they are currently degraded (FEMAT 1993).

Study Area

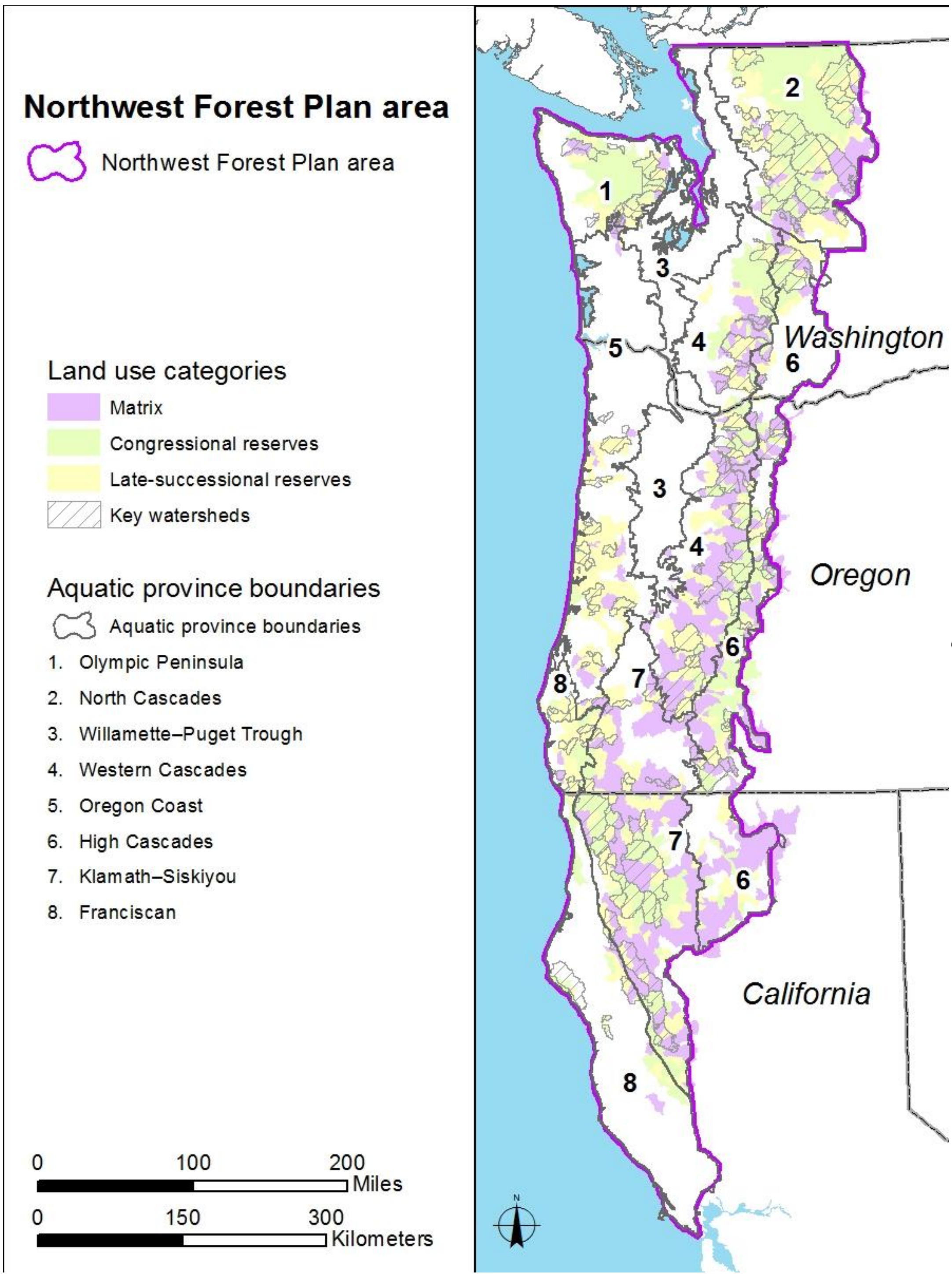
The Northwest Forest Plan (NWFP) encompasses more than 24 million ac of federal lands in western Washington, western Oregon, and northwestern California and includes the entire geographic range of the northern spotted owl (*Strix occidentalis caurina*) (fig. 1). Stream and riparian habitat conditions differ greatly across the NWFP area because of natural and management-related factors. Geologic and climatic history influence topographic relief, landforms, channel patterns, and the dominant erosion processes. Precipitation ranges from more than 200 inches per year in some areas near the coast to less than 20 inches on the east side of the Cascade Range. Riparian vegetation communities are structured by climate and the disturbance regime of the area, including hydrologic processes and disturbances such as forest fires (Benda et al. 1998, Naiman et al. 1992). Many of these critical components of landscape form and function are in distinctive combinations characteristic of each physiographic province in the region. Physiographic provinces incorporate physical, biological, and environmental factors that shape broad-scale landscapes and therefore reflect differences in responses such as soil development and plant community structure.

Physiographic provinces are useful in describing both terrestrial and aquatic ecosystems, and different processes dominate the functioning of these ecosystems. Consequently, the Forest Ecosystem Management Assessment Team (FEMAT 1993) used different physiographic province boundaries for aquatic and terrestrial ecosystems. The physiographic boundaries used in this analysis were developed from those used in the aquatic ecosystem assessment (FEMAT 1993), and were based on broadly drawn precipitation and geologic zones, as well as political boundaries (state lines). These province boundaries differ from those used by the other effectiveness monitoring components (e.g., the late-successional old-growth and the northern spotted owl), which were delineated primarily by vegetation type and political boundaries. The aquatic province boundaries used by the FEMAT (1993) were not available in a digital format, so their province boundary lines were refined by using level-four lines described by Omernik in Oregon and Washington (Bryce et al. 1999), Bailey ecological subsections lines in California (Bailey et al. 1994), and the Cascade crest derived from the Forest Service Pacific Northwest Region sixth-field HU watershed layer.

The NWFP area contains eight aquatic physiographic provinces including the Olympic Peninsula, North Cascades, Willamette-Puget Trough, West Cascades, Washington-Oregon Coast, High Cascades, Klamath-Siskiyou, and Franciscan (fig 1). Land ownership in the Willamette-Puget Trough is predominantly private, and none of the watersheds in this province met the monitoring program minimum criterion of federal land ownership. Consequently, this province was not included in the analysis. Descriptions of the provinces based largely on those presented by FEMAT (1993) are available in Gallo et al. (2005).

Because the NWFP applies only to federally managed lands, watersheds must contain a minimum of 25 percent of the total length of the stream (1:100,000 National Hydrography Dataset stream layer) within federal ownership (USDA Forest Service [FS], USDI Bureau of Land Management [BLM], or USDI National Park Service [NPS]) to be considered for sampling and analysis in the stream monitoring program. The ownership criterion was recommended by Reeves et al. (2004) to gauge the influence of the strategy while avoiding sampling watersheds in which the contribution of federal lands to the condition of the watershed was less significant. To be more consistent with the Forest Service National Watershed Condition Framework (USDA FS 2011) and to include a greater percentage of Bureau of Land Management land, we increased the

Figure 1—Map of the Northwest Forest Plan area. The Northwest Forest Plan (NWFP) encompasses the range of the northern spotted owl and includes seven aquatic provinces used to assess watershed condition. Lands being evaluated include USDA Forest Service, USDI Bureau of Land Management, and the USDI National Park Service. Within these federal lands, land use allocations and key and nonkey categories assign different management guidelines and priorities shared by all federal partners.



amount

of land area analyzed to watersheds with a little as 5 percent federal lands by area for this upslope/riparian condition analysis. Feedback from the local managers suggested that it would be more useful to the local units to have more watersheds included in the upslope analysis. The NWFP area contains 2810 watersheds, of which 2039 contain some land that is federally owned, and 1,974 have at least 5 percent federal ownership by area. The ownership criterion excludes about 1 percent of the federal lands in the NWFP area from this analysis. Only the federal portion of watersheds was included when determining watershed condition status and trend because federal agency land managers have no jurisdiction over management of nonfederal lands.

Land Use Categories

Land use categories provide a key spatial component of the NWFP by assigning different management guidelines and priorities to zones within the NWFP area. We review our two monitoring questions in the context of two types of land classification: the general NWFP land use allocations (congressionally reserved, late-successional reserve, matrix) and the NWFP aquatic conservation strategy designations of key versus nonkey watersheds. The land use allocation categories presented here are the same as those described by Tuchmann et al. (1996). Boundaries for land use categories did not follow watershed boundaries; consequently multiple land use categories may have been present in individual watersheds. Upslope/riparian analysis uses actual boundaries for each land use category. For the stream assessment, classification for each watershed into a single land use category was based on the category covering the largest amount of its area. The following paragraphs briefly describe each allocation.

Congressional reserves (CR): lands reserved by the U.S. Congress such as wilderness, wild and scenic rivers, national parks and monuments.

Late-successional reserves (LSR): lands reserved for the protection and restoration of late-successional and old-growth forest ecosystems and habitat for associated species; including marbled murrelet reserves and northern spotted owl activity core reserves. Adaptive management areas managed under LSR guidelines were included in LSR (see below).

Matrix: lands not included in one of the other allocations. Scheduled timber harvest activities may take place in matrix lands. For analysis and reporting purposes, we grouped some adaptive management with matrix (see below).

Riparian reserves: these reserves were not included as a separate land allocation because they have not been mapped; they are included as part of the above land allocations in which they fall. The upslope/riparian assessment approximates riparian reserve areas for a number of its indicators.

Adaptive management areas: areas identified to develop and test innovative management approaches to integrate and achieve ecological, economic, and other social and community objectives (USDA and USDI 1994). They are a mix of lands where timber production can occur and where timber production must follow LSR guidelines. For analysis and reporting purposes, we grouped watersheds in adaptive management areas into either matrix lands or LSR, depending on which allocation covered the largest amount of its area.

Key watersheds: areas intended to "serve as refuge for aquatic organisms, particularly in the short term for at-risk fish populations, to have the greatest potential for restoration, or to provide sources of high-quality water" (Haynes et al. 2006). Key watersheds were identified as part of the ACS and independent of the land use allocations in the NWFP, thus key and nonkey watershed designations overlay the other land use allocations. Key watershed delineation was begun prior to the development of the interagency standard fifth- and sixth-field watershed boundaries, so their boundaries are not always coincident. For this analysis, 520 of our 1,974 watersheds are considered key because they have more than 50 percent of the area designated as key watershed. The remaining 1,454 watersheds are considered as nonkey in this assessment.

Study Design

Assessment of Watershed Condition

For this assessment, models were developed separately for stream and upslope/riparian condition following the processes defined by the monitoring plan and the data sets available for each. Upslope/riparian evaluations were combined in one model because they were based on the same data sources; watershed-wide mapped data (e.g., road density, canopy cover) derived from satellite imagery and other corporate data sets (circa 1993 and 2013, 1,974 watersheds). The stream status evaluation was based on sampling of stream data (e.g., seven day maximum average water temperature, physical habitat, and macroinvertebrates) collected in watersheds by AREMP field crews from 2002 to 2013. Each model comprises three basic elements: a list of measurable watershed attributes to evaluate, evaluation criteria for rating each attribute, and a model structure, which defines how the attribute scores were aggregated into an overall score. Data from each watershed were analyzed through the appropriate models to produce scores on a scale from 0 to 100, where 0 indicates “poor” condition and 100 indicates “good” condition.

Monitoring Questions

1. What is the status and trend of stream conditions?

Study design

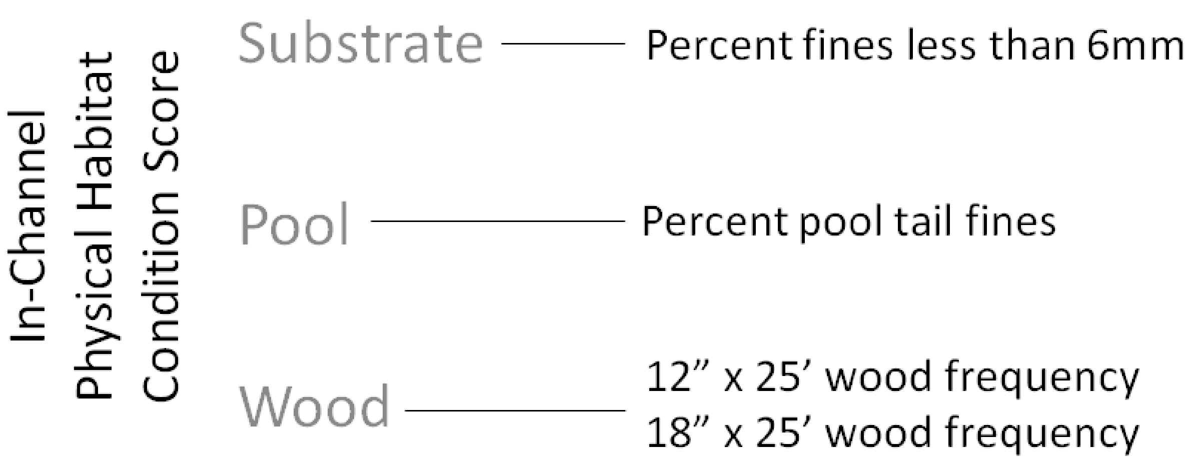
At the inception of the Northwest Forest Plan, 1,373 watersheds in the sixth-field watershed coverage (version 1.1, dated 2002) with greater than 25 percent federal ownership were identified and 250 were randomly selected using a spatially balanced sampling method (Stevens and Olsen 2003, 2004). The original study design called for sampling 50 watersheds per year, with repeat visits to watersheds beginning on the sixth sampling year. Due to funding limitations this goal was not realized. The study design was altered to complete approximately 28 watersheds per year, with repeat visits beginning in the ninth year of sampling. An eight year cycle of visits is referred to as a rotation. As of 2013, we have visited a total of 214 watersheds and are halfway through the second rotation; 189 watersheds were visited during the first rotation and so far 25 new watersheds have been visited during the second rotation; 110 watersheds have been repeated.

Within each watershed, stream data were collected at multiple (4-11) sites. These sites were also selected using a spatially balanced procedure subject to logistical constraints (e.g. unable to sample 4 sites minimum, fire, or illegal activity). Sample points were drawn from the 1:100,000 National Hydrological Data Layer (dated 2000), where points represent the downstream starting location for stream surveys. The survey length at each site was determined as 20 times the average bankfull width, with a minimum and maximum of 160 and 460 meters, respectively. Eleven equally spaced transects over the stream length were surveyed at each site.

Attributes

Stream attributes were collected at each site; details on data collection methods can be found in the AREMP field protocol (AREMP 2013). Data for each transect attribute were summarized together at the site scale. Each site level attribute was classified into one of four metrics: pools, wood, substrate, or macroinvertebrates. Water temperature, collected at the lowest point on federal lands within each watershed, was analyzed separate from the physical habitat and macroinvertebrates. Three metrics, pools (pool tail fines), wood (medium and large frequency), and substrate (percent fines under 6mm), were used as the basis for calculating physical habitat stream condition score from the site level individual attributes (fig. 2). Using these metrics allows for increased comparability of scores across aquatic physiographic provinces and retains much of the framework for watershed condition defined through provincial expert workshops. Ultimately, the attributes selected for inclusion in each model element (fig. 2) were those that were able to detect a management signal (Stoddard et al. 2007, Al-Chokhacky et al, 2011).

Figure 2—Stream physical habitat condition model evaluation structure included three metrics: pools, wood, and substrate. Each metric contains individual site level attributes used as the basis for calculating the metric. Site level stream physical habitat condition values were aggregated and analyzed hierarchically at the watershed level. Nearest neighbor intrinsic characteristics used to describe individual attributes can be referenced in table 8.



A change from previous models was to evaluate macroinvertebrates separately from physical habitat. Previously, both macroinvertebrates and amphibians data were collected and summarized together into a biological condition score. As of 2012, we no longer sample for amphibians due to unreliability of presence / absence data. While macroinvertebrates are a useful indicator of degradation in a system (Hawkins et al 2000), reliability on a single indicator of biological condition can lead to erroneous interpretation of health of a system (Barbour et al. 1999). Similar to temperature, we have chosen to analyze macroinvertebrates separately and not integrate this score into our overall stream condition score. For the macroinvertebrate metric we are using an observed to expected (O/E) index developed specifically for the AREMP sample frame (Miller, Miller, Vander Laan, and Hawkins, in prep). Instead, macroinvertebrate and temperature scores will be assessed separately and then used in concert with the physical habitat index as multiple lines of evidence for the condition of system.

Data analysis

While the field-sampled attributes were expected to remain constant over time, analytical procedures were anticipated to change as new science became available (Reeves et al 2004). For this report, each stream physical habitat attribute was evaluated and scored using an updated approach from previous reports. Past evaluations relied on a decision support model, with scoring thresholds taken directly from the literature, expert opinion, and/or data from other studies that had sampling protocols that were not comparable to those used by AREMP. In addition, many threshold values did not encompass the range of values collected in the AREMP data and often the threshold range was smaller than the AREMP measurement error of a given attribute. Rather than defining new thresholds, which would take information we do not currently have, we chose to use a reference condition approach for scoring.

The reference condition approach is frequently used by bioassessment programs throughout the world that monitor ecological condition (Pont et al. 2006, 2009, Herlihy et. al. 2009, Whittier et al. 2007, Pollock et al. 2012). Here we define reference condition as areas with minimal management that characterize the range of natural variability across the region (Miller et al in prep). We used GIS and remote sensing data summarized at two spatial extents, true watershed (broad level disturbance) and a smaller 2km polygon watershed above a site (localized disturbance), to quantify stressor and natural (intrinsic) variables. Over 5500 candidate sites, compiled from 5 agencies, were used to define minimal management. Each watershed was characterized using a suite of land-use and land-cover variables that quantified both anthropogenic stressors and natural characteristics. Reference was defined as sites that fell below the 25th percentile for all disturbance variables (table 1) and then, subsequently passed inspection based on visual assessment of aerial photographs. Approximately 260 AREMP sites passed the screening process.

Table 1—Reference percentile thresholds. Candidate reference sites were defined as sites that fell below the 25th percentile for all disturbance variables with the exception of distance to dam where the 75th percentile* was used. Candidate reference sites were visually inspected using aerial photos before passing into the reference network used for nearest neighbor analysis. The 90th percentile was used to define sites with the most disturbances.

			Percentile	
Disturbance variables	**Source**	**Unit**	**25th**	**90th**
Road density	a	km/km^2	1.35	3.87
Stream crossing	a	count / km^2	0.24	1.01
Agriculture	b	%	0.05	2.74
Developed open space	b	%	2	7.82
Mines	c	%	0.21	26.64
Gravel mines	c	mines / km^2	0.01	0.06
Canals	d	%	1.7	29.27
Distance to dam	d	km	20.56*	3.56

[a] Custom dataset completed from Forest Service, Bureau of Land Management, and Chico State University data
[b] Jin, S., Yang, L., Danielson, P., Homer, C., Fry, J., and Xian, G. 2013. A comprehensive change detection method for updating the National Land Cover Database to circa 2011. *Remote Sensing of Environment*, 132: 159 – 175.
[c] Mine data (mineral.usgs.gov)
[d] National hydrology dataset (nhd.usgs.gov)

The reference condition approach to scoring each attribute was based on the deviation of an attribute from an individual site to the expected value estimated from a network of minimally managed sites with similar intrinsic environmental characteristics. Intrinsic environmental characteristics are variables that do not change based on management activities (i.e. geology). Expected values of stream attributes will vary with intrinsic characteristics. For example, intrinsic characteristics such as stream gradient or elevation can strongly influence what we would expect the values of attributes to be in minimally managed systems; as such, these types of characteristics must be accounted for when using a reference approach (Stoddard et al. 2007). We used a nearest-neighbor approach (described by Bates Prins and Smith 2007) to account for intrinsic environmental characteristics, where the "distance" between a site and reference was calculated based on these intrinsic environmental characteristics (app. 1) (Yates and Bailey 2010). Expected values of an attribute at an individual site were estimated from its reference network of minimally managed sites "nearest" that site based on intrinsic environmental characteristics. The neighbors for a site are not necessarily close in space, but rather close in similarity based on these environmental characteristics.

The nearest neighbor approach requires that we select both the number of neighbors that match a site and the intrinsic characteristics to match on. These were selected for each attribute by finding the combination of the number of neighboring sites and a subset of intrinsic environmental characteristics that minimized the mean squared error (MSE) of the reference network chosen as outlined above (Bates Prins and Smith 2007). This procedure was performed separately for each attribute, so the number of neighbors, the intrinsic environmental characteristics, and the size of the reference network used varies among attributes (Appendix B). Scores were calculated on a continuous scale from 0 to 10 based on the 90 percent prediction intervals around the expected value of an attribute for each site (see Stoddard et al. 2007, Al-Chokhacky et al. 2011).

Individual attribute scores were averaged within their respective metric to create a metric score for each site (e.g. pools, substrate, wood). If an attribute was missing within a metric for a site, only the non-missing attributes were used to calculate the metric score. If an entire metric was missing for a site, no metric score or final score was calculated and the site was not used in any subsequent analyses. To determine the overall site condition, all physical habitat metrics were averaged together and the final scores scaled from 0 to 100. If a site had no pools, the final score was only based on substrate and wood metric scores. Watershed level stream physical habitat condition scores were calculated as the average site level condition scores within each respective watershed that contained three or more sites using the spsurvey package in R (R Core Team 2013, Kincaid and Olsen 2013). Watersheds with fewer than three sites were not used in any analysis.

Macroinvertebrates were assessed at the site level using an observed to expected index developed by the Center for Monitoring and Assessment of Freshwater Ecosystems in Logan, UT. The O/E model compares the taxa at an observed site to similar reference sites (see Hawkins et al 2000 for detail). Sites were grouped into classes based on macroinvertebrate assemblage composition similarity. The expected class membership was predicted using a number of intrinsic predictor attributes (similar to intrinsic environmental characteristics used in the nearest neighbor analysis above). All data were standardized to their appropriate operational taxonomic unit prior to analysis and re-sampled to a 300 fixed count. O/E scores are interpreted by the value 1 indicating that all expected species were found at a site, while a value of 0 indicated that no expected species were found. Watershed level macroinvertebrate O/E scores were calculated based aggregated site level O/E scores using the spsurvey package in R (R Core Team 2013, Kincaid and Olsen 2013).

Water temperature loggers were deployed in early spring at the lowest point on federal lands within each watershed and data collected typically in late fall. Data were collected hourly and summarized as the seven day maximum average temperature. To calculate the seven day maximum average temperature we defined the season to June 1 to September 15 and then calculated the daily maximum average from the hourly recordings. Temperature data were summarized across watersheds using the spsurvey package in R (R Core Team 2013, Kincaid and Olsen 2013).

We used descriptive statistics and graphical displays to present stream physical habitat and macroinvertebrate scores, and water temperature data for the entire Northwest Forest Plan area, as well, grouped by physiographic aquatic province, land-use allocations, key and nonkey watershed. Mean overall condition was estimated with 95 percent confidence intervals for each group within each rotation. We tested for differences in the cumulative frequency distributions (cdf) among the levels, as described by the ACS, within the above groups using the contcdf.test in the spsurvey package within the program R (Kincaid and Olsen 2013, R Core 2013). This was done only within the first rotation and for the Northwest Forest plan overall. No tests were performed within the second rotation for the above groups since we have limited power to detect true biological differences having not yet reached a sufficient sample size (i.e. second rotation is not complete until 2017). To assess whether the overall mean cumulative frequency distributions (cdf) shifted toward better condition we used a two-sample t-test (Sokal and Rohlf 1995). The ACS is considered effective if the mean frequency distribution of scores shift toward a better condition category (Reeves et al 2006).We used a linear mixed model fit with package lme4 (Bates et al. 2014) to test for a linear relationship between the stream metric status scores and time, after accounting for province. Individual year and watershed, as well as province were used as random effects in this model to account for year, watershed and province variability. An F-test with a Kenward-Roger approximation was used to test significance of linear trend for each indicator.

2. What is the status and trend of upslope/riparian conditions?

Study design

In past assessments, the upslope/riparian analysis used the same criteria as the stream evaluation (at least 25 percent of stream channels along the 1:100,000 stream layer in federal ownership) to define the scope of watersheds to include. For this report, we broadened the scope to any watershed with 5 percent or greater federal ownership in order to be more compatible with recent USFS national watershed assessment guidelines (USDA FS 2011) and to include more Bureau of Land Management lands. Only the federal portion of watersheds was included when determining watershed condition since federal agency land managers have no jurisdiction over management of nonfederal lands. The NWFP area contains 1,974 watersheds that met this sampling threshold. We further subdivided these watersheds by the NWFP land use allocations and key/nonkey watersheds, as described above, for reporting purposes.

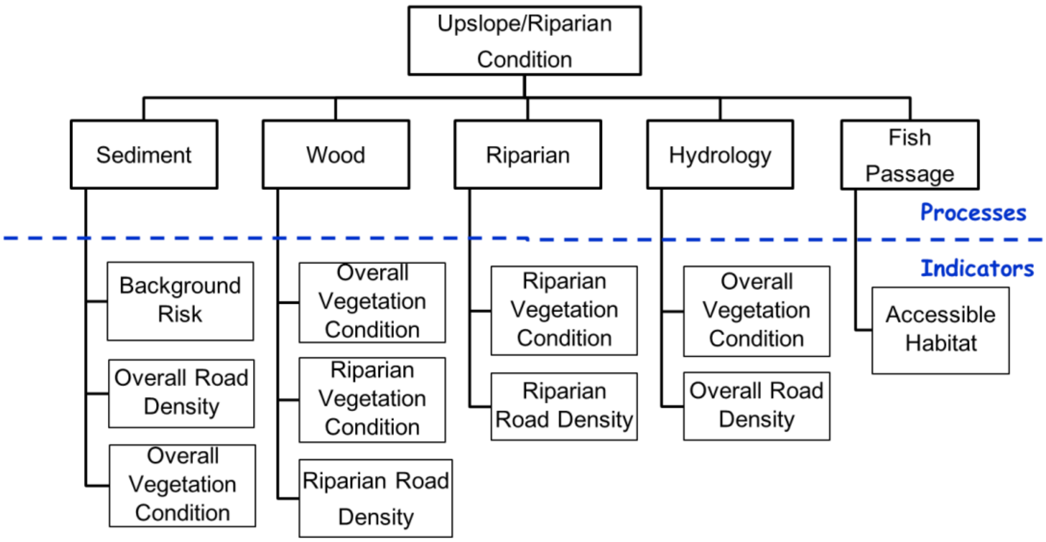
Riparian reserves were defined in the NWFP to have widths varying from 100-300 feet based on a combination of 100-year flood plains, breaks in slope, riparian vegetation, and site potential trees (USDA and USDI 1994), but these boundaries have yet to be delineated. For this report we have delineated riparian areas using a uniform 90 m buffer (~300 ft) on either side of the 1:100,000 stream layer. This wide buffer was chosen given the coarse resolution of the satellite vegetation data (30 meters) and the uncertain positional accuracy of the stream layer. Higher resolution stream lines (1:24,000) were not used because of uneven density over the Plan area that would make comparability among areas inconsistent.

Upslope attributes were calculated for the entire federal portion of the watershed, including the riparian area. Although this approach may count riparian areas twice, the upslope/riparian attributes are assessed as proxies for different processes and multicollinearity is not an issue because we are not statistically estimating the influence of explanatory factors. Watershed-wide metrics also avoid the problem of wide variation in the amount of non-riparian areas in watersheds, and they tend to be consistent with available studies on watershed impacts (e.g., road density was typically measured as total watershed density).

Attributes

In past reports, an assessment model and associated metrics were developed for each aquatic province through regional expert workshops (Gordon and Gallo 2011). This flexibility was intended to account for broad biophysical differences (vegetation, geology, precipitation, etc.), but it also decreased the consistency between provinces. For this report, we combined the different models into a single unified model structure based on an analysis of commonalities and differences. Biophysical differences are now handled by setting vegetation evaluation criteria relative to appropriate vegetation zones, as developed by Davis et al. (in press), along with the integration of geology, landform, and precipitation layers in the sedimentation metric. Additionally, the attributes are now organized explicitly to represent key watershed processes (Beechie and Bolton 1999, Beechie et al. 2010) (fig. 3). The following sections describe indicators used for each of these key watershed processes. Some indicators were repeated under different processes and so were effectively double counted; this was an intentional choice to

Figure 3—Overall upslope/riparian condition was based on the combination of 5 process indicators, which were in turn derived from a number of finer grained metrics. Description of each process and individual indicator components can be referenced in table 2.



