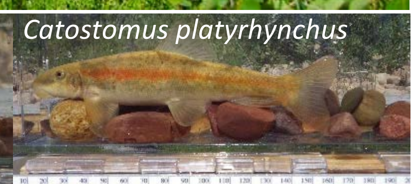

Multispecies Aquatic Assessments for the Bonneville, Lahontan, and Central Nevada Basins

Daniel C. Dauwalter

7/31/22

Trout Unlimited report to DFHP

Multispecies Aquatic Assessments for the Bonneville, Lahontan, and Central Nevada Basins

Report by Trout Unlimited to the Desert Fish Habitat Partnership

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Assessment Webmap: LINK

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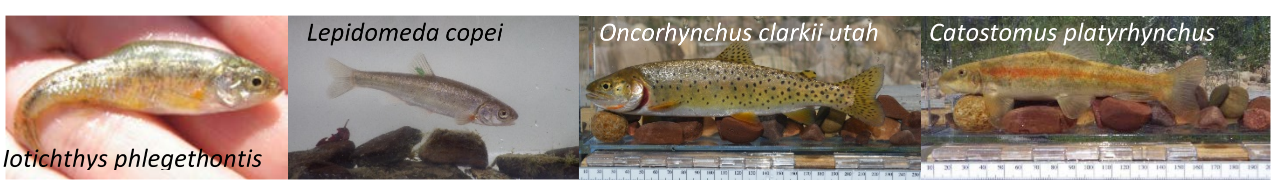

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DESERT FISH HABITAT PARTNERSHIP

WESTERN NATIVE TROUT INITIATIVE

Executive Summary

Limited resources for conservation require that conservation be strategic. Spatial conservation prioritization focuses on networks of conservation areas that efficiently maximize the representation of species. The algorithms and software underlying spatial prioritization can now account for the dendritic nature of freshwater systems. As such, spatial prioritization approaches have been applied to native fishes, in part to identify Native Fish Conservation Areas as a framework on which to focus conservation.

The Desert Fish Habitat Partnership (DFHP) is represented by multiple agencies and organizations and focuses on protection and restoration of fish habitats across the western U.S. for 179 native fish species. Likewise, the Western Native Trout Initiative (WNTI) is a multiagency partnership focused on habitat conservation for 21 native trout and char species in 12 western states. These partnerships use multispecies assessments that rank watersheds from 0 (low value for native fishes) to 1 (high value) to help understand whether projects proposed as part of their granting programs fall in important watersheds. The assessments also highlight opportunities for collaboration. However, no such assessments exist for the Bonneville, Lahontan, and Central Nevada basins in the Great Basin.

For this project, multispecies aquatic assessments focused on native fishes were completed for the Bonneville Basin and Lahontan and Central Nevada Basins. The Bonneville Basin assessment was completed for over 29,000 catchments and 19 native fish species, as well as life history diversity (resident, fluvial, adfluvial), genetic diversity, and abundance of Bonneville Cutthroat Trout populations. The Lahontan and Central Nevada Basins assessment covered over 2,000 subwatersheds (HUC12) and 41 native fish species or subspecies, as well as life history diversity, genetic diversity, and abundance of Lahontan Cutthroat Trout populations. Both assessments accounted for aquatic connectivity, and discounted species information in areas of high risk to habitat degradation (e.g., urban areas).

The multispecies assessments highlighted watersheds of high conservation value. In the Bonneville Basin, the Bear River watershed had several areas of high value, such as Bear Lake because of of four species endemic to the lake and adfluvial Bonneville Cutthroat Trout. The Upper Bear River and Smith and Thomas forks of the Bear River ranked high because of the migratory populations of Bonneville Cutthroat Trout and occurrence of native non-game fishes such as Northern Leatherside Chub, Mountain Sucker, Mountain Whitefish, and others. Utah Lake ranked high because it is the only habitat occupied by June Sucker, several wetland complexes ranked high because of the presence of the rare Least Chub, and the Sevier River and its tributaries ranked high because of Bonneville Cutthroat Trout populations and the occurrence of Southern Leatherside Chub and other native species.

In the Lahontan Basin, the Truckee River basin ranked high because of Lahontan Cutthroat Trout in high elevation tributaries, and due to adfluvial Lahontan Cutthroat Trout and Cui-ui in Pyramid Lake at its terminus. The Walker River basin ranked high for similar reasons (but absent of Cui-ui). Willow and Whitehorse creeks in the Coyote Lake basin ranked high because of the genetic distinctness of Lahontan Cutthroat Trout. And many of the endorheic basins in the central Nevada ranked high because of the unique forms of Speckled Dace, Tui Chub, Poolfish, and Springfish that occupy them. Ash Meadows and Devils Hole ranked high as well because of the presence of endemic species found nowhere else.

Some of the high value watersheds identified have both native trout and native non-game species. These Native Fish Conservation Areas represent opportunities for DFHP and WNTI collaboration and have a high return on conservation investment due to their diverse native aquatic communities.

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Introduction

Finite resources dictate that conservation be strategic, and part of being strategic is deciding where to invest in conservation. Systematic conservation planning as a field has yielded a suite of data-driven analytical tools to identify sets of areas (e.g., a network of protected areas) that most efficiently conserve biological diversity, and these tools are often underlying what is referred to as spatial conservation prioritization. Some of these prioritization algorithms, and the software the implement them, maximize the representation, redundancy, and resiliency (3 Rs; Shaffer and Stein 2000) of biodiversity targets among set of conservation units in the most efficient manner (Ferrier and Wintle 2009; Moilanen et al. 2009). For this reason, spatial prioritization historically has been used to identify efficient networks of protected areas or wildlife reserves (Moilanen et al. 2009).

More recently, spatial conservation prioritization has been used for other forms of conservation assessment, such as identifying high-value areas of a landscape on which to focus conservation resources. This includes prioritizing landscapes based on aquatic biodiversity because the tools can now account for the connectivity of dendritic river systems (Moilanen et al. 2008). These technical assessments can be integrated with other conservation planning processes for stakeholder engagement and conservation implementation (Knight et al. 2006; Birdsong et al. 2019; Garrett et al. 2019).

While systematic conservation planning has often focused on the representation, redundancy, and resiliency of species to gage the efficiency of conservation area networks, the 3-R concept has been applied to other aspects of ecological diversity. Haak and Williams (2012) applied the 3-R framework to inland Cutthroat Trout *Oncorhynchus clarkii* focusing on representation and redundancy of life history diversity (resident, fluvial, and adfluvial), geographic diversity (core and peripheral populations; Haak et al. 2010), and genetic purity within habitat patches large enough for long-term population persistence. They argued that managing for a portfolio of ecological diversity will give Cutthroat Trout subspecies the best chance of persisting in an uncertain future. The rangewide conservation team for Bonneville Cutthroat Trout *O. c. utah* has integrated these 3-R concepts into the Conservation Agreement and Strategy developed for the subspecies (UDNR 2019).

The Desert Fish Habitat Partnership (DFHP) is a multi-agency partnership that is organized under the National Fish Habitat Partnership (http://www.fishhabitat.org/). DFHP conserves aquatic habitats in the arid West through protecting, restoring, and enhancing streams, rivers, springs, and ciénegas in cooperation of state fish and wildlife agencies, federal agencies, tribes, conservation organizations, local partners, and other stakeholders (DFHP 2015). The partnership covers a large geographic area inhabited by 179 native fish species and subspecies that includes several river basins, including the Great Basin (Figure 1). That is, the partnership has a large geography and large number of species on which to effect change with its limited resources. Similarly, the Western Native Trout Initiative (WNTI) is a multi-agency fish habitat partnership focused on conserving and restoring habitat for 21 native trout and char species across 12 western states (https://westernnativetrout.org).

The DFHP and WNTI focus much of their conservation efforts towards on-the-ground habitat protection, restoration, and enhancement projects, and they fund these projects through granting programs. The partnerships use information from multispecies aquatic (fish) assessments to help understand whether projects proposed to them for funding occur within watersheds important to native fishes (see Appendix IV in DFHP 2015; Dauwalter et al. 2019). More specifically in the case of DFHP, the project location is overlain onto the appropriate assessment, and the conservation value (ranges from 0 [low value] to 1 [high value]) is extracted from the watershed in which each project is proposed (Figure 1). This helps to determine, in addition to proposal information, whether that project is proposed in an important watershed for native fishes. In some cases, the assessments have been used to identify Native Fish Conservation Areas (NFCAs) as focal conservation units on which to conduct conservation planning and implementation efforts (Dauwalter et al. 2011; Labay et al. 2018; Birdsong et al. 2019; Williams et al. 2019).

Native Fish Conservation Areas

Native Fish Conservation Areas (NFCAs) were proposed as a watershed-scale concept focused on conservation of entire aquatic communities while allowing for compatible uses (Williams et al. 2011). Critical elements of NFCAs are: 1) maintain ecological processes that create habitat complexity, diversity, and connectivity; 2) nurture all life history stages of fishes; and 3) include a large enough watershed to provide for the long-term persistence of native fish populations.

The NFCA concept has been used in various ways for strategic planning of conservation initiatives. The concept provided the basis for large-scale, long-term initiatives of conservation foundations focused on native trout and native non-game fishes in the Colorado River Basin (Dauwalter et al. 2011), it has been used to direct state-based conservation funding and action in Texas (Birdsong et al. 2019; Garrett et al. 2019), and it has been used to identify focal areas for conservation of native fishes in the Rio Grande basin and Great Plains by fish habitat partnerships (Labay et al. 2018; Labay et al. 2019). Because native trout are recognized sportfish, they can help jumpstart and anchor watershed-scale conservation efforts for native aquatic assemblages (Haak and Williams 2013); this is similar to using native black basses to guide watershed-scale planning efforts in the southeastern U.S. (Birdsong et al. 2015).

Multispecies Aquatic Assessments in the West

Across the western U.S., multi-species aquatic assessments focused on native fishes have only been completed for the Upper Colorado River Basin (Whittier and Sievert 2014), Lower Colorado River Basin (Whittier et al. 2011), the Upper Snake River Basin (Williams et al. 2019); the Rio Grande basin (Labay et al. 2018), and in California (Howard et al. 2018). No similar aquatic assessments have been completed in the Great Basin (Bonneville and Lahontan and Central Nevada basins; Figure 1).

