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Research

Patterns of riparian policy standards in riverscapes of the Oregon Coast Range

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ABSTRACT. A riverscape perspective considers the ecological and social landscape of the river and its valley. In this context, we examined the spatial arrangement of protective policies for river networks. Riparian land-management standards are policy efforts that explicitly restrict certain management actions, e.g., timber harvest or land clearing, in stream-adjacent lands in order to protect water quality and aquatic habitat. In western Oregon, USA, management standards for riparian lands vary across federal, state, and private landownerships and land uses, projecting a patchwork of protective efforts across the landscape. The resulting variability in protection can complicate coordinated recovery efforts for threatened and endangered aquatic organisms, including migratory coho salmon (*Oncorhynchus kisutch*), that rely on stream habitats throughout the river network. Using a geographic information system, we quantified the spatial distribution of riparian management standards at multiple spatial extents: across the entire Oregon Coast Range, within the region's 84 HUC-10 watersheds, and in stream segments with high intrinsic potential to support coho salmon habitat. We found that the proportion of streams falling under protective efforts varied across watersheds in the region. In particular, watersheds containing streams of high intrinsic potential to support coho salmon habitat were associated with gaps in protective standards. By comparing the policy landscape to the biophysical landscape, our approach provides a novel framework for examining the spatial overlay of social and ecological concerns, and has direct relevance to assessments of population-scale restoration and recovery efforts.

Key Words: *coho salmon recovery; ecosystem management; fragmentation; Pacific Northwest; protective policy efforts; riparian management*

INTRODUCTION

Maintaining riparian vegetation allows for multiple processes important to the formation, availability, and arrangement of instream habitats (Naiman and Décamps 1997, Tabacchi et al. 1998, Richardson et al. 2005). To protect water quality and instream habitat conditions, riparian-management standards are developed by state, federal, and local entities to specifically restrict certain management actions, for example, timber harvest or thinning, and often include the adoption of buffers that maintain streamside vegetation (Lee et al. 2004, Richardson et al. 2012). Linkages between upstream land use and downstream habitat make assessments of riparian protection at a riverscape scale informative for conservation planning across management entities (Fausch et al. 2002, Wiens 2002, Allan 2004). Riverscape-scale studies seek to comprehensively assess biophysical processes throughout river systems, from estuary to headwaters, rather than in isolated segments or reaches. A riverscape approach is thus useful for characterizing and evaluating the distribution of specific riparian land-management standards across broad geographic extents of diverse landownerships and land uses.

Though the riverscape concept has informed new ideas in ecological research (Falke et al. 2013, Pichon et al. 2016), its foundation in the broader field of landscape ecology also included social considerations of land-use policy and management (Wiens 2002). The current U.S. policy framework for resource management divides ecosystems into individual components, e.g., air, water, land, or individual species, each managed by numerous state and federal agencies with varied management goals (Marcus 1980, Wood 2013). This bureaucratic structure creates a fragmented approach to ecosystem management, requiring considerable coordination to develop integrated management strategies at the scale of the river basin (Rabe 1986, De Groot et al. 2010, Vogel 2012, Flitcroft et al. 2018). In coastal Oregon, state and federal agencies create separate rules for riparian land management based on jurisdiction, resulting in a range of accepted standards for riparian condition (Boisjolie et al. 2017). The spatial manifestation of varied policy efforts results in a "policy landscape" of diverse protective efforts, influencing ecological conditions and representing an important human imprint on the riverscape (Fig. 1).

The fragmentation of aquatic ecosystems due to diminished habitat (Bradford and Irvine 2000, Fagan 2002, Fullerton et al. 2010) and variable riparian standards (Adams 2007, Olson et al. 2007) is a primary concern in the management of anadromous fishes such as Pacific salmon (*Oncorhynchus* spp.) (NMFS 2016*a*), and ultimately for the maintenance of resilient social-ecological systems (Bottom et al. 2009, Reeves and Duncan 2009). Salmonids are highly mobile species that require diverse habitats throughout the river network to complete their life cycle (Flitcroft et al. 2012, 2014). In the journey from their natal stream to the ocean and back, these fishes must navigate a mosaic of landownerships and jurisdictions with differing riparian protections (Wilkinson 1993). The variability of policy measures along the river network includes key discontinuities in the protection of river corridors (Spies et al. 2007, Boisjolie et al. 2017). Gaps in protective standards have led to recent concerns that current policies may not provide adequate protection for aquatic ecosystems in the region (NOAA and EPA 2015, NMFS 2016*a, b*). Federal regulators continue to tie the efficacy of recovery for threatened and endangered fish species to adjacent

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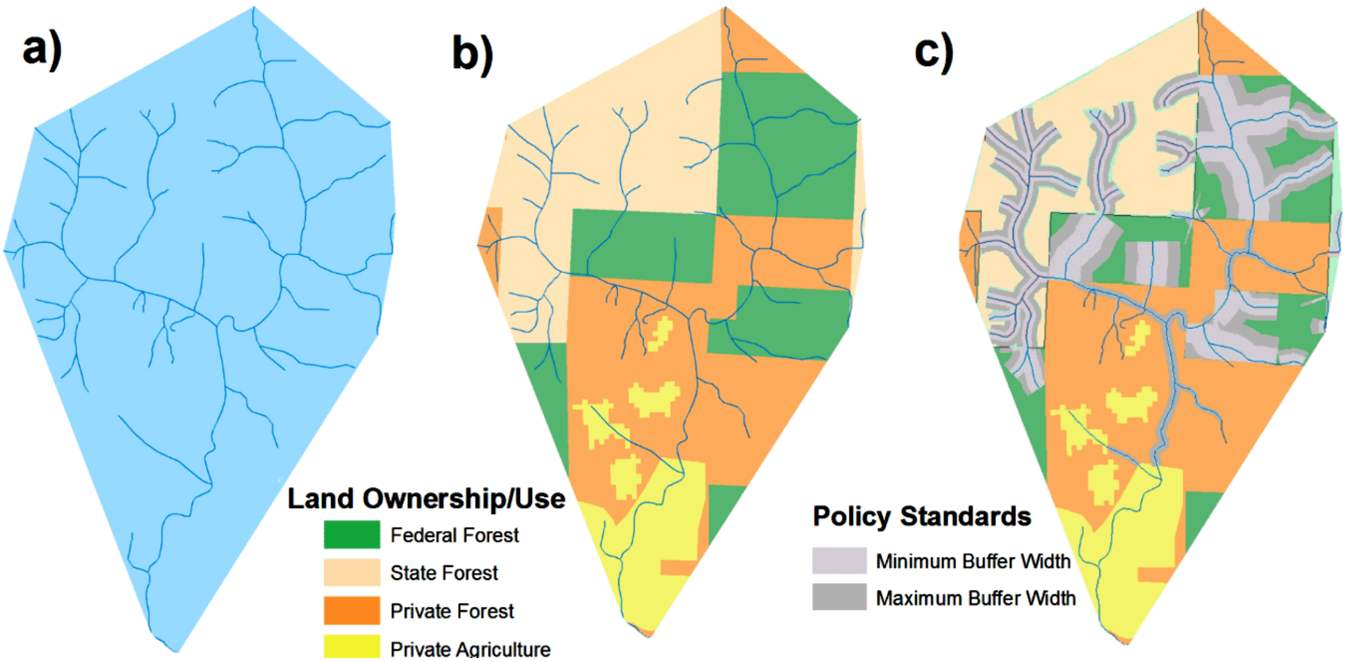
Fig. 1. Conceptual illustration of how the spatial distribution of riparian-management policies manifests as a “policy landscape” of variable standards influencing the structure and function of ecosystems. (a) An example riverscape, encompassing the river network and its valley; (b) the fragmentation of management efforts based on landownership and land uses; and (c) the resulting variability in mandatory riparian buffers, or stream-adjacent lands of specific protective standards, across managing agencies. The illustration is a general example of jurisdictional patterns of HUC-10 watersheds in coastal Oregon.

