Conservation Science Partners

FINAL REPORT

30 June 2021

For the project titled:

California State of Our Rivers Report

Commissioned by:

The Pew Charitable Trusts

Recommended citation: Conservation Science Partners, Inc. 2021. California State of Our Rivers Report. Final Report. Truckee, CA.

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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 California with the highest potential for 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 36,653 miles considered, rivers and streams with the highest ONRW potential are most often found in northwest California and the southern Sierra Nevada range. A total of 1,192 river miles scored in the top 10% statewide for all ONRW objectives (water quality, ecological significance, and recreation potential). These rivers, found primarily in the southern Sierras (Tuolumne and Merced rivers and tributaries) and the far northwest (Smith River) are especially remarkable in representing multiple values that overlap to a limited degree statewide. California's rivers support high numbers of aquatic species identified by the state as Species of Greatest Conservation Need (SGCN); 11,506 river miles are within the ranges of at least 15 aquatic SGCN. These are most prominent in the northwest, north of the Bay Area, and in the northern Sierras; other rivers, though less diverse overall, are expected to support at-risk species not found elsewhere in the state. In all, 1,920 river miles scored in the top 50% statewide for all Wild & Scenic potential indicators; these rivers are remarkable in achieving higher-than-average scores in attributes that share little overlap in California. The top-scoring watershed for Wild & Scenic potential (South Fork Smith River) contained nearly 342 river miles within the top 25% of stream segment-level scores. We found that although some overlap occurs among watersheds with the highest ONRW and the highest W&S potential, this overlap is incomplete, suggesting that these designations can serve as complementary tools for California's rivers. Twelve of the top 20 ONRW watersheds and 11 of the top 20 W&S watersheds contained drinking water sources; protection of these waters would help to maintain provision of this vital ecosystem service for generations to come.

In short, many thousands of river miles across California 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 California 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. 2007) 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, climate regulation, aesthetic enjoyment; Brauman et al. 2007).

As our planet warms and climate patterns change (Masson-Delmotte et al. 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. 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). Currently, less than 0.5% of river miles in the United States are 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 River 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 California 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. 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 California, there are currently only two water bodies designated as ONRW (Lake Tahoe and Mono Lake); fewer than 1,550 miles are designated as state 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 and 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. 2012). 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 achieves each criterion is assessed based on one or more indicators, which are defined by the available data. These criteria, indicators, and the weights assigned to each to achieve priority scores are described in detail below.