Sediment Production and Delivery (mass wasting)

High rates of sediment delivery to streams from episodic mass wasting events such as landslides and erosion have been shown to have detrimental effects on salmonids and other aquatic biota (Cover et al 2008; Jensen et al 2009). Natural rates for these processes are determined by a variety of factors, including slope, concavity, soils, geology, geomorphology, and precipitation. Within the range of the Northern spotted owl, federal forest management affects these rates primarily through road and vegetation disturbances. To evaluate the process of sedimentation production and transport, the AREMP model used the difference between an estimated background rate of sediment delivery and the rate estimated given the status of road and vegetation disturbances.

Factors considered in the background risk of sediment delivery were estimated differently in California (USFS Region 5) from Oregon/Washington (USFS Region 6) due to the availability of differing datasets (see table 2). On Region 5 Forest Service lands, background risk was estimated using a simplified version of a Forest Service geomorphic terranes model (Elder 2008). Forest Service geologists assigned sediment delivery multipliers to bedrock geology types combined with three slope classes. For areas outside the Forest Service geologic mapping, geologists crosswalked these slope-geology multipliers to the 10 classes in a state-wide deep-seated landslide risk map produced by the California Geologic Survey (Wills et al. 2011).

Table 2—Upslope/riparian indicators and evaluation thresholds: (a) roads, (b) vegetation, (c) landslide risk.

(a) Roads		
	Scoring Thresholds	
Metric	**0**	**100**
Riparian Road Density (miles road per mile stream)	≥ 0.4	≤ 0.1
Overall Road Density (miles road per sq mile area)	≥ 2.4	≤ 1
Fish Passage (percent habitat available)	0	100

(b) Vegetation								
	Overall Vegetation				**Riparian Vegetation**			
	Canopy Cover (%)		**DBH (cm)**		**Canopy Cover (%)**		**DBH (cm)**	
Scoring Thresholds>	**0**	**100**	**0**	**100**	**0**	**100**	**0**	**100**
Vegetation Zone								
Douglas-fir	12	64	10	35	11	61	10	35
Grand-white fir	17	64	16	41	18	64	16	43
Juniper	0	12	0	32	0	11	0	28
Mountain hemlock	42	83	16	41	42	82	15	41
Oak woodland	5	44	7	30	5	41	6	28
Other pine	4	37	11	32	5	40	13	31
Ponderosa pine	2	29	7	31	1	31	6	30
Port orford cedar	17	74	13	38	12	71	13	42
Redwood	58	88	21	40	62	85	20	38
Shasta red fir	8	50	7	35	8	47	7	33
Silver fir	44	85	12	40	42	84	11	43
Sitka spruce	34	78	13	35	30	74	11	43
Subalpine	10	67	11	30	10	69	10	31
Tanoak	47	81	14	39	33	79	11	41
Western hemlock	41	77	12	37	31	75	10	40
Western redcedar	5	70	4	37	6	68	3	38

(c) Landslides / Sediment Delivery		Scoring Thresholds		
	Base Standard Deviation	0	100	
Oregon / Washington (landslides/km^2	0.45	0.2	0.9	
California (cu yds/acre)	1.5	0.75	3.0	
Oregon / Washington				
Bedrock geology	**Susceptibility Rating**			
Unconsolidated	100	high		
Volcanic (tuffs,pumice, ash, lahars)	80			
Sedimentary	50			
Metamorphic/Peridotite	25			
Extrusive (andesite/basalt)	0			
Intrusive	0	low		
Landform Associations				
Categorical ratings on 150 types (contact authors for details)				
Precipitation	**Susceptibility Thresholds**			
	0	**100**	**Units**	
Winter (Dec-Mar)	≤ 700	≥ 1200	mm	
Storm maxima				
Westside (24 hr, 25 yr)	≤ 5	≥ 10	inches	
Eastside (6 hr, 100 yr)	≤ 1.7	≥ 2.1	inches	
Rain on snow zones	FALSE	TRUE		
California				
Bedrock geology				
USFS - Quantitative ratings on ~1700 types by 3 slope classes (contact authors for details)				
CA Geologic Survey Types		**Base delivery by slope class (percent)**		
	CGS Susceptibility Class	**≤ 15**	**15-55**	**≥ 55**
Cascade volcanic, metavolcanic, plutons, sandstones	0	0.0005	0.005	0.01
	3	0.005	0.015	0.25
	6	0.005	0.02	0.1
schistose rocks, metasediments, argillite, serp	5	0.005	1.5	4
	7	0.05	0.3	1
	8	0.05	1	2.5
unconsolidated Q deposits, Galice, qtz-mica schist	9	0.1	0.5	2
	10	0.1	2	4.5
Impact Multipliers (all NW Forest Plan area)		**Multiplier**		
Roads	(any road)	20		
Vegetation Score	0-25	5		
	26-40	2		
	41-55	1.5		
	55-70	1.1		
	71-100	1		

In Oregon/Washington, background risk was based on slope steepness and convergence, as calculated in the Netmap model (LSDEL parameter; Benda et al. 2007), and adjusted using multipliers for geology, landform associations, and three precipitation factors (winter rainfall, storm maxima, and rain-on-snow areas), all based on expert judgment of agency soil scientists and geologists.

The impacts of road and vegetation conditions on landslide risk were modeled similarly across the two regions based on multipliers adapted from the USFS R5 geomorphic terranes model. Road and vegetation multipliers were applied to the background risk layer and the average risk over the unit recalculated. The indicator of sediment production was then the risk with roads and vegetation minus the background risk. No explicit thresholds for sediment level impacts on aquatic habitat were found in the literature, so the model uses a range based on the standard deviations of the background risk. Note that the OR/WA and CA models are based on different units, so the thresholds used also differ.

Wood Production and Delivery

Large wood plays a major role in structuring aquatic habitat in the PNW (Andrus et al 1988). Reeves et al. (2004) recommended assessing the wood production and delivery process by measuring forest composition and structure class. Previous reports used expert-derived thresholds for average tree size and canopy cover set by province (and in a few cases subprovinces). In this assessment, we transitioned to a more empirical approach. For each NWFP vegetation zone as defined by Davis et al. (in press) we calculated a reference distribution for mean tree diameter and canopy cover from areas with less than 10 percent disturbance based on historical data (Landsat 1985 to 2012; Kennedy et al. 2007, 2010). Each attribute score was then based on the departure from the mean of this reference distribution, with a less than -5 percent departure receiving an undisturbed score of 100 and a greater than -45 percent departure receiving a score of 0. The minimum of the size and cover scores was taken as the watershed-wide vegetation indicator score because reference condition departures may be indicated by either metric alone (e.g. early and late seral may share the same cover metric but will differ by size). Because a large proportion of stream wood comes from the riparian area, a separate indicator was calculated explicitly for riparian vegetation condition, effectively giving it equal weight to the overall vegetation condition indicator.

Riparian Shading and Habitat

Riparian conditions play a key role in a number of aquatic processes, including the effect of shading on stream temperatures, roots on bank stability, and the provision of habitat for a number of species (Naiman and Decamps 1997). The AREMP model rates the condition of these processes using the average of two indicators: riparian vegetation condition and riparian road density. Riparian vegetation condition was measured as the departure of riparian vegetation from less than 10 percent disturbed vegetation conditions, as described above under Wood Production and Transport. Riparian road density was measured as road miles in the riparian area per stream mile and evaluation thresholds were derived as an average of values used by different provinces in the 15-year assessment.

Hydrology

Upslope/riparian conditions affect the quantity and timing of water reaching the stream system and consequently the habitat of aquatic and riparian biota (Poff et al. 1997). No consistent regional data were available on dams and diversions, so this analysis was limited to the influences of road and vegetation changes on peak flows. Grant et al. (2008) attempted to synthesize a diverse set of studies on the effects of forest practices on peak flows. Results showed considerable variability among watersheds in the hydrologic response of streams to the same changes in forest cover or road densities. However, most of the drivers of these differences are not yet well understood or quantified, so we have based this indicator on average response values. One driver addressed in Grant's synthesis was that mid-elevation "rain-on-snow" zones have been found to be particularly sensitive because of the potential fast release of water from accumulated snowpack They divided their results by two zones: rain-on-snow and rain-dominated (and additionally reasoned that snow-dominated zones would behave similarly to rain-dominated areas). In the rain-on-snow zone, their linear estimate shows a +10 percent change in peak flow at 15 percent area harvested; it reaches +15 percent change in peak flow at a 50 percent harvest level, and culminates at a 25 percent flow change at 100 percent harvested. These effects were expected to double in watersheds with a high percentage of road area (greater than 2 percent or 5.4 mi/mi^2) (Grant et al. 2008). For rain-dominated zones, their linear estimate showed a possible effect on peak flow at 15 percent area harvested; it reaches +10 percent change in peak flow at a 50 percent harvest level, and culminated at a 30 percent flow change at 100 percent harvested. All studies in the rain zones contained roads. Additionally, Grant et al. (2008) noted that only low gradient streams were likely to be susceptible to peak flow effects.

Using a linear approximation based on the thresholds above, and assuming roads contributed half the total increase, we estimated the percent peak flow increase in rain-dominant zone from vegetation as 0.14 * [percent of vegetation disturbance]. Increases in the rain-on-snow zone were approximately 50 percent higher or multiplier of 0.21. As flow with greater than 2 percent roading approximately doubled, we estimated a separate roads effect using a linear interpolation between the origin (0,0) and a point equivalent to the 100 percent vegetation loss at 2 percent road density (5.4 mi/mi^2) for a multiplier of 2.5 in rain-dominated and 3.8 in rain-on-snow zones. The percent increases from roads and vegetation were then summed to estimate the overall indicator for peak flow change.

We found little information in the literature on which to base scoring thresholds; only one indirect estimate of an acceptable or unacceptable level of peak flow was identified. Beamer et al. (2003) rated subbasins with more than 50 percent watershed area in hydrological immature vegetation due to land use and more than 2 km of road length per km^2 of watershed area as “very likely impaired.” Based on our multipliers above, this level of impact would result in a 36 percent increase in peak flow. Therefore, the AREMP model uses 36 percent increase as the poor threshold (score 0) and a minor increase of 5 percent is used as the good threshold (score 100). In order to adjust the impacts by stream susceptibility, we weighted the overall score against the other processes using the proportion of low gradient stream (less than 4 percent, based on Grant et al. (2008) and input from specialists). A unit with no low gradient stream was not counted this indicator, while a unit with 50 percent low gradient stream was weighted 50 percent compared to the other indicators.

Fish Passage

Much of the connectivity of habitat used by anadromous salmonids has been reduced by man-made barriers in streams, particularly dams and culverts used at road-stream crossings (Chelgren and Dunham, in press; Kemp and O'Hanley 2010; Sheer and Steel 2006; Steel et al. 2004). The AREMP model indicator for this process was the percentage of potential salmonid habitat estimated to be accessible (i.e. not blocked by a man-made barrier). Streams with gradient less the 20 percent were assumed to be potential fish habitat based on previous studies and state assessment guidelines (Sheer and Steel 2006). While a regional Forest Service fish passage database is in preparation, no comprehensive assessment of barriers was available at the time of this report. As such, our assessment used road-stream crossings generated with GIS layers as an estimate of barriers. Regional databases were used to determine crossings that were bridges, and therefore not a fish passage issue. Since the bridge databases were incomplete, the average catchment size above the bridge crossings was calculated and other crossing catchments that were equal or larger in size were also assumed to be bridges. All miles of fish habitat above a non-bridge crossing were assumed to be blocked. Because no consistent database of barrier removals was available, only the removal of crossings from road decommissioning were counted. The percentage of habitat available was used directly as the score; no further evaluation criteria were applied.

Data analysis

The AREMP upslope/riparian assessment uses a multi-criteria evaluation approach, similar to previous reports, where attributes representing each process were scored to a common 0-100 scale and then these scores were combined using a weighted average approach (Keeney and Raiffa 1976; Gordon 2014). Each process was given an equal weight (1). For analysis units where a particular attribute was missing (e.g. some small land use allocation areas lacked a stream segment and riparian area), only the remaining attribute scores were used. The normalized watershed condition scores ranged from 0 to 100 where watersheds in good condition have higher scores than those in poor condition.

Using historical datasets, scores for each of the attributes were determined for two time periods: 1993, before the NWFP, and 2012 using the latest data available. Trend in condition scores for attributes and the overall watershed condition score was calculated by simply subtracting 1993 scores from 2012 scores. Positive trend scores indicate an improvement in condition and negative scores a decline.

Because data on every watershed in the target population were analyzed, inferential statistics were not needed to test the reliability of generalizing results from a sample to a larger population. All differences were effectively statistically significant, so what remains for judgment was whether differences were meaningful in terms of biology or management. Nevertheless, there was measurement error in the underlying data attributes and model uncertainty in terms of how the composite index was composed. Error estimates for the vegetation data can be found in (Davis et al., in press) and error estimates for the roads indicators remain the same as detailed in the 15-year assessment (Lanigan et al. 2011).

Chapter 3: Results

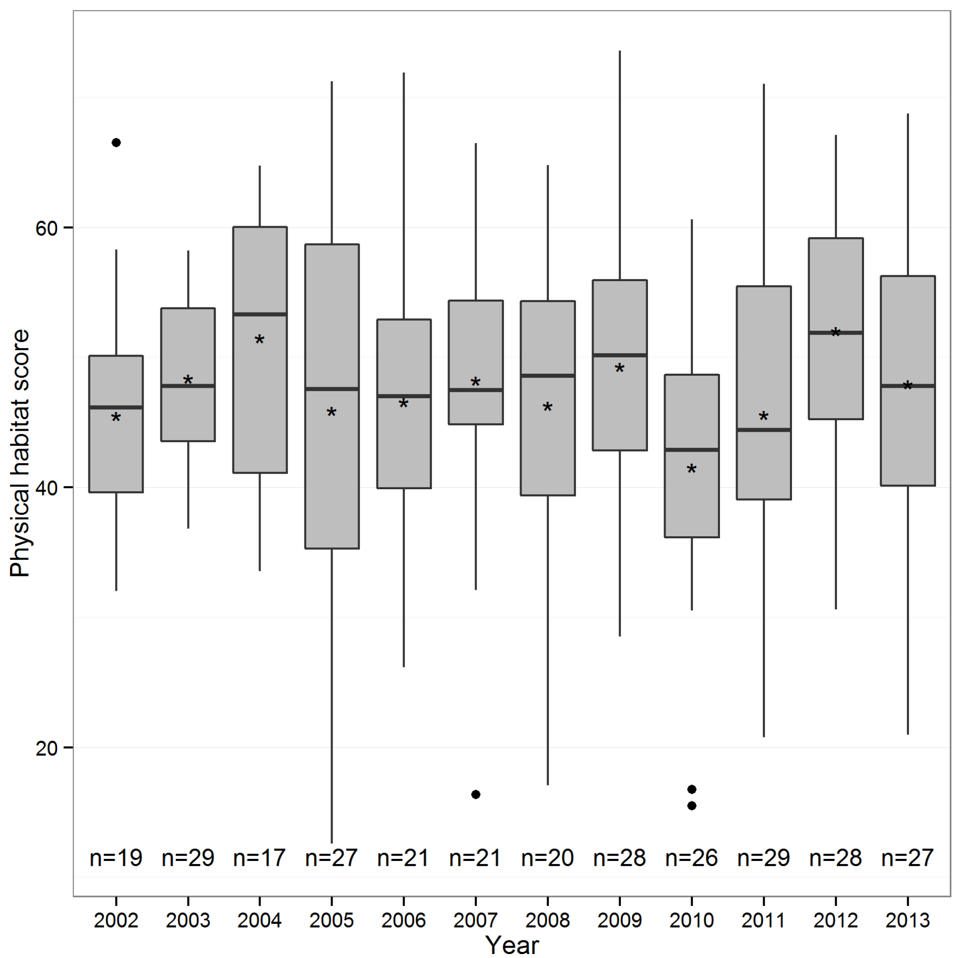
Results are presented for each of the key monitoring questions, the answers to which provide insight for evaluating the success of the aquatic conservation strategy for the entire Northwest Forest Plan (NWFP) area and by land use allocation. As described in the "Methods" section, normalized condition model scores range from 0 to 100.

1. What Is the Status and Trend of Stream Conditions?

Northwest Forest Plan Area and Provinces

Within the Northwest Forest Plan area, stream physical habitat condition status scores varied each year (y-axis, fig. 4).We are currently halfway done with the second rotation and have completed surveys in 110 watersheds as of 2013; 104 watersheds will be visited over the next 4 years to complete the second rotation. Here we report status for each rotation and as well as an estimate of a linear trend through time.

Figure 4—Distribution of stream physical habitat condition status scores (y-axis) for each year (x-axis). Mean stream physical habitat scores are represented by the solid line, asterisks represent median values. The number of watersheds visited each year is denoted by n along the bottom of the graph.



Stream physical habitat scores ranged from 12 to 74 with a mean score of 47.7 with a 95 percent confidence interval (95 percent CI) ranging from 46.6-48.8 during the first rotation and 46.8 (95 percent CI = 45.3 – 48.4) during rotation two. Only 2 percent of the scores fell below 20 during either rotation. The majority of stream attribute scores for both rotations fell between 40 and 60 (64 and 67 percent, respectively), and no watershed was above 80 during either rotation (fig. 4, 5). There was no evidence of an overall linear trend in physical habitat status over time (table 3). Figure 6 displays the spatial distribution of stream physical habitat scores across the plan area for both rotations. Low scores were primarily found in Washington/Oregon Coast province.

Figure 5—Distribution of estimated physical habitat scores by rotation using weighted density plot. Scores are weighted based on sampling design attributes as a function of the number of watersheds randomly selected and stream density within each watershed where sites were randomly selected. Rotation 1 denotes 2002-2008 and rotation 2 2009-2012. Density represents a continuous probability distribution based on the percentage of watersheds.

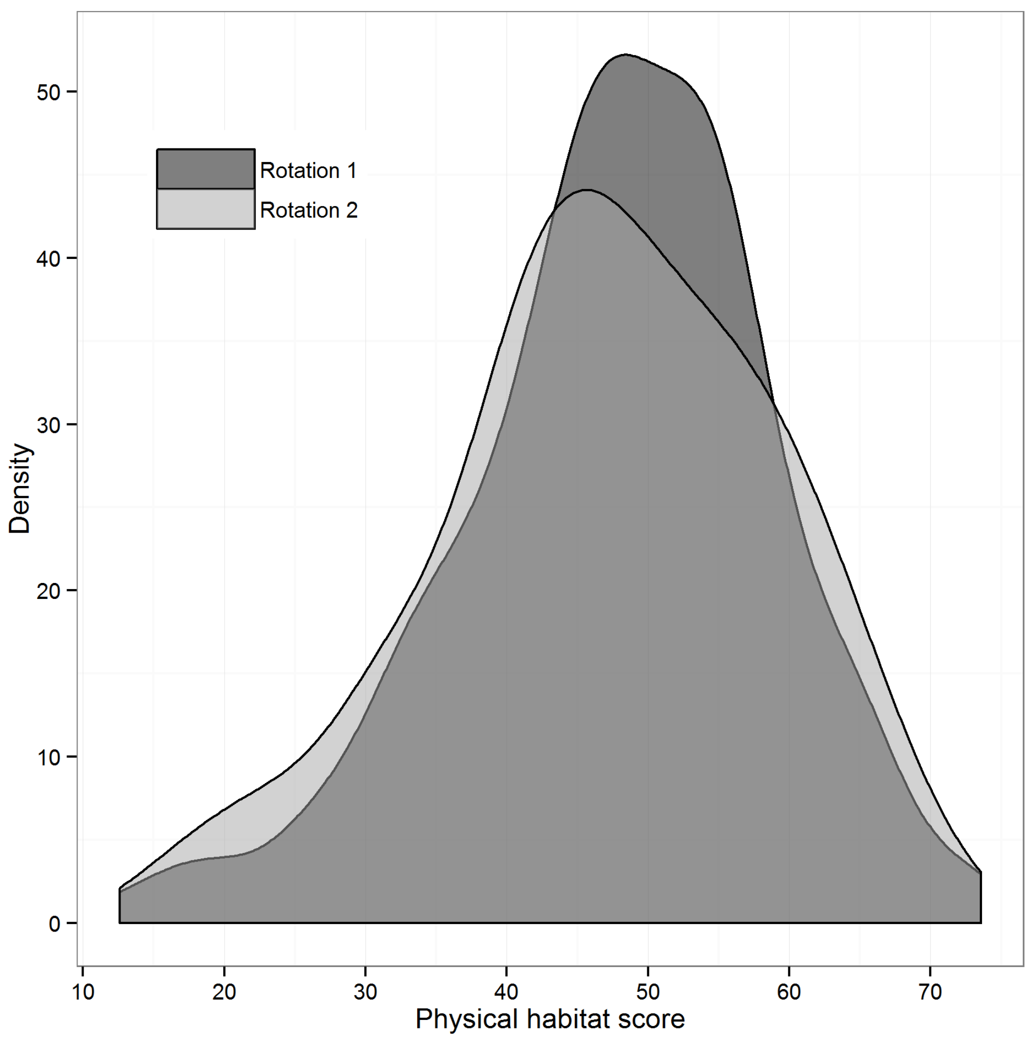


Figure 6—Spatial distribution of stream physical habitat scores for the Northwest Forest Plan (NWFP) area for each rotation. Rotation 1 denotes 2002-2008 and rotation 2 2009-2012.

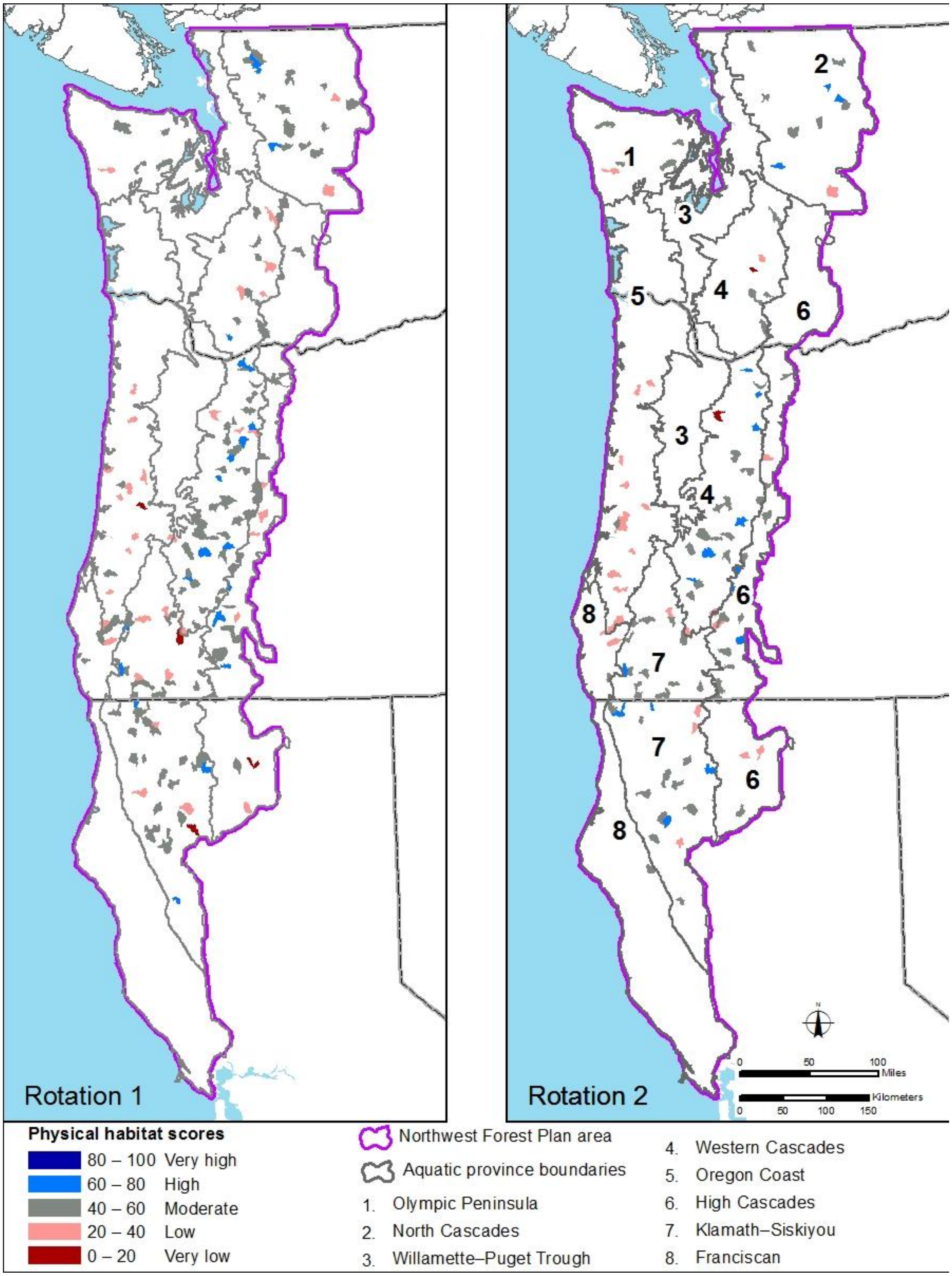


Figure 7—Distribution of stream physical habitat condition scores (y-axis) for each rotation (x-axis) separately for each aquatic province. Mean stream physical habitat scores are represented by the solid line, dashed line represent median values. Rotation 1 denotes 2002-2008 and rotation 2 2009-2012.

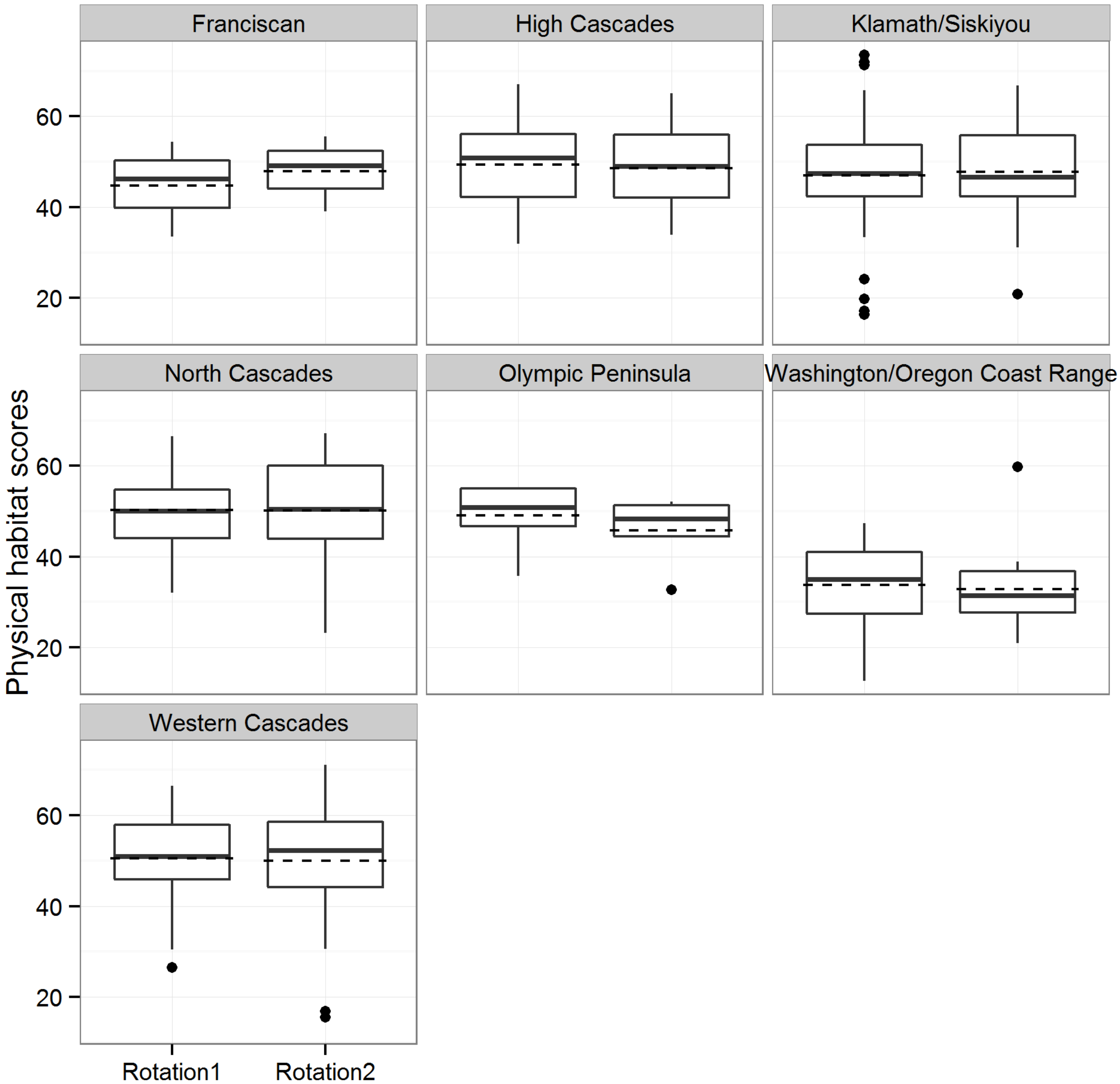


Figure 8—Distribution of stream pool scores (y-axis) for each rotation (x-axis) separately for each aquatic province. Mean stream pool scores are represented by the solid line, dashed line represent median values. Rotation 1 denotes 2002-2008 and rotation 2 2009-2012.