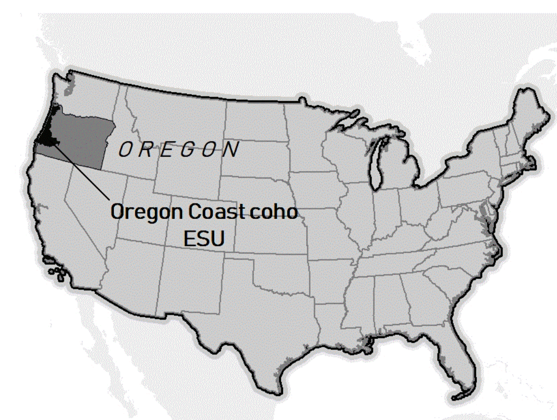


land uses, placing a strong emphasis on a cumulative policy approach to riparian land management in the region.

Concerns over the fragmentation inherent in current policy approaches have only rarely been followed by an empirical assessment of the way these various protective efforts are distributed across the landscape (Fremier et al. 2015). To help fill this gap, we investigated patterns created by variable riparian-management standards along streams throughout the Oregon Coastal Coho Evolutionarily Significant Unit (OCC-ESU) for threatened coho salmon (*Oncorhynchus kisutch*) and the unit’s 84 HUC-10 watersheds (Fig. 2; Weitkamp et al. 1995). We delineated stream segments based on management jurisdiction in a geographic information system (GIS), and overlaid the location of stream reaches with intrinsic potential to support habitat for coho salmon (Burnett et al. 2003). To quantify the spatial distribution of policies among watersheds and streams of interest, we calculated and compared the proportion of stream length subject to each set of standards at varying spatial extents, for the entire ESU, across watersheds, and for streams of specific management concern. Our research questions of interest were the following:

1. Among watersheds in the OCC-ESU, what is the spatial distribution of stream segments managed under the various riparian standards?
2. What proportion of stream segments with high intrinsic potential (hereafter, “IP”) to support coho salmon are managed under each of the four major riparian-management policies applied in the region?
3. Are policy standards for riparian management similar in watersheds containing high-IP streams compared with watersheds that do not contain such streams?

Fig. 2. The study area is the Oregon Coastal Coho Evolutionarily Significant Unit in western Oregon, USA.



METHODS

Study area

The National Marine Fisheries Service (NMFS) designated the OCC-ESU as a distinct management region for the purposes of conservation and recovery of coho salmon after the species was listed as federally threatened under the Endangered Species Act (NMFS 1998, 2011). The OCC-ESU covers coastal drainages in western Oregon from the mouth of the Columbia River southward to Cape Blanco (Fig. 2). Rivers in the region originate in the Oregon Coast Range, with the exception of portions of the Umpqua River that drain from the Cascade Range. Much of the region is mountainous, with occasional interior valleys and areas of coastal plain; elevations range 0–1250 m. The climate of the OCC-ESU is temperate maritime, with moderate, wet winters and cool, dry summers (Franklin and Dyrness 1973). Peak streamflows occur during winter rainstorms, and base-flow conditions occur from July to October. The vegetation of the region is highly productive conifer forest, characterized by a mix of Douglas-fir (*Pseudotsuga menziesii*), western hemlock (*Tsuga heterophylla*), western redcedar (*Thuja plicata*), and Sitka spruce (*Picea sitchensis*). In addition to coho salmon, four other salmonid species are found in the OCC-ESU in numbers relevant for fisheries management, including steelhead/rainbow trout (*Oncorhynchus mykiss*), cutthroat trout (*O. clarkii*), Chinook salmon (*O. tschawytscha*), and chum salmon (*O. keta*). The region is a complex mosaic of federal, state, and private landownerships, with land uses generally characterized as forest, agriculture, or urban (Spies et al. 2007).

Riparian-management policies

Box 1:

Overview of protective standards in the four major riparian land-management policies of the Oregon Coastal Coho ESU.

Northwest Forest Plan (NWFP)
Regulatory approach: Prescriptive
Goals: Halt declines in watershed condition; protect watersheds containing high-quality water, habitat, and healthy fish populations. Develop a network of functioning watersheds that support populations of aquatic and riparian-dependent organisms (USDA and USDI 1994).
Stream attributes: Fish-bearing, streamflow duration, site-potential tree-height.
Land-management standards: Direct land-use activities based on conservation goals, allow occasional feathering, salvage, and thinning.

State Forest Management Plan (SFMP)
Regulatory approach: Prescriptive
Goals: Along fish-bearing and large nonfish-bearing streams: retain vegetation so that riparian and aquatic habitat conditions become similar to those associated with mature forest stands. Along small nonfish-bearing streams: retain vegetation sufficient to support important functions and processes that contribute to properly functioning conditions in downstream fish-bearing streams (ODF 2010).
Stream attributes: Fish-bearing, streamflow duration, mean annual flow, material transport potential.
Land-management standards: Specify retention requirements for live and dead trees, no-cut buffers.

Forest Practices Administrative Rules (FPAR)
Regulatory approach: Prescriptive
Goals: Provide resource protection during timber operations adjacent to and within streams so that, while continuing to grow and harvest trees, the protection goals for fish, wildlife, and water quality are met (Oregon Secretary of State:§ 629-635-0100 (7) 2017).
Stream attributes: Fish-bearing, mean annual flow, domestic water use, streamflow duration.
Land-management standards: Specify retention requirements for live and dead trees, no-cut buffers.

Agricultural Water Quality Management Plan (AWQMP)
Regulatory approach: Outcome-based
Goals: To prevent and control water pollution from agricultural activities and to achieve applicable water-quality standards (Oregon State Legislature 2017:§ 568.900-933).
Stream attributes: Standards implemented voluntarily or because of repeated violation of water-quality standards.
Land-management standards: None.

