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Executive Summary

Rivers are crucial to supporting biodiversity and providing ecosystem services such as clean drinking water and recreation opportunities, offering far more value to people, wildlife, and ecosystems than might be expected given their small global footprint. Yet rivers are under increasing threat as the climate warms and our populations grow, placing greater stress and demand on freshwater resources. Despite their life-giving importance, few rivers and streams are currently protected from human impacts to their integrity and flow. We have the opportunity now to protect more of these waterways in the United States through a variety of mechanisms.

We offer a rigorous assessment of wild rivers that are currently unprotected and, using various criteria for evaluating their ecological value, quantify and highlight those that are most ecologically important to protect. We focused in particular on identifying rivers and streams throughout Oregon with the highest potential for state Outstanding National Resource Water (ONRW) or state Wild and Scenic River (W&S) designation, although we anticipate the data provided to be valuable for supporting river protection through other mechanisms, such as the federal Wild and Scenic Rivers Act. Here, we connect designation criteria to statewide data to identify rivers with the greatest potential to achieve formal protection via ONRW or W&S designation. We summarize our key findings and map these rivers statewide to help visualize the "best of the best" river segments and other ecologically important places to seek new protections.

Our assessment shows that, of the 54,115 miles considered, rivers and streams with the highest ONRW potential are generally found in the western half of the state, particularly in the Coast and Cascade ranges, but that high-value rivers are also found in the Blue and Wallowa mountains in the northeast, as are portions of the Owyhee River, the Donner und Blitzen River, and the South Fork John Day River, among others. All told, 4,383 river miles demonstrate outstanding overall ecological value in that they score in the top third of all rivers statewide for each of our indicators of ecological significance (at-risk aquatic species diversity, rarity-weighted species richness, and ecosystem type rarity). Oregon's rivers support high numbers of aquatic species identified by the state as Species of Greatest Conservation Need (SGCN); 5,784 river miles are within the ranges of at least 30 aquatic SGCN, while 41,872 river miles are within the ranges of at least 20 of these at-risk species. Many high-scoring, high-elevation rivers and streams also offer crucial thermal refuges for cold-water species. Rivers and streams with the highest W&S potential are widely distributed across the less densely developed portions of the state, offering additional protection opportunities and value. Furthermore, 14 of the top 20 watersheds for ONRW designation and eight of the top 20 watersheds for W&S designation contain drinking water sources; protection of these waters would help to maintain provision of this vital ecosystem service for generations to come. At the watershed level, the Chetco River watershed is extraordinary in that it contains the greatest total river miles with high ONRW potential as well as the greatest total miles with high W&S potential. However, we find in general that rivers with high W&S potential are different from those with high ONRW potential, suggesting that these designations are complementary tools for Oregon's rivers.

In short, tens of thousands of river miles across Oregon possess a wide range of ecological values and ecosystem services worthy of protection, whether through state-level designations, federal Wild & Scenic designation, or other available mechanisms. This assessment and the data accompanying it offer scientifically grounded support for identification of the values associated with rivers, streams, and watersheds across Oregon that can inform and support efforts to ensure those values persist.

Introduction

Rivers are the lifeblood of our wild lands. Although rivers, lakes, and other freshwater habitats represent less than 1% of the Earth's surface, they support approximately 10% of all known animal species (Balian et al. 2008) and one-third of all known vertebrates (Dudgeon et al. 2006). They are also estimated to provide one-fifth of the value of all of Earth's ecosystem services (Costanza et al. 1997). Rivers are hot spots of biodiversity and endemism that enable native plants and animals to thrive (Strayer and Dudgeon 2010); they provide clean drinking water for more than half the United States population (Dieter et al. 2018); they offer a wealth of recreation opportunities; and they offer myriad other ecosystem services supporting ecological and human health and well-being (e.g., fisheries, flood mitigation, aesthetic enjoyment; Brauman et al. 2007).

As our planet warms and climate patterns change (IPCC 2018), we will see increasing human demands on freshwater systems as well as variability in water supplies (Strayer and Dudgeon 2010, Jackson et al. 2001) such that protecting our freshwater resources will become even more important and more difficult. This is critical for biodiversity, too: Freshwater ecosystems host tremendous biodiversity, including one-third of all vertebrate species, yet freshwater species population declines continue to outpace those of terrestrial and marine systems (Reid et al. 2019; Tickner et al. 2020). Emerging and accelerating threats include changing climatic conditions, biological invasions, infectious diseases, microplastic pollution, and expanding hydropower, among others. Globally, just over one-third of rivers longer than 1,000 kilometers (620 miles) remain free-flowing over their entire length (Grill et al. 2019). Less than 0.5% of river miles in the United States are currently protected under the Wild and Scenic Rivers Act, which was passed by Congress in 1968 to "preserve certain rivers with outstanding natural, cultural, and recreational values in a free-flowing condition for the enjoyment of present and future generations" (Public Law 90-542; 16 U.S.C. 1271 et seq.; National Wild and Scenic Rivers System 2020). With mounting public support and growing political will, especially at the federal level, we have the opportunity now to protect more of these important waterways through both state and federal mechanisms.

The goal of this study was to provide a rigorous assessment of wild rivers that are currently unprotected and, using various criteria for evaluating their ecological value, quantify and highlight those that are most ecologically important to protect. Specifically, we sought to identify the factors most important for identifying rivers of high ecological value and with the greatest potential to achieve formal protection. We also sought to map those rivers and streams to help visualize the "best of the best" river segments and the most important ecological places to seek new protections.

We focused in particular on identifying rivers and streams throughout Oregon with the highest potential for Outstanding National Resource Water (ONRW) or state Wild and Scenic River (W&S) designation, especially due to their ecological value. (In Oregon, these designations are termed Outstanding Resource Waters and State Scenic Waterways.) Under the Clean Water Act, states can apply the ONRW designation to waterways and thereby mandate that water quality be protected and maintained and that any degradation during a particular activity be temporary, minimized, and reversed (in some states, no degradation at all is permitted). In 2017, Oregon designated the North Fork Smith River as an

ONRW—the first in the state; there are approximately 1,825 miles designated W&S. While other means of achieving river protection exist (e.g., the federal Wild and Scenic Rivers Act), which may also benefit from our data, we begin with an emphasis on these regulatory tools because criteria for these designations are clearly defined in a number of states and, when defined, are fairly consistent among states. We matched the best available statewide data to established or likely designation criteria to evaluate each stream segment's designation potential and to identify watersheds with particularly high mileage of high-potential streams. We then illustrate the distribution of these high-value streams and watersheds across the state, highlight the ecological values driving their potential, and assess their potential contribution to drinking water sources. We describe a variety of intended applications of our results, as well as their limitations. Finally, we provide the results of our assessment, along with underlying data layers, as an interactive map hosted by Data Basin for further exploration and visualization.

Methods

Overview

Many spatial prioritization approaches have been developed to identify the "best" targets for conservation action. Some highly sophisticated systematic approaches (e.g., Moilanen & Kujala 2006, Watts et al. 2009, Tallis et al. 2011) are designed to simultaneously identify suites of priority areas that together maximize all prioritization criteria while minimizing costs or risks (based on, e.g., monetary cost of protection, total area, or river miles protected). Some of these methods have even been adapted to directional stream networks such that up- and downstream costs and benefits can be factored into solutions (Moilanen et al. 2008, Hermoso et al. 2011). However, many of these approaches are data-hungry, require considerable technical skill to implement, and produce solutions that are difficult to trace back to the objectives that defined them; in other words, they can behave as "black boxes," the inner workings of which are not always transparent to outside observers.

Our objective was to identify rivers and streams with high ecological value and potential for ONRW or W&S designation using an easy-to-understand, easy-to-communicate, and easy-to-adjust approach. It was not necessary to identify an optimized suite of conservation targets that achieve complementarity in their representation of the various designation criteria or that are subject to constraints defined by risks or costs. Therefore, we chose a simpler prioritization approach that has been used in similar applications with similar objectives (e.g., Hoenke et al. 2014, Martin 2019).

We applied an objective hierarchy framework, which serves to organize nested objectives (after Hoenke et al. 2014; see Fig. 1 for illustrative example). We developed one hierarchical framework for scoring ONRW potential and a second, separate framework for scoring W&S potential (i.e., two distinct analyses). These frameworks allowed us to combine various quantitative datasets to score each river or stream in a transparent, structured, and goal-oriented way. The primary objective defining each hierarchy (e.g., top tier of Fig. 1) was to identify the rivers and streams with the highest potential for

ONRW or W&S designation, respectively. Each of these objectives was defined by multiple designation criteria, which formed the second tier of each hierarchy (as in Fig. 1). Finally, the degree to which each river or stream achieved each criterion was assessed based on one or more indicators, which were defined by the available data. These criteria, indicators, and the weights assigned to each to achieve priority scores are described in detail below.