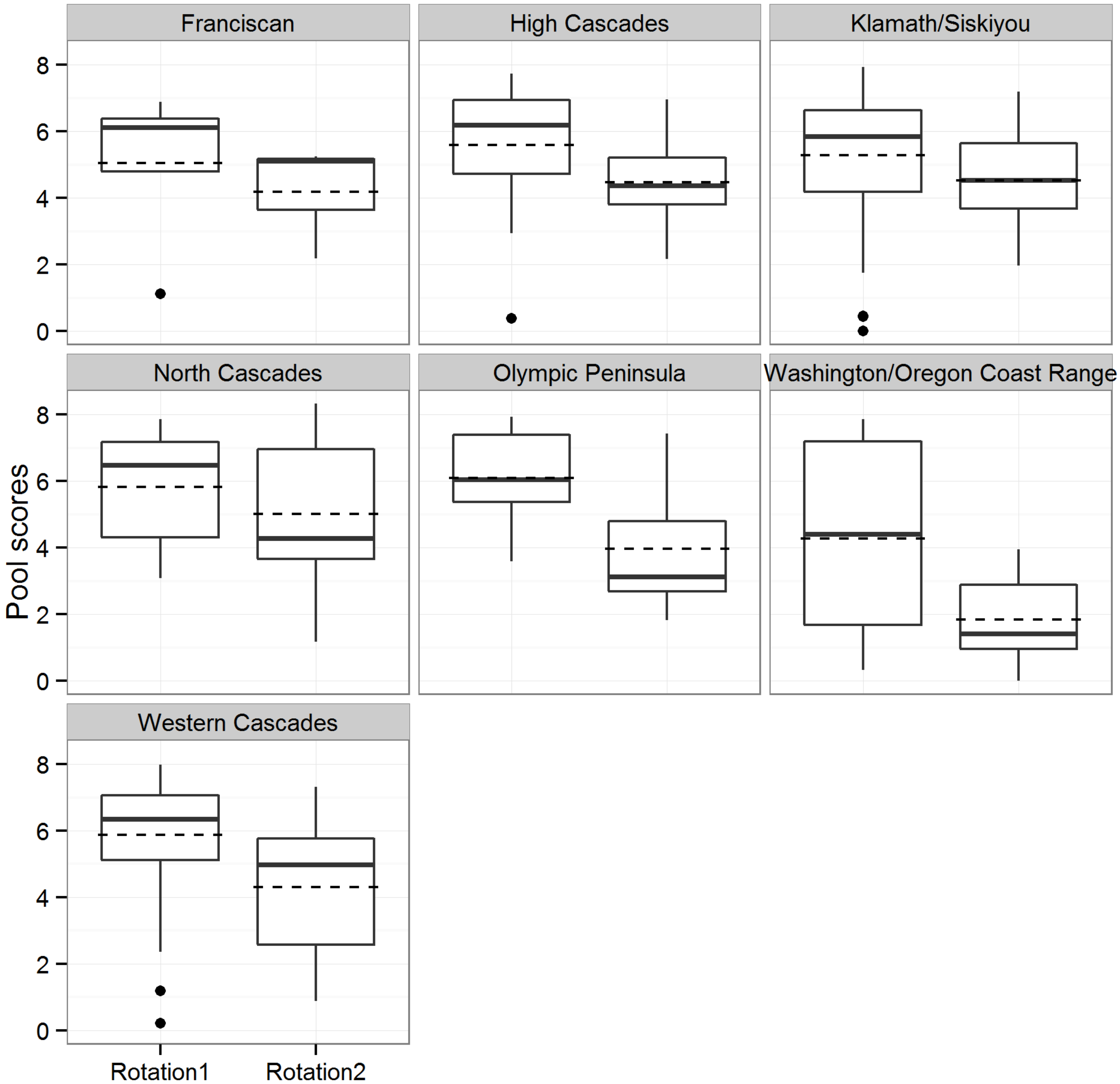


Figure 9—Distribution of stream wood scores (y-axis) for each rotation (x-axis) separately for each aquatic province. Mean stream wood scores are represented by the solid line, dashed line represent median values. Rotation 1 denotes 2002-2008 and rotation 2 2009-2012.

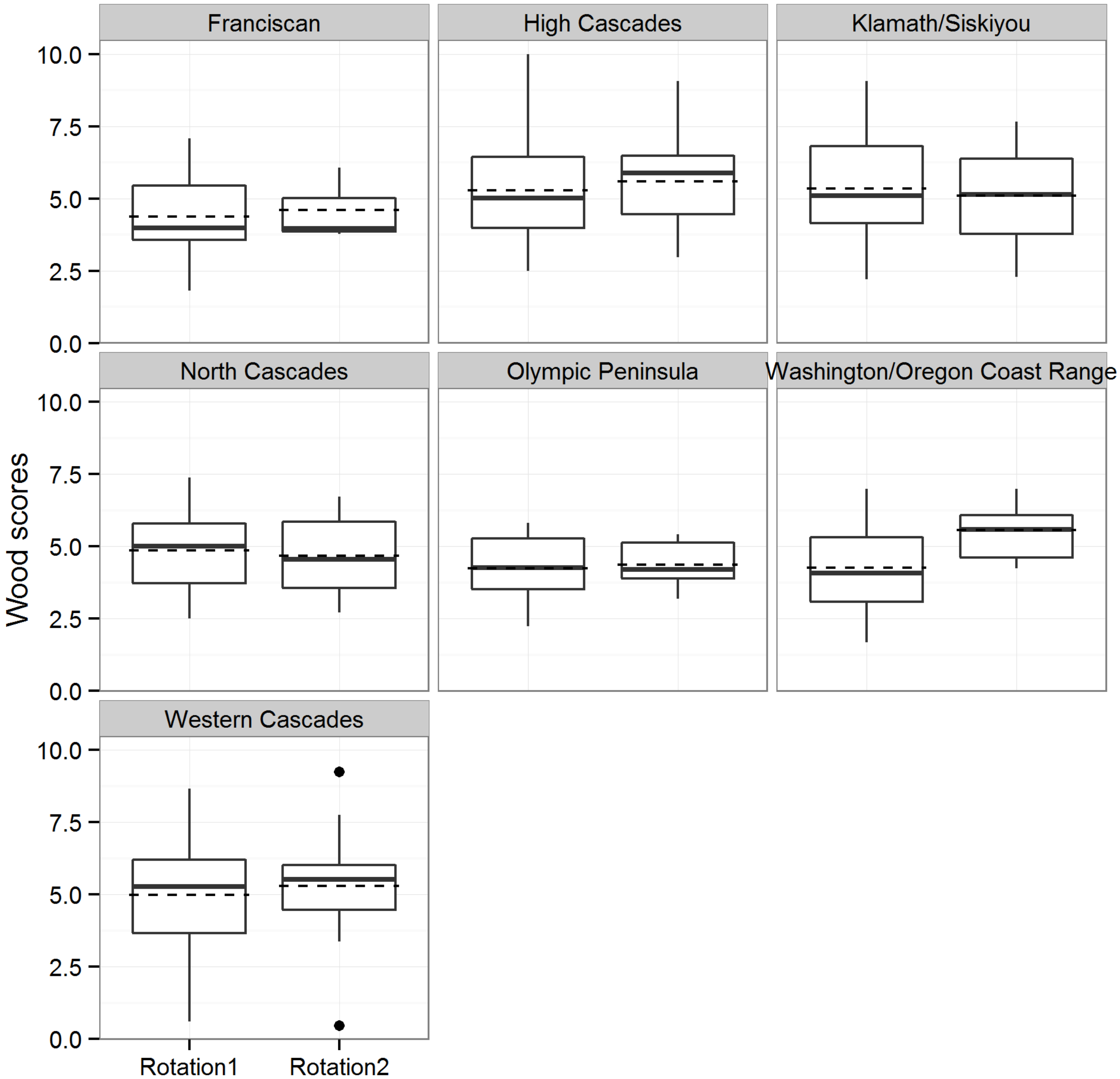
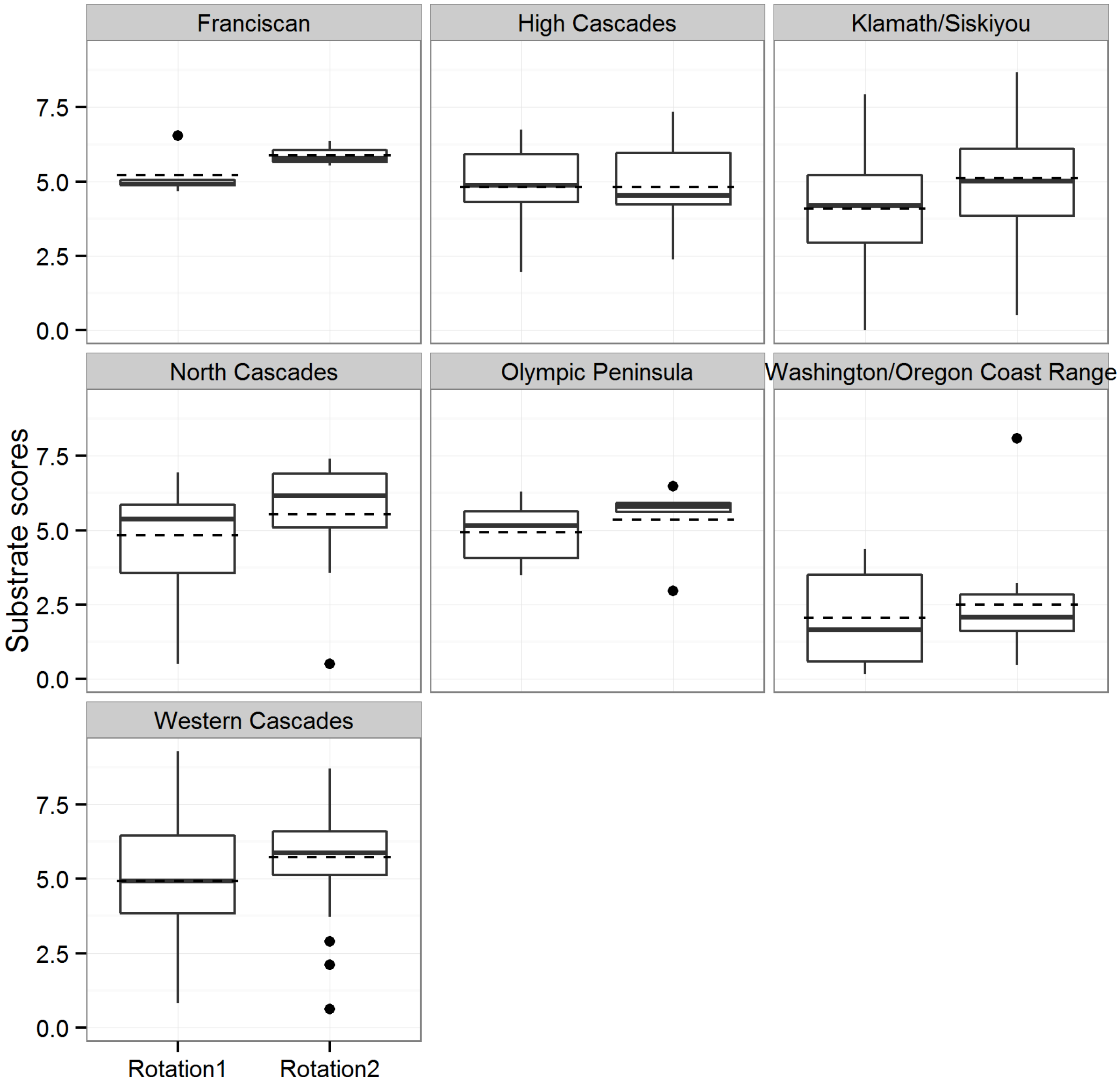


Figure 10—Distribution of stream substrate scores (y-axis) for each rotation (x-axis) separately for each aquatic province. Mean stream substrate scores are represented by the solid line, dashed line represent median values. Rotation 1 denotes 2002-2008 and rotation 2 2009-2012.



For the low -scoring watersheds (scores less than 40), pool score was usually the most influential in both rotations (fig. 8). Here scores are reported on a scale of 0-10. Only Washington/Oregon Coast Range province had mean and median pool scores below 5 during the first rotation. For the Northwest Forest Plan area, as well as, the Washington/Oregon Coast Range, and West Cascade provinces, median and mean pool score values were below 5 during the second rotation. Mean estimated pools scores also differed between rotations (table 4) and we detected evidence of a negative trend in pool scores across time for the NWFP (table 3, fig. 8). Both wood and substrate scores were centered around 5 with the exception of the Oregon Coast province where the mean and median substrate scores were below 2.5 (fig. 9 and 10). Mean estimated substrate scores differed between rotation (table 4); however, no difference was detected in wood scores (table 4, fig. 9 and 10). Evidence of a positive trend was detected in substrate scores for the Northwest Forest Plan area but no trend was detected in wood scores (table 3).

Table 3—Results from the trend analysis testing for a linear relationship between the stream metric scores and time, after accounting for province. Year, individual watershed, and province were used as random effects in this model. The upper and lower 95% confidence limit was included for each trend estimate. An F-test with a Kenward-Roger approximation was used to test significance of linear trend for each indicator. The denominator degrees of freedom (df) are listed (numerator df was two for all tests). Bold p-values denote significant trend in annual status estimates. The sign for each trend estimate denotes the trend direction.

Indicator	**Trend estimate**	**95% LCL**	**95% UCL**	**F-test**	**df**	**p-value**
Physical habitat	+0.10	-0.26	0.47	0.33	5.69	0.59
Pools	-0.21	-0.38	-0.04	6.22	9.44	**0.03**
Wood	+0.09	-0.01	0.18	3.14	7.89	0.11
Substrate	+0.10	0.03	0.16	9.90	5.76	**0.02**
O/E	+0.01	0.00	0.01	10.84	5.67	**0.02**
Temperature	-0.09	-0.24	0.08	1.19	6.86	0.31

For aquatic macroinvertebrates, we found that at least 25 percent of the watersheds had more stream invertebrate assemblages than expected, as denoted by scores above 1. At the same time, approximately 25 percent of the watersheds had scores below 0.6; scores of 0.6 signify 40 percent fewer stream invertebrate assemblages than expected from reference condition. Mean and median OE scores from each province did not fall below 0.7 in either rotation (fig. 11). We found a mean difference in rotations and a positive trend over time (table 3).

Figure 11—Distribution of stream macroinvertebrate observed to expected values (y-axis) for each rotation (x-axis) separately for each aquatic province. Mean stream macroinvertebrate observed to expected values are represented by the solid line, dashed line represent median values. Rotation 1 denotes 2002-2008 and rotation 2 2009-2012.

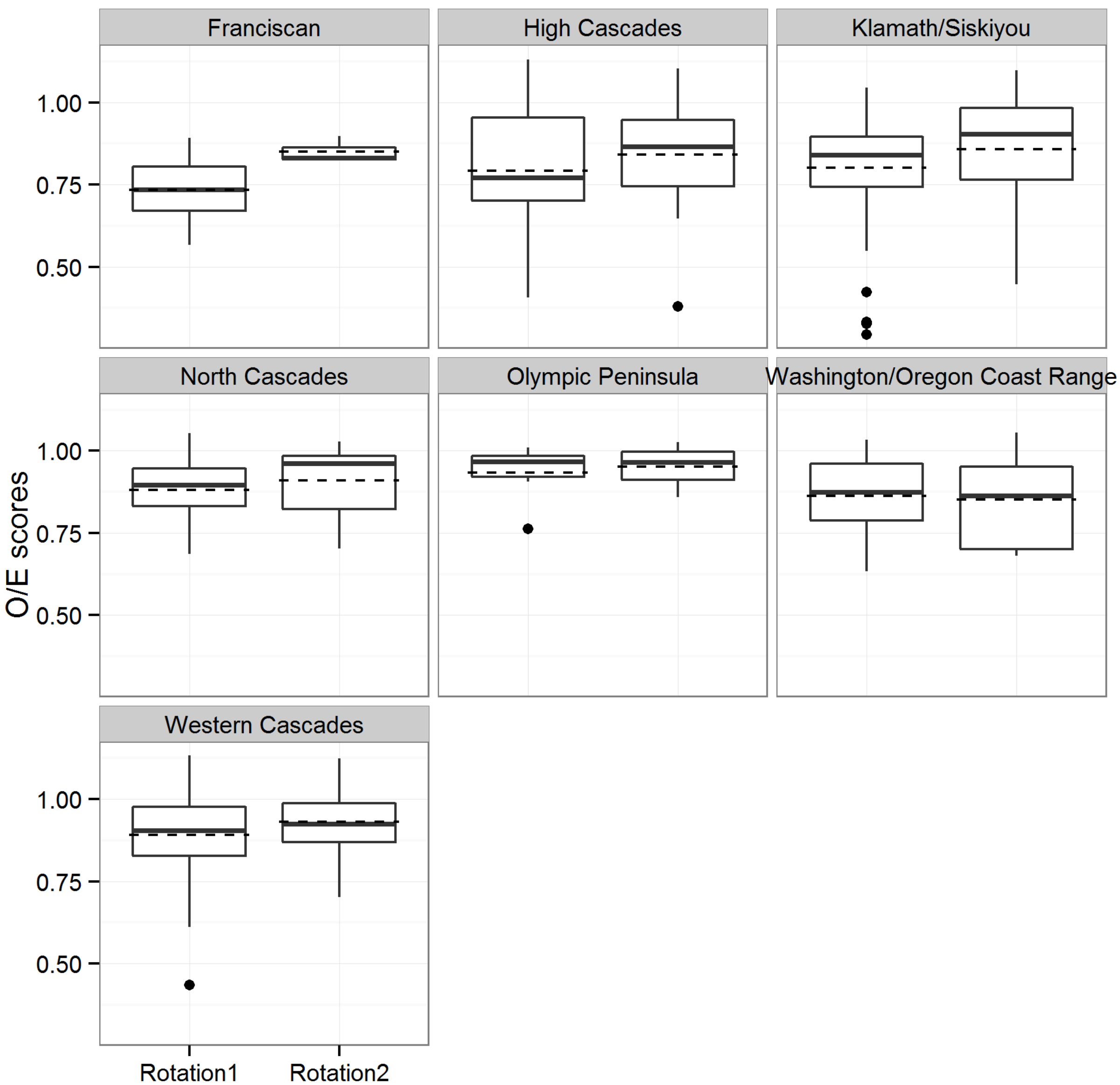
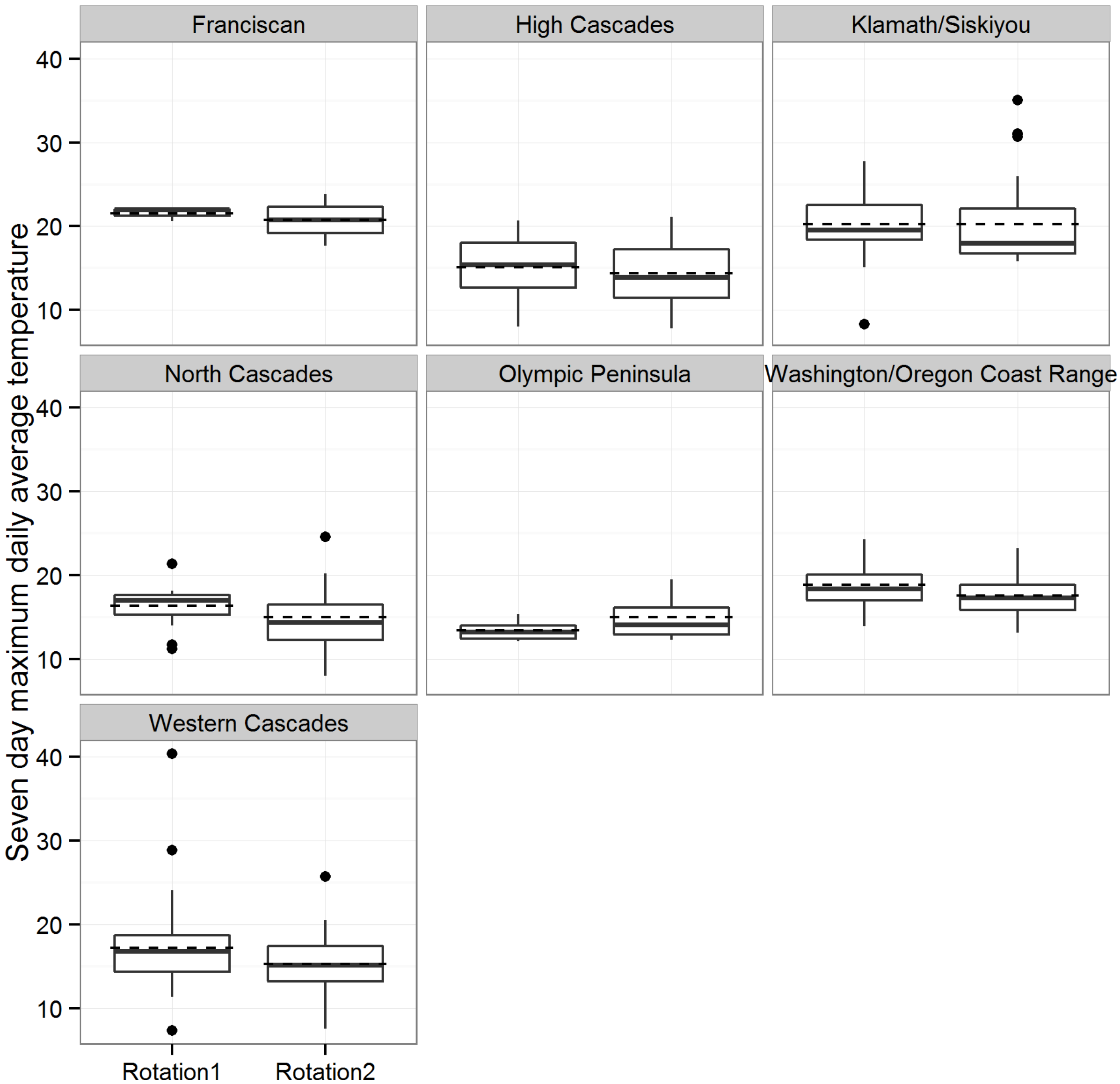


Figure 12—Distribution of stream seven day maximum average temperature (C) (y-axis) for each rotation (x-axis) separately for each aquatic province. Mean stream seven day maximum averages are represented by the solid line, dashed line represent median values. Temperature represented by C. Rotation 1 denotes 2002-2008 and rotation 2 2009-2012.

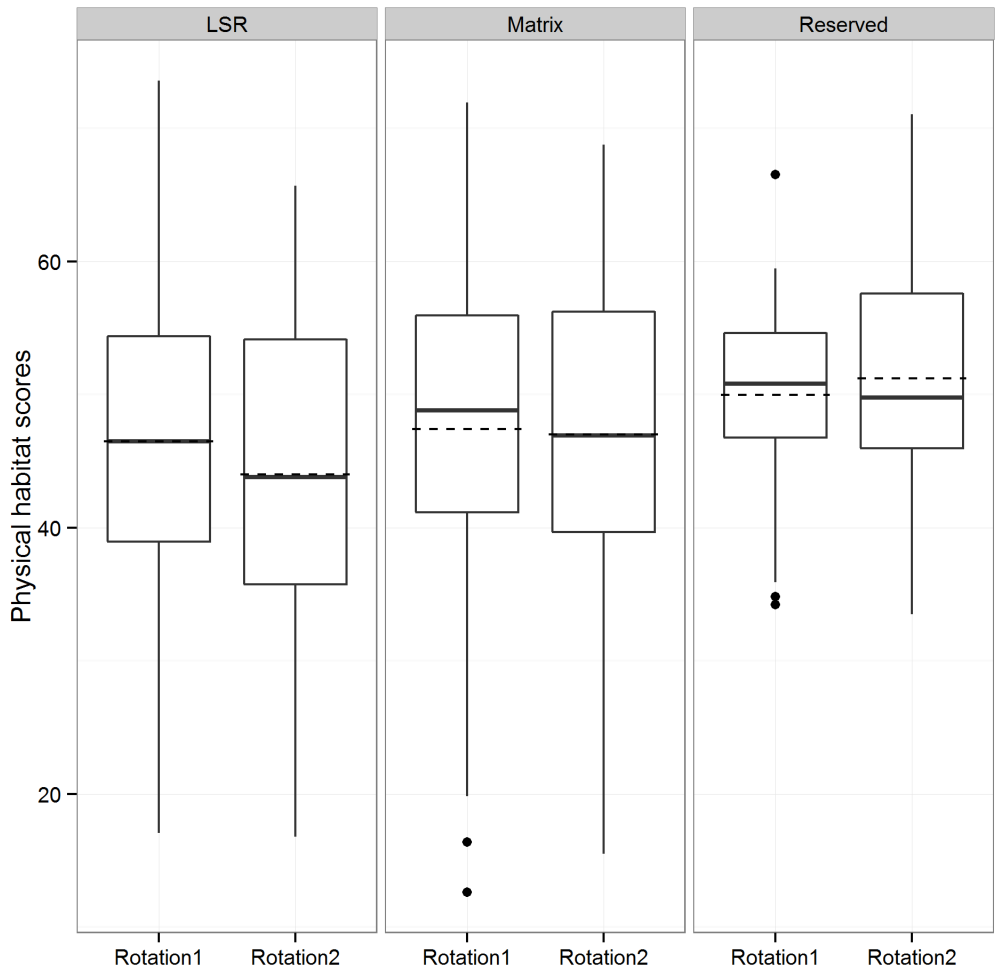


The National Marine Fisheries Service standards for a properly functioning system for anadromous fish is accepted as 15 degrees C, while the state of Oregon standard for core temperatures in salmonid habitat is 16 degrees C (based on the seven day maximum average temperature). Mean and median seven day average temperature values ranged from 16 to 19 degrees C over the 13 survey years, indicating that federal lands located in lower reaches within these watersheds do not meet desired criteria based on both National Marine Fisheries and State of Oregon standards (fig. 12). Temperature was the only metric estimate with a significantly negative sloping trend indicating an improving trend with decrease in mean temperatures over time (table 4).The mean estimated distribution scores were significantly different between rotations (table 4).