We used the classification of policy protection developed in a review by Boisjolie et al. (2017) as the basis for this quantitative comparison of the different policy approaches to riparian management throughout the OCC-ESU. The review identified four major riparian land-management policies with jurisdictions related to landownership and use (see Box 1):

1. The Aquatic Conservation Strategy of the Northwest Forest Plan (NWFP) for federal forests (USDA and USDI 1994),
2. Oregon State Forest Management Plans (SFMPs) for state forests (ODF 2010),
3. Oregon Forest Practices Administrative Rules (FPAR) for private forests (Oregon Secretary of State:§ 629.600-670 2017),
4. Oregon Agricultural Water Quality Management Plans (AWQMPs) for agricultural lands (ODA 2012).

Boisjolie et al. (2017) found that AWQMPs do not require a vegetated riparian buffer on stream-adjacent land for any stream type. The AWQMPs recommend management practices and rely on voluntary adoption. Agency intervention is limited to violations of water quality standards, rather than riparian condition. Thus, agricultural lands are the only major land jurisdiction that relies on outcome-based policy standards, which are intended to respond to, rather than prevent, pollution. The NWFP, SFMPs, and FPAR are prescriptive policy approaches that specify buffer widths for stream-side vegetation and restrict management actions within these areas. Management standards and buffer widths vary by stream context, with specific standards based on stream attributes of annual streamflow volume, streamflow duration, fish presence, and domestic water use (Box 1).

Under the four major riparian-management policies of the OCC-ESU, 25 categories of standards were identified, containing different specific requirements and corresponding buffer widths (see Boisjolie et al. 2017 for a detailed comparison of these standards). Across all policies, buffer-width designations vary from 0 to an estimated 152 m from the stream-channel edge (Table

Table 1. Comparison of vegetated buffer-width requirements across the four major policies specifying standards for riparian lands in the Oregon Coastal Coho Evolutionarily Significant Unit.

Policy	Applicable lands	Buffer requirements	Buffer width (m)
Northwest Forest Plan (NWFP)	Federal forests	Prescribed	30–152
State Forest Management Plan (SFMP)	Oregon state forests	Prescribed	7.6–52
Forest Practices Administrative Rules (FPAR)	Private industrial and non-industrial forests	Prescribed	0–30.5
Agricultural Water Quality Management Plans (AWQMP)	Agricultural lands	None	0

1). The buffer widths include protective gradients, where more management restrictions are imposed on lands closest to streams and fewer on lands further from streams.

Geospatial datasets

Oregon Coastal Coho ESU and HUC-10 watersheds
The Oregon Coastal Coho ESU was delineated in a GIS by the National Oceanic and Atmospheric Administration (NOAA [date unknown]). The 84 hydrologic units (10-digit Hydrologic Unit Codes [HUC-10]) that correspond to watersheds in the OCC-ESU were delineated by the U.S. Department of Agriculture (USDA) Natural Resource Conservation Service (NRCS), and those spatial data were acquired for this project from the Watershed Boundary Dataset (USDA NRCS 2013).

Jurisdiction (landownership and land use)
We obtained information on jurisdiction based on landownership and land use from the Oregon Department of Fish and Wildlife (ODFW 2005; hereafter referred to as the "ODFW layer"). This dataset includes four base layers: records of public ownership, private ownership, U.S. Geological Survey land cover, and zoning. These base layers were combined by ODFW to identify six land uses, including federal forest, state forest, private forests, agricultural lands, and other (ODFW 2005).

Hydrographic data
The Oregon Forest Practices Administrative Rules require the Oregon Department of Forestry (ODF) to "maintain a map showing the classification of waters of the state... For streams, the maps shall indicate the size class and, when known, extent of fish use and domestic water use classification" (Oregon Secretary of State:§ 629-635-0210 2017). The ODF statewide GIS hydrography (1:24,000) is used by the agency as the official record for stream classification and riparian protection (hereafter referred to as the "ODF stream layer"). The layer was derived from a variety of sources, including federal (Bureau of Land Management, U.S. Forest Service, U.S. Geological Survey) and state agencies (Oregon Department of Forestry). Numerous methods for stream delineation were used to create the dataset, including cartographic feature files, digital elevation models, global positioning system, and heads-up digitizing. The ODF stream layer includes information on fish-bearing status, streamflow duration, stream size, and domestic water use designations for individual stream segments. These data are intended for interagency data exchange, digital analysis, cartographic display, and fish-presence documentation (ODF 2007).

Intrinsic potential (IP)
Intrinsic potential is an estimate of the capability of a stream segment to provide suitable habitat for a fish species. For coho salmon, IP is based on channel gradient, valley constraint, and mean annual discharge (Burnett et al. 2003). The IP approach uses index curves converted from stream-attribute values (Van Horne and Wiens 1991). These values range from zero to one. Larger values specify streams with a higher potential to provide high-quality habitat for coho salmon. Streams with high-IP values (> 0.75) have been positively correlated with distribution of juvenile coho salmon in coastal Oregon (Flitcroft et al. 2014).

From Terrain Works (http://www.terrainworks.com/terrainworks), we acquired a stream layer containing coho salmon IP values for stream reaches in Oregon, developed in the ESRI ArcGIS tool Netmap from 10-m DEMs. We used the field calculator tool in ArcMap (ESRI 2011) to delineate stream segments with high IP, identified as stream segments where IP values were at least 0.8 (hereafter, "high-IP streams"; Burnett et al. 2003). We further defined streams with high IP for coho salmon based on a maximum downstream gradient threshold (less than or equal to 0.07 slope), and removed any stream segments upstream of a natural barrier to fish passage, based on a review of the Oregon Bioscience Framework Fish Passage dataset (ODFW 2015).

Geospatial analysis

Research question 1: Spatial distribution of stream segments under the various riparian standards
Using the ODF stream layer in conjunction with the ODFW layer at the stream-segment scale (20–200 m), we mapped riparian-management jurisdiction with ESRI ArcGIS 10.1. We delineated streams based on categories of riparian management, including agency jurisdiction, fish-bearing status, streamflow duration, stream size, and domestic water-use designations. For streamflow duration and domestic-use attributes, we made information consistent to more accurately place stream segments in the appropriate policy categories (for further information on methods used in this categorization see Boisjolie 2016). To allow us to quantify the spatial extent of standards across the OCC-ESU and compare among its 84 HUC-10 watersheds, we measured and summed the length of stream segments falling under each policy and calculated the proportion of the stream length in each HUC-10 watershed. Additionally, we calculated the percent of streams within each key stream-attribute designation, e.g., total % of: fish-bearing streams, nonfish-bearing streams, etc.

Research question 2: Proportion of high-IP stream reaches managed under each of the four major riparian-management *policies*

Differences in hydrographic line-work led to spatial inconsistencies between the ODF stream layer attributed with riparian-management standards and the NetMap layer that modeled high IP for coho salmon. Evaluating policy patterns in areas of high IP required transposing information from NetMap onto the ODF stream layer. In order to ensure accuracy, we used a heads-up digitizing approach, combined with 1-m buffer and intersect tools provided in ArcGIS 10.1 (Goodchild and Hunter 1997). Additional high-IP stream segments matching ODF stream segments were also added manually to ensure completeness. The resulting stream layer was continuously attributed with policy designations and specified segments with high IP. This enabled us to calculate the proportion of high-IP streams falling under each riparian land-management policy within and across watersheds in the OCC-ESU.