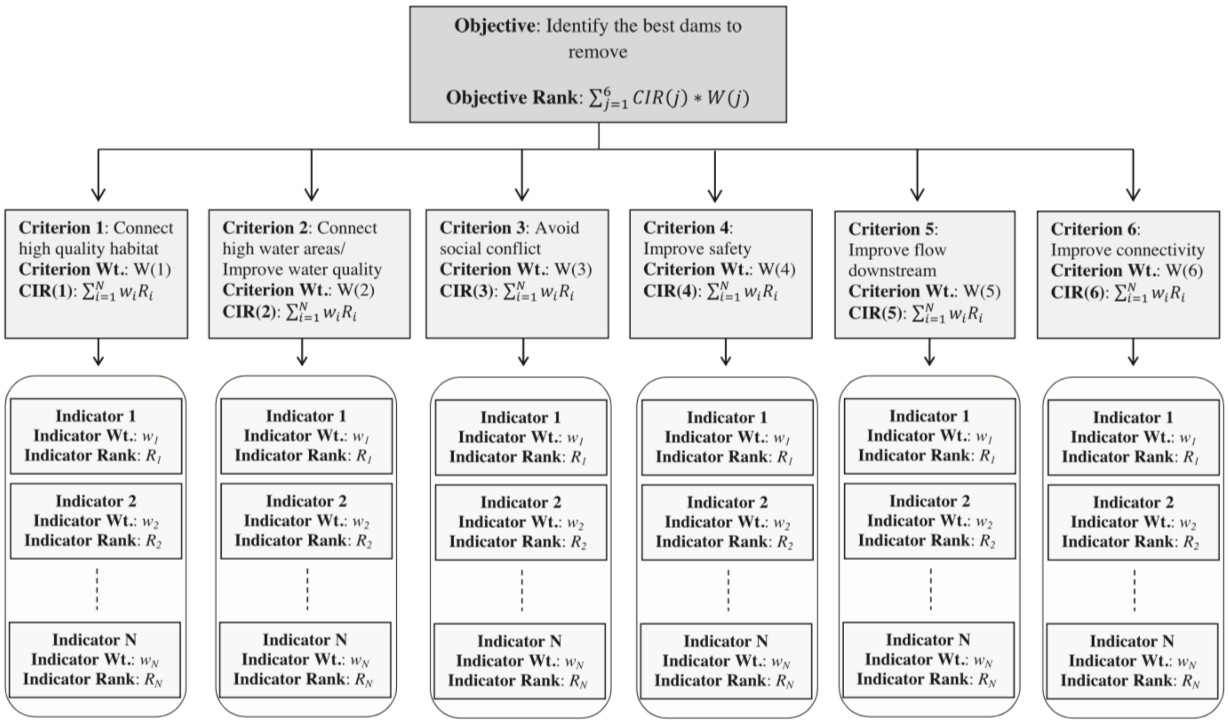

Figure 1. Example of an objective hierarchy framework, in which weighted indicators are used to assess the extent to which criteria defining an overall objective are met. In this example, the framework is used to identify the best dams for removal to achieve ecological and social benefits (Hoenke et al. 2014).

Our analysis was based on hydrography data derived from the publicly available National Hydrography Dataset (NHD; medium resolution, 1:100,000; USGS 2016), with integrated geospatial data (e.g., flow estimates) from NHDPlus Version 2 (1:100,000; U.S. EPA 2016). Harrison-Atlas et al. (2017) subsetted this dataset to focus on perennial rivers and streams with continuous flow throughout the year. To do so, they selected River/Stream features, perennial streams, and digitized centerlines for large rivers. These features were further subsetted to include only those with mean annual flow > 1 cubic foot per second (cfs). Finally, they excluded stream segments intended exclusively for mapping purposes to focus only on those representing meaningful water bodies (see Harrison-Atlas et al. 2017 for further details). This subsetted flowlines dataset—of 54,115 miles total—served as the basis for all analyses summarized in this report. Although intermittent and ephemeral rivers and streams are thereby excluded from consideration, their ecological value cannot be overstated, and they are highly worthy of protection as well (Datry et al. 2018; Shanafield et al. 2020).

Outstanding National Resource Waters

To score ONRW potential, we first identified existing criteria or guidelines established by the state of Oregon for ONRW designation. Oregon recognizes general guidelines for the intent of ONRWs, but has not yet detailed formal criteria for designation (see Box 1). We therefore borrowed from standard ONRW criteria established in other states with consistent intent. We matched each criterion to the best available spatial data with statewide coverage (Table 1); these datasets are described in further detail in Appendix A. In some cases, multiple datasets pertaining to different components of a criterion were considered together; we hereafter refer to these components as indicators. We then integrated each indicator, then each criterion, into a single overall ONRW potential score.

Box 1. Oregon Outstanding Resource Waters guideline (Oregon Department of Environmental Quality 2020).

The Oregon Department of Environmental Quality offers the following guideline to describe the intent of Outstanding Resource Waters designation:

"Outstanding Resource Waters are high quality waters that constitute an outstanding state resource due to their extraordinary water quality or ecological values, or where special protection is needed to maintain critical habitat areas."

Table 1. Indicators used to assess ONRW potential for all rivers and streams in the state of Oregon. See Appendix A for details on the source data and/or derivation of these datasets.

Designation Criterion	Indicator	Data Source
Exceptional water quality	Assessed stream's water quality categorization (see Table 2)	Oregon Dept. of Environmental Quality 2019
	Protected status of adjacent lands (GAP status; see Table 2)	Protected Areas Database of the U.S. (PAD-US v1.4; USGS GAP 2018)
	Total flow and valley bottom modification	Harrison-Atlas et al. 2017 (derived from NHD [USGS 2016], NID [USACE 2016], and Theobald et al. 2016)
Ecological significance	At-risk aquatic species richness	Derived from WDAFS 2012, USFWS 2019
	Rarity-weighted richness of critically imperiled and imperiled species	NatureServe 2013
	Ecosystem type rarity	Derived from USGS GAP 2011
Cold-water refuge	Projected mean August stream temperature (2050)	NORWeST stream temperature model (Isaak et al. 2017)
Recreational significance	Sufficient mean annual flow to support wading and/or boating	Harrison-Atlas et al. 2017 (derived from NHD [USGS 2016])
Occurs on protected lands*	Categorical designation type	Protected Areas Database of the U.S. (PAD-US v1.4; USGS GAP 2018)

**Did not contribute numerically to ONRW potential score; see below*

Abbreviations not yet noted in the text include USGS GAP = U.S. Geological Survey Gap Analysis Program; USACE = U.S. Army Corps of Engineers; NID = National Inventory of Dams; WDAFS = Western Division of the American Fisheries Society; USFWS = U.S. Fish and Wildlife Service.

To quantify "exceptional water quality," we first obtained water quality data from the Oregon Department of Environmental Quality (Table 1). This public dataset assigns an ordinal water quality category to each assessed river or stream that represents the degree to which the stream supports beneficial uses (e.g., aquatic life, drinking water, recreation) and whether total maximum daily loads

(TMDL) for pollutants have been established, based on multiple measured stream properties. Because not all streams across the state have been assessed, we supplemented this dataset with water quality proxies that are available statewide: First, we considered the protected status of the lands through which the stream passes (using PAD-US v1.4; USGS GAP 2018), under the assumption that waters passing through lands with higher degrees of protection are more likely to be in good condition (Johnson and Spildie 2014). We also considered a derived metric representing the total degree of modification of a stream, which integrates both the degree of flow modification from upstream barriers and the degree of modification of the surrounding valley bottom (or flood plain; Harrison-Atlas et al. 2017).

"Ecological significance" is a broad concept that may encompass many attributes of natural systems (e.g., diversity [Noss 1990, Davis et al. 2008], rarity [Chaplin et al. 2000], integrity or intactness [Angermeier and Karr 1994, Parrish et al. 2003], resilience [Ackerly et al. 2010, Beier & Brost 2010]). For this statewide assessment, we considered three indicators that together represent a high-level assessment of streams that are ecologically remarkable and/or have conservation value. First, we developed a state-specific indicator of at-risk aquatic species richness. We identified aquatic species designated as Species of Greatest Conservation Need (SGCN) by the Oregon Department of Fish and Wildlife (ODFW 2016), compiled geographic range data for these species, and counted the number of at-risk species expected to be present in each stream segment. We also considered a nationwide indicator of rarity-weighted richness of critically imperiled and imperiled species (NatureServe 2013; see Appendix A). Although this indicator is not specific to aquatic species, we assume that the presence of ecologically significant streams and rivers and the unique habitats they create is a driving factor in the occurrence of higher numbers of rare species in a given area. Similarly, we consider ecosystem type rarity (see Appendix A) based on the assumption that the presence of ecologically significant streams and rivers drives the formation of unique ecosystem types. Other aspects of ecological significance certainly exist and are likely to vary geographically across the state; we encourage *post hoc* consideration of local datasets available in a given area of interest to identify significant ecological attributes that may have been overlooked in this statewide assessment and to further target high-priority areas within rivers or watersheds prioritized by this assessment.

"Cold-water refuges" are streams where temperatures are cold enough and are projected to remain cold enough to support native cold-water species such as bull and cutthroat trout now and in the future (Isaak et al. 2015). Although many states that have established formal ONRW criteria do not consider cold-water refuges, these features are considered to be important in Washington state and are expected to be important in Oregon as well given the occurrence of cold streams supporting cold-water species. While others have defined cold-water refuges specific to the thermal needs of individual focal species (Isaak et al. 2015), we broaden this approach to estimate the potential for a given stream to support any number of cold-water species that may be present. We do not incorporate threshold temperatures required by particular species; rather, we simply assign higher scores to streams projected to maintain colder August temperatures in the future (2080; Isaak et al. 2017).

Rivers and streams may support a wide variety of recreational opportunities, including fishing, swimming, floating, kayaking, whitewater rafting, motorized boating, and others. It is therefore difficult to identify particular attributes most likely to confer "recreational significance," as these attributes differ among activities. Furthermore, consistent spatial data representing potentially meaningful attributes (e.g., presence of whitewater, boat ramp access, sportfish distributions) are generally unavailable at the state level. Even with such data in hand, recreational significance may still be difficult to estimate due to the complex interaction of these attributes with site accessibility from population centers and historical drivers of recreational use patterns. Consistent statewide data on actual recreational activity patterns and use frequency are also unavailable at meaningful spatial resolutions. We therefore rely on a very coarse indicator of recreation potential for this assessment based on flow. A previous analysis (Harrison-Atlas et al. 2017) categorized rivers and streams into three classes of mean annual flow: flow sufficient to support boating, flow sufficient to support wading, and flow insufficient to support either of these activities (e.g., headwater streams). Here, we very simply consider streams and rivers with sufficient flow to support boating or wading (i.e., with a flow of at least 6 cfs) as having recreation potential, while those with lower flow are not considered to have recreation potential. Though coarse, we expect this indicator to effectively filter out most streams that do not provide recreation opportunities. We encourage *post hoc* assessments of recreational value and activity in high-priority rivers and watersheds using local data where available.

Aside from including GAP protected status as one proxy for water quality (above), we did not consider whether a stream "occurs on protected lands" as a distinct criterion in our ONRW prioritization score because we wished to support flexibility in how protected status is considered and how that status might promote different strategies for nominating and advocating for a given river's ONRW designation. Instead, we include protected status information (i.e., designation type) in the streams database (see below) so that it can be used as a *post hoc* filter when exploring the prioritization results.