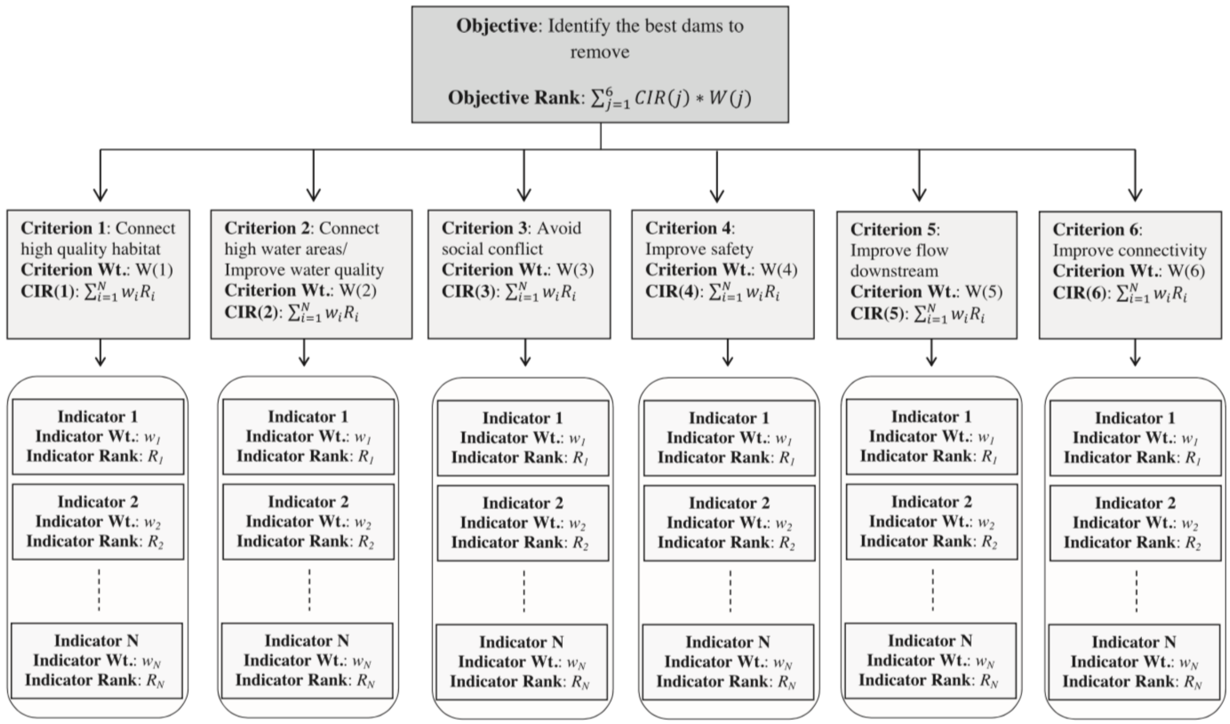


Figure 1. Example of an objective hierarchy framework, in which weighted indicators are used to assess the extent to which criteria defining an overall objective are met. In this example, the framework is used to identify the best dams for removal to achieve ecological and social benefits (Hoenke et 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; 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 36,653 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 California for ONRW designation. Although California has not yet established formal criteria for designation, the state's regional water quality control boards have, on several occasions, supported ONRW designation as a means of protecting high-quality waters, and recognize that designation affords these waters the greatest protection under the U.S. Clean Water Act through implementation of federal antidegradation policy 40CFR131.12, which generally prohibits the lowering of water quality. We borrowed from ONRW criteria established in other states, which also uphold the intent of the Clean Water Act and are similar across states. 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 each of these components as indicators. We then integrated each indicator, then each criterion, into a single overall ONRW potential score.

Table 1. Indicators used to assess ONRW potential for all rivers and streams in California. 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)	California State Water Resources Control Board 2016
	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	Total freshwater aquatic diversity	Freshwater Species Database v2 (Howard et al. 2015)
	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
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*	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*

To quantify "exceptional water quality," we first obtained water quality data from the California State Water Resources Control Board (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), 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. 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 and Brost 2010]). For this statewide assessment, we considered four indicators that together represent a high-level assessment of streams that are ecologically remarkable and/or have conservation value. First, we accessed a comprehensive database of freshwater aquatic species occurrence across the state of California that is summarized at the HUC12 watershed level (Howard et al. 2015; see Appendix A). This database is inclusive of fish, herpetofauna, mollusks, birds, crustaceans, plants, mammals, insects, and other invertebrates. Second, 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 California Department of Fish and Wildlife (2015), 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.

Rivers and streams may support a wide variety of recreational opportunities, including fishing, swimming, floating, kayaking, whitewater rafting, and motorized boating. 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., having 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 part of 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 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 GAP protected status levels established by USGS (2018) and water quality ordinal ranks established by the California State Water Resources Control Board (2016).

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 we had no *a priori* reason to score one criterion higher than another. 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 & Scenic Rivers

To assess state Wild and Scenic (W&S) potential, we followed a similar procedure to that described for ONRW potential. We first identified existing criteria or guidelines established by the state of California for W&S designation. California has specified criteria for three W&S designations: Wild Rivers (WR), Scenic Rivers (SR), and Recreational Rivers (RR; Box 1). While WR are defined by their inaccessibility by roads and their primitive, unaltered nature, SR and RR 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 WR (i.e., the most stringent) designation. Rivers that achieve moderate scores may be suitable for nomination as SR or RR, 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 1. California Wild and Scenic River criteria (Public Resources Code Section 5093.50 et seq.).

Those rivers or segments of rivers included in the system shall be classified as one of the following:

(a) *Wild rivers, which are those rivers or segments of rivers that are* ***free of impoundments*** *and generally* ***inaccessible*** *except by trail, with watersheds or shorelines essentially* ***primitive*** *and waters* ***unpolluted****.*

(b) *Scenic rivers, which are those rivers or segments of rivers that are* ***free of impoundments****, with shorelines or watersheds still largely* ***primitive*** *and shorelines largely* ***undeveloped****, but* ***accessible*** *in places by roads.*

(c) *Recreational rivers, which are those rivers or segments of rivers that are* ***readily accessible*** *by road or railroad, that may have some development along their shorelines, and that may have undergone some impoundment or diversion in the past.*

As seen in Table 3, there is 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 "unpolluted," "primitive," and "free of impoundments" characteristics, respectively, 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, unpolluted rivers are expected to have high water quality unaltered by pollution and sedimentation. Lands with the highest degree of protection and minimal valley bottom modification are expected to be the most primitive and to remain so. And the degree of flow alteration is a direct indicator of the extent to which a river is free of impoundments.

The requirement that potential W&Ss be inaccessible except by trail 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).

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. 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.

Table 3. Indicators used to assess W&S potential for all rivers and streams in California. 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
Unpolluted	Assessed stream's water quality categorization (see Table 2)	California Department of Environmental Quality 2019
Primitive and free of impoundments	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)

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 Nature Conservancy in California and overlaid these polygons with our results. Drinking water source areas were delineated using methods detailed in Klausmeyer and Fitzgerald (2012). Briefly, public data sources were used to map the surface drinking water sources (rivers, reservoirs, lakes, etc.) for 80% (30 million) of California's residents, along with the watersheds that supply water to those sources. This effort produced the most comprehensive map to date of surface drinking water sources for California.

