Conservation Success Index: Gila Trout

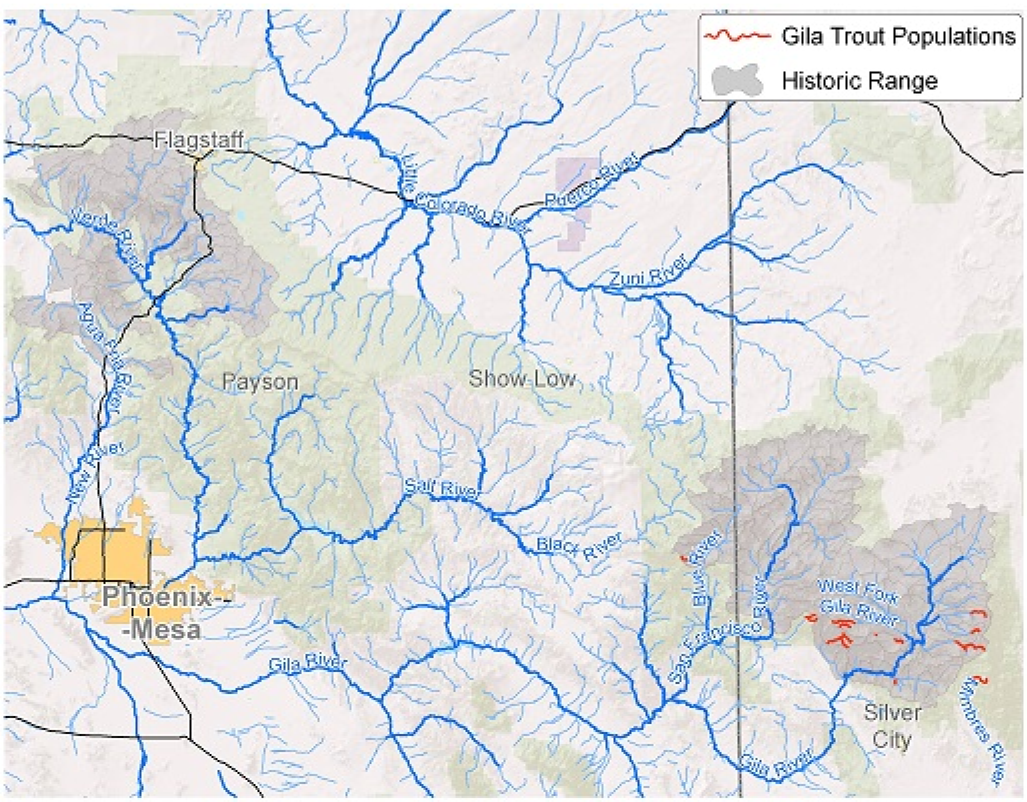
ONCORHYNCHUS CLARKII UTAH

Rev. 1.0 - 5/2010

SPECIES SUMMARY

Gila trout are native to headwater streams in the Gila, San Francisco, Agua Fria, and Verde river drainages in New Mexico and Arizona. The species is listed as threatened pursuant to the Endangered Species Act because of the small number and extent of remaining populations as well as threats posed by non-native species invasion. Most remaining populations are located in the upper Gila River drainage in New Mexico. Our understanding of historical conditions and populations in the Arizona portion of the range is relatively poor despite the good efforts of Robert Miller, W.L. Minckley and other ichthyologists who studied the species during the 1950s through 1970s.

Current Populations and Historic Range Map



Gila trout was not described as a separate species until 1950, at which time populations and distribution had decreased dramatically from historic times. By 1975, only four genetically pure populations remained. Recovery actions by New Mexico Department of Game and Fish, U.S. Fish and Wildlife Service and others have since secured additional populations, but some of these have been extirpated by wildfire and debris flows or have been contaminated with rainbow trout, which hybridize with Gila trout and degrade the genetics of the native species.

Only 13 genetically pure populations remain at the time this analysis was conducted. Most occur in relatively short stream segments that fail to meet the 9.3 km minimum length described by Hilderbrand and Kershner in their 2000 paper describing minimum persistence needs in stream populations of cutthroat trout. Three of 13 populations – Black Canyon, Mogollon Creek, and White Creek – meet long-term persistence criteria. Populations that have less than about 1,500 fish (> 150 mm TL), which is equivalent to an effective population size of about 500 interbreeding adults, will have a lower likelihood of persistence into the coming decades. Although we recognize that persistence criteria established for cutthroat trout may not be directly equivalent to needs of Gila trout, our analysis points to the need to establish additional Gila trout populations in larger stream reaches and to develop at least a few populations that occur in a larger interconnected stream network.

Key CSI Findings

- 13 populations remain, primarily in the Upper Gila River drainage in New Mexico
- Most remaining populations are very small and occupy limited stream segments – only 3 of 13 populations meet long-term persistence criteria
- Habitat conditions are high in most occupied and historic habitat, indicating a good potential for reintroduction success if non-native species can be controlled or eliminated
- The introduction and spread of non-native species, such as rainbow trout, brown trout, smallmouth bass, and crayfish, pose a significant problem
- Climate change, particularly wildfire and drought, pose a high risk to most remaining populations
- Reestablishing larger populations in interconnected stream networks will be critical for the species to survive future disturbances and uncertainty
- Note that all subwatersheds scored a 5 for Percent Historic Lake Area Occupied because there were no historic lake populations for Gila Trout

Photo courtesy David L. Propst and New Mexico Department of Game and Fish

In general, habitat integrity scores are high both within currently occupied subwatersheds but also throughout much of the historic range. CSI indicators for watershed connectivity, watershed condition, and flow regime were uniformly high. Land stewardship and water quality scores were rather bimodal; that is scoring either very high or very low with not many areas in between. The lack of effective livestock grazing management has been a historical problem in some Gila trout subwatersheds and better management should be a priority for the future. Nevertheless, the high quality habitat scores are encouraging for the potential success of reintroduction efforts.

Non-native species are a constant threat and management concern for most populations. The potential for additional non-native species introductions is high. Although there are few remaining populations, they have high genetic purity scores and relatively high population density scores. Countering these high scores are low scores for the population extent indicator. Ideally, a diverse conservation portfolio including both small, well-isolated populations, and larger, interconnected populations are needed to deal with multiple threat factors. Regardless, additional populations are needed, including reestablished populations in those portions of the historic range in Arizona.

Table 1. CSI scoring result summary for Gila Trout

		Number of Subwatersheds Receiving Scores					**Total Subwatersheds Scored**
	CSI Indicator	**1**	**2**	**3**	**4**	**5**	
Range-wide Conditions	Percent historic stream habitat occupied	5	3	1	1	2	12
	Percent subbasins (4th) occupied	12	0	0	0	0	12
	Percent subwatersheds (6th) occupied	11	0	0	0	1	12
	Percent habitat by stream order occupied	2	0	0	1	9	12
	Percent historic lake area occupied	0	0	0	0	12	12
Population Integrity	Population Density	0	0	2	2	4	8
	Population Extent	7	4	1	0	0	12
	Genetic Purity	0	0	0	0	12	12
	Disease vulnerability	0	0	3	9	0	12
	Life history diversity	12	0	0	0	0	12
Habitat Integrity	Land Stewardship	92	0	24	0	55	171
	Watershed connectivity	0	2	4	3	162	171
	Watershed conditions	2	2	7	17	143	171
	Water quality	58	5	12	21	75	171
	Flow regime	5	0	1	3	162	171

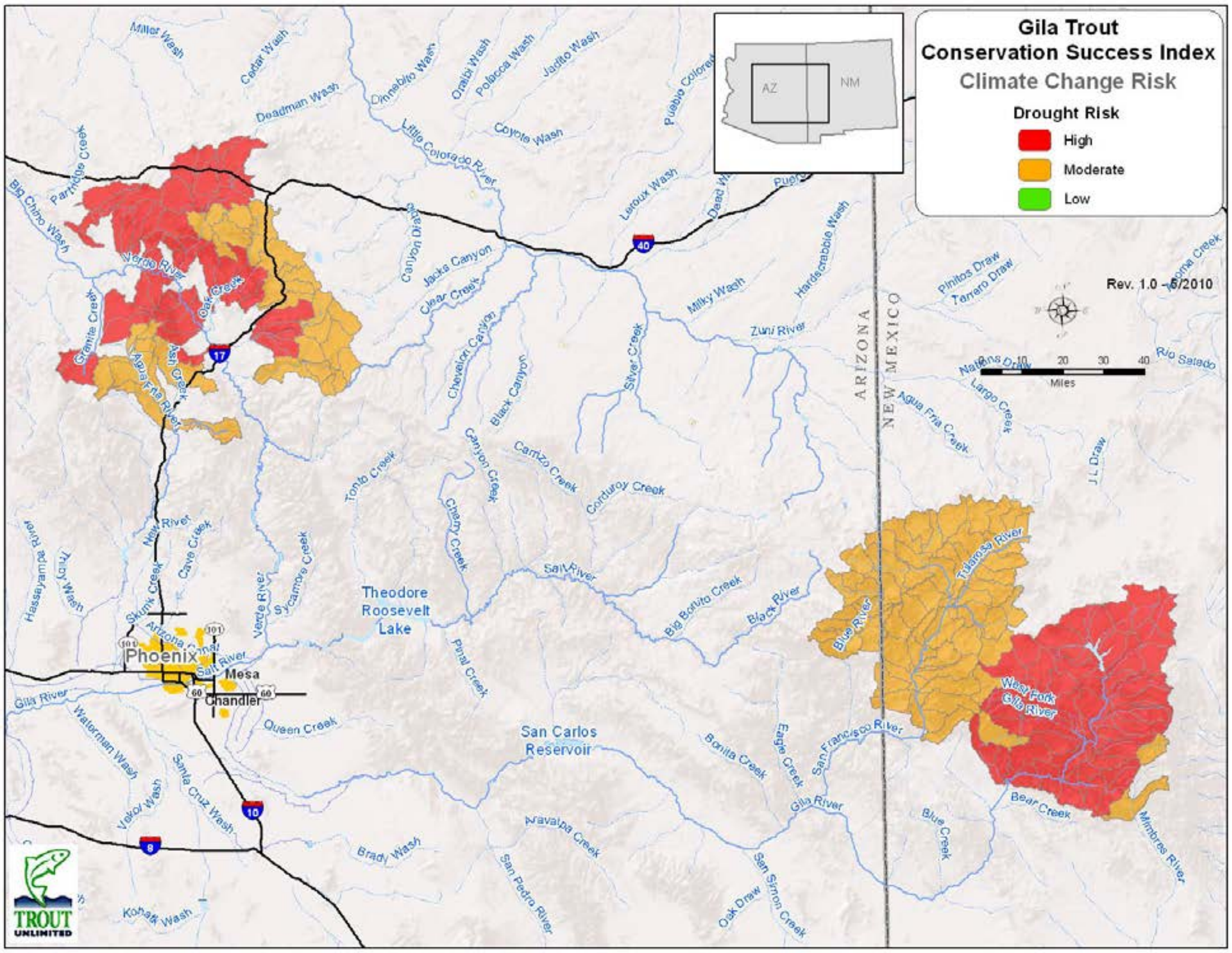
Future Security	Land conversion	0	0	3	7	161	171
	Resource extraction	1	3	10	39	118	171
	Energy development	0	10	1	19	141	171
	Climate change	109	59	3	0	0	171
	Introduced species	2	2	5	19	143	171

Climate change poses a substantial risk to remaining populations. Of the climate change factors examined, wildfire and drought pose the greatest risks. Wildfire and drought are both rated as high risk for most remaining populations in the Upper Gila, but much of the historic habitat also ranks at high risk for these factors. The small population sizes and habitat extents increase the vulnerability of remaining populations to disturbances. In a 2001 paper reviewing extinction risk in Gila trout, Brown and colleagues documented the loss of six populations during the previous decade as a result of wildfires followed by summer rains and accompanying debris flows. We expect such problems to escalate in the future.