Scaling the data. First, we rescaled all continuous values using a quantile reclassification to account for sometimes drastic differences in distributions of values. For example, one indicator may be heavily right-skewed, such that most places statewide have low values and very few places have high values, while another may be heavily left-skewed, such that most places have high values and only a few have low values. These distributions need to be "equalized" prior to combining them into a single score so that each contributes equally to the criterion score. We therefore reclassified them such that their reclassified values represent a percentile rank: e.g., the top 10% of values are reclassified as 0.9 - 1, and the lowest 10% of values are reclassified as 0 - 0.1, regardless of their original distribution. We then rescaled all indicators to range from 0 to 1 to ensure that each contributed equally to criteria scores. For ordinal data, we simply distributed the ordinal values evenly from 0 to 1 (Table 2).

Table 2. Rescaling ordinal indicator values for scoring ONRW potential, including protected status levels established by the USGS Gap Analysis Program (2018) and water quality ordinal ranks established by Oregon Department of Environmental Quality (2019).

Indicators	Original Values	Scaled Values
GAP status	1: Permanent protection from conversion of natural land cover and a mandated management plan in operation to maintain a natural state within which disturbance events (of natural type, frequency, intensity, and legacy) are allowed to proceed without interference or are mimicked through management.	1

	2: Permanent protection from conversion of natural land cover and a mandated management plan in operation to maintain a primarily natural state, but which may receive uses or management practices that degrade the quality of existing natural communities, including suppression of natural disturbance.	0.75
	3: Permanent protection from conversion of natural land cover for the majority of the area, but subject to extractive uses of either a broad, low-intensity type (e.g., logging, Off Highway Vehicle recreation) or localized intense type (e.g., mining).	0.5
	4: Included in Protected Areas Database (PAD-US), but no known public or private institutional mandates or legally recognized easements or deed restrictions held by the managing entity to prevent conversion of natural habitat types to anthropogenic habitat types. The area generally allows conversion to unnatural land cover throughout or management intent is unknown.	0.25
	0: Private land not included in the PAD-US database	0
Water quality	1: All beneficial water uses are supported	1
	2: One or more beneficial water uses are supported	0.75
	3: Unassessed water/no data	0.5
	4: Beneficial uses are not supported but a total maximum daily load (TMDL) has not been established	0.25
	5: Impaired water, TMDL established	0

Integrating indicators. We then combined indicators within a given criterion using a fuzzy algebraic sum approach (Bonham-Carter 1994; after Theobald 2013), which produced a score ranging from 0 to 1. The fuzzy sum is an “increasive” function in that values are, at minimum, equal to the largest contributing indicator, but never exceed 1. It is useful for combining indicators that may not be entirely independent of one another (e.g., the occurrence of rare species is partially dependent on the occurrence of rare ecosystem types) in a parsimonious way because the effects of these related quantities are not strictly additive; i.e., their combined contributions to the total criterion score level off as they approach the maximum value of 1.

Integrating criteria. After achieving a single combined score for each criterion, we simply summed those criteria scores to estimate overall ONRW potential. We used a simple unweighted sum because, in states that have formally established ONRW designation criteria, there is no language indicating that any criterion is to be given more weight than others. However, this approach lends itself to straightforward adjustment of priorities at a later time as needed by simply assigning weights to each criterion when summing their values. Still, it is important to note that the simple unweighted summation of multiple criteria that forms the basis of our assessment here is but one of many possible prioritization schemes. Rivers that have already been designated as ONRWs were excluded from this process.

Aggregating to watersheds. Our assessment is conducted at the level of stream segments, which are defined somewhat arbitrarily by the National Hydrography Dataset (USGS 2016) as the continuous stretches between points at which tributaries join one another. These segments can thus vary drastically in length and generally do not correspond to units that one might nominate or designate as an ONRW. Aggregation of segments by stream or river name is not straightforward because stream and river names are often not unique (e.g., multiple “Smith Creeks” may occur in disparate geographies) and many segments in the NHD (USGS 2016) are unnamed. Therefore, to aggregate segment-level priority scores to meaningful units, we aggregated to HUC10 watersheds. We chose these units because they are defined consistently statewide, they have physical and ecological significance, and their size and extent are consistent with the designation of groups of streams as ONRWs elsewhere (e.g., North Fork Smith River and associated tributaries and wetlands in Oregon; all tributaries within a given wilderness area in Colorado).

A variety of methods can be applied to summarize segment-level prioritization scores across watersheds. We chose a method that answers the question: "Which watersheds contain the most river miles with high ONRW potential?" We calculated the total length of stream segments in each watershed that had ONRW scores in the top 25% of all segment-level scores statewide. This approach best emphasizes watersheds with many rivers and streams of high value relative to others across the state.

State Wild and Scenic Rivers

To assess state Wild and Scenic potential, we followed a similar procedure to that described for ONRW potential. We first identified existing criteria or guidelines established by the state of Oregon for W&S designation. Oregon has specified criteria for three W&S designations: Natural River Areas (NRAs), Scenic River Areas (SRAs), and Recreational River Areas (RRAs; Box 2), similar to those specified under the federal Wild and Scenic Rivers Act (Public Law 90-542; 16 U.S.C. 1272). While NRAs are defined by their inaccessibility by roads and their primitive, unaltered nature, SRAs and RRAs allow for increasing levels of access and development, especially as they pertain to recreational use. We therefore focus on prioritizing rivers and streams with potential for NRA (i.e., the most stringent) designation. Rivers that achieve moderate scores may be suitable for nomination as SRAs or RRAs, as discussed in more detail below. We matched each criterion to the best available spatial data with statewide coverage (Table 3), which are further described in Appendix A.

Box 2. Oregon State Scenic Waterway criteria (Oregon Administrative Rule 736-040-0040).

Natural River Areas:

(A) Those designated scenic waterways or segments thereof that are generally **inaccessible** except by trail or the river, with related adjacent lands and shorelines essentially primitive. These represent vestiges of **primitive** America;

(B) Natural River Areas may include an occasional lightly traveled road, airstrip, habitation, or other kind of improvement already established, provided the **effects are limited** to the immediate vicinity;

(C) Natural River Areas will be administered to preserve their **natural, wild, and primitive condition**, essentially **unaltered** by the effects of man, while allowing compatible recreational uses, other compatible existing uses, and protection of fish and wildlife habitat.

Scenic River Areas:

(A) Those designated scenic waterways or segments thereof with related adjacent lands and shorelines still **largely** **primitive** and **largely undeveloped**, except for agriculture and grazing, but **accessible in places** by roads. Scenic River Areas may not include long stretches of conspicuous or well-traveled roads paralleling the river in close proximity, but may include extensive areas in agricultural use;

(B) Scenic Areas will be administered to maintain or enhance their **high scenic quality, recreational value, fishery and wildlife habitat**, while preserving their **largely undeveloped** character and allowing continuing agricultural uses.

Recreational River Areas:

(A) Those designated scenic waterways or segments thereof that are **readily accessible** by road or railroad, that may have **some development** along their shorelines and related adjacent lands, and that may have undergone some impoundment or diversion in the past;

(B) Recreational River Areas will be administered to allow continuance of compatible existing uses, while **allowing a wide range of compatible river-oriented public outdoor recreation opportunities**, to the extent that these do not impair substantially the **natural beauty** of the scenic waterway or diminish its **aesthetic, fish and wildlife, scientific, and recreational values**.

As seen in Table 3, there is some overlap in the indicators used to assess W&S potential and ONRW potential. Specifically, the indicators contained within the ONRW "exceptional water quality" criterion—water quality categorization, protected status of adjacent lands, and total flow and valley bottom modification—are also applied here to capture the "primitive and unaltered" status of potential W&Ss. Although the ONRW and W&S designation criteria are described by different terms, we determined that the same assumptions regarding the suitability of these indicators can be applied to both. Here, primitive and unaltered rivers are expected to have high water quality unaltered by pollution and sedimentation. Lands with the highest degree of protection are expected to be the least developed and to remain so. And the degree of flow alteration and valley bottom modification is expected to provide a very direct measure of a river's primitive and unaltered state.

The requirement that potential W&S rivers be inaccessible except by trail or the river itself is distinct from the criteria used to assess ONRW potential. To assess accessibility, we relied on a recent analysis of accessibility from major population centers based on travel time via surface transport (Weiss et al. 2018; see Appendix A for further details).

As in our ONRW assessment described above, we did not consider whether lands adjacent to a stream or river are "administered to preserve primitive condition" within the prioritization process because we wished to support flexibility in how protected status is treated; we encourage use of this information as a *post hoc* filter when exploring the prioritization results.

Integrating criteria. Unlike the ONRW prioritization process, we did not treat indicators related to streams' "primitive and unaltered" character as indicators or combine them using a fuzzy sum approach when assessing W&S potential. Instead, due to the smaller and simpler set of W&S criteria, we allowed each to contribute equally to the prioritization score along with our indicator of accessibility. We used a simple unweighted sum of these four indicators because, again, we had no *a priori* reason to score one criterion higher than another based on the regulation language. However, this approach lends itself to future adjustment of weights as needed. All indicator values were rescaled as described above for ONRWs prior to summing. Rivers that have already been designated as W&Ss were excluded from this process.

Aggregating to watersheds. As described above for prioritization of ONRWs, we aggregated segment-level scores to HUC10 watersheds, using a method that answers the question: "Which watersheds contain the most river miles with high W&S potential?" We calculated the total length of stream segments in each watershed that had W&S scores in the top 25% of all segment-level scores statewide. This approach best emphasizes watersheds with many rivers and streams of high value relative to others across the state.

Other approaches to aggregation and watershed-level prioritization certainly exist, and will alter the resulting ranking of watersheds. For example, one might simply calculate the mean segment-level score in each watershed; this approach would tend to de-emphasize watersheds that are dense in rivers and streams and instead might highlight watersheds with few, but high-scoring, rivers. We determined, in consultation with Pew, that an emphasis on watersheds with high mileage of high-scoring rivers made the most sense as priority candidates for potential ONRW designation. However, we encourage consideration of other approaches that might best suit different questions and applications.