Land Use Category

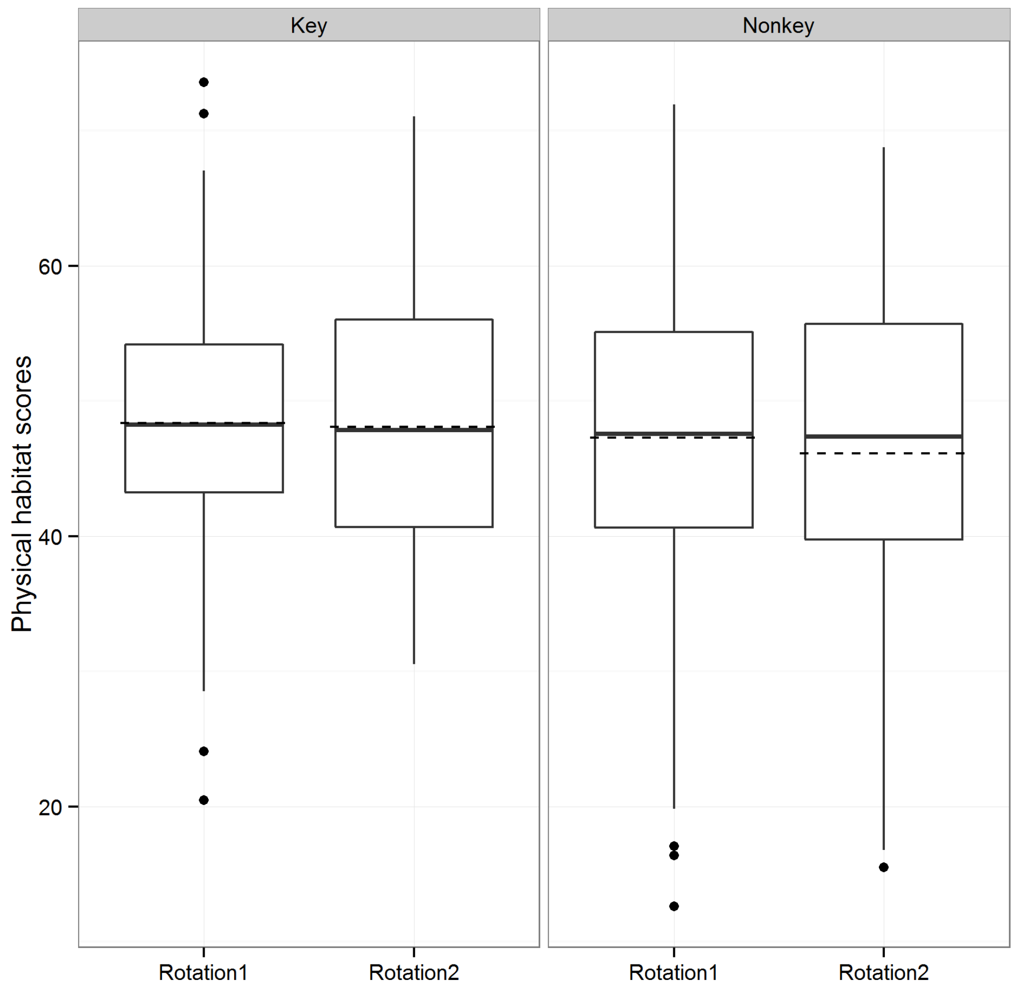
Congressionally reserved land estimated physical habitat condition score was 50 (95 percent confidence interval (CI) 48.1-51.8) in the first rotation and 51.2 (95 percent CI 48.6 to 53.8) during the second rotation. LSR land estimated mean score was 46.5 (CI 44.3-48.6) in the first rotation and 44 (95 percent CI 41.5-46.5) during the second rotation. Matrix land status score was 47.4 (95 percent CI 45.3-49.5) in the first rotation and 47 (95 percent CI 43.6-50.3) in the second. The congressional reserved lands had the smallest range of scores during the both rotations (fig. 13). Examination of overall stream physical habitat score results in the context of land use allocations within rotations shows a statistically significant difference in cumulative frequency distributions between congressionally reserved lands and late-successional reserve (LSR) and congressionally reserved lands and matrix during the first rotation (table 3). No statistical tests between levels among land use categories were performed for the second rotation since this rotation has not been completed.

Figure 13—Distribution of stream physical habitat condition scores (y-axis) for each rotation (x-axis) separately for each landuse allocation. Mean stream physical habitat scores are represented by the solid line, dashed line represent median values. (LSR = late-successional reserves, Reserved = congressional reserves). Rotation 1 denotes 2002-2008 and rotation 2 2009-2012.



There was a statistically significant difference between the distributions of the key and nonkey categories during the first rotation (table 5, fig. 14). Again, no statistical tests between levels between key and non-key categories were performed for the second rotation since this rotation has not been completed. The scores for nonkey watersheds in the first rotation only ranged from 12 to 72, which key watersheds ranged from 20 to 73 (fig. 14).

Figure 14—Distribution of stream physical habitat condition scores (y-axis) for each rotation (x-axis) separately for key and nonkey watersheds. Mean stream physical habitat scores are represented by the solid line, dashed line represent median values. Rotation 1 denotes 2002-2008 and rotation 2 2009-2012.



The distributions of individual attribute scores (e.g. pools, wood, substrate) were more variable in regard to land use categories (fig. 15). Statistically significant differences in mean cumulative frequency distributions between attribute scores by land use category are summarized in Table 5. Pool scores mean estimates were highest in congressionally reserved lands during both rotations (table 5). No evidence of differences in pool or wood score was found between key and nonkey watersheds in the first rotation (table 4). No differences in wood distributions were confirmed between the reserved/LSR/matrix categories during the first rotation. There was little evidence that substrate scores distributions differed between key and nonkey watersheds; however, the distribution of substrate scores significantly differed in congressionally reserved lands from LSR and Matrix lands during the first rotation (table 5). Substrate score mean estimates in congressionally reserved lands were higher than all other land use categories during both rotations (table 5).

Table 4—Estimates for stream metric scores, the number of watersheds used in the analysis (n), standard error (SE), along with the lower (LCL) and upper (UCL) 95% confidence limit, by rotation. Bold t value represents significant difference (two-sample t-test) testing mean estimates between rotations for the NWFP.

Indicator	**Landuse category**	**n**	**Rotation 1 estimate**	**SE**	**95% LCL**	**95% UCL**	**n**	**Rotation 2 estimate**	**SE**	**95% LCL**	**95% UCL**	**t**
Physical Habitat	NWFP	182	47.7	0.6	46.6	48.8	110	46.8	0.8	45.3	48.4	-0.9
	LSR	66	46.5	1.1	44.3	48.6	45	44.0	1.3	41.5	46.5	
	Matrix	73	47.4	1.1	45.3	49.5	37	47.0	1.7	43.6	50.3	
	Reserved	43	50.0	0.9	48.1	51.8	28	51.2	1.3	48.6	53.8	
	Nonkey	115	47.3	0.7	45.8	48.7	70	46.1	1.1	44.1	48.2	
	Key	67	48.3	1.0	46.3	50.4	40	48.1	1.2	45.7	50.4	
Pools	NWFP	180	5.5	0.1	5.3	5.7	108	4.1	0.1	3.9	4.4	**-8.3**
	LSR	66	5.4	0.2	5.0	5.9	45	3.6	0.2	3.3	3.9	
	Matrix	71	5.4	0.2	5.1	5.8	36	4.3	0.2	3.8	4.8	
	Reserved	43	5.7	0.2	5.3	6.2	27	4.8	0.3	4.3	5.4	
	Nonkey	113	5.5	0.1	5.2	5.8	68	4.3	0.2	4.0	4.6	
	Key	67	5.5	0.2	5.1	5.9	40	3.9	0.2	3.5	4.4	
Wood	NWFP	184	5.0	0.1	4.8	5.2	111	5.2	0.1	5.0	5.4	+1.2
	LSR	67	4.9	0.2	4.6	5.2	45	5.3	0.2	5.0	5.7	
	Matrix	73	5.1	0.2	4.7	5.5	37	5.0	0.2	4.6	5.4	
	Reserved	44	5.0	0.2	4.7	5.4	29	5.3	0.2	4.9	5.6	
	Nonkey	116	4.9	0.1	4.7	5.2	70	4.9	0.1	4.7	5.2	
	Key	68	5.2	0.2	4.9	5.5	41	5.6	0.2	5.3	6.0	
Substrate	NWFP	184	4.4	0.1	4.2	4.6	111	5.0	0.1	4.7	5.3	**+3.6**
	LSR	67	4.1	0.2	3.7	4.4	45	4.5	0.2	4.0	4.9	
	Matrix	73	4.4	0.2	4.0	4.7	37	5.1	0.3	4.6	5.7	
	Reserved	44	5.0	0.2	4.7	5.4	29	5.6	0.2	5.3	6.0	
	Nonkey	116	4.4	0.1	4.2	4.7	70	4.9	0.2	4.6	5.2	
	Key	68	4.4	0.2	4.0	4.7	41	5.1	0.2	4.7	5.6	
O/E	NWFP	183	0.8	0.0	0.8	0.9	108	0.9	0.0	0.9	0.9	**+2.9**
	LSR	67	0.9	0.0	0.8	0.9	43	0.9	0.0	0.9	0.9	
	Matrix	71	0.8	0.0	0.8	0.9	36	0.9	0.0	0.9	0.9	
	Reserved	45	0.8	0.0	0.8	0.9	29	0.8	0.0	0.8	0.9	
	Nonkey	116	0.8	0.0	0.8	0.9	68	0.9	0.0	0.9	0.9	
	Key	67	0.9	0.0	0.8	0.9	40	0.9	0.0	0.9	0.9	
Temperature	NWFP	165	17.9	0.2	17.5	18.4	130	16.6	0.2	16.1	17.1	**-4.1**
	LSR	58	18.6	0.3	18.1	19.2	52	17.0	0.4	16.3	17.7	
	Matrix	70	18.6	0.4	17.8	19.5	47	17.2	0.6	16.1	18.3	
	Reserved	37	15.6	0.4	14.8	16.3	31	14.9	0.4	14.1	15.7	
	Nonkey	106	18.1	0.3	17.5	18.7	83	16.7	0.3	16.0	17.3	
	Key	59	17.6	0.3	17.0	18.2	47	16.4	0.5	15.5	17.3	

Table 5—Results from testing mean cumulative frequency distributions (cdf) among the landuse categories and key and nonkey watershed. These tests were performed only within the first rotation. Significant differences in cdfs between categories for physical habitat scores and individual metric elements are noted in bold (α 0.05).

Metric	Landuse category		Wald F	DF	P Value
Physical habitat	LSR	Matrix	0.44	132	0.65
	LSR	Reserve	5.39	101	**0.01**
	Matrix	Reserve	6.39	108	**0.00**
	Nonkey	Key	3.17	174	**0.04**
Pools	LSR	Matrix	6.11	131	**0.00**
	LSR	Reserve	1.00	101	0.37
	Matrix	Reserve	3.13	107	**0.05**
	Nonkey	Key	0.45	172	0.64
Wood	LSR	Matrix	0.64	133	0.53
	LSR	Reserve	2.38	103	0.10
	Matrix	Reserve	2.16	109	0.12
	Nonkey	Key	1.80	176	0.17
Substrate	LSR	Matrix	0.56	133	0.57
	LSR	Reserve	5.16	103	**0.01**
	Matrix	Reserve	4.62	109	**0.01**
	Nonkey	Key	1.65	176	0.20
O/E	LSR	Matrix	1.50	132	0.23
	LSR	Reserve	0.89	104	0.41
	Matrix	Reserve	0.64	109	0.53
	Nonkey	Key	1.26	176	0.29

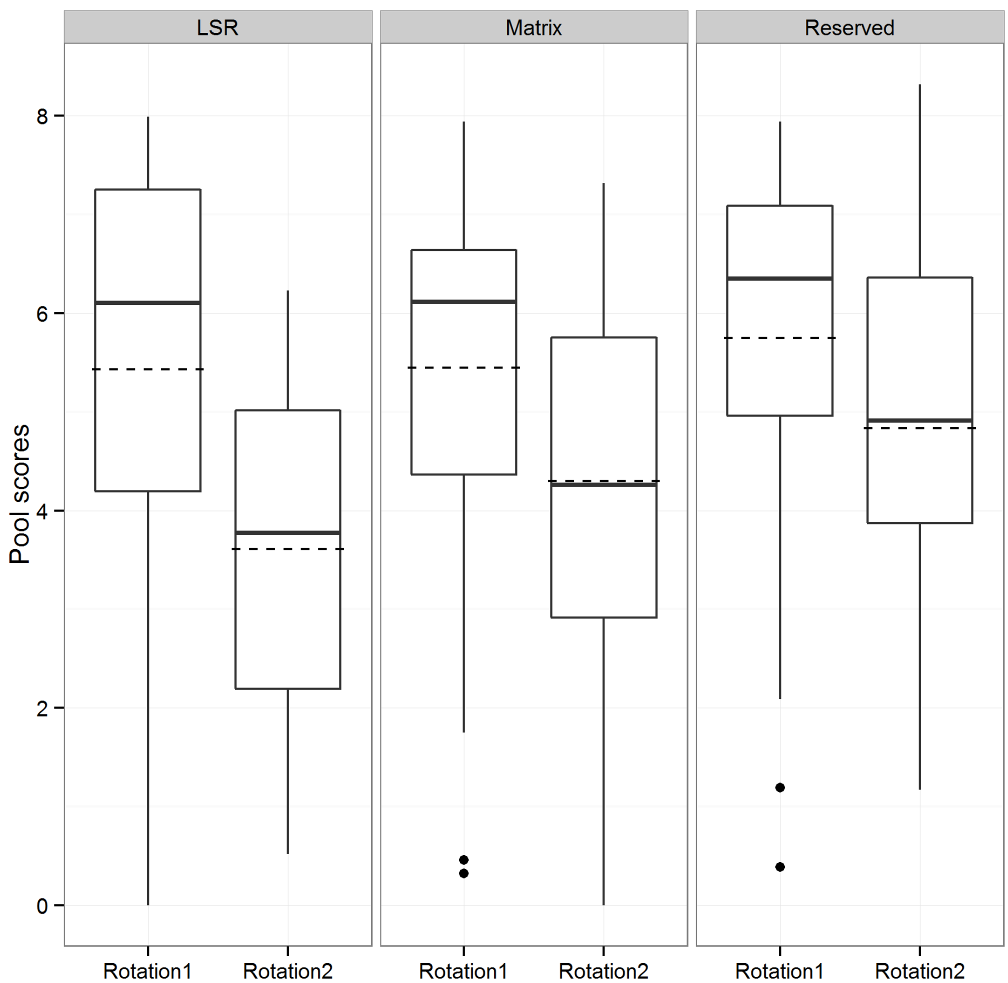
Examining the distribution of aquatic invertebrate O/E scores by land use allocation indicated that, in the first rotation, landuse categories and key and nonkey watershed did not differ (table 5, fig. 15, fig. 16).

Table 6—Results from testing mean cumulative frequency distributions (cdf) among the landuse categories and key and nonkey watershed based on seven day maximum average temperature. Data from a climate change vulnerability project were used to augment samples which increased sample size to levels adequate to test for differences within categories. Significant differences in cdfs between categories are noted in bold (α 0.05).

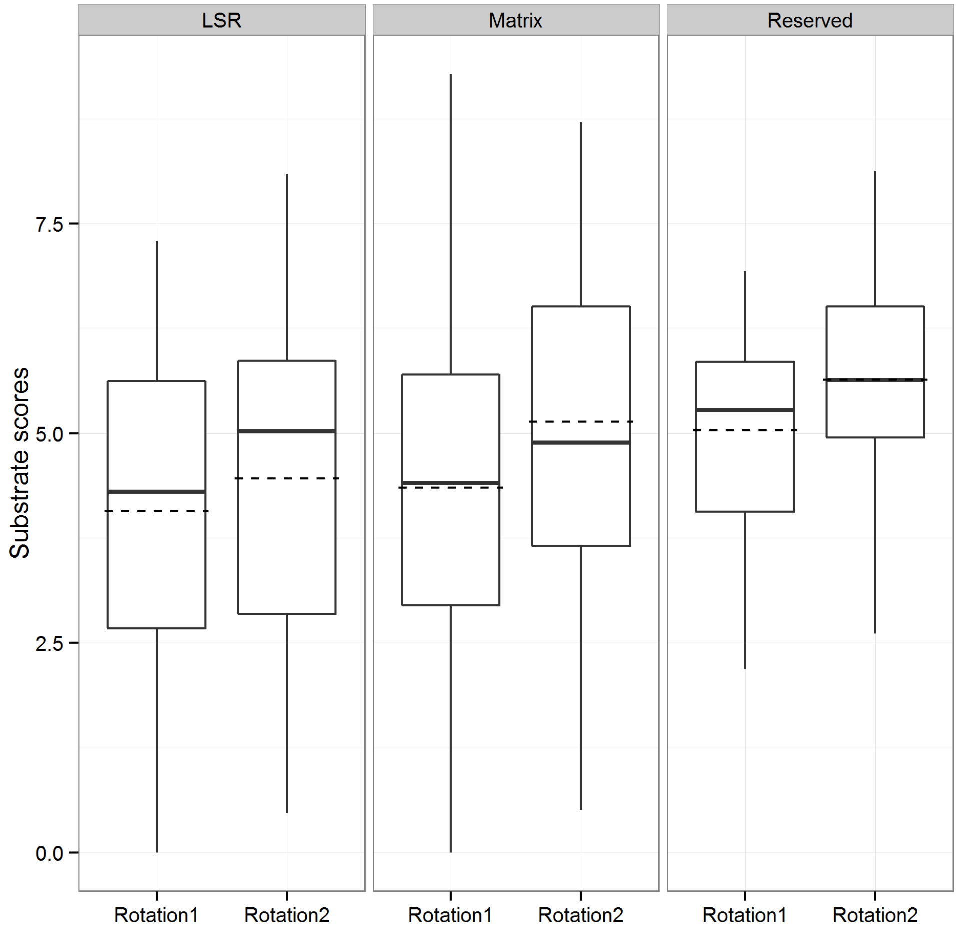
Rotation	Metric	Landuse category		Wald F	DF	P Value
1	Temperature	LSR	Matrix	4.47	121	**0.01**
		LSR	Reserve	16.06	87	**0.00**
		Matrix	Reserve	8.57	99	**0.00**
		Nonkey	Key	0.04	157	0.96
2	Temperature	LSR	Matrix	0.98	93	0.38
		LSR	Reserve	5.97	78	**0.00**
		Matrix	Reserve	5.45	74	**0.01**
		Nonkey	Key	0.12	125	0.89

Seven day maximum average temperature statistically differed in distributions among all land use categories during the first rotation (Table 6, fig. 15, fig. 16). No difference in distributions was seen between key and nonkey watersheds (table 6). Estimated mean temperatures were lowest on congressionally reserved lands in both rotations (table 6).

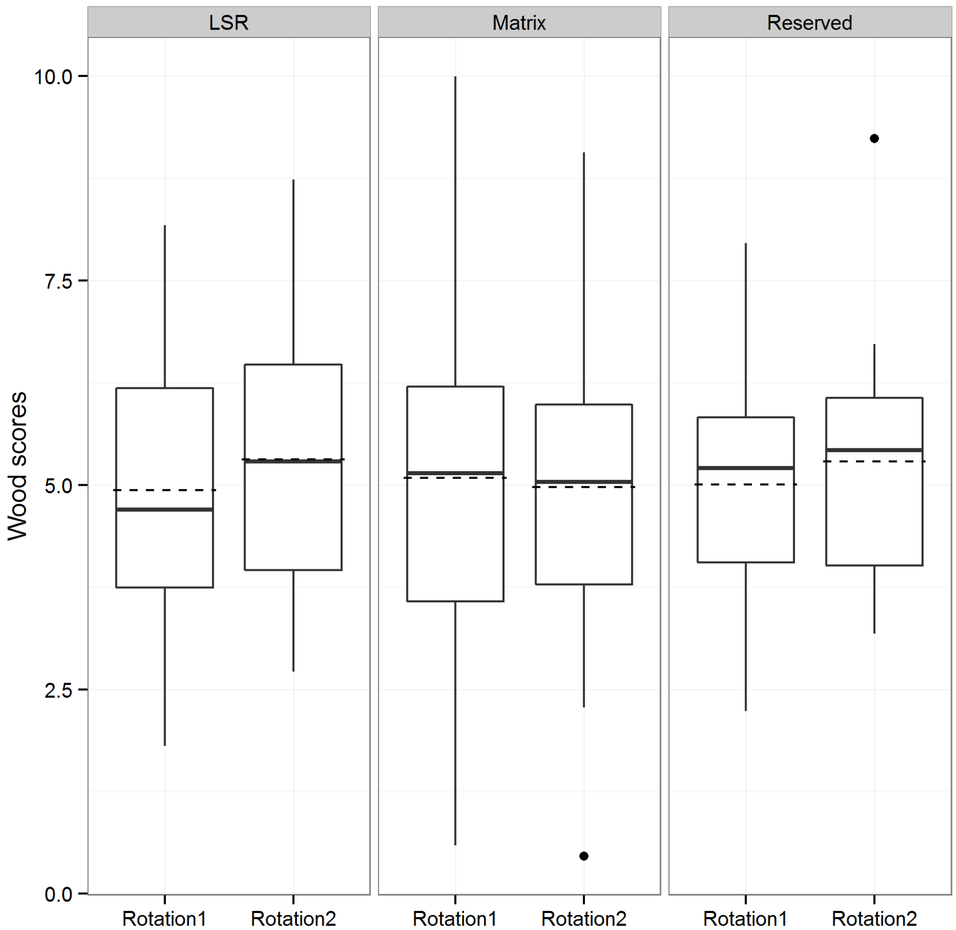
Figure 15—Distribution of each individual stream metric included in the physical habitat score scores: (a) Pools, (b) wood, (c) substrate, as well as (d) macroinvertebrate observed to expected values (O/E), and (e) seven day maximum average temperature (C) (y-axis) for each rotation (x-axis) separately for each landuse allocation. Mean stream physical habitat scores are represented by the solid line, dashed line represent median values. (LSR = late-successional reserves, Reserved = congressional reserves). Rotation 1 denotes 2002-2008 and rotation 2 2009-2012.



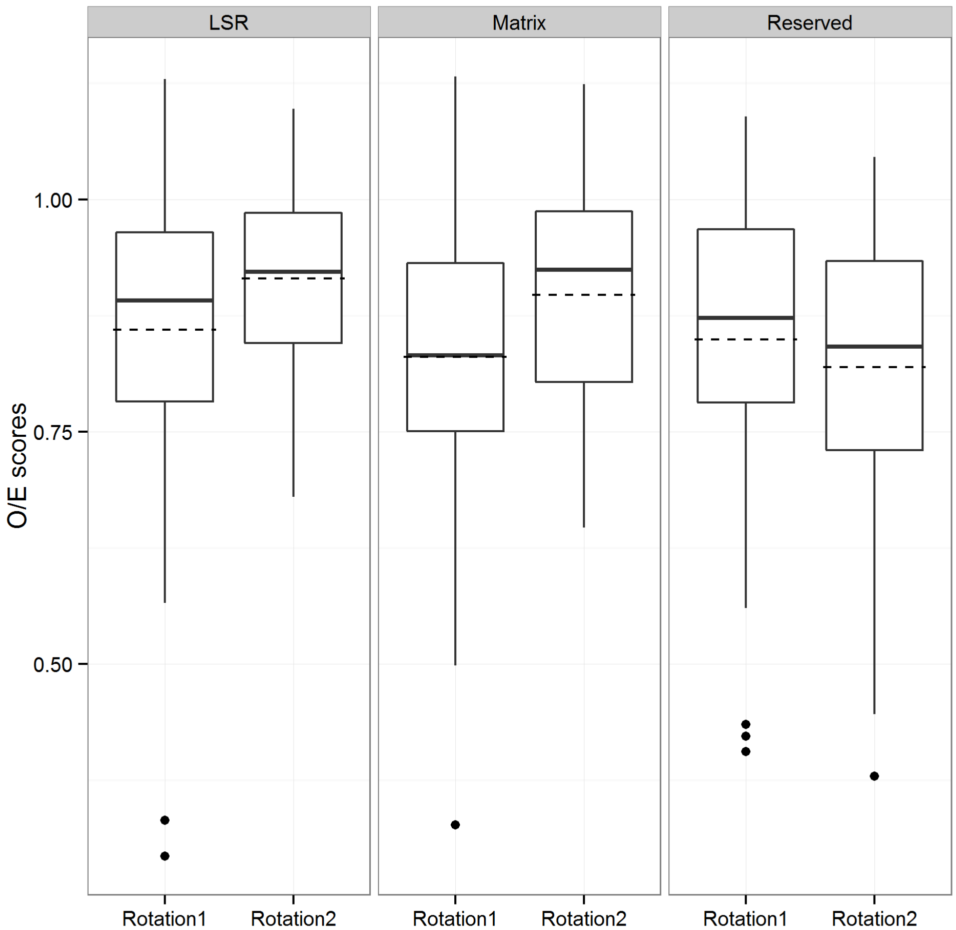
(a)


LSR
Matrix
Reserved
Substrate scores
7.5
5.0
2.5
0.0
Rotation1
Rotation2
Rotation1
Rotation2
Rotation1
Rotation2

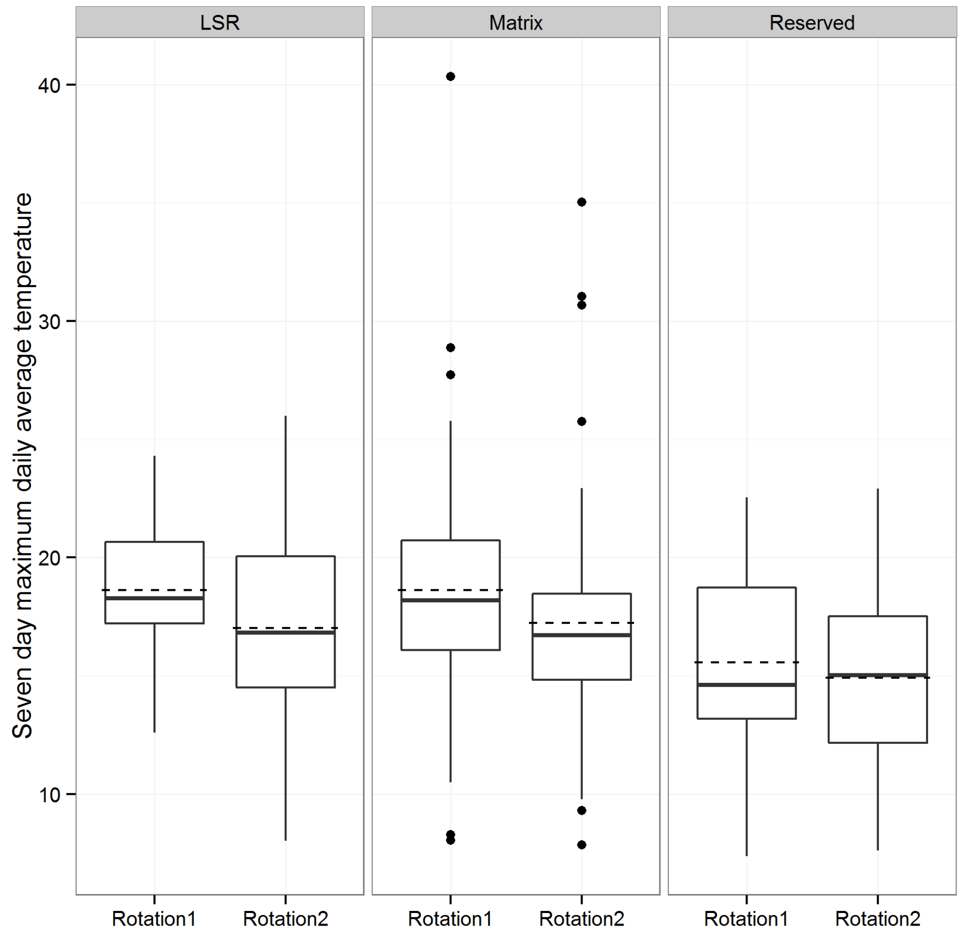
(b)


LSR
Matrix
Reserved
Wood scores
10.0
7.5
5.0
2.5
0.0
Rotation1
Rotation2
Rotation1
Rotation2
Rotation1
Rotation2

(c)

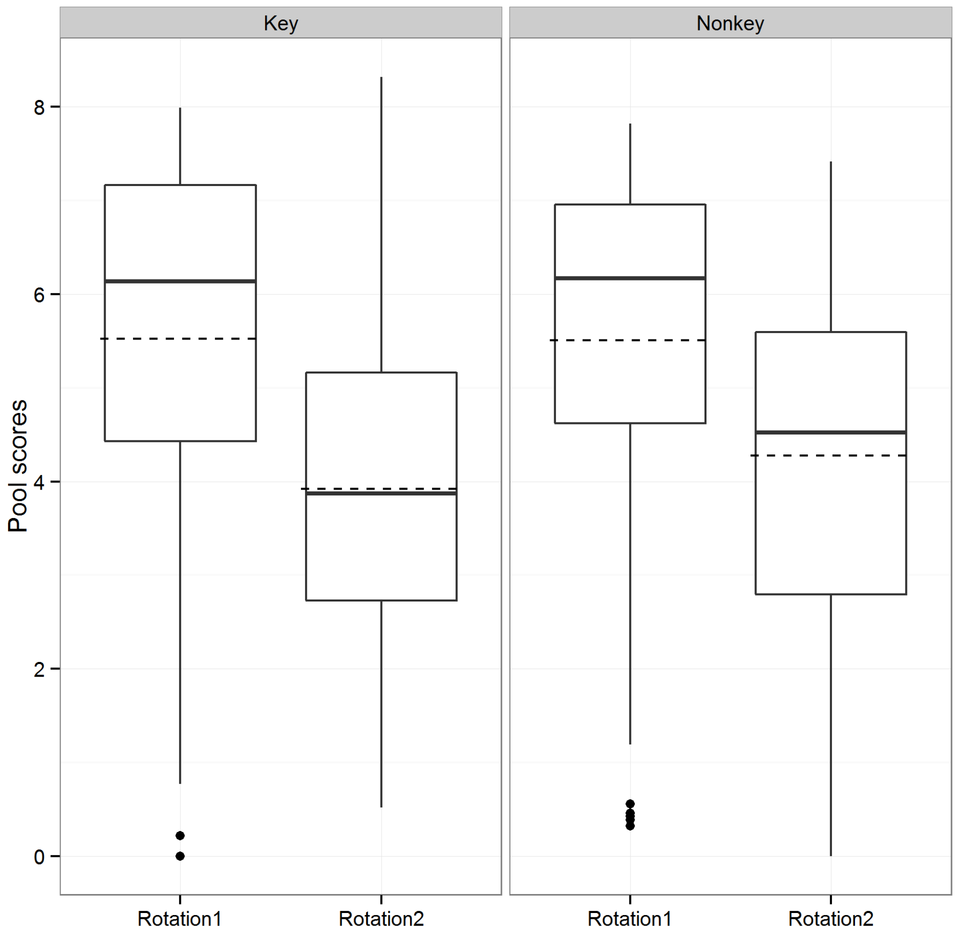

LSR
Matrix
Reserved
O/E scores
1.00
0.75
0.50
Rotation1
Rotation2
Rotation1
Rotation2
Rotation1
Rotation2