Database Delivery

The goal of this assessment was not only to prioritize rivers and streams for potential ONRW or W&S designation, but also 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 northwest corner of the state and in the Sierra Nevada Range, especially the more highly protected southern Sierras south of Lake Tahoe (Map 1). Scores were generally lower in the central Sierras (Plumas and Tahoe national forests), and were mixed in other portions of the state. Few rivers or streams in dry southern California had sufficient flow to be considered in this analysis. This pattern is reflected in the geographic distribution of the top-scoring 20 watersheds, which are concentrated in forested northwest California, the southern Sierras, and one watershed (Deer Creek) in Lassen National Forest in the northern Sierras. Each of these top 20 watersheds contained at least 67 river miles that scored within the top 25% of segment-level ONRW scores (Table 4). The top-scoring watershed (Middle Fork Kings River) contained 165.7 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 northwest California and the southern Sierra Nevada range.

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	Middle Fork Kings River	1803001003	165.7
2	Headwaters Merced River	1804000801	160.7
3	Headwaters Tuolumne River	1804000901	151.7
4	Deer Creek	1802015702	136.1
5	South Fork Salmon River	1801021001	135.7
6	North Fork Kings River	1803001006	133.7
7	South Fork Merced River	1804000802	124.5
8	Yosemite Creek-Merced River	1804000803	124.5
9	Falls Creek-Tuolumne River	1804000905	107.5
10	Upper South Fork Kings River	1803001002	97.7
11	Upper South Fork San Joaquin River	1804000602	95.9
12	Smith River	1801010104	94.7
13	Middle Fork San Joaquin River	1804000604	89.4
14	South Fork Smith River	1801010103	87.7
15	Middle Fork Smith River	1801010102	86.4
16	Tangle Blue Creek-Trinity River	1801021102	86.0
17	Indian Creek	1801020901	85.5
18	Redwood Creek	1801010201	82.3
19	Humboldt Bay-Frontal Pacific Ocean	1801010206	68.9
20	North Fork Smith River	1801010101	67.7

Rivers and streams with high ONRW potential varied in their strengths and weaknesses (Maps 4-5). For example, many of these top-scoring watersheds that are in high mountain settings, with a history of glaciation such that rates of endemism are relatively low and that now support nonnative trout. Still, these watersheds rose to the top in our integration of multiple ONRW criteria that include but also extend beyond biodiversity considerations. In all, 1,192 river miles scored in the top 10% statewide for all ONRW objectives (water quality, ecological significance, and recreation potential), primarily in the southern Sierras (Tuolumne and Merced rivers and tributaries) and the far northwest (Smith River). A total 1,935 miles scored in the top 25%, which ranged more broadly (e.g., Big Sur, Kings River). These rivers are remarkable in their representation of multiple conservation values that often do not co-occur so strongly. And 401 particularly exceptional river miles statewide scored in the top 25% for all ecological significance indicators (freshwater species diversity, at-risk aquatic species diversity, rarity-weighted species richness, ecosystem type rarity); these were found near the coast north of the San Francisco Bay Area.

A total of 1,935 river miles scored in the top 25% statewide for all Outstanding National Resource Water objectives, including water quality, ecological significance, and recreation potential, primarily in the southern Sierras; 1,192 river miles scored in the top 10% statewide for all objectives.

Particularly exceptional were 401 river miles that scored in the top 25% statewide for all indicators of ecological significance, including freshwater aquatic species diversity at-risk aquatic species diversity, rarity-weighted species richness, and ecosystem type rarity; they were found near the coast north of the San Francisco Bay.

Rivers and streams in the southern Sierras typically had high ecosystem type rarity, while those in the northern Sierras were often high in total freshwater species diversity. The northwest corner of the state had high at-risk aquatic species diversity. At-risk species diversity and rarity-weighted species richness were both high in coastal areas north of the San Francisco Bay. Water quality was particularly high throughout much of the Sierra Nevada range as well as in the extreme northwest of the state. A total of 11,506 river miles were within the ranges of at least 15 aquatic SGCN, in the northwest, north of the Bay Area, and in the northern Sierras; 853 river miles were within the ranges of at least 20 aquatic SGCN, which were found in the northern Central Valley and along the northern border (Klamath River and tributaries). Twelve of the top 20 watersheds contain drinking water sources. Most of these were priority watersheds in the Sierras, but they also included the Tangle Blue Creek-Trinity River watershed in the Cascade range.

A total of 11,506 river miles were within the known ranges of at least 15 aquatic species of greatest conservation need; 853 river miles were within the ranges of at least 20 species, in the northern Central Valley and in the Klamath River and tributaries.

