Conservation Success Index: Goose Lake Redband Trout

ONCORHYNCHUS MYKISS SSP.

Rev. 1.0 - 8/2009

SPECIES SUMMARY

Goose Lake is a 90,000 acre shallow, turbid, and highly variable alkaline lake on the California and Oregon border. In most years, tributary streams drain locally out of southern Oregon around the town of Lakeview and off of the west flank of the Warner Mountains into the lake as a closed basin. During extremely dry years – only 4 times since 1420, most recently in 1992 - the lake completely dries up. On the other extreme, following successive wet springs, the lake spills over its southern, historic outlet into the headwaters of the Pit River and the Sacramento River system.

Goose Lake redband trout, a unique subspecies of rainbow trout, have adapted to these conditions for thousands of years. Recent genetic research suggests that coastal rainbow trout that had occupied the connected Upper Pit and Goose Lake systems during a wetter climate were isolated from their ancestors by natural barriers on the Pit and Sacramento Rivers (Currens et al., 2009). These isolated redband trout of the Upper Sacramento and McCloud River system are known as *Oncorhynchus mykiss stonei*, first recognized by Livingston Stone in 1885. Like other forms of trout found in the Great Basin, redband trout in the Goose Lake system are tolerant of warm, alkaline water and have adopted an adfluvial life history. Large adults, up to 20 inches in length, reside in the lake and feed on Goose Lake tui chubs and fairy shrimp. During the spring runoff, these adults migrate up the connected tributary streams to spawn. Some individuals also exhibit a resident life history in these streams, a strategy that has allowed the subspecies to disperse and recolonize Goose Lake following periods where it is completely dry. All redband trout persisting in headwater streams of the Upper Pit express a resident life history.

Beginning in the 1800's, Goose Lake was utilized as a commercial fishery to support logging camps in the basin. Increasing development followed and by the late 20th century, the water quality and connectivity effects of agriculture severely reduced the productivity of the Goose Lake system. Additionally, introduced non-native trout competed with redbands in Goose Lake tributaries and portions of the Upper Pit. In the 1990s, prolonged drought and the threat of Endangered Species Act listing of Goose Lake redbands and other endemic fish led to the formation of the Goose Lake Fishes Working Group. Initial actions included identifying and modifying diversion structures to ensure fish passage, protection of critical spawning and rearing habitats to the east of Goose Lake, and limits to non-native fish stocking in Goose Lake tributaries. Perhaps due to uncertainty regarding their relation to trout in the Goose Lake system, redbands in the Upper Pit system have received less attention. The subspecies is designated as a Sensitive and Management Indicator Species by the U.S. Forest Service, as Sensitive by Oregon Department of Fish and Wildlife, and as a State Species of Special Concern in California.

Reconnecting headwater populations to Goose Lake remains the highest conservation priority in the Goose Lake basin. Other threats include the competition, exclusion, and hybridization impacts of non-native trout introductions, particularly in California, flow alteration associated with dams and diversions,

and sedimentation and channelization associated with livestock grazing and pasture irrigation. Trout Unlimted supports the continued efforts to conserve this unique and highly adaptive native trout.

Our CSI analysis incorporated data from Oregon Department of Fish and Wildlife's Status and Distribution of Native Fishes in the Goose Lake Basin assessments from 2007 and 2008, the 2004 Upper Pit River Watershed Assessment, the 1996 Goose Lake Fishes Conservation Strategy, the 2008 *SOS: California's Native Fish Crisis* report, and additional information from Claude Singleton, Bureau of Land Management; Stephanie Gunkel and Shannon Hurn, Oregon Department of Fish and Wildlife; Marty Yamagiwa, Modoc National Forest; and Stewart Reid, Western Fishes. We are grateful for these contributions to our understanding of this species. A complete list of data sources is provided separately.

Data for several CSI indicators affecting Goose Lake redband are unavailable or uncertain in California, including a clear understanding of the historic distribution, a complete picture of the artificial barriers in the system, and abundance data that would allow more robust comparisons of productivity between different streams. Quantitative estimates of introgression are unavailable in Oregon or California. These data would further refine the CSI results.

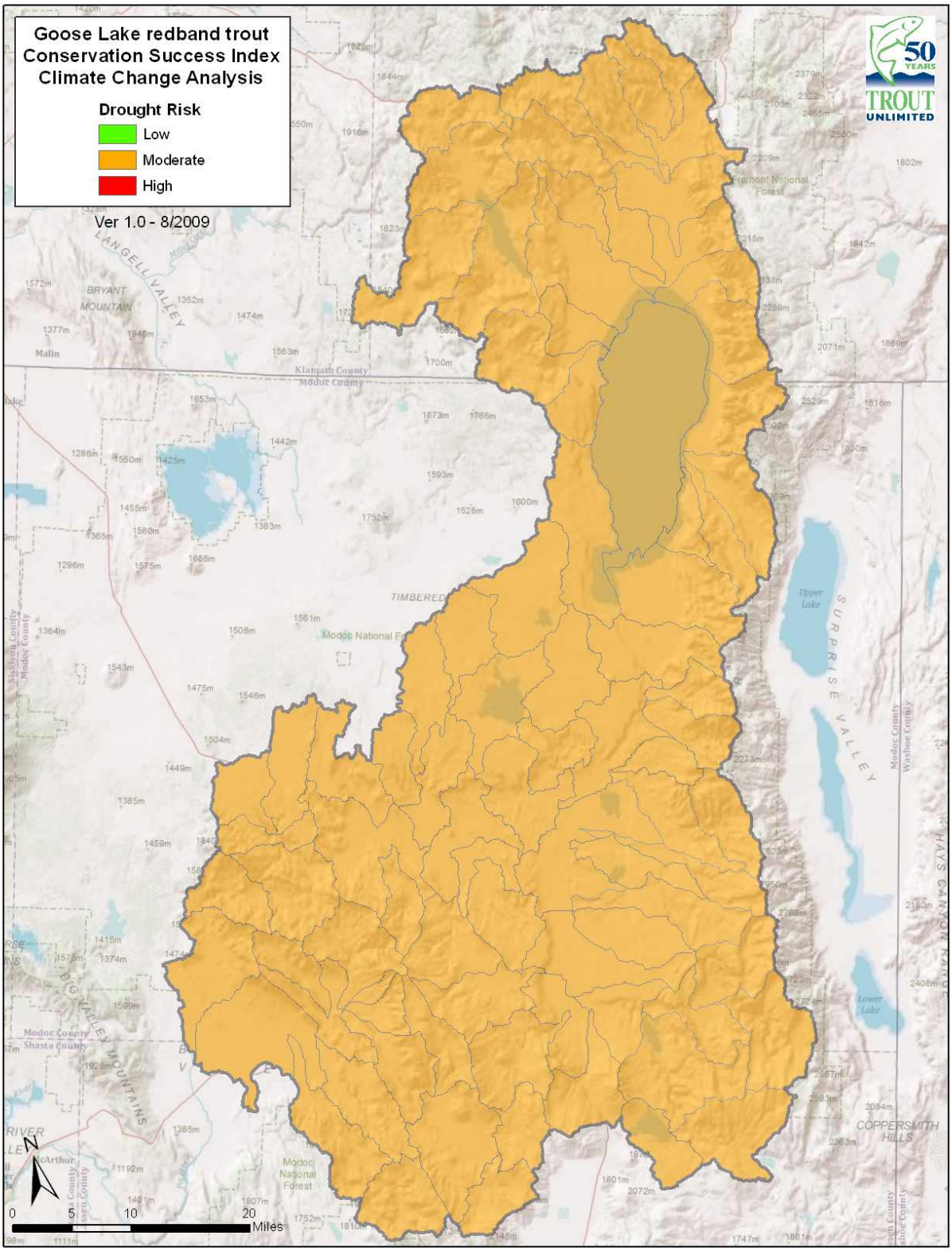
Prepared by Kurt Fesenmyer, TU, 8/11/2009