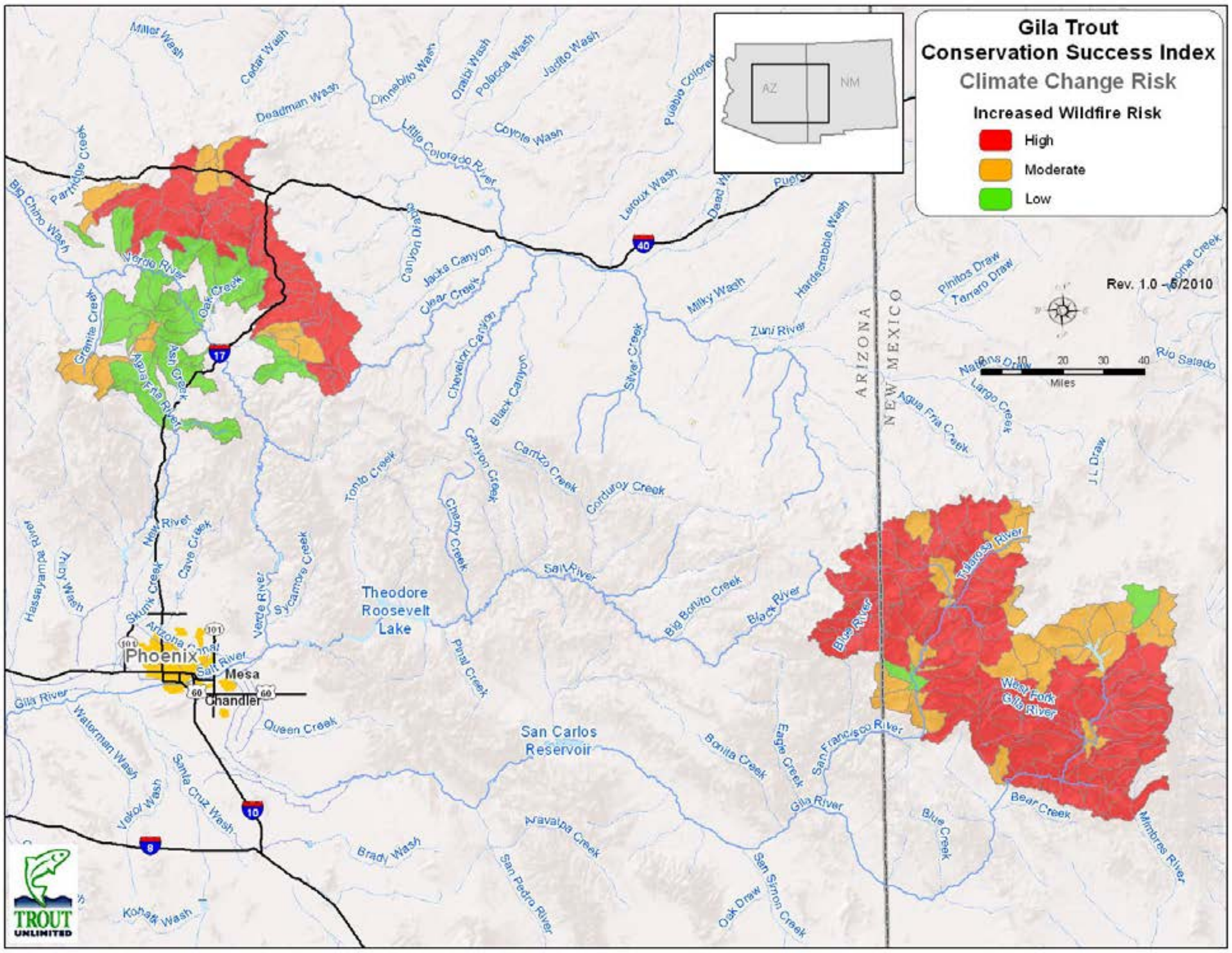
Fortunately, there are numerous restoration and recovery opportunities for Gila trout, especially in the Arizona portion of the range, which is almost completely unoccupied. Habitat conditions in potential reintroduction sites are good, however non-native species control efforts will be needed. We also strongly encourage the development of larger, interconnected populations of Gila trout as a way to provide resilience to future disturbances. The West Fork Gila River in New Mexico and Oak Creek in Arizona are two examples of watersheds that could provide habitat for expanded Gila trout populations, including larger migratory trout. Threatened status remains appropriate for this species as there is a considerable effort required to protect remaining populations, create larger metapopulations, and reintroduce the species into unoccupied historic habitat. Monitoring needs are substantial considering the vulnerability of populations, increased likelihood of disturbances, and potential for additional invasive species.

We thank David Propst (New Mexico Department of Game and Fish), Jim Brooks (U.S. Fish and Wildlife Service), and Julie Meka Carter (Arizona Game and Fish Department) for sharing their data and insights on Gila trout, which provided the bulk of the population data upon which this CSI report is based. Additional fish information was provided by the 2003 Gila Trout Recovery Plan (3rd Revision), USDA Forest Service, and a paper authored by D. Kendall Brown and colleagues that was published in 2001 in the Western North American Naturalist [title: Catastrophic wildfire and number of populations as factors influencing risk of extinction for Gila trout *(Oncorhynchus gilae)*].

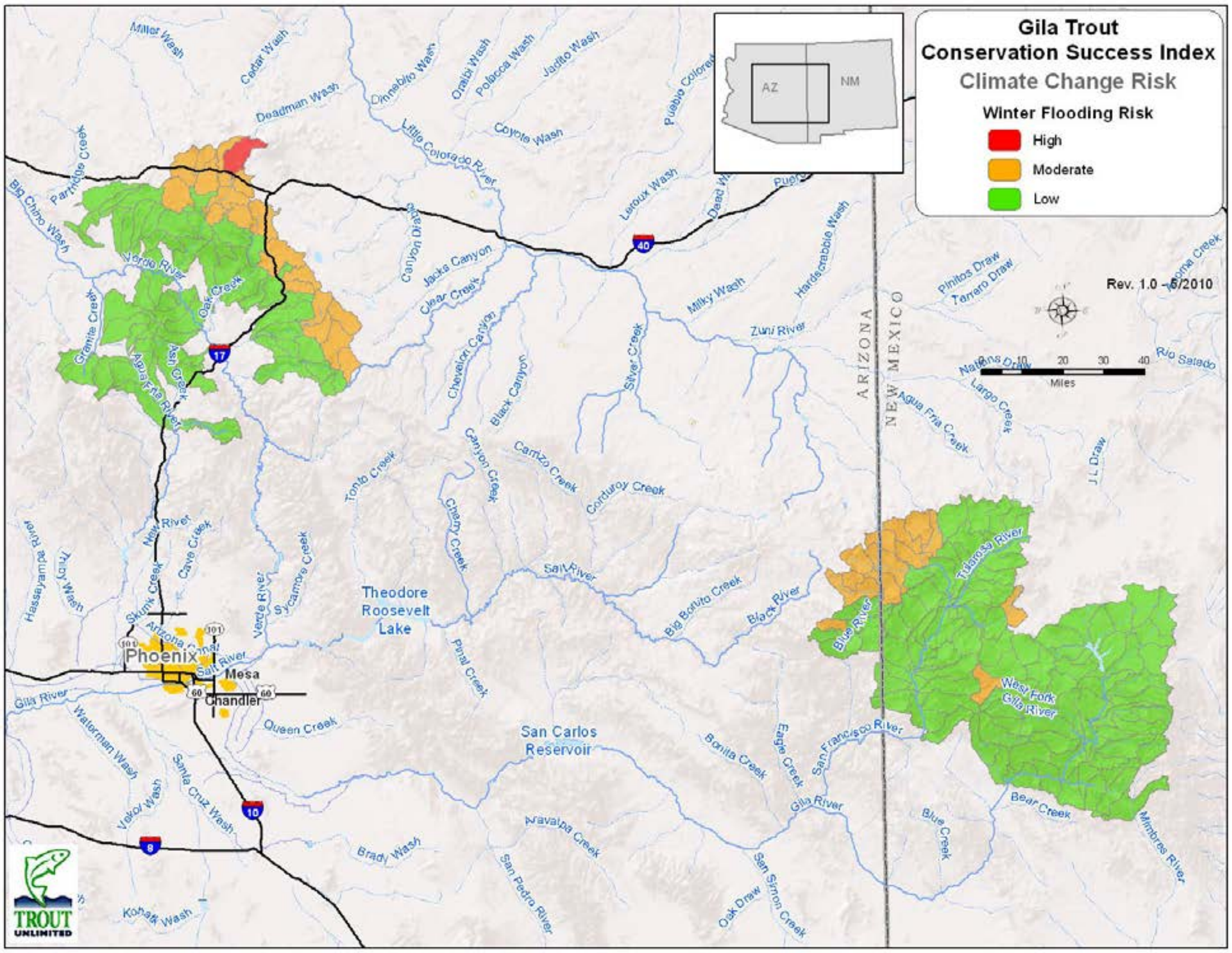
Prepared by Jack E. Williams, TU, 6/10/2010