State Wild & Scenic River Prioritization

Rivers and streams with high W&S potential were even more highly concentrated in northwest California and in the southern Sierras (Map 2). Low scores occurred throughout the San Francisco Bay Area and the Central Valley, where accessibility from population centers is high. These patterns are evident in the distribution of the top-scoring 20 watersheds. These high-scoring watersheds overlapped substantially but not entirely with the top 20 watersheds for ONRW potential. Many of California's rivers and watersheds therefore possess value distinct from those 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. Each of the top 20 watersheds contained at least 116 river miles that scored within the top 25% of segment-level W&S scores (Table 5). The top-scoring watershed (South Fork Smith River) contained nearly 342 river miles within the top 25% of segment-level W&S scores.

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	South Fork Smith River	1801010103	341.9
2	Middle Fork Kings River	1803001003	254.7
3	Headwaters Merced River	1804000801	235.2
4	New River	1801021110	213.4
5	South Fork Salmon River	1801021001	207.1
6	Headwaters Tuolumne River	1804000901	178.3
7	North Fork Kings River	1803001006	167.9
8	Upper South Fork San Joaquin River	1804000602	165.1
9	Wooley Creek	1801021003	164.0
10	North Fork Salmon River	1801021002	159.4
11	Upper Middle Fork Eel River	1801010402	157.8
12	Middle Fork Smith River	1801010102	157.2
13	Falls Creek-Tuolumne River	1804000905	146.6
14	Headwaters East Walker River	1605030101	146.3
15	Upper South Fork Kings River	1803001002	145.9
16	North Fork Trinity River	1801021109	133.3
17	Mattole River	1801010702	127.1
18	Middle Fork San Joaquin River	1804000604	123.9
19	Yosemite Creek-Merced River	1804000803	122.7
20	South Fork Merced River	1804000802	116.5

A total of 1,920 river miles scored in the top 50% statewide for all W&S potential indicators; these rivers are remarkable in achieving higher-than-average scores in attributes that share little overlap in California.

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). A total of 1,920 river miles scored in the top 50% statewide for all indicators of W&S potential (inaccessible, unpolluted, primitive, free of impoundments), almost entirely in the Cascade, Coastal, and Sierra ranges. Eleven of the top 20 watersheds contain drinking water sources, primarily in the southern Sierras but also including the Upper Middle Fork Eel River watershed in the Coast range.

Twelve of the top 20 ONRW watersheds and 11 of the top 20 W&S watersheds contained 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 W&S designation or by other means) 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., Regions 6, 9), 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, many rivers and streams in the Warner Mountains in the northeast corner of the state have high water quality and are expected to support species like the northern leopard frog (*Lithobates pipiens*) and Pit-Klamath brook lamprey (*Lampetra lethophaga*), which are not found in top 20 watersheds or other high-scoring areas of the state.

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., water quality), 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.

We highlight only a handful of major applications of the results and data here, but others surely 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.

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.

