Conservation Success Index: Eagle Lake Rainbow Trout

ONCORHYNCHUS MYKISS AQUILARUM

Rev. 1.0 - 6/2009

SPECIES SUMMARY

Eagle Lake rainbow trout are a long-lived, adfluvial subspecies of rainbow trout found in Eagle Lake and its tributary streams on the east side of the Sierra Nevadas in Lassen County, California. First described by J. O. Snyder in 1917, Eagle Lake rainbow trout were initially thought to be the hybrid offspring of Lahontan cutthroat and introduced rainbow trout. Recent genetic studies have shown the species to be a distinct form of rainbow trout that colonized Eagle Lake through an ancient connection to the Feather River and the larger Sacramento River system.

Eagle Lake rainbow trout are uniquely adapted to the conditions in Eagle Lake, a 3 mi^2 alkaline (pH 8 – 9) lake seasonally connected to its source tributaries only during the late spring snowmelt. Historically, long-lived and large adults – up to 11 years old and 24 inches long – ran up the largest tributaries to reproduce in the spring-fed headwater streams. The perennial waters in the meadows of Upper Pine Creek, the largest tributary and primary spawning habitat, are 30 miles from Eagle Lake. Additional reproduction areas may have existed in other perennial stretches of Pine Creek and in Merrill Creek, Little Merrill Creek, and Papoose Creek. After one year in the stream habitats, the juveniles migrated down to Eagle Lake. As the fish grow, their diet shifts from invertebrates to the tui chubs that abound in the lake.

As the area around Eagle Lake was settled in the late 1800s, the fish became vulnerable to overexploitation, particularly in the spring, when adults assembled for spawning runs at the mouth of Pine Creek. The fishery was further stressed as grazing, logging, and road and railroad development in the basin degraded habitat and blocked access to the spawning areas. The species was saved from extinction only because California Fish and Game initiated a hatchery program from the few remaining fish in the 1950s. Today a popular sport fishery is maintained by the hatchery program, but minimal opportunity for natural reproduction occurs, as the hatchery's fish weir and spawner trap blocks passage at the mouth of Pine Creek.

In 1987, the Pine Creek Coordinated Resources Management Planning group was organized to build upon earlier restoration activities with the goal of reestablishing naturally reproducing populations of Eagle Lake rainbow trout. The group has guided a number of positive changes in the basin, including grazing closures, road closure and rehabilitation, culvert replacement, diversion removal, and channel restoration. Further activities are described in the 2007 Conservation Plan for Pine Creek and Eagle Lake Rainbow Trout. Based on recent discoveries of young rainbow trout in the headwaters, ongoing research is tracking the ability of adult fish to again reach and spawn in Upper Pine Creek.

Nonetheless, the legacies of habitat degradation - loss of meadow habitats and altered hydrology - and the complete dependence on and potentially pernicious effects of the hatchery still threaten the survival of Eagle Lake rainbow trout. Other threats include competition with introduced brook trout and natural factors that threaten any species with a limited distribution.

Our CSI analysis incorporated data from the 2008 *SOS: California's Native Fish Crisis* report, the 2007 Conservation Plan for Pine Creek and Eagle Lake Rainbow Trout, and information from Teresa Pustejovsky (former Lassen National Forest fisheries biologist), Lisa Thompson (UC – Davis Cooperative Extension), and Paul Divine (California Department of Fish and Game). We are grateful for these contributions to our understanding of this species. A complete list of data sources is provided at the end of this document. This analysis for Eagle Lake rainbow trout considered 2008 adult telemetry and juvenile sampling information and is summarized at the catchment scale (500 – 25,000 acres), a finer scale than the typical CSI.

Key CSI Findings

- The Eagle Lake rainbow trout occupies Eagle Lake and 12.5 miles of stream in the headwaters of Pine Creek. Perennial streams that may have historically supported populations occur in Little Merrill Creek, Merrill Creek, Papoose Creek, Martin Creek, and Middle Harvey Valley.
- Two population groups exist – a hatchery-dependent lake population and low densities of escaped and experimental adults and their offspring in the headwaters of Pine Creek.
- High population integrity scores related to genetic purity and life history diversity are mitigated by the selection effects and disease risks associated with hatchery management.
- Habitat integrity scores are lowest in catchments with high road densities and high mileage of roads that cross or parallel riparian areas.
- Eagle Lake rainbow trout are at moderate risk to the future threats of forest management, wind development, land conversion, and drought and temperature changes related to climate change.
- Introduced species and changes in fire regime and winter flooding associated with potential climate change represent the largest threat to the future security of the species.

Our CSI analysis shows that the range-wide conditions related to species distribution are high for Eagle Lake rainbow trout. Though adults only rarely reach the headwaters and juveniles persist at low densities, the species occupies a stream network and catchment area equivalent to half the size and extent of its historic distribution. Unoccupied historic catchments include Upper Pine Creek below Highway 44, Little Merrill Creek, Merrill Creek, Papoose Creek, Martin Creek, and Middle Harvey Valley. All streams in the current distribution are second order or higher, with the exception of Stephen's Meadow and the western-most Pine Creek headwaters, suggesting that the small populations may persist in relatively stable environmental conditions.