Table 3. Indicators used to assess W&S potential for all rivers and streams in Oregon. See Appendix A for details on the source data and/or derivation of these datasets.

Designation Criterion	Indicator	Data Source
Inaccessible	Accessibility from major population centers	Weiss et al. 2018
Primitive and unaltered	Assessed stream's water quality categorization (see Table 2)	Oregon Dept. of Environmental Quality 2019
	Protected status of adjacent lands (GAP status; see Table 2)	Protected Areas Database of the U.S. (PAD-US v1.4; USGS GAP 2018)
	Total flow and valley bottom modification	Harrison-Atlas et al. 2017 (derived from NHD [USGS 2016], NID [USACE 2016], and Theobald et al. 2016)
Adjacent lands administered to preserve primitive condition	Designation type	Protected Areas Database of the U.S. (PAD-US v1.4; USGS GAP 2018)

Overlay of Drinking Water Sources

To assess the degree to which ONRW and W&S priorities also serve as drinking water sources across the state, we obtained spatial data on surface water source areas for drinking water from the Oregon

Department of Environmental Quality and overlaid these polygons with our results. This dataset does not necessarily indicate that all rivers and streams within a given source area are used for drinking water. Rather, source areas represent the full extent of the watershed contributing to a surface water intake used for drinking water. Spatial data on intake points are not publicly available for security reasons. Drinking water source areas are delineated in accordance with Oregon's Source Water Assessment Methodology (Oregon Department of Environmental Quality 2017).

Database Delivery

The goal of this assessment was not only to prioritize rivers and streams for potential ONRW or W&S designation, but to compile the data necessary to conduct these prioritizations and to assess the ecological value of rivers and streams more generally. We compiled all data used in this analysis in a geodatabase to support exploration and visualization of the priority scores and the indicators driving them, future adjustment of the prioritization results described below, and other future analyses. The database contains rescaled indicator values, criteria scores, and overall priority scores for ease of display, interpretation, and comparison. It also contains additional attributes pertinent to interpretation and filtering of the results (e.g., flow class, GAP protected status, protected lands designation type). The geodatabase and associated interactive map display are provided via Data Basin (www.databasin.org) for ease of use by those without GIS experience or access to such tools. The dataset currently has limited access, but access permission can be granted to additional users as Pew staff see fit.

Results & Discussion

Outstanding National Resource Water Prioritization

Rivers and streams with high ONRW potential tended to be found in the western half of the state, particularly in the Coast and Cascade ranges, as well as the northeast corner, namely the Blue and Wallowa mountains (Map 1). Although scores were generally lower in the dry southeast and in the more densely populated Willamette Valley, a number of exceptions include portions of the Owyhee River, the Donner und Blitzen River and tributaries, the South Fork John Day River, and the North Fork Santiam River. This general pattern at the river level is logically reflected in the geographic distribution of the top-scoring 20 watersheds, which are concentrated in the Coast and Cascade ranges, with one exception in the Wallowa Mountains to the northeast (Minam River watershed). Each of these top 20 watersheds contained at least 118 river miles that scored within the top 25% of segment-level ONRW scores (Table 4). The top-scoring watershed (Chetco River) contained 253.6 river miles within the top 25% of segment-level ONRW scores.

Rivers and streams with the highest ecological value (and thus the highest potential for ONRW designation) are found in the Coast and Cascade ranges and in the Blue and Wallowa mountains.

Table 4. Summary of the top-scoring HUC10 watersheds across the state for ONRW potential, based on total river miles that scored within the top 25% of segment-level ONRW scores.

Rank (by miles)	Name	HUC10 ID	River miles in Top 25%
1	Chetco River	1710031201	253.6
2	Headwaters Rogue River	1710030701	249.7
3	Nestucca River	1710020302	199.2
4	Middle Clackamas River	1709001104	167.8
5	Headwaters North Santiam River	1709000502	162.4
6	South Fork Coquille River	1710030502	156.8
7	Headwaters McKenzie River	1709000402	155.7
8	East Fork Hood River	1707010505	151.9
9	Trask River	1710020304	149.8
10	South Fork McKenzie River	1709000403	148.0
11	Upper Metolius River	1707030109	147.8
12	White River	1707030609	146.8
13	Wilson River	1710020305	145.2
14	Minam River	1706010505	138.3
15	Youngs River-Frontal Columbia River	1708000602	137.9
16	Horse Creek	1709000401	129.5
17	Upper Clackamas River	1709001102	126.8
18	Salmon River	1708000103	125.1
19	South Fork Rogue River	1710030702	120.0
20	Bull Run River	1708000105	118.9

Rivers and streams with high ONRW potential varied in their strengths and weaknesses (Maps 4-5). A total of 1,141 river miles scored in the top 25% statewide for all ONRW objectives (water quality, ecological significance, and cold-water refuge potential), while 578 particularly exceptional river miles scored in the top 10% statewide for all ONRW objectives. Most of these rivers were found in the western Cascades, but some were found in the Upper Wallowa and adjacent watersheds in the northeast. What's more, 4,383 river miles scored in the top third of all rivers statewide for all three ecological significance indicators (at-risk aquatic species diversity, rarity-weighted species richness, and ecosystem type rarity); these rivers are remarkable in their representation of multiple sources of ecological value that do not otherwise tend to coincide so strongly.

A total of 1,141 river miles scored in the top 25% statewide for all Outstanding National Resource Water objectives, including water quality, ecological significance, and cold-water refuge potential; 578 particularly exceptional river miles scored in the top 10% for all ONRW objectives.

What's more, 4,383 river miles scored in the top third statewide for all indicators of ecological significance, including at-risk aquatic species diversity, rarity-weighted species richness, and ecosystem type rarity.

Rivers and streams in the northwest corner of the state generally had very high at-risk species richness, ecosystem type rarity, and thus overall ecological value; many also had high water quality and potential to serve as cold-water thermal refuges. Those in the northern Cascades also had high at-risk species richness, but were particularly strong in their water quality and cold-water refuge potential. In contrast, rivers in the Minam River watershed had low at-risk species richness and mixed overall ecological value, but high water quality and cold-water refuge potential. Priority watersheds in southwest Oregon were perhaps most strongly driven by high water quality. In total, 5,784 river miles were within the ranges of at least 30 aquatic SGCN, all in western Oregon, while 41,872 river miles were within the ranges of at least 20 aquatic SGCN, distributed throughout western and into northeast Oregon. These SGCN include threatened and endangered species such as Chinook, Chum, and Coho salmon (*Oncorhynchus tshawytscha, O. keta, O. kisutch*, respectively), the Lost River sucker (*Deltistes luxatus*), and the Oregon spotted frog (*Rana pretiosa*) that could particularly benefit from permanent protection of these rivers and streams. Fourteen of the top 20 watersheds contain drinking water sources. Most of these were along the east slope of the Cascades, with the exception of the South Fork Coquille River watershed in the southern portion of the Coast Range. Only small portions of the four priority watersheds in the northwest corner of the state overlap with drinking water source areas.

In total, 5,784 river miles were within the known ranges of at least 30 aquatic Species of Greatest Conservation Need (SGCN), all in western Oregon; 41,872 river miles were within the ranges of at least 20 species, extending into northeast Oregon.

State Wild and Scenic River Prioritization

Rivers and streams with high W&S potential were more widely distributed throughout the state (Map 2). High-scoring rivers were clustered in the southern portion of the Coast Range, throughout the Cascade Range, and higher-elevation watersheds across eastern Oregon. Low scores were ubiquitous throughout the Willamette and Umpqua valleys of western Oregon, where accessibility from population centers is high. These patterns are evident in the distribution of the top-scoring 20 watersheds. Each of the top 20 watersheds contained at least 96 river miles that scored within the top 25% of segment-level W&S scores (Table 5). The top-scoring watershed (Chetco River) contained nearly 280 river miles within the top 25% of segment-level W&S scores.

The Chetco River watershed in southwest Oregon contained the highest total river miles with high potential for both ONRW and W&S designation across the state, as a result of its high ecological value, water quality, and remoteness.

Table 5. Summary of the top-scoring HUC10 watersheds across the state for W&S potential, based on total river miles that scored within the top 25% of segment-level W&S scores.

Rank (in miles)	Name	HUC10 ID	River miles in Top 25%
1	Chetco River	1710031201	279.9
2	Minam River	1706010505	205.3
3	Headwaters Malheur River	1705011601	184.4
4	Upper Donner und Blitzen River	1712000301	160.9
5	South Fork McKenzie River	1709000403	155.4
6	Headwaters Rogue River	1710030701	151.3
7	Eagle Creek	1705020310	147.8
8	Lower Imnaha River	1706010205	140.9
9	South Fork Coquille River	1710030502	138.7
10	Upper North Fork Malheur River	1705011611	135.0
11	Silver Creek	1712000502	129.0
12	Middle North Umpqua River	1710030108	128.3
13	Potamus Creek-North Fork John Day River	1707020207	126.9
14	Headwaters Middle Fork Willamette River	1709000101	126.3
15	Headwaters North Santiam River	1709000502	124.6
16	Horseshoe Bend-Rogue River	1710031004	122.7
17	Wenaha River	1706010603	116.2
18	Big Creek-North Fork John Day River	1707020203	110.6
19	Horse Creek	1709000401	109.8
20	Klondike Creek-Illinois River	1710031108	96.7

Over 150 river miles scored in the top 10% statewide for all indicators of State Scenic Waterway potential, including inaccessibility, water quality, protected status, and primitive, unaltered nature. A total of 1,347 river miles scored in the top 25% statewide; these were distributed widely across the state.

Rivers and streams with high W&S potential were consistently characterized by both high water quality and high inaccessibility by surface transport (Map 5a, d). Over 150 river miles scored in the top 10% statewide for all indicators of State Scenic Waterway potential (inaccessibility, water quality, protected status, and primitive, unaltered nature), while 1,347 river miles scored in the top 25% statewide for all indicators. These rivers were widely distributed across the state in patterns that did not mirror those of high-scoring rivers for ONRW objectives. These rivers therefore possess value distinct from that of rivers with high ONRW potential, suggesting that W&S and ONRW designations may be complementary tools that, together, can ensure protection of a range of values and ecosystem services offered by rivers and streams. Eight of the top 20 watersheds contain drinking water sources, primarily along the east slope of the Cascades. The South Fork Coquille River watershed in the southwest and Eagle Creek watershed in the northeast also contain drinking water sources.