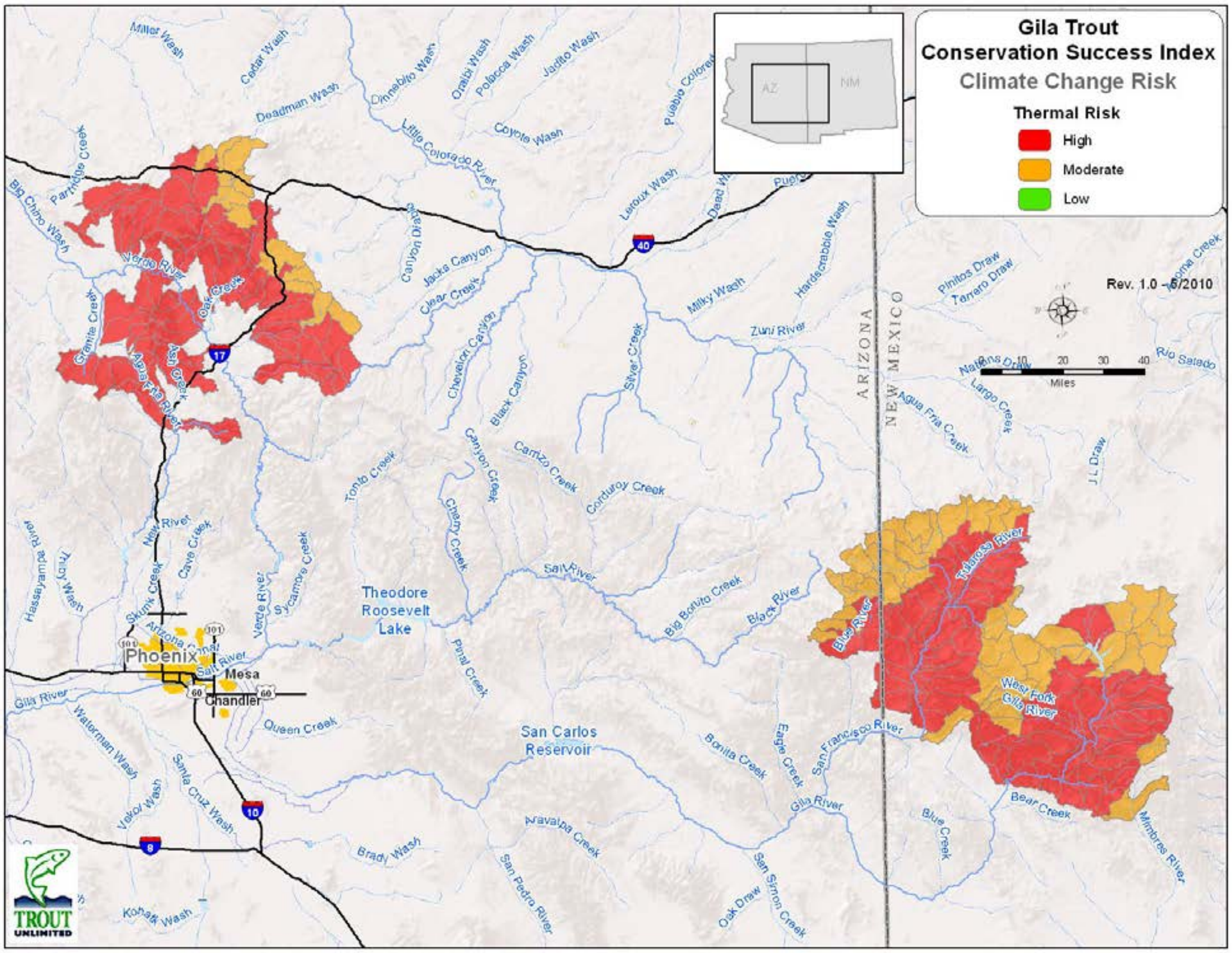


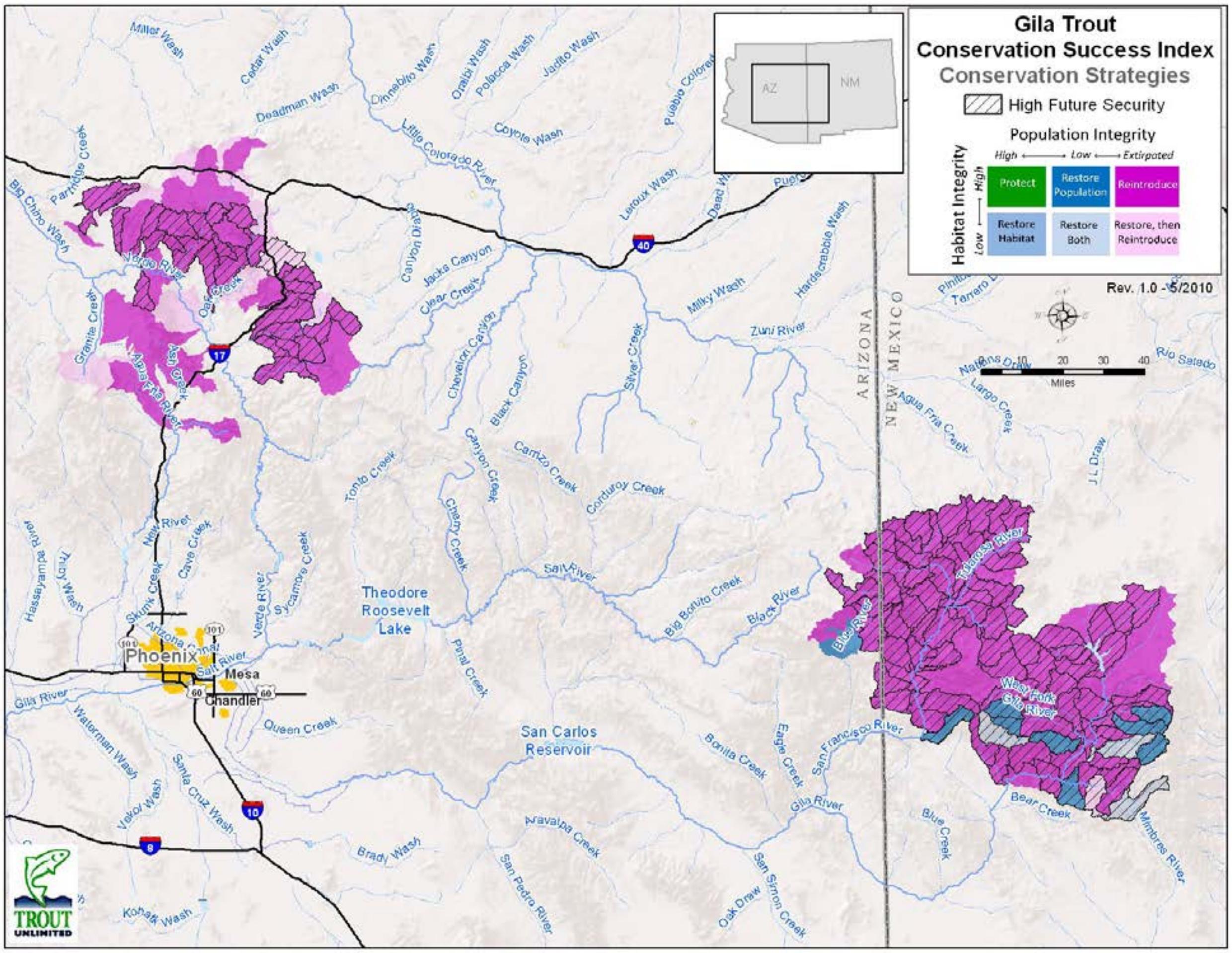
Gila Trout
Conservation Success Index
Climate Change Risk
Drought Risk
High
Moderate
Low
Rev. 1.0 - 5/2010
AZ
NM
ARIZONA
NEW MEXICO
Phoenix
Mesa
Chandler
Theodore Roosevelt Lake
San Carlos Reservoir
Salt River
Gila River
Verde River
West Fork Gila River
San Francisco River
Tularosa River
Blue River
Black River
Little Colorado River
Zuni River
Bear Creek
Mimbres River
Miles
TROUT UNLIMITED

