Conservation Success Index: Apache Trout

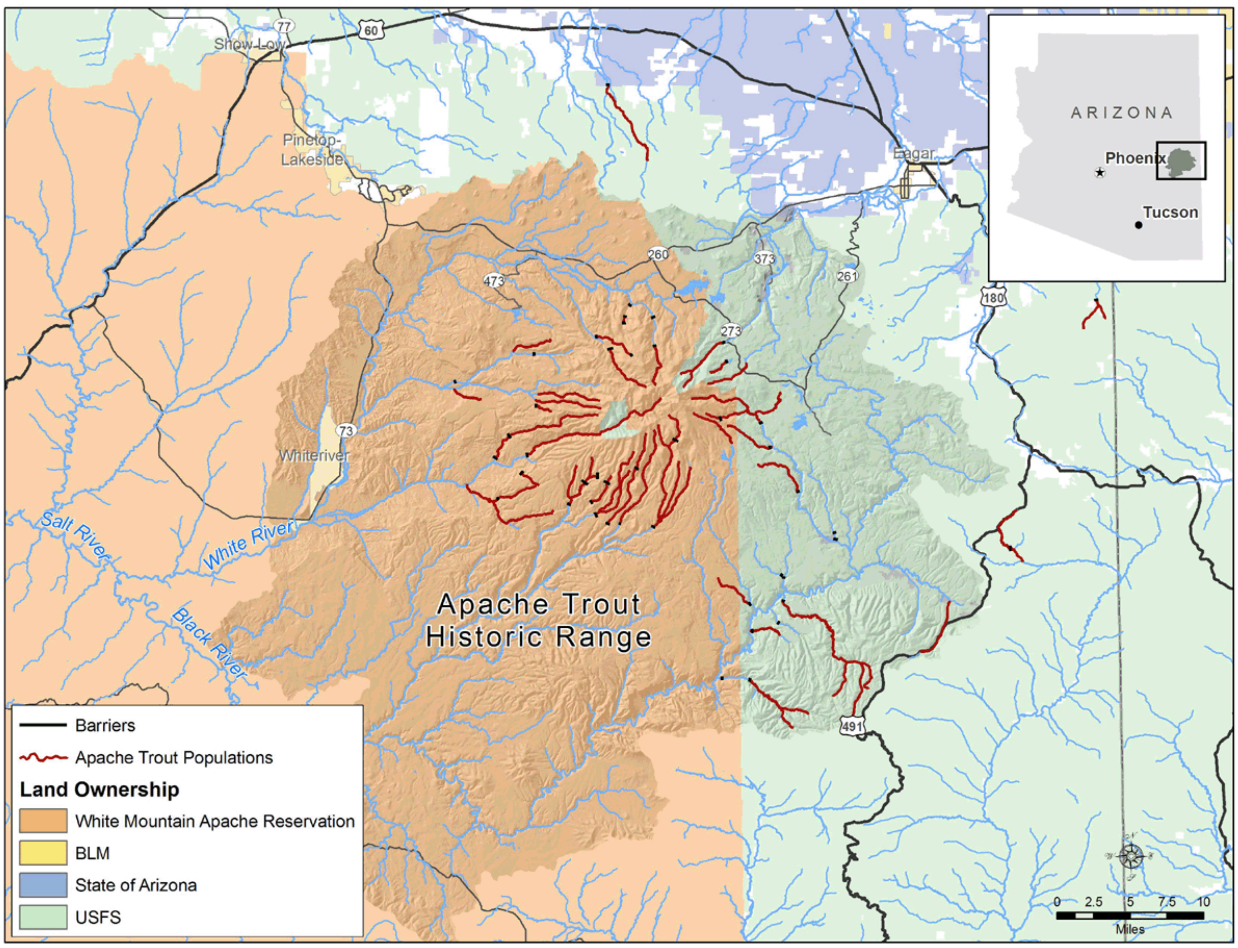
ONCORHYNCHUS APACHE

Rev. 2.0 - 9/2009

SPECIES SUMMARY

Apache trout are native to streams above 6,000 feet (1,800 m) elevation in the Black, White, and Little Colorado river drainages in east-central Arizona. One or two headwater streams in the nearby San Francisco River drainage also may be within the historic range of this species. All populations are clustered around 11,420 feet (3,480 m) Mt. Baldy, the highest peak in the White Mountains.

Current Populations and Historic Range Map



The Apache trout was described as a separate species by Robert Miller of the University of Michigan in 1972, when it was considered to be distinct from its closest taxonomic neighbor, the Gila trout.

Although Gila and Apache trout, along with Mexican golden trout, are closely related, they represent a long-isolated lineage of western North American trouts, that, according to Robert Behnke, share more similarities with rainbow than with cutthroat trout. Despite long isolation, Apache trout are quite similar to rainbow, brown, and brook trout in terms of thermal tolerance and habitat preferences.

By the time the Apache trout was described in 1972, it had already undergone extensive declines from its historic status. The species was included under provisions of the Endangered Species Preservation Act of 1966 and was listed as "endangered" when the modern Endangered Species Act (ESA) was passed in 1973. The Apache trout was then reclassified from "endangered" to "threatened" in 1975, which allowed limited sport fishing for the species. Apache trout continue to be listed as threatened although some parties have expressed interest in removing the species from ESA protection.

Our CSI analysis utilized data from various versions of the Apache Trout Draft Recovery Plan, updated information provided in 2008 by staff from the Arizona Game & Fish Department, U.S.D.A. Forest Service, and U.S. Fish and Wildlife Service. We are grateful for their contributions to our understanding of this species. A complete list of data sources is provided separately.

Key CSI Findings

- 35 populations of Apache trout remain.
- Most remaining populations occupy small, fragmented stream segments and contain relatively small numbers of fish (< 500).
- 7 of 35 populations meet persistence criteria for long-term survival.
- No large, interconnected metapopulations currently exist.
- Small populations are highly vulnerable to climate change, and to a lesser extent, non-native species invasions.
- Habitat integrity indicators typically scored high and generally reflect low road densities and intact flow regimes in most subwatersheds.


Apache trout taken from North Fork of the White River. Photo by Fred Fillmore.

In general, CSI analysis shows 35 populations currently existing within 20 subwatersheds. Most but not all populations are genetically pure. Nearly all remaining populations are clustered in small, higher elevation streams. Only 20 of 65 subwatersheds (31%) within the historic range are currently occupied. Many stream segments immediately downstream of Apache trout are occupied by exotic brown trout, which prey upon native trout.

The small isolated populations that characterize the current status of Apache trout tend to score relatively well in the CSI Genetic Purity and Disease Vulnerability indicators because most populations are isolated above small instream barriers and therefore are clearly separated from downstream non-native fishes. These same populations, however, score low on Population Extent and Life History Diversity because of the small, fragmented nature of their habitat. Seven of 35 existing populations meet persistence criteria, which includes sufficient habitat and population size to support an effective population of 500 fish. No habitats or populations are large enough to support a migratory life history except for a few small reservoirs where fish may ascend streams tributary to the lake for spawning. CSI indicator scoring is summarized in Table 1.

Habitat conditions for Apache trout typically scored higher than for most other native trouts in the West. Habitats are managed by the U.S. Forest Service (Apache-Sitgreaves National Forest) or White Mountain Apache Tribe. Almost no private land exists within the historic range. Riparian and stream degradation from livestock grazing are problems in certain subwatersheds, but road densities are low, flow regimes largely are undisturbed, and overall watershed conditions and water quality are quite good within most of the historic range.

Despite these relatively positive findings about habitat quality across the species' historic range, reports about the lack of monitoring and enforcement of livestock grazing programs continues to be a cause for concern. Further fine-scale investigation of grazing management and localized habitat conditions are warranted.

Historically, Apache trout occurred in well-connected stream systems that included small headwater streams but also larger mainstem rivers. The interconnected nature of such populations provided natural resilience to disturbances such as flood, drought, or wildfire. If a headwater stream was degraded by such a disturbance, the fish could move downstream and then recolonize the upstream habitat once it recovered. But under existing conditions, Apache trout are unable to escape such threats because movement is blocked by dams and other instream barriers.