Research question 3: Comparing policy standards in watersheds containing high-IP streams compared with watersheds that do not contain such streams

We divided watersheds into two groups: (1) those in which we identified > 10 km of stream segments with high intrinsic potential (hereafter, "high-IP watersheds"); and (2) those in which we did not identify streams with high intrinsic potential (hereafter, "low-IP watersheds"). We used a 10-km cutoff to better identify watersheds of significant high-IP stream reaches where conservation and recovery efforts may be focused. For each watershed, we calculated the total stream length and proportion of stream length in each riparian-management policy. We used R Statistical Software (3.4.3) to calculate summary statistics for the two groups of watersheds. The resulting values allowed us to calculate a ratio comparing the average percent of streams under a given management policy in high-IP watersheds and low-IP watersheds.

RESULTS

Research Question 1: Among watersheds in the OCC-ESU, what is the spatial distribution of stream segments managed under the various riparian standards?

We examined the spatial extent of the four major riparian-management policies as well as the reach-specific standards applied to individual stream segments. We mapped these standards across the 112,034 km of streams of the Oregon Coastal Coho ESU as delineated on the ODF stream layer. At the spatial extent of the ESU, the percent of total stream length covered by any given riparian-policy jurisdiction ranged from 12 to 40% (Table 2). The FPAR, covering commercial timber operations on private land, set riparian standards for the largest percentage of the total stream length (40%, 44,810 km). The NWFP for federal lands sets land-management standards adjacent to 32% of the total stream length (35,731 km). The AWQMPs governing agricultural lands (13%, 14,130 km) and the SFMPs governing state forest land (12%, 13,851 km) had similar percentages of the stream network under their jurisdictions. Other plans (tribal, urban, and local standards) are in place for the remaining 3% of mapped streams in the region (3512 km).

Table 2. Spatial extent of streams managed under the four major riparian-management policies of the Oregon Coastal Coho Evolutionarily Significant Unit (ESU).

Policy	Total stream length (km)	% of ESU stream network
Northwest Forest Plan	35,731	32
State Forest Management Plans	13,851	12
Forest Practices Administrative Rules	44,810	40
Agricultural Water Quality Management Plans	14,130	13
Other plans	3512	3

Management standards vary within policies as well as across policies. Information on select stream attributes (fish-bearing potential, streamflow duration, stream size, and domestic water use) is required to specify the applicable standard for a given stream segment under the prescriptive policies (NWFP, SFMPs, and FPAR). The streams of the OCC-ESU were attributed with their unique management standards based on these considerations, varying by policy. However, it was not possible to classify many of the stream segments in the region because of a lack of information on one or more important stream attributes in the ODF stream layer (Table 3). Designations on key stream attributes were missing for 59% of streams in the OCC-ESU.

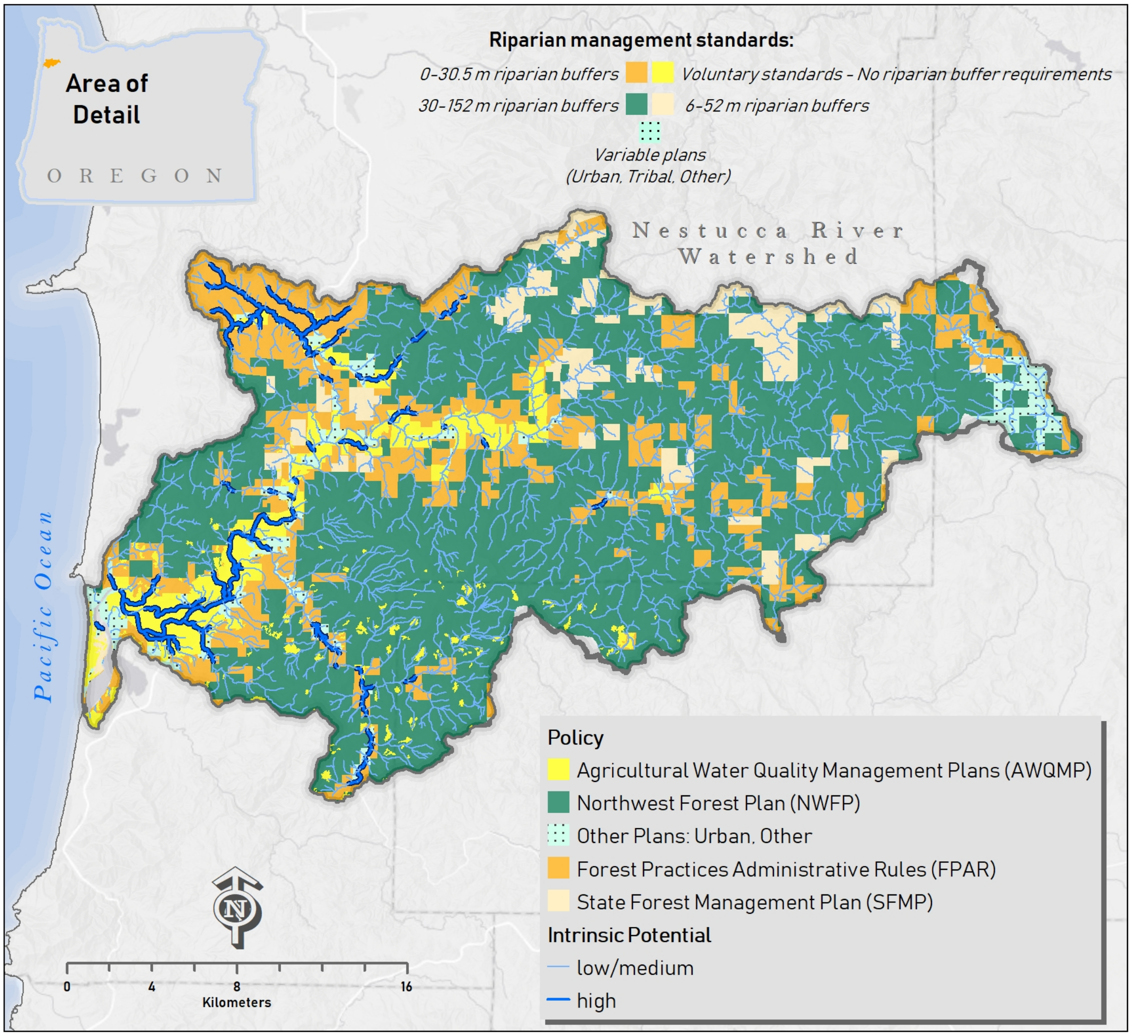
Table 3. Proportion of streams in the Oregon Department of Forestry stream layer where key designations on stream attributes were present or absent. Designations of stream attributes (fish-bearing, streamflow duration, stream size, and/or domestic water use) are necessary for specifying management standards and the degree of policy protection for streams. OCC-ESU = Oregon Coastal Coho Evolutionarily Significant Unit.