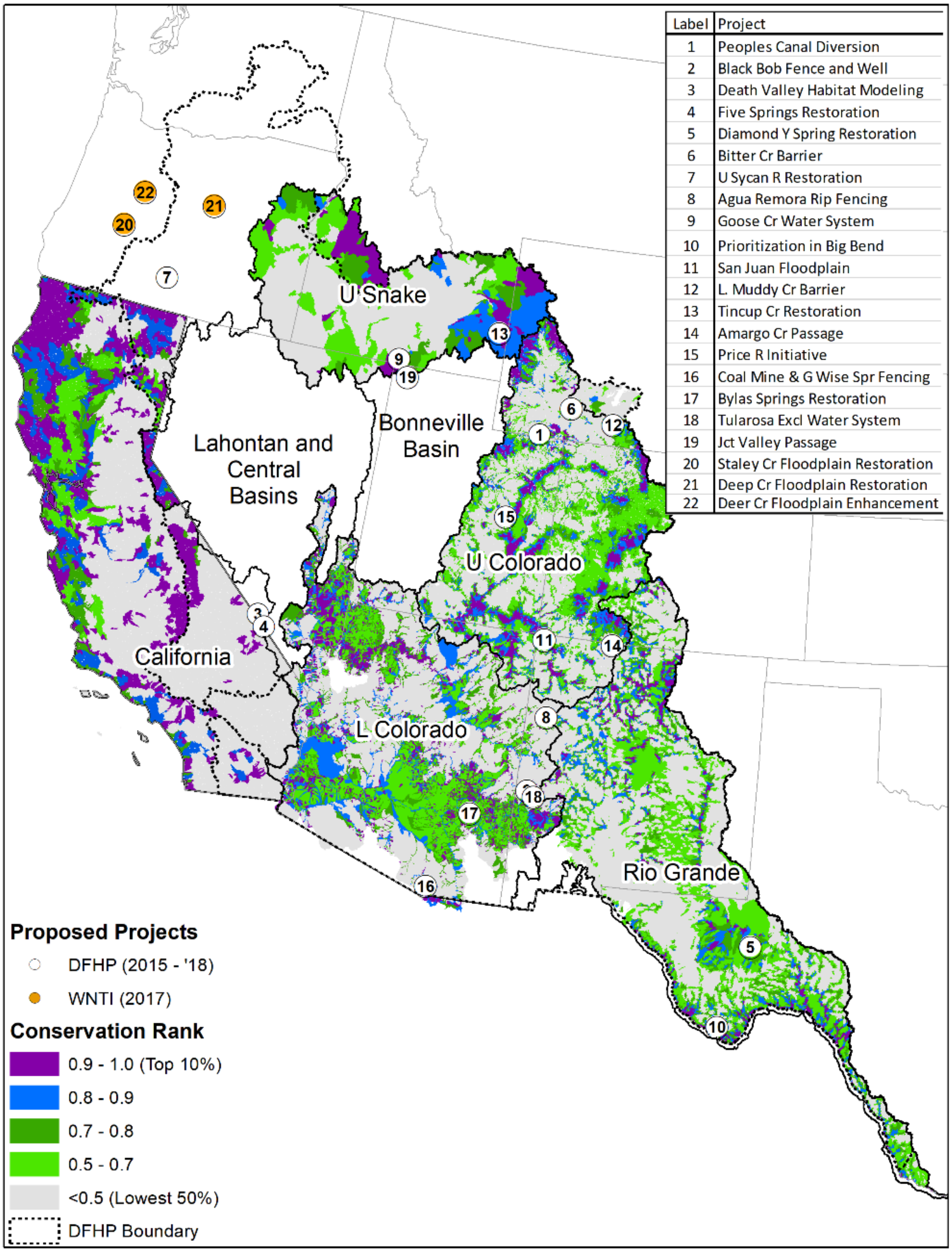


Figure 1. Multispecies aquatic (fish) assessments completed in the Rio Grande, Upper Colorado, Lower Colorado, and Upper Snake basins and California overlain with locations of projects proposed to DFHP for funding from 2015 – 2018 (legend in upper right). Purple catchments and subwatersheds represent the top 10% of native fish conservation value in each basin. Completing similar assessments for the Bonneville Basin and Lahontan and Central Nevada basins is the focus of this project. From Dauwalter et al. (2019).

The Great Basin

The Great Basin in the western United States is the largest inland drainage in North America with no outlet to the sea (Sigler and Sigler 1987). It resides between the Rocky Mountains to the east and Sierra Nevada to the west, and it is south of the Columbia River basin to the north and the Colorado River Basin is to the south. The Great Basin is not one drainage basin but rather numerous drainages resulting from geological folds and is a region characterized by mountains and deserts that drive large environmental gradients. Lake Bonneville and Lake Lahontan were the two largest pluvial lakes in the Great Basin with maximum elevations reached across various periods of the Pleistocene (Reheis et al. 2002). Other basins include the Central (mostly Nevada but also California), Northwest Desert, and Northwest Oregon Lakes basins, and the Mohave-Death Valley region. While some separate the Humboldt Basin from Lake Lahontan and combine it with the Central Basin (Sigler and Sigler 1987), for this project the Humboldt was retained with the pluvial Lake Lahontan basin due to a shared fish species pool. The Central Basins are the collective basins to the south (Reheis et al. 2002; Peacock et al. 2018).

Fish assemblages generally reflect the Great Basin drainages. However, they also reflect evolution during isolation since the subsidence of the pluvial lakes, and there also have been notable interchanges of fish species with other basins (Smith et al. 2002). One example of the latter is the Bonneville Basin shares fish species with the Snake River Basin. These shared species are a result of changes in the courses of rivers from lava flows associated with the Yellowstone Hotspot, as well as inter-basin connections during flood events associated with maximum pluvial lake elevations (Sigler and Sigler 1987; Loxterman and Keeley 2012; Link and Keeley 2018). In fact, fishes in the Great Basin reflect broader patterns of the southwestern U.S. in that some species are found nowhere else on Earth, and many of them are in peril as evidenced by the fact that nearly half are listed as threated or endangered under the Endangered Species Act (ESA) (Overpeck and Bonar 2021).

Project Goals

The three goals of this project to aid in native fish conservation decision making were:

- **Goal #1**: Complete multispecies aquatic assessments for the Bonneville Basin and the Lahontan and Central Nevada basins, including accounting for the ecological diversity of native trout. The assessments will highlight important watersheds for native fish conservation and inform fish habitat partnership decision making. Completing these assessments will fill important assessment gaps in the West and facilitate their use by DHFP and partners (Dauwalter et al. 2019).
- **Goal #2**: Identify potential Native Fish Conservation Areas in the Bonneville Basin and Lahontan and Central Nevada Basins where DFHP and WNTI could collaborate to co-fund habitat protection and restoration projects that benefit both native salmonids and native non-game fishes. The aquatic assessments completed to date in the western U.S. include information on native salmonids as well as native non-game fishes to help inform these cross-partnership collaborations (discussed in Birdsong et al. 2018; Dauwalter et al. 2019). Identification of potential NFCAs will help inform future collaborations in the Bonneville and Lahontan and Central Nevada basins.
- **Goal #3**: Develop a webmap application that allows users to access all multispecies aquatic assessments developed for the western U.S. so that DFHP, WNTI, and other conservation partners can easily access the information to determine the conservation value of watersheds for native fishes and identify collaborative native fish conservation opportunities.

Bonneville Basin Assessment

The conservation ranking 29,869 catchments (drainage areas associated with ~1-km confluence-to-confluence stream segments) in the Bonneville Basin based on 19 native fish species – as well as the life history diversity, genetic diversity, and abundance of Bonneville Cutthroat Trout - using Core Area Zonation highlighted four main types of high values watersheds (Figure 2; Table 1). First, lakes with endemic fish species ranked highest. Utah Lake ranked high because it provides habitat for June Sucker *Chasmistes liorus* found nowhere else. Bear Lake ranked high because it is habitat to four endemic non-game species and adfluvial Bonneville Cutthroat Trout. Catchments representing some main tributaries to Bear Lake also received a high rank because they are spawning habitat for the adfluvial Bonneville Cutthroat Trout in Bear Lake, and they also harbor resident Bonneville Cutthroat Trout populations. Second, aggregations of high-ranking catchments in the Weber River reflected numerous migratory populations of Bonneville Cutthroat Trout and Bluehead Sucker *Catostomus discobolus* that have strong connectivity requirements. Aggregations of high-ranking catchments in the upper Bear River reflect migratory Bonneville Cutthroat Trout and habitat for Mountain Sucker *Catostomus platyrhynchus* (Figure 3), Northern Leatherside Chub *Lepidomeda copei* (Figure 4), Mountain Whitefish *Prosopium williamsoni*, and other native fishes. Third, the mainstem of the Sevier River and its main tributaries ranked high because they represent habitat for the Southern Leatherside Chub *Lepidomeda aliciae* and contain resident populations of Bonneville Cutthroat Trout, but the lower connectivity needs of these species and populations did not result in large clusters of watersheds receiving ranks >0.90. Fourth, the few wetland complexes and other habitats with extant populations of Least Chub *Iotichthys phlegethontis* ranked high because of the rarity of that species (Figure 2).

Native Fish Conservation Areas: Bonneville Basin

The Bonneville Basin has several potential Native Fish Conservation Areas – that is, watersheds with native trout and non-game species – that could synergize collaborative conservation between DFHP and WNTI. Many are in the Bear River basin, but they also occur in other regions of the Bonneville Basin:

Bear Lake – Bear Lake is notable for the four endemic fishes found only in that lake: Bonneville Cisco *Prosopium gemmifer*, Bonneville Whitefish *Prosopium spilonotus*, Bear Lake Whitefish *Prosopium abyssicola*, and Bear Lake Sculpin *Cottus extensus*. Bear Lake is also habitat to fluvial Bonneville Cutthroat Trout that ascend Bear Lake tributaries to spawn (Heller et al. 2022a) and provide a unique fishery in the lake (Heller et al. 2022b).

Upper Bear River – The Upper Bear River watershed has numerous populations of Bonneville Cutthroat Trout that have a fluvial life history in its main forks and tributary streams. It also has local populations of Northern Leatherside Chub in Mill Creek, Yellow Creek, and Otter Creek, as well as Mountain Sucker, Mountain Whitefish, and other native non-game species that have been documented in the drainage.

Smith Fork and Thomas Fork – The Smith Fork and Thomas Fork of the Bear River have Bonneville Cutthroat Trout populations with a well-documented fluvial life history where they ascend tributary streams to spawn but then descend to over winter in the Bear River mainstem (Colyer et al. 2005; Schrank and Rahel 2006; Carlson and Rahel 2010). These systems also have a diverse suite of native non-game fishes that include Northern Leatherside Chub, Mountain Sucker, Mountain Whitefish, and more (Roberts and Rahel 2008).

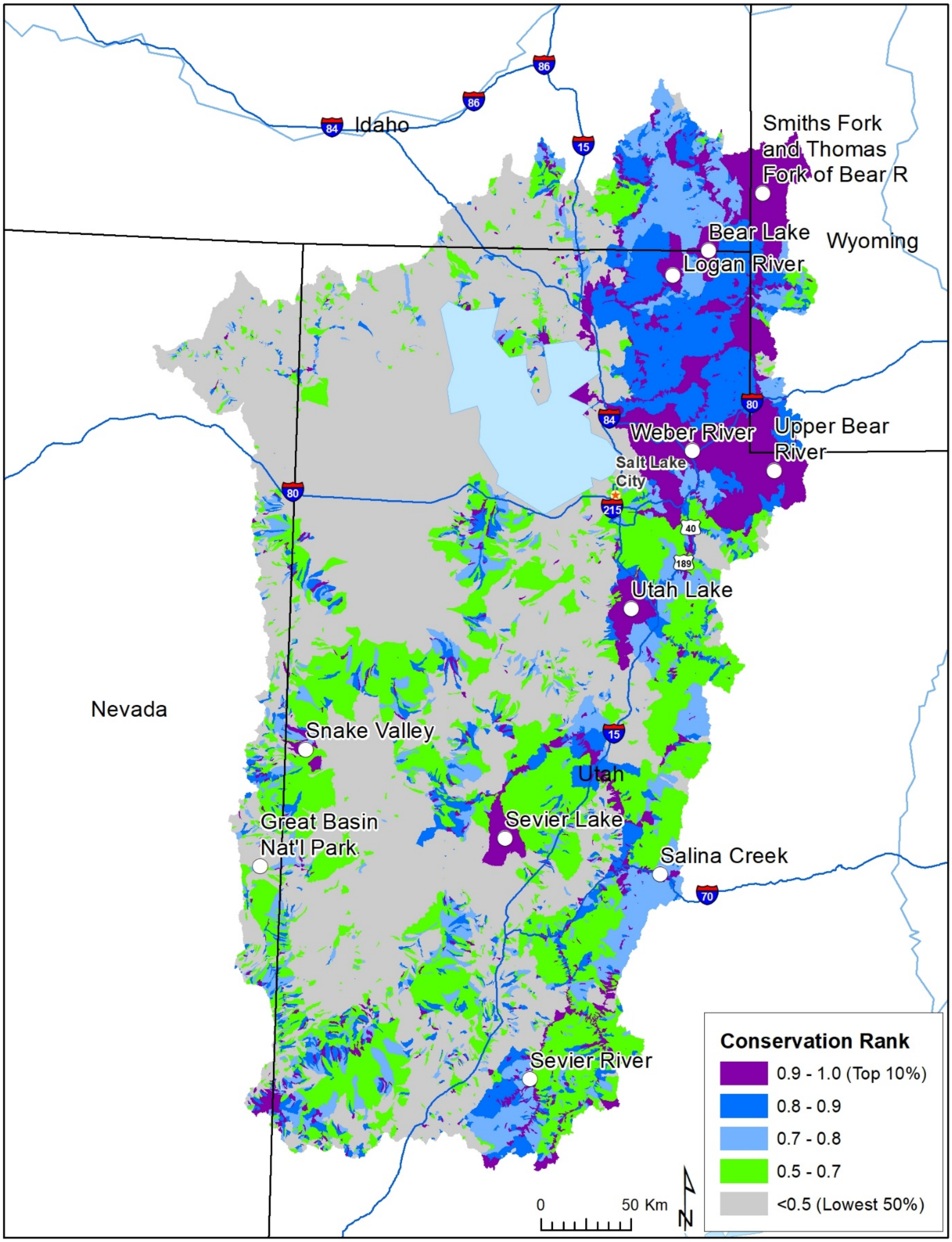


Figure 2. Catchment conservation rankings (0 [low] to 1 [high]) for native fishes in the Bonneville Basin. High ranking catchments and other areas of interest are labeled.