(d)

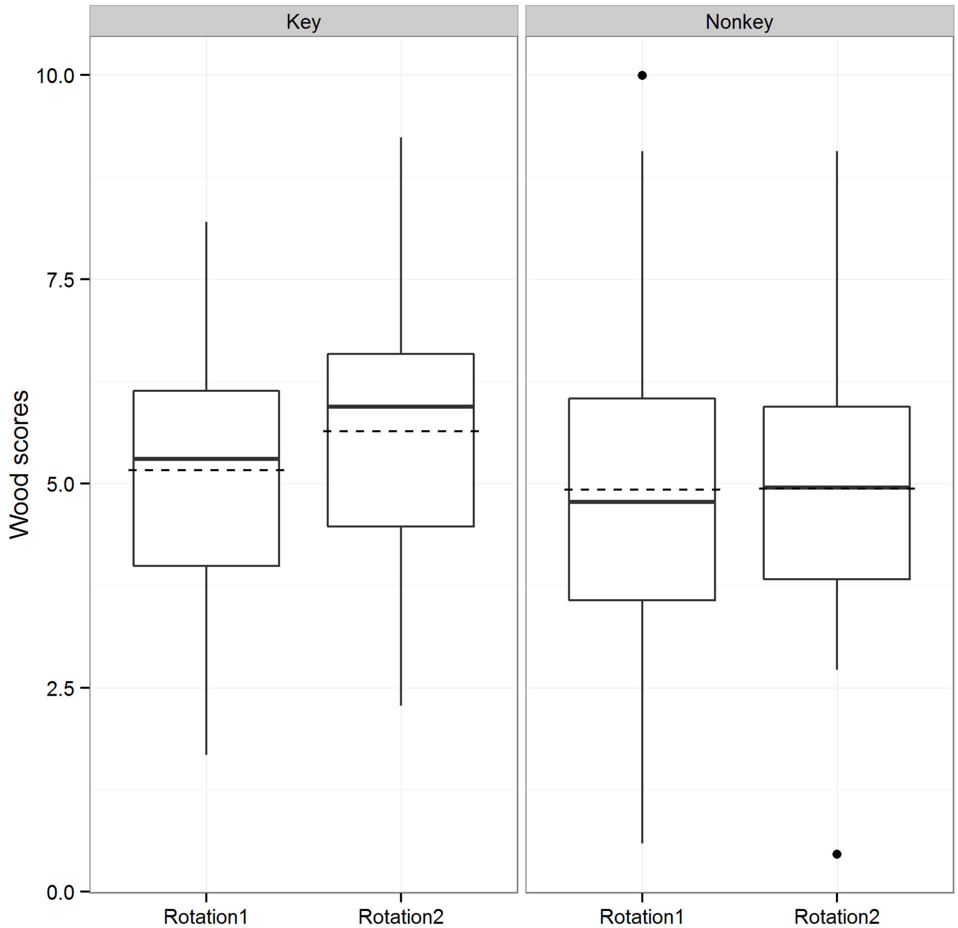

LSR
Matrix
Reserved
Seven day maximum daily average temperature
40
30
20
10
Rotation1
Rotation2
Rotation1
Rotation2
Rotation1
Rotation2

(f)

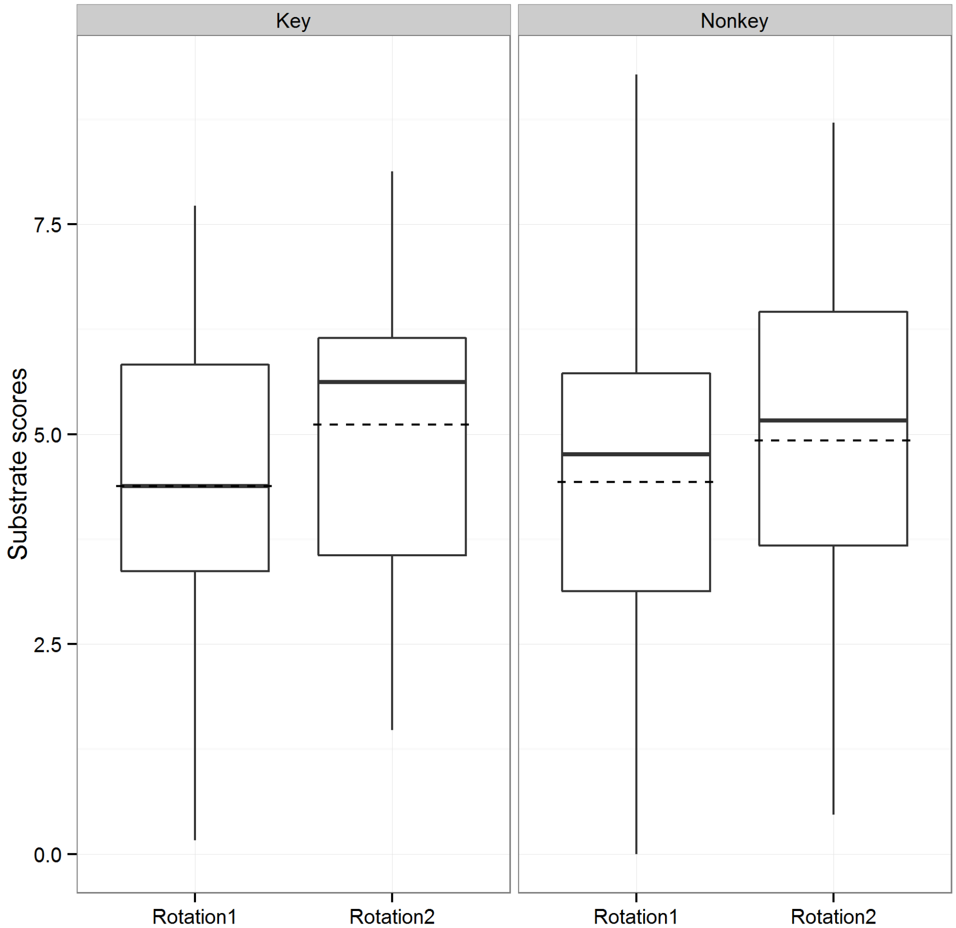
Figure 16—Distribution of each individual stream metric included in the physical habitat score scores: (a) Pools, (b) wood, (c) substrate, as well as (d) macroinvertebrate observed to expected values (O/E), and (e) seven day maximum average temperature (C) (y-axis) for each rotation (x-axis) separately for key and nonkey watersheds. Mean stream physical habitat scores are represented by the solid line, dashed line represent median values. Rotation 1 denotes 2002-2008 and rotation 2 2009-2012.



(a)

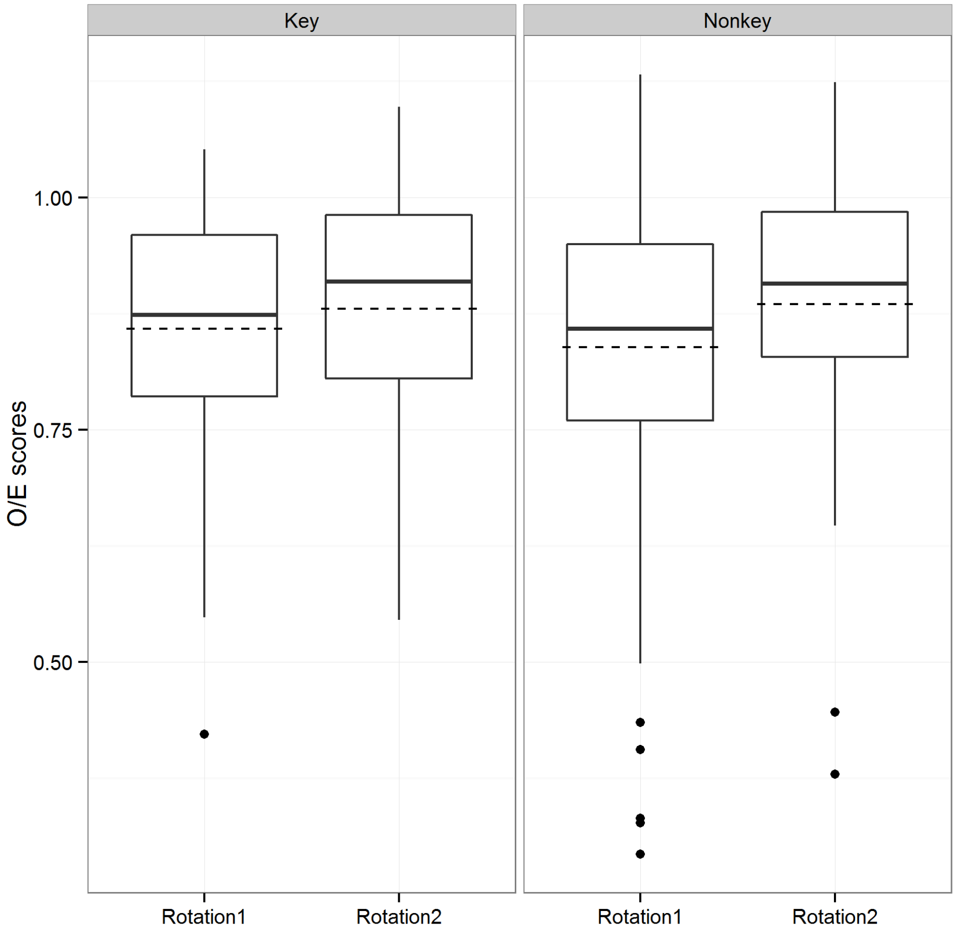

Key
Nonkey
10.0
7.5
5.0
2.5
0.0
Wood scores
Rotation1
Rotation2
Rotation1
Rotation2

(b)



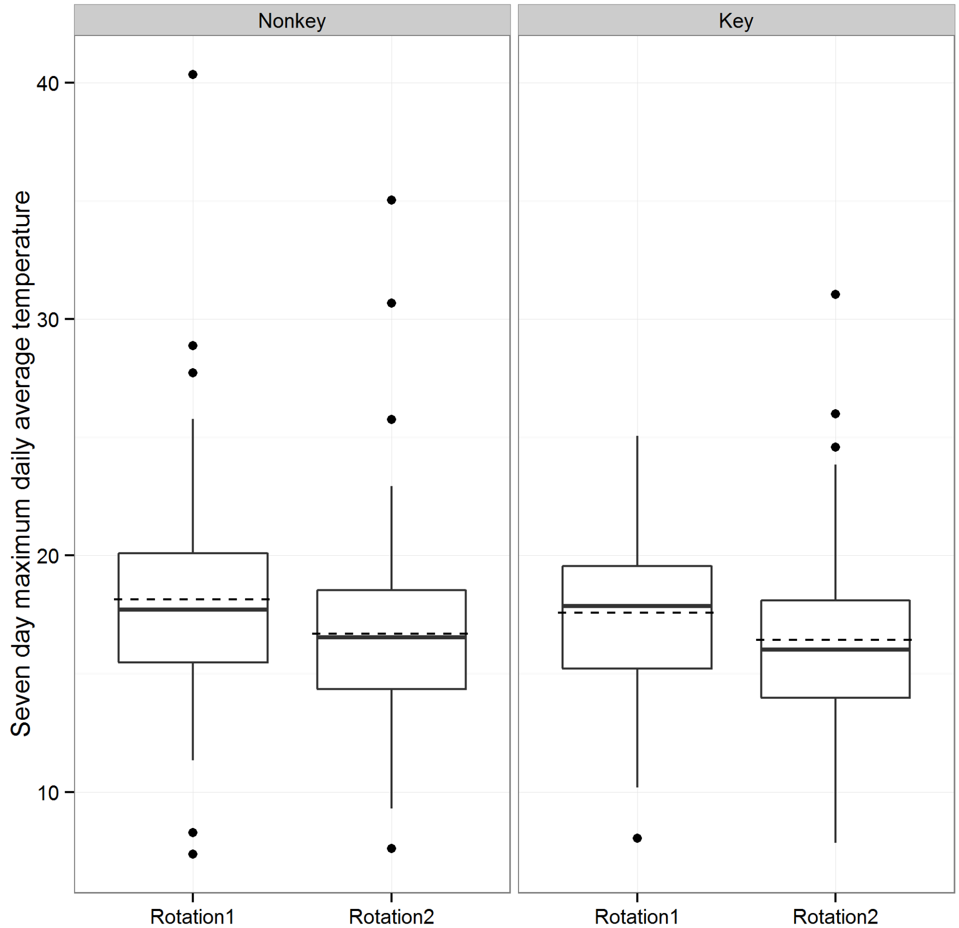
Key
Nonkey
Substrate scores
7.5
5.0
2.5
0.0
Rotation1
Rotation2
Rotation1
Rotation2

(c)



Key
Nonkey
O/E scores
1.00
0.75
0.50
Rotation1
Rotation2
Rotation1
Rotation2

(d)


Nonkey
Key
Seven day maximum daily average temperature
40
30
20
10
Rotation1
Rotation2
Rotation1
Rotation2
(e)

2. What Is the Status and Trend of Upslope/riparian Conditions?

The conditions of upslope/riparian processes were estimated by scoring and integrating a variety of indicators derived from remote sensing and other mapped data sets (see "Methods" section and app. 4 for details). Data were aggregated by HUC, ownership, and land use allocation and so were reported as area-weighted scores rather than watershed counts (some watersheds contained very little federal land). Data on every watershed in the target population were analyzed. Measurement error inherent in the attributes was still an issue. However, precise error estimates for all the attributes were not known and so were only discussed in general terms in these results (see "Discussion" section and app. 6 for more details).

Figure 17—Upslope/riparian status and trend scores.

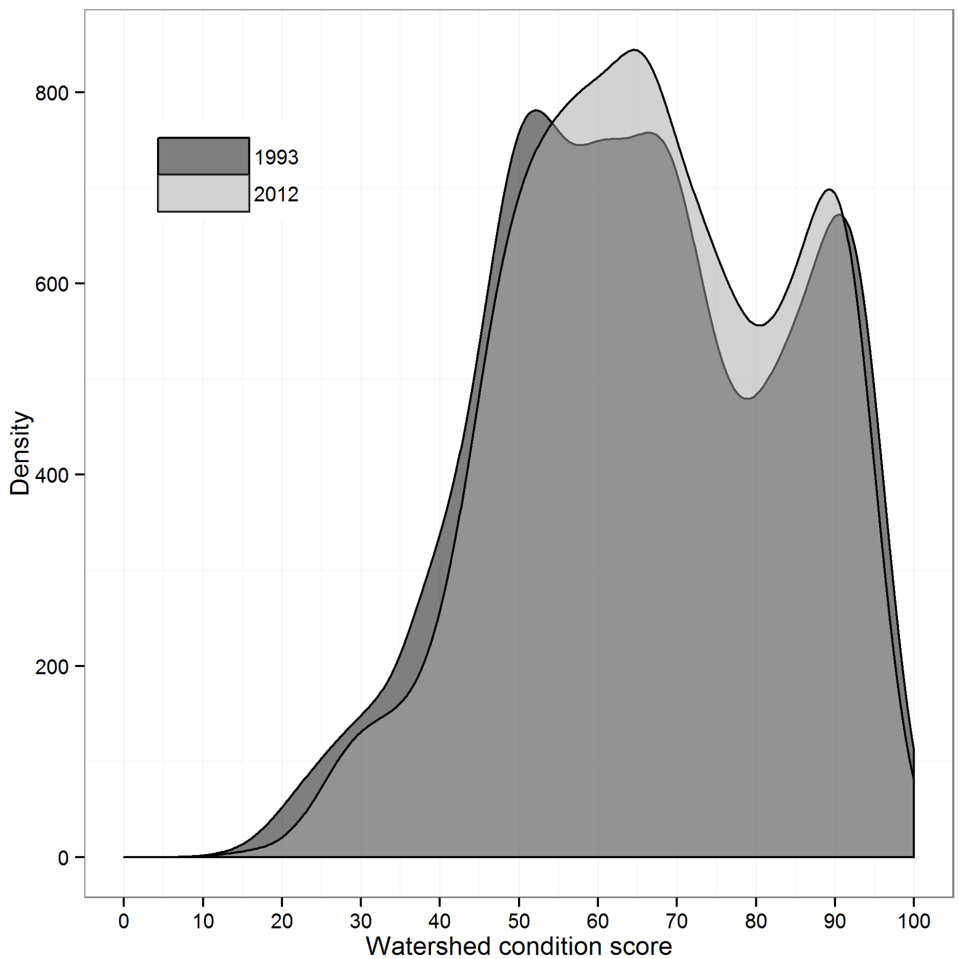
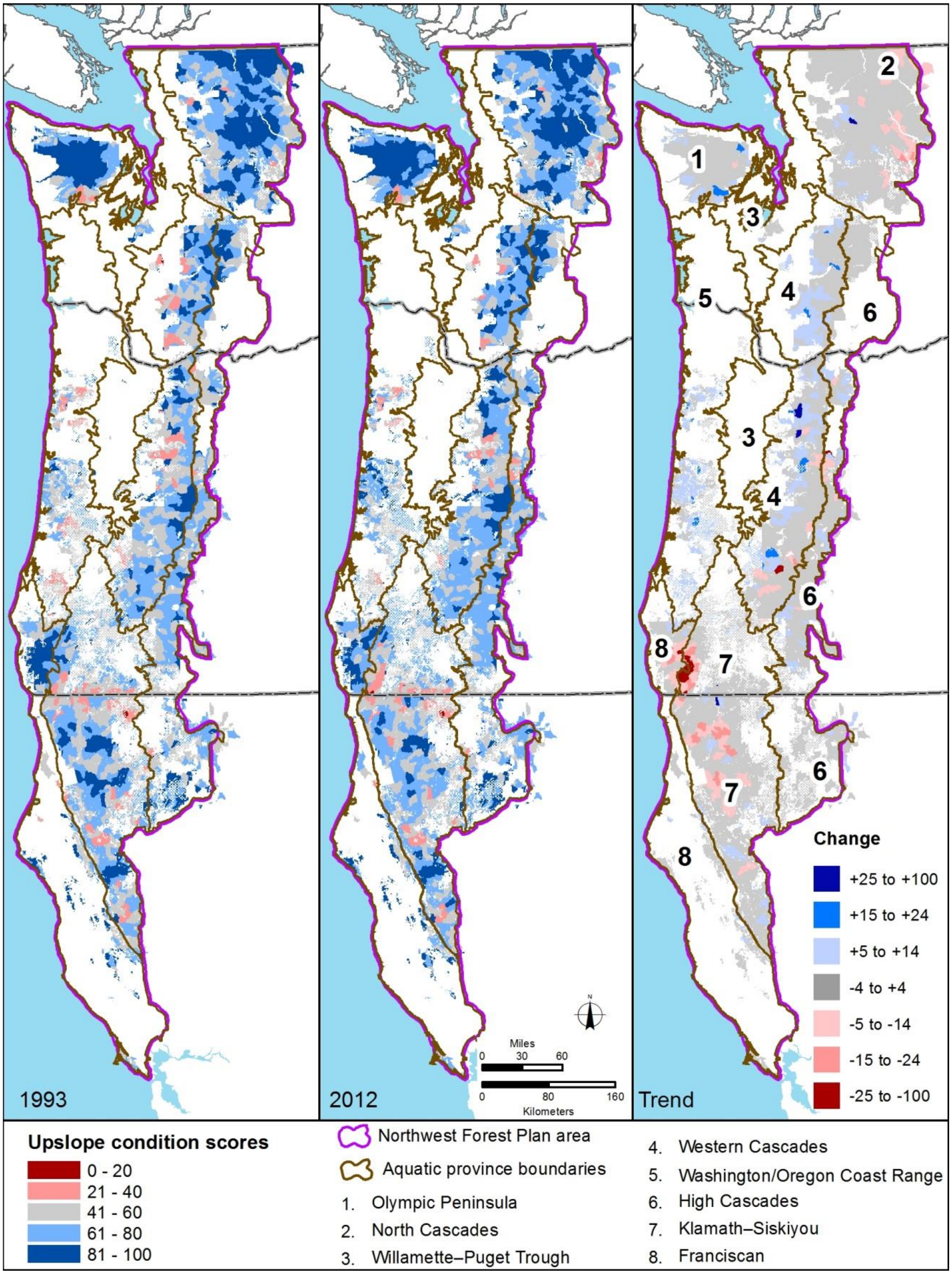
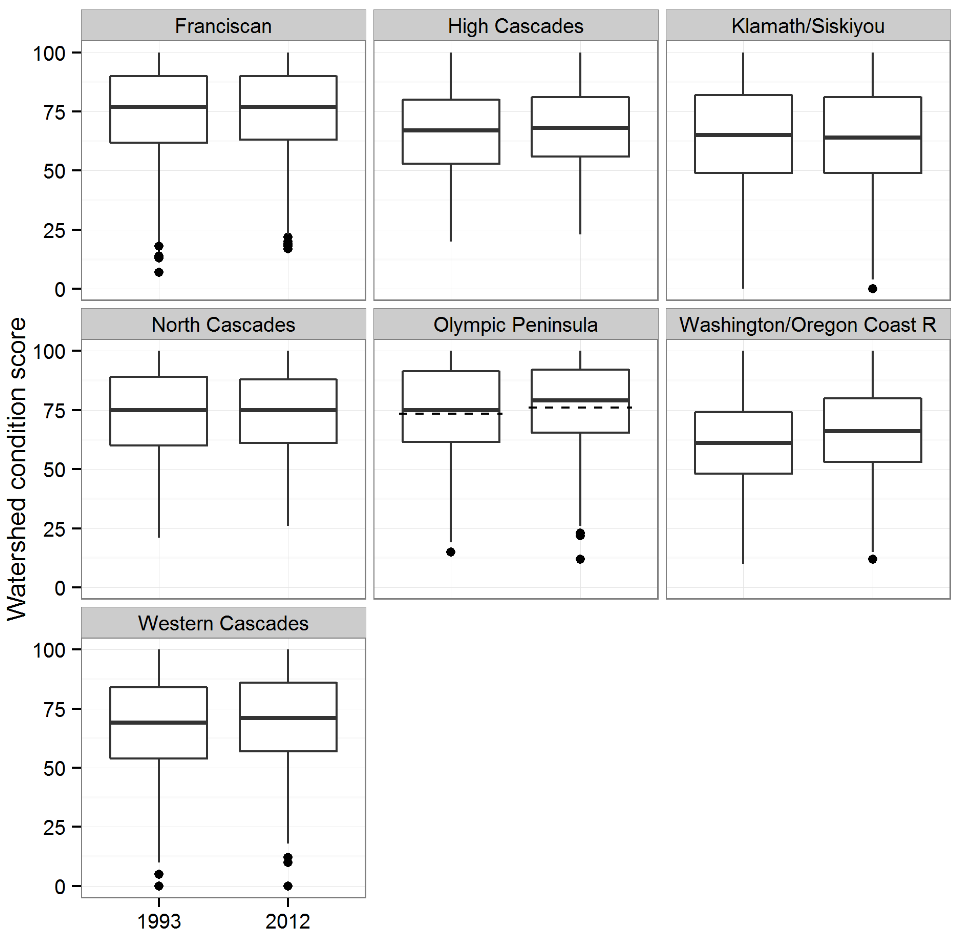


Figure 18—Upslope/riparian status and trend score maps.



Overall, there was a very slight positive change in upslope/riparian condition scores, from a mean score of 68 in 1993 to 69 in 2012 (standard deviation (sd) = 20-19). An increase in scores (a shift to the right) was especially noticeable as a shift from scores in the low to mid-range (15-50) to the higher range (60-90) (fig. 17). The area in the high ranges (more than 90) actually decreased slightly. Excluding minor changes, which may be due to error inherent in the satellite imagery classification process, we also calculated a conservative estimate looking at only condition score changes of greater than 5 percent (± 5). Using this threshold, 16 percent of the area increased versus 7 percent that decreased.

Figure 19—Upslope/riparian score distributions by aquatic province. Mean upslope/riparian scores are represented by the dashed line, solid line represent median values.



The spatial distribution of upslope/riparian condition scores showed some noticeable patterns (fig. 18). The highest scores (>80) were found in the central Olympic Peninsula (Olympic National Park), the north central Cascades and scattered along the Cascades in Oregon and Washington, often corresponding to designated wilderness areas. Other high-scoring areas occur in the Siuslaw National Forest, in the northeast and southwest areas of the Rogue River-Siskiyou National Forest, and in scattered wilderness areas in the Klamath mountain range in northern California. Low scores (<40) were seen in the southern Olympic region, and along the eastern flank of the Oregon Coast range and western flanks of the Cascade Range in Oregon and Washington, generally lower elevation areas closer to transportation routes which have been the most heavily roaded and harvested in the past.

The upslope/riparian condition trend map uses seven categories (instead of five used in the status maps), along with smaller central categories to better discriminate changes in scores since trend scores tended to be more tightly grouped than the status scores. Areas that showed a downward trend included north-central California, SW Oregon, and patches in the central Oregon Cascades and along the eastern edge of the North Cascades in Washington. The pattern in positive changes was similar to the pattern of lower scores mentioned above: the southern Olympic region, the Oregon Coast range and along the western flanks of the Cascade Range in Oregon and Washington.

Breaking these scores down by aquatic province revealed some small differences (fig. 19). Most provinces had scores very near the regional average (mean = 68, sd = 19), although the Olympic, Franciscan and North Cascades showed somewhat higher scores (mean = 76, 74, 73, sd = 18, 19, 17, respectively) and the Klamath/Siskiyou somewhat lower (mean = 64, sd = 20). The Washington/Oregon Coast Range had the largest increase in scores (mean = 61 to 66, sd = 20, 18).