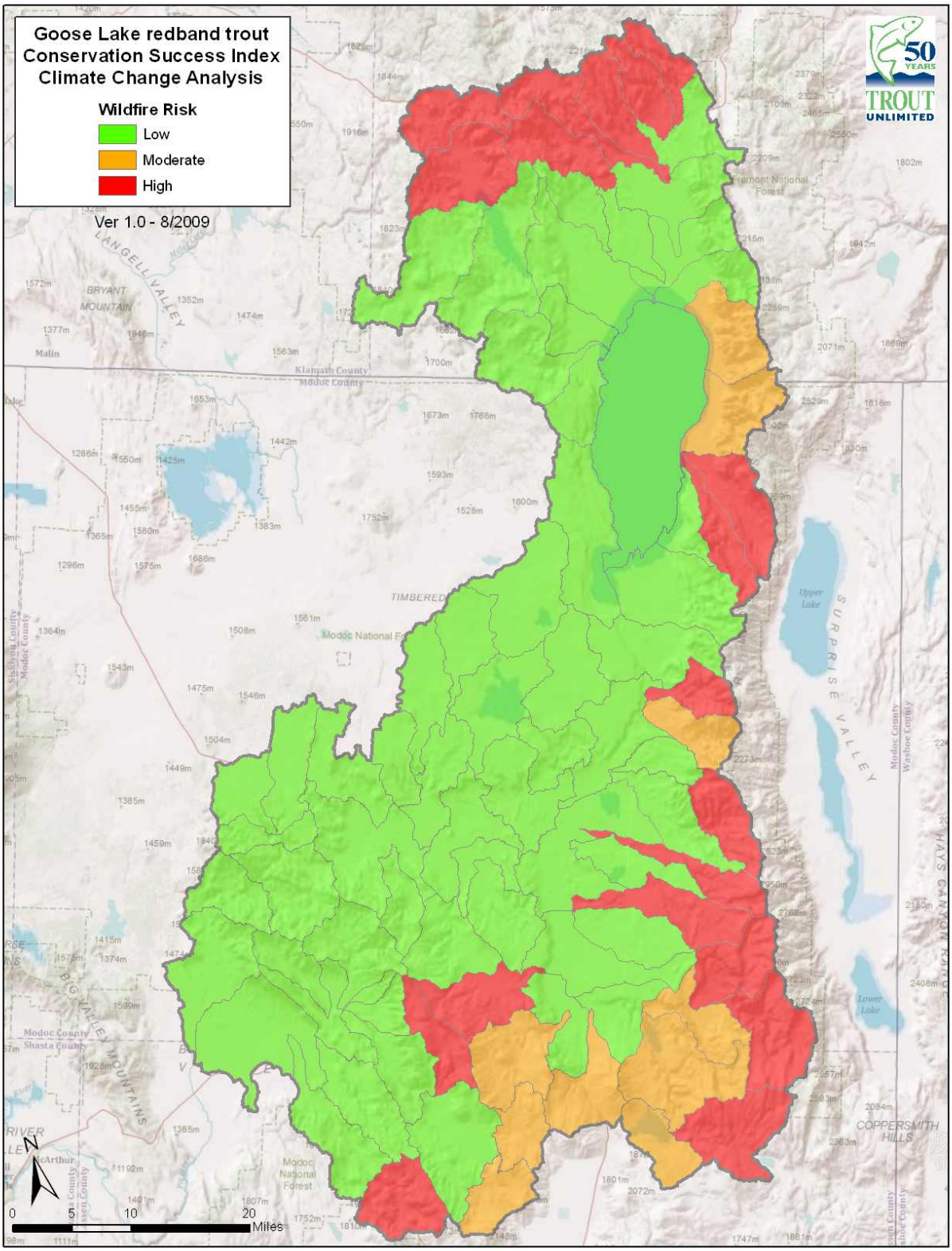
Key CSI Findings

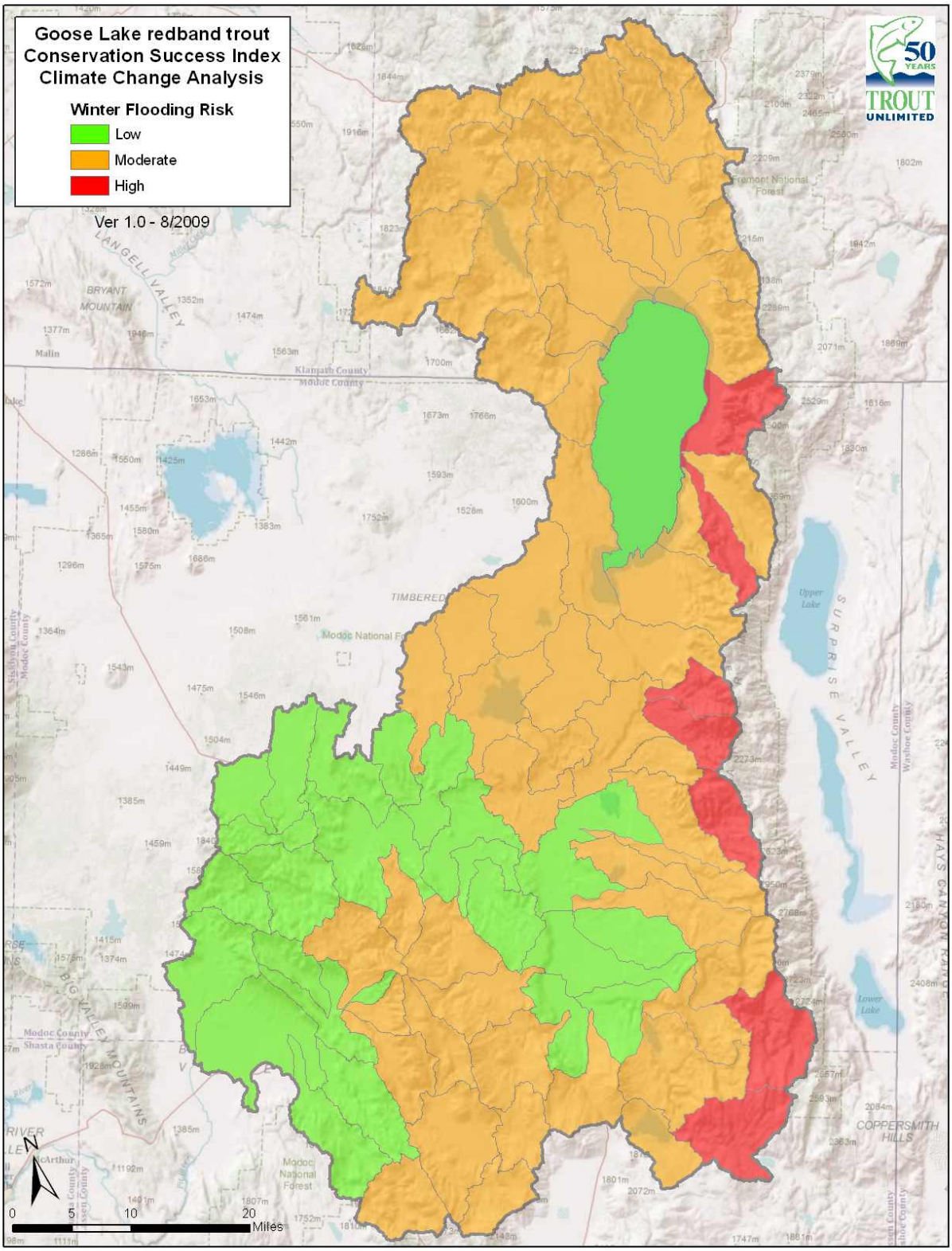
- The current distribution of Goose Lake redband trout is nearly equivalent to its historic distribution.
- Two population groups of Goose Lake redband exist. The adfluvial and resident population in the Goose Lake basin is large and has generally higher population integrity scores than the resident population in the Upper Pit system.
- The lowest population integrity scores reflect limited population extents, decreased by agricultural diversions, dams, and natural barriers.
- Headwater streams have the highest habitat integrity scores. In the lowlands and along mainstem streams, habitat integrity scores are degraded by fragmentation and water quality impacts associated with agriculture, roads, and dams.
- Most subwatersheds have high future security scores associated with minimal threats of land conversion and resource extraction.
- Multiple climate change factors, continued competition with non-native trout species, and wind and geothermal energy development represent the greatest additional future risk to this subspecies.