Table 1. Common name, scientific name, Heritage Ranks, model input type (known presence from sources [conservation agreement and strategy, or recovery plan] or occurrence probability from a species distribution model [SDM]), and DFHP rank for fish species and subspecies included in the Bonneville Basin multispecies aquatic assessment.

Common name	Scientific name	Heritage Rank	Model Input	DFHP Rank
Utah Chub	*Gila atraria*		SDM (0 – 1)	1.78
Least Chub	*Iotichthys phlegethontis*	N2 (UT S2)	Known (CAS)	2.22
Northern Leatherside Chub	*Lepidomeda copei*	N3 (ID S2; NV S1; UT S2; WY S1)	SDM (0 – 1)	2.00
Southern Leatherside Chub	*Lepidomeda aliciae*	N2 (UT S2)	SDM (0 – 1)	2.11
Longnose Dace	*Rhinichthys cataractae*	N5 (ID S5; NV S2; UT S3; WY S5)	SDM (0 – 1)	1.22
Speckled Dace	*Rhinichthys osculus*	N5 (ID S5; NV S5; UT S4; WY S4)	SDM (0 – 1)	1.00
Redside Shiner	*Richardsonius balteatus*	N5 (ID S5; NV S5; UT S3; WY S5)	SDM (0 – 1)	0.89
Mountain Sucker	*Catostomus platyrhynchus*	G5 (ID S4)	SDM (0 – 1)	0.89
Utah Sucker	*Catostomus ardens*	G5 (ID S4)	SDM (0 – 1)	1.56
Bluehead Sucker	*Catostomus discobolus*	N4 (ID SNR; UT S3; WY S3)	SDM (0 – 1)	1.89
June Sucker	*Chasmistes liorus*	N2 (UT S2)	Known (RP)	1.67
Mountain Whitefish	*Prosopium williamsoni*	G5 (ID S5)	SDM (0 – 1)	1.44
Bear Lake Whitefish	*Prosopium abyssicola*	N3 (ID S1; UT S1)	Known	1.50
Bonneville Whitefish	*Prosopium spilonotus*	N3 (ID S1; UT S1)	Known	1.50
Bonneville Cisco	*Prosopium gemmifer*	N3 (ID S1; UT S1)	Known	1.50
Bonneville Cutthroat Trout	*Oncorhynchus clarkii utah*	N4 (ID S3; NV S1; UT S4; WY S1)	Rangewide DB	2.00
	Bear River - resident			0.33
	Bear River - fluvial			0.33
	Bear River - adfluvial			0.33
	Non-Bear River - resident			0.33
	Non-Bear River - fluvial			0.33
	Non-Bear River – adfluv.			0.33
Mottled Sculpin	*Cottus bairdii*		SDM (0 – 1)	1.25
Paiute Sculpin	*Cottus beldingii*	G5 (ID S4, NV S4, UT S3)	Data deficient	--
Bear Lake Sculpin	*Cottus extensus*	N3 (ID S1; UT S1)	Known	1.50
Utah Lake Sculpin	*Cottus echinatus*	NX (UT SX)	Excluded	--

Weber River – The entire Weber River watershed had a high conservation ranking for native fishes. There are numerous populations of Bonneville Cutthroat Trout with diverse life histories in the watershed. The Weber River also has the only self-reproducing population of Bluehead Sucker in the Bonneville Basin. Both Bonneville Cutthroat Trout with migratory life histories and Bluehead Sucker have strong connectivity needs, which drives the aggregated nature of high-value catchments throughout the watershed. Other native non-game species are found throughout the watershed as well, and the watershed has an organized watershed group undertaking conservation actions – the Weber River Partnership (Thompson and Burnett 2019).

Sevier River tributaries – Numerous high-ranking tributaries to the Sevier River have both Bonneville Cutthroat Trout populations and Southern Leatherside Chub, in addition to other native fishes. These watersheds in the Sevier River basin with both Cutthroat Trout and native non-game species have the potential to serve as NFCAs. Examples of these watersheds include: Threemile Creek, East Fork Sevier River, and Salina Creek, but each of them have the potential to represent NFCAs at different spatial scales.

Figure 3. Mountain Sucker collected from the East Fork Bear River. Credit: R. Lee

Figure 4. Northern Leatherside Chub collected from the East Fork Bear River. Credit: R. Lee

Lahontan and Central Nevada Basins Assessment

The rankings of 2,042 subwatersheds (12-digit Hydrologic Unit Code) in the Lahontan and Central Nevada basins (including the Coyote Lake and Susan River basins) based on 41 native fish species and subspecies - as well as the life history diversity, genetic diversity, abundance, and historical distribution of Lahontan Cutthroat Trout - using Core Area Zonation highlighted several regions of high conservation value for native fishes (Figure 5; Table 2). First, much of the western Lahontan Basin that heads in the Sierra Nevada mountains ranked high, including the Walker River basin. Also ranking high was the Truckee River basin from its headwaters, including Lake Tahoe, down to Pyramid Lake. This highlights the importance of the western basin to Lahontan Cutthroat Trout life history and genetic diversity, the presence of endemics such as Cui-ui *Chasmistes cujus* in Pyramid Lake, the connectivity needs of species like Lahontan Cutthroat Trout (Figure 6) and Mountain Whitefish, and habitat for other widely distributed non-game species such as the Lahontan Redside *Richardsonius egregius*, Tahoe Sucker *Catostomus tahoensis*, and Mountain Sucker (Figure 7). Second, many of the small valleys throughout central Nevada contain endemic subspecies or forms of Speckled Dace *Rhinichthys osculus* and Tui Chub *Siphateles bicolor*. Examples include: Newark Valley, Railroad Valley, Fish Lake Valley, Oasis Valley, Independence Valley, and Dixie Valley (Figure 8; Figure 9). Other habitats also ranked high such as the Soldier Springs region that is habitat to Desert Dace *Eremichthys acros*.

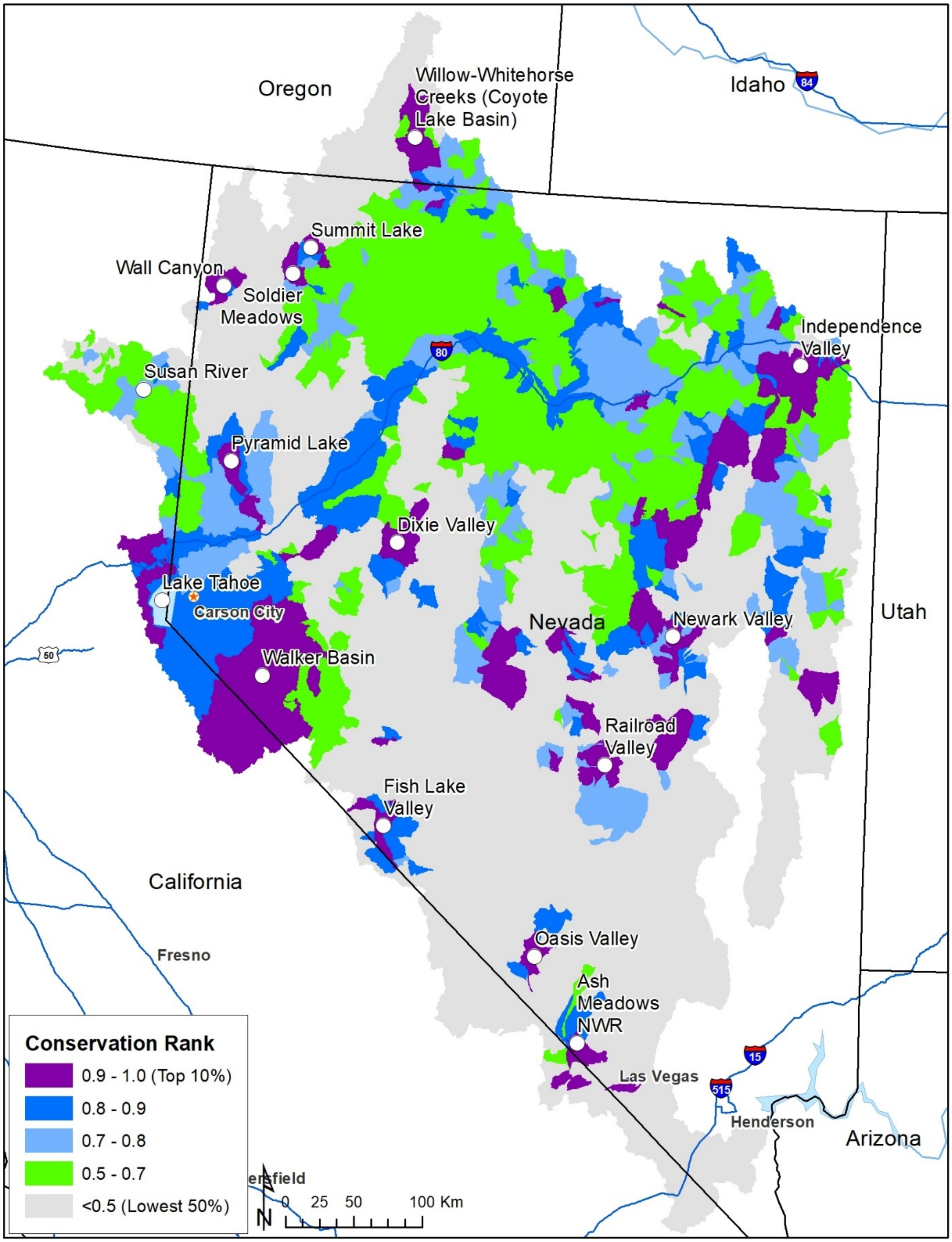


Figure 5. Subwatershed conservation rankings (0 [low] to 1 [high]) for native fishes in the Lahontan and Central Nevada basins. High ranking subwatersheds and other areas of interest are labeled.

Third, Ash Meadows National Wildlife Refuge has several endemic species, and Devils Hole, home to Devils Hole Pupfish *Cyprinodon diabolis*, is in the same subwatershed. Fourth, Lahontan Cutthroat Trout in Willow and Whitehorse Creeks in the Coyote Lake Basin represent a Uniquely Identifiable Ecological Unit (Peacock et al. 2018), the Susan River basin historically had Lahontan Cutthroat Trout and has populations of other native fishes, and Summit Lake, Independence Lake (Figure 10), and Pyramid Lake have Lahontan Cutthroat Trout populations with an adfluvial life history. The high ranks of subwatersheds reflect these unique attributes, but also habitat for non-game species predicted by the species distribution models (Figure 5). Last, other subwatersheds in the eastern Lahontan Basin that are tributaries to the Humboldt River (Interstate 80 corridor) are ranked 0.7 and higher, indicating that habitat exists across the eastern Lahontan/Humboldt Basin for a diverse suite of native species (Figure 6).

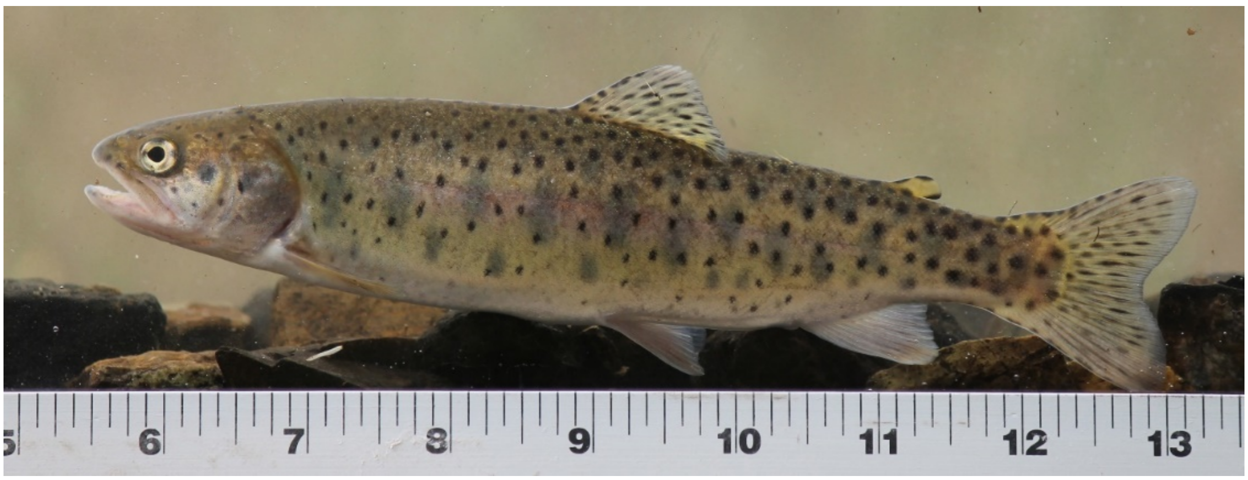


Figure 6. Lahontan Cutthroat Trout from Little Jack Creek, Maggie Creek Basin. Credit: J. Zablocki

Figure 7. Mountain Sucker from the Little Truckee River. Credit: J. Zablocki

Table 2. Common name, scientific name, Heritage Ranks, model input type (presence from Nevada Division of Natural Heritage [NDNH] or occurrence probability from a species distribution model [SDM]), and DFHP rank for fish species and subspecies included in the Lahontan and Central Nevada basins multispecies aquatic assessment. Heritage ranks are from Nevada Wildlife Action Plan. Species occurring in Nevada but in the Columbia River Basin, Oregon Closed Basins, and Lower Colorado River Basin (White River, Muddy River, Meadow Valley Wash, Alvord Basin) are not listed. An asterisk indicates a species was omitted.