	Proportion (%) of stream length (OCC-ESU) for which one or more key stream designation attributes are:	
Standards	Present	Absent
Northwest Forest Plan	11.1	20.8
State Forest Management Plan	6.6	5.8
Forest Practices Administrative Rules	7.9	32.1
Total[†]	25.6	58.7

[†]The 16% of stream length not included in this table includes streams managed under Agricultural Water Quality Management Plans (13%), which do not prescribe management standards, and other plans (3%) including urban, tribal, and other lands outside the scope of the study.

To better understand the distribution of standards in the region, we examined the percentage of streams in the ODF stream layer that had designations for one or more of the attributes used for land-management standards (fish-bearing, streamflow duration, stream size, and domestic water use; Table A1). For example, information designating a stream as fish-bearing or nonfish-bearing was absent for 36.6% of the stream network (41,011 km)

Fig. 3. An example of the "policy landscape" of riparian-management standards with respect to stream reaches of high intrinsic potential (IP) to support coho salmon in the Nestucca watershed. Standards for fixed-width buffers vary across the patchwork landownerships and land uses of the Oregon Coast Range. High-IP stream reaches fall largely on agricultural lands without buffer requirements.



falling under jurisdictions with prescriptive policies (NWFP, SFMPs, FPAR). Only 1% of streams in FPAR jurisdiction are designated as having domestic water-use status in the ODF stream layer.

Because it was difficult to delineate stream segments based on sets of attributes invoked in the most detailed categories of policy designations, we focused our assessment on the extent of streams regulated under each individual policy (NWFP, SFMPs, FPAR, and AWQMPs). The proportion of streams falling under these riparian-management standards varied across the 84 watersheds of the OCC-ESU, creating policy contexts unique to each watershed (Table A2). Some watersheds contain complex checkboard patterns of policy jurisdiction, where applicable standards varied at the stream-segment scale, for example, the Upper Smith River watershed. A number of watersheds were similar to the conceptual example (Fig. 1), where riparian areas in headwater streams are managed under more restrictive standards of the NWFP, whereas lower reaches fall in agricultural regions governed by AWQMPs (Fig. 3). In some watersheds, streams largely fell within one primary landownership and land use, and thus were largely managed under one set of policy standards. For example, in the Calapooya, Deer Creek, and Lower North Umpqua River watersheds, agricultural lands make up 63–78% of streamside lands. Thus, these watersheds rely heavily on the outcome-based policy approach of AWQMPs.

Most watersheds in the OCC-ESU contained streams where riparian conditions are managed under FPAR standards (n = 79). Across all individual HUC-10 watersheds of the OCC-ESU, an average of 37% of the watershed stream length is managed under FPAR. In 25 watersheds, more than 50% of the watershed stream length was managed under FPAR standards. Among all watersheds, an average of 38% of watershed stream length is managed under federal NWFP standards, whereas an average of 11% of watershed stream length is managed under AWQMP outcome-based standards. Other riparian policies outside of the four reviewed here average less than 4% of the stream length in the individual watersheds of the OCC-ESU. However, in certain watersheds, land managed under these other policies makes up a substantial proportion of stream length, for example, 24% of watershed stream length in the Tillamook Bay watershed.

Research Question 2: What proportion of stream segments with high IP to support coho salmon are managed under each of the four major riparian-management policies applied in the region?
We classified a total of 2403 stream kilometers as having high IP to support coho salmon habitat in the OCC-ESU, encompassing 2% of the total stream network (Table 4). The most common riparian policy for high-IP streams was AWQMPs, totaling 1081 km (45%) of high-IP streams. The FPAR also sets land-management standards adjacent to a large proportion of high-IP streams (29%, 697 km). Stream segments flowing through urban, tribal, and local lands contained 20% of high-IP streams (481 km). A total of 6% of high-IP stream segments occur on state and federal forest land (1% and 5%, respectively).

Table 4. Spatial extent of streams of high intrinsic potential to support coho salmon, managed under the four major riparian-management policies of the Oregon Coastal Coho Evolutionarily Significant Unit.

Policy	High-IP stream length (km)	% of high-IP stream length
Northwest Forest Plan	120	5
State Forest Management Plans	24	1
Forest Practices Administrative Rules	697	29
Agricultural Water Quality Management Plans	1081	45
Other	481	20

We identified 55 watersheds that contained some length of high-IP stream segments (Table A3). In these 55 watersheds, high-IP streams averaged about 4.7% of the watershed stream-network length. High-IP streams made up a relatively large proportion (10% or more) of the stream network in the Coos, Coquille, and Lower Yaquina systems. Five watersheds (Coos Bay, Siltcoos River, Coquille River, North Fork Coquille, and New River) had more than 100 km of high-IP streams, amounting to 30% of the high-IP stream reaches in the OCC-ESU.

Research Question 3: Are policy standards for riparian management similar in watersheds containing high-IP streams compared with watersheds that do not contain such streams?
In the OCC-ESU, we identified 44 watersheds containing at least 10 km of high-IP stream segments, and 29 low-IP watersheds. Ten other watersheds had a small amount (< 10 km) of high-IP stream segments, however those watersheds were not included in this analysis. In both high-IP watersheds and low-IP watersheds, the stream length managed under each of the four policies and other plans was highly variable. However, the average proportion of watershed stream lengths did differ between the two populations of watersheds (Table 5). High-IP watersheds have on average half the amount of streams under NWFP standards compared to other watersheds. The proportion of streams falling under the standards of the SFMP and FPAR were similar in both high-IP and low-IP watersheds. The largest difference between high-IP watersheds and low-IP watersheds was in the proportion of streams falling under the voluntary standards of the AWQMPs: high-IP watersheds had three times more stream length falling under the AWQMPs on average compared with low-IP watersheds. Streams with riparian areas managed under other plans were also more common on average in high-IP watersheds compared with low-IP watersheds.

DISCUSSION

By mapping administrative authorities of land management under different standards, we were able to quantify protective measures in watersheds and identify streams of conservation and recovery interest. We found that protective standards for riparian areas in the Oregon Coast Range, USA, reflect complex patterns of landownership that do not consistently align with habitat requirements for threatened coho salmon. Previous work has found that streams of high intrinsic potential to support coho salmon are concentrated on private lands across the Oregon Coast Range (Burnett et al. 2003, 2007, Spies et al 2007). Results from this work found that a majority of high-IP stream segments (45% of high-IP streams; Table 4) are managed under Agricultural Water Quality Management Plans lacking specific prescriptive riparian standards. Further emphasizing the importance of AWQMPs to recovery efforts for coho salmon, we also found that, compared with low-IP watersheds, high-IP watersheds have more streams managed under AWQMPs (Table 5). Aquatic ecosystems adjacent to agricultural lands rely on the voluntary efforts of landowners to manage for ecological goals, including the development of native streamside vegetation. There are many important examples of private landowners adopting innovative management approaches balancing use and resource protection in western Oregon (CWA 2005), as well as successful governance structures to support such efforts (Flitcroft et al. 2009). However, uncertainty remains regarding the overall efficacy of a reach-based voluntary approach for ensuring the riverscape-scale ecological functions necessary for recovery of threatened fish species and their habitat across the entire OCC-ESU (ODA 2012, NOAA and EPA 2015, NMFS 2016*a, b*).