Trout Unlimited is encouraging efforts by the Arizona Game and Fish Department, U.S. Forest Service, White Mountain Apache Tribe, and U.S. Fish and Wildlife Service to reestablish larger, interconnected metapopulations for Apache trout. A larger reconnected population is currently proposed for the West Fork of the Black River on national forest land. Additional metapopulations are desired on tribal and national forest lands. Reestablishing these larger metapopulations would involve removal of existing instream barriers, creation of a new barrier downstream, and likely non-native fish control efforts. However, once established, these larger populations would be much more resistent to disturbances, including brown trout invasion, and would have a better chance of surviving impacts resulting from climate change.

Rapid climate change poses a substantial risk for Apache trout. Small populations are inherently vulnerable to global warming and climate change, especially through greater intensity and duration of drought and wildfire. Severe drought conditions are likely to become commonplace in this portion of Arizona by midcentury. As noted by NOAA meterologist Martin Hoerling and Jon Eischeid, "by about 2050, average moisture balance conditions will mimic conditions experienced only rarely at the height of the most severe historical droughts." Already, the drought of 2002-2003 significantly reduced existing populations in many streams.

Expanding populations by increasing available downstream habitat is important in most drainages. Larger streams not only support more fish but also larger fish, which have higher reproductive capacity and improve the population's ability to survive and to resist brown trout invasions. However, barriers also play a vital role deflecting non-native fish invasions but need increased monitoring and maintenance to ensure their long-term effectiveness. Thus, fishery managers face tradeoffs in their use and maintenance of artificial barriers.

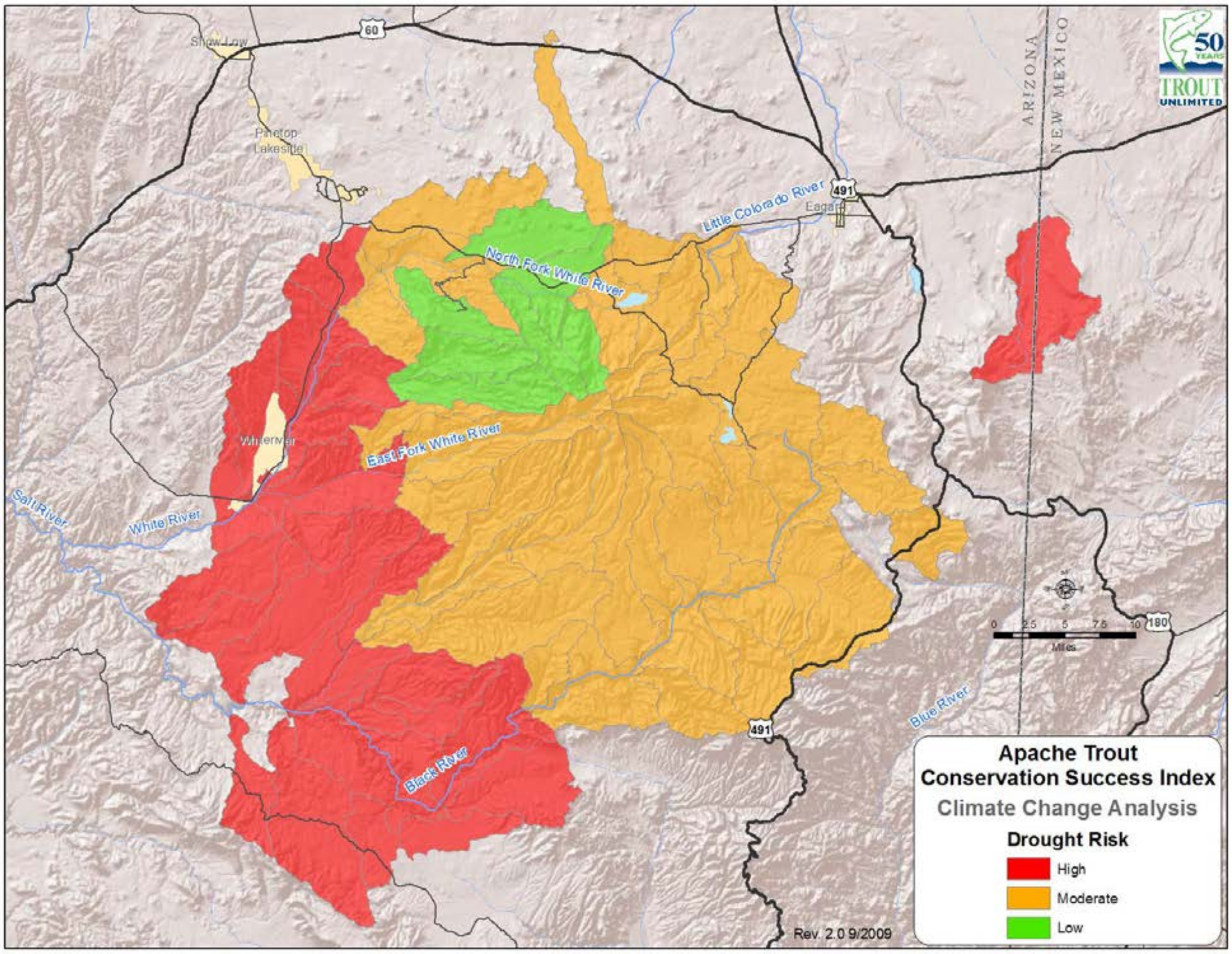
Apache trout remain threatened with extinction and should retain their status as a threatened species pursuant to the Endangered Species Act. The primary concern is increased vulnerability of remaining small, fragmented populations, particularly to drought and wildfire.

Prepared by Jack E. Williams, TU, 12/1/2008

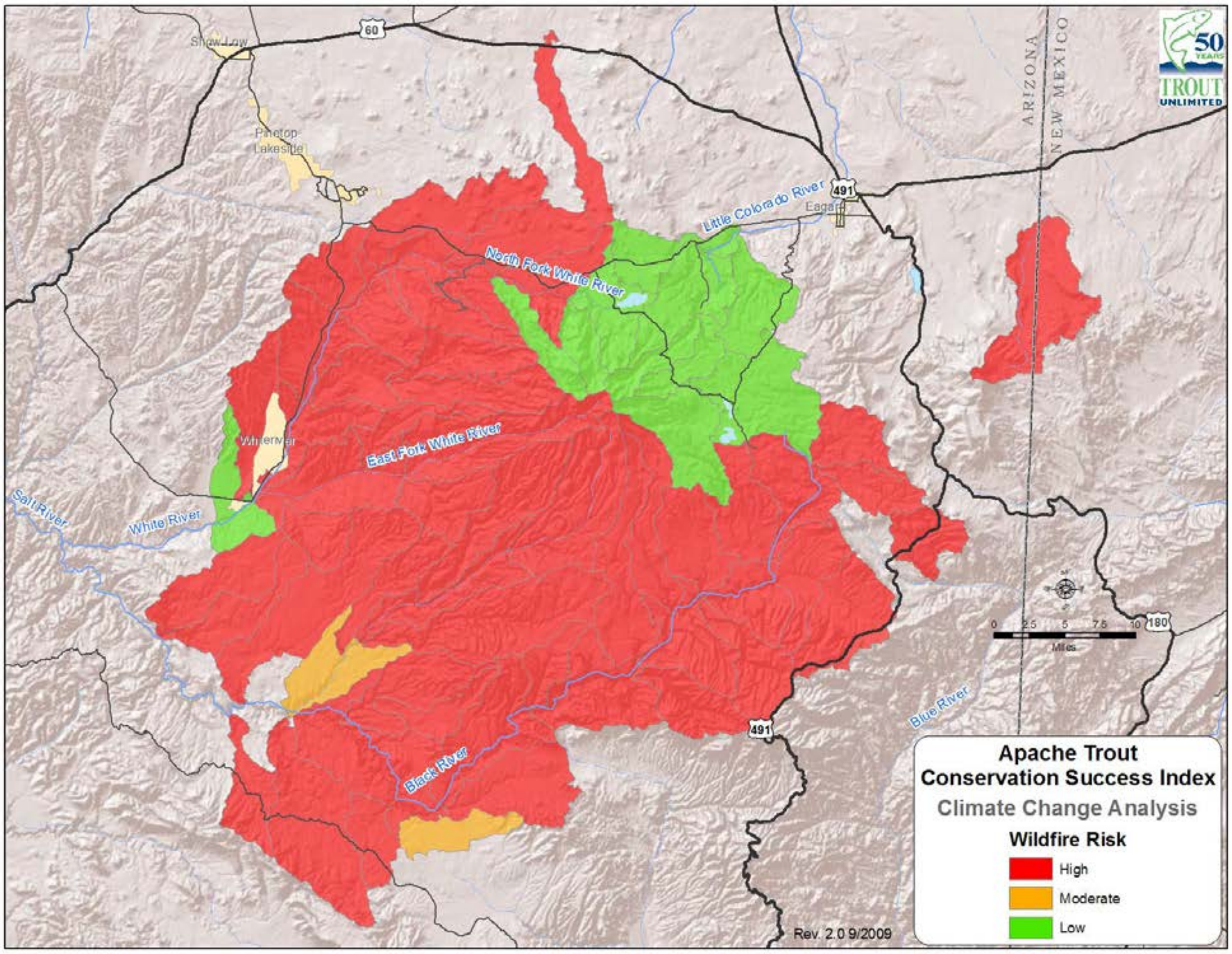
Table 1. CSI scoring result summary for currently occupied and historic habitat for Apache trout. Rangewide Conditions and Population Integrity indicators were scored only for currently occupied habitat (20 subwatersheds), while Habitat Integrity and Future Security indicators were scored for all 65 subwatersheds within historic range. All indicators are scored from 1 (poorest) to 5 (best): see detailed methods for rule sets for scoring this species.