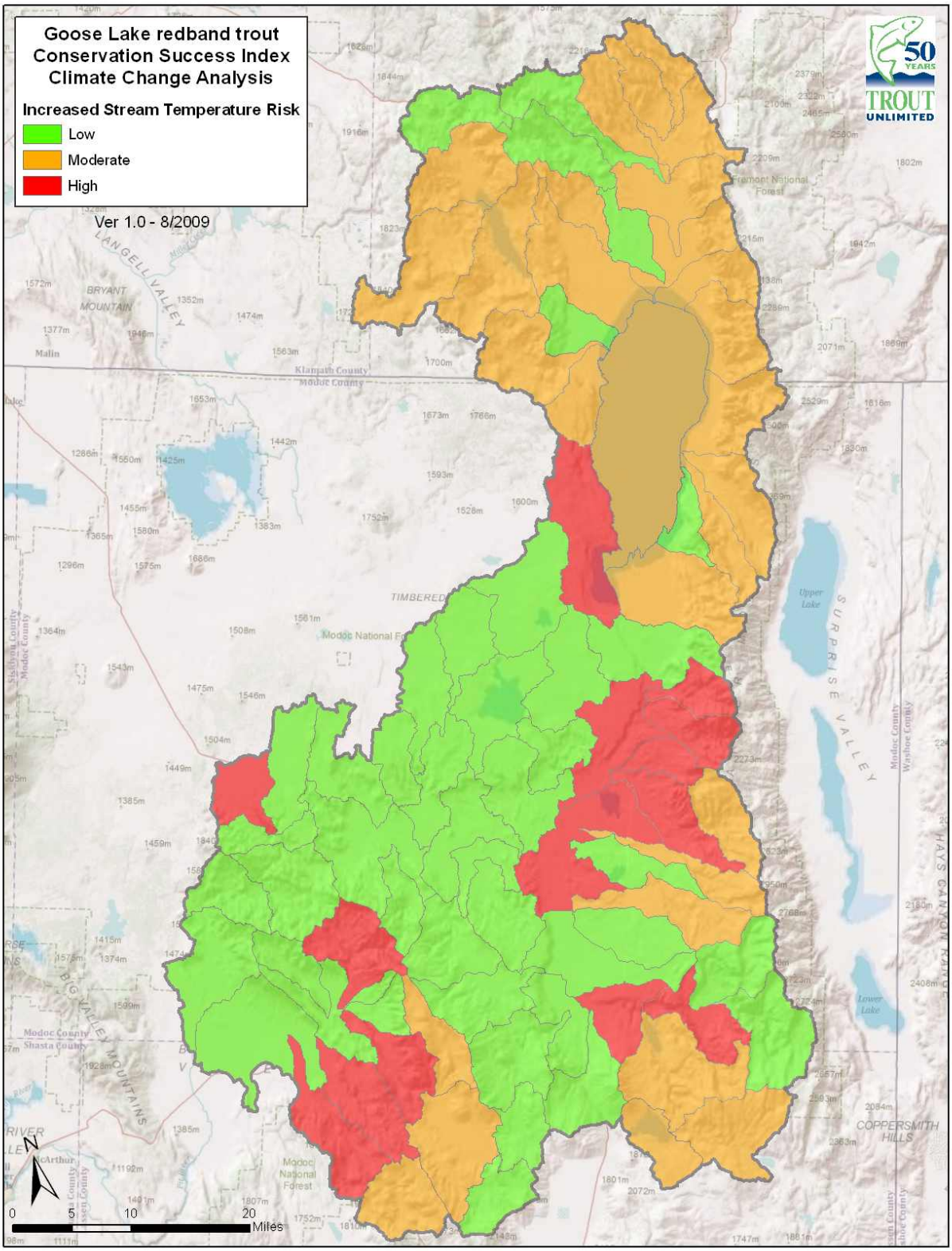
Table 1. CSI scoring results for Goose Lake redband trout. All indicators are scored from 1 (poorest) to 5 (best): see framework documentation for details.

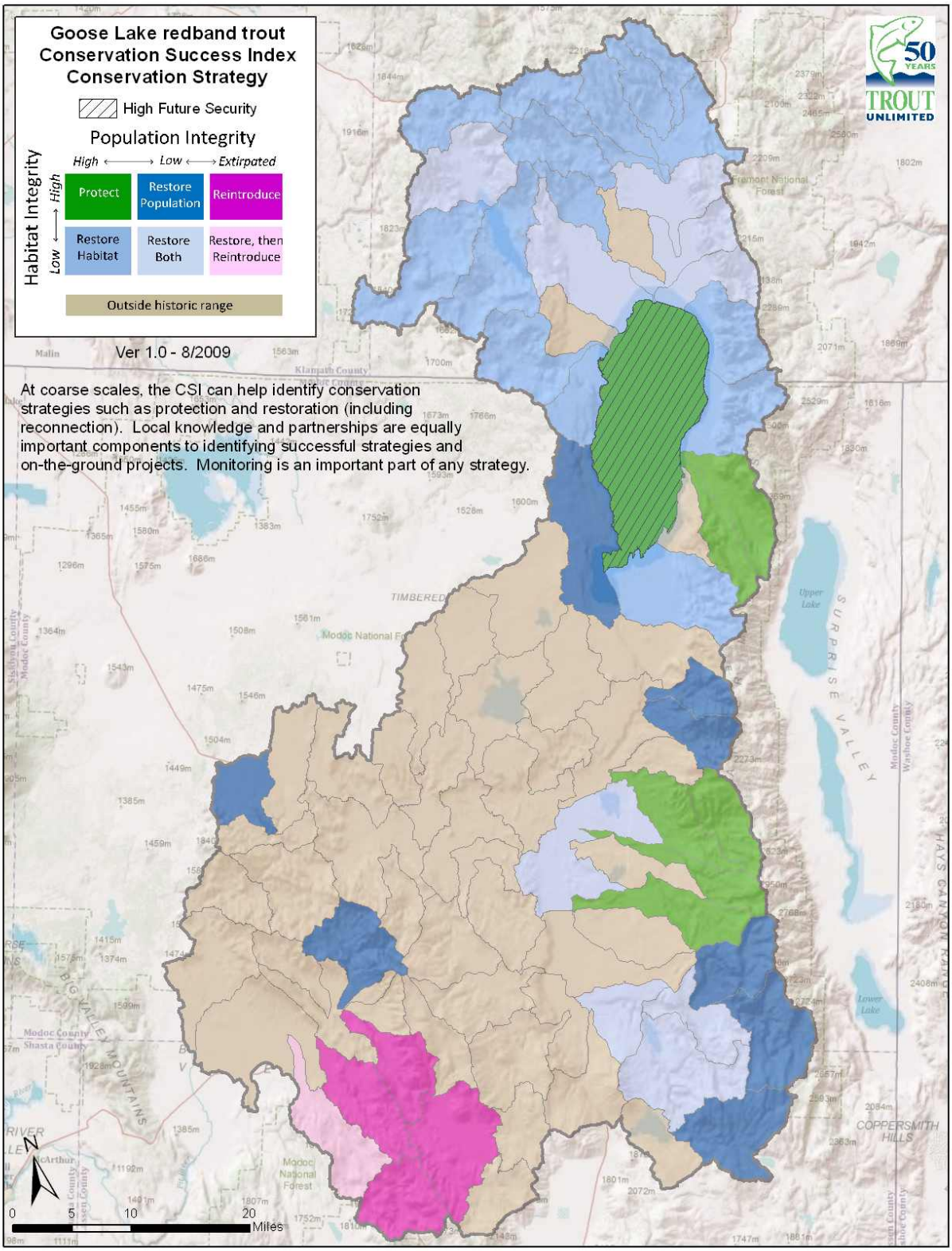
		Number of Subwatersheds Receiving Scores					Total Subwatersheds Scored
	CSI Indicator	**1**	**2**	**3**	**4**	**5**	
Range-wide Conditions	Percent historic stream habitat occupied	0	0	0	0	39	39
	Percent subbasins (4th) occupied	0	0	0	0	39	39
	Percent subwatersheds (6th) occupied	0	0	0	15	24	39
	Percent habitat by stream order occupied	2	1	1	1	34	39
	Percent historic lake area occupied	0	0	0	0	39	39
Population Integrity	Population Density	0	3	16	8	12	39
	Population Extent	7	8	10	7	7	39
	Genetic Purity	0	0	8	30	1	39
	Disease vulnerability	0	0	0	3	36	39
	Life history diversity	0	0	3	0	36	39
Habitat Integrity	Land Stewardship	77	1	1	3	4	86
	Watershed connectivity	7	6	15	13	45	86
	Watershed conditions	11	13	8	34	20	86
	Water quality	12	12	50	9	3	86
	Flow regime	6	6	21	23	30	86
Future Security	Land conversion	0	1	5	28	52	86
	Resource extraction	2	8	29	20	27	86
	Energy development	4	59	23	0	0	86
	Climate change	6	27	19	16	18	86
	Introduced species	70	0	9	7	0	86