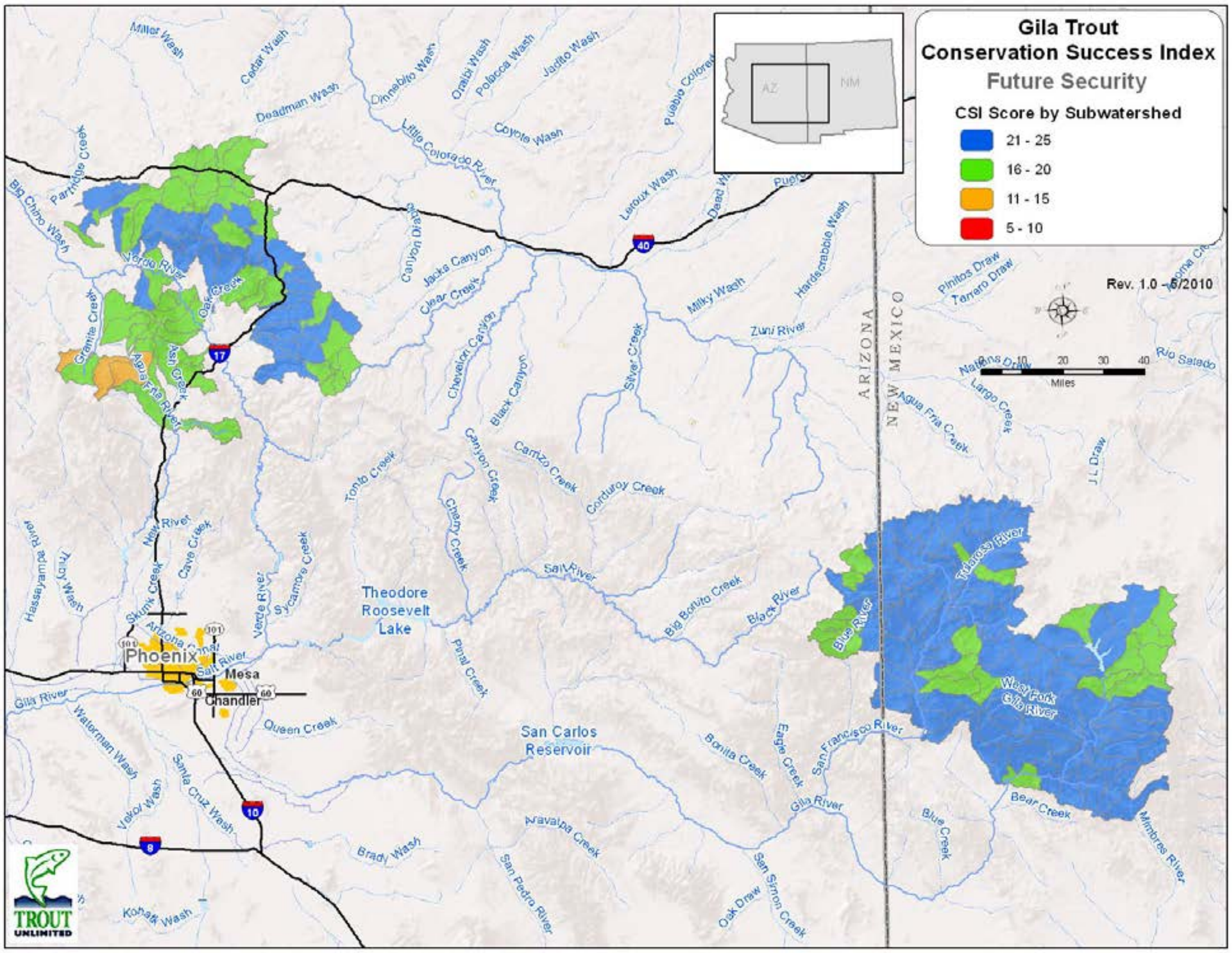


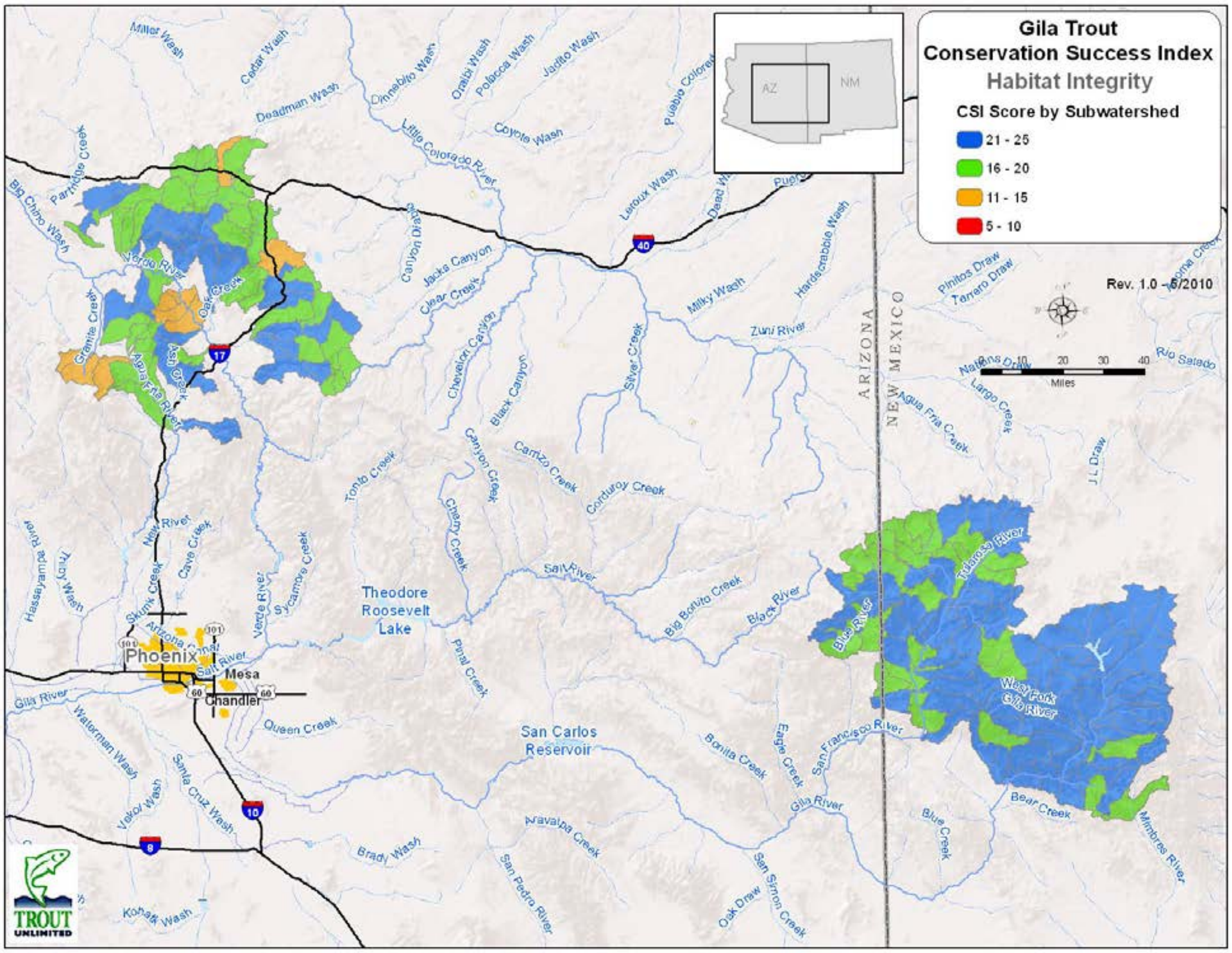
Gila Trout
Conservation Success Index
Climate Change Risk
Increased Wildfire Risk
High
Moderate
Low
Rev. 1.0 - 5/2010
Miles
Theodore Roosevelt Lake
San Carlos Reservoir
Phoenix
Mesa
Chandler
ARIZONA
NEW MEXICO


Gila Trout
Conservation Success Index
Climate Change Risk
Winter Flooding Risk
High
Moderate
Low
AZ
NM
Rev. 1.0 - 5/2010
Miles
ARIZONA
NEW MEXICO
Phoenix
Mesa
Chandler
Theodore Roosevelt Lake
San Carlos Reservoir
Verde River
Salt River
Gila River
Little Colorado River
Zuni River
Black River
Blue River
Tularosa River
West Fork Gila River
San Francisco River
Bear Creek
Mimbres River
San Pedro River
Agua Fria River
Tonto Creek
Cherry Creek
Carrizo Creek
Corduroy Creek
Canyon Creek
Big Bonito Creek
Queen Creek
Santa Cruz Wash
Aravaipa Creek
Brady Wash
San Simon Creek
Bonita Creek
Eagle Creek
Blue Creek
Rio Salado
TROUT UNLIMITED


Gila Trout
Conservation Success Index
Climate Change Risk
Thermal Risk
High
Moderate
Low
Rev. 1.0 - 5/2010
Miles
AZ
NM
ARIZONA
NEW MEXICO
Theodore Roosevelt Lake
San Carlos Reservoir
Phoenix
Mesa
Chandler
Salt River
Gila River
Verde River
Tonto Creek
Cherry Creek
Carrizo Creek
Corduroy Creek
Big Bonito Creek
Black River
Blue River
Tularosa River
West Fork Gila River
San Francisco River
Bonita Creek
Eagle Creek
Bear Creek
Mimbres River
Blue Creek
San Simon Creek
Oak Draw
San Pedro River
Aravaipa Creek
Brady Wash
Queen Creek
Santa Cruz Wash
Waterman Wash
Vekol Wash
Kohatk Wash
Pinal Creek
Sycamore Creek
Cave Creek
New River
Skunk Creek
Arizona Canal
Trilby Wash
Hassayampa River
Granite Creek
Oak Creek
Big Chino Wash
Partridge Creek
Miller Wash
Cedar Wash
Deadman Wash
Dinnebito Wash
Oraibi Wash
Polacca Wash
Jadito Wash
Little Colorado River
Coyote Wash
Leroux Wash
Canyon Diablo
Jacks Canyon
Clear Creek
Chevelon Canyon
Black Canyon
Canyon Creek
Silver Creek
Milky Wash
Zuni River
Hardscrabble Wash
Pinitos Draw
Tenaro Draw
Agua Fria Creek
Largo Creek
J L Draw
Rio Salado
TROUT UNLIMITED


Gila Trout
Conservation Success Index
Conservation Strategies
High Future Security
Population Integrity
High
Low
Extirpated
Habitat Integrity
Protect
Restore Population
Reintroduce
Restore Habitat
Restore Both
Restore, then Reintroduce
Rev. 1.0 - 5/2010
AZ
NM
Miles
ARIZONA
NEW MEXICO
Phoenix
Mesa
Chandler
Theodore Roosevelt Lake
San Carlos Reservoir
Verde River
Salt River
Gila River
Black River
Blue River
West Fork Gila River
San Francisco River
Tularosa River
Zuni River
Little Colorado River
Agua Fria River
Oak Creek
Tonto Creek
Cherry Creek
Canyon Creek
Carrizo Creek
Corduroy Creek
Big Bonito Creek
Bonita Creek
Eagle Creek
Blue Creek
Bear Creek
Mimbres River
San Pedro River
San Simon Creek
Aravaipa Creek
Queen Creek
Pinal Creek
Silver Creek
Chevelon Canyon
Black Canyon
Clear Creek
Jacks Canyon
Milky Wash
Hardscrabble Wash
Leroux Wash
Coyote Wash
Deadman Wash
Cedar Wash
Miller Wash
Partridge Creek
Big Chino Wash
Granite Creek
Ash Creek
Sycamore Creek
Cave Creek
New River
Skunk Creek
Hassayampa River
Trilby Wash
Waterman Wash
Santa Cruz Wash
Vekol Wash
Brady Wash
Kohatk Wash
Oak Draw
Largo Creek
Agua Fria Creek
J L Draw
Rio Salado
Arizona Canal
TROUT UNLIMITED


Gila Trout
Conservation Success Index
Future Security
CSI Score by Subwatershed
21 - 25
16 - 20
11 - 15
5 - 10
Rev. 1.0 - 5/2010
ARIZONA
NEW MEXICO
Phoenix
Mesa
Chandler
Theodore Roosevelt Lake
San Carlos Reservoir
West Fork Gila River
Salt River
Gila River
Verde River
Tularosa River
Blue River
Black River
San Francisco River
Miles