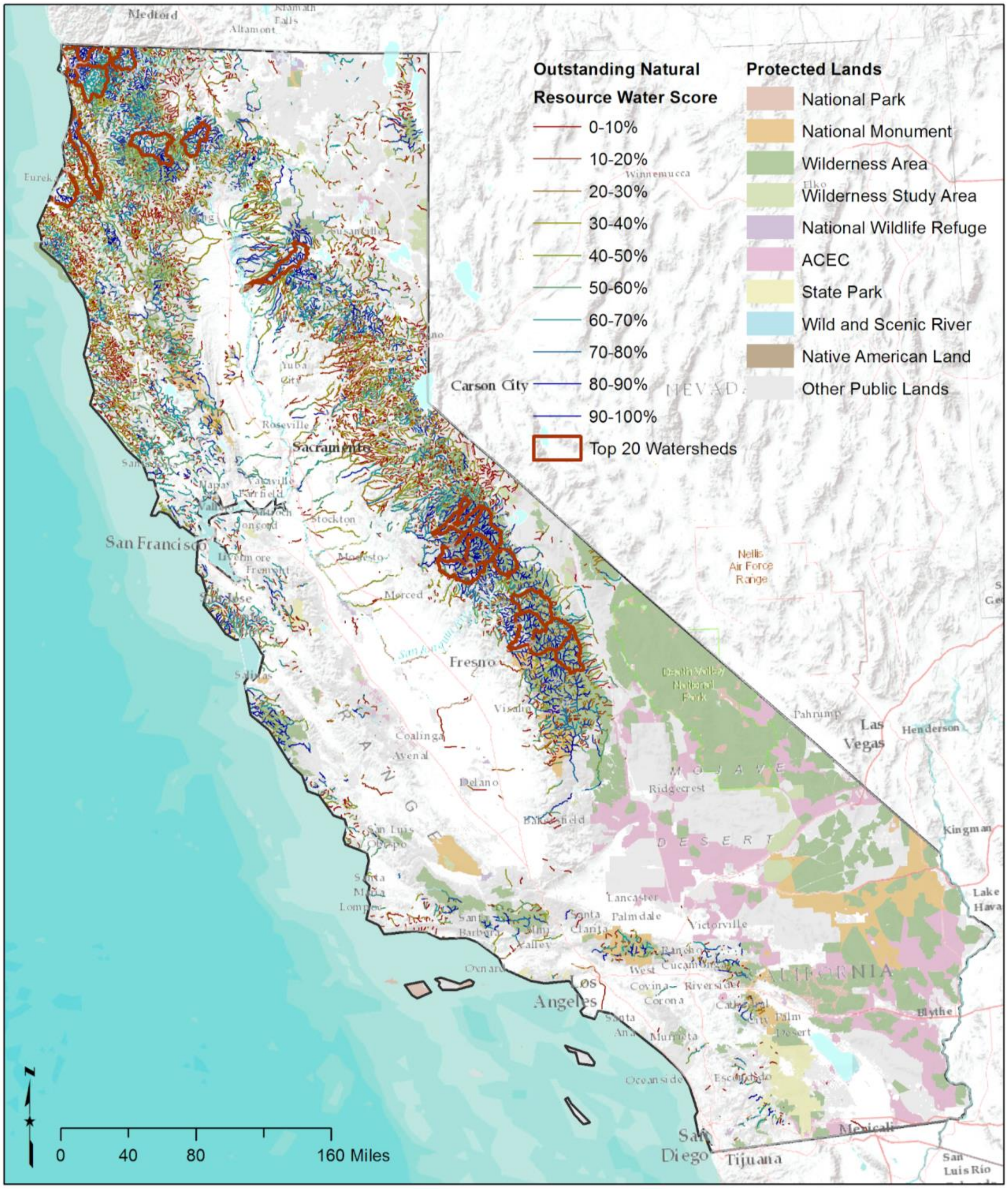
Third, our prioritization and underlying database are not (nor are they intended to be) a one-size-fits-all solution. This work was focused on statewide identification of rivers and streams with the highest potential for ONRW or W&S designation. Other similar efforts may exist at different scales (e.g., Trout Unlimited assessment of W&S eligibility in the Rogue River basin of Oregon); these efforts will likely differ in their approach and findings due to differences in data availability across these extents or differences in objectives. Likewise, 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 California 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.