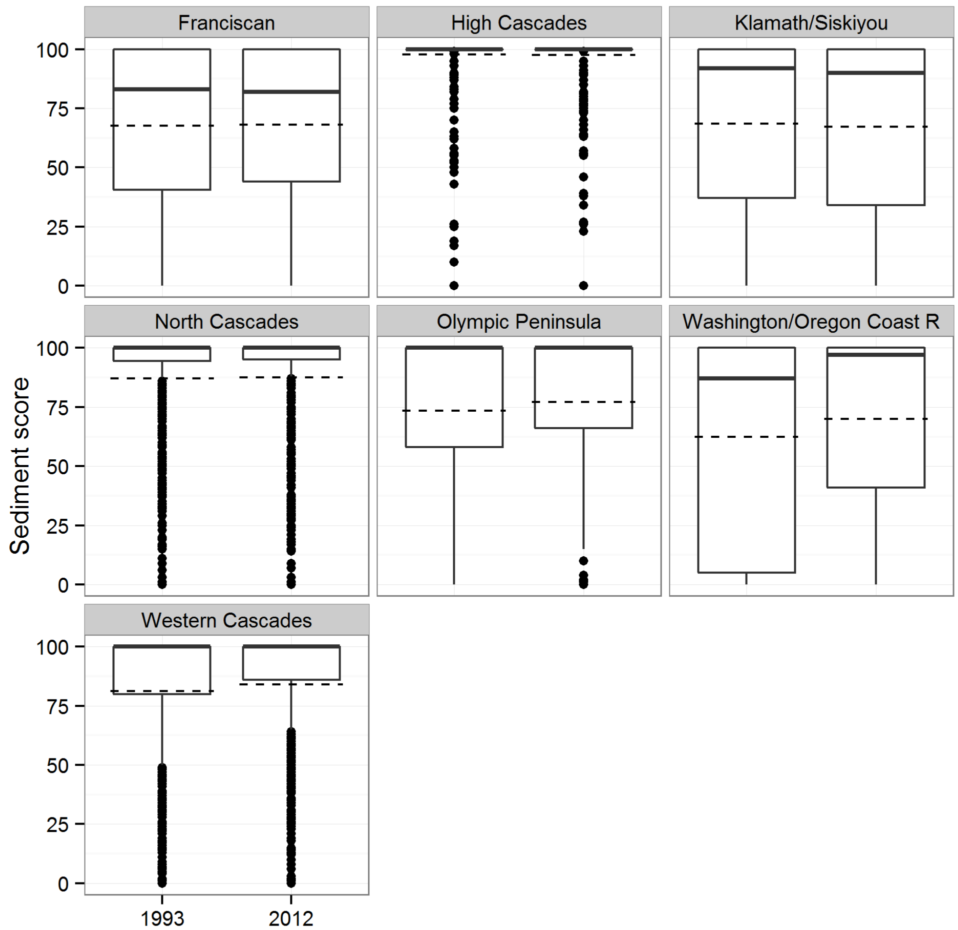
In terms of the individual process indicators contributing to the overall upslope/riparian condition score (fig. 20), sediment scores were generally high, with overall mean scores of 77, 78 (1993 and 2012, sd = 36, 35). The West, High and North Cascades and the Olympic had greater than 50 percent of scores at the maximum level (100). The Franciscan, Klamath/Siskiyou, and Washington/Oregon Coast provinces had higher variability and more scores in the mid to low range.

Wood scores were moderate compared to the other indicators (mean = 67, 69, sd = 19, 19). The Olympic province had the highest mean scores (74, 77, sd = 19, 17) and the High Cascades the lowest (mean = 59, 61, sd = 19, 19). Trends in wood scores resembled overall trends, with downward trends seen in north-central California, SW Oregon, the central Oregon Cascades, and the eastern edge of the North Cascades in Washington and positive trends the southern Olympic region, and along the Oregon Coast range and western flanks of the Cascade Range in Oregon and Washington.

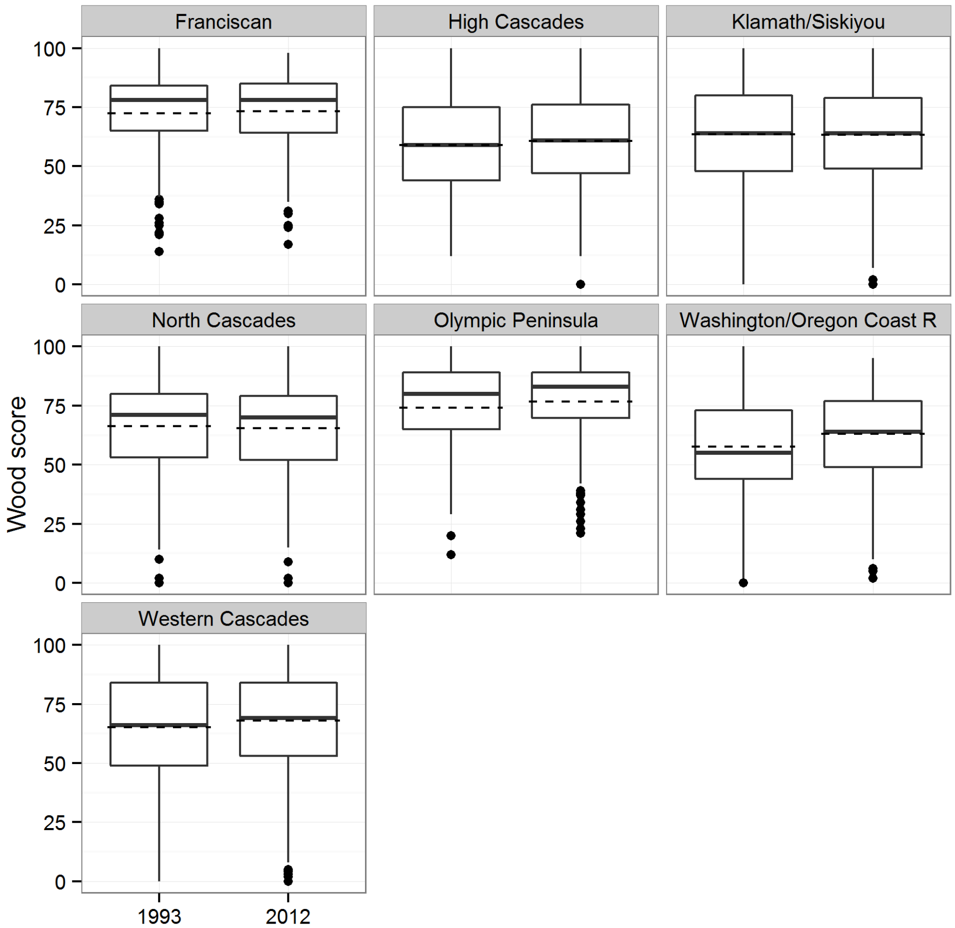
Riparian scores, a combination of riparian vegetation and riparian road indicators, averaged 62, 64 (sd = 25, 24) across the Plan area. Scores in the Franciscan and Olympic provinces were the highest, while scores in the High Cascades, Klamath/Siskiyou, and WA/OR Coast were lower and more variable. Spatial pattern showed the distinct effect of roads, with high scores in the Olympic and Northern Cascades and low scores along the eastern side of the Oregon Coast Range and the western and eastern sides of the Cascades from Washington to northern California.

Figure 20—Upslope/riparian process indicator scores by province. Mean upslope/riparian scores are represented by the dashed line, solid line represent median values.

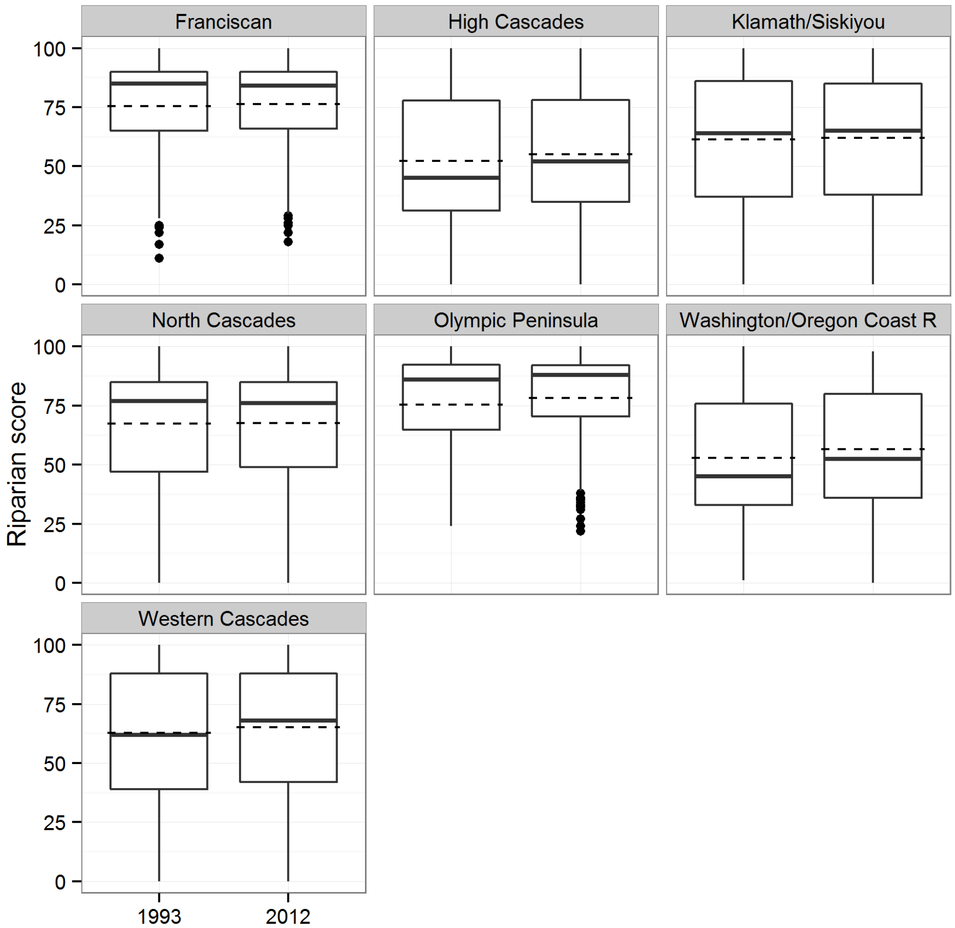
(a)



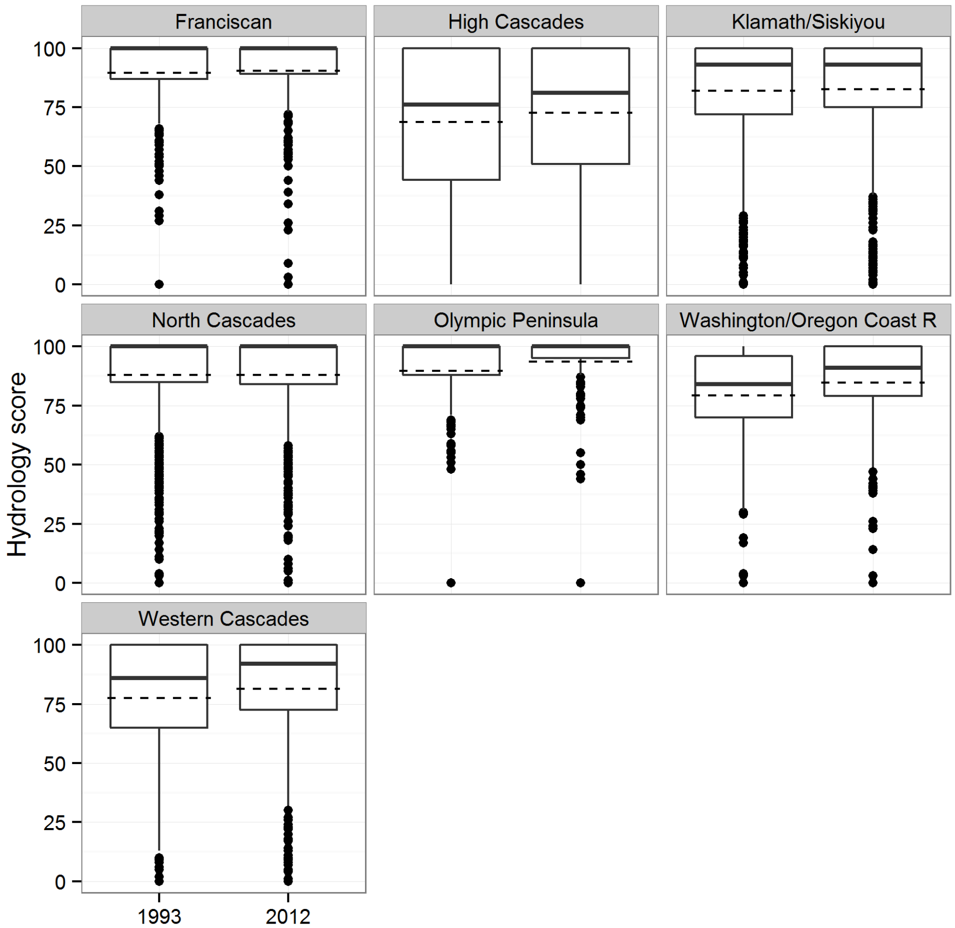
(b)


Franciscan
High Cascades
Klamath/Siskiyou
North Cascades
Olympic Peninsula
Washington/Oregon Coast R
Western Cascades
Wood score
100
75
50
25
0
1993
2012

(c)

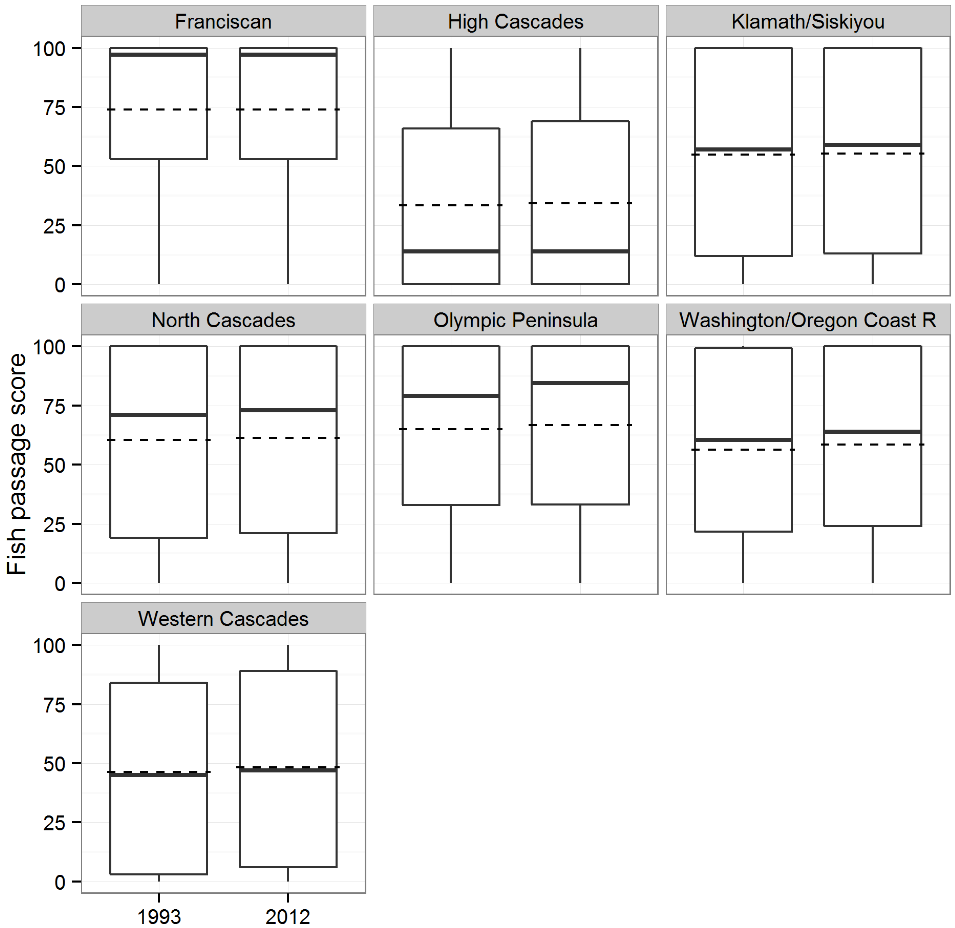

Franciscan
High Cascades
Klamath/Siskiyou
North Cascades
Olympic Peninsula
Washington/Oregon Coast R
Western Cascades
Riparian score
100
75
50
25
0
1993
2012

(d)



Franciscan
High Cascades
Klamath/Siskiyou
North Cascades
Olympic Peninsula
Washington/Oregon Coast R
Western Cascades
Hydrology score
100
75
50
25
0
1993
2012

(e)



Franciscan
High Cascades
Klamath/Siskiyou
North Cascades
Olympic Peninsula
Washington/Oregon Coast R
Western Cascades
Fish passage score
100
75
50
25
0
1993
2012

Hydrology scores, derived from overall road density and vegetation condition, were the highest of the process indicators (mean = 81, 83, sd = 26, 25). Scores in the Franciscan, North Cascades, and Olympic were noticeably higher than the other four provinces. Low scores occurred primarily along the eastern margin of the High Cascades. Decreasing trends followed vegetation trends more generally (i.e. wood scores), while concentrated increases were seen in the southern Olympics, the southwestern Cascades in Washington, and the southern end of Mt. Hood National Forest.

Fish passage had the lowest mean scores and greatest variability of all the indicators (54, 55, sd = 40, 40, in 1993-2012). Scores varied considerably between provinces. The Franciscan, North Cascades, and Olympic all had mean scores greater than 60; while the West and High Cascades had the lowest scores (46, 48 and 33, 34, sd = 38, 39 and 39, 39, respectively). Broader spatial patterns predictably followed road densities, with low scores along the eastern margin of the Plan area and in the around the central valley between the Coast range and the Cascades. No declines in scores occurred and increases were highly dispersed over the Plan area.

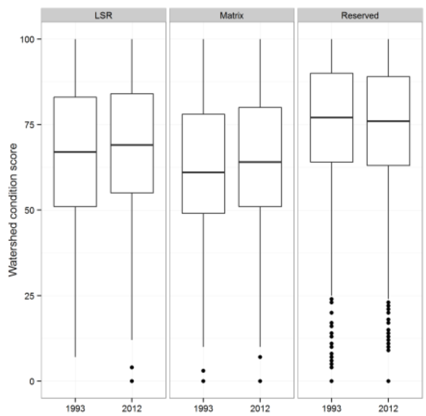
Land Use Category

There were noticeable differences in overall upslope scores between land use allocations (fig. 21): Congressionally reserved (CR) areas had the highest scores (mean = 75, 74, sd = 18,18, for 1993 and 2012, respectively), followed by late-successional reserves (LSR) (mean = 66, 68, sd = 20, 19) and matrix lands (mean = 62, 65, sd = 19, 19). Changes over the 20-year period were slight, with CR showing a very slight decline (-1, sd = 7), while LSR and matrix lands had small increases (+2 and3, sd = 8 and 6).

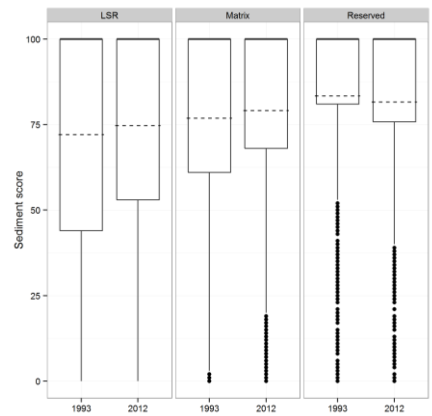
Looking at the contributing process indicators, average scores for wood, riparian and hydrology indicators followed the general pattern of resource protection levels (CR > LSR > matrix); however, for sediment and passage, reserved areas still had the highest scores but matrix scores were actually higher than LSR scores. In terms of trend, matrix lands had the greatest average increases (+3 for hydrology, riparian and wood; +2 for sediment; +1 for passage, sd = 6-10). LSR areas showed similar gains (+3 for hydrology and sediment; +2 for riparian and wood; +1 for passage, sd = 8-13). In reserved areas, only passage increased slightly (+1), while riparian showed no change and sediment and wood scores actually declined slightly (-2 and -1, sd = 7-11).

There were only very slight differences in average upslope condition scores between key and nonkey watersheds in 1993 and 2012 (mean = 68, 68 versus 67, 69, sd = 20, 19 and 20, 19, respectively), but nonkey watersheds did show a slight increase (+2, sd = 6) while key watersheds did not (fig. 22). Wood, riparian and hydrology process indictors all were higher in key watersheds (+2 to +4, sd = 19-26 in 2012), while passage and sediment scores were actually higher in nonkey watersheds (+4 and +5, sd = 40, 34). Hydrology, riparian and passage scores all increased slightly in both designations, but sediment and wood scores increased only in nonkey watersheds. None of the indicators showed an overall decline in either designation.

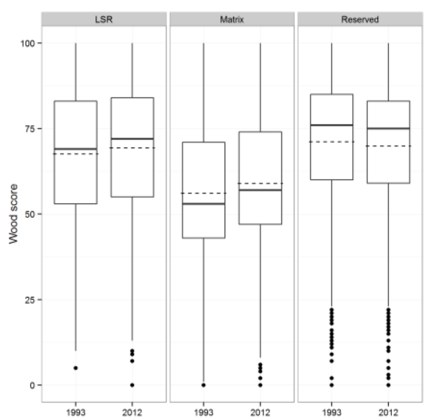
Figure 21—Upslope/riparian scores by land use allocation:(a) overall upslope/riparian scores, (b) sediment, (c) wood, (d) riparian, (e) hydrology, (f) fish passage. Mean upslope/riparian scores are represented by the dashed line, solid line represent median values.



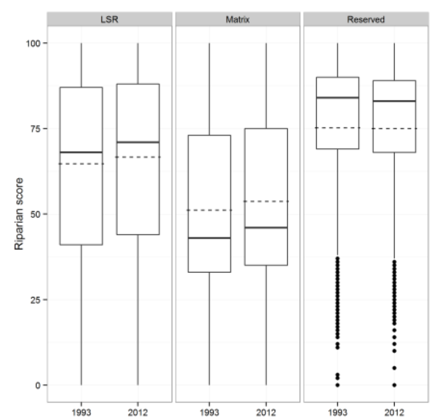
(a)



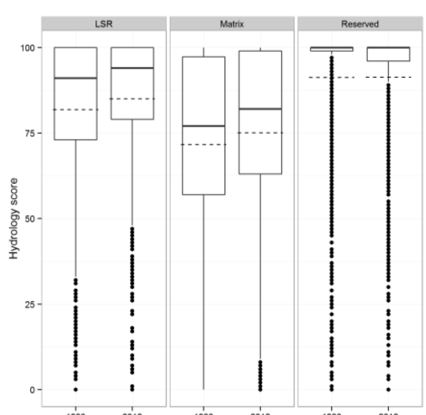
(b)



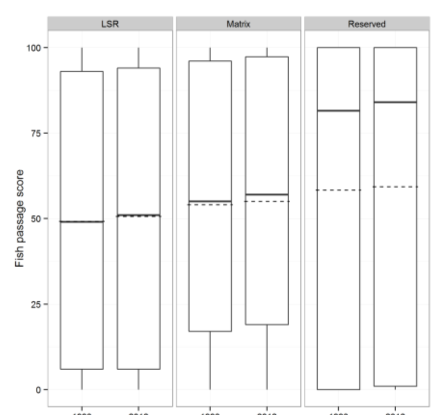
(c)



(d)

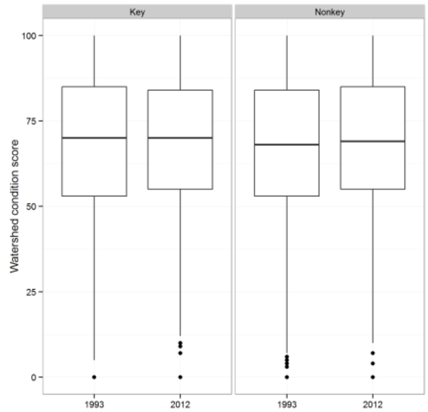


(e)

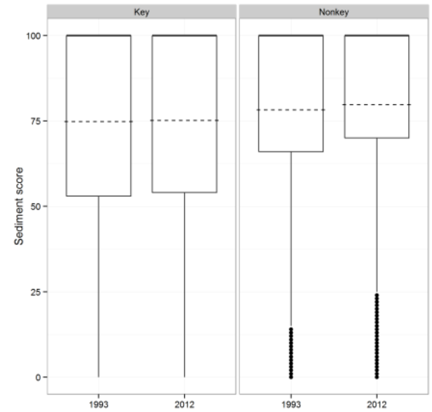


(f)

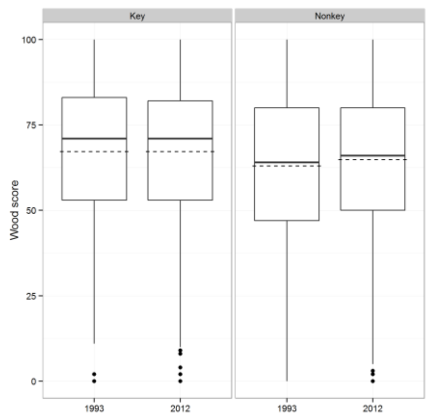
Figure 22—Upslope/riparian scores by key/nonkey watershed designation. Mean upslope/riparian scores are represented by the dashed line, solid line represent median values.



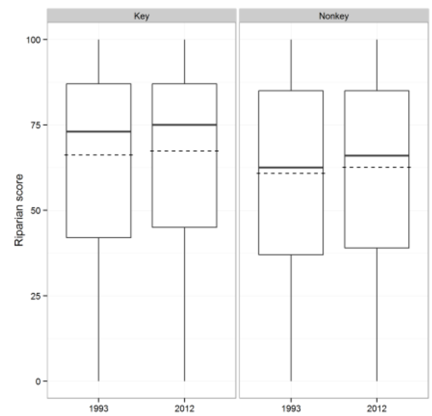
(a)



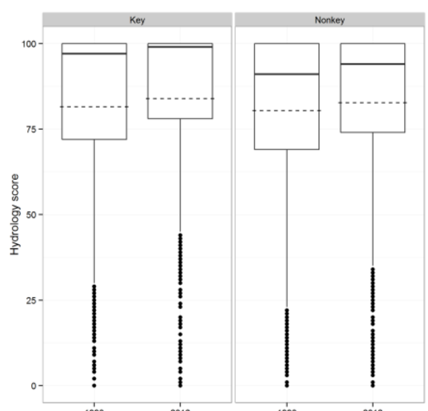
(b)



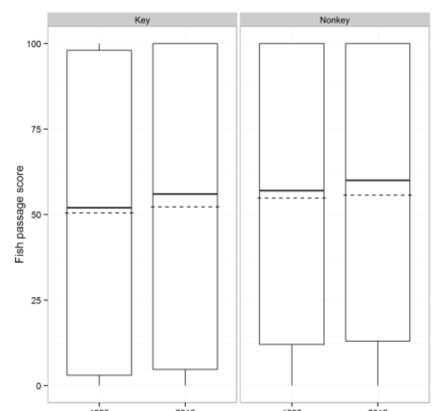
(c)



(d)



(e)



(f)

Chapter 4: Discussion

Assessment of watershed condition over such a broad area involves considerable challenges, such as an adequate level of field sampling, the quality and consistency of available GIS datasets, and the setting of meaningful assessment thresholds for scoring these data. A number of methodological advances were employed for this report since the 15-year report, including deriving reference conditions for more empirically-based evaluation of stream and upslope vegetation data, as well as the consolidation of diverse provincial models into common unified approaches for both stream and upslope assessment.

Stream Trend

Stream condition was based on three separate elements: physical habitat, macroinvertebrates, and water temperature. Changes in stream condition will likely only be detectable after multiple rotations are completed, particularly for areas that were highly impacted by disturbance prior to the inception of the Northwest Forest Plan (Reeves et al 2006). Recovery may take decades and, in fact, was not expected in fewer than three or four sampling rotations (25 years or more); we are currently in year 13 (Reeves et al 2004). The lack of a statistically significant trend in physical habitat condition may signify that these systems have not fully recovered from a historic disturbance(s) event. These results are consistent with expectation under FEMAT 1993. Completing future rotations should increase our ability to detect if any change is occurring.

Repeat sampling began in 2009 for the stream data. As of 2013, we have completed half of the second rotation. We will not be able to truly estimate any changes in watershed condition until all watersheds have been revisited in 2017. In this analysis, we assess trend in yearly status estimates rather than repeated watersheds since we have not yet completed all resampling. In the meantime, comparing the first rotation of visits (2002-2009) to the first four years of the second rotation (2010-2013) gives a general idea of current patterns. The number of watersheds visited each year does not represent the number paired for the four year comparison since not all watersheds visited during the first four years of the rotation were revisited during the second rotation and vice versa. Events such as wildfires, illegal marijuana plantations, high water events, and other safety issues warranted use of alternate watersheds.

Watersheds that scored low were primarily driven by poor pool scores, particularly during the second rotation. Wood and substrate generally increased in nearly all provinces and land use categories; particularly congressionally reserved lands which tended to be less variable than other land use categories. Since substrate scores generally increased between rotations (reduction in fines less than 6 mm throughout sites), we do not believe that fines overall were increasing but instead that this phenomenon was related to pool tail fines. Pools scores were estimated using the amount of fines (less than 2 mm) that accumulate within the downstream portion of pools (pool tailout). These are areas often used for spawning by salmon and trout. Sites within each watershed were compared to reference sites with similar gradient and bankfull width, coarse level geology, precipitation, mineral content within watersheds of similar size, and wood density (Appendix B). While, we worked toward creating a reference network of sites with similar environmental variability, we hope to include more fine level variables as they become available in future assessments. Levels of fine sediment that are higher than expected naturally can indicate disturbance in a system. In the case of pools, high levels of fines can suffocate developing eggs (McHenry et al 1994), reduce salmonid fry emergence (Lisle 1989, Kondolf 2000), and reduce habitat available for invertebrates.