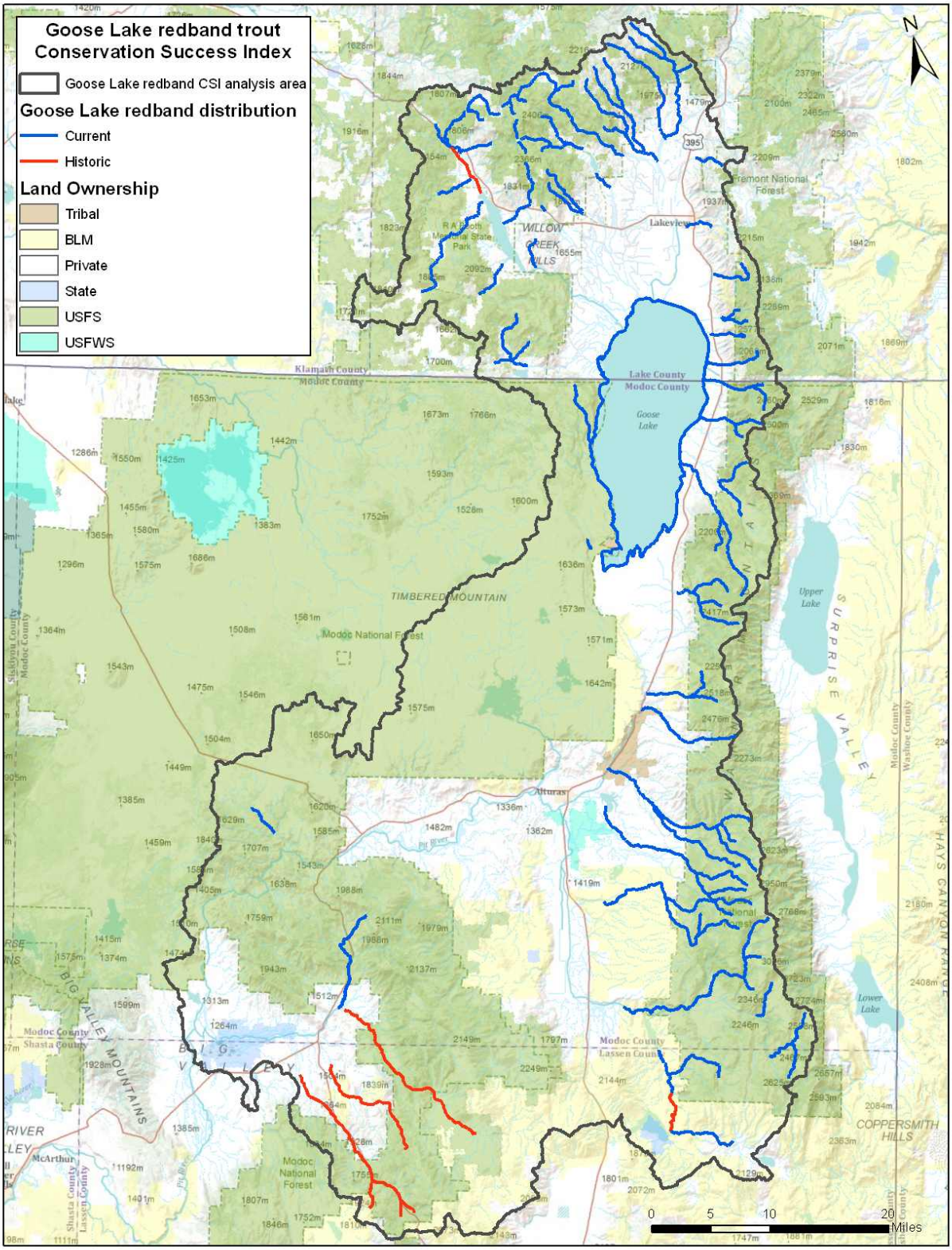

Goose Lake redband trout
Conservation Success Index
Climate Change Analysis
Drought Risk
Low
Moderate
High
Ver 1.0 - 8/2009
50 YEARS
TROUT UNLIMITED
LANGELL VALLEY
BRYANT MOUNTAIN
Malin
Klamath County
Modoc County
Fremont National Forest
TIMBERED
Modoc National Forest
SURPRISE VALLEY
Upper Lake
Lower Lake
Modoc County
Washoe County
HAYS CANYON RANGE
COPPERSMITH HILLS
BIG VALLEY MOUNTAINS
Modoc County
Shasta County
RIVER
McArthur
Modoc National Forest
0 5 10 20
Miles

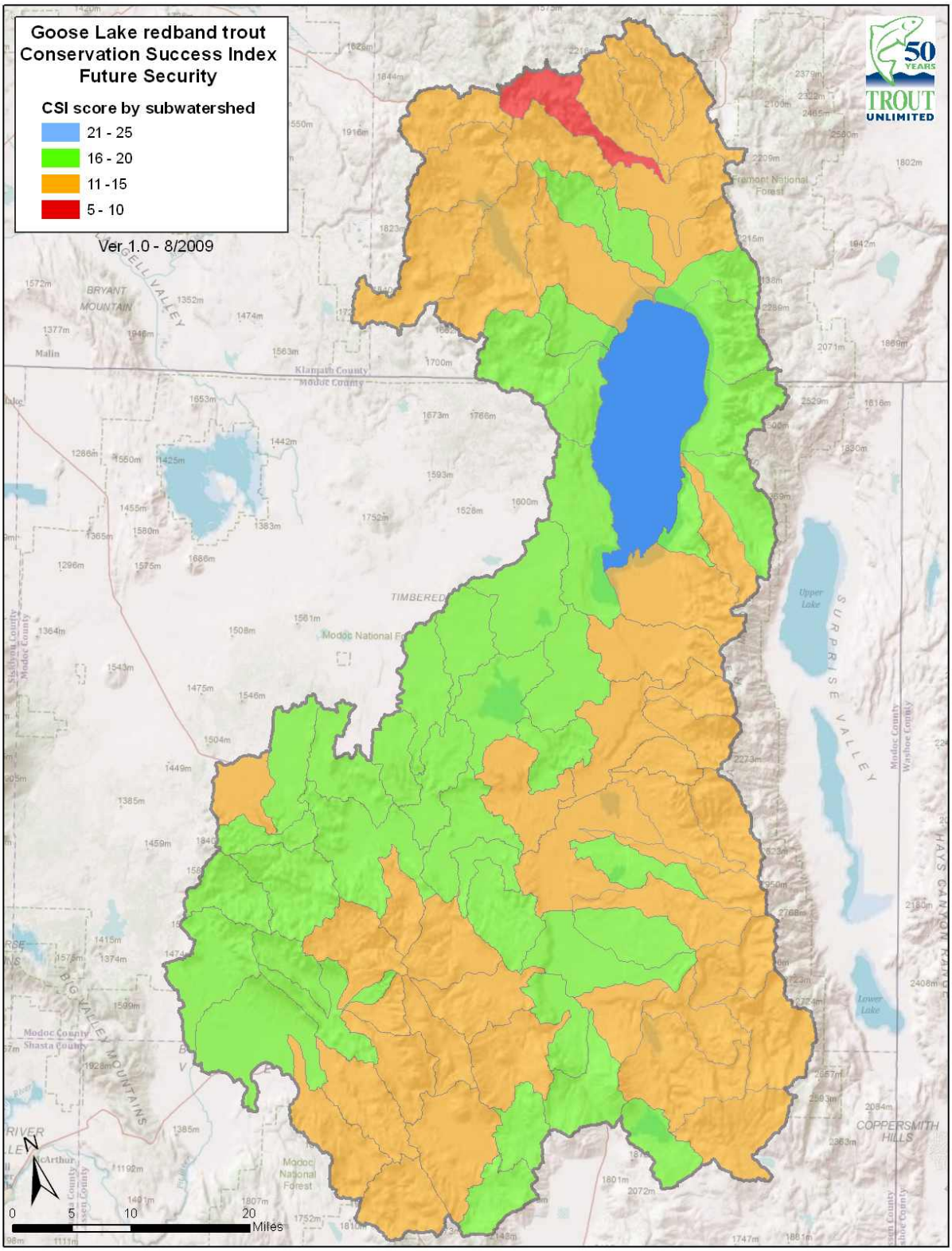

Goose Lake redband trout
Conservation Success Index
Climate Change Analysis
Wildfire Risk
Low
Moderate
High
Ver 1.0 - 8/2009
50 YEARS
TROUT UNLIMITED
LANGELL VALLEY
BRYANT MOUNTAIN
Malin
Klamath County
Modoc County
TIMBERED
Modoc National Forest
SURPRISE VALLEY
Upper Lake
Lower Lake
Fremont National Forest
Modoc County
Shasta County
Siskiyou County
Washoe County
BIG VALLEY MOUNTAINS
COPPERSMITH HILLS
HAYS CANYON
McArthur
0 5 10 20
Miles