Understanding the distribution of areas of high IP and their relationship to policy standards has important implications for recovery planning and implementation efforts. The wide, low-gradient valley bottoms preferred by coho salmon have been heavily converted to agricultural uses (Sedell and Luchessa 1982), thereby reducing local habitat quality (Bradford and Irvine 2000, Steel et al. 2012). In response to habitat alteration, it is possible that coho salmon may have migrated upstream into habitats that have lower IP, but that currently have higher habitat quality than reaches lower in the system. Current restoration and recovery efforts for coho salmon often focus on stream reaches outside areas of high IP. However, recovery efforts that also include streams of high IP may provide better habitats and enhance population-scale resilience in the long term.

To complete their life-cycle, migratory fishes such as coho salmon must be able to use and move within and among stream segments managed under different policy protections. The varied patterns

Table 5. Comparison of the percent of stream length for high-intrinsic potential (IP) watersheds (those containing > 10 km of stream length denoted as high-IP for coho salmon; n = 44) with low-IP watersheds (those containing no high-IP stream segments; n = 29) under each of the four primary riparian policies (and "other") in the Oregon Coastal Coho Evolutionarily Significant Unit.

Policy	% High-IP watershed mean (SD)	% High-IP watershed range	% Low-IP watershed mean (SD)	% Low-IP watershed range	Ratio of means (% high IP:low IP)
Northwest Forest Plan	28.1 (26.9)	85.6	52.3 (35.3)	99.4	1:1.9
State of Oregon Forest Management Plan	10.8 (20.3)	77.9	8.3 (17.6)	59.6	1.3:2
Forest Practices Administrative Rules	42 (20.8)	75.9	32.1 (25.7)	92.9	1.3:2
Agricultural Water Quality Management Plan	13.9 (19)	78.2	5.1 (8.2)	31.6	2.7:1
Other	5.2 (5.8)	24.4	2.2 (6.5)	35.4	2.4:1

of policy standards across watersheds (Tables A2 and A3), and the wide range of stream lengths in high-IP-watersheds managed under each policy (Table 5) confound consistent habitat protections across the riverscape. The Nestucca River watershed provides a real-world example of the overlay of the policy landscape with the biophysical landscape (Fig. 3), encompassing a patchwork of lands managed under each of the riparian standards. High-IP streams are concentrated on lower elevation agricultural lands managed under AWQMPs. However, some high-IP stream reaches also occur on lands under the jurisdiction of NWFP, FPAR, and other riparian-management plans. Upstream of high-IP streams is a patchwork of ownerships and land uses. As jurisdiction and stream size shift from stream-segment to stream-segment, so do gradients of buffer widths and protective requirements (Table 1). These varied jurisdictions create a complex riverscape of protections that may contribute to and enhance the fragmentation of aquatic habitats at the stream-segment and watershed scale.

In practice, policy protection is not always synonymous with functional protections (Wood 2013, Fremier et al. 2015). The purpose of this study was to describe the spatial distribution of the conceptual policy landscape of riparian buffers and standards, and to consider how it overlays the biophysical landscape. In order to examine how fragmented policy responses actually manifest on the landscape, more advanced remote-sensing work is necessary to understand the extent and attributes of streams in the region. Field-based assessments can also be used to improve existing models of river networks and inform the classification of streams that is central to protective goals (Labbe 2016). We were unable to completely characterize streams by the most detailed categories of management standards because of a lack of data on stream characteristics, including fish-bearing status, mean annual streamflow, streamflow duration, and domestic water use (Table 3). Accurate determinations of key biophysical and human-use landscape components are crucial for representing policy systems within riverscapes, and thus for better understanding linkages between policy efforts and biophysical processes.

Application of this method to other regions requires adequate spatial datasets, an understanding of jurisdictional patterns, and a detailed assessment of protective efforts across jurisdictions. Although spatial patterns of threats to conservation goals have been investigated at international scales (e.g., Sala et al. 2000, Vörösmarty et al. 2010), few approaches have used spatial assessments of policy efforts to promote conservation or protection. As the spatial extent of recovery efforts increases, a broader range of actors are involved, from local governments and regional interests to state and federal entities, up to cooperative alliances for international or global governance. As the number of jurisdictions involved in the management of a given ecosystem increases, a wide variety of protective policy approaches and even greater variability in land-management standards can result (Lee et al. 2004). Given the complexity of integrating legal and biophysical datasets, our work focused on one type of protective effort: riparian land-management standards. Other research examining spatial patterns of policy protection have focused on other policy tools adopted across diverse regional contexts, for example the distribution of voluntary actions to mitigate climate change at the state level (Brody et al. 2008). Future efforts to quantify riverscape-scale policy approaches would benefit from an integrated consideration of multiple protective policy actions overlaid on the landscape, as well as broader scale questions of global significance.

In response to the challenges of fragmented policy responses across management entities with diverse goals, regulatory efforts to promote water quality and aquatic conservation may benefit by aligning and connecting protective practices, e.g., incentives, restoration projects, conservation designations, governance, technical assistance, and management standards. Targeting efforts and considering gaps in management practices using spatially specific approaches may support riparian connectivity and balance watershed-scale management goals (Fremier et al. 2015, Flitcroft et al. 2018). The large proportion of high-IP stream length that exists on private forest and especially agricultural lands highlights the importance of working with private landowners in incentive-based efforts to improve habitat for threatened fishes in the areas that have the highest potential to benefit the species. Collaborative programs such as watershed councils that leverage efforts to target key problem areas may help to make restoration both more effective and cost-efficient (Huntington and Sommarstrom 2000), in addition to building community interest in the health of local streams and ecosystems (Lurie and Hibbard 2008, Flitcroft et al. 2009). Although traditional ownership-based management is a long-established political reality, recurring opportunities for negotiation and compromise can offer the potential for change and collaboration at the scale of the river basin (Vogel 2012). Effective riparian and riverine protection will require a riverscape perspective that connects social actors and ecological environments throughout the river and its valley.

Responses to this article can be read online at:
http://www.ecologyandsociety.org/issues/responses.php/10676

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Appendix 1. Percent of stream length under the four major riparian-management policies within each of the 84 watersheds in the Oregon Coastal Coho ESU and within streams of high intrinsic potential for coho salmon.

Table A1.1. Proportion (percent) of stream length falling under key stream-attribute designations across the Oregon Coastal Coho ESU. Stream attributes are used to specify riparian-management standards.