Common name	Scientific name	Heritage Rank	Model input	DFHP Rank
Devils Hole Pupfish	*Cyprinodon diabolis*	G1S1	NDNH (0 or 1)	1.89
Ash Meadows Amargosa Pupfish	*Cyprinodon nevadensis mionectes*	G2T2S2	NDNH (0 or 1)	1.67
Warm Springs Amargosa Pupfish	*Cyprinodon nevadensis pectoralis*	G2T1S1	NDNH (0 or 1)	2.22
Desert Dace	*Eremichthys acros*	G1S1	NDNH (0 or 1)	2.22
Relict Dace	*Relictus solitarius*	G2G3S2S3	NDNH (0 or 1)	2.56
Ash Meadows Speckled Dace	*Rhinichthys osculus nevadensis*	G5T1S1	NDNH (0 or 1)	2.00
Big Smoky Valley Speckled Dace	*Rhinichthys osculus lariversi*	G5T1S1	NDNH (0 or 1)	1.89
Clover Valley Speckled Dace	*Rhinichthys osculus oligoporus*	G5T1S1	NDNH (0 or 1)	1.89
Diamond Valley Speckled Dace	*Rhinichthys osculus ssp.*	G5THSH	NDNH (0 or 1)	2.33
Grass Valley Speckled Dace	*Rhinichthys osculus reliquus*	G5T5SX	NDNH (0 or 1)	2.11
Independence Valley Speckled Dace	*Rhinichthys osculus lethoporus*	G5T1S1	NDNH (0 or 1)	1.89
Lahontan Basin Speckled Dace	*Rhinichthys osculus*	G5S5	SDM (0 – 1)	1.00
Monitor Valley Speckled Dace	*Rhinichthys osculus spp.*	G5T1S1	NDNH (0 or 1)	2.44
Oasis Valley Speckled Dace	*Rhinichthys osculus spp.*	G5T1S1	NDNH (0 or 1)	2.11
Lahontan Redside	*Richardsonius egregius*	G5SNR	SDM (0 – 1)	1.56
Big Smoky Valley Tui Chub	*Siphateles bicolor ssp. 8*	G4T1S1	NDNH (0 or 1)	2.33
Charnock Springs Tui chub	*Siphateles bicolor ssp. 10*	G4T1QS1	NDNH (0 or 1)	2.33
Dixie Valley Tui Chub	*Siphateles bicolor ssp. 9*	G4T1QS1	NDNH (0 or 1)	2.33
Duckwater Creek Tui Chub	*Siphateles bicolor ssp. 3*	G4T1S1	NDNH (0 or 1)	2.33
Fish Creek Springs Tui Chub	*Siphateles bicolor euchila*	G4T1QS1	NDNH (0 or 1)	2.33
Fish Lake Valley Tui Chub	*Siphateles bicolor ssp. 4*	G4T1QS1	NDNH (0 or 1)	2.44
High Rock Spring Tui Chub	*Siphateles bicolor ssp. 11*	G4TXSX	NDNH (0 or 1)	2.22
Hot Creek Valley Tui Chub	*Siphateles bicolor ssp. 5*	G4T1QS1	NDNH (0 or 1)	2.33
Independence Valley Tui Chub	*Siphateles bicolor isolata*	G4T1QS1	NDNH (0 or 1)	2.33
Lahontan Creek Tui Chub	*Siphateles bicolor obesa*	G4T4S4	NDNH (0 or 1)	1.44
Little Fish Lake Valley Tui Chub	*Siphateles bicolor ssp. 6*	G4T1S1	NDNH (0 or 1)	2.33
Newark Valley Tui Chub	*Siphateles bicolor newarkensis*	G1T1S1	NDNH (0 or 1)	2.11
Railroad Valley Tui Chub	*Siphateles bicolor ssp. 7*	G4T1QS1	NDNH (0 or 1)	2.00
Railroad Valley Springfish	*Crenichthys nevadae*	G2S2	NDNH (0 or 1)	1.89
Ash Meadows Poolfish	*Empetrichthys merriami*	GXSX	NDNH (0 or 1)	2.11*
Pahrump Poolfish	*Empetrichthys latos latos*	G1T1S1	NDNH (0 or 1)	2.11
Big Spring Spinedace	*Lepidomeda bicolor pratensis*	G2T1S1	NDNH (0 or 1)	1.89
Paiute Sculpin	*Cottus beldingii*	G5SNR	SDM (0 – 1)	1.33
*Shorthead Sculpin (*omitted)	*Cottus confusus*	G5S1	NDNH (0 or 1)	1.33
Meadow Valley Wash Desert Sucker	*Catostomus clarkii spp. 2*	G3G4T2S2	NDNH (0 or 1)	2.22
Mountain Sucker	*Catostomus platyrhynchus*	G5SNR	SDM (0 – 1)	0.89
Tahoe Sucker	Catostomus tahoensis	G5S5	SDM (0 – 1)	1.89
Wall Canyon Sucker	*Catostomus sp.*	G1S1	NDNH (0 or 1)	2.67
Cui-ui	*Chasmistes cujus*	G1S1	NDNH (0 or 1)	1.56
Mountain Whitefish	*Prosopium williamsoni*	G5S3	SDM (0 – 1)	1.44
Lahontan Cutthroat Trout	*Oncorhynchus clarkii henshawi*	G4T3S3	Rangewide DB	2.25*
Western Lahontan UIEU - Resident			#/km	0.250
Adfluvial			#/km	0.250
NW Lahontan UIEU - Resident			#/km	0.250
Adfluvial			#/km	0.250
Eastern Lahontan UIEU - Resident			#/km	0.167
Fluvial			#/km	0.167
Adfluvial			#/km	0.167
Coyote Lakes UIEU Resident			#/km	0.500
Historical Streams			SDM (0 – 1)	0.125
Lakes			Presence = 1	0.125

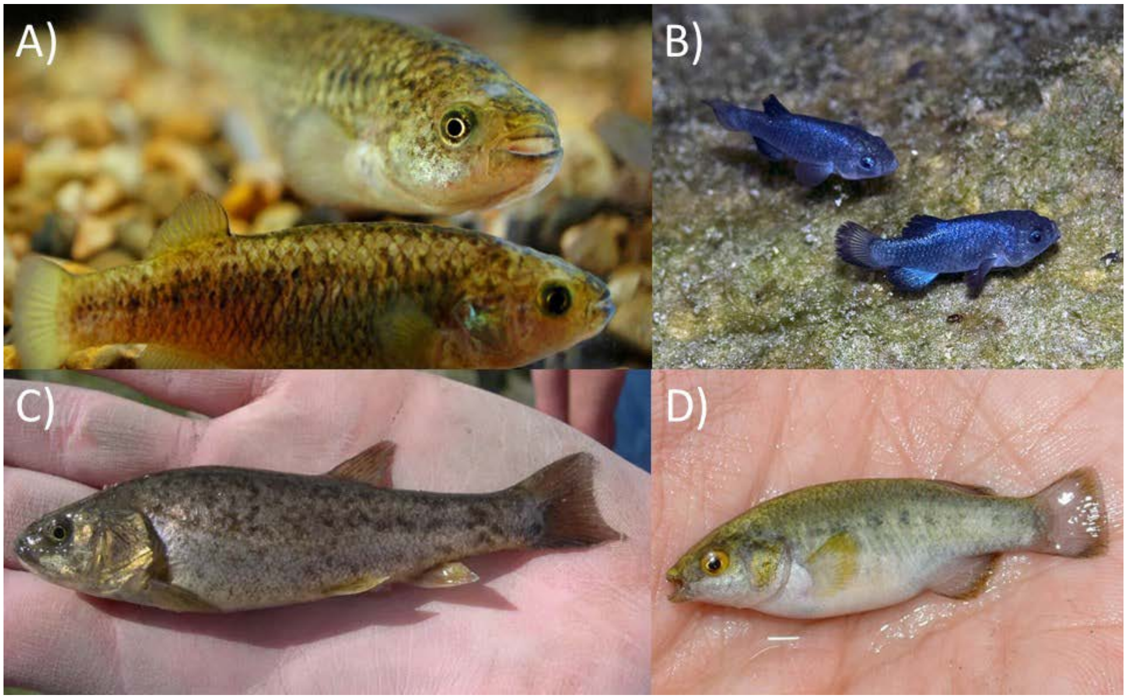


Figure 8. Native fishes of the Central Nevada Basins: A) Pahrump Poolfish (credit: USFWS), B) Devils Hole Pupfish (credit: O. Feuerbacher, USFWS), C) Relict Dace (credit: Nevada Department of Wildlife), and D) Railroad Valley Springfish (credit: E. Miskow, Nevada Division of Natural Heritage).

Figure 9. Spring-fed wetlands in the Goshute Valley, Elko County, northeast Nevada, inhabited by Relict Dace. Credit: NDOW

Figure 10. Independence Lake, Truckee River Basin. Credit: J. Barnes

Native Fish Conservation Areas: Lahontan Basin

The rarest species in the Lahontan and Central Nevada Basins primarily occur in the central basins where no trout is native. Thus, there are no watersheds with both native trout and non-game species to serve as Native Fish Conservation Areas in the Central Nevada basins south of the Lahontan Basin. The Lahontan Basin does have a few endemic fishes with restricted ranges, but they either occur in places outside the historical range of Lahontan Cutthroat Trout (Wall Canyon) or they occupy very unique habitats with no real nexus to trout habitat in a watershed context (Desert Dace in thermal springs). However, the Lahontan Basin does have several potential Native Fish Conservation Areas that could be the focus of DFHP and WNTI collaboration. While none of the native non-game species in the Lahontan Basin are rare with one exception (Cui-ui in Pyramid Lake), the documented occurrences and species distribution models highlight high priority areas for multiple native non-game species in addition to Lahontan Cutthroat Trout:

Walker River Basin – The Walker River Basin has a small number of Lahontan Cutthroat Trout populations, but potential to re-establish populations as well as suitable habitat for a suite of native non-game species such as Mountain Whitefish (Figure 11), Tahoe Sucker, Mountain Sucker, and others. It also has Walker Lake at its terminus, a historical and unique Lahontan Cutthroat Trout habitat.

Figure 11. Mountain Whitefish from the Little Truckee River. Credit: J. Zablocki

Truckee River Basin – The Truckee River Basin similarly has a small number of Lahontan Cutthroat Trout populations in its headwaters, but it also contains the historical habitat of Lake Tahoe as its headwaters, Fallen Leaf Lake that has been the focus of reintroduction efforts (Al-Chokhacky et al. 2009), and Pyramid Lake at its terminus that contains not only a high profile Lahontan Cutthroat Trout fishery (Figure 12)(Al-Chokhachy et al. 2020) but also represents the only waterbody occupied by Cui-ui. The basin also represents habitat for a suite of other native non-game species.

Humboldt River tributaries – Some tributaries to the Humboldt River in the eastern Lahontan Basin have a high ranking subwatershed and, thus, have some potential for smaller NFCAs where targeted conservation may benefit native non-game fishes in addition to native trout (Figure 6). These include the South Fork Humboldt, the Rock-Willow watershed (Figure 13), tributaries to the North Fork Humboldt (Gance Creek), the upper Marys River, and upper Reese River. Native non-game species have not been well-documented in the eastern Humboldt Basin, but the predictive models suggest that habitat is suitable for a diverse complement of native fishes in several places.