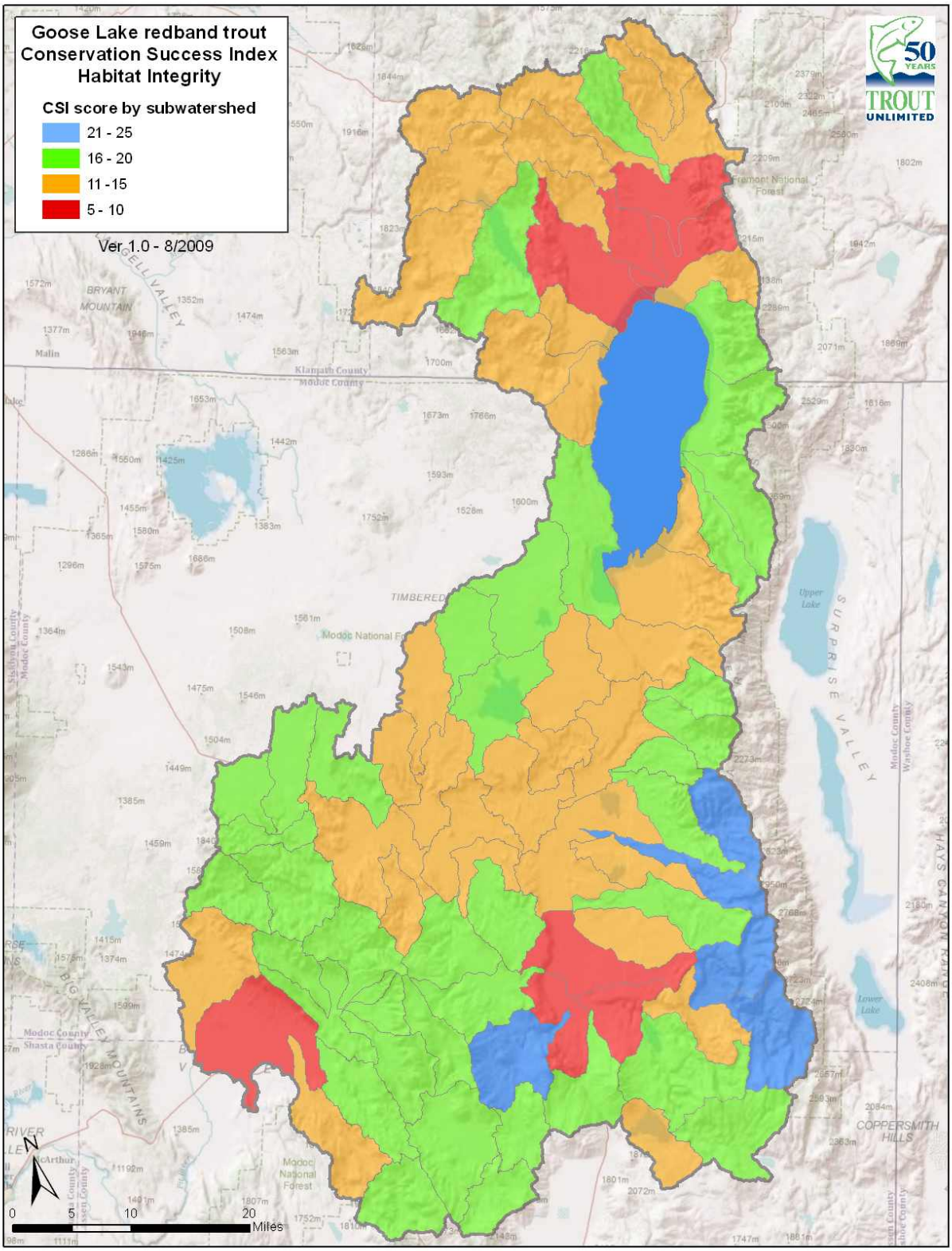

Goose Lake redband trout
Conservation Success Index
Climate Change Analysis
Winter Flooding Risk
Low
Moderate
High
Ver 1.0 - 8/2009
50 YEARS
TROUT UNLIMITED
0
5
10
20
Miles

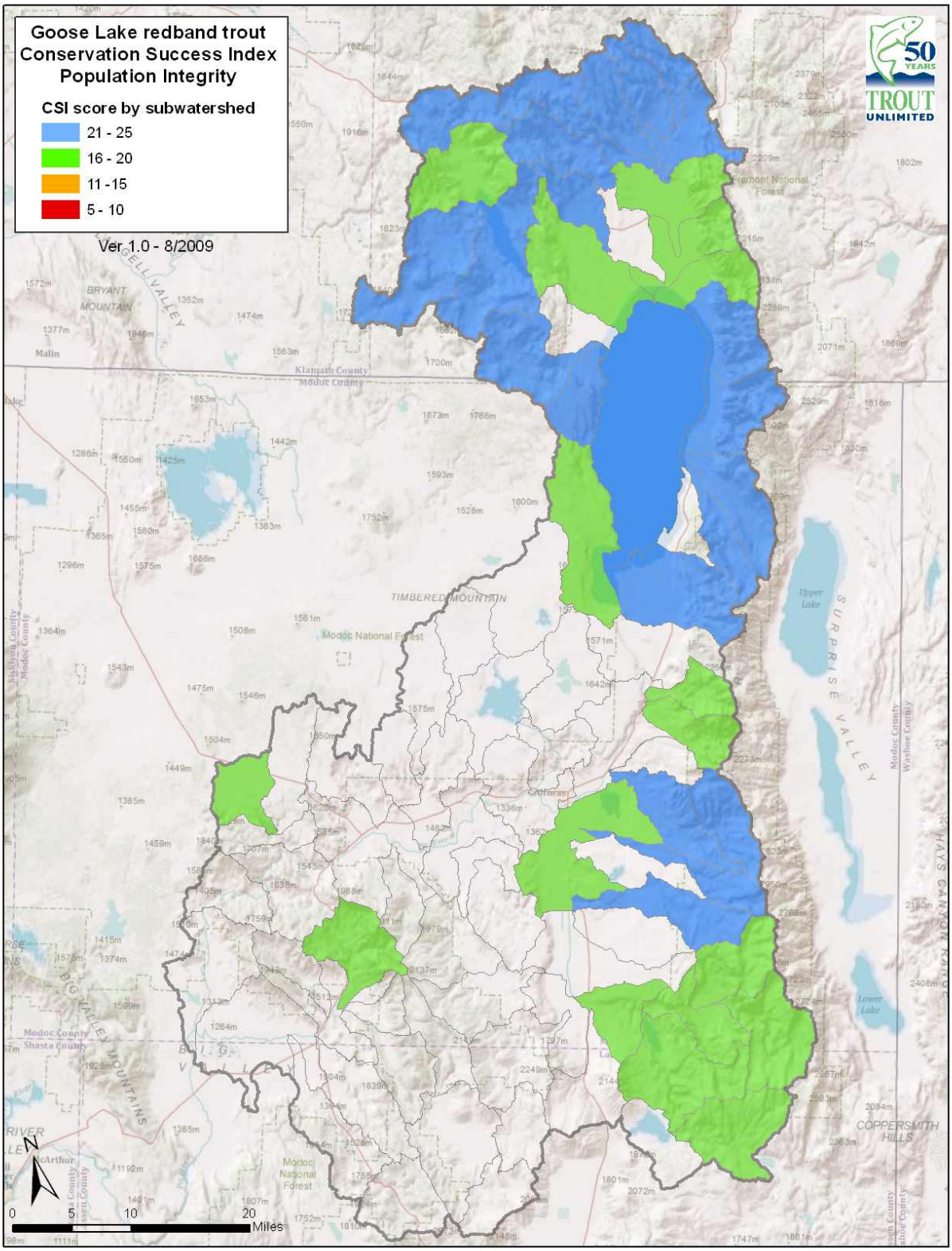

Goose Lake redband trout
Conservation Success Index
Climate Change Analysis
Increased Stream Temperature Risk
Low
Moderate
High
Ver 1.0 - 8/2009
50 YEARS
TROUT UNLIMITED
0
5
10
20
Miles

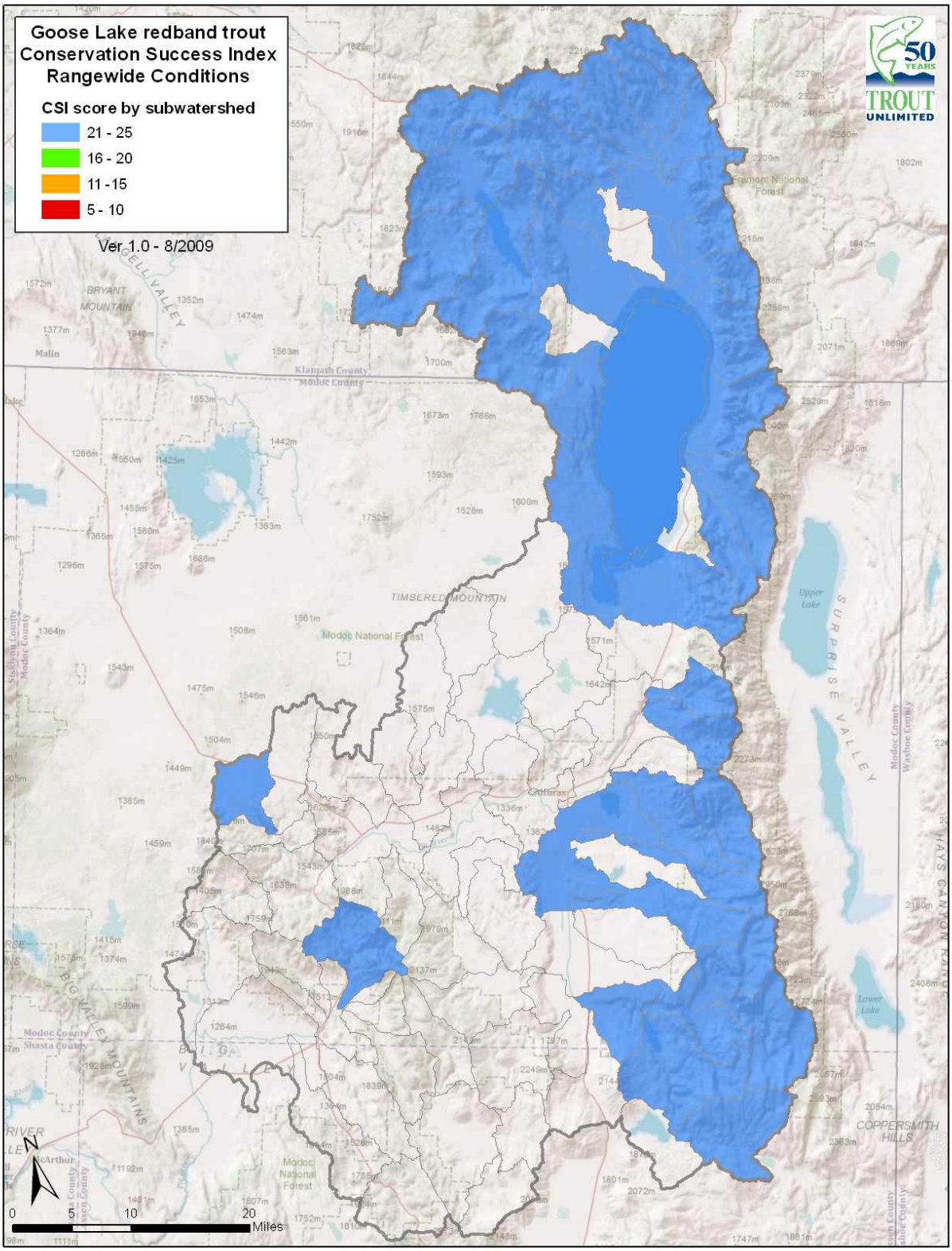

Goose Lake redband trout
Conservation Success Index
Conservation Strategy
High Future Security
Population Integrity
High ⟷ Low ⟷ Extirpated
Habitat Integrity
High ⟷ Low
Protect
Restore Population
Reintroduce
Restore Habitat
Restore Both
Restore, then Reintroduce
Outside historic range
Ver 1.0 - 8/2009
At coarse scales, the CSI can help identify conservation strategies such as protection and restoration (including reconnection). Local knowledge and partnerships are equally important components to identifying successful strategies and on-the-ground projects. Monitoring is an important part of any strategy.
50 YEARS
TROUT UNLIMITED
0 5 10 20 Miles