Gila Trout
Conservation Success Index
Habitat Integrity
CSI Score by Subwatershed
21 - 25
16 - 20
11 - 15
5 - 10
Rev. 1.0 - 5/2010
AZ
NM
ARIZONA
NEW MEXICO
Miles
Phoenix
Mesa
Chandler
Theodore Roosevelt Lake
San Carlos Reservoir
Verde River
Salt River
Gila River
West Fork Gila River
Tularosa River
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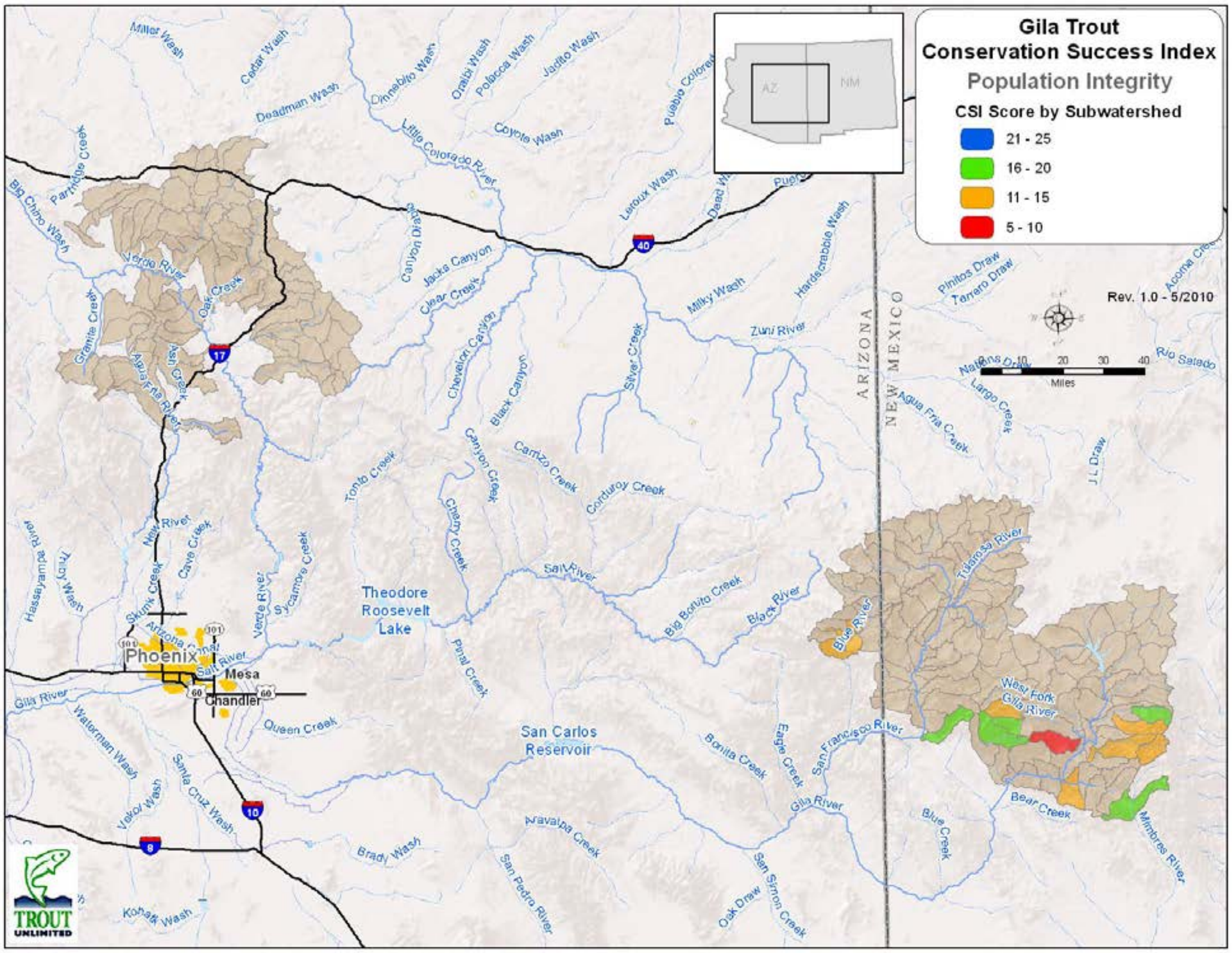
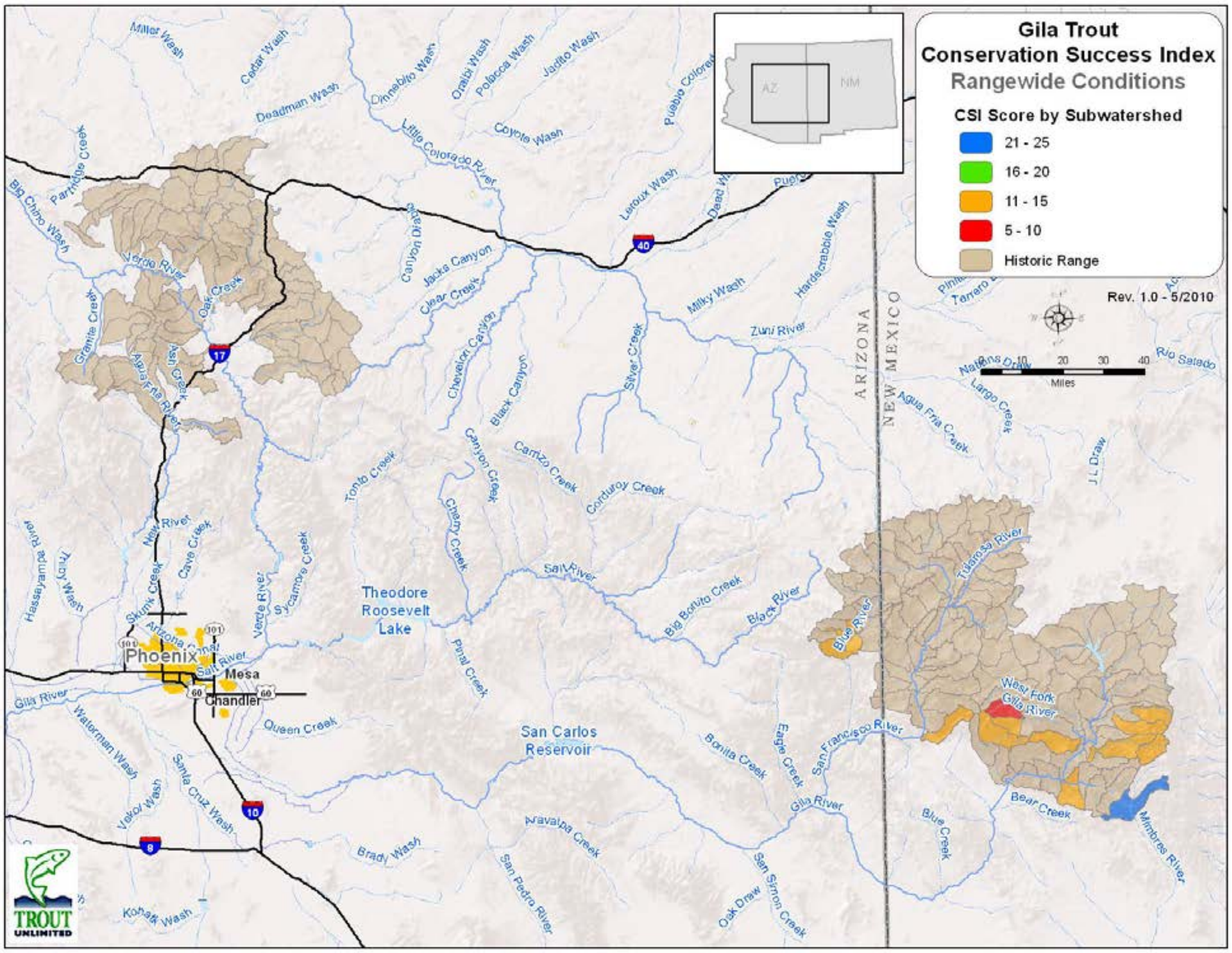
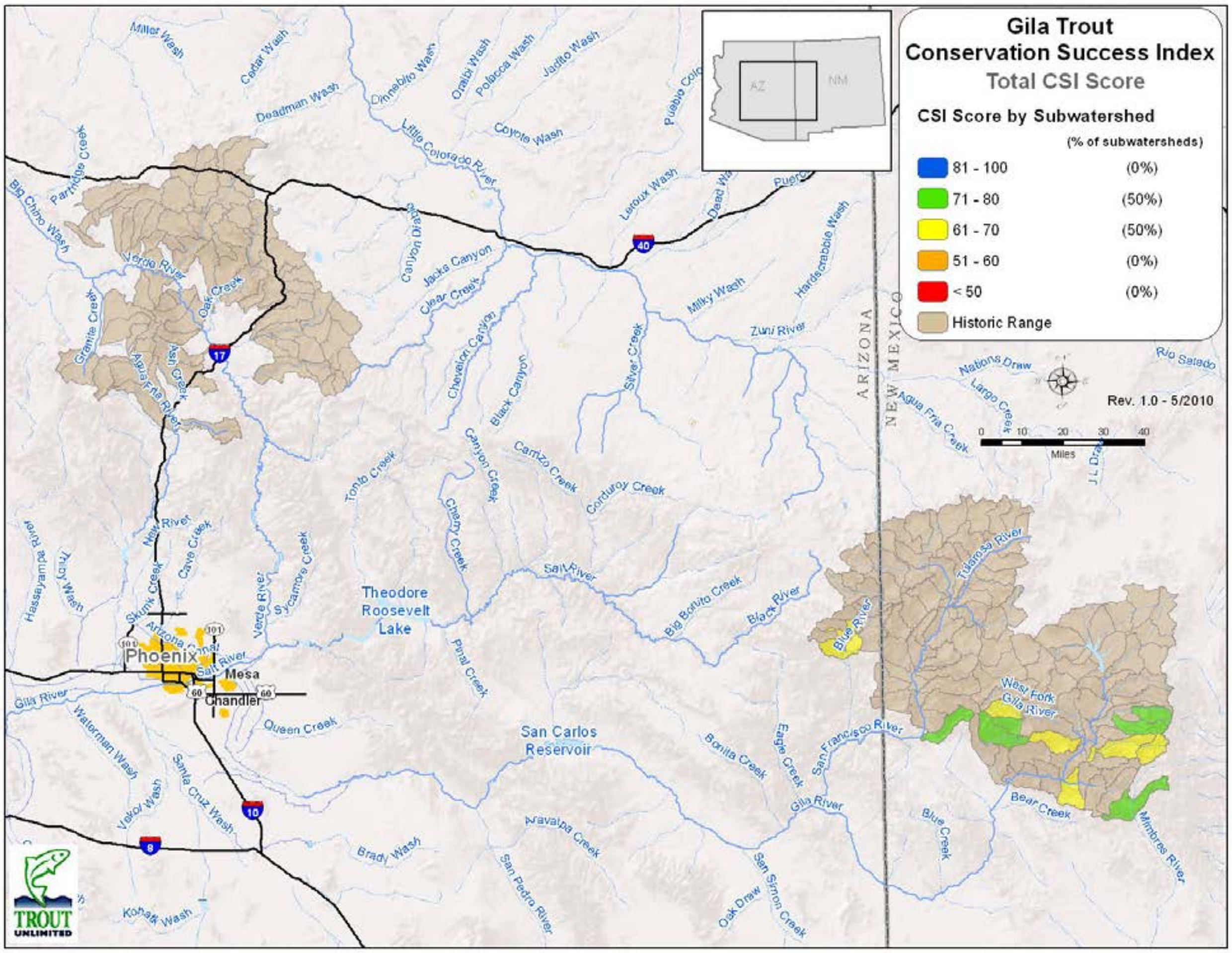
Little Colorado River
Zuni River
Tonto Creek
Oak Creek
Agua Fria River
Cherry Creek
Canyon Creek
Carrizo Creek
Corduroy Creek
Silver Creek
Chevelon Canyon
Big Bonito Creek
Bonita Creek
Eagle Creek
Pinal Creek
Queen Creek
Aravaipa Creek
San Pedro River
San Simon Creek
Bear Creek
Mimbres River
Blue Creek
Rio Salado
TROUT UNLIMITED