In this study, we did not consider other aspects of pools in our pool score (e.g. pool frequency, pool spacing, percent of pools) for several reasons. First, pools are very difficult to consistently measure. Many monitoring programs tend to simplify their approach to quantifying pools which likely underestimates the actual number of pools (i.e. methodology that only consider channel spanning pools). Second, the mechanisms by which pools are formed vary tremendously within a stream. Some pools are formed by geological condition while others through wood inputs. While management may impact the amount of wood in a stream, thus impacting pool formation, management is unlikely to have much impact in streams where pools are geologically formed (e.g. step cascade systems). We found no indication that stream wood differed between rotations, yet pool scores did drop. Finally, not all pools are equal. We tend to think about pools in terms of how many are necessary to adequately provide habitat, yet more important to that end is whether pools have the complexity necessary to provide cover, food, and thermal refuge rather than just quantity of pools alone.

Until 2012, AREMP measured only pools that extended across the entire wetted width of the channel, and with the exception of pool tail fines, no other data were collected about each pool. We have implemented additional data collection measures to quantify smaller pools within each reach, as well as the amount, and size of wood pieces within each pool. With these additional parameters we can easily calculate the original attributes for consistency in comparison over time while also use the new components for a better estimate of pool condition in the future. As with any assessment of condition, it depends on the knowledge base at the time of development. As we refine our understanding of watershed process we are able to better assess condition (Reeves et al 2004).

Previous provincial models also included macroinvertebrates and amphibians in the overall stream condition score. In 2012, amphibian surveys were dropped from our survey program due to unreliability of presence / absence data. AREMP continues to collect macroinvertebrates but, at present, does not collect any other biological data. While macroinvertebrates are commonly used as measures of environmental health, using a single metric to describe watershed biological integrity can lead to erroneous interpretation of biological condition particularly if that estimate is to represent multiple organisms (Barbour et al 1999, Carlisle and Hawkins 2008). As such, we report macroinvertebrates separate from physical habitat condition and temperature to provide additional information to more comprehensively evaluate the system.

We detected a positive trend in the status of observed to expected macroinvertebrate scores between rotations. For macroinvertebrates, often the level of biological degradation is determined by the number of sites within an area that fall below a species loss threshold (Barbour et al 1999). In the NWFP area, macroinvertebrate biological integrity was quite high. Only about 25 percent of sites had scores below 0.6, indicating only a 40 percent difference in stream invertebrate assemblages as expected from reference. The majority of watersheds with scores below 0.6 occurred in nonkey watersheds. A consistent pattern of 40 percent difference in stream invertebrate assemblages from reference expectations may indicate that these systems have not fully recovered from some disturbance. A small percentage of scores were above 1 indicating stream invertebrate assemblages than expected. While one could consider this an area of high biological diversity, this score could also represent poor model representation, or an early warning sign that the system is moving into a state of disturbance. More investigation is needed to understand why these areas score higher than expected by reference conditions.

In prior provincial models, water temperature carried more weight than other attributes because it was only measured once for each watershed (at the lowest elevation on federal land), in contrast to the other attributes, which were averaged over 4 to 11sites. Since the placement of the thermographs was separate from the site survey and only reflected the downstream point on federal land, we felt that it does not adequately characterize the variability of temperature for an entire watershed. Here, we chose to analyze temperature separately from physical habitat condition as independent information about watershed condition. Congressional reserved (CR) lands had the fewest number of watersheds with temperatures exceeding 25C, while matrix lands had the most in both rotations. The overall mean trend was significantly negative, reflecting an improvement (decrease) in water temperatures. The negative slope indicates that overall seven day maximum average temperatures decreased between rotations in all lands. This pattern could correspond to higher levels of shading in streams due to increases in vegetation along riparian reserves (Moore et al 2005). Despite the improvement in stream temperatures, we found that some lower reaches within these watersheds do not meet desired conditions based on both National Marine Fisheries and State of Oregon standards (fig. 12). While these standards are the current guidelines for evaluating stream temperature it is important to recognize that a single threshold without environmental context is inadequate for assessment (Moore et al 2005). AREMP stream temperature assessment will continue to evolve as new assessment tools become available (e.g. NorWeST) and can serve as a baseline of spatially representative sites to evaluate trends (Arismendi et al 2012).

Upslope/riparian

Although the change in mean upslope/riparian condition scores was negligible, a clear increase was seen in areas that were more highly impacted (scores 30-60) at the beginning of the NWFP. Looking only at the mean scores, this increase was largely offset by declines in some areas which were relatively pristine at the start of the plan. These declines clearly follow the pattern of large fires during the assessment period, including the Biscuit fire in SW Oregon, the B&B complex in the central Oregon Cascades, and numerous fires along the eastern edge of the North Cascades in Washington. While we evaluate the short term effect of fire as a loss in vegetation and therefore a negative impact, this is a simplistic view. Fires are an essential component of long-term stream ecosystem dynamics (Bisson et al. 2003, Reeves et al. 1995). AREMP will continue to work towards adjusting scores to account for the positive effects of fire in future reports as the science becomes available. In terms of area, and using a conservative estimate of change (5 percent or greater), increases outweighed declines by 2:1 (16 percent versus 7 percent). The majority of these moderate positive changes occurred in areas that had previously been considered the most heavily roaded and harvested, including the southern Olympic region, and along the eastern flank of the Oregon Coast range and western flanks of the Cascade Range in Oregon and Washington. Growth in vegetation and decommissioning of roads made a considerable positive impact on the upslope/riparian condition scores in these areas.

In terms of the process indicators, sediment and fish passage scores showed the broadest range and drove scores lower in certain areas. Both of these indicators are largely driven by road densities, and so showed considerable positive changes in watersheds where roads had been decommissioned, but this effect was small in terms of Plan-wide averages. Wood production and transport, as the only process weighted more on vegetation than road metrics, did help drive the distinct spatial pattern described above for the overall upslope scores. There were broad, moderate increases in previously impacted areas and sharp declines in many areas that experienced large wildfires.

In terms of land use allocations, the general pattern of higher scores in the more protected categories still held true, but trends, although slight, continue to move these classes in opposite directions: matrix scores are increasing the most, while Congressionally reserved (CR) scores appear to be declining. Given the dynamic nature of ecosystems, this decline is not unexpected, and since many of these CR lands are at the top of the scoring range, they can only maintain condition or decrease due to disturbance events such as fire.

Stream versus Upslope/Riparian

Scores from the stream and upslope evaluations were not strictly comparable, since they are based on different types of evaluation thresholds. Stream scores were relative to reference conditions, while upslope scores were a combination of deviation from reference expectations and expert-derived impact thresholds. Further, the upslope-riparian model was assessed only for the years 1993 and 2012, while stream condition was assessed over an eight year rotating pattern; this creates temporal incongruence. The overall distributions of the scores likely reflect this difference, with the majority of stream scores falling between 40- 60, while the majority of upslope scores were above 60. In terms of land use categories, both upslope and stream condition scores generally followed a pattern consistent with the amount of allowable vegetation management (i.e., timber harvest). Mean upslope and stream physical habitat scores were highest in the congressional reserves. In both LSR and matrix lands, no statistical difference was detected for stream scores, but the upslope model rated LSR lands higher. No difference was detected in distributions for key versus nonkey watersheds based on stream scores, and upslope key watershed scores were only slightly different (±1). We are currently halfway through the second rotation of watershed visitations for the stream component of the program and as result, the reported results are incomplete until the rotation can be finished (2017).

Management Implications

AREMP was design as a broad-scale monitoring and assessment program. Broad-scale land use protections offered by the Northwest Forest Plan and the Aquatic Conservation Strategy are the bedrock of our regional efforts to restore aquatic ecosystems. Change occurs slowly, but will be realized through restoring processes over regional extents, not just features in the stream channels (Roni et al. 2002). In the meantime, active management actions (i.e. wood additions, barrier removal, etc.) are short term solutions but cannot substitute for the broader extent of passive efforts such as land use protections. As such, it should be realized that restoration actions and local level projects are planned and implemented at finer scales and can provide higher resolution data more sensitive to the local context.

At the regional level under current landscape level aggregated management practices, we did not detect any trend in stream physical habitat conditions, but we did detect improvements in macroinvertebrate score and temperature. Though we did not detect a trend in physical habitat condition, this does not imply that one does not exist, making it difficult to understand whether we are truly “maintaining” condition. Improvement in macroinvertebrates scores and temperature conditions does suggest positive shifts since the inception of the plan. However, understanding whether these positive shifts are a response to specific management actions is difficult to ascertain given that the program was designed to measure regional trends and not individual projects. For example, over the last twenty years managers have been using additions of large wood to streams. Yet, at the Northwest Forest Plan area scale, we did not detect a positive trend in large wood frequency. Project specific wood placement is unlikely to be accounted for in the AREMP sample design unless a site happens to fall within a wood placement restoration area. Further, placing wood in the stream doesn't affect the mechanism by which wood enters the stream. The process by which wood enters a stream is typically through trees from the riparian area falling into the stream. Thus, maintain a healthy riparian area capable of providing wood additions is a key process that does not change through wood additions but rather management or restoration of riparian areas.

To identify whether any relationships exist between specific landscape level management practices and stream attributes (see Hough-Snee et al 2014, and Meredith et el. 2014 as examples), we are working on analyzing existing AREMP data. Here, we are using GIS defined management actions, road density and road/stream crossing, to predict stream sediment and wood at varying spatial extents. The results of this future analysis could serve to illustrate how well typical measures of GIS defined management actions can predict stream conditions at varying spatial scales. When possible, AREMP will continue to use our regionally collected field data to focus on these types of iterative explicit hypotheses about large-scale cause effect relationships to further our understanding of management of stream systems on federal lands (Frissell et al 2014).

According to the upslope model, sediment and impacts to fish passage drove low scores over the broadest area. Sediment delivery increases with roads and vegetation loss on steeper slopes and erosion-prone geologies that are topographically positioned to deliver material to streams. As part of this analysis, AREMP has helped to build a regional landslide risk model, which better defines these vulnerable areas and could contribute to broader ongoing discussions on the refinement of riparian buffers. Based on our model, protecting riparian buffers by minimizing vegetation loss and road density are strategies which are likely to increase scores for all of the process indicators. Our estimate of fish passage was based simply on the existence of road-stream crossings, so the removal of these crossings was the only management action which will have an effect and benefits are highly conditional. The beneficial effects of numerous aquatic organism passage projects occurring over the last decade on existing roads was not accounted for. However, our metric may be improved in the near future with the completion of regional fish passage databases, which will recognize passable and semi-passable crossings, account for corrected barriers, and allow more targeted barrier removal strategies. The decommissioning of roads in riparian areas has multiple benefits according to our model by improving both the riparian scores directly and typically the sedimentation scores.

Future of Monitoring

While AREMP was designed with the goal of assessing the effectiveness of the Northwest Forest Plan as a region, we have actively worked on providing more localized reports for the individual Forest Service forests, BLM districts, and National Parks. To do this, we summarize our findings at various local levels and are able to provide customized reports. We are working to ensure that these reports can be used for monitoring requirements under any new planning rules or records of decision as the agencies move forward with revisions of forest and resource management plans within the area of the NWFP.

We can draw some management implications from this type of broad-scale monitoring and assessment, but it must be realized the intent was to inform at a landscape level. If a local unit has a management question of interest or would like a site level evaluation of stream metrics, the current physical habitat and macroinvertebrate tools are capable of being used to make site level assessments of condition. However, it is important to recognize that this is dependent on the goals of the project and the types of processes that the individuals would like to better understand. The reference network that was developed allows for assessment at the individual site against sites with similar intrinsic environmental characteristics. In particular, macroinvertebrate data collected by local units can be directly processed through the AREMP O/E tool and easily assessed for expected aquatic invertebrate assemblages. This tool is available for any organization that collects macroinvertebrate data using a minimum set of standard sampling requirements. At a minimum, these tools can help inform practitioners as to whether a site is outside the range of reference expectation. The evaluation capabilities of these tools could be used to update ACS resource monitoring objectives by evaluating sites to reference sites within the context of environmental similarity. However, additional site level information would be required as to determine cause if a site deviates from expectation.

Similarly, although the resolution of the upslope/riparian data was coarser than some locally available sources, it was well-suited for forest or district level analyses and even for initial project-level assessment. The evaluation model itself was constructed on a platform (ArcGIS) commonly used by most if not all of the agencies involved in the NWFP, so it can be easily transferred and modified to meet different assessment needs. Further work is anticipated to better integrate AREMP data and results with the USFS National Watershed Condition Class framework and efforts from other agencies. In particular, compiling the science to set well-justified evaluation criteria for different indicators is important for generating common expectations and goals across agencies. AREMP will also continue to work on improvements to specific indicators, such as landslide risk and vegetation reference conditions, which have utility beyond watershed assessment. Currently, many of the GIS sources that are used by AREMP to evaluate upslope/riparian condition are available nation-wide. Some customized datasets, such as landslide risk can be applied to areas outside the Northwest Forest Plan area. AREMP is investigating ways to extend use of the upslope/riparian model to areas throughout FS Region 6 with PACFISH/INFISH (PIBO), another program that monitors the effectiveness of the Aquatic Conservation Strategy across FS Region 6 outside the NWFP area.

Both AREMP and the PIBO have a core set of metrics and evaluate data based on a reference network framework. Further, both programs used multimetric physical stream evaluation tools that were normalized to the same scale. The two programs are currently working together to investigate ways to make integrated region-wide assessments as well as assessments for forests that are partially within the Northwest Forest Plan area. These investigations should illustrate a possible framework for broad scale monitoring for Forest Service forests served by both programs pursuing forest plan revisions. AREMP also continues to work with Western River and Stream Assessment program (WRSA), a BLM national monitoring program, to collect core metrics. In the summer 2015, we will perform a protocol overlap study that will allow us to assess differences in data collection protocols, but more importantly provide us with the framework to integrate data between programs for a BLM wide assessment of streams within the Pacific Northwest.

AREMP is already working with other organizations (Oregon Department of Water Quality and the Department of Fish and Game) as well as other federal agency monitoring programs such as PIBO and WRSA to standardize physical habitat data to increase the ability to share and develop high level categorical metrics. Integrating monitoring programs across the region will allow for a greater understanding of the condition of our aquatic systems at multiple spatial extents.

AREMP's principal purpose is to evaluate the change in aquatic ecosystems at the regional level (ie., the area of the NWFP). This is done using data collected from a statistically derived sampling program with sites distributed across the areas of interest and, more recently, with the integration of data from other sources. The former is the primary data source, and the amount of data and number of monitoring sites has continually increased since AREMP's inception. Coordination with entities that collect the latter has increased the potential usefulness of the data to AREMP and expand the amount of available data . AREMP now has a robust data set, expertise, and tools from which to assess broad-scales changes in aquatic ecosystem on federal lands and to provide insights into factors that influence aquatic ecosystems. This will be invaluable for the development and evaluation of new management and policy options for aquatic ecosystems in the Northwest Forest Plan area and elsewhere, including non-federal lands.

Metric Equivalents

Metric Equivalents

When you know:	Multiply by:	To find:
Inches (in)	2.54	Centimeters
Feet (ft)	0.305	Meters
Acres (ac)	0.405	Hectares
Square miles (mi2)	2.59	Square kilometers
Miles (mi)	1.609	Kilometers
Trees per acre	2.47	Trees per hectare
Degrees Fahrenheit	0.55(F-32)	Degrees Celsius

English Equivalents

When you know:	Multiply by:	To find:
Centimeters (cm)	0.394	Inches
Meters (m)	3.28	Feet
Hectares (ha)	2.47	Acres
Square kilometers (km2)	0.386	Square miles
Kilometers (km)	0.621	Miles
Trees per hectare	0.405	Trees per acre
Degrees Celsius (C)	1.8C + 32	Degrees Fahrenheit

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Appendix 1. Natural gradient variables used for examining the range of natural variation among reference sites.

Variables were calculated at the true watershed scale where the lowest downstream point was an individual site. Five site level variables, latitude, longitude, gradient, elevation, and stream bankfull width (m) were also analyzed. Stream density, watershed area, and conifer wood density were additional watershed level variables included in analysis.

Intrinsic characteristics	Source	Unit
2000-2009 mean annual precipitation	a	mm
2000-2009 mean monthly temperature	a	°C
Mean annual air temperature	a	°C
Maximum annual air temperature	a	°C
Minimum annual air temperature	a	°C
Mean annual precipitation	a	mm/100
Maximum monthly precipitation	a	mm/100
Minimum monthly precipitation	a	mm/100
1994-2006 annual weighted atmospheric mean Calcium	c	mg/L
1994-2006 annual weighted atmospheric mean Magnesium	c	mg/L
1994-2006 annual weighted atmospheric mean SO4	c	mg/L
1961-1990 annual mean number of wet days	c	# days
1994-2006 annual mean maximum number of wet days	c	# days
Calcite mineral content	b	%
Magnesium oxide mineral content	b	%
Nitrogenous mineral content	b	%
Phosphorus mineral content	b	%
Sulphur mineral content	b	%
Percent gneiss geology in catchment	b	%
Percent granitic geology in catchment	b	%
Percent mafic/ultramafic geology in catchment	b	%
Percent quaternary, geology in catchment	b	%
Percent sedimentary geology in catchment	b	%
Percent volcanicgeology in catchment	b	%
Predicted reference condition conductivity	d	uS/cm
Catchment mean unconfined Compressive Strength	e	MPa
Catchment mean bulk density	e	g/cm^3
Catchment mean soil erodability (K) factor	e	None
Catchment mean soil permeability	e	In/hour
Catchment mean log geometric mean hydraulic conductivity	e	10^{-6} m/s

[a] PRISM http://www.prism.oregonstate.edu

[b] Olson and Hawkins (in Review)

[c] National Atmospheric Deposition Program National Trends Network http://nadp.sws.uiuc.edu/ntn/

[d] Olson and Hawkins, 2012

[e] Baker et al. 2003. Olson and Hawkins (in Review)

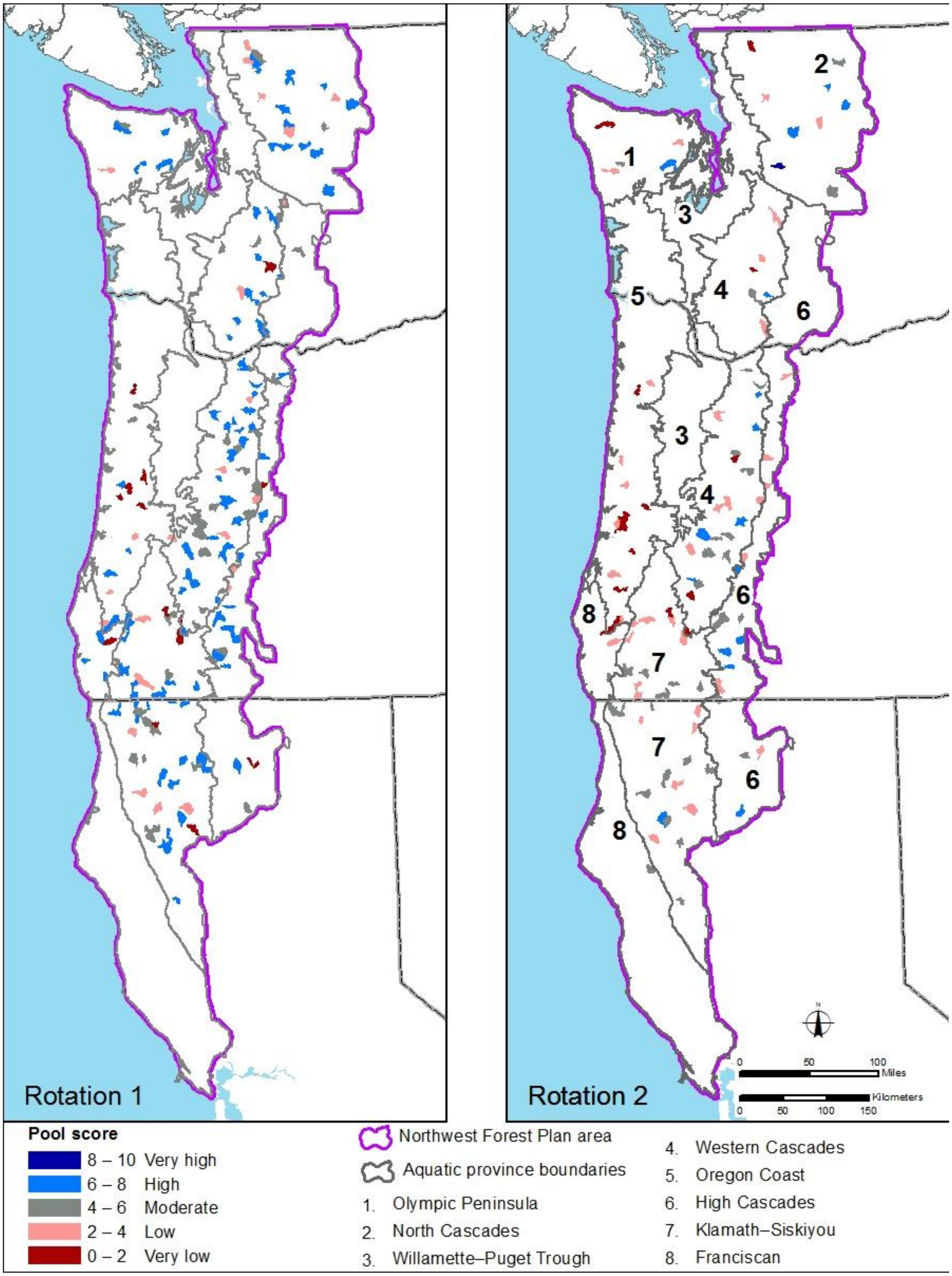
Appendix 2. Natural intrinsic characteristic variables used to define nearest neighbor reference network

All natural gradient variables (Appendix 1) were included in nearest neighbor analysis; however, the intrinsic characteristic variables in this table represent those that were best able to define similarity among sites for each individual attribute. K represents the number of neighbors (network of reference sites).

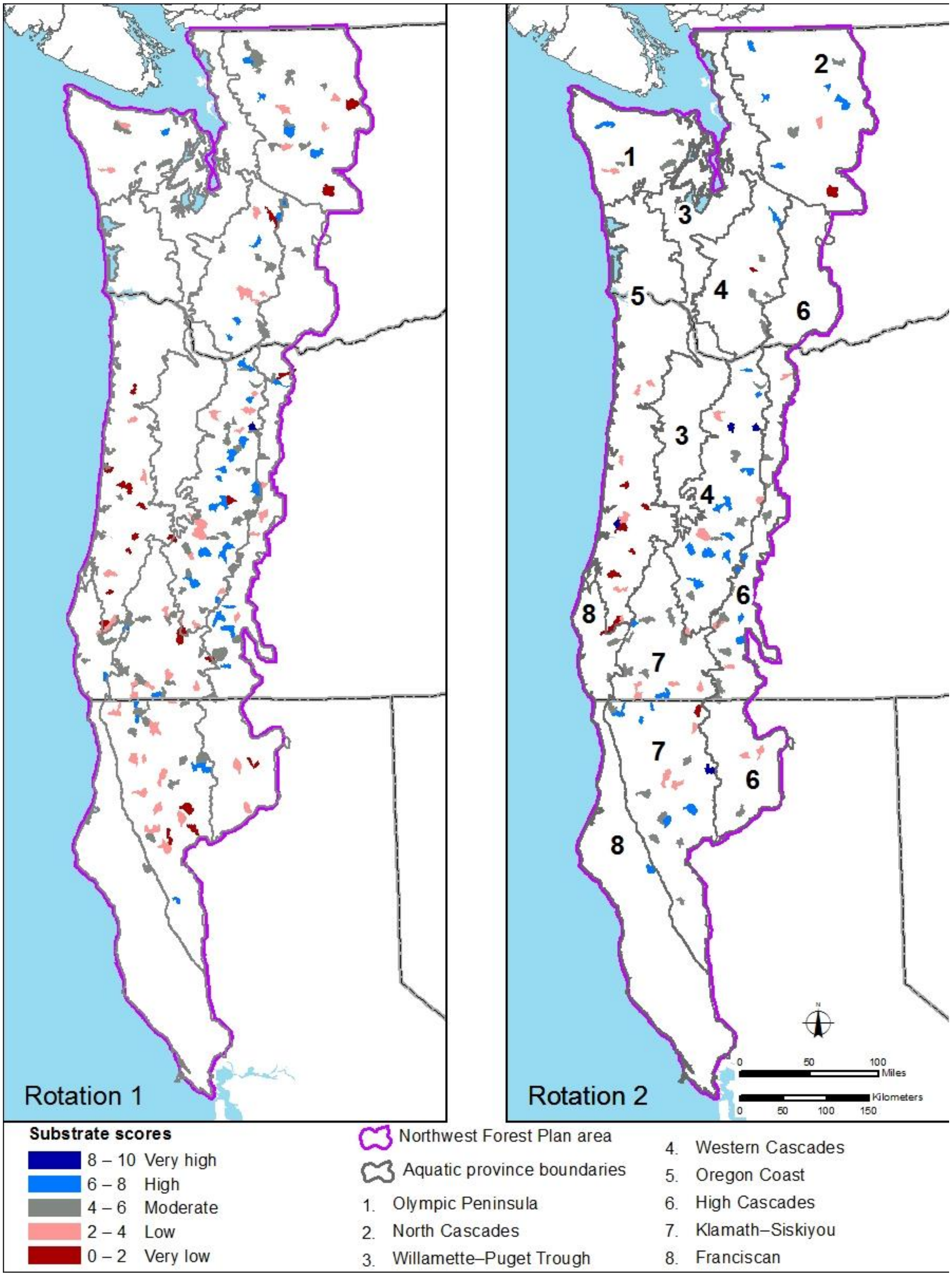
Attribute	Intrinsic characteristics	K
% pool tail fines	gradient, percent sedimentary, stream density, wood density, watershed area, mean precipitation 2000-2009, mean soil permeability mean bankful width, phosphorus mineral content maximum annual air temperature, predicted reference condition conductivity	8
% fines > 6mm	gradient, percent sedimentary, site elevation, 1994-2006 annual weighted atmospheric mean calcium, stream density, watershed area, mean bankful width	5
Wood 12”x 25’	longitude, mean bankfull width, predicted reference condition conductivity, watershed area	7
Wood 18”x 25’	longitude, mean bankfull width, watershed area, mean log geometric mean hydraulic conductivity	6

Appendix 3: Spatial distribution maps of stream model components by rotation.

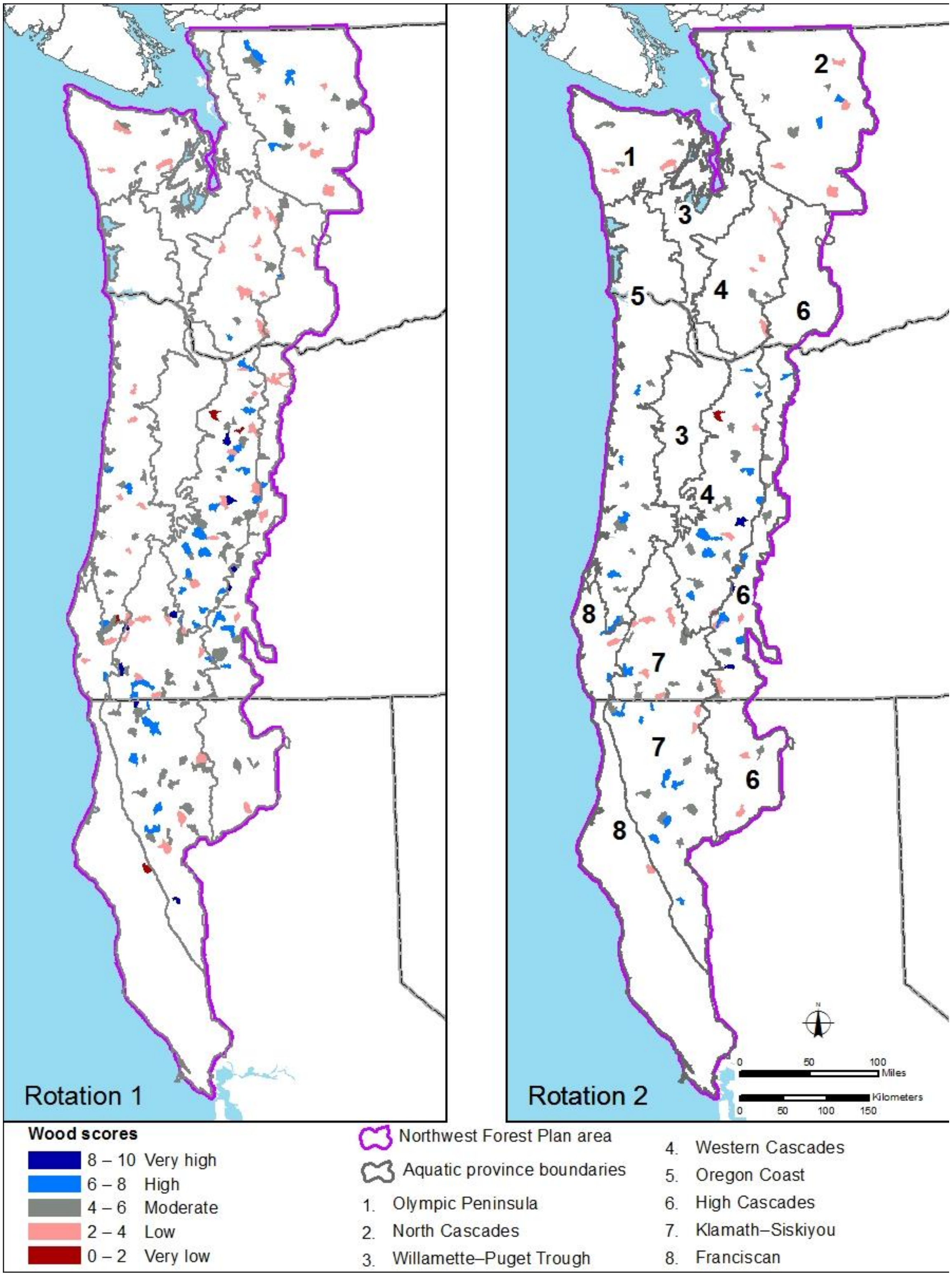
Pool status score map.