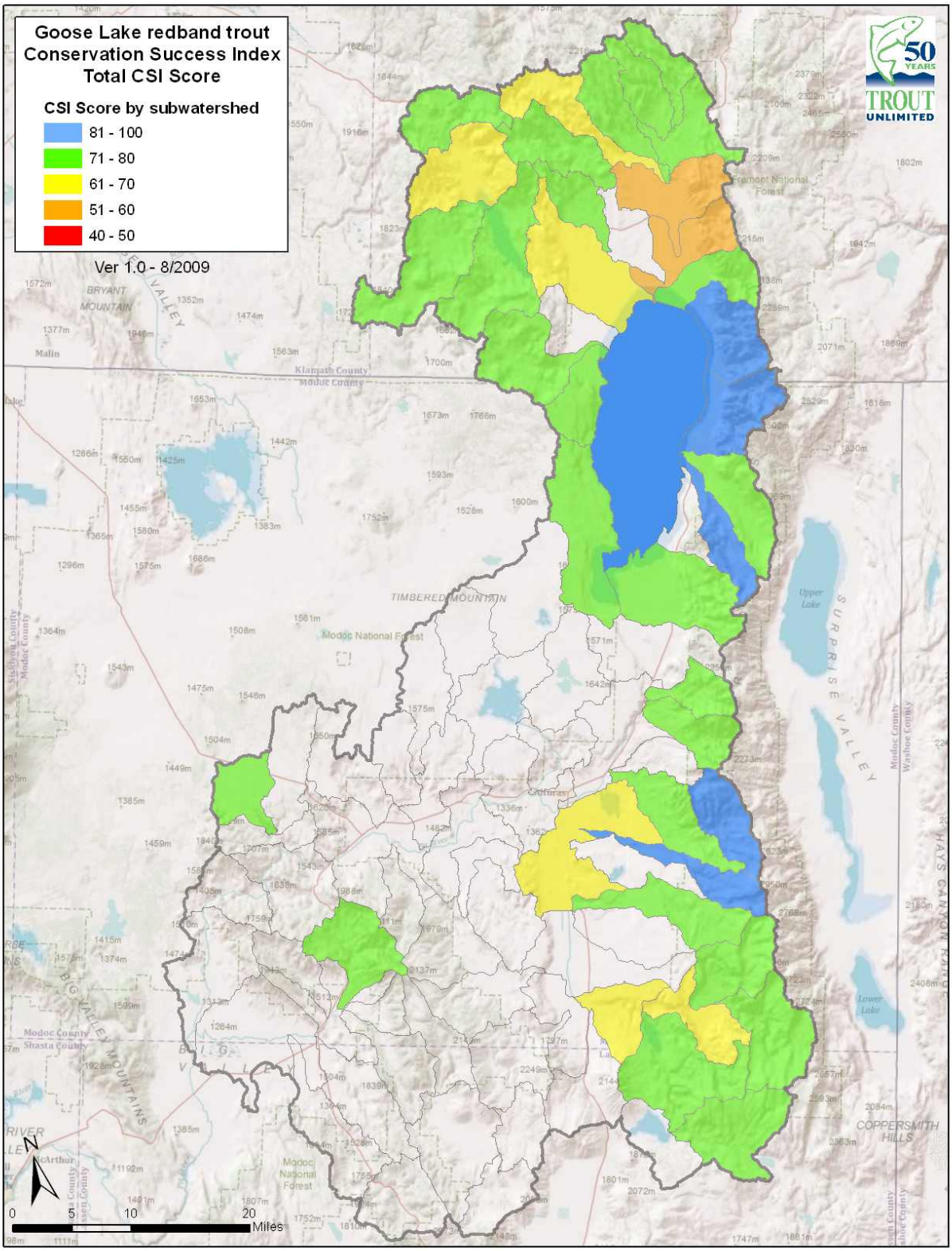

Goose Lake redband trout
Conservation Success Index
Goose Lake redband CSI analysis area
Goose Lake redband distribution
Current
Historic
Land Ownership
Tribal
BLM
Private
State
USFS
USFWS
N
Fremont National Forest
Lakeview
WILLOW CREEK HILLS
Lake County
Modoc County
Goose Lake
Klamath County
Modoc County
TIMBERED MOUNTAIN
Modoc National Forest
Upper Lake
SURPRISE VALLEY
Alturas
Modoc County
Shasta County
BIG VALLEY MOUNTAINS
Modoc County
Lassen County
Lower Lake
COPPERSMITH HILLS
McArthur
Modoc National Forest
0 5 10 20
Miles


Goose Lake redband trout
Conservation Success Index
Future Security
CSI score by subwatershed
21 - 25
16 - 20
11 -15
5 - 10
Ver 1.0 - 8/2009
50 YEARS
TROUT UNLIMITED
N
0
5
10
20
Miles


Goose Lake redband trout
Conservation Success Index
Habitat Integrity
CSI score by subwatershed
21 - 25
16 - 20
11 -15
5 - 10
Ver 1.0 - 8/2009
50 YEARS
TROUT UNLIMITED
BRYANT MOUNTAIN
Malin
Klamath County
Modoc County
Fremont National Forest
Modoc National Forest
TIMBERED
Upper Lake
SURPRISE VALLEY
Lower Lake
HAYS CANYON
COPPERSMITH HILLS
BIG VALLEY MOUNTAINS
Modoc County
Shasta County
Washoe County
N
0 5 10 20
Miles


Goose Lake redband trout
Conservation Success Index
Population Integrity
CSI score by subwatershed
21 - 25
16 - 20
11 - 15
5 - 10
Ver 1.0 - 8/2009
50 YEARS
TROUT UNLIMITED
Fremont National Forest
BRYANT MOUNTAIN
Klamath County
Modoc County
TIMBERED MOUNTAIN
Modoc National Forest
Upper Lake
SURPRISE VALLEY
Lower Lake
COPPERSMITH HILLS
Modoc County
Shasta County
BIG VALLEY MOUNTAINS
N
0
5
10
20
Miles


Goose Lake redband trout
Conservation Success Index
Rangewide Conditions
CSI score by subwatershed
21 - 25
16 - 20
11 - 15
5 - 10
Ver 1.0 - 8/2009
50 YEARS
TROUT UNLIMITED
Fremont National Forest
BRYANT MOUNTAIN
Klamath County
Modoc County
TIMBERED MOUNTAIN
Modoc National Forest
Upper Lake
SURPRISE VALLEY
Lower Lake
COPPERSMITH HILLS
Modoc County
Shasta County
BIG VALLEY MOUNTAINS
N
0
5
10
20
Miles


Goose Lake redband trout
Conservation Success Index
Total CSI Score
CSI Score by subwatershed
81 - 100
71 - 80
61 - 70
51 - 60
40 - 50
Ver 1.0 - 8/2009
50 YEARS
TROUT UNLIMITED
BRYANT MOUNTAIN
Malin
Klamath County
Modoc County
TIMBERED MOUNTAIN
Modoc National Forest
Fremont National Forest
Upper Lake
SURPRISE VALLEY
Lower Lake
COPPERSMITH HILLS
BIG VALLEY MOUNTAINS
Modoc County
Shasta County
Modoc County
Washoe County
0 5 10 20
Miles

ver. 1.0 – 6/2009

Conservation Success Index:
California Native Trout: McCloud Redband Trout, Goose Lake Redband Trout, Paiute Cutthroat Trout and Eagle Lake Rainbow 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 or catchment, 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 or catchment condition for a Group, and Group scores are added for a CSI score for a subwatershed or catchment (Figure 1). CSI scores can then be summarized to obtain the general range of conditions within the historical or current distribution of the species.