Informing Native Fish Conservation Decisions

The multispecies aquatic assessments highlight watersheds that have high conservation value due to the known or predicted occurrence of native fishes (or abundance of Cutthroat Trout), riverine connectivity, and risk to habitat degradation. The high rankings highlight watersheds with high richness of native fishes, watersheds occupied by rare species, clusters of high value watersheds due to their hydrologic connectivity and species connectivity needs, and low risk to habitat degradation. The Bonneville Basin and Lahontan and Central Nevada basins assessments help to fill and important information gap in the western U.S. (Figure 14), and these assessments can be used in various ways to aid in conservation decision making for native fishes.

Figure 12. Angler with a Lahontan Cutthroat Trout from Pyramid Lake. Credit: J. Barnes

Figure 13. Willow Creek in the Rock-Willow Basin. Credit: J. Zablocki

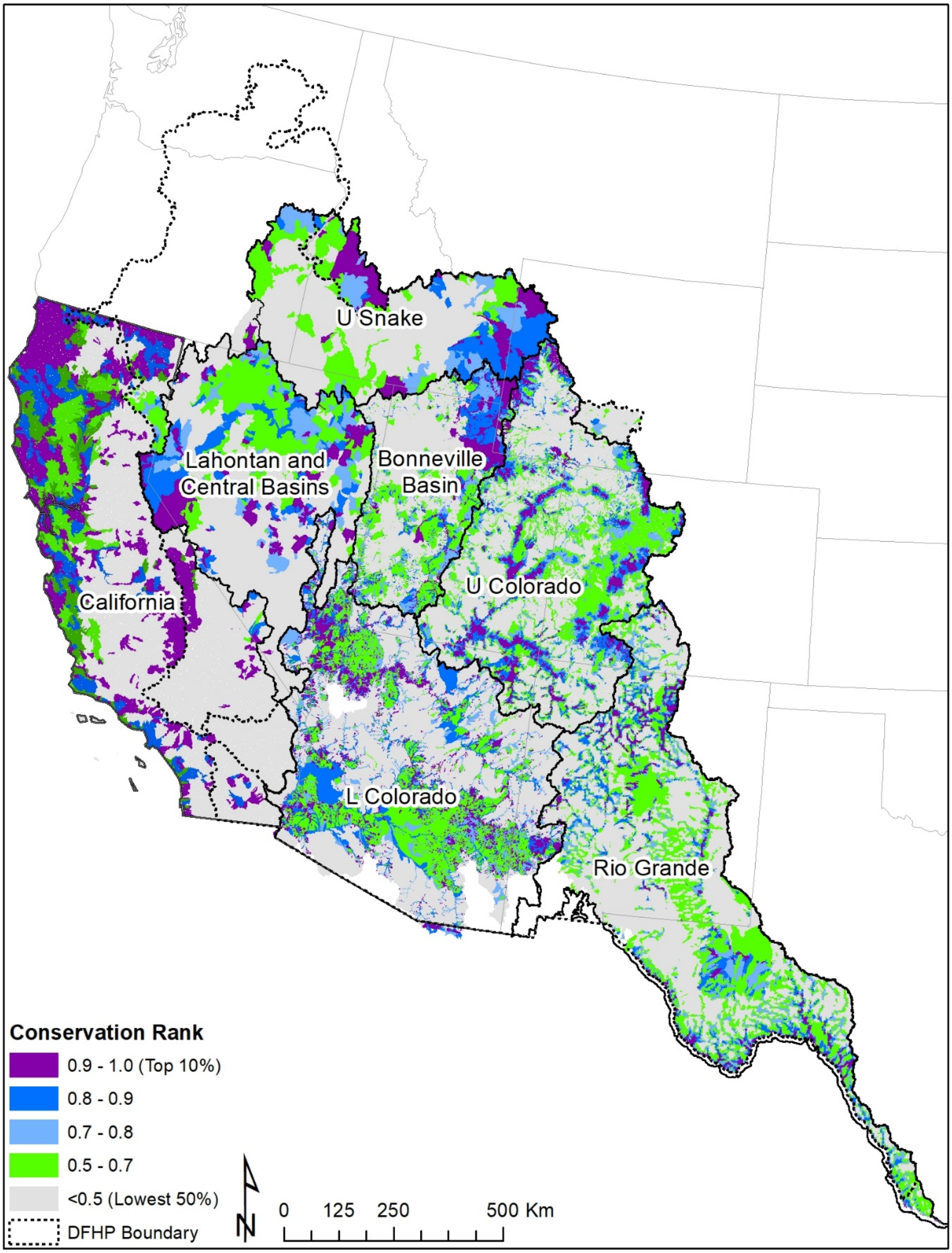


Figure 14. Multispecies aquatic assessments focused on native fishes completed for specific basins (and California) in the western U.S., including the Bonneville Basin and Lahontan and Central Nevada assessments completed per this project.

These assessments can be used to determine whether proposed conservation actions are in important watersheds for native fishes. As discussed by Dauwalter et al. (2019), DFHP has used the assessments to determine whether habitat restoration (or other) projects proposed to them for funding through their granting program are located in important watersheds. Extracting the conservation value (rank) of the watershed in which a project is proposed helps to understand the importance of that project within the broader landscape context of a hydrologic basin. This is especially helpful since the partnership steering committee is comprised of representatives from various agencies and organizations that may not be familiar with the suite of species or watersheds in specific basins where projects are being proposed.

Likewise, the assessments can be used to inform conservation planning. For example, high value areas from the assessments can inform selection of focal areas in which to focus conservation efforts. Focal areas can be used to guide solicitation of proposals from potential grantees or be used to assess whether projects are proposed in areas with high conservation value. The potential Native Fish Conservation Areas highlighted could serve as these focal areas. They were called out based on high value watersheds identified in the assessments but they are also based on having documented native trout populations *and* native non-game species; that is, they are not based on the predictions from species distribution models that underly the conservation rankings. These potential NFCAs are thus watersheds in which DFHP and WNTI can engage in collaborative conservation, whether it be jointly funding projects proposed to one or both partnerships as a result of a Request for Proposals (RFP) or planning a proactive effort to engage in conservation in watersheds where actions have not yet been initiated. Because more is typically known about native trout as sportfish than non-game fishes, planning in high value watersheds can be jumpstarted using native trout with an eye towards watershed-scale work that also benefits native non-game fishes downstream (Haak and Williams 2013).

Multispecies Aquatic Assessment Webmap (LINK)

Completion of the Bonneville Basin and Lahontan and Central Nevada Basins multispecies assessments fills an important assessment gap within the DFHP geography. Their completion leads to nearly complete coverage of the DFHP geography across the western U.S. The only gap is in eastern Oregon and Washington (Figure 14).

All multispecies assessments completed to date have been integrated into a webmap to facilitate their accessibility and use (Figure 15). As previously mentioned, the DFHP has used the assessments to help understand whether projects proposed to them for funding are in important watersheds for native fishes. The webmap allows a user, including potential grantees, to pan around and zoom in to understand the conservation rankings in specific watersheds or how the conservation value for native fishes varies across the focal landscape. The user can also upload a .csv file of specific locations to plot them on the webmap. The .csv file simply needs to have a Latitude field and a Longitude field in decimal degrees (e.g., Latitude: 41.04262, Longitude: -109.73700)(Figure 16). Once uploaded, the user can then download the same file but with the conservation value (Rank) of the catchment or subwatershed underlying each location attached. Click the link in the heading above to access the webmap. It is also available on DFHP's website.

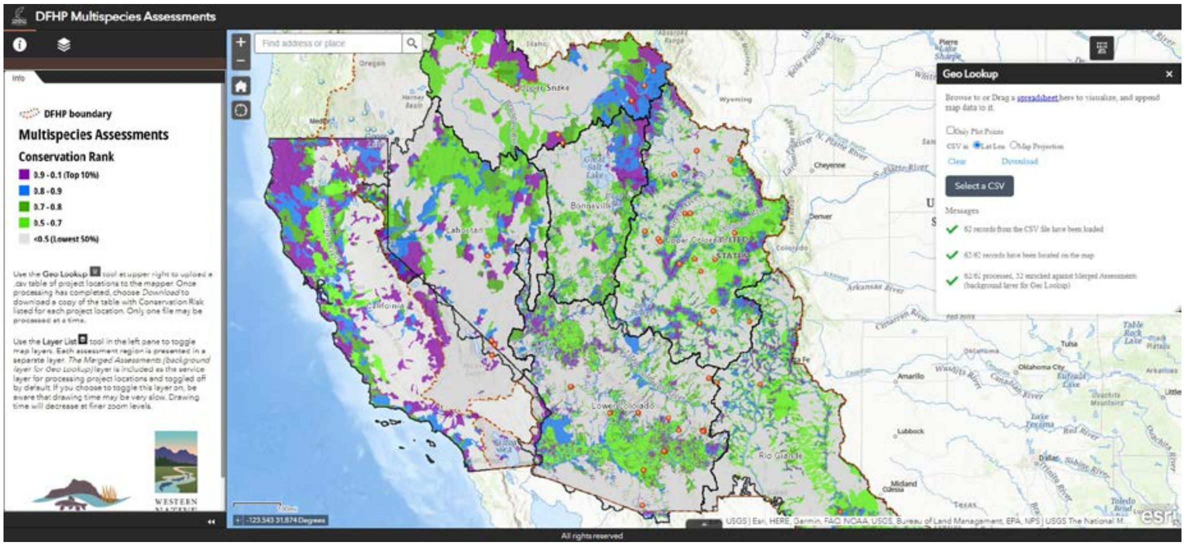
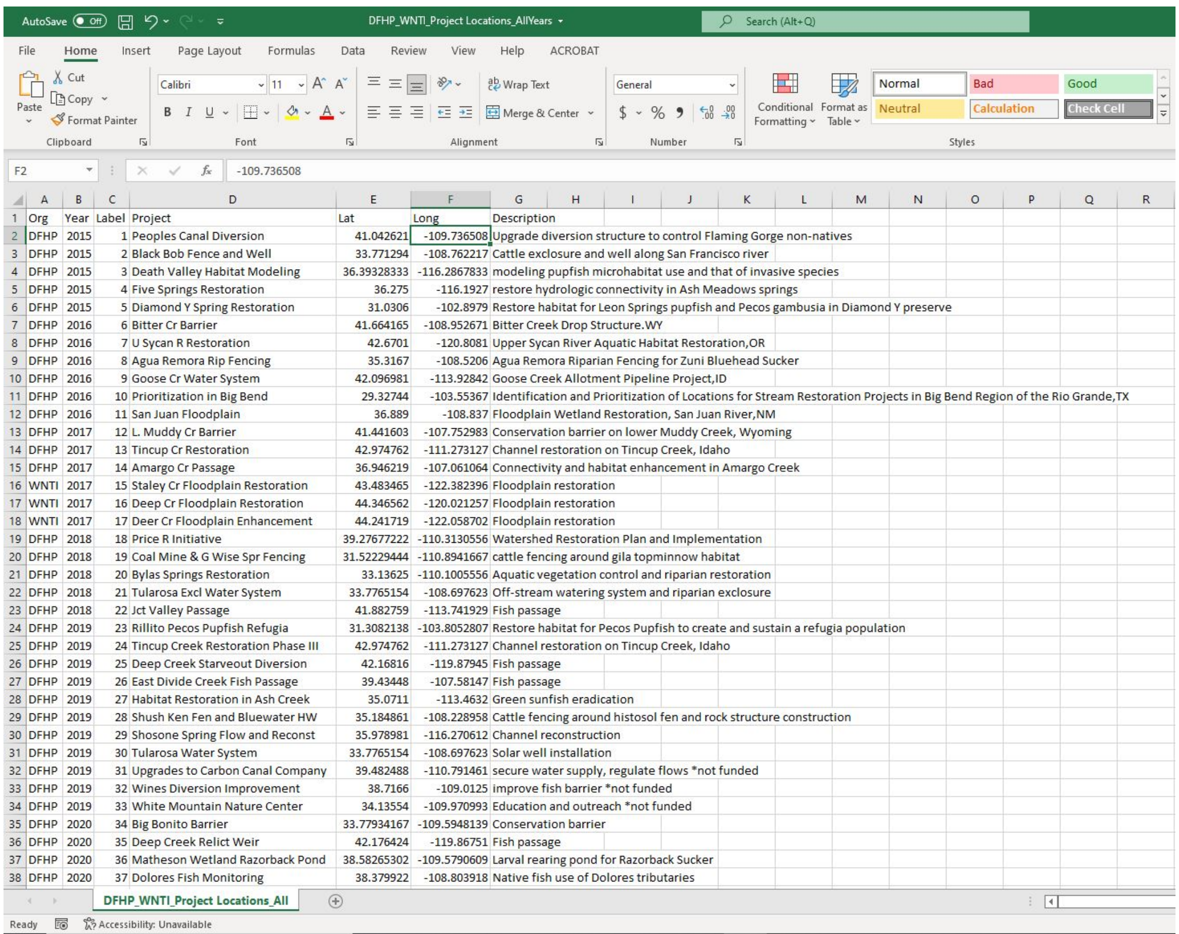


Figure 15. Interactive webmap that serves the multispecies aquatic assessments completed to date. The user can upload a .csv file with spatial coordinates (latitude and longitude) that will plot over the assessments. The user can also download the .csv file with the conservation ranking associated with each coordinate. Orange points are the locations of projects proposed to DFHP for funding since 2015. Webmap developed by M. Mayfield, Trout Unlimited.