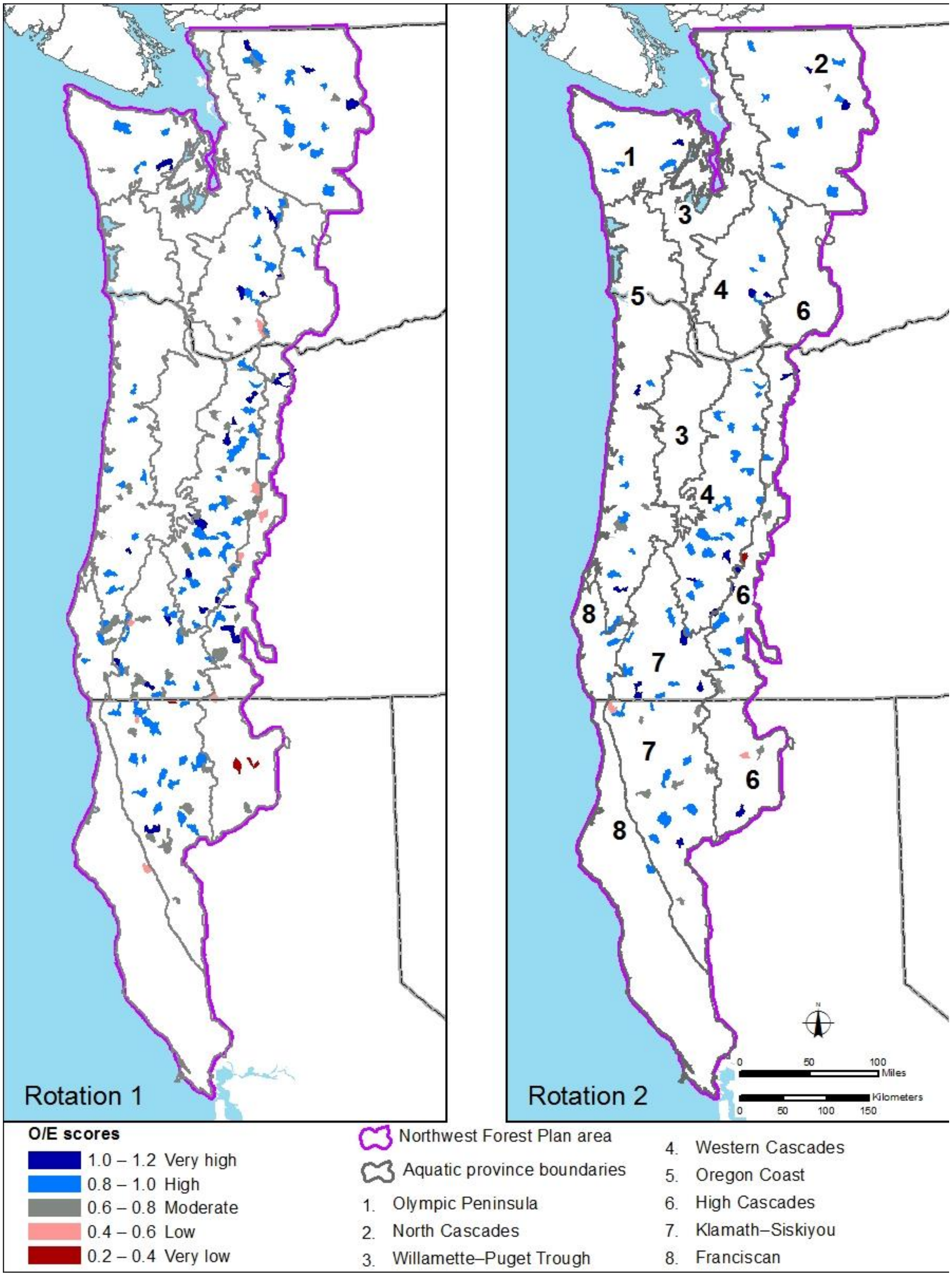
Substrate status score map.



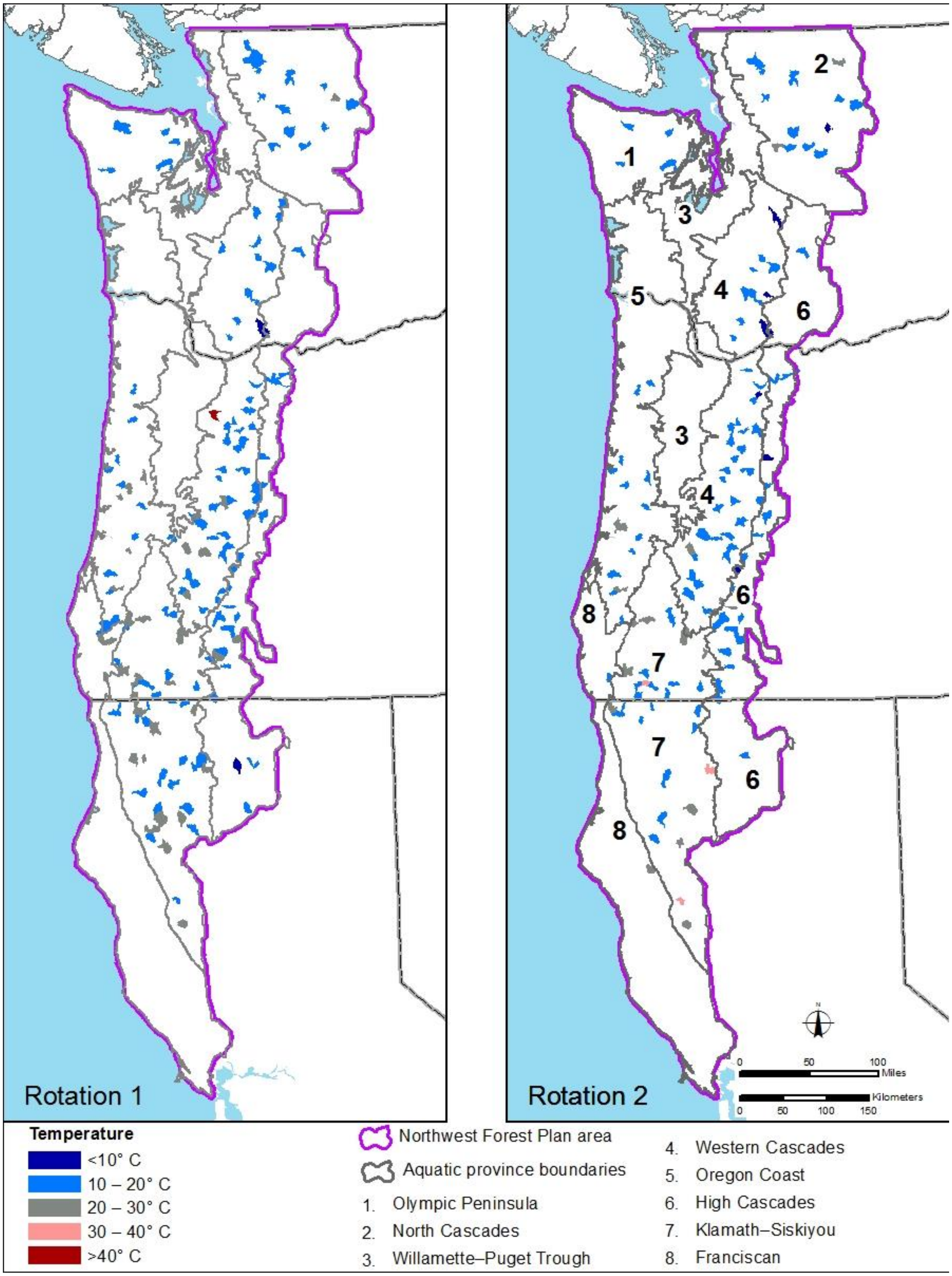
Wood status score map.



Macroinvertebrate status score map.

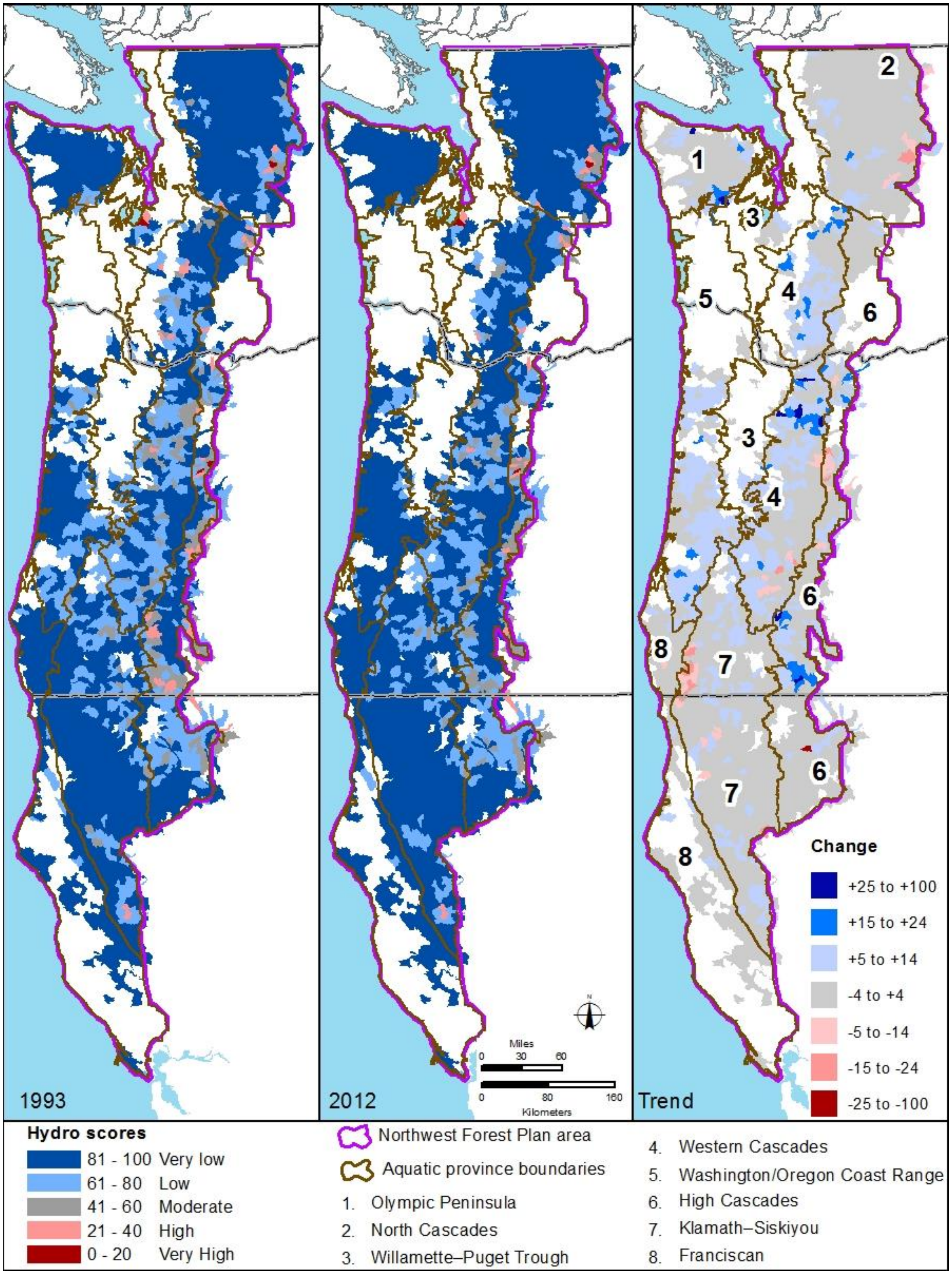


Temperature status score map.

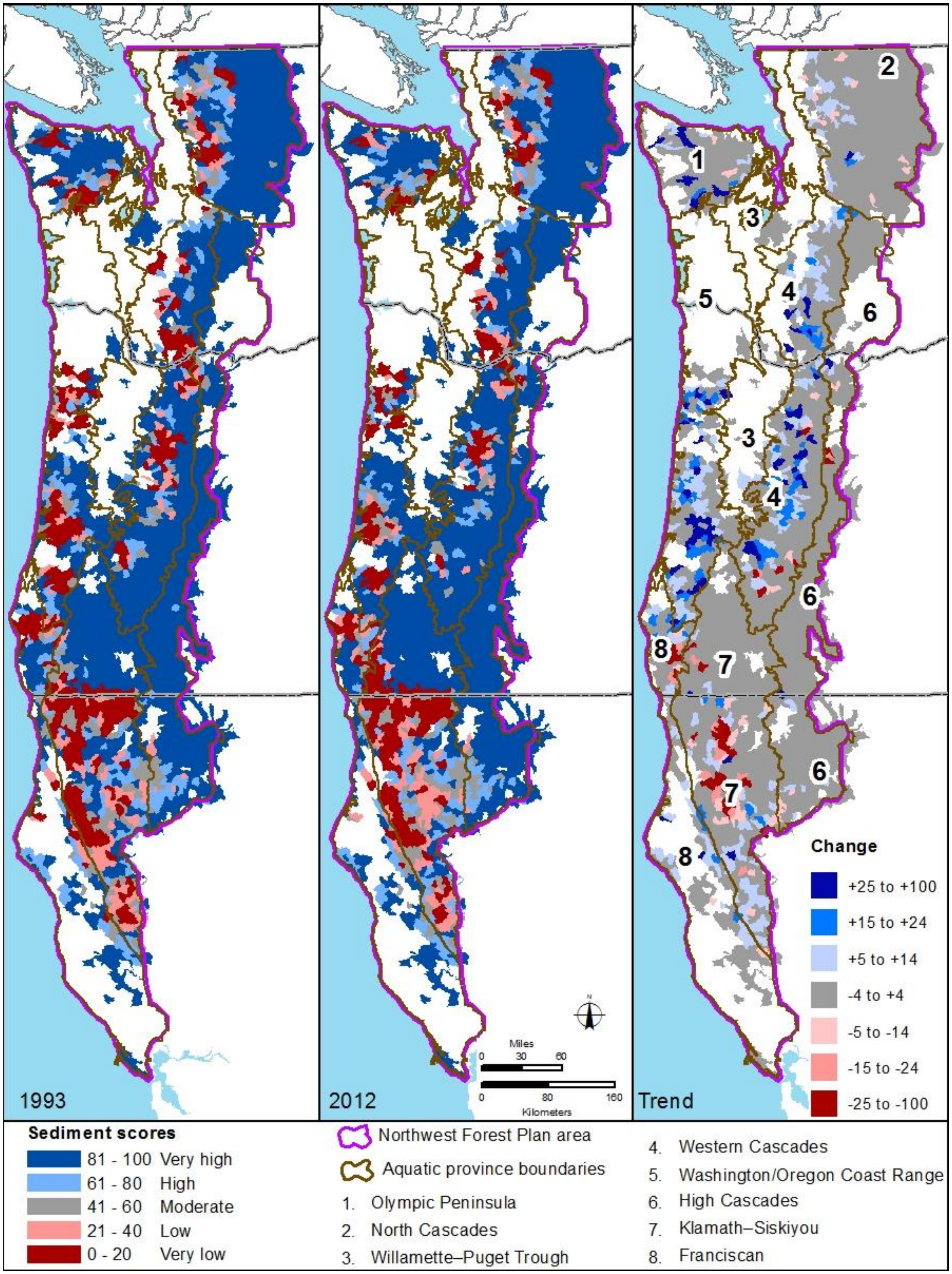


Appendix 4: Upslope/riparian process indicators scores status and trend maps

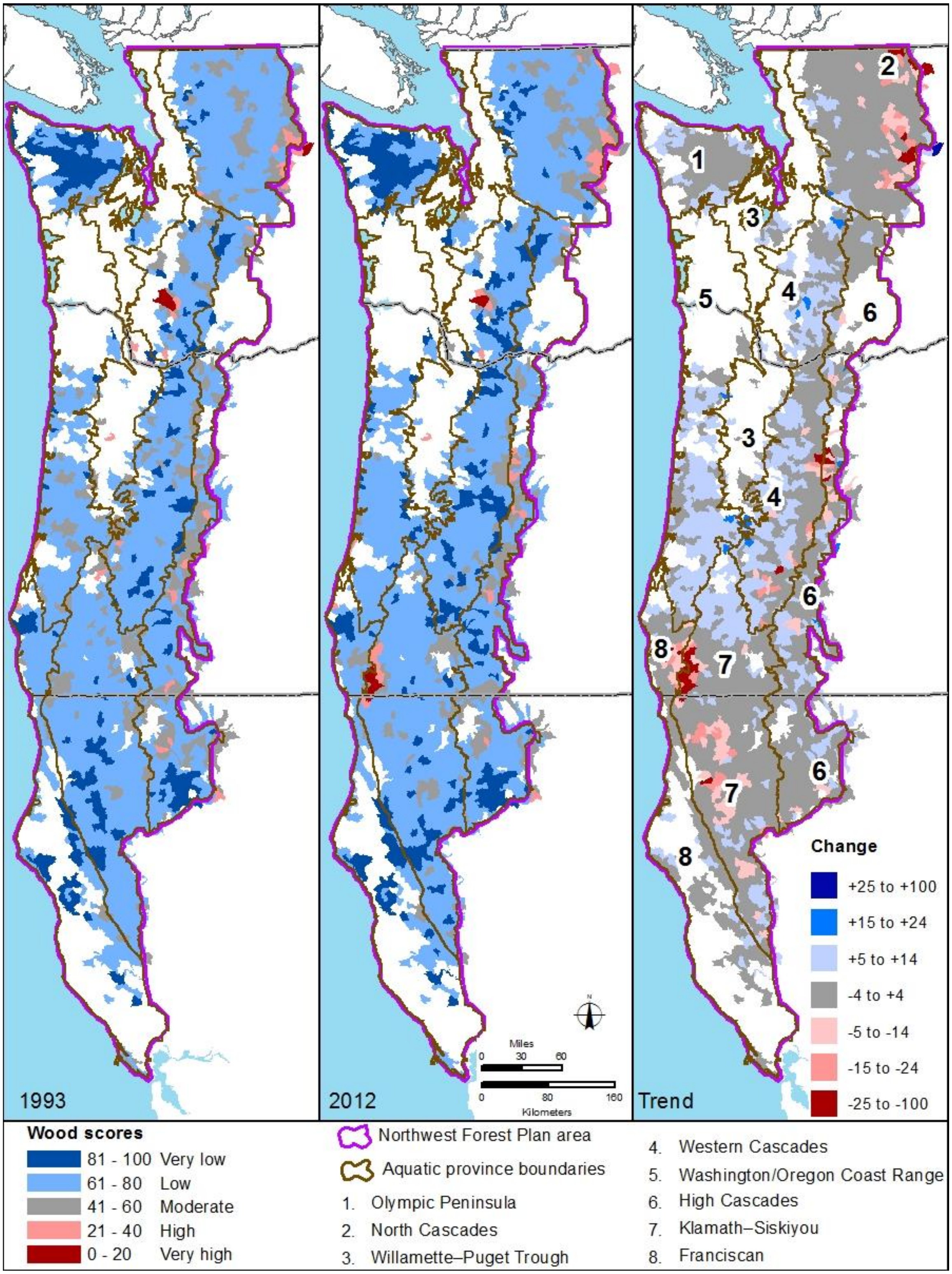
Hydrology status and trend score map.



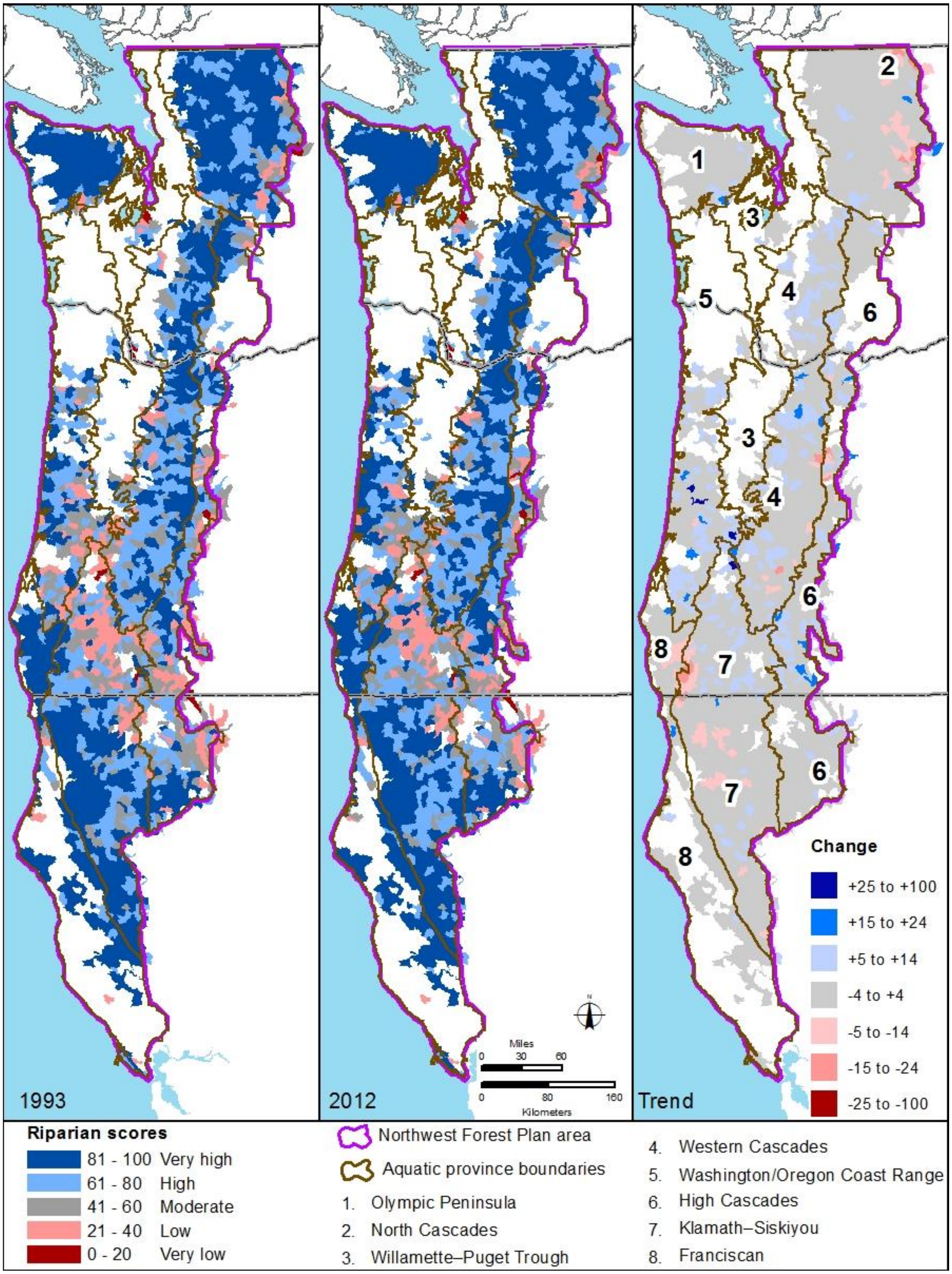
Sediment status and trend score map.



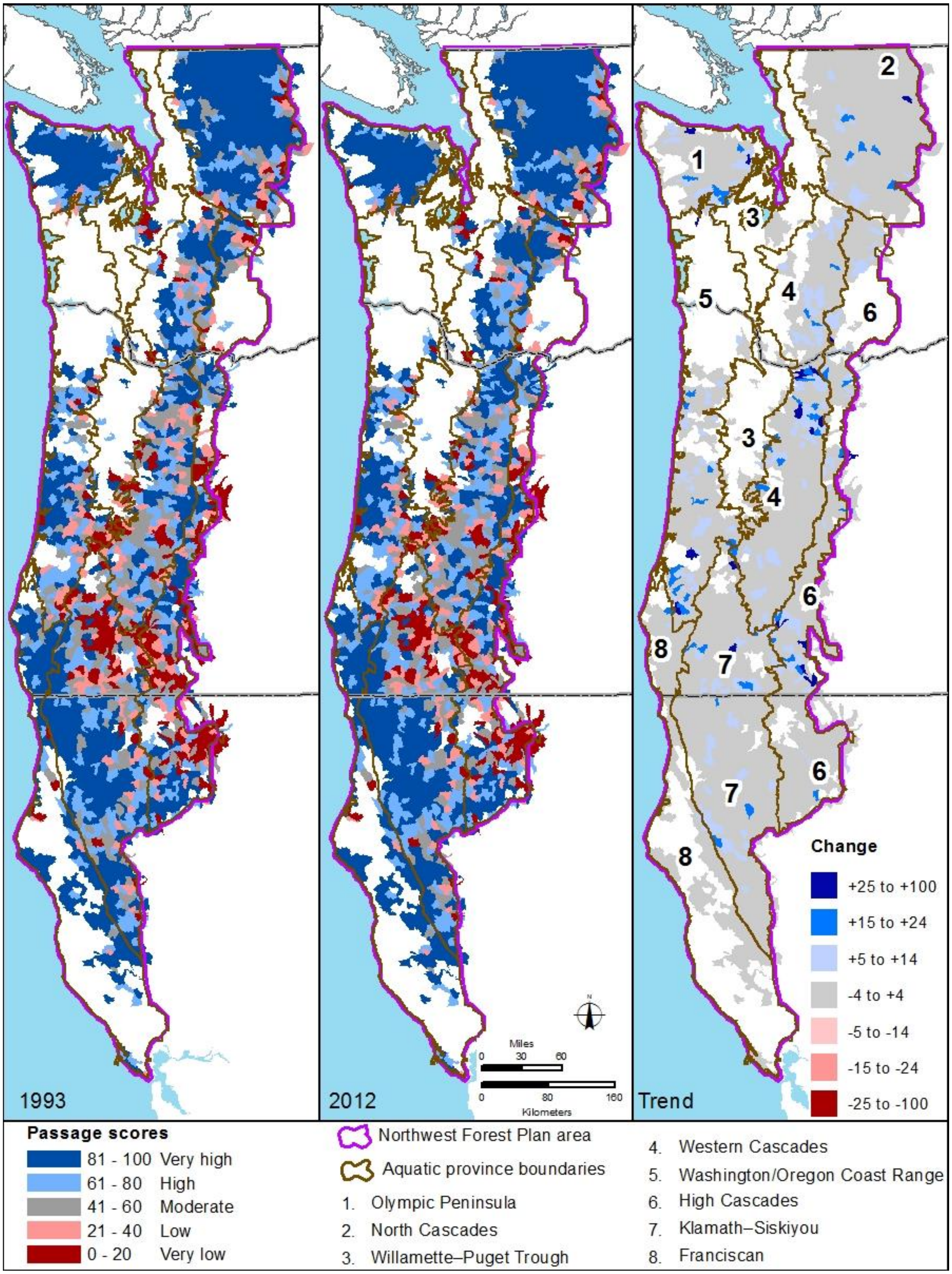
Wood delivery status and trend score map.



Riparian status and trend score map.



Fish passage status and trend score map.



Appendix 5: Contact Information

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