Gila Trout
Conservation Success Index
Population Integrity
CSI Score by Subwatershed
21 - 25
16 - 20
11 - 15
5 - 10
Rev. 1.0 - 5/2010
Miles
ARIZONA
NEW MEXICO
Phoenix
Mesa
Chandler
Theodore Roosevelt Lake
San Carlos Reservoir
Salt River
Gila River
Verde River
Tonto Creek
Black River
Blue River
San Francisco River
West Fork Gila River
Bear Creek
Mimbres River
Zuni River
Little Colorado River
Silver Creek
San Pedro River
Aravaipa Creek
Santa Cruz Wash
Queen Creek
Pinal Creek
Cherry Creek
Canyon Creek
Carrizo Creek
Corduroy Creek
Big Bonito Creek
Bonita Creek
Eagle Creek
Blue Creek
San Simon Creek
Tularosa River
Agua Fria River
Hassayampa River
Sycamore Creek
Cave Creek
New River
Oak Creek
Big Chino Wash
Granite Creek
Clear Creek
Chevelon Canyon
Black Canyon
Milky Wash
Hardscrabble Wash
Dead Wash
Deadman Wash
Cedar Wash
Dinnebito Wash
Oraibi Wash
Polacca Wash
Jadito Wash
Coyote Wash
Leroux Wash
Jacks Canyon
Largo Creek
Agua Fria Creek
J L Draw
Pinitos Draw
Tanaro Draw
Rio Salado
Waterman Wash
Vekol Wash
Brady Wash
Kohatk Wash
Oak Draw
Skunk Creek
Arizona Canal
TROUT UNLIMITED



Gila Trout
Conservation Success Index
Rangewide Conditions
CSI Score by Subwatershed
21 - 25
16 - 20
11 - 15
5 - 10
Historic Range
Rev. 1.0 - 5/2010
Miles
ARIZONA
NEW MEXICO
Phoenix
Mesa
Chandler
Theodore Roosevelt Lake
San Carlos Reservoir
Salt River
Gila River
West Fork Gila River
San Francisco River
Black River
Blue River
Verde River
Tularosa River
Bear Creek
Mimbres River
TROUT UNLIMITED


Gila Trout
Conservation Success Index
Total CSI Score
CSI Score by Subwatershed
(% of subwatersheds)
81 - 100 (0%)
71 - 80 (50%)
61 - 70 (50%)
51 - 60 (0%)
< 50 (0%)
Historic Range
Rev. 1.0 - 5/2010
Miles
AZ
NM
ARIZONA
NEW MEXICO
Phoenix
Mesa
Chandler
Theodore Roosevelt Lake
San Carlos Reservoir
Salt River
Gila River
Verde River
Little Colorado River
Zuni River
Black River
Blue River
San Francisco River
West Fork Gila River
Tularosa River
Bear Creek
Mimbres River
San Pedro River
Tonto Creek
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Corduroy Creek
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Silver Creek
Queen Creek
Bonita Creek
Eagle Creek
Aravaipa Creek
San Simon Creek
Blue Creek
Santa Cruz Wash
Agua Fria River
Oak Creek
Sycamore Creek
Pinal Creek
Chevelon Canyon
Black Canyon
Clear Creek
Jacks Canyon
Canyon Creek
Silver Creek
Milky Wash
Hardscrabble Wash
Leroux Wash
Coyote Wash
Deadman Wash
Cedar Wash
Miller Wash
Partridge Creek
Big Chino Wash
Granite Creek
Cave Creek
New River
Skunk Creek
Arizona Canal
Hassayampa River
Trilby Wash
Waterman Wash
Vekol Wash
Brady Wash
Kohatk Wash
Oak Draw
Rio Salado
Agua Fria Creek
Largo Creek
Nations Draw
J L Draw
TROUT UNLIMITED

v. 1.0 May 2010

Conservation Success Index:
Gila Trout:
Subwatershed Scoring and Rule Set

Introduction:

The CSI is an aggregate index comprised of four different component groups: Range-wide Condition; Population Integrity; Habitat Integrity; and Future Security. Each CSI group has five indicators that describe a specific component of each group. Each indicator is scored from 1 to 5 for each subwatershed, with a score of 1 indicating poor condition and a score of 5 indicating good condition. Indicator scores are then added to obtain the subwatershed condition for a Group, and Group scores are added for a CSI score for a subwatershed (Figure 1). CSI scores can then be summarized to obtain the general range of conditions within the historical or current distribution of the species.

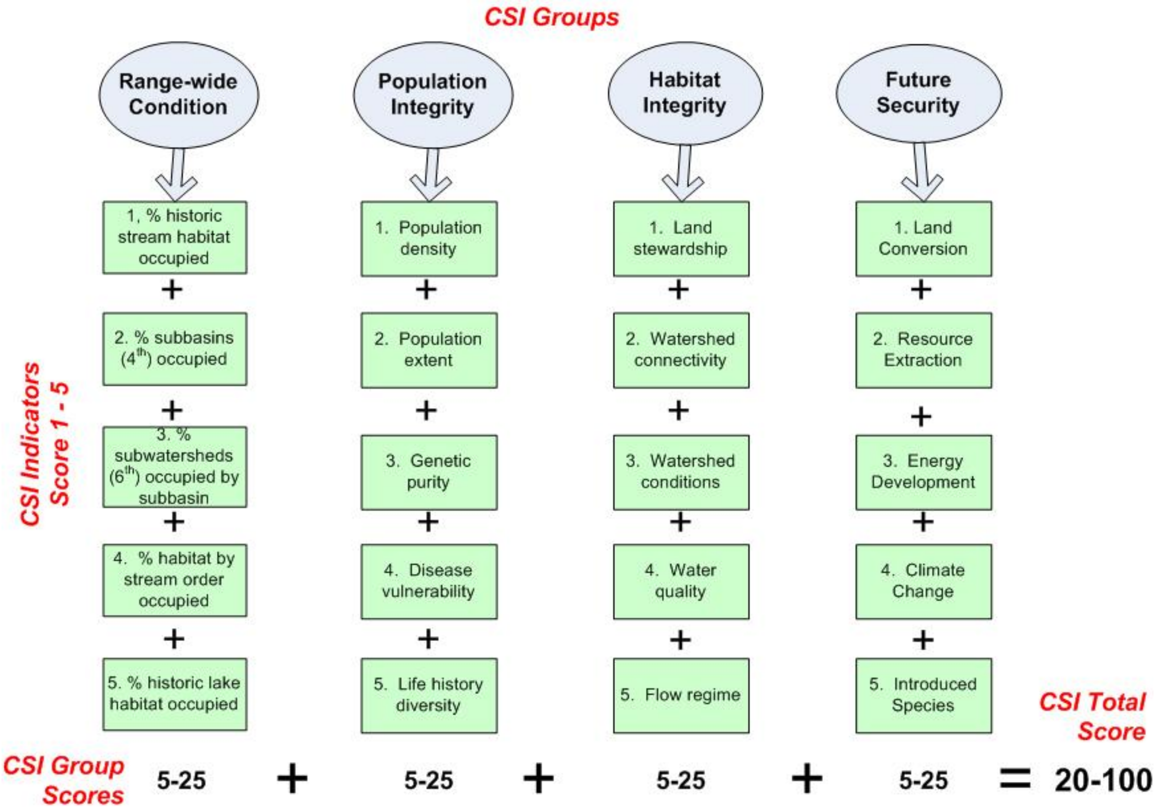


Figure 1. Each subwatershed is scored from 1 to 5 using 20 indicators within four main groups. Indicator scores are added per group to obtain an overall group score. Group scores are then added to obtain a composite CSI score for each subwatershed.

CSI Groups and Indicators

The CSI consists of four main groups of indicators:

1. Range-wide condition
2. Population integrity
3. Habitat integrity
4. Future Security

Below is an overview of each CSI group and the indicators within each group. Each section contains an overview of the group indicators

Range-wide Condition: *Indicators for range-wide condition:*

Overview:

1. Percent of historic stream habitat occupied
2. Percent of subbasins occupied by populations.
3. Percent of subwatersheds (6^{th} level HUC) occupied within subbasin.
4. Percent of habitat by stream order occupied.
5. Percent of historic lake habitat by surface area occupied.

Indicator: 1. Percent historic stream habitat occupied.

Indicator Scoring:

Occupied stream habitat	CSI Score
0 – 9%	1
10 – 19%	2
20 – 34%	3
35 – 49%	4
50 – 100%	5

Explanation: Historic habitat is all perennial streams and connected natural lakes across the historic range of the species. Lakes less than 2 hectares connected to streams are considered stream habitat while lakes greater than 2 hectares or isolated lakes are considered to be lake habitat.

Rationale: Species that occupy a larger proportion of their historic range will have an increased likelihood of persistence.

Data Sources: Current and historic distribution from New Mexico Game & Fish, unpublished data.

Indicator: 2. Percent subbasins occupied.

Indicator Scoring:

Subbasins occupied	CSI Score
1-49%	1
50-69%	2
70-79%	3
80-89%	4
90-100%	5

Explanation: The percentage of subbasins within the historical range of the species that are currently occupied by the species. The same percentage is applied to all subwatersheds scored.

Rationale: Larger river basins often correspond with Distinct Population Segments or Geographic Management Units that may have distinct genetic or evolutionary legacies for the species.[1]

Data Sources Current and historic distribution from New Mexico Game & Fish, unpublished data. Subwatersheds from NRCS National Watershed Boundary data.

Indicator: 3. Percent subwatersheds occupied within subbasin.

Indicator Scoring:

Subwatersheds occupied by subbasin	CSI Score
1 – 20%	1
21-40%	2
41-60%	3
61-80%	4
81-100%	5

Explanation: The percentage of subwatersheds in the historic range of the species that are currently occupied by the species within each subbasin. The percentage is the same for all subwatersheds within a subbasin.

Rationale: Species that occupy a larger proportion of their historic subwatersheds are likely to be more broadly distributed and have an increased likelihood of persistence.

Data Sources: Current and historic distribution from New Mexico Game & Fish, unpublished data. Subwatersheds from NRCS National Watershed Boundary data.

Indicator: 4. Habitat by stream order occupied.

Indicator Scoring:

Occupied 2nd order streams and higher	CSI Score
0 – 9%	1
10 – 14%	2
15 – 19%	3
20 – 24%	4
25 – 100%	5

Explanation: The percentage of currently occupied habitat that is first order streams.

Rationale: Species that occupy a broader range of stream sizes will have an increased likelihood of persistence. This is especially true because small, first order streams tend to have more variable environmental conditions and smaller populations than larger streams.[2]

Data Sources: The current distribution from New Mexico Game & Fish, unpublished data. Stream order was determined using the National Hydrography Dataset Plus[3].

Indicator: 5. Historic lake habitat occupied.

Indicator Scoring:

Occupied lake habitat	CSI Score
0 – 9%	1
10 – 19%	2
20 – 34%	3
35 – 49%	4
50 – 100%	5

Explanation: Historic lake populations only considered natural lakes while current populations have been identified in reservoirs thus leading to an increase in lake habitat for some subwatersheds.