Org	Year	Label	Project	Lat	Long	Description
DFHP	2015	1	Peoples Canal Diversion	41.042621	-109.736508	Upgrade diversion structure to control Flaming Gorge non-natives
DFHP	2015	2	Black Bob Fence and Well	33.771294	-108.762217	Cattle exclosure and well along San Francisco river
DFHP	2015	3	Death Valley Habitat Modeling	36.39328333	-116.2867833	modeling pupfish microhabitat use and that of invasive species
DFHP	2015	4	Five Springs Restoration	36.275	-116.1927	restore hydrologic connectivity in Ash Meadows springs
DFHP	2015	5	Diamond Y Spring Restoration	31.0306	-102.8979	Restore habitat for Leon Springs pupfish and Pecos gambusia in Diamond Y preserve
DFHP	2016	6	Bitter Cr Barrier	41.664165	-108.952671	Bitter Creek Drop Structure.WY
DFHP	2016	7	U Sycan R Restoration	42.6701	-120.8081	Upper Sycan River Aquatic Habitat Restoration,OR
DFHP	2016	8	Agua Remora Rip Fencing	35.3167	-108.5206	Agua Remora Riparian Fencing for Zuni Bluehead Sucker
DFHP	2016	9	Goose Cr Water System	42.096981	-113.92842	Goose Creek Allotment Pipeline Project,ID
DFHP	2016	10	Prioritization in Big Bend	29.32744	-103.55367	Identification and Prioritization of Locations for Stream Restoration Projects in Big Bend Region of the Rio Grande,TX
DFHP	2016	11	San Juan Floodplain	36.889	-108.837	Floodplain Wetland Restoration, San Juan River,NM
DFHP	2017	12	L. Muddy Cr Barrier	41.441603	-107.752983	Conservation barrier on lower Muddy Creek, Wyoming
DFHP	2017	13	Tincup Cr Restoration	42.974762	-111.273127	Channel restoration on Tincup Creek, Idaho
DFHP	2017	14	Amargo Cr Passage	36.946219	-107.061064	Connectivity and habitat enhancement in Amargo Creek
WNTI	2017	15	Staley Cr Floodplain Restoration	43.483465	-122.382396	Floodplain restoration
WNTI	2017	16	Deep Cr Floodplain Restoration	44.346562	-120.021257	Floodplain restoration
WNTI	2017	17	Deer Cr Floodplain Enhancement	44.241719	-122.058702	Floodplain restoration
DFHP	2018	18	Price R Initiative	39.27677222	-110.3130556	Watershed Restoration Plan and Implementation
DFHP	2018	19	Coal Mine & G Wise Spr Fencing	31.52229444	-110.8941667	cattle fencing around gila topminnow habitat
DFHP	2018	20	Bylas Springs Restoration	33.13625	-110.1005556	Aquatic vegetation control and riparian restoration
DFHP	2018	21	Tularosa Excl Water System	33.7765154	-108.697623	Off-stream watering system and riparian exclosure
DFHP	2018	22	Jct Valley Passage	41.882759	-113.741929	Fish passage
DFHP	2019	23	Rillito Pecos Pupfish Refugia	31.3082138	-103.8052807	Restore habitat for Pecos Pupfish to create and sustain a refugia population
DFHP	2019	24	Tincup Creek Restoration Phase III	42.974762	-111.273127	Channel restoration on Tincup Creek, Idaho
DFHP	2019	25	Deep Creek Starveout Diversion	42.16816	-119.87945	Fish passage
DFHP	2019	26	East Divide Creek Fish Passage	39.43448	-107.58147	Fish passage
DFHP	2019	27	Habitat Restoration in Ash Creek	35.0711	-113.4632	Green sunfish eradication
DFHP	2019	28	Shush Ken Fen and Bluewater HW	35.184861	-108.228958	Cattle fencing around histosol fen and rock structure construction
DFHP	2019	29	Shosone Spring Flow and Reconst	35.978981	-116.270612	Channel reconstruction
DFHP	2019	30	Tularosa Water System	33.7765154	-108.697623	Solar well installation
DFHP	2019	31	Upgrades to Carbon Canal Company	39.482488	-110.791461	secure water supply, regulate flows *not funded
DFHP	2019	32	Wines Diversion Improvement	38.7166	-109.0125	improve fish barrier *not funded
DFHP	2019	33	White Mountain Nature Center	34.13554	-109.970993	Education and outreach *not funded
DFHP	2020	34	Big Bonito Barrier	33.77934167	-109.5948139	Conservation barrier
DFHP	2020	35	Deep Creek Relict Weir	42.176424	-119.86751	Fish passage
DFHP	2020	36	Matheson Wetland Razorback Pond	38.58265302	-109.5790609	Larval rearing pond for Razorback Sucker
DFHP	2020	37	Dolores Fish Monitoring	38.379922	-108.803918	Native fish use of Dolores tributaries

Figure 16. Example of .csv filed that can be uploaded to the webmap as viewed in Microsoft Excel. The .csv file has latitude and longitude fields expressed in decimal degrees.

Methods

The Approach: Native Fish Conservation Value of Catchments

The native fish conservation value of catchments (~1km stream segments) in the Bonneville Basin and subwatersheds (12-digit Hydrologic Unit Code) in the Lahontan and Central Nevada basins was assessed using Core Area Zonation. Core Area Zonation results in a conservation value (aka, rank) for each watershed in the analysis landscape that ranges from 0 (no value) to 1 (highest value in landscape). The conservation value is based on the Core Area Zonation algorithm. Core Area Zonation is a hierarchical analysis that integrates species data with habitat condition and upstream and downstream connectivity of planning units (catchments or subwatersheds) in a way that maximizes the representation of all focal species and their weighting in the analysis. The analysis was implemented using the core-area function in Zonation 4.0 conservation planning software (Moilanen et al. 2008; Moilanen et al. 2014).

Core Area Zonation

Core Area Zonation iteratively removes the planning unit (catchment or subwatershed) that results in the smallest aggregate loss in value across all species inputs while accounting for the species weights and species-specific connectivity needs. The least valuable planning units are removed first, the next least valuable planning unit remaining is then removed and so on, and this removal process continues until there is only one planning unit left - the most important one based on the collective species inputs. The iterative removal process through Core Area Zonation results in the hierarchical ranking of planning units that are then scaled from 0 to 1.

More specifically, the ranking is hierarchical and based on the minimum marginal loss across species specific input values (see below):

$$\delta_i = max_j \frac{q_{ij} w_j}{c_i}$$

where δ_i= the marginal loss across all *j* species for watershed planning unit *i*; c_i= is the cost associated with the planning unit *i*, set at 1 for all planning units (i.e., it has no influence in the analysis); w_j=the weight for species *j*, which in this case was based on DFHP species rankings that are based on Global Heritage Rank (natureserve.org), desert endemism, need for cross-jurisdictional cooperation, federal listing status, population status, and level of management available for the species as outlined in its strategic plan (DFHP 2015); and q_{ij}= the proportion of the remaining distribution of species *j* located in planning unit *i* for a given set of planning units (those planning units – catchments or subwatersheds – remaining). The species inputs were defined as the occurrence probability from a species distribution model (range: 0-1) or known occurrence (present=1, absent=0) for non-game species and was a linear density (#/km) for a Cutthroat Trout population based on field data. The equation selects the planning unit (catchment or subwatershed) with the highest species input values across all species while also retaining biodiversity-poor catchments that have high occurrence values for rare (and highly weighted) species (Di Minin et al. 2014). The planning unit removal process was repeated iteratively until only one planning unit remained on the landscape during the last iteration. This last planning unit was the most important watershed across all watersheds and received the highest rank.

Planning Units

Core Area Zonation is a cell-based removal algorithm, but it allows the use of planning units so that all cells within a planning unit are removed together. The multispecies analysis used NHD Plus catchments as the planning units in the Bonneville Basin and 12-digit hydrologic unit code subwatersheds (HUC12) as planning units in the Lahontan and Central Nevada basins. The subwatershed planning units were used due in the Lahontan and Central Nevada basins due to the computational requirements associated with the larger analysis extent; it would have taken ~10 days using a computer with a 2.6GHz processor with six cores and 64GB RAM to complete one Core Area Zonation analysis using the 30-m grid cell size required for use of NHD catchments as planning units because catchments were developed using a 30-m grid. Regardless of whether catchments or subwatersheds were used planning units, all grid cells within a planning unit were removed simultaneously during the iterative removal algorithm.

Fish Species Data

The 3 Rs for Native Trout

The 3 Rs – Representation, Redundancy, and Resiliency - have provided a foundation for efficient conservation planning. They have also provided a framework for understanding the status of a species (Smith et al. 2018). Haak and Williams (2012) applied the 3R framework into a conservation portfolio for western native trout management. They purported that maximizing the representation and redundancy of ecological elements of genetic purity, life history diversity, and geographic diversity across populations, and managing for a high likelihood of population persistence conferring resilience (high abundance and occupancy of large habitat patches), would provide the best hedge for Cutthroat Trout in an uncertain future.

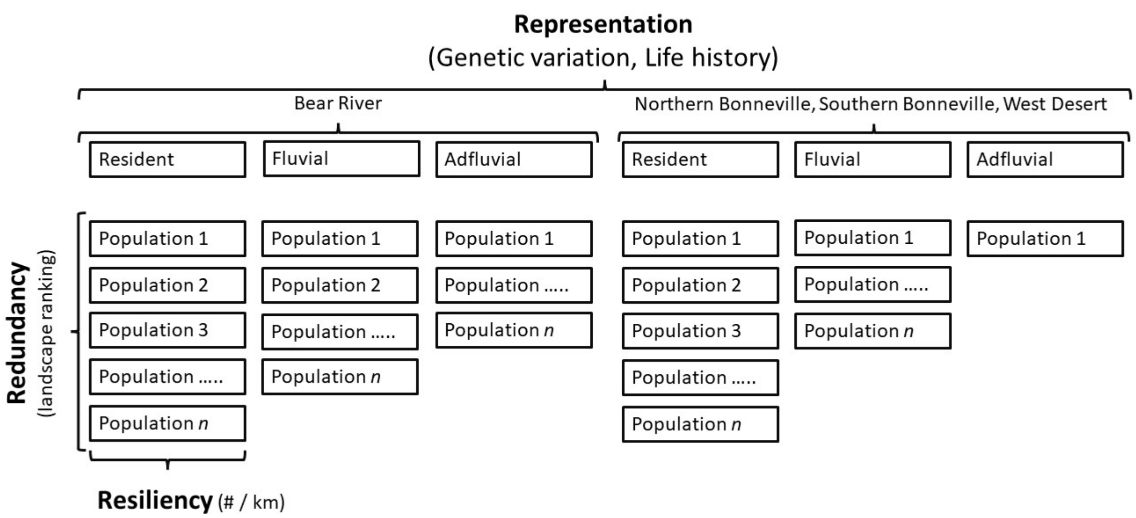


Figure 17. The 3 Rs showing conceptually how Bonneville Cutthroat Trout populations are represented by genetic variation associated with the Bear River Geographic Management Unit and the North Bonneville, Southern Bonneville, and West Desert GMUs, and life history diversity – resident, fluvial, and adfluvial life histories - within those GMUs, as well as how they are redundant by being represented in multiple populations. Resiliency is conferred by linear density within a population.