		Number of Subwatersheds Receiving Scores					Total Subwatersheds Scored
	CSI Indicator	**1**	**2**	**3**	**4**	**5**	
Range-wide Conditions	Percent historic stream habitat occupied	0	3	1	5	11	20
	Percent subbasins (4th) occupied	0	0	0	0	20	20
	Percent subwatersheds (6th) occupied	0	15	0	3	2	20
	Percent habitat by stream order occupied	6	0	2	2	10	20
	Percent historic lake area occupied	0	0	0	0	20	20
Population Integrity	Population Density	7	2	5	5	0	19
	Population Extent	17	3	0	0	0	20
	Genetic Purity	2	1	2	0	15	20
	Disease vulnerability	3	1	3	1	12	20
	Life history diversity	17	2	1	0	0	20
Habitat Integrity	Land Stewardship	58	1	0	0	6	65
	Watershed connectivity	7	12	4	5	37	65
	Watershed conditions	0	0	0	21	44	65
	Water quality	3	4	16	13	29	65
	Flow regime	2	3	8	13	39	65
Future Security	Land conversion	1	2	18	20	24	65
	Resource extraction	0	0	2	9	54	65
	Energy development	1	0	1	8	55	65

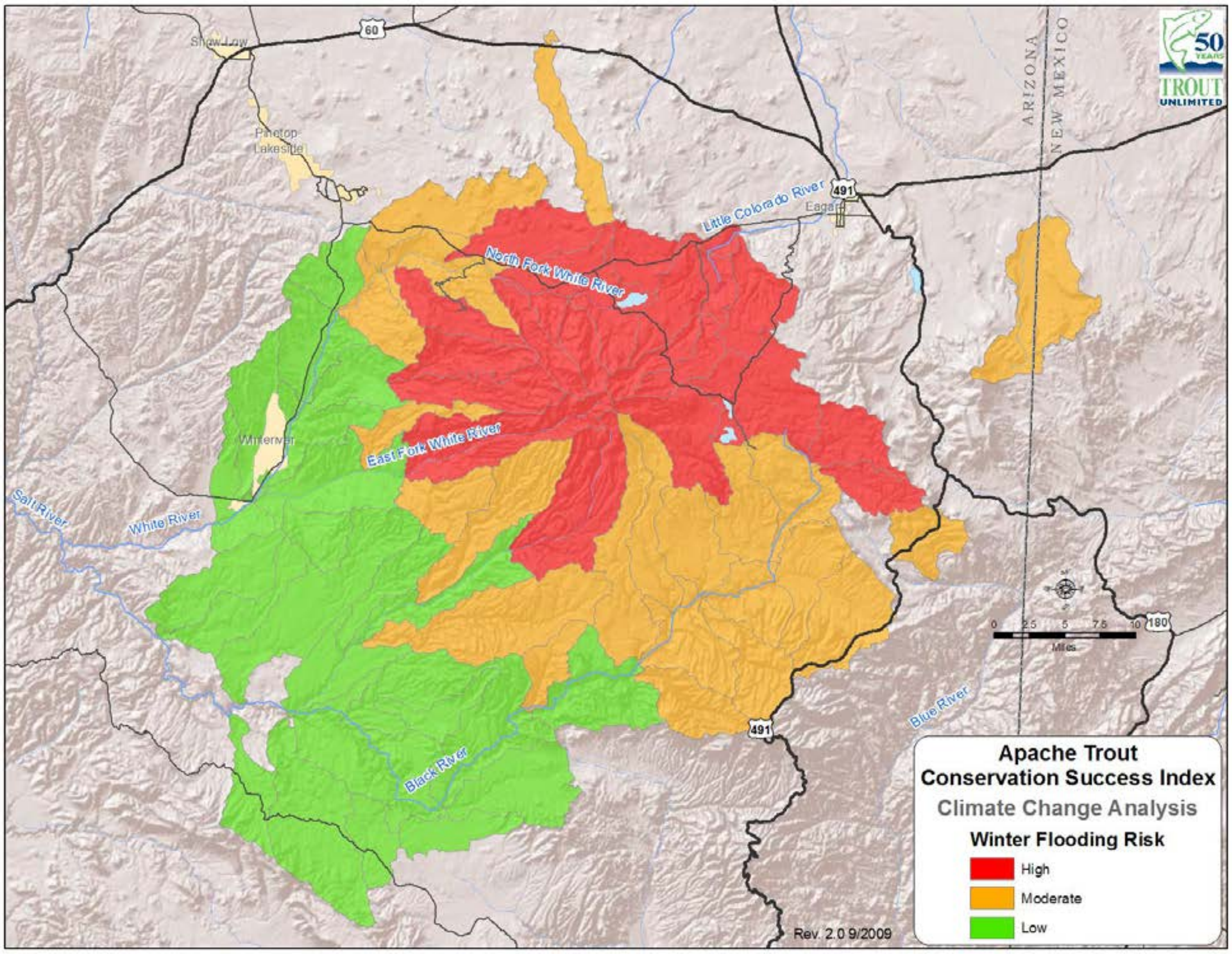
Climate change	36	29	0	0	0	65
Introduced species	0	0	4	17	44	65