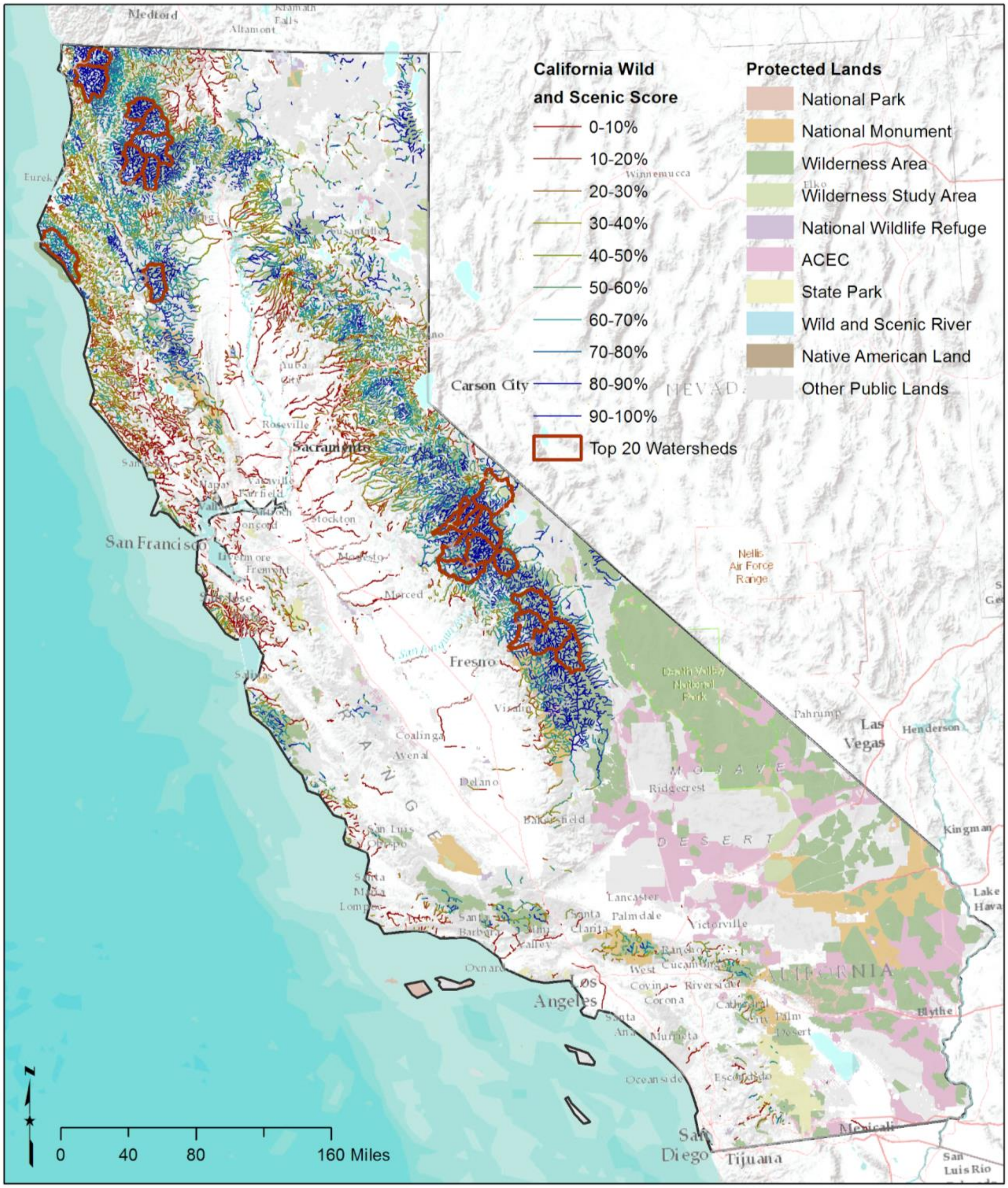
Acknowledgments

This analysis was commissioned and funded by The Pew Charitable Trusts, which is not responsible for errors in this report and which does not necessarily endorse the findings. Meredith McClure, Robert George, Caitlin Littlefield, and Brett Dickson conducted the analyses and wrote the report with support from Patrick Freeman. Valuable feedback was provided by the following peer reviewers: Lise Comte, Ted Grantham, Dan Isaak, Carri LeRoy, Peter Moyle, Julian Olden, and Brian Richter.