Fourteen of the top 20 watersheds for ONRW potential and eight of the top 20 for W&S potential contain drinking water sources.

Potential Applications of the Data and Results

These analyses were intended to support scientifically grounded identification of ONRW and W&S candidates with the greatest potential for designation. Specifically, we aimed to provide scientific information quantifying the ecological value and thus the positive ecological impacts of potential designations. Here we have demonstrated the application of these results to identifying watersheds containing the best candidates for ONRW and W&S designation statewide. However, our prioritization results and the underlying database supporting them can be applied in a variety of ways.

First, the results and database could be used to identify the best candidates for conservation (whether by ONRW or state W&S designation or by other means, e.g., federal Wild and Scenic) within a smaller region of interest. For example, if planning efforts are focused on a region that did not contain any of the highest-priority streams or watersheds (e.g., Crook or Malheur DEQ planning regions), our results could be used to identify the best candidates *within the focal region alone.* The database may show that these candidates have, for example, lower diversity of rare species and habitats than other parts of the state, but still have high water quality, minimal human modification, and importance for SGCN that are not present in higher-scoring areas, making them valuable targets for protection. For example, high-scoring portions of the Owyhee River may support the western ridged mussel (*Gonidea angulata*) and winged floater (*Anodonta nuttalliana*), which occur in relatively few watersheds across the state, as well as the Columbia spotted frog (*Rana luteiventris*), which is not found in western Oregon; high-scoring segments of the Donner und Blitzen River are expected to support Great Basin redband trout (*Oncorhynchus mykiss newberrii*), which only occurs in east-central Oregon.

The results can also be used to assess the ONRW or W&S potential of a specific river or watershed of interest. This may be useful for supporting existing grassroots efforts to protect a given river or watershed, to bolster other localized, place-based information, or to respond to local or regional conservation opportunities as they arise. Relatedly, the database can be used to identify the criteria and indicators that are strengths and weaknesses in a given place.

Additionally, filters can be applied to the database to identify all streams and rivers that meet a threshold ONRW or W&S score, that meet a threshold for a particular criterion of interest (e.g., cold-water refuge potential, Map 6), or that may qualify for both ONRW and W&S designation. Similarly, filters could be used to select and explore only rivers occurring within wilderness areas or meeting a particular flow volume threshold. The complete database provides many opportunities to adapt the information to a variety of needs and purposes. Alternatively, filters could be applied to the hydrography dataset itself as a first step in creating a similar analysis that considers a different universe of rivers and streams. For example, the hydrography dataset could be filtered based on additional characteristics, such as stream discharge or reach slope. Application of such filters would, upfront, reduce the number of rivers and streams considered in the analysis. They could, for example, allow for more explicit focus on rivers (as opposed to streams) by applying a flow threshold of 100 cfs (as opposed to 1 cfs). Similarly, use of a 15% reach slope threshold could restrict the focus of the analysis to rivers and streams accessible to fish and macroinvertebrates that cannot traverse waterfalls and cascades that become more common in steeper reaches (D. Isaak, pers. comm.). Application of such filters would likely produce different and complementary results to those presented here because they reframe the question and need.

We highlight only a handful of major applications of the results and data here, but others certainly exist (e.g., scenic or recreational river areas, other state legislative or administrative protections). For example, criteria scores could be recombined using weighted sums to reprioritize rivers with greater or lesser emphasis on particular criteria, additional datasets could be added to represent particular user interests or as new information becomes available, or the data could be used to assess restoration potential (i.e., where water quality or flow modification might be detracting from otherwise high ecological values).

Limitations of the Data and Results

We compiled the most robust data available to us at statewide extents and co-developed a transparent, flexible means of scoring ONRW and W&S potential. However, our analyses and the underlying data do have limitations.

First, our analysis is intended as a coarse-filter, first-pass identification of potential priorities. Consideration of finer-scale, local information and circumstances is needed before taking policy or on-the-ground actions to protect high-scoring rivers. This is due in part to the coarse spatial or thematic resolution of some of the data available for our analyses. For example, our estimate of at-risk aquatic species richness is based on species range data that typically have spatial resolution of HUC8 watershed units or counties. Thus, we can predict the potential presence of a given species of greatest conservation need in a given stream from state-level data, but local-scale information—including expert opinion—should subsequently be considered to confirm the presence of the species of interest in a particular stream. Similarly, we assume that streams with cooler projected August temperatures are most likely to offer cold-water thermal refuges to cold-water species, but it is necessary to consult fish distribution data and species-specific physiological temperature thresholds to determine whether a given stream of interest is likely to serve as a refuge for a particular species of concern (Isaak et al. 2015).

Second, we used a simple prioritization method that achieves transparency in the results, supports communication around the process, and enables the flexibility to make future adjustments. However, our use of this approach means that our results do not offer an optimized suite of priorities that maximize ecological benefits, minimize costs or risks, and achieve balanced representation across designation criteria. There are inherent tradeoffs between our chosen approach and the use of more complex spatial optimization algorithms. We determined that use of a simple objective hierarchy best fit the stated needs (i.e., transparency, ease of communication, flexibility) and that a more complex optimization approach did not. Furthermore, the data necessary to maximize benefits of an optimization approach (i.e., costs and risks associated with protection of a given river or watershed) were not available to us statewide. Nevertheless, it is important to be aware of what this analysis does not do and was not intended to do.

Third, our prioritization and underlying database are not (nor are they intended to be) a one-size-fits-all solution. This work was focused on statewide identification of rivers and streams with the highest potential for ONRW or W&S designation. Other similar efforts may exist at different scales (e.g., Trout Unlimited assessment of W&S eligibility in the Rogue River basin); these efforts will probably differ in their approach and findings due to differences in data availability across these extents or differences in objectives. Other means of preparing, scoring, and summarizing the data used here also exist that may better address different questions. For example, we discuss the potential for use of different methods of aggregating scores to the watershed level and application of different filters to the underlying hydrography dataset to address different questions and needs. Other opportunities for river protection outside of ONRW or W&S designation are available that may be defined by different criteria or consider additional tradeoffs. Our findings are meant to be interpreted and applied in the context of other complementary information offered by other researchers and conservation efforts. This may include local-scale data or other contextual information (e.g., local community and political support) that may help to narrow down a feasible set of priorities that diverse partnerships can agree to support.

Finally, it is critical to acknowledge that ongoing climatic changes will continue to have direct and dramatic implications on freshwater systems in Oregon and elsewhere in the American West. This is particularly true for watersheds that have historically been snow-dominant, but that are projected to transition to rain-dominance (Barnett et al. 2005). The resulting changes and variability associated with the magnitude, frequency, duration, and timing of river flows are not incorporated in this prioritization scheme but certainly warrant consideration in evaluating how well ONRW designation may afford protection in a warming world.