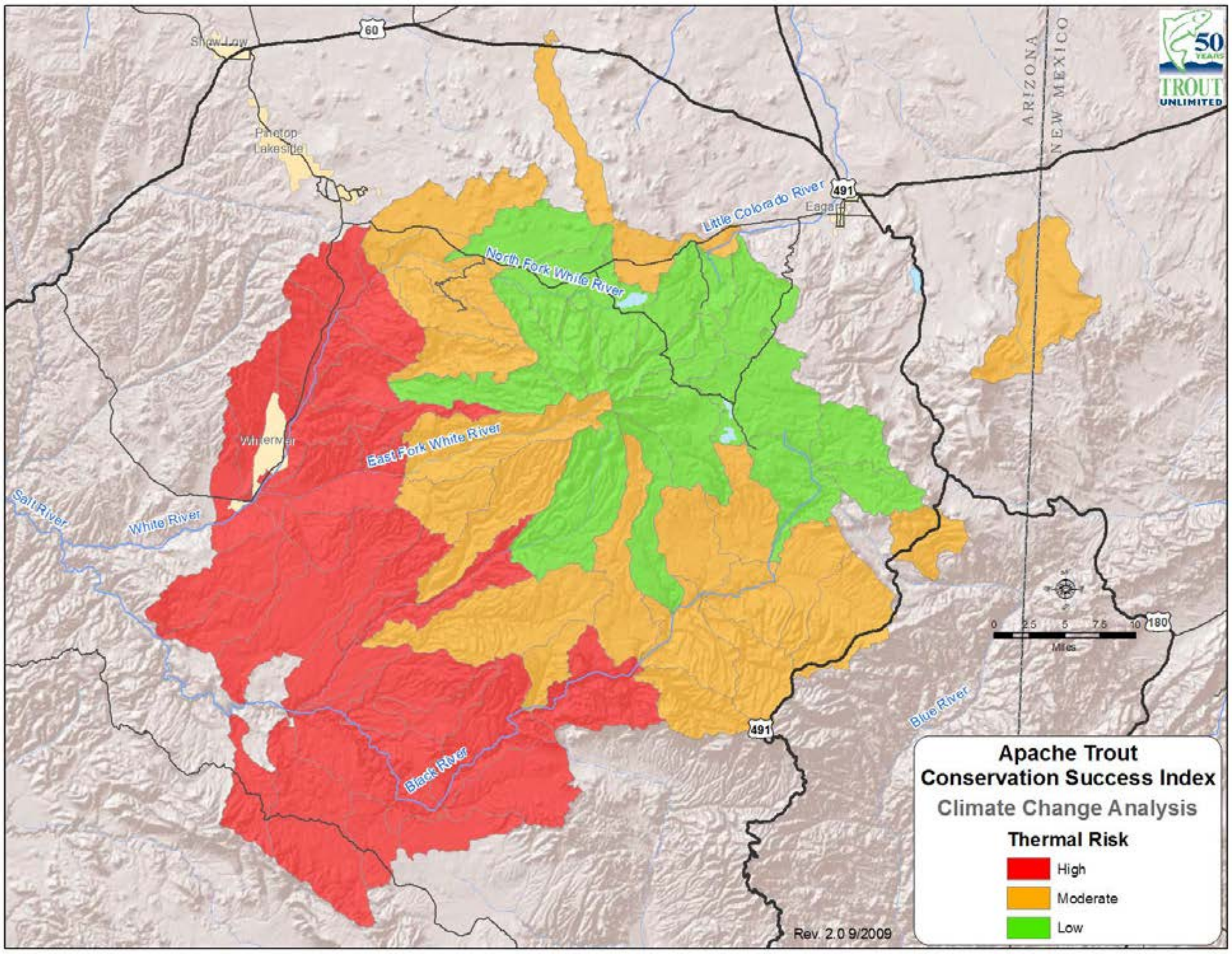


Apache Trout
Conservation Success Index
Climate Change Analysis
Drought Risk
High
Moderate
Low
Rev. 2.0 9/2009
North Fork White River
East Fork White River
White River
Salt River
Black River
Little Colorado River
Blue River
Show Low
Pinetop-Lakeside
Whiteriver
Eagar
ARIZONA
NEW MEXICO
60
491
180
Miles



Apache Trout
Conservation Success Index
Climate Change Analysis
Wildfire Risk
High
Moderate
Low
Show Low
Pinetop-Lakeside
Whiteriver
Eagar
Little Colorado River
North Fork White River
East Fork White River
White River
Salt River
Black River
Blue River
ARIZONA
NEW MEXICO
60
491
180
Miles
Rev. 2.0 9/2009


Apache Trout
Conservation Success Index
Climate Change Analysis
Winter Flooding Risk
High
Moderate
Low
Rev. 2.0 9/2009
North Fork White River
East Fork White River
Little Colorado River
White River
Salt River
Black River
Blue River
Show Low
Pinetop Lakeside
Whiteriver
Eagar
ARIZONA
NEW MEXICO
60
491
180
Miles
TROUT UNLIMITED