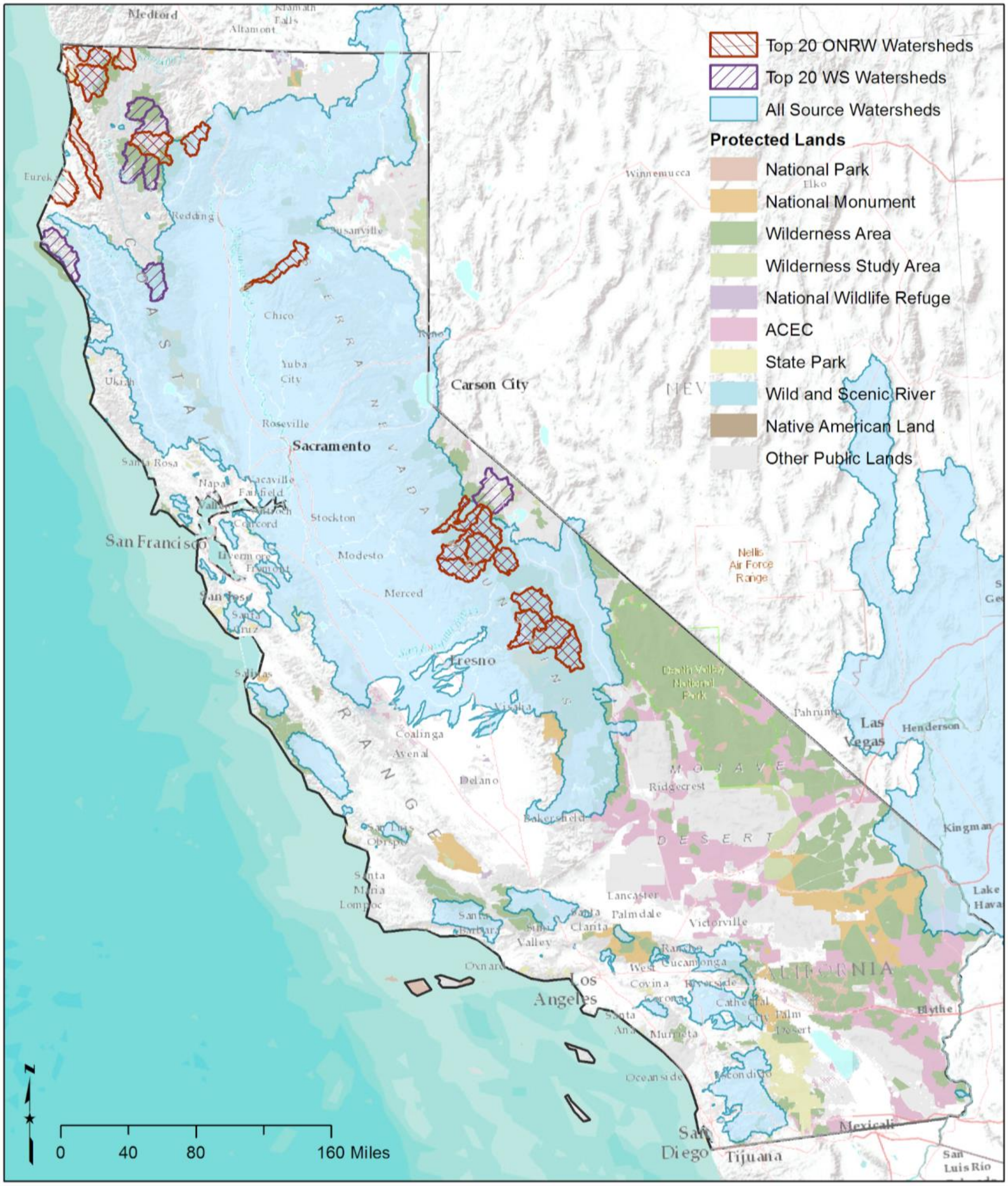
Maps



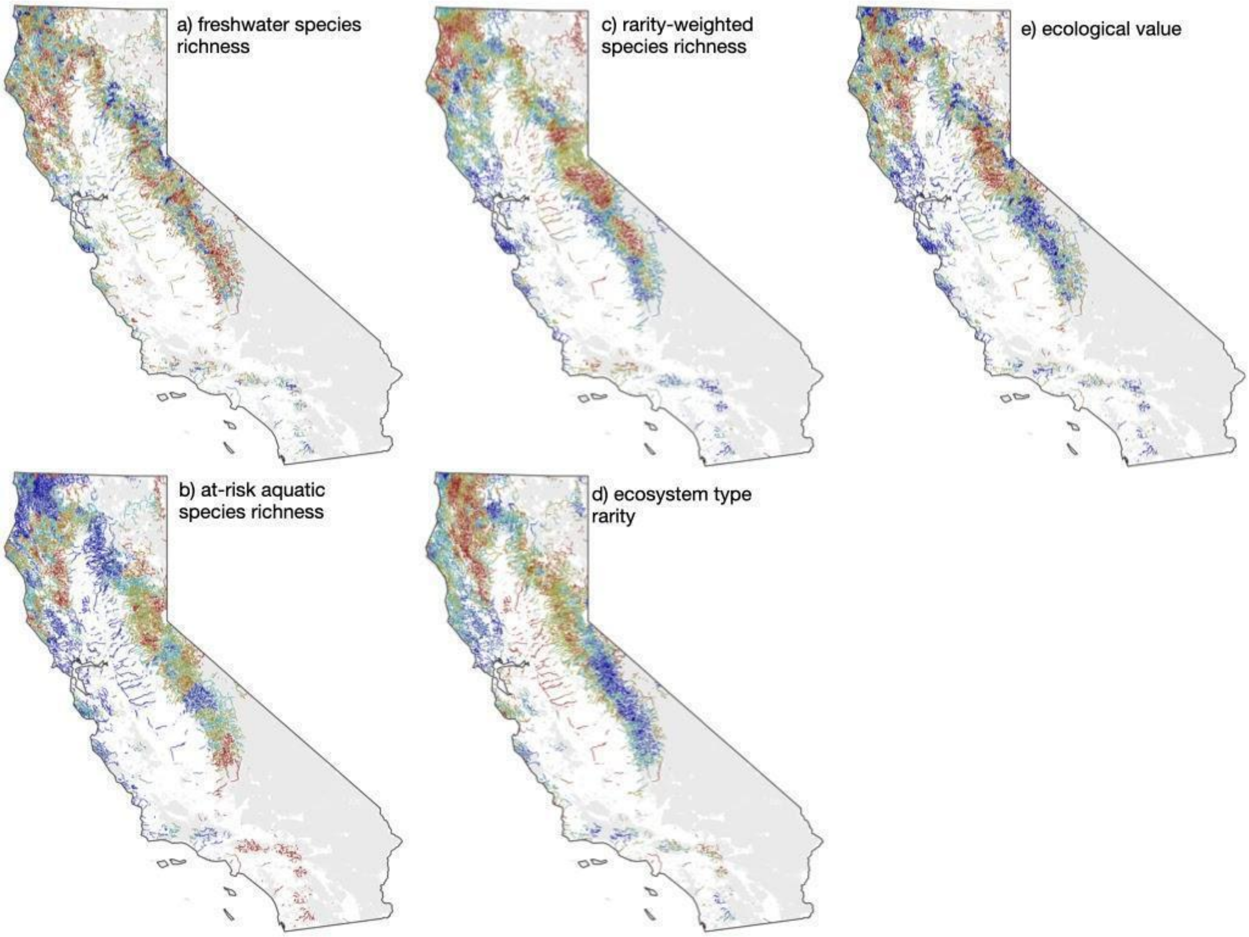
Map 1. Map of segment-level Outstanding National Resource Water scores highlighting top 20 watersheds.