Rationale: Lakes often harbor unique life histories and large populations that are important to long-term persistence of the species.[4]

Data Sources: Current and historic distribution from New Mexico Game & Fish, unpublished data.

Population Integrity: *Indicators for the integrity of populations.*

Overview:

1. Population density
2. Population extent
3. Genetic purity
4. Disease vulnerability
5. Life history diversity

Indicator: 1. Population density.

Indicator Scoring:

Fish / mile	Total Population	CSI Score
1 - 50	≤500	1
1 - 50	≥500	2
51 - 150	≥1	3
151 - 400	≥1	4
>400	≥1	5

Explanation: Population density within each subwatershed. When multiple populations were present within a subwatershed, population density was calculated as a weighted average with the length of each stream occupied by a population as the weight.

Rationale: Small populations, particularly those below an effective size of 500 individuals, are more vulnerable to extirpation.[5;6]

Data Sources: Population density from Brown et al., 2001[53]. Subwatersheds from NRCS National Watershed Boundary data. Scoring rules were based, in part, on May and Albeke[6] and Williams et al.[1].

Indicator: 2. Population extent.

Indicator Scoring:

Connectivity	CSI Score
< 6.2 mi (10 km) connected habitat	1
6.2 – 12.4 mi (10-20 km) connected habitat	2
12.4 – 18.6 mi (20-30 km) connected habitat	3
18.6 – 31.3 mi (30-50 km) connected habitat	4
> 31.3 mi (50 km) connected habitat	5

Explanation: Population extent is the amount of connected habitat available to the population.

Rationale: Populations with less available habitat are more vulnerable to extirpation[7] as a result of small, localized disturbances.

Data Sources: Score based on extent of connected habitat for the contiguous populations using populations identified for population density (see above) and the barriers from New Mexico Game & Fish, unpublished data. Scoring rules were based, in part, on May and Albeke[6] and Williams et al.[1].

Indicator: 3. Genetic purity.

Indicator Scoring:

Genetic purity (introgression)	CSI Score
< 80%	1
80 – 89%	2
	3
90 – 99%	4
100%	5

Explanation: Genetic purity represents the genetic purity of the population.

Rationale: Hybridization and loss of the native genome via introgression with non-native salmonids are among the leading factors in the decline of native salmonids.[8] Introgression with other subspecies can also cause a loss of genetic variation.

Data Sources: Genetic information from New Mexico Game & Fish, unpublished data.

Indicator: 4. Disease vulnerability.

Indicator Scoring:

Disease Vulnerability	CSI Score
Disease/pathogens present in target species	1
Disease/pathogens in habitat but not target fish	2
None present but proximity <10 km	3
None present but proximity >10 km	4
No diseases/pathogens present	5

Explanation: The risk of each population to disease.

Rationale: Non-native pathogens and parasites, including the myxozoan parasite that causes whirling disease, can infect native trout and reduce their populations.

Data Sources: *Information regarding disease vulnerability was unavailable.*

Indicator: 5. Life history diversity.

Indicator Scoring:

Life History Diversity	CSI Score
One life history form present: resident only	1
One historical life history was lost	3
All historical life history forms present	5

Explanation: The number of life histories present in the population: resident, fluvial, adfluvial.

Rationale: Loss of life history forms, particularly migratory forms, increases the risk of extirpation and may reduce genetic diversity.[7;9;10]

Data Sources: Life history information from New Mexico Game & Fish, unpublished data.

***Habitat Integrity**: Indicators for the integrity of aquatic habitats.*

Overview:

1. Land stewardship
2. Watershed connectivity
3. Watershed conditions
4. Water quality
5. Flow regime

Indicator: 1. Land stewardship.

Indicator Scoring:

Protected occupied habitat*	Subwatershed protection	CSI Score
none	any	1
1 – 9%	<25%	1
1 – 9%	≥25%	2
10 – 19%	<25%	2
10 – 19%	≥25%	3
20 – 29%	<50%	4
20 – 29%	≥50%	5
≥30%	any	5

*If subwatershed only contains currently unoccupied habitat then scores are based only on subwatershed protection: <25% =1; 25 – 50%=3; >50%=5.

Explanation: The percent of occupied stream habitat AND percent subwatershed that is protected lands. Protected lands are federal or state lands with regulatory or congressionally-established protections, such as: federal or state parks and monuments, national wildlife refuges, wild and scenic river designations, designated wilderness areas, inventoried roadless areas on federal lands, Research Natural Areas, Areas of Critical Environmental Concern, others areas of special protective designations, or private ownership designated for conservation purposes.

Rationale: Stream habitat and subwatersheds with higher proportions of protected lands typically support higher quality habitat than do other lands.

Data Sources: Protected areas data were compiled from the ESRI, Tele Atlas North American / Geographic Data Technology dataset on protected areas[11] and the U.S. Department of Agriculture, Forest Service's National Inventoried Roadless Areas dataset.[12]

Indicator: 2. Watershed connectivity.

Indicator Scoring:

Number of stream/canal intersections	Current/historic connectivity 6th	CSI Score
GE 12	LT 50%	1
8 – 11	50 – 74%	2
5 – 7	75 – 89%	3
1 – 4	90 – 94%	4
0	95 – 100%	5

Current/historic connectivity 4th:

- >90%: +1
- <50%: -1

Score for worst case

Explanation: The number of stream-canal intersections and reduction in historical connectivity in the subwatershed and subbasin. Connectivity is measured by determining the longest continuous section of stream habitat uninterrupted by man-made structures impassable by fish in the subwatershed and dividing that by the longest continuous section of historically connected stream habitat. Connectivity is also computed for the subbasin. Man-made barriers may include dams, water diversion structures, or human-caused dewatered stream segments that impede fish movement.

Rationale: Increased hydrologic connectivity provides more habitat area and better supports multiple life histories, which increases the likelihood of persistence.[7] Diversions, when they do not directly inhibit fish passage, can represent false movement corridors, cause fish entrainment, and act as population sinks.[13;14]

Data Sources: Stream network from National Hydrography Dataset Plus[3] and barrier sources developed by New Mexico Game & Fish.

Indicator: 3. Watershed condition.

Indicator Scoring:

Riparian Buffer (300 ft.) Vegetation	Land conversion	CSI Score
0%	≥30%	1
	20 – 29%	2
	10 – 19%	3
	5 – 9%	4
	0 - 4%	5

*Score for worst case

CSI score is downgraded 1 point if road density is ≥1.7 and <4.7 mi/square mile.
If road density is ≥4.7 mi/square mile it is downgraded 2 points.

CSI Score downgraded 1 point if riparian vegetation in 300 ft. buffer is 0.1 to 10%

Explanation: The percentage of converted lands in the subwatershed, road density, and percent riparian vegetation along the stream within a 300 ft. buffer.

Rationale: Habitat conditions are the primary determinant of persistence for most populations.[15] Converted lands are known to degrade aquatic habitats.[16;17] Road density is computed for the subwatershed; roads are known to cause sediment-related impacts to stream habitat.[18-20] Lee et al.[19] recognized 6 road density classifications as they related to aquatic habitat integrity and noted densities of 1.7 and 4.7 mi/mi^2 as important thresholds. Percent riparian vegetation is a remotely sensed measure of riparian conditions[21] that is often related to aquatic habitat conditions[22], and 300 ft. is a useful buffer width in which to measure riparian vegetation[22] and the National Hydrography Dataset Plus.[3]

Data Sources: Converted lands were determined using the National Land Cover Database[23], with all Developed, Pasture/Hay, and Cultivated Crops land cover types considered to be converted lands. Road density was determined using ESRI, Tele Atlas North American / Geographic Data Technology dataset on roads.[52] Riparian vegetation was determined using the National Land Cover Database[23], using Woody Wetlands, Emergent Herbaceous Wetlands, Deciduous Forest, Evergreen Forest, and Mixed Forest land cover classes.

Indicator: 4. Water quality.

Indicator Scoring:

Miles 303(d) Streams	Agricultural Land	Number Active Mines	Road mi/ Stream mi	Number OG Wells	CSI Score
>0	58-100%	≥10	0.5 – 1.0	≥ 400	1
	28-57%	7-9	0.25 – 0.49	300 - 399	2
	16-27%	4-6	0.24 - 0.10	200 - 299	3
	6-15%	1-3	0.05 – 0.09	50 - 199	4
	0-5%	0	0 – 0.04	0 - 49	5

Score for worst case.

Explanation: The presence of 303(d) impaired streams, percentage agricultural land, number of active mines and oil and gas wells, and miles of road within 150 ft of perennial streams in the subwatershed.

Rationale: Decreases in water quality, including reduced dissolved oxygen, increased turbidity, increased temperature, and the presence of pollutants, reduces habitat suitability for salmonids. Agricultural land can impact aquatic habitats by contributing nutrients and fine sediments, and deplete dissolved oxygen. Mining activity can deteriorate water quality through leachates and sediments. Oil and gas development is associated with road building, water withdrawls, and saline water discharge.[24;25] Roads along streams can also contribute large amounts of fine sediments that smother benthic invertebrates, embed spawning substrates, and increase turbidity.[26;27]

Data Sources: 303(d) impaired streams was determined using US EPA data[27]. The National Land Cover Database[23] was used to identify agricultural lands; Hay/Pasture and Cultivated Crops were defined as agricultural land. Active mines were identified by using the Mineral Resources Data System[28]. Road density within a 150 ft buffer was computed using ESRI, Tele Atlas North American / Geographic Data Technology dataset on roads.[52] and the National Hydrography Dataset Plus[3].

Indicator: 5. Flow regime.

Indicator Scoring:

Number of dams	Storage (acre-ft)/stream mile	CSI Score
≥5	≥2,500	1
3 – 4	1,000 – 2,499	2
2	250 – 999	3
1	1- 249	4
0	0	5

Score for worst case.

Explanation: Number of dams and acre-feet of reservoir storage per perennial stream mile.

Rationale: Natural flow regimes are critical to proper aquatic ecosystem function[29]. Dams, reservoirs, and canals alter flow regimes[30]. Reduced or altered flows reduce the capability of watersheds to support native biodiversity and salmonid populations.

Data Sources: The National Inventory of Dams[31] was the data source for dams and their storage capacity. Data on canals were obtained from the National Hydrography Dataset Plus[3].

Future Security *Indicators for the future security of populations and aquatic habitats.*

Overview:

1. Land conversion
2. Resource extraction
3. Energy development
4. Climate change
5. Introduced species

Indicator: 1. Land conversion.