Apache Trout
Conservation Success Index
Climate Change Analysis
Thermal Risk
High
Moderate
Low
Show Low
Pinetop-Lakeside
Whiteriver
Eagar
Little Colorado River
North Fork White River
East Fork White River
White River
Salt River
Black River
Blue River
ARIZONA
NEW MEXICO
60
491
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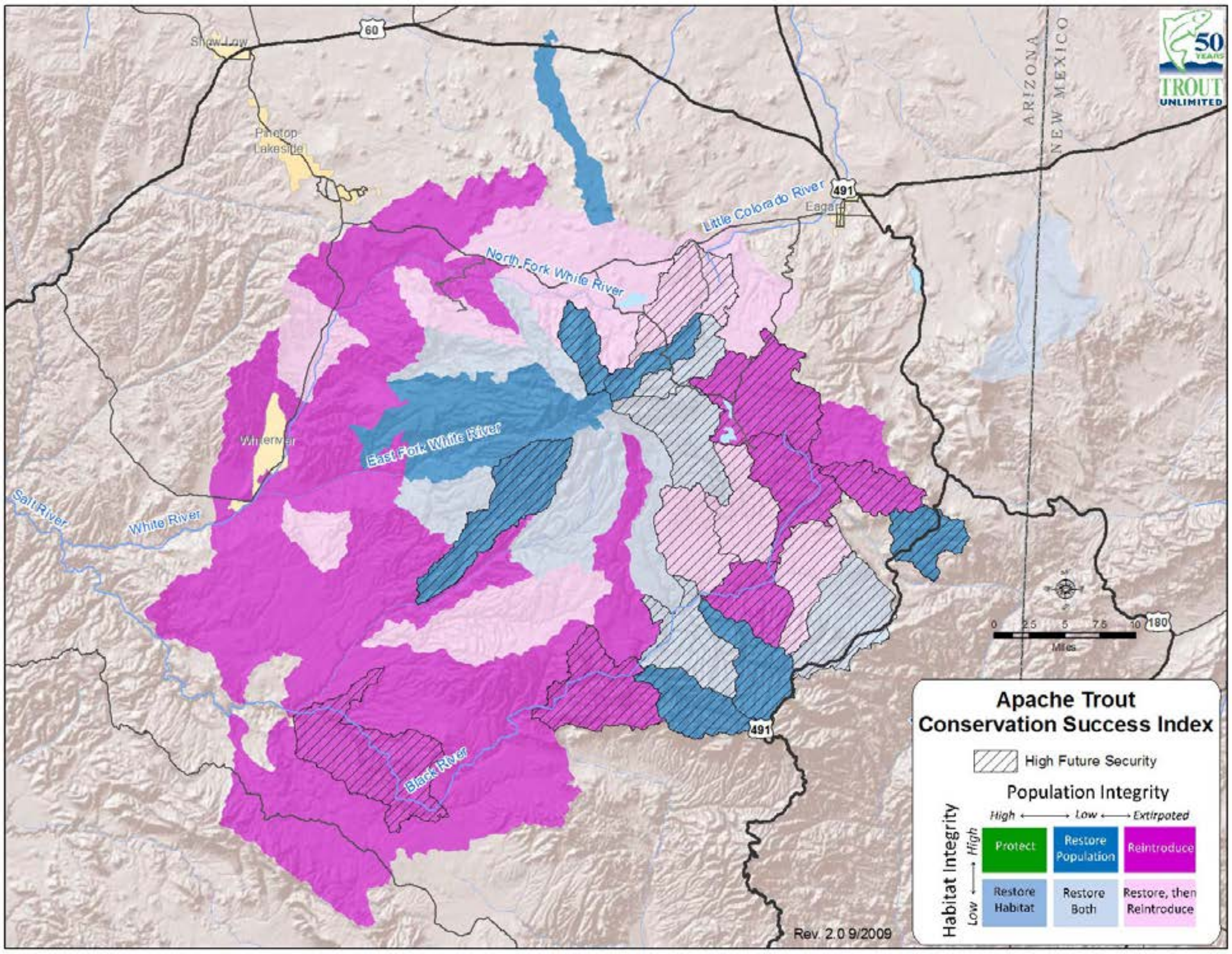
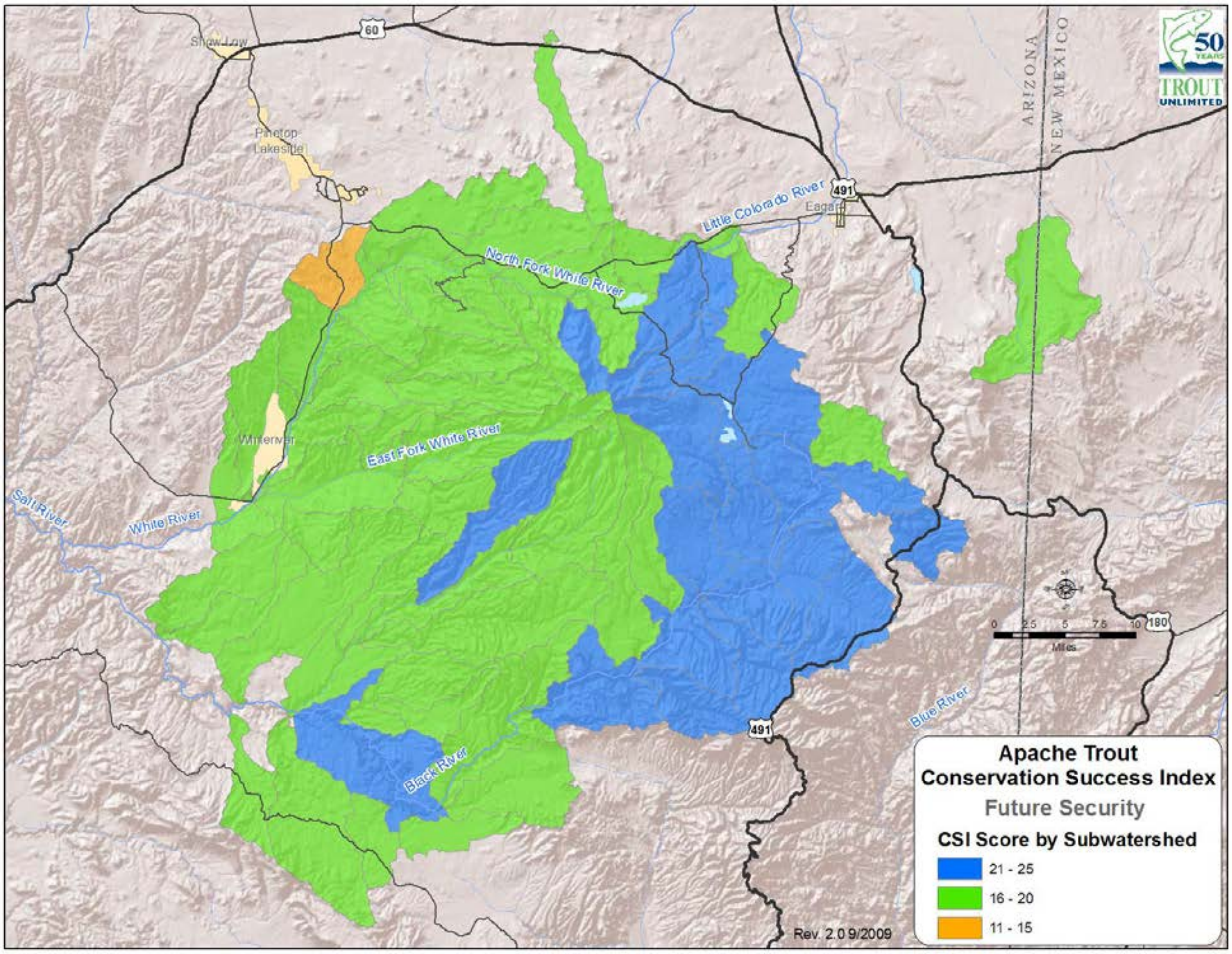
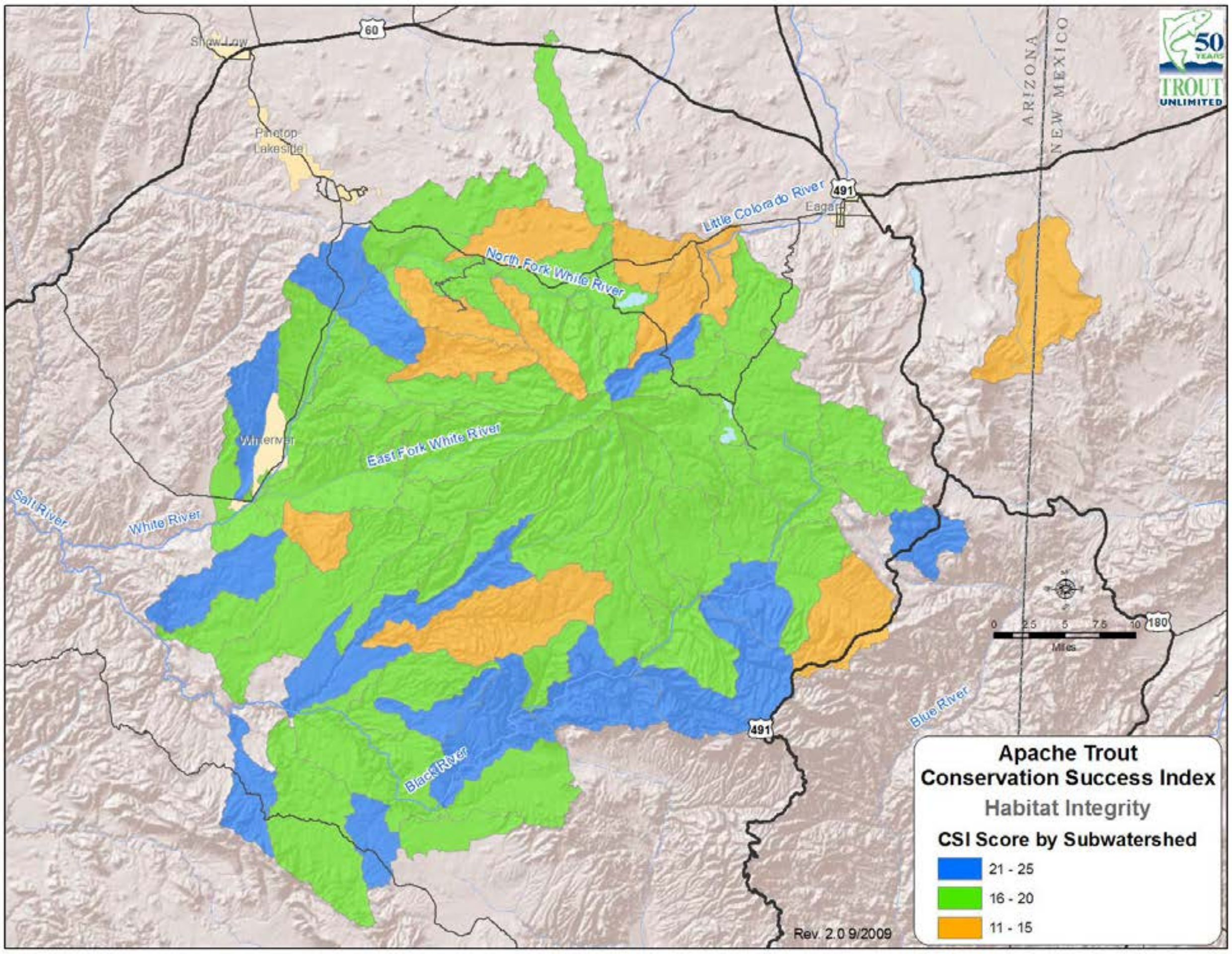
Miles
Rev. 2.0 9/2009