Stream attribute	Percent of total stream length (OCC-ESU)					
	Total	NWFP	SFMPs	FPAR	AWQMPs	Other
Fish-bearing						
Fish	17.9	3.6	1.8	7.9	3.3 †	1.3
Non-fish	41.1	8.8	5.5	20.1	6.1 †	0.7
No data	41.0	19.5	5.1	12.0	3.3 †	1.1
Streamflow duration						
Perennial	34.1	11.9	3.9	12.6	4.1 †	1.5
Seasonal	56.5	16.0	7.2	24.0	7.7 †	1.5
No data	9.4	4.0	1.2	3.3	0.8 †	0.1
Stream size						
Small	86.4	28.6 †	11.0	34.7	10.0 †	2.2
Medium	6.4	2.0 †	0.7	2.6	0.9 †	0.2
Large	7.2	1.4 †	0.7	2.7	1.7 †	0.7
No data	0.0	0.0 †	0.0	0.0	0.0 †	0.0
Domestic water use						
Domestic use	0.3	0.0 †	0.0 †	0.2	0.0 †	0.0
No domestic use	0.2	0.0 †	0.2 †	0.0	0.0 †	0.0
No data	99.5	31.8 †	12.1 †	39.8	12.6 †	3.1

†These stream attributes are not considered when designating standards for a particular jurisdiction (for example, NWFP and SFMPs do not designate standards based on domestic water use, AWQMPs do not designate standards based on stream attributes, etc.).

Table A1.2. Proportion (percent) of stream length under the four major riparian-management policies within each of the 84 watersheds in the Oregon Coastal Coho ESU. Differences in sum of total stream length between the 84 watersheds and the ESU are due to rounding errors.

Watershed (HUC 10)	Total stream length (km)	Percent of total stream length under management policy				
		NWFP	SFMPs	FPAR	AWQMPs	Other plans
Beaver Creek	633	50.3	1.3	37.9	2.4	8.1
Big Elk Creek	900	33.7	14.8	43.0	8.4	0.1
Calapooya Creek	1827	6	0	29.3	62.9	1.8
Canton Creek	468	69.5	0	29.2	1.3	0
Clark Branch (South Umpqua)	926	8.9	0.1	14.9	68.6	7.6
Clearwater River	164	98.5	0	0	0.6	1
Coos Bay	1805	3.8	10.0	59.1	15.0	12.0
Coquille River	1316	3.8	0.1	56.6	28.9	10.6
Days Creek (South Umpqua)	2214	37.2	0	37.2	24.2	1.5
Deadwood Creek	758	80	2.4	15.5	2	0
Deer Creek (South Umpqua)	1235	2.7	0	3.2	78.5	15.6
Diamond Lake	50	64.6	0	0	0	35.4
Drift Creek	565	66.6	0.6	30.8	2.0	0
Dumont Creek (South Umpqua)	762	84.2	0	11.0	4.7	0.2
East Fork Coquille River	1839	51.6	0	43.6	3.6	1.2
Elk Creek (South Umpqua)	253	58.9	0	26.8	14.3	0.1
Elk Creek (Umpqua)	2642	24.8	0.1	36.7	36.9	1.4
Fish Creek	273	99.4	0	0	0.5	0.2
Five Rivers	1458	80.3	0	12.5	7.2	0
Headwaters Nehalem River	2283	3.4	28.8	65.6	1.0	1.2
Headwaters North Umpqua River	234	95.1	0	0	0.2	4.7
Indian Creek	659	82.3	0	15.9	1.8	0.1

Watershed (HUC 10)	Total stream length (km)	Percent of total stream length under management policy				
		NWFP	SFMPs	FPAR	AWQMPs	Other plans
Jackson Creek	906	93.9	0	5.7	0.3	0.1
Kilchis River	1619	7	86.6	4.2	1.1	1.2
Lake Creek	1105	46.9	12.5	32.8	6.0	1.8
Little Nestucca River	1034	48.6	2.4	36.4	10.0	2.6
Little River	1567	57.3	0	31.2	9.2	2.3
Lower Alsea River	1529	57.4	0.3	32.9	7.4	2.0
Lower Cow Creek	1856	35.2	0.1	44.5	18.6	1.7
Lower Nehalem River	1697	0	66.0	25.0	4.3	4.7
Lower North Umpqua River	1467	4.4	0	5.7	78.3	11.6
Lower Siletz River	1933	19.3	1.1	70.3	6.1	3.2
Lower Siuslaw River	1997	47.8	4.8	39.5	2.8	5.1
Lower Smith River	3015	52.3	0	40.0	6.8	0.9
Lower Umpqua River	1051	23	22.0	36.3	12.1	6.6
Lower Yaquina River	763	6.9	0.4	67.8	9.0	15.8
Miami River	730	0	64.6	28.9	5.1	1.4
Middle Cow Creek	1937	38.1	6.4	35.3	18.4	1.8
Middle Fork Coquille River	3782	28.1	0	60.0	9.3	2.6
Middle Nehalem River	2705	0	53.7	40.5	3.6	2.2
Middle North Umpqua River	760	87.6	0	11.4	0.5	0.6
Middle Siletz River	723	0	0.3	92.9	3.1	3.6
Mill Creek	1196	27.9	8.7	56.4	6.3	0.6
Millicoma River	1309	0	43	55.2	1.3	0.5
Myrtle Creek	1411	33.4	0	32.8	31.6	2.2
Necanicum River	1338	0	8.9	79.1	3.2	8.8
Nestucca River	4196	61.2	7.2	21.7	6.7	3.3
New River	1513	4.0	0.8	68.7	23.6	2.9
North Fork Coquille River	1710	35.9	0.3	48.9	14.0	0.9
North Fork Nehalem River	1553	0	35.6	56.6	5.0	2.8

Watershed (HUC 10)	Total stream length (km)	Percent of total stream length under management policy				
		NWFP	SFMPs	FPAR	AWQMPs	Other plans
North Fork Siuslaw River	878	76.2	0	15.8	7.5	0.5
Olalla Creek	1512	21.4	0	28.2	46.5	3.9
Rock Creek (North Umpqua)	723	41.5	0	56.3	1.8	0.4
Rock Creek (Siletz-Yaquina; Coastal)	620	4.6	1.1	72.7	0.8	20.8
Rock Creek (Siletz-Yaquina; Interior)	453	6.5	24.7	65.2	2.2	1.5
Salmon River	825	29.4	2.4	57.0	3.1	8.1
Salmonberry River	989	0	59.6	40.4	0	0
Sand Lake	1173	27.4	1.8	57.0	2.6	11.1
Siltcoos River	1853	37.4	0	51.2	3.3	8.1
Sixes River	1350	22.9	0.5	72.8	2.9	1.0
South Fork Coos River	2913	22.6	0.1	74.5	2.4	0.3
South Fork Coquille River	2466	23.5	0	46.7	28.4	1.4
Steamboat Creek	1023	98.6	0	1.2	0.2	0
Tenmile Creek (Alsea)	1101	85.6	3.0	8.8	0.3	2.4
Tenmile Creek (Coos)	805	0.8	36.2	36.9	13.8	12.3
Tillamook Bay	290	0	17.2	44.5	13.8	24.4
Tillamook River	1181	1.1	8.2	66.1	14.6	10.1
Trask River	2580	8.5	57.6	26.5	4.2	3.3
Umpqua River-Sawyers Rapids	972	32.2	0.5	43.3	20.9	3.1
Upper Alsea River	1482	53.7	0.1	39	7.2	0.1
Upper Cow Creek	1009	65.3	1.0	25.3	7.5	1.0
Upper Nehalem River	1369	0	51.1	44.4	3.4	1.1
Upper North Umpqua River	304	98.8	0	0	0.4	0.8
Upper Siletz River	907	25.6	0	73.6	0.8	0
Upper Siuslaw River	2126	42.6	0.6	50.5	5.6	0.7
Upper Smith River	1886	59.4	0	40.2	0.4	0