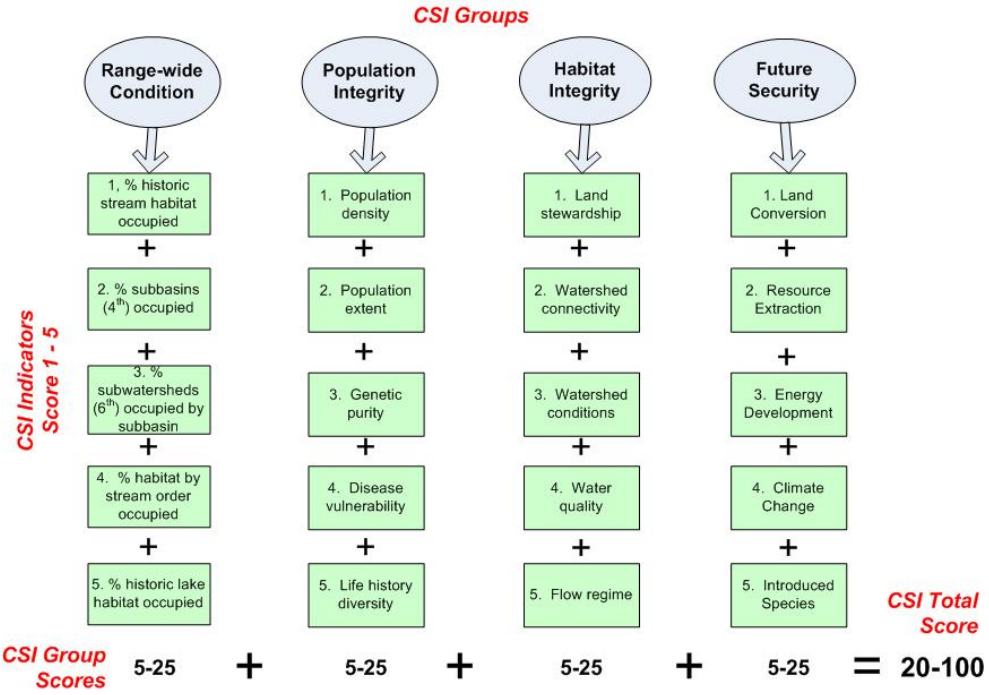


Figure 1. Each subwatershed or catchment is scored from 1 to 5 using 20 indicators within four main groups. Indicator scores are added per group to obtain an overall group score. Group scores are then added to obtain a composite CSI score for each subwatershed or catchment.

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 historical stream habitat occupied.
2. Percent of subbasins occupied by populations.
3. Percent of subwatersheds (6th level HUC) or catchments occupied within subbasin.
4. Percent of habitat by stream order occupied.
5. Percent of lake or by surface area occupied.

Indicator: 1. Percent of historic streams occupied by populations

Indicator Scoring:

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

Explanation: The percentage of streams currently occupied by the species, based on sampling data.

Rationale: Populations occupying a larger extent of habitat will have an increased likelihood of persistence.

Data Sources: The current and historical distribution of McCloud Redband Trout provided by Shasta-Trinity National Forest;[1] current and historical distribution of Paiute cutthroat trout from USFWS;[2;3] current and historical distribution of Eagle Lake rainbow trout from Pine Creek RMPG;[4] current distribution of Goose Lake redband from Oregon DFW[5] and Modoc National Forest,[6] historic distribution assumed to be all perennial streams in the upper Pit/Goose Lake system, excluding the mainstem North and South Fork Pit and mainstem Pit below Alturas; subwatersheds based on NRCS data[7] (for Goose Lake Redband Trout); catchments based on NHD Plus[8] (all other species).

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 historically occupied subbasins that are currently occupied by the species. The same percentage is applied to all subwatersheds or catchments scored.

Rationale: Larger river basins often contain populations functioning as distinct populations.

Data Sources: The current and historical distribution of McCloud Redband Trout provided by Shasta-Trinity National Forest;[1] current and historical distribution of Paiute cutthroat trout from USFWS;[2;3] current and historical distribution of Eagle Lake rainbow trout from Pine Creek RMPG;[4] current distribution of Goose Lake redband from Oregon DFW[5] and Modoc National Forest,[6] historic distribution assumed to be all perennial streams in the Upper Pit/Goose Lake system; subbasins based on NRCS data[7]

Indicator: 3. Percent subwatersheds or catchments occupied within subbasin.

Indicator Scoring:

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

Explanation: The percentage of historically occupied subwatersheds or catchments 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 percentage of subwatersheds or catchments are likely to be more broadly distributed and have an increased likelihood of persistence.

Data Sources: The current and historical distribution of McCloud Redband Trout provided by Shasta-Trinity National Forest;[1] current and historical distribution of Paiute cutthroat trout from USFWS;[2;3] current and historical distribution of Eagle Lake rainbow trout from Pine Creek RMPG;[4] current distribution of Goose Lake redband from Oregon DFW[5] and Modoc National Forest,[6] historic distribution assumed as all perennial streams in the Upper Pit/Goose Lake system, excluding the mainstem North and South Fork Pit and mainstem Pit below Alturas; subwatersheds based on NRCS data[7] (for Goose Lake Redband Trout); catchments based on NHD Plus[8] (all other species).

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.[9]

Data Sources: The current distribution of McCloud Redband Trout provided by Shasta-Trinity National Forest;[1] current distribution of Paiute cutthroat trout from USFWS;[2;3] current distribution of Eagle Lake rainbow trout from Pine Creek RMPG;[4] subwatersheds based on NRCS data[7] (for Goose Lake Redband Trout); current distribution of Goose Lake redband from Oregon DFW[5] and Modoc National Forest;[6] catchments based on NHD Plus[8] (all other species); stream order was determined using the NHD Plus.[8]

Indicator: 5. 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: Percentage of natural and artificial lakes that contain populations of wild trout.

Rationale: Lakes often harbor unique life histories and large populations that are important to long-term persistence of the species.[10]

Data Sources: The current distribution of McCloud Redband Trout provided by Shasta-Trinity National Forest;[11] current distribution of Paiute cutthroat trout from USFWS;[2;3] current distribution of Eagle Lake rainbow trout from Pine Creek RMPG;[4] current distribution of Goose Lake redband from Oregon DFW[5] and Modoc National Forest[6], subwatersheds based on NRCS data[7] (for Goose Lake Redband Trout); catchments based on NHD Plus[8] (all other species); lakes from the National Hydrography Dataset.[12]

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

Overview:

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

Indicator: 1. Population density.

Indicator Scoring:

Fish / mile	CSI Score
1 – 50 (total pop < 500)	1
1 – 50 (total pop ≥ 500)	2
51 - 150	3
151 - 400	4
>400	5

Explanation: Population density within each subwatershed or catchment. When multiple populations were present within a subwatershed or catchment, 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.[13;14]

Data Sources: Density of McCloud Redband trout from the Draft McCloud Redband Conservation Agreement;[15] density of Paiute cutthroat trout from USFWS;[2;3] abundance data for Goose Lake redband from Oregon DFW [16;17] and personal communication with Claude Singleton (BLM), Stewart Reid (Western Fishes), and Marty Yamagiwa (USFS); subwatersheds based on NRCS data[7] (for Goose Lake Redband Trout); catchments based on NHD Plus[8] (all other

species). Because of incomplete data, some subwatersheds/catchments were scored based on expert opinion considering the landscape context. Scoring rules were based, in part, on May and Albeke[14] and Williams et al.[18]

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 – 31.1 mi (30-50 km) connected habitat	4
> 31.1 mi (>50 km) connected habitat	5

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

Rationale: Populations with less available habitat are more vulnerable to extirpation[19] 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). McCloud barriers data from Steve Bachmann, USFS (personal communication). Paiute cutthroat barriers data from USFWS;[2;3] Eagle Lake rainbow trout barriers described in Pine Creek RMPG;[4] Goose Lake redband barriers from Oregon DFW[20] and personal communication with Claude Singleton (BLM), Stewart Reid (Western Fishes), and Marty Yamagiwa (USFS). Natural barriers from National Hydrography Dataset.[21] Scoring rules were based, in part, on May and Albeke[14] and Williams et al.[18]

Indicator: 3. Genetic integrity.