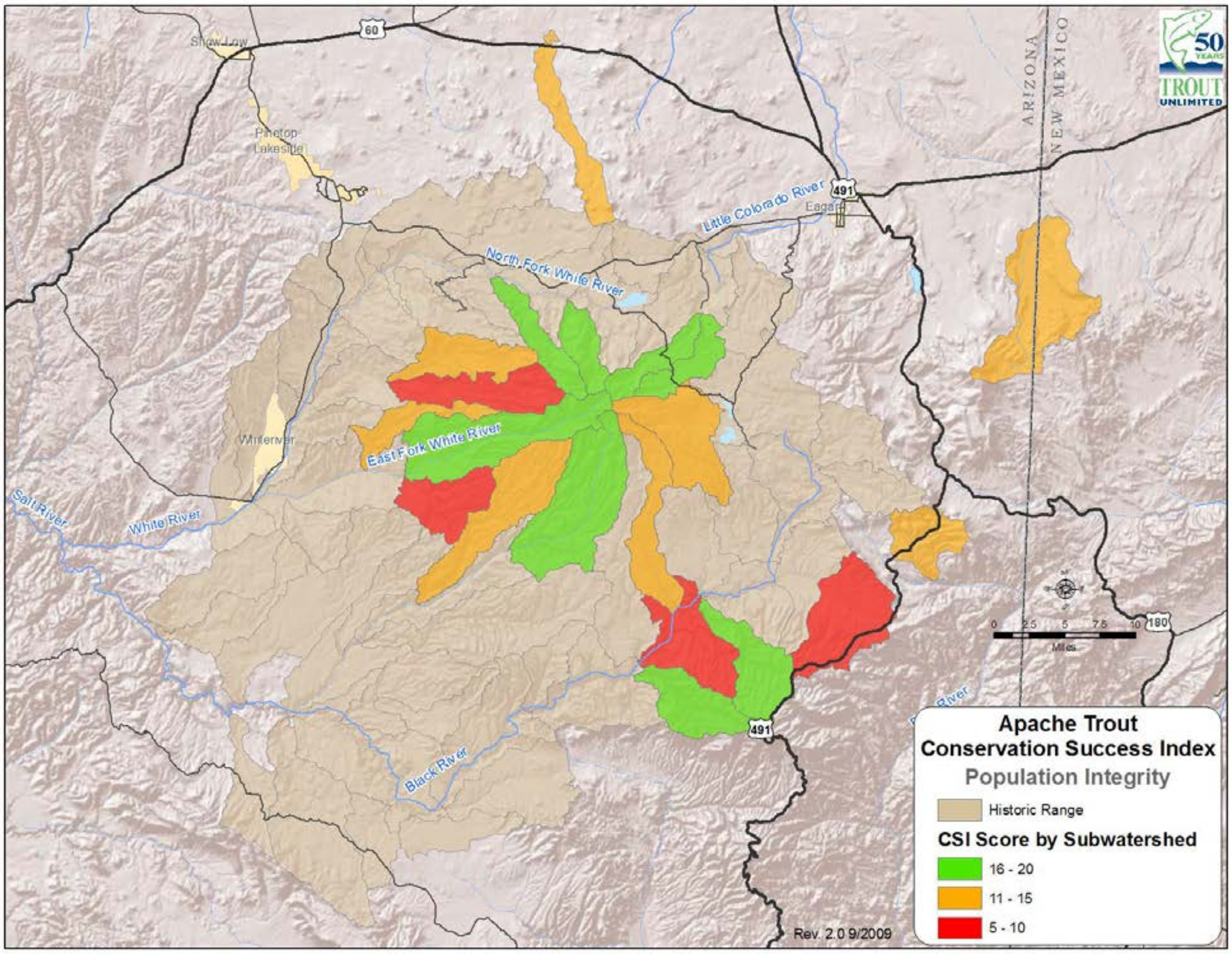


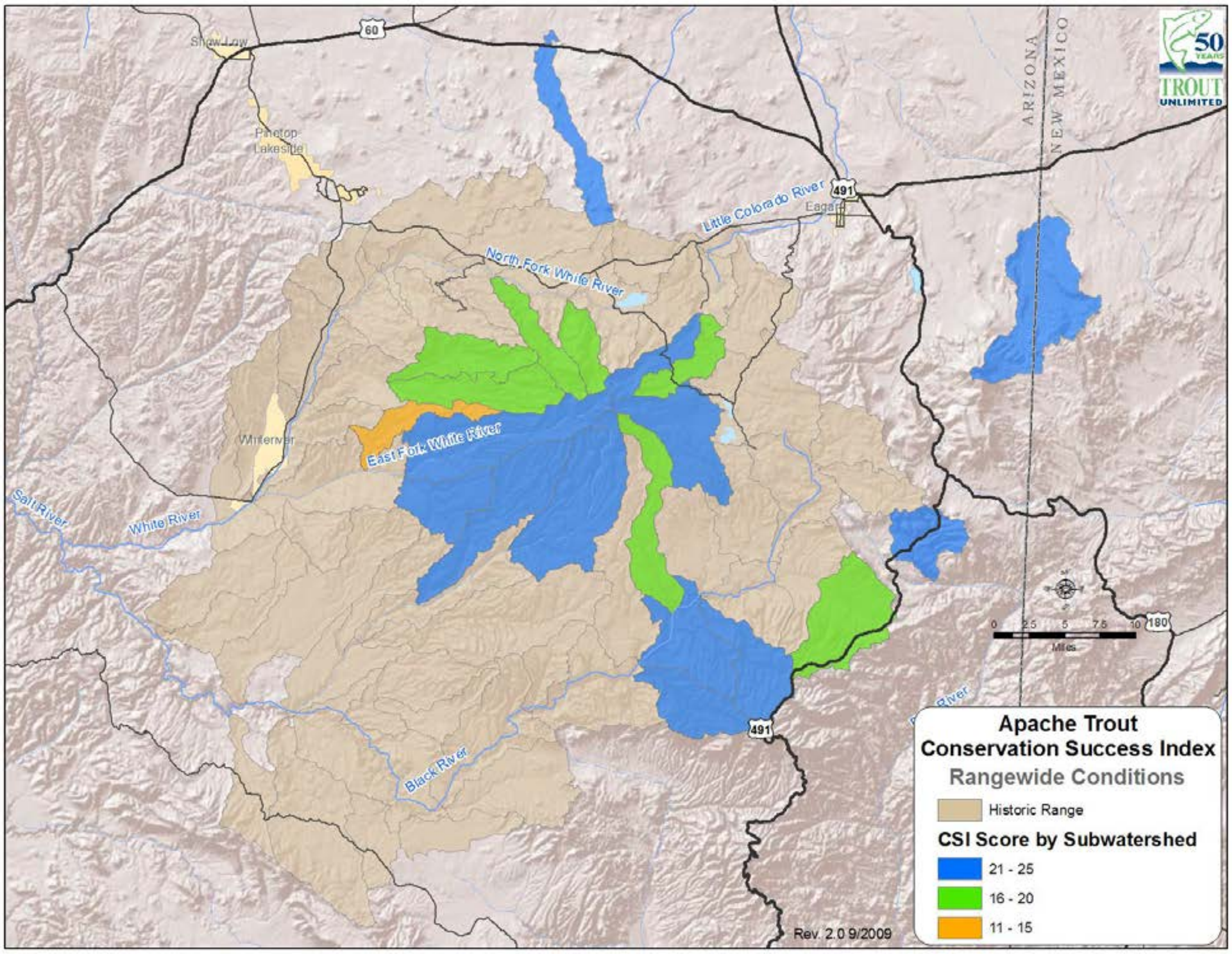
Apache Trout
Conservation Success Index
High Future Security
Population Integrity
High
Low
Extirpated
Habitat Integrity
Protect
Restore Population
Reintroduce
Restore Habitat
Restore Both
Restore, then Reintroduce
Show Low
Pinetop Lakeside
Whiteriver
Eagar
North Fork White River
East Fork White River
White River
Salt River
Black River
Little Colorado River
ARIZONA
NEW MEXICO
60
491
180
Miles
Rev. 2.0 9/2009


Apache Trout
Conservation Success Index
Future Security
CSI Score by Subwatershed
21 - 25
16 - 20
11 - 15
Rev. 2.0 9/2009
Show Low
Pinetop-Lakeside
Whiteriver
Eagar
Little Colorado River
North Fork White River
East Fork White River
White River
Salt River
Black River
Blue River
ARIZONA
NEW MEXICO
60
491
180
Miles