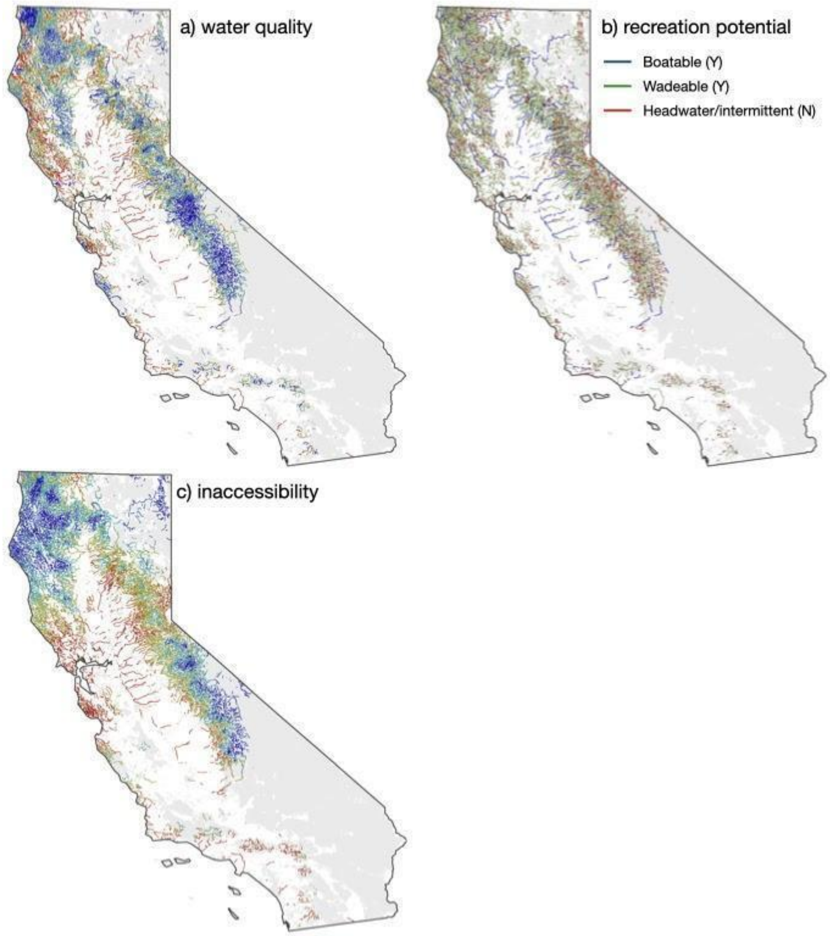
Map 2. Map of segment-level state Wild & Scenic river scores highlighting top 20 watersheds.



Map 3. Map of top 20 watersheds for ONRW (red) and W&S (purple) designation, overlaid on surface drinking water source watersheds.



Map 4. Maps of a) freshwater species richness, b) at-risk species richness, c) rarity-weighted species richness, d) ecosystem type rarity, and e) ecological value, scored as the fuzzy sum of a-d, across the state of California. 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) potential recreational value, and c) inaccessibility across California. In each map (except (b)), 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.

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Appendix A. Derivation of Indicators

Descriptions of source data and derivation methods for indicators used to assess Outstanding National Resource Water (ONRW) and state Wild & Scenic river (W&S) criteria across California.

Total freshwater aquatic diversity. Many species rely on freshwater aquatic resources, including fish, herpetofauna, mollusks, birds, crustaceans, plants, mammals, insects, and other invertebrates. Howard et al. (2015) compiled a list of species and subspecies known to use freshwater habitats within California from databases such as NatureServe as well as taxon-specific reviews and checklists. The final, expert-curated list included 3,906 taxa. Spatial data related to the occurrence and distribution of listed taxa were compiled from a variety of sources, producing the most comprehensive database of freshwater species occurrence in the state. Data layers for each unique species were then summed and mapped by HUC12 watershed units. Note that comprehensive data were not available for nonvascular plants (e.g., benthic algae, mosses), planktonic microcrustacea, segmented worms, or water mites; these taxa are excluded from the database. The database can be accessed here.

At-risk aquatic species richness. The at-risk aquatic species richness score represents the number of aquatic California 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 California). 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).

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 California). 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 California 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 California).

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 for quantifying the inverse property of landscapes—inaccessibility—associated with the remote, undisturbed places of interest here. 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 California).

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 (CA_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.

ONRW analysis

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) * (1 - FWRichPerc)]

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 (3).

   ONRWSegMean = EcoScorePerc + WQScorePerc + RecScore

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).

<u>Wild & Scenic analysis</u>

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.

<u>Generating reported summary statistics</u>

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.

Literature Cited

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