Indicator Scoring:

Genetic purity	CSI Score
< 80%	1
80 – 89 %	2
	3
90 – 98 %	4
99 - 100 %	5

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

Rationale: McCloud Redband trout genetics from the Draft McCloud Redband Conservation Agreement;[15] Paiute cutthroat genetics from UC-Davis;[22] Eagle Lake rainbows are not

hydridized, but history of hatchery selection for fish size and reproduction timing degrade genetic integrity by 1 point; Goose Lake redband hybridization estimations from ODFW,[23] Claude Singleton (BLM), Stewart Reid (Western Fishes), and Marty Yamagiwa (USFS) (personal communication); subwatersheds based on NRCS data[7] (for Goose Lake Redband Trout); catchments based on NHD Plus[8] (all other species). Because of incomplete data, some subwatersheds/catchments were scored based on expert opinion considering the landscape context. Scoring rules were based, in part, on May and Albeke[14] and Williams et al.[18]

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 < 6.2 mi (10 km)	3
None present but proximity > 6.2 mi (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: Stocking hatchery fish contributes to the 1 point degradation of the mainstem and tributaries of the Upper McCloud. The proximity of the popular Silver King Creek fishery contributes to the 1 point degradation to the otherwise isolated populations of Paiute cutthroat. Hatchery dependent Eagle Lake rainbows = 3. Goose Lake redband considers the presence of active stocking of non-native salmonids.[23]

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.[19;24;25]

Data Sources: Life History Diversity of McCloud Redband trout based on data from the Draft McCloud Conservation Agreement[26] and personal communication with Steve Bachmann, USFS,

and Curtis Knight, Caltrout. Paiute cutthroat trout from USFWS.[2;3] Eagle Lake rainbow trout from Pine Creek RMPG;[4] Goose Lake redband from ODFW[16;17] and Modoc National Forest. Scoring rules were based, in part, on May and Albeke[14] and Williams et al.[18]

***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%=2; >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[27] and the U.S. Department of Agriculture, Forest Service's National Inventoried Roadless Areas dataset.[28] McCloud Redband also considers areas designated as Late Successional Reserves by the Northwest Forest Plan.[29]

Indicator: 2. Watershed connectivity.

Indicator Scoring:

Number of stream/canal intersections	Current/historical connectivity subwatershed or catchment	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/historical connectivity 4th:

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

Score for worst case

Explanation: The number of stream-canal intersections and reduction in perennial stream 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 connected perennial 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.[19] Diversions, when they do not directly inhibit fish passage, can represent false movement corridors, cause fish entrainment, and act as population sinks.[30;31]

Data Sources: McCloud barriers data from Steve Bachmann, USFS (personal communication). Paiute cutthroat barriers data from USFWS;[2;3] Eagle Lake rainbow trout barriers described in Pine Creek RMPG;[4] Goose Lake redband barriers from Oregon DFW[20] and personal communication with Claude Singleton (BLM), Stewart Reid (Western Fishes), and Marty Yamagiwa (USFS). Stream data and additional natural barriers from National Hydrography Dataset.[21]

Indicator: 3. Watershed condition.

Indicator Scoring:

Land conversion	CSI Score

≥30%	1
20 – 29%	2
10 – 19%	3
5 – 9%	4
0 - 4%	5

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.

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

Rationale: Habitat conditions are the primary determinant of persistence for most populations.[32] Converted lands are known to degrade aquatic habitats.[33;34] Road density is computed for the subwatershed; roads are known to cause sediment-related impacts to stream habitat.[35-37] Lee et al.[36] 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,[38]with all Developed, Pasture/Hay, and Cultivated Crops land cover types considered to be converted lands. Road density was determined using TIGER Census,[39] National Forest roads data,[40-42] and Oregon BLM data.[43]

Indicator: 4. Water quality.

Indicator Scoring:

Miles 303(d) Streams	Agricultural Land	Number Active Mines	Active oil and gas wells	Road mi/ Stream mi	CSI Score
>0	58-100%	≥10	>= 400	0.5 – 1.0	1
	28-57%	7-9	300 – 399	0.25 – 0.49	2
	16-27%	4-6	200 – 299	0.24 - 0.10	3
	6-15%	1-3	50 – 199	0.05 – 0.09	4
	0-5%	0	0 - 49	0 – 0.04	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 all perennial, intermittent, and ephermeral 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. [7;28] Roads along streams can also contribute large amounts of fine sediments that smother benthic invertebrates, embed spawning substrates, and increase turbidity.[44;45]

Data Sources: 303(d) impaired streams from USEPA.[46] The National Land Cover Database[38] 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.[47] Oil and gas wells from USGS. Road density within a 150 ft buffer was computed using TIGER Census,[39] National Forest roads data,[40-42] and Oregon BLM data[43] and the National Hydrography Dataset.[21]

Indicator: 5. Flow regime.

Indicator Scoring:

Number of dams	Miles of canals	Storage (acre-ft)/stream mile	CSI Score
≥5	≥20	≥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

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

Rationale: Natural flow regimes are critical to proper aquatic ecosystem function.[48] Dams, reservoirs, and canals alter flow regimes.[49] Reduced or altered flows reduce the capability of watersheds to support native biodiversity and salmonid populations.

Data Sources: The National Inventory of Dams[50] provided data on dams and their storage capacity and supplemented with additional information for Lakin Dam on the McCloud River. Data on canals were obtained from the National Hydrography Dataset[21] Perennial and intermittent streams were obtained from the National Hydrography Dataset.[21]

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. Invasive 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 conservation easements are not available for conversion.

Rationale: Conversion of land from its natural condition will reduce aquatic habitat quality and availability.[51]

Data Sources: Slope was computed from the National Elevation Dataset.[52] Land cover was determined from the National Land Cover Database,[38] and all land cover classes except developed areas and cultivated crops cover types were considered for potential conversion. Urban areas were determined using 2000 TIGER Census data,[53] roads from TIGER Census[39] and National Forest data,[40;41] and land ownership using Public, Conservation, and Trust Lands v05.2.[54] Conservation easement data from The Pacific Forest Trust and the California Protected Areas Database.[55] Stephen's Meadow easement manually added for Eagle Lake rainbow trout.

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 or catchment available industrial timber production and the percent of subwatershed with hard metal mining claims (assuming an average of 20 acres per claim) outside of protected areas. Protected lands 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: Increased resource development will increase road densities, modify natural hydrology, and increase the likelihood of pollution to aquatic systems. If lands are protected then the watersheds will be less likely to be developed.

Data Sources: The number of mining claims was determined using Bureau of Land Management data,[56] and each claim was assumed to potentially impact 20 acres. Timber management potential identifies productive forest types from the existing vegetation type in Landfire[57] without formal protection as protected areas or Late Successional Reserves under the Northwest Forest Plan.[58] Protected areas data were compiled from the ESRI, Tele Atlas North American / Geographic Data Technology dataset on protected areas,[27] and the U.S. Department of Agriculture, Forest Service's National Inventoried Roadless Areas dataset.[28]

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 or catchment.

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 are likely to reduce habitat suitability for native salmonids and increase the likelihood of invasion by non-native species.[59] 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).[60] Coal leases are mineable types from the Coal Fields of the United States dataset.[61] Geothermal known and closed lease areas and oil and gas leases and agreements from BLM Geocommunicator.*[62] Potential dam sites are based on Idaho National

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

Laboratory (INL) hydropower potential data.[63] Protected areas data were compiled from the ESRI, Tele Atlas North American / Geographic Data Technology dataset on protected areas[27] and the U.S. Department of Agriculture, Forest Service's National Inventoried Roadless Areas dataset.[28] Goose Lake redband trout also reports miles of proposed energy transmission corridor by subwatershed.[64] This value is not considered in the scoring.

Indicator: 4. Climate change.

Indicator Scoring:

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

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

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.

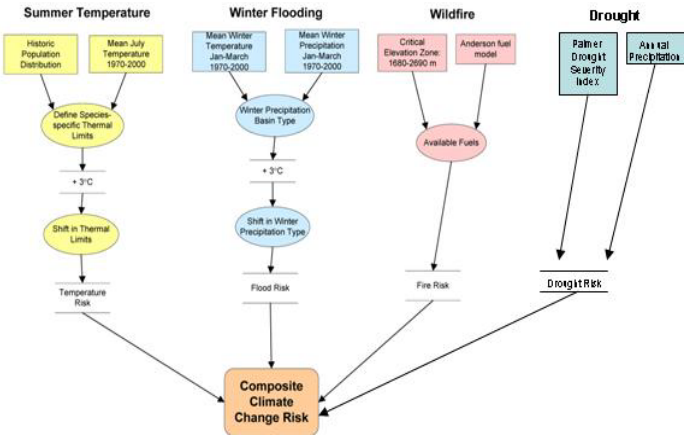
Communitization: Combining smaller federal tracts to meet the necessary minimum acreage required by the BLM (for spacing purposes).

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 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. Droughts occur as a result of increases in water-loss from higher temperatures and less 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.[65;66] 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.[67] These risks are further discussed by Williams et al.[65]

Data Sources: Temperature and precipitation data were obtained from the PRISM Group.[68] Elevation data were obtained from the National Elevation Dataset[52], and LANDFIRE data for the Anderson Fire Behavior Fuel Model 13[57] was used as input for wildfire risk. McCloud redband thresholds: low < 19 C, high > 21 C. Paiute cutthroat threshold: low < 18 C. Eagle Lake rainbow: low < 20 C, high > 22 C. Goose Lake redband: low < 20 C, high > 22 C.

Indicator: 5. Introduced species.

Indicator Scoring:

Present in basin	Present in catchment/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 a subbasin and subwatershed or catchment 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.[69] 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.[70]

Data Sources: Information on McCloud introduced species from the Draft Conservation Agreement;[26] Paiute cutthroat trout from USFWS;[2;3] Eagle Lake rainbow trout from Pine Creek RMPG;[4] and Goose Lake from ODFW[23] and Upper Pit River Watershed Assessment.[71] Road density calculated for the Watershed Conditions indicator also informs the introduced species indicator.

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