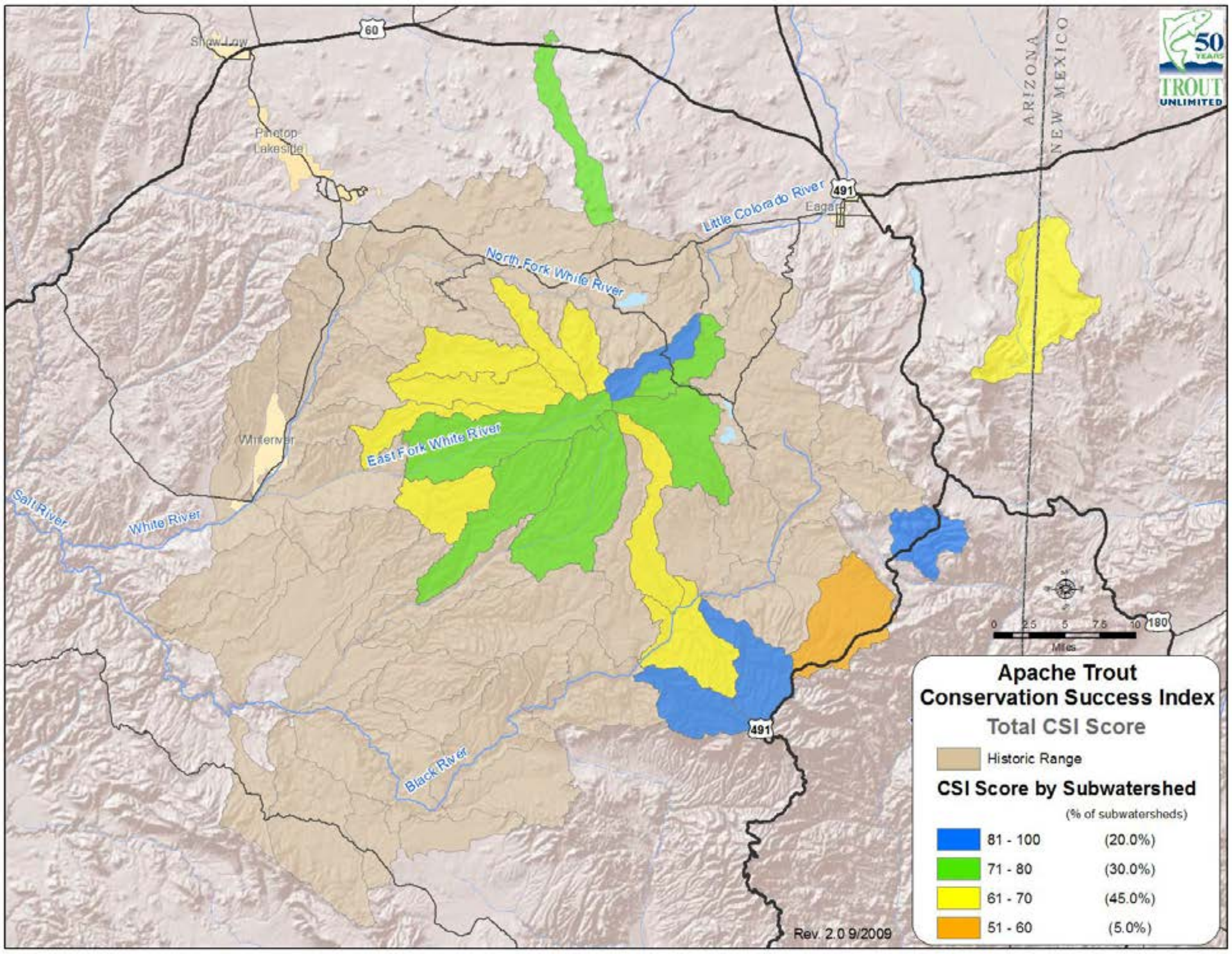


Apache Trout
Conservation Success Index
Habitat Integrity
CSI Score by Subwatershed
21 - 25
16 - 20
11 - 15
North Fork White River
East Fork White River
White River
Salt River
Black River
Blue River
Little Colorado River
Show Low
Pinetop Lakeside
Whiteriver
Eagar
ARIZONA
NEW MEXICO
60
491
180
Miles
Rev. 2.0 9/2009


Apache Trout
Conservation Success Index
Population Integrity
Historic Range
CSI Score by Subwatershed
16 - 20
11 - 15
5 - 10
Rev. 2.0 9/2009
Show Low
Pinetop-Lakeside
Whiteriver
Eagar
North Fork White River
East Fork White River
Little Colorado River
White River
Salt River
Black River
ARIZONA
NEW MEXICO
60
491
180
Miles
TROUT UNLIMITED



Apache Trout
Conservation Success Index
Rangewide Conditions
Historic Range
CSI Score by Subwatershed
21 - 25
16 - 20
11 - 15
Show Low
Pinetop-Lakeside
Whiteriver
Eagar
Little Colorado River
North Fork White River
East Fork White River
White River
Salt River
Black River
ARIZONA
NEW MEXICO
60
491
180
Miles
Rev. 2.0 9/2009



Apache Trout
Conservation Success Index
Total CSI Score
Historic Range
CSI Score by Subwatershed
(% of subwatersheds)
81 - 100 (20.0%)
71 - 80 (30.0%)
61 - 70 (45.0%)
51 - 60 (5.0%)
Show Low
Pinetop-Lakeside
Whiteriver
Eagar
Little Colorado River
North Fork White River
East Fork White River
White River
Salt River
Black River
ARIZONA
NEW MEXICO
60
491
180
Miles
Rev. 2.0 9/2009

v. 1 November 2008

Conservation Success Index:
Apache trout *Oncorhynchus apache*:
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.

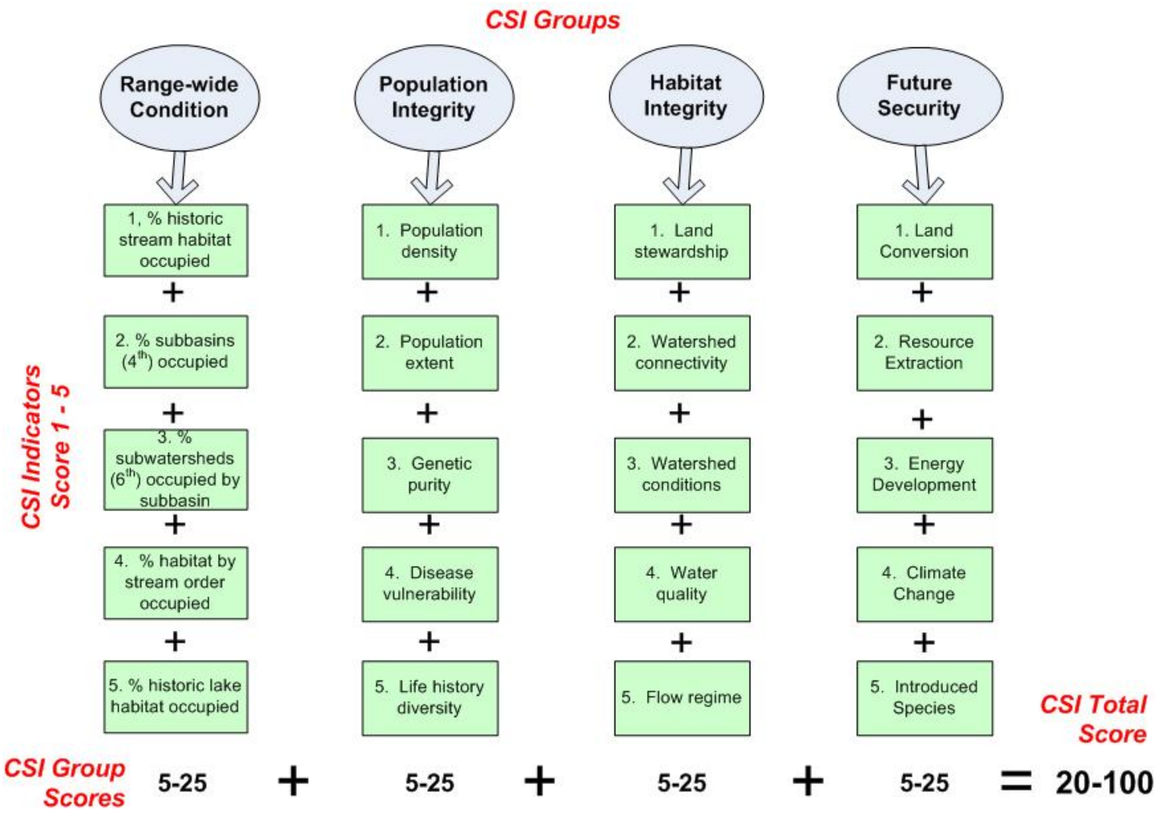


Figure 1. Each subwatershed is scored from 1 to 5 using 20 indicators within four main groups. Indicator scores are added per group to obtain an overall group score. Group scores are then added to obtain a composite CSI score for each subwatershed.

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 (6th level HUC) occupied within subbasin.
4. Percent of habitat by stream order occupied.
5. Percent of historic lake or 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: The historic and current distribution of Apache trout was based on data in the draft Apache Trout Recovery Plan developed by Arizona Game & Fish, US Fish & Wildlife

Service, and White Mountain Apache Tribe[1]. Spatial data were developed in coordination with Arizona Game & Fish.

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[2].

Data Sources: The historic and current distribution of Apache trout was based on data in the draft Apache Trout Recovery Plan developed by Arizona Game & Fish, US Fish & Wildlife Service, and White Mountain Apache Tribe[1]. Spatial data were developed in coordination with Arizona Game & Fish. Subbasins were based on NRCS National Watershed Boundary data[3].

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: The historic and current distribution of Apache trout was based on data in the draft Apache Trout Recovery Plan developed by Arizona Game & Fish, US Fish & Wildlife Service, and White Mountain Apache Tribe[1]. Spatial data were developed in coordination with Arizona Game & Fish. Subwatersheds were based on NRCS National Watershed Boundary data[3].

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[4].

Data Sources: The historic and current distribution of Apache trout was based on data in the draft Apache Trout Recovery Plan developed by Arizona Game & Fish, US Fish & Wildlife Service, and White Mountain Apache Tribe[1]. Spatial data were developed in coordination with Arizona Game & Fish. Stream order was determined using the National Hydrography Dataset Plus[5].