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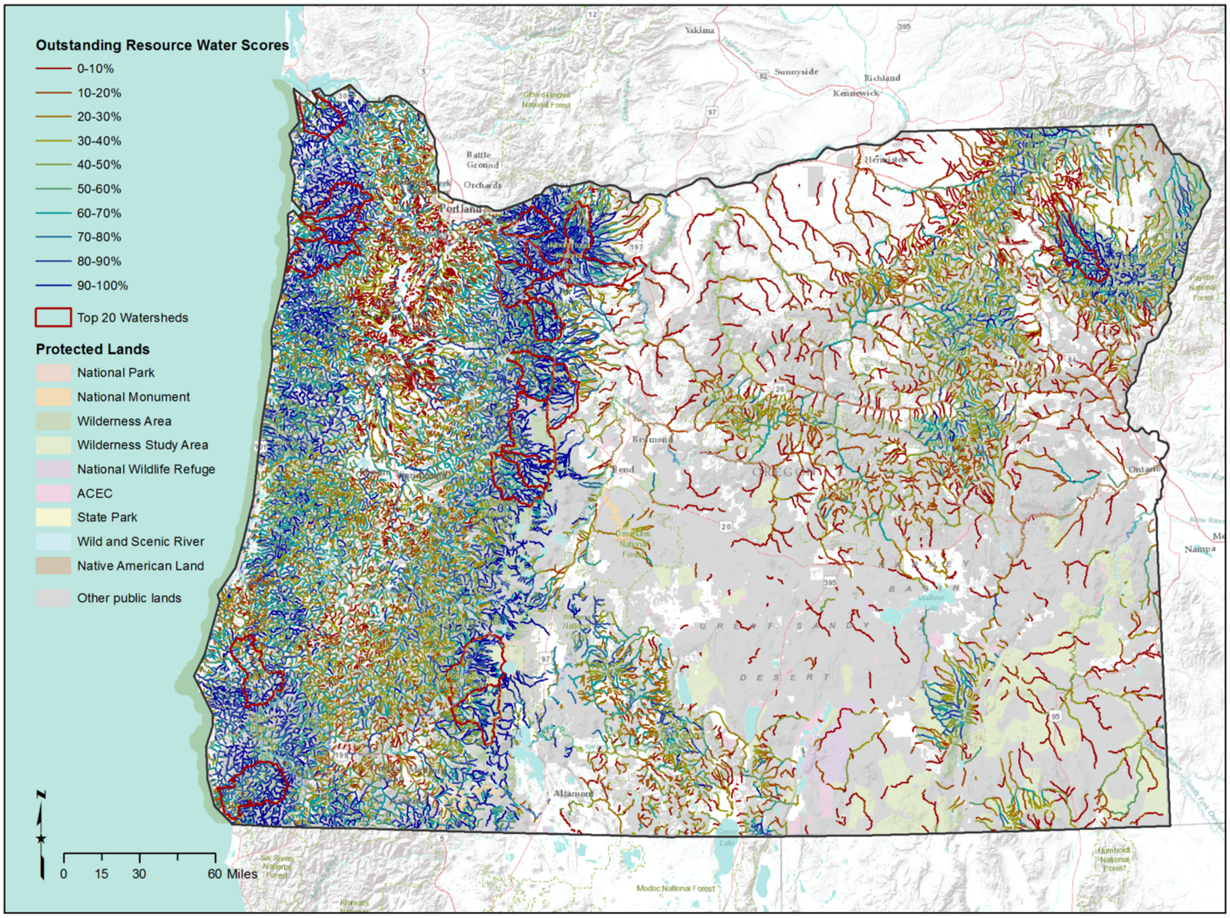
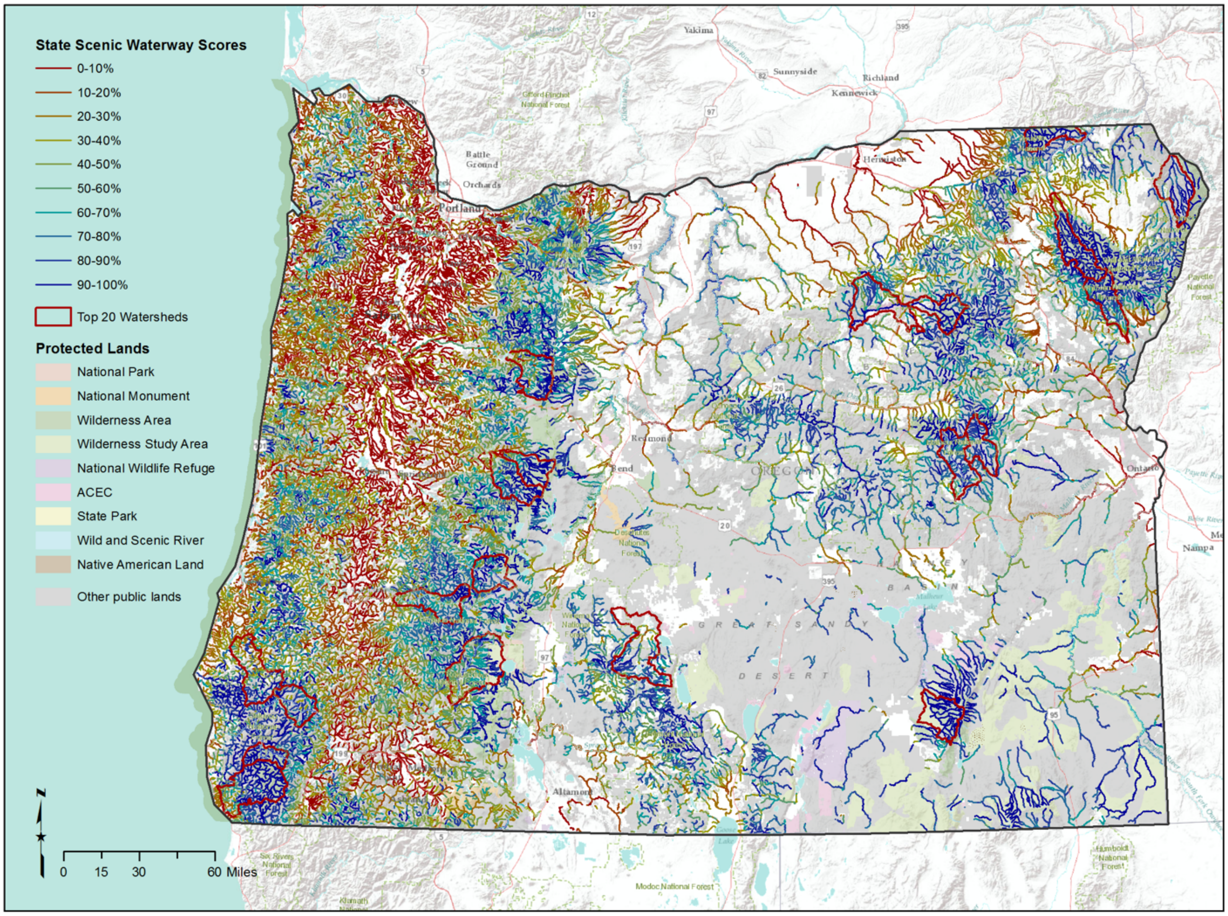
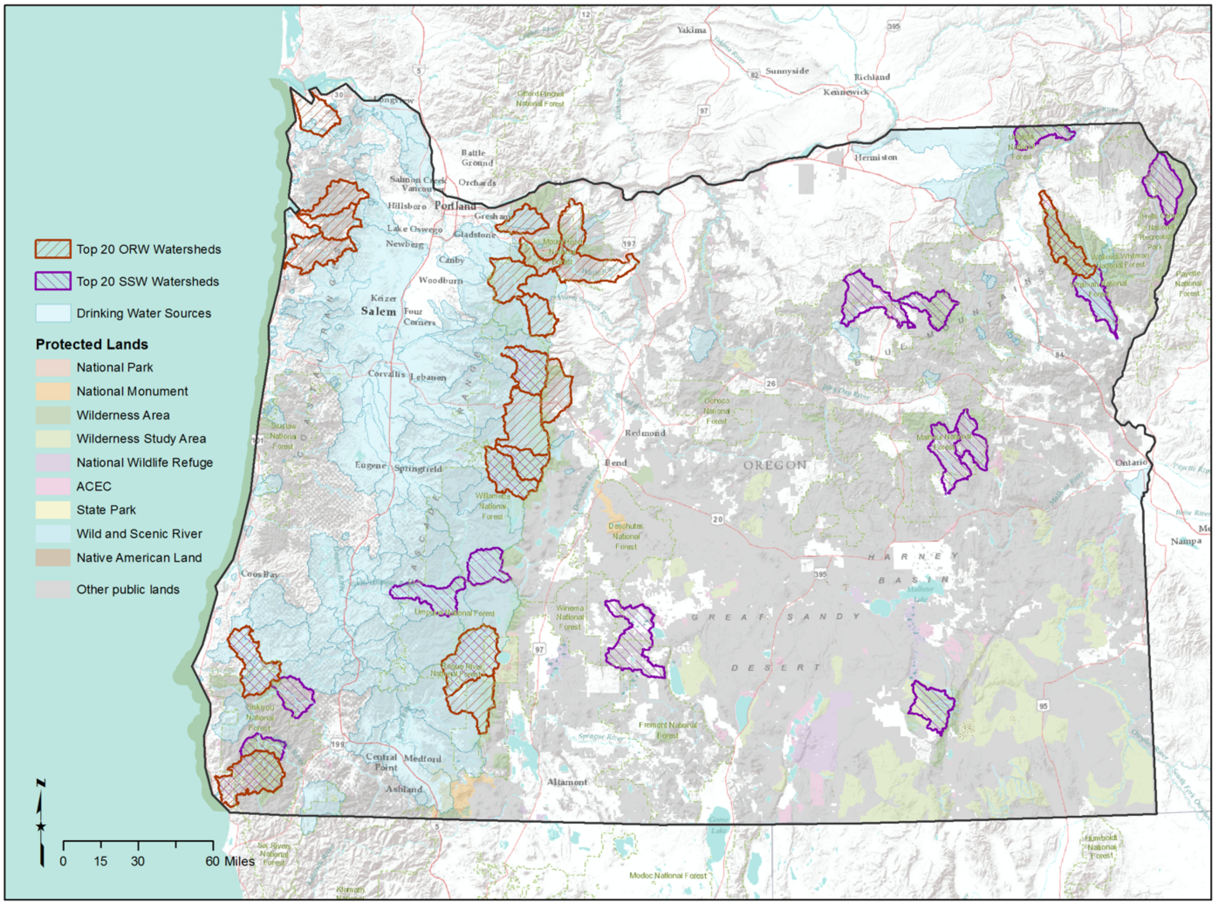
Maps



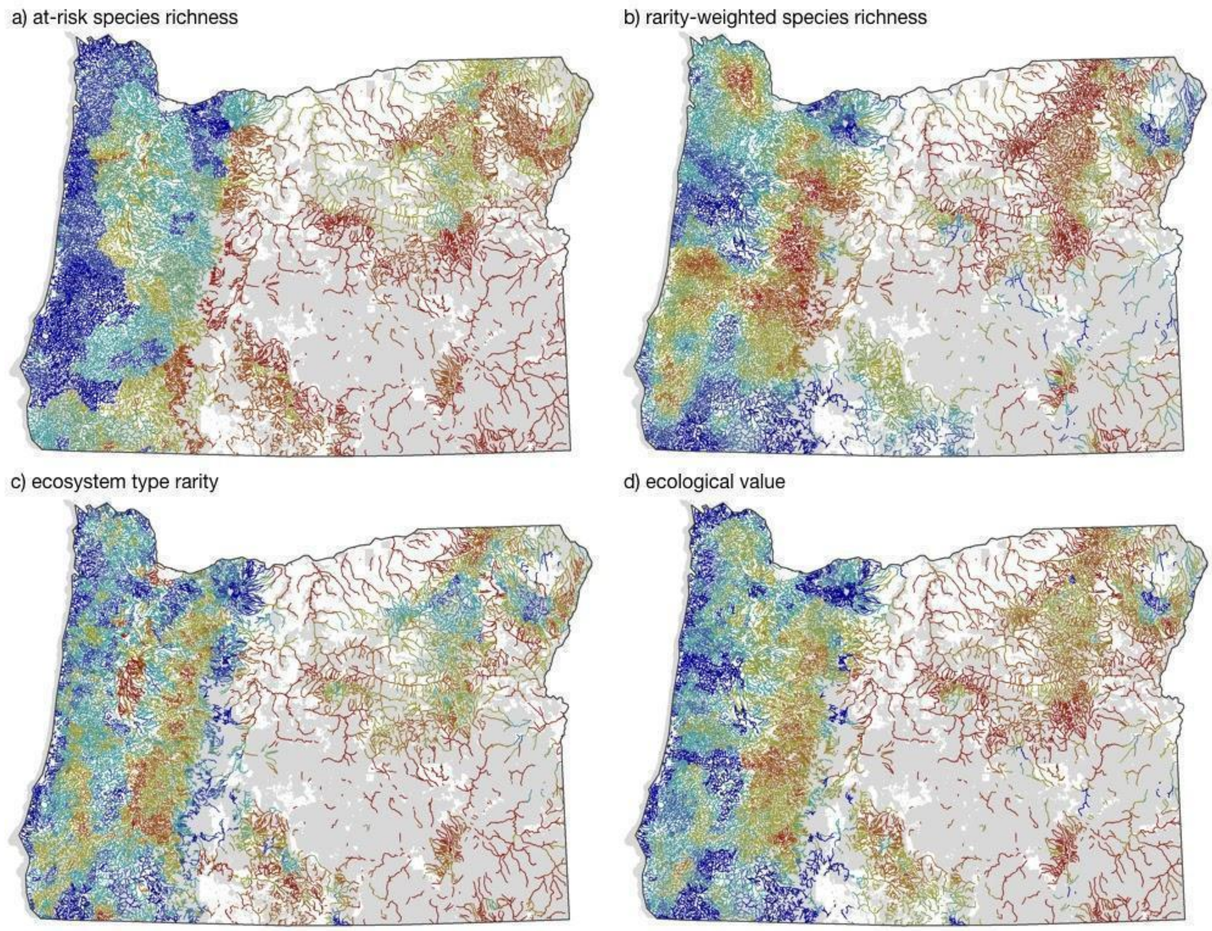
Map 1. Map of segment-level Outstanding Resource Water (Oregon's term for ONRW waters) scores highlighting the top 20 watersheds in red outlines.