The representative elements of genetic purity, life history diversity, and geographic and genetic diversity among different Cutthroat Trout populations, and linear density as a measure of resiliency, were integrated in the multispecies aquatic assessments for the Bonneville Basin and Lahontan and Central Nevada basins (Figure 17). Information on native trout populations was obtained from rangewide databases for Bonneville Cutthroat Trout *Oncorhynchus clarkii utah* and Lahontan Cutthroat Trout *O. c. henshawi* compiled to inform the status of each subspecies (May and Albeke 2005; USFWS 2009). Populations were delineated using field data and professional judgment on 1:24,000 National Hydrography Dataset (NHD) flowline and waterbody feature classes (May and Albeke 2005; May and Albeke 2008; USFWS 2009). Each database contained information on genetic purity and life history (resident, fluvial, adfluvial). For Bonneville Cutthroat Trout four geographic management units were considered for the representation of geographic diversity; the Bear River was retained as a unit, and the Northern Bonneville, Southern Bonneville, and West Desert GMUs were combined into one additional unit because of the unique genetics associated with the Bear River in contrast to the remaining Bonneville Basin (Loxterman and Keeley 2012; Campbell et al. 2018). For Lahontan Cutthroat Trout, the Uniquely Identifiable Evolutionary Units (UIEU) proposed by Peacock et al. (2018) were used: Eastern Lahontan, Western Lahontan, Northwestern Lahontan, and Coyote Lakes units (the Lake Alvord unit was outside of our analysis domain). Because the assessment analyses were built on representation and redundancy concepts, we treated unique ecological elements of populations as separate 'species' in the analysis and divided the species-level rank among these constituent elements (see Table 1; Table 2).

Bonneville Basin Non-Game Species

Inputs for non-game species in the Bonneville Basin were waterbodies attributed with known occurrences or occurrence probabilities from species distribution models (SDMs)(Figure 18). The SDMs predictions were made on the 1:100,000 National Hydrography Dataset (NHD). Locality data for the SDMs were obtained from the Utah Natural Heritage Program (received 3 February 2020) and Global Biodiversity Information Facility databases (GBIF.org 2020). These training presence data for each species were coupled with randomly generated pseudo absences and environmental data known to influence species distributions to fit random forest models for each species (Breiman 2001). The number of pseudo-absences was 10 times the number of occurrences for each species to maximize model accuracy (Liu et al. 2019). Random forest models when fit to binary (presence-absence) data are an ensemble of classification trees that predict a binary outcome from a suite of environmental predictor variables (Breiman 2001). The environmental predictor variables were: mean August stream temperature (°C), percent canopy cover, latitude (Albers Equal Area Northing), stream slope (unitless), mean annual precipitation in watershed (mm), and cumulative drainage area (km^2). Predictor variables were obtained from the NorWeST database for the Bonneville Basin (Isaak et al. 2017). The models exhibited good fit (Out of Bag [OOB] error < 3.7%, and AUC = 1.0; Table 3) and predictions were made to the entire analysis domain for the Bonneville Basin; predictions in basins not occupied by a species were set to zero for that species. For lacustrine species such as Bear Lake Whitefish, Bonneville Whitefish, Bonneville Cisco, Bear Lake Sculpin, June Sucker, and Least Chub whose distributions are known with high precision (i.e., they occur only known waterbodies such as Bear Lake) their occurrence was attributed to NHD waterbody or flowlines. Both occurrence probabilities (range: 0-1) and known occurrences (value=1) were converted to 30m grid cells for input into Zonation.

Lahontan and Central Nevada Non-Game Species

Zonation inputs for non-game species in the Lahontan and Central Nevada basins were lines (streams or rivers) or polygons (lakes, ponds, wetlands) attributed with species occurrences (value=1) from the Nevada Division of Natural Heritage (Figure 19). For broadly distributed species not tracked by NDNH, species distribution models were developed as for the Bonneville Basin (Table 3). These NDNH data and

SDM predictions on NHD medium resolution (1:100,000 scale) were converted to 300m grid cells for input into Zonation.

Table 3. Number of occurrences and percent prevalence given pseudo-absences used to fit random forest models, and out-of-bag error rate and area under the curve (AUC) of a ROC plot of models by species in the Bonneville and Lahontan. The Lahontan Cutthroat Trout model was a general linear model fit with true absences. Species not listed were not modeled.

Common name	Occurrences (prevalence)	OOB (AUC)
Bonneville Basin		
Utah Chub	54 (9.3%)	3.7% (1.00)
Northern Leatherside Chub	110 (9.1%)	0.5% (1.00)
Southern Leatherside Chub	2413 (9.6%)	0.6% (1.00)
Longnose Dace	2209 (9.6%)	0.2% (1.00)
Speckled Dace	949 (9.2%)	0.8% (1.00)
Redside Shiner	348 (9.1%)	1.8% (1.00)
Mountain Sucker	273 (9.1%)	0.6% (1.00)
Utah Sucker	48 (9.1%)	1.0% (1.00)
Bluehead Sucker	619 (9.9%)	0.4% (1.00)
Mountain Whitefish	720 (9.3%)	0.2% (1.00)
Mottled Sculpin	17 (9.1%)	1.2% (1.00)
Lahontan Basin		
Lahontan Basin Speckled Dace	6461 (9.2%)	2.2% (1.00)
Lahontan Redside	2507 (9.1%)	3.9% (1.00)
Mountain Sucker	1249 (9.1%)	3.1% (1.00)
Tahoe Sucker	8304 (9.2%)	1.8% (1.00)
Mountain Whitefish	2508 (9.2%)	1.0% (1.00)
Lahontan Cutthroat Trout	1795 (10.9%)	--- (0.79)
Paiute Sculpin	1241 (9.1%)	2.1% (1.00)

Distribution Discounting

Robust assessment outputs account for the uncertainty associated with inputs (Moilanen et al. 2006). The species occurrences are based on known occurrences from field observations, but some of the observations were made over a decade ago. Likewise, the species distribution models were based on natural features of the landscape or climate factors, but they did not account for anthropogenic factors, such as land use, that can negatively impact aquatic ecosystems and the distribution of fishes. We used distribution discounting to downweight species data in watersheds with high threat to aquatic habitat conditions using the 2015 National Assessment of Fish Habitat (Wang et al. 2011; Crawford et al. 2016). The assessment describes threats to aquatic habitat condition at the ~1 km stream segment scale using a cumulative index that ranges from 1 (very high risk of habitat degradation) to 5 (very low risk). Whelan (2019) describes the conceptual foundation for the NFHP assessment.

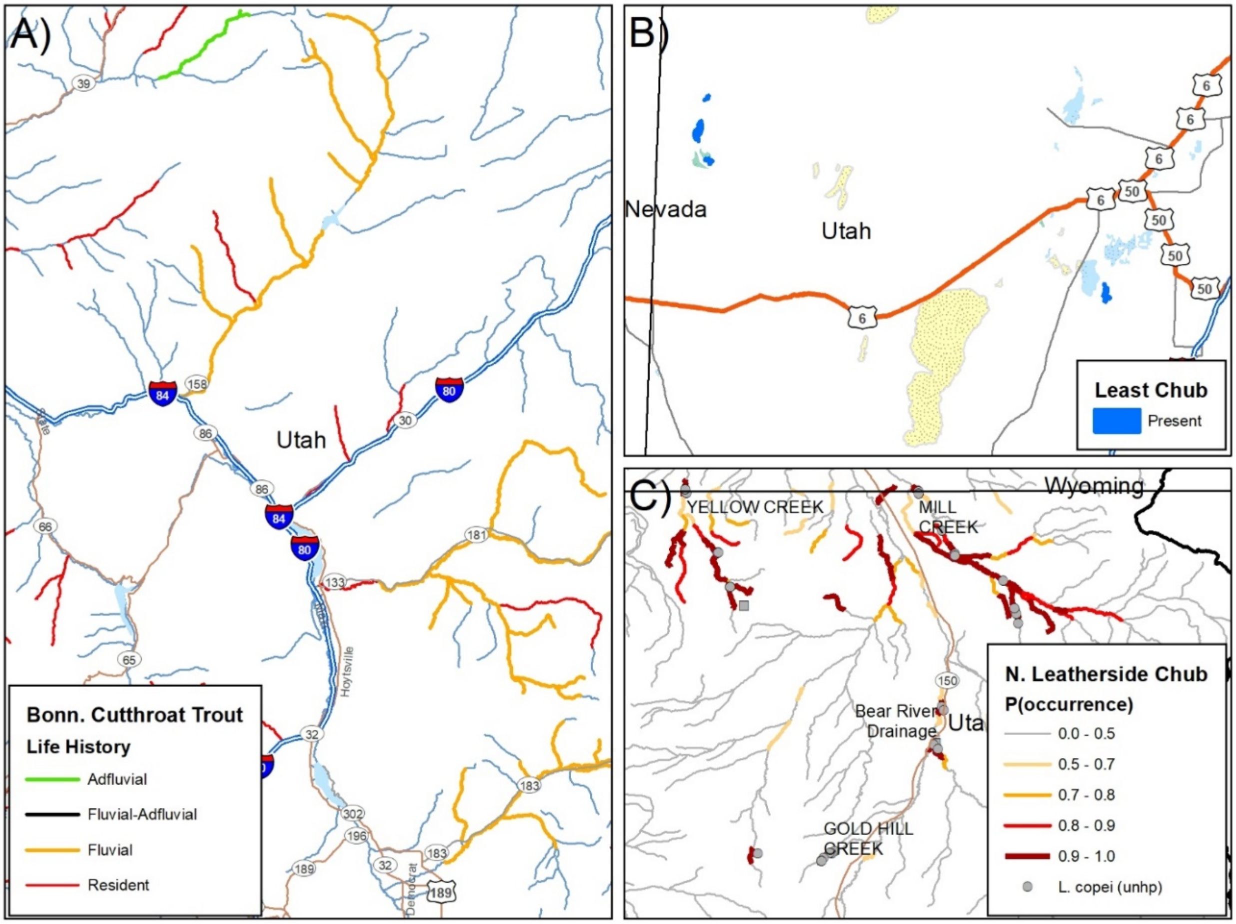


Figure 18. Examples of species inputs for the Bonneville Basin multispecies assessment that included: A) life history, linear density, and genetically unique Geographic Management Units (GMUs) from the Bonneville Cutthroat Trout rangewide database (left panel), B) waterbodies representing known occupied lacustrine habitat of Least Chub (upper right), and C) occurrence probabilities from species distribution models for species with wider distributions than captured in occurrence records (lower right; Northern Leatherside Chub SDM); Utah Natural Heritage Program (UNHP) database occurrence records shown for Northern Leatherside Chub (in grey).

Species inputs were discounted using distribution discounting in Core Area Zonation. Distribution discounting reduces species input values based on uncertainty, where α is the degree of uncertainty. When α = 0.0 then there is no uncertainty, and when α = 0.5 then the uncertainty is one half of the nominal estimate of the uncertainty model (Moilanen et al. 2014). Habitat condition index (HCI) scores from the 2015 National Fish Habitat Partnership (NFHP) status of fish habitats report were used to discount distributions (Figure 20)(Wang et al. 2011; Crawford et al. 2016). This is because habitats with high degradation risk are less likely to have species occur there, and the species distribution models do not have predictors that reflect anthropogenic impacts to aquatic habitats. The HCI scores reflect risk of degradation as: 1 = Very High, 2 = High, 3 = Moderate, 2 = Low, 5 = Very Low. Since habitats with low risk of degradation were scored highest (Very Low Risk = 5), HCI scores were rescaled from 0 to 1 as a measure of species distribution uncertainty so that high risk areas represented the highest uncertainty (UC): $UC = (5 - HCI)/(4 - 1)$. Then, α was set to 0.5, and so species input data were discounted by: species $\text{value}_{\text{discounted}}$ = species value - $\alpha \times UC$. Thus, if a stream segment has an occurrence probability of 0.5 for a species and the HCI was 3 (moderate risk of degradation; UC = (5-

3)/(4-1) = 0.67), then the species input for that stream segment was: $P_{occ\_discounted} = P_{occ} - \alpha \times UC = 0.5 - 0.67 \times 0.5 = 0.165$; that is, the species input is reduced from a probability of 0.5 to 0.165. The HCI for a stream segment was used to discount all species inputs in the same way for that segment.