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[6].

Data Sources: The historic and current distribution of Apache trout was based on data in the draft Apache Trout Recovery Plan developed by Arizona Game & Fish, US Fish & Wildlife Service, and White Mountain Apache Tribe[1]. Spatial data were developed in coordination with Arizona Game & Fish. However, the historical distribution of Apache trout did not intersect any lakes in the National Hydrography Dataset Plus[5].

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[7;8].

Data Sources: Population density of Apache trout was based on data in the draft Apache Trout Recovery Plan developed by Arizona Game & Fish, US Fish & Wildlife Service, and White Mountain Apache Tribe[1] and unpublished Arizona Game & Fish data. Scoring rules were based, in part, on May and Albeke[8] and Williams et al.[2].

Indicator: 2. Population extent.

Indicator Scoring:

Connectivity	CSI Score
<10 km connected habitat	1
10-20 km connected habitat	2
20-30 km connected habitat	3
30-50 km connected habitat	4
>50 km connected habitat	5

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

Rationale: Populations with less available habitat are more vulnerable to extirpation[9] as a result of small, localized disturbances.

Data Sources: Population extent of Apache trout was based on data in the draft Apache Trout Recovery Plan developed by Arizona Game & Fish, US Fish & Wildlife Service, and White Mountain Apache Tribe[1] and unpublished Arizona Game & Fish data. Scoring rules were based, in part, on May and Albeke[8] and Williams et al.[2].

Indicator: 3. Genetic integrity.

Indicator Scoring:

Genetic Stability Ranking	CSI Score
Hybridizing species sympatric	1
Hybridizing species <10 km	2
	3
Hybridizing species >10 km	4
No Risk of Hybridization	5

Explanation: Genetic integrity 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[10]. Introgression with other subspecies can also cause a loss of genetic variation.

Data Sources: of Apache trout was based on data in the draft Apache Trout Recovery Plan developed by Arizona Game & Fish, US Fish & Wildlife Service, and White Mountain Apache Tribe[1] and unpublished Arizona Game & Fish data. Scoring rules were based, in part, on May and Albeke[8] and Williams et al.[2].

Indicator: 4. Disease vulnerability.

Indicator Scoring:

Disease Risk	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: Disease Risk of Apache trout was based on data in the draft Apache Trout Recovery Plan developed by Arizona Game & Fish, US Fish & Wildlife Service, and White Mountain Apache Tribe[1] and unpublished Arizona Game & Fish data. Scoring rules were based, in part, on May and Albeke[8] and Williams et al.[2].

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[9;11;12].

Data Sources: Life History Diversity of Apache trout was based on data in the draft Apache Trout Recovery Plan developed by Arizona Game & Fish, US Fish & Wildlife Service, and White Mountain Apache Tribe[1] and unpublished Arizona Game & Fish data. Scoring rules were based, in part, on May and Albeke[8] and Williams et al.[2].

***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 perennial 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

Explanation: The percent of perennial 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 (e.g., easements).

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[13] and the U.S. Department of Agriculture, Forest Service's National Inventoried Roadless Areas dataset[14].

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 current 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[9]. Diversions, when they do not directly inhibit fish passage, can represent false movement corridors, cause fish entrainment, and act as population sinks[15;16].

Data Sources: Connectivity was determined using all perennial streams in the National Hydrography Dataset Plus [5] and fish barriers based on unpublished Arizona Game & Fish data.

Indicator: 3. Watershed condition.

Indicator Scoring:

Land conversion	CSI Score
GE 30%	1
20 – 29%	2
10 – 19%	3
5 – 9%	4
0 - 4%	5

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

Explanation: The percentage of converted lands in the subwatershed and the density of roads.

Rationale: Habitat conditions are the primary determinant of persistence for most populations[17]. Converted lands are known to degrade aquatic habitats[18;19]. Road density is computed for the subwatershed; roads are known to cause sediment-related impacts to stream habitat[20-22]. Lee et al.[21] 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.

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[24].

Indicator: 4. Water quality.

Indicator Scoring:

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

Score for worst case.

Explanation: The presence of 303(d) impaired streams, percentage agricultural land, number of active mines, 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. Roads along streams can also contribute large amounts of fine sediments that smother benthic invertebrates, embed spawning substrates, and increase turbidity[25;26].

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[24] and the National Hydrography Dataset Plus[5].

Indicator: 5. Flow regime.

Indicator Scoring:

Number of dams	Miles of Canals	Storage (acre-ft)/stream mile	CSI Score
GE 5	GE 20	GE 2,500	1
3 – 4	10 – 19.9	1,000 – 2,499	2
2	5 – 9.9	250 – 999	3
1	1 – 4.9	1- 249	4
0	0 – 0.9	0	5

Score for worst case.

Explanation: Number of dams, percent of runoff diverted or withdrawn, 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. No canals existed in the study area based on the National Hydrography Dataset Plus[5]. Perennial streams were obtained from the National Hydrography Dataset Plus[5].

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

Overview:

1. Land conversion
2. Resource extraction
3. Flow modification
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.

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[5]. 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[24], and land ownership using USGS data on Land Ownership in Western North America[34].

3. Energy Development

Leases or reserves	New Dams 4^{th}	New Dams 6^{th}	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.

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

4. Climate Change

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

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

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* 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.

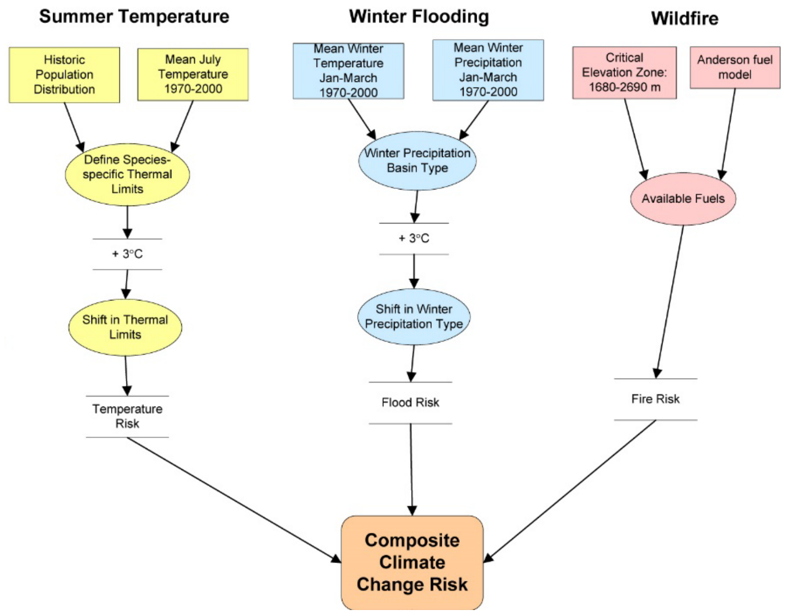
Communitization: Combining smaller federal tracts to meet the necessary minimum acreage required by the BLM (for spacing purposes).

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.



Each of the three 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.

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[39;40]. A 3°C increase in summer temperature has the potential to impact coldwater species occupying habitat at the edge of their thermal tolerance. However, there is low risk to mountain whitefish in the Big Lost River because the historic distribution[41] was not limited by temperature, and thermal tolerance data[42] showed mountain whitefish to be tolerant of temperatures throughout the basin after a 3°C projected increase; all subwatersheds were scored low for the risk of increased summer temperature. 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[43]. These risks are further discussed by Williams et al.[39]

Data Sources: Temperature and precipitation data were obtained from the PRISM Group[44]. Elevation data was obtained from the National Elevation Dataset[45], and LANDFIRE data for the Anderson Fire Behavior Fuel Model 13[46] was used as input for wildfire risk.

Indicator: 5. Introduced species.

Indicator Scoring:

Road Density	CSI Score
>4.7	1
3.7 – 4.7	2
2.7 – 3.7	3
1.7 – 2.7	4
<1.7	5

Explanation: The presence of introduced, injurious species in a subbasin and subwatershed and 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[10]. 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[47].

Data Sources: Information on introduced species was not available across the Apache trout historic range. Road density was used as a surrogate indicator of risk to introduction of exotic species. Roads were obtained from ESRI, Tele Atlas North American / Geographic Data Technology dataset on roads[24]

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