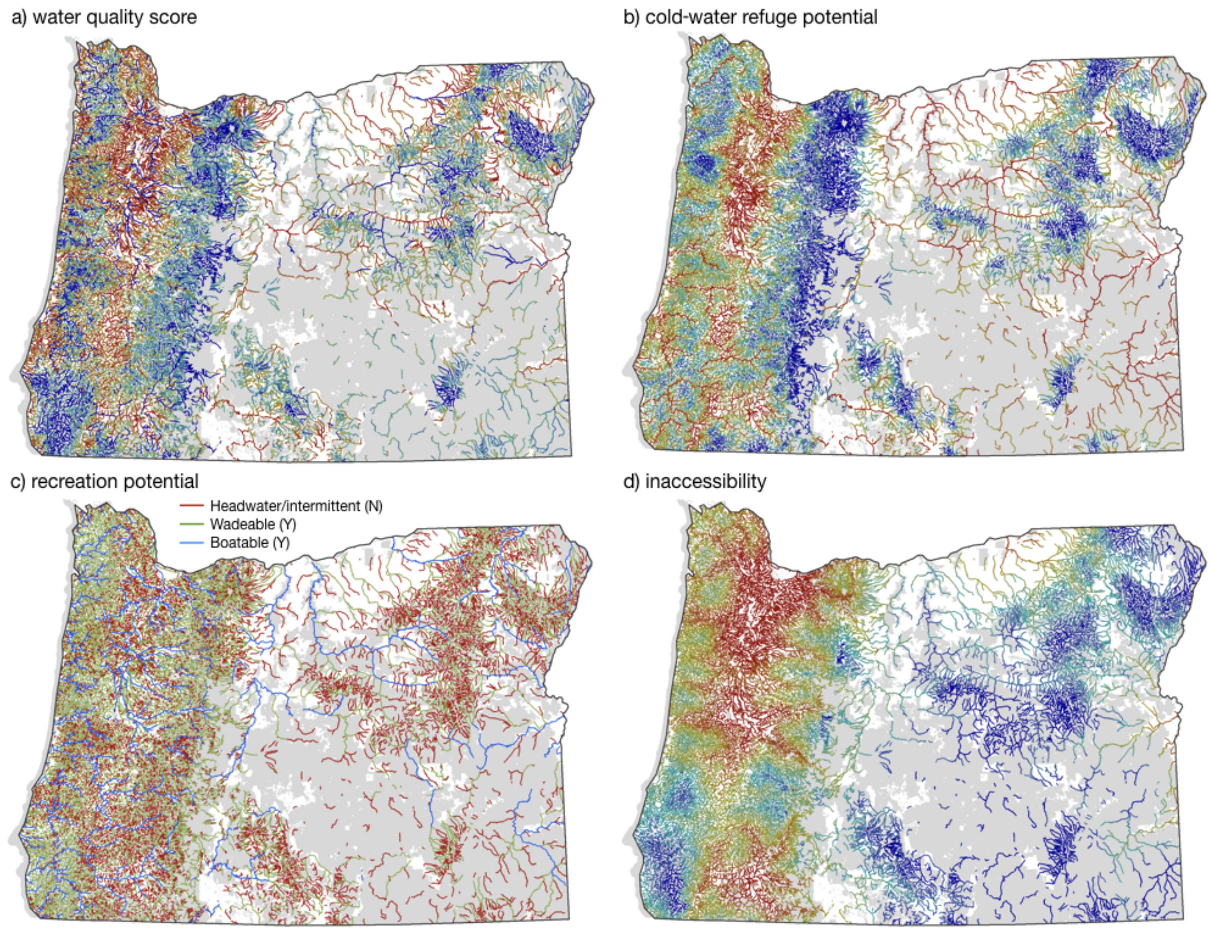
Map 2. Map of segment-level state Wild & Scenic waterway scores highlighting the top 20 watersheds in red outlines.



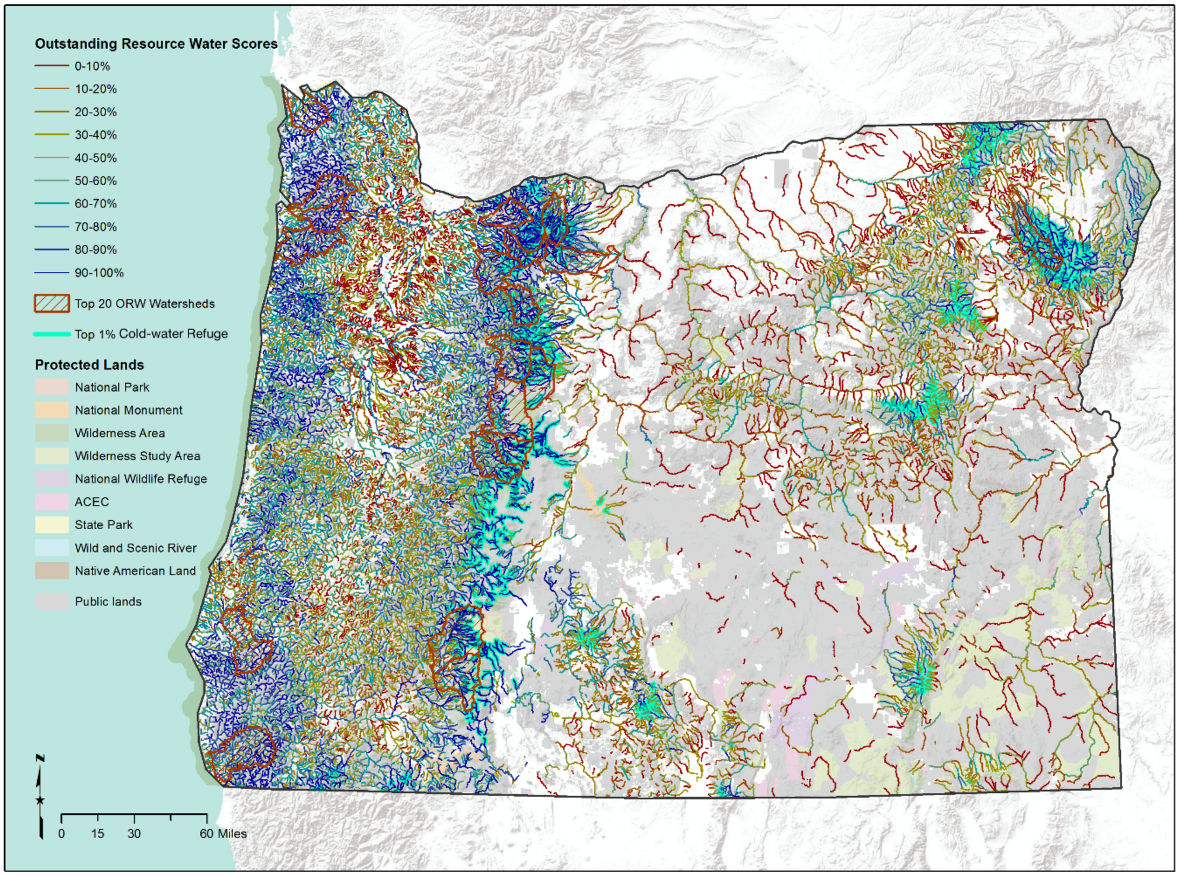
Map 3. Map of top 20 watersheds for ONRW (red) and W&S (purple) designations, overlaid on surface drinking water source watersheds. Note that watersheds scoring in the top 20 for both ONRW and W&S potential appear with crosshatching.



Map 4. Maps of a) at-risk species richness, b) rarity-weighted species richness, c) ecosystem type rarity, and d) ecological value, scored as the fuzzy sum of a, b, and c, across Oregon. In each map, values are quantile scaled such that the highest-scoring 10% of stream segments are shown in dark blue and the lowest-scoring 10% are shown in red.



Map 5. Maps of a) water quality score (calculated as the fuzzy sum of water quality category, GAP protected status, and total degree of modification), b) cold-water refuge potential, c) potential recreational value, and d) inaccessibility across Oregon. In each map (except (c)), values are quantile scaled such that the highest-scoring 10% of stream segments are shown in dark blue and the lowest-scoring 10% are shown in red.



Map 6. Map of segment-level Outstanding Resource Water scores, with top 1% of cold-water refuge scores highlighted in turquoise, demonstrating one example of application of additional *post hoc* filters to identify river and stream segments that best support particular protection targets.

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Appendix A. Derivation of Indicators

Descriptions of source data and derivation methods for indicators used to assess criteria for potential ONRW and W&S designation. (In Oregon, these designations are termed Outstanding Resource Waters and State Scenic Waterways.)