Watershed (HUC 10)	Total stream length (km)	Percent of total stream length under management policy				
		NWFP	SFMPs	FPAR	AWQMPs	Other plans
Upper South Umpqua River	492	99.1	0	0.3	0.3	0.3
Upper Umpqua River	2612	30.9	0	31.7	35.4	2.0
Upper Yaquina River	716	0.7	19.8	67.4	10.8	1.2
West Fork Cow Creek	1052	54.1	0.6	43.8	1.6	0
Wildcat Creek	472	41.1	11.9	45.6	0.9	0.5
Wilson River	3122	5.0	77.9	13.3	1.6	2.2
Wolf Creek	558	44.0	2.4	52.6	1.0	0.1
Yachats River	573	75.7	0.5	17.6	5.1	1.1
AVERAGE	1334	37.6	10.3	37.4	11.0	3.8

Table A1.3. Percent of stream length per watershed identified as having high intrinsic-potential (high IP) for coho salmon under the four major riparian-management policies in the Oregon Coastal Coho ESU. "Percent high-IP stream length" is the proportion of the watershed stream length having high IP, also expressed in kilometers.

Watershed (HUC 10)	Percent high-IP stream length [km]	Percent of high-IP stream length under management policy				
		NWFP	SFMPs	FPAR	AWQMPs	Other plans
Beaver Creek	7.3 [46]	8.4	1.0	65.8	10.5	14.3
Big Elk Creek	1.6 [14]	0	16.9	49.0	34.2	0
Calapooya Creek	5.6 [103]	0	0	3.1	92.8	4.1
Clark Branch (South Umpqua)	1.0 [9]	0	0	0	57.0	43.0
Coos Bay	12 [216]	0	6.4	30.5	38.0	25.2
Coquille River	11.2 [148]	0	0.3	25.2	59.7	14.7
Deadwood Creek	2.5 [19]	25.5	0	62.7	11.9	0
Deer Creek (South Umpqua)	5 [62]	0	0	0	63.4	36.6
Drift Creek	0.9 [5]	2.7	0	47.7	49.6	0
East Fork Coquille River	1.4 [25]	16.4	0	27.3	56.2	0.1
Elk Creek (Umpqua)	0.2 [5]	5.0	0	19.2	75.9	0
Five Rivers	3 [44]	43.5	0	30.8	25.6	0
Indian Creek	5 [33]	50.0	0	43.9	6.0	0
Kilchis River	0.4 [6]	0	1.4	12.5	76.9	9.1
Lake Creek	0.2 [2]	100.0	0	0	0	0
Little Nestucca River	1.1 [11]	0	0	0	99.6	0.4
Little River	0.3 [5]	0	0	0	100.0	0
Lower Alsea River	2.1 [32]	4.3	0.6	51.3	40.0	3.8
Lower Nehalem River	1.8 [31]	0	0	29.8	36.3	33.9
Lower North Umpqua River	5.3 [78]	0	0	0	74.2	25.8
Lower Siletz River	3.4 [65]	0.3	0	57.4	30.9	11.4
Lower Siuslaw River	3.6 [72]	4.9	0	55.2	15.3	24.6
Lower Smith River	2.2 [65]	3.0	0.2	46.1	35.0	15.8
Lower Umpqua River	8.1 [85]	1.3	3.7	37.4	36.7	20.9

Watershed (HUC 10)	Percent high-IP stream length [km]	Percent of high-IP stream length under management policy				
		NWFP	SFMPs	FPAR	AWQMPs	Other plans
Lower Yaquina River	11 [84]	0	0.9	48.2	25.0	25.9
Miami River	1.5 [11]	0	2.4	4.8	74.7	18.0
Middle Fork Coquille River	1.5 [1]	0	0	0	70.9	29.1
Mill Creek	<1 [<1]	0	100.0	0	0	0
Millicoma River	1.9 [25]	0	2.2	80.2	13.5	4.1
Necanicum River	4.6 [62]	0	7.1	19.4	15.2	58.3
Nestucca River	1.9 [80]	2.1	0	32.2	55	10.8
New River	7.3 [110]	1.5	0.5	23.3	59.6	15.1
North Fork Coquille River	7 [120]	12.8	0	33.9	47.5	5.9
North Fork of Nehalem River	1.7 [26]	0	8.7	7.8	66.2	17.3
North Fork Siuslaw River	5.8 [51]	11.5	0	28.2	57.4	2.9
Olalla Creek-Lookingglass Creek	2.4 [37]	0	0	0	89.4	10.6
Rock Creek (Siletz-Yaquina; Coastal)	6.6 [41]	0	5.0	39.2	4.0	51.8
Salmon River	2.7 [22]	6.8	0.9	24.3	28.8	39.2
Sand Lake	3.5 [41]	4.0	1.3	30.8	15.5	48.4
Siltcoos River	8 [149]	5.4	0	37.1	7.7	49.7
Sixes River	1.3 [18]	3.5	0	32.2	32.3	32.0
South Fork Coos River	0.8 [24]	2.0	0	55.5	26.6	15.9
South Fork Coquille River	2.6 [64]	0	0	12.9	79.9	7.2
Tenmile Creek (Alsea)	2.1 [23]	33.5	4.9	17.2	0.8	43.6
Tenmile Creek (Coos)	<1 [<1]	0	0	0	0	100
Tillamook Bay	4.5 [13]	0	0	13.7	53.4	32.9
Tillamook River	4.7 [56]	0	0	28.6	58.9	12.5
Trask River	1.8 [47]	0	0	8.7	65.2	26.1
Umpqua River-Sawyers Rapids	1.1 [11]	6.3	0	10.2	74.4	9.1

Watershed (HUC 10)	Percent high-IP stream length [km]	Percent of high-IP stream length under management policy				
		NWFP	SFMPs	FPAR	AWQMPs	Other plans
Upper Alsea River	2.4 [35]	4.2	0	13.9	79.1	2.8
Upper Smith River	0.4 [8]	37.8	0	62.2	0	0
Upper Umpqua River	0.8 [21]	0.8	0	2.6	92.6	4.0
Upper Yaquina River	3.2 [23]	0	1.5	51.4	45	2.1
Wilson River	0.5[16]	0	7.9	11.0	68.2	12.9
Yachats River	0.2 [1]	21.5	0	34.6	42	1.9
AVERAGE	[44]	7.6	3.2	26.5	45.0	17.7