Indicator Scoring:

Land Vulnerable to Conversion	CSI Score
81 – 100%	1
61 – 80%	2
41 - 60%	3
21 - 40%	4
0 – 20%	5

Explanation: The potential for future land conversion is modeled as a function of slope, land ownership, roads, and urban areas. Land is considered vulnerable to conversion if the slope is less than 15%, it is in private ownership and not already converted, it is within 0.5 miles of a road, and within 5 miles of an urban center. Lands encumbered by a conservation easement are not available for conversion.

Rationale: Conversion of land from its natural condition will reduce aquatic habitat quality and availability[32].

Data Sources: Slope was computed from elevation data from the National Hydrography Dataset Plus[3]. Land cover was determined from the National Land Cover Database[23], and all land cover classes except developed areas, hay/pasture, and cultivated crops cover types were considered for potential conversion. Urban areas were determined using 2000 TIGER Census data[33], roads from ESRI, Tele Atlas North American / Geographic Data Technology dataset on roads[52] , and land ownership using USGS data on Land Ownership in Western North America[34].

Indicator: 2. Resource extraction.

Indicator Scoring:

Forest management	Hard Metal Mine Claims	CSI Score
51-100%	51 -100%	1
26 – 50%	26-50%	2
11 – 25%	11-25%	3
1 – 10%	1 – 10%	4
0%	0%	5

Score for worst case.

Explanation: Percentage of subwatershed available for industrial timber production (productive forest types only, minimum stand size of 40 acres) and the percent of subwatershed with hard metal mining claims (assuming an average of 20 acres per claim) outside of protected areas. Protected lands were removed from availability and include: federal or state parks and monuments, national wildlife refuges, wild and scenic river designations, designated wilderness areas, inventoried roadless areas on federal lands, Research Natural Areas, Areas of Critical Environmental Concern, others areas of special protective designations, or private ownership designated for conservation purposes.

Rationale: Productive forest types have a higher likelihood of being managed for timber production than unproductive types, and, hence, future logging poses a future risk to aquatic habitats and fishes[18]. Areas with hard metal claims pose a future risk to mining impacts than areas without claims. Claims indicate areas with potential for hard mineral mining, and mining can impact aquatic habitats and fishes [35].

Data Sources: Timber management potential identifies productive forest types using the existing vegetation type in the Landfire dataset.[36] The number of mining claims was determined using Bureau of Land Management data[37], and each claim was assumed to potentially impact 20 acres. Protected areas data were compiled from the ESRI, Tele Atlas North American / Geographic Data Technology dataset on protected areas[11] and the U.S. Department of Agriculture, Forest Service's National Inventoried Roadless Areas dataset[12].

Indicator: 3. Energy Development.

Indicator Scoring:

Leases or reserves	New Dams 4th	New Dams 6th	CSI Score
51-100%	≥0	≥1	1
26 – 50%	3		2

11 – 25%	2		3
1 – 10%	1		4
0%	0		5

Score for worst case

Explanation: The acreage of oil, gas, and coal reserves; geothermal or wind development areas; and the number of dam sites located for potential development outside of protected areas within each subbasin and subwatershed.

Rationale: Increased resource development will increase road densities, modify natural hydrology, and increase the likelihood of pollution to aquatic systems. Changes in natural flow regimes associated with dams are likely to reduce habitat suitability for native salmonids and increase the likelihood of invasion by non-native species.[38] If lands are protected then the watersheds will be less likely to be developed.

Data Sources: Wind resources ("Good" and better) from Wind Powering America/National Renewable Energy Lab (NREL).[39] Coal leases are mineable types from the Coal Fields of the United States dataset.[40] Geothermal known and closed lease areas and oil and gas leases and agreements from BLM Geocommunicator. [*][41] Potential dam sites are based on Idaho National Laboratory (INL) hydropower potential data[42]. Protected areas data were compiled from the ESRI, Tele Atlas North American / Geographic Data Technology dataset on protected areas[11] and the U.S. Department of Agriculture, Forest Service's National Inventoried Roadless Areas dataset[12].

Indicator: 4. Climate change.

Indicator Scoring:

TU Climate Change Analysis	
Climate Risk Factors	**CSI Score**

[*] Several geospatial data types are available from Geocommunicator, and they have the following definitions:

Lease: Parcel leased for oil and gas production.

Agreement: An 'agreement' between operator and host (private or public) to evaluate geological, logistic, geophysical, etc issues involving a concession. The agreement essentially allows a technical evaluation of lease feasibility.

Unit Agreements: Multiple entities go in collectively on an agreement. Implied: there are limits to the number of agreements that one individual entity can have outstanding, and a unit agreement allows them to get around the limit.

Communitization: Combining smaller federal tracts to meet the necessary minimum acreage required by the BLM (for spacing purposes).

Authorized: Bid on and sold lease or authorization, ready for production.

Lease Sale Parcel: Parcel slated for auction but not yet sold.

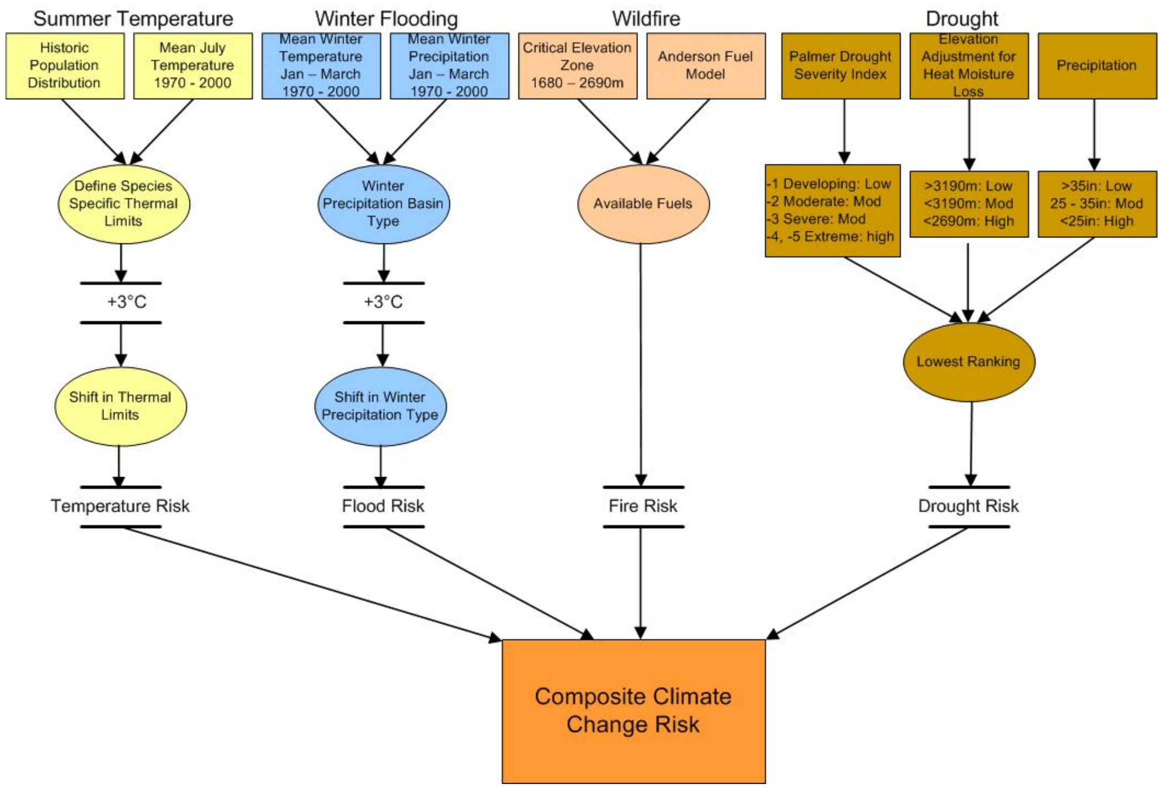
Closed: Not retired, just expired and may become available and open to resubmittal.

Other Agreements: Catch-all for other agreement types.

High, High, Any., Any	1
High, Any, Any, Any	2
Mod., Mod., Mod, (Mod or Low)	3
Mod, Mod, Low, Low	4
Low, Low, Low, (Mod or Low)	5

Explanation: Climate change is based on TU Climate Change analysis, which focuses on 4 identified risk factors related to climate change:

a. Increased Summer Temperature: loss of lower-elevation (higher-stream order) habitat impacts temperature sensitive species
b. Uncharacteristic Winter Flooding: rain-on-snow events lead to more and larger floods
c. Uncharacteristic Wildfire: earlier spring snowmelt coupled with warmer temperatures results in drier fuels and longer burning, more intense wildfire
d. Drought: moisture loss under climate warming will overwhelm any gains in precipitation and lead to higher drought risk



Each of the four factors is ranked as low, moderate, or high. Increased summer temperature due to climate change was modeled as a 3°C increase. Uncharacteristic winter flooding can result from basins transitioning from snow dominated to rain-on-snow dominated with increased winter flooding. Uncharacteristic wildfires result from changes in climate and fire fuels. Drought risk is based on the Palmer Drought Severity Index, but was adjusted for elevation and precipitation.

Rationale: Climate change is likely to threaten most salmonid populations because of warmer water temperatures, changes in peak flows, and increased frequency and intensity of disturbances such as floods and wildfires.[43;44] A 3°C increase in summer temperature has the potential to impact coldwater species occupying habitat at the edge of their thermal tolerance. Increased winter flooding can cause local populations to be extirpated. Wildfire can change aquatic habitats, flow regimes, temperatures, and wood inputs that are important to salmonids.[45] Drought is expected to reduce water availability[46;47] and the availability of aquatic habitat. These risks are further discussed by Williams et al.[43]

Data Sources: Temperature and precipitation data were obtained from the PRISM Group.[48] Elevation data was obtained from the National Elevation Dataset,[49] and LANDFIRE data for the Anderson Fire Behavior Fuel Model 13[36] was used as input for wildfire risk. The Palmer Drought Severity Index was used for drought risk[50], but was adjusted for elevation (elevations above 2690 have lower risk[47]) and the deviation from mean annual precipitation (areas with more precipitation on average have lower risk).

Indicator: 5. Introduced species.

Indicator Scoring:

Present in subbasin	Present in subwatershed	Road Density	CSI Score
Yes	Yes	Any	1
Yes	No	> 4.7	2
Yes	No	1.7 – 4.7	3
Yes	No	<1.7	4
No	No	Any	5

Explanation: The presence of introduced, injurious species in any stream reach connected to the subbasin and subwatershed (see Watershed Connectivity region group); also road density. Road density is the length of road per subwatershed, and represents the potential for future introduction of species not native to the basin.

Rationale: Introduced species are likely to reduce native salmonid populations through predation, competition, hybridization, and the introduction of non-native parasites and pathogens.[8] In the absence of data on presence of non-native species, road density can be used as a surrogate for risk of non-native fish introductions by purpotrators.[51]

Data Sources: Roads were obtained from ESRI, Tele Atlas North American / Geographic Data Technology dataset on roads.[52]

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