At-risk aquatic species richness. The at-risk aquatic species richness score represents the number of aquatic Oregon Species of Greatest Conservation Need (SGCN) potentially present in a given river or stream. Species range data were obtained from the Western Division of the American Fisheries Society via Data Basin (WDAFS 2012) at HUC8 resolution and from U.S. Fish and Wildlife Service species profiles (variable resolution; USFWS 2019). Ranges were overlaid and counted, then counts were percentile scaled (i.e., a score of 0.9 indicates that on average over its length, the segment is within the geographic range of more SGCN than 90% of other segments across Oregon). Rivers and streams in watersheds with high at-risk species richness are likely to support fish, amphibians, reptiles, and/or invertebrates that the state has designated as SGCN.

Rarity-weighted species richness*.* Rarity-weighted species richness provides a relative measure of the concentration of rare and irreplaceable species across the U.S. (Chaplin et al. 2000). High rarity-weighted species richness is often indicative of the presence of numerous endemic species and/or sites that contain critically imperiled or imperiled species with restricted distributions (i.e., G1-G2–ranked species). These sites are essential for maintaining species diversity, particularly rare, sensitive, and irreplaceable species. We used NatureServe's rarity-weighted richness index of critically imperiled (G1) and imperiled (G2) species (refreshed 2013) 1-km resolution data layer as an indicator of species rarity and irreplaceability (see Chaplin et al. 2000 for references and description of methods). Additional information on this metric is available here.

Ecological system type rarity. Areas with high ecological system rarity are those that support rare, unique, or irreplaceable natural systems. These systems are likely to consist of species that are rare, unique, or irreplaceable. Ecological systems are defined as "groups of plant community types that tend to co-occur within landscapes with similar ecological processes, substrates and/or environmental gradients" (Comer et al. 2003), thus they incorporate physical components such as landform position, substrates, hydrology, and climate in addition to vegetation. To characterize ecological system type rarity, we calculated the areal extent of USGS GAP ecological system types at 30-m resolution (USGS 2011), then normalized the values based on the maximum value so that they ranged from 0 (least rare) to 1 (most rare).

Cold-water refuge**.** Cold-water refuge potential was estimated based on projected stream temperature (Isaak et al. 2017). We assumed that streams with colder projected mean August temperatures in 2050 are most likely to continue to provide habitat for cold-water-dependent species into the future. This assumption was based on the approach of Isaak et al. (2015), but our approach was generalized to multiple cold-water-dependent species (i.e., it is independent of species-specific temperature thresholds).

Absence of human modification. Harrison-Atlas et al. (2017) quantified the total degree of modification of rivers and streams in the western U.S. by considering both flow modification due to upstream barriers and modification of the adjacent valley bottom (or flood plain) by human activities such as agriculture, transportation, and residential development. We percentile scaled this integrated estimate (i.e., a score of 0.9 indicates that on average over its length, the segment has lower modification than 90% of other segments across Oregon). Watersheds with high scores have near-natural levels of flow due to absence of dams and diversions upstream and flow through mostly intact valley bottoms with little alteration for human use.

Water quality. Water quality was categorized by the Oregon Department of Environmental Quality (2019) for assessed streams and rivers such that: 1 = all designated water uses are supported; 2 = some but not all designated uses are supported; 3 = insufficient data are available to make a determination; 4 = not all designated uses are supported but a total maximum daily load (TMDL) designation is not required because a) it has already been completed, b) other control measures are expected to result in attainment of supported use, or c) the impairment is not caused by a pollutant; and 5 = impaired, such that not all designated uses are supported and a TMDL has been identified. These ordinal values were rescaled 0-1 as described in Table 2 for integration into ONRW and W&S prioritization scores. A water quality score was developed to fill gaps in water quality information for streams that have not yet been assessed. This proxy was calculated as a fuzzy sum of the rescaled water quality category (where available), rescaled GAP protected status (Table 2), and total degree of modification, then percentile scaled (i.e., a score of 0.9 indicates that on average over its length, the segment is expected to have higher water quality than 90% of other segments across Oregon).

Recreation potential. Due to the absence of consistent, inclusive statewide data on recreation value of rivers and streams, we relied on a coarse proxy for recreation potential, which indicates whether a river or stream has sufficient mean annual flow to support recreational activities such as swimming, fishing, boating, and rafting (Harrison-Atlas et al. 2017). A value of 1 indicates that the river has sufficient flow to be considered “wadeable” or “boatable” (i.e., > 6 cubic feet per second). This should be considered an initial screen for potential recreational value; local datasets and information should be consulted for additional details pertaining to recreational opportunities and/or use.

***Accessibility**.* Weiss et al. (2018) quantified and validated global accessibility to high-density urban centers at a resolution of 1 km for 2015, as measured by travel time via surface transport. They first completed a global-scale synthesis of two leading roads datasets—Open Street Map (OSM) data and distance-to-roads data derived from the Google roads database. They then integrated 10 global-scale surfaces that characterize factors affecting human movement rates and 13,840 high-density urban centers to quantify and map travel time to cities using a least-cost path algorithm (Dijkstra 1959). Weiss et al. (2018) aimed to quantify inequities in access to the human goods and services that are heavily concentrated in cities and to highlight needs for increasing accessibility to meet Sustainable Development Goals established by the United Nations. However, their analysis is equally useful here for quantifying the inverse property of landscapes—inaccessibility—associated with the remote, undisturbed places of interest. Here, values are percentile scaled (i.e., a score of 0.9 indicates that on average over its length, the segment is more inaccessible than 90% of other segments across Oregon).

Appendix B. Detailed prioritization methods

Score calculations below are performed using the flowlines shapefile (common to all statewide flowline layers in the map) contained in the map package associated with this report (OR_StateOfOurRivers_data.mpk). Most relevant fields have already been prepared and scaled appropriately for prioritization as described in the methods section above, except as noted below. For most steps, and unless otherwise noted, simply add a new field (type: double) and use the Field Calculator in ArcMap (10.8) to generate the field's values.

<u>*ONRW analysis*</u>

1. Rescale categorical variables (water quality category and GAP protected status) as described in Table 2 (above) for use in score calculation. Note: if segments have a water quality category value of 0 or NoData, they should be rescaled to a value of 3 (corresponding to 'unassessed/no data').

2. Assign a recreation potential score (RecScore) based on SizeClass (if SizeClass > 1, RecScore = 1, otherwise RecScore = 0).

3. Calculate the ecological significance criterion score as the fuzzy sum of ecological indicators (Bonham-Carter 1994; after Theobald 2013). Field names are defined and described in the accompanying attribute definitions documents.

   EcoScorePerc = 1 - [(1 - SGCNRichPerc) * (1 - RWRichPerc) * (1 - EcoRarPerc)]

4. Calculate the water quality proxy score as the fuzzy sum of water quality and additional relevant proxies:

   WQScorePerc = 1 - product(1 - WQCat_scaled[1], 1 - GapStatus_scaled[1], 1 - HumModPerc)

   [1]*Rescaled as described in step 1*

5. Rescale the ecological significance and water quality scores above to percentile scores. To do this in ArcGIS:
   a. Convert polylines to raster format (90 m resolution)
   b. Use the Slice tool (equal area method, 100 zones) to redistribute values as percentile ranks. Note: Depending on the distribution of the raw values, it may not be possible to create 100 equal-area zones. If this is the case, create the maximum possible number of zones given the distribution.
   c. Use Zonal Statistics as Table to extract the mean raster value intersected by each flowline segment (zone data = original flowlines, zone = FID, value raster = the sliced raster created in step b, statistics type = MEAN).
   d. Rescale values to 0-1 by dividing by the maximum value
   e. Join values back to the working flowlines attribute table by FID; rename the joined fields EcoScorePerc and WQScorePerc.

6. Calculate the ONRW potential score for each stream segment as simply the sum of all relevant criteria (differential weights could be applied at this step in the future, but for purposes of this analysis, equal weights were used). Then rescale the ONRW potential score to 0-1 for easier interpretation by dividing by the maximum value (4).

    ONRWSegMean = EcoScorePerc + WQScorePerc + RecScore + ColdwaterPerc

7. Aggregate segment-level scores to HUC10 watersheds:
    a. Select and export the top 25% of segment-level ONRW scores as a new shapefile.
    b. Sum the length of these top-scoring segments in each watershed using the Summarize tool on the HUC10 field in the exported top 25% flowlines attribute table. Choose the sum of Length_mi as the summary statistic to be included.
    c. In the resulting summary table, sort the summed length field in decreasing order, then select and export the top 20 HUC10 units.
    d. Join the summed length field in the summary table back to the full working flowlines dataset by HUC10 to produce the ONRWHUC25perc field (aggregated watershed-level score).

Wild & Scenic analysis

1. The state Wild & Scenic potential score is a simple sum of the relevant indicators. As in step 5 above for ONRW scores, differential weights could be applied at this step in the future, but for purposes of this analysis, equal weights were used.

    WSSegMean = WQScorePerc + GapStatus_scaled[1] + HumModPerc + AccessPerc

    [1]*Rescaled as described in step 1 of the ONRW analysis*

2. Rescale the result to 0-1 for easier interpretation by dividing by the maximum possible value (4).

3. Aggregate segment-level scores to HUC10 watersheds as described in step 7 of the ONRW analysis. This will generate the top 20 HUC10 units for W&S scores as well as the WSHUC25perc aggregate score field.

Generating reported summary statistics

1. To identify the total number of river miles meeting a given threshold for multiple criteria:
    a. Perform a selection by attributes. For example, to select segments within the top 25% of all ecological indicator scores, use the following selection query:

        "SGCNRichPerc" >= 0.75 AND "RWRichPerc" >= 0.75 AND "EcoRarPerc" >= 0.75

b. Use the Statistics function in the drop-down menu on the Length_mi field to identify the total river mileage of the selected segments.

2. To identify the total number of river miles expected to support a given number of Species of Greatest Conservation Need (SGCN):
    a. Select features of the Raw SGCN Counts layer that have a Join_Count greater than the target number of species (e.g., 30).
    b. Perform a selection by location. Select features from the flowlines dataset that intersect the selected Raw SGCN Counts features.
    c. Use the Statistics function in the drop-down menu on the Length_mi field to identify the total river mileage of the selected segments.

3. To identify the number of top 20 HUC10 watersheds that contain drinking water sources perform a selection by location. Select top 20 HUC10 watersheds that intersect the drinking water source areas layer.

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