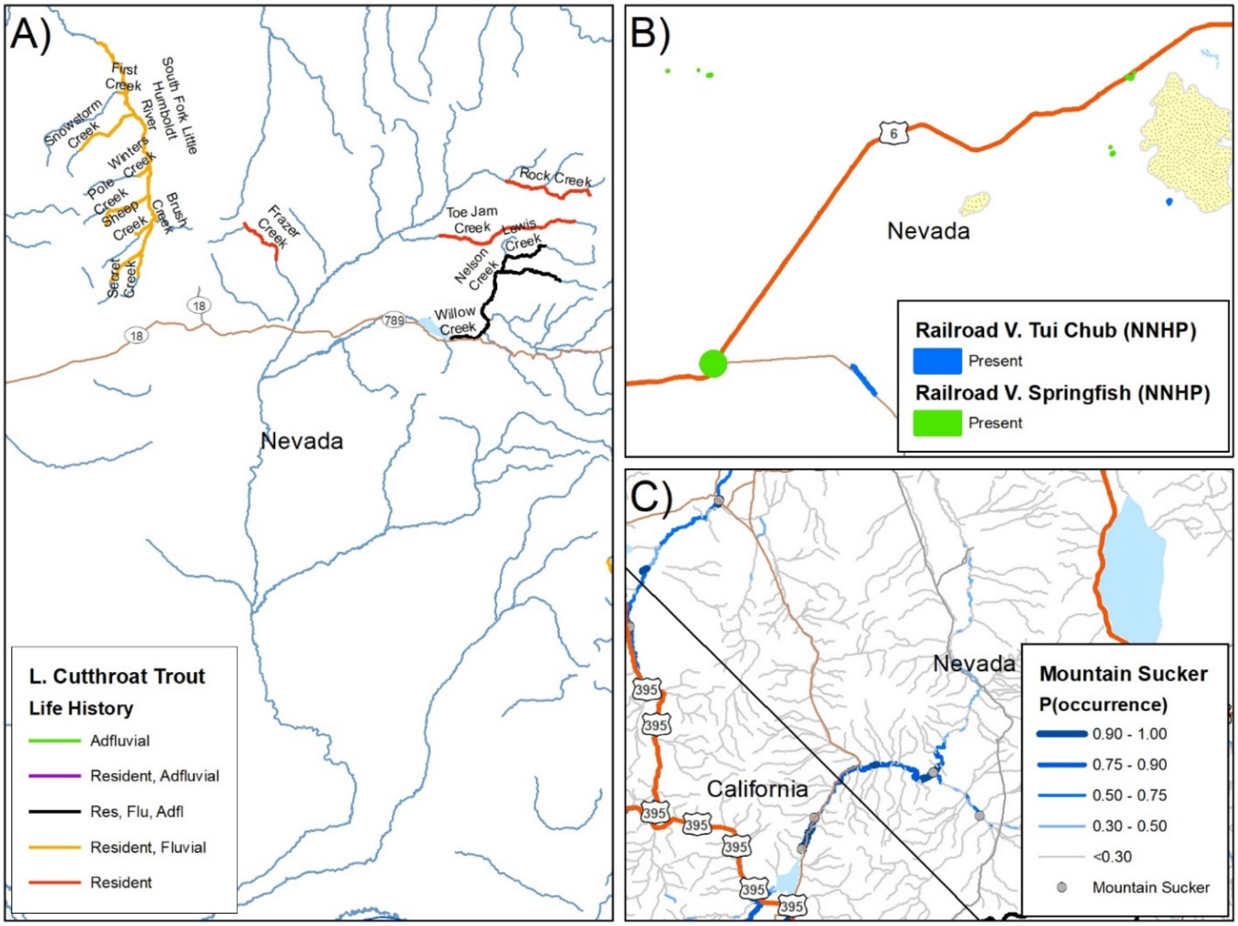


Figure 19. Examples of species inputs for the Lahontan and Central Nevada basins multispecies assessment that included: A) life history, linear density, and Uniquely Identifiable Ecological Unit for each Lahontan Cutthroat Trout population from the 2009 status assessment, B) lines representing streams and polygons representing lacustrine habitat of Railroad Valley Tui Chub and Railroad Valley Springfish from the Nevada Division of Natural Heritage (NDNH) database, and C) occurrence probabilities from species distribution models for non-sensitive species when data were not available from the NDNH (Mountain Sucker SDM); Global Biodiversity Information Facility (GBIF) occurrence records shown for Mountain Sucker (in grey).

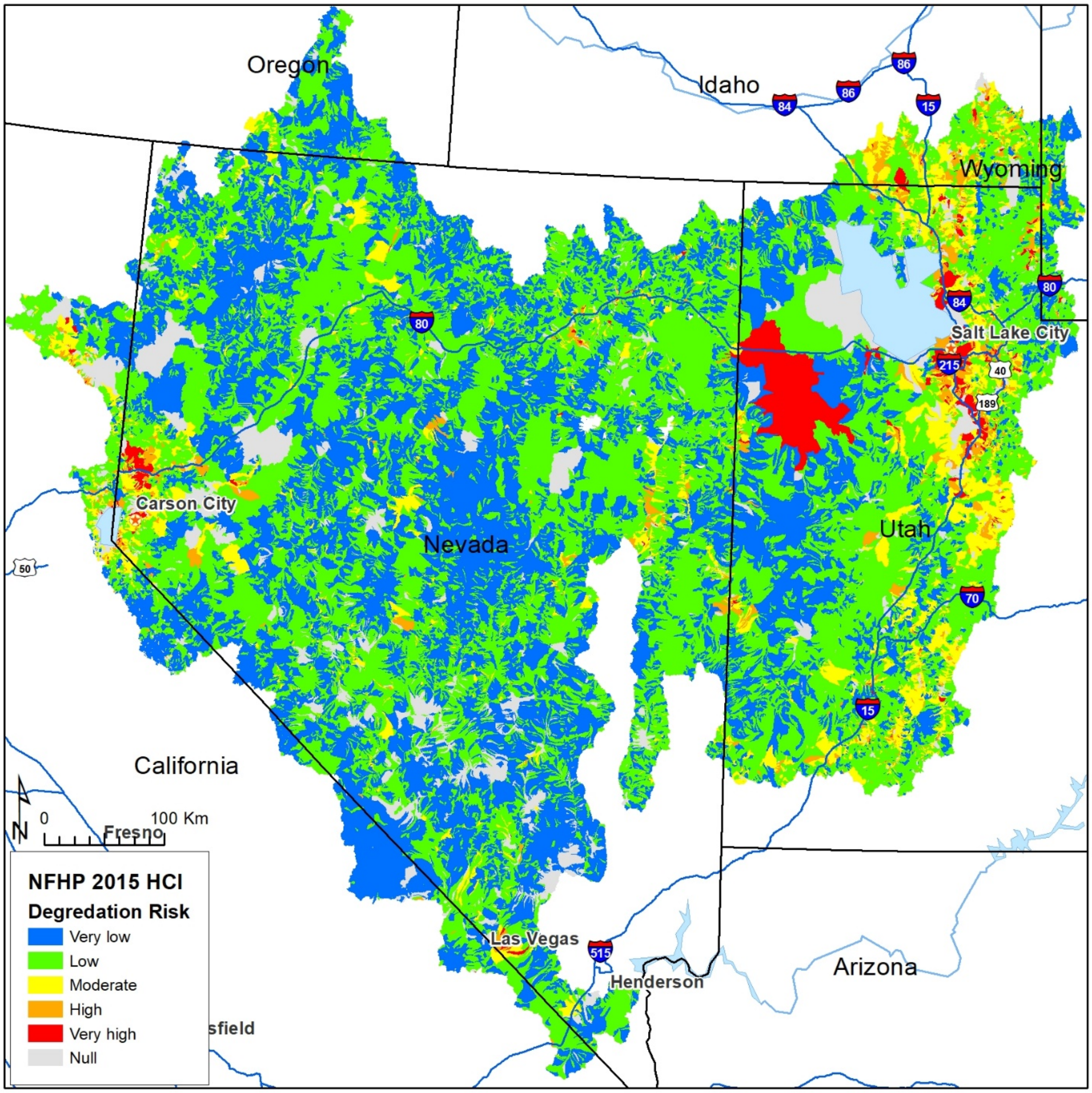


Figure 20. Risk of stream and river habitat degradation from the 2015 National Fish Habitat Partnership (NFHP) Habitat Condition Index (HCI) for the Bonneville Basin and Lahontan and Central Nevada basins.

Aquatic Connectivity

Directed connectivity was used in Core Area Zonation to account for the dendritic nature of stream and river systems (Moilanen et al. 2008). Connectivity was accounted for in the assessments through a proportional loss function. The assessed value of a planning unit (δ_i; catchment or subwatershed) was penalized based on the proportion of planning units upstream or downstream of the focal planning unit that had already been removed during the planning unit removal process. National Hydrography Dataset Plus (NHD+, 1:100,000 scale) specifies which catchments are upstream and downstream of focal catchments, as does the Watershed Boundary Dataset for subwatersheds. Different loss curves were used for different species depending on their connectivity needs. For example, connectivity was unimportant to the Devil's Hole Pupfish that resides in a single water-filled cavern in Death Valley National Park but very important to adfluvial populations of Cutthroat Trout that migrate between lakes and streams to meet life history requirements (Curve 1 in Figure 21). Penalties for upstream connectivity were sometimes slightly stronger than downstream to account for the fact that many fishes move upstream to spawn (Carlson and Rahel 2010). However, connectivity was intentionally interrupted at large dams (>6168 hectare-meters, or >50,000 acre-feet) in the National Inventory of Dams database (USACE 2008); smaller dams or other barriers were not used to break connectivity because they are more capable of being managed for fish passage (Williams et al. 2019).

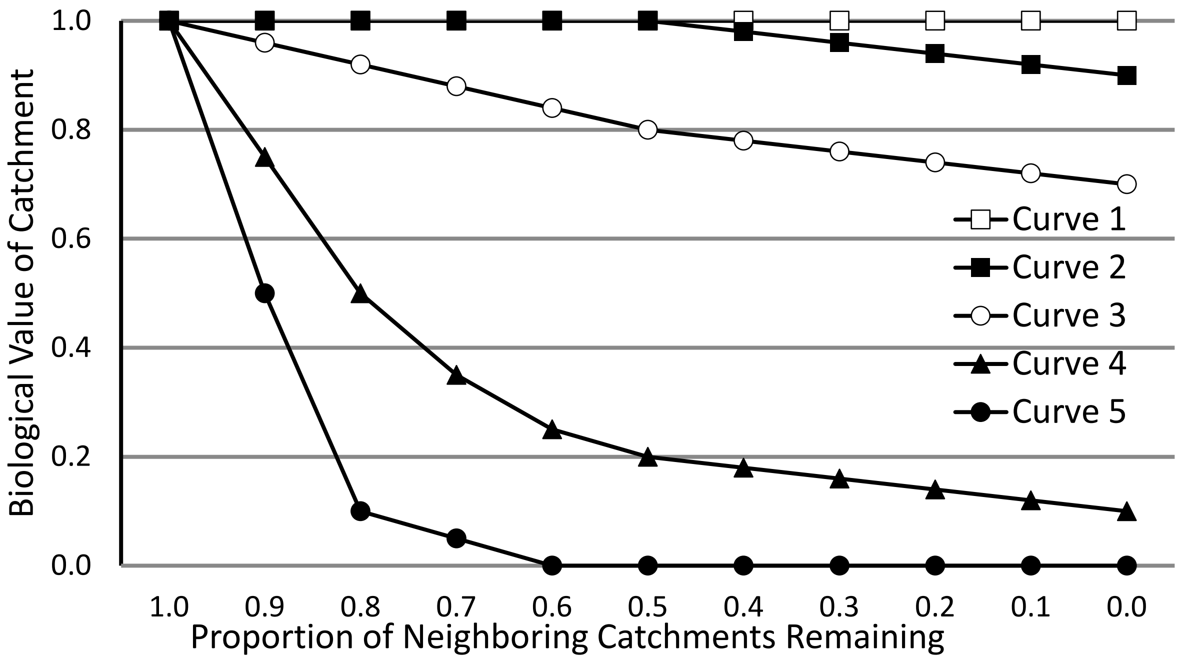


Figure 21. Proportional loss function curves specifying how the species-specific value of a catchment is reduced based on the proportion of neighboring catchments upstream and downstream of the focal catchment have been removed during the iterative removal process. Each species is assigned a connectivity curve to specify the importance of upstream and downstream connectivity

NFCA Identification

The multispecies assessments were used to identify Native Fish Conservation Areas (NFCAs) as other have done (Labay et al. 2019; Williams et al. 2019). Watersheds with high conservation value (>0.9) were identified, and those with known populations of native trout or recent occurrences of native non-game species were highlighted as potential NFCAs for future fish habitat partnership collaboration. The term 'potential' is used as there should be a planning process to identify the exact boundaries based on existing watershed groups and other logistical considerations (including agency priorities) and determining whether conservation goals for native trout and other native species are compatible. Potential NFCAs were not delineated because it should be a collaborative exercise among relevant the partnerships and their constituent agencies and organizations.

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