Most population integrity scores for Eagle Lake rainbow trout are moderate. All populations of the species except the lake population persist at low densities and in precariously short segments of stream. Moderately high genetic purity scores for all populations reflect the lack of hybridizing species in the basin, but also the possible degrading effect of hatchery selection of adults for size and spawning timing at the mouth of Pine Creek. The possibility that the hatchery could introduce pathogens into the system makes all populations vulnerable to disease. Given the persistence of the adfluvial form, all populations score high for life history diversity. Based on the Hilderbrand and Kershner criteria, only the lake population in the Eagle Lake catchment is assumed to meet the desired persistence threshold.

Overall habitat integrity scores are moderate. The primary source of habitat degradation in the Eagle Lake basin mapped within the CSI is the extensive road network. Nearly half of the catchments in the basin have at least ¼ mile of road in the riparian zone for every mile of stream. Those catchments and

Eagle Lake, which is a 303(d) listed water body for metals, organic enrichment, and low dissolved oxygen, have low water quality scores. A small portion of the Pine Creek headwaters catchment contains land with a formal protection status; all other catchments score low for land stewardship. Because of seasonal disconnections between the headwaters of Pine Creek and Eagle Lake, the basin has limited inherent connectivity. Recent restoration activities have removed the majority of barriers in the headwaters; the primary remaining anthropogenic barriers to fish passage are the hatchery collection weir at the mouth of Pine Creek and the "prevent loss" barriers at the mouths of Little Merrill, Merrill, and Papoose Creeks. Accordingly, watershed connectivity scores for these catchments are lower. The CSI lacks a specific indicator for addressing instream habitat conditions. The legacy effects of over a century of logging and cattle and sheep grazing may not be fully reflected in the habitat integrity score.

The CSI analysis of future security suggests the Eagle Lake rainbow trout is at moderate risk. Conversion risk is greatest in the flat private lands in the Little Merrill and Merrill Creek catchments. The possibility of additional resource extraction – primarily related to forest management – is greatest in the higher elevation, wetter catchments in the western two-thirds of the basin. Most catchments have minimal risk of energy development, although eleven catchments have between 1 - 25% of their surface area identified as viable wind resource development areas. Geothermal resources also exist in the catchments surrounding Eagle Lake. The primary threat to future security comes from non-native brook trout that remain present and abundant in all perennial streams in the basin. Eagle Lake has an equally low score related to introduced species due to the ease with which non-native species, from bass to bullhead to mussels, could be introduced to potentially devastating consequence.

The CSI considers the effects of a + 3°C climate change scenario on the species. In all catchments, our analysis suggests that the Eagle Lake rainbow trout is at high to moderate risk to increased winter flooding associated with rain-on-snow events, high risk to the effects of altered fire regimes associated with earlier spring warming in mid-elevation zones (except in the catchments around Eagle Lake, where risk is low and moderate), and moderate risk to drought (except in the highest elevation Upper Pine Creek catchments, where risk is low). Based on the current distribution of the species relative to air temperature, the species is at low to moderate risk to increased summer temperatures. Because Eagle Lake rainbow trout have historically persisted through periods of high temperatures in Eagle Lake, the species may be uniquely tolerant of higher temperatures.

Total CSI scores and conservation strategies are consistent with the current management plan for Eagle Lake rainbow trout. Populations in Eagle Lake have the highest overall CSI score and protecting this population is an appropriate priority. Key spawning areas in Upper Pine Creek - especially in the Bogart Springs, Stephen's Meadow, and Upper Pine Creek (Leaky Louie's) catchments – warrant continued restoration work to bolster populations through improvements to habitat and fish access. The high road to riparian mileage ratio for many catchments – again, especially in Bogart Springs and Upper Pine Creek - indicates that decommissioning and/or relocating roads away from riparian areas should be a high restoration priority, particularly in meadows, where roads can alter hydrologic flow. Efforts to increase the water storage capacity of the entire Upper Pine Creek area through meadow restoration will increase the amount of perennial stream habitat available to support juvenile fish, especially in the Upper Pine Creek catchment at Highway 44. Eliminating introduced brook trout will also allow the habitat to support greater densities of juvenile fish and reduce one of the largest stressors to the future security of species.

Trout Unlimited strongly supports the continued restoration efforts of the Pine Creek Coordinated Resources Management Planning Group and California Department of Fish and Game, the U.S. Forest

Service, the U. S. Fish and Wildlife Service, University of California - Davis, and California Trout. These entities have made great strides in the conservation of Eagle Lake rainbow trout since coordinated efforts began in the late 1980s. Consistent with CSI findings related to habitat and population integrity, restoring habitat in Upper Pine Creek as a means to promote naturally reproducing populations should remain a top priority. Moving towards a naturally reproducing fishery, providing large interconnected habitats, and bolstering population size will ensure the persistence of the subspecies to both natural and anthropogenic disturbances.

Prepared by Kurt Fesenmyer, TU, 3/20/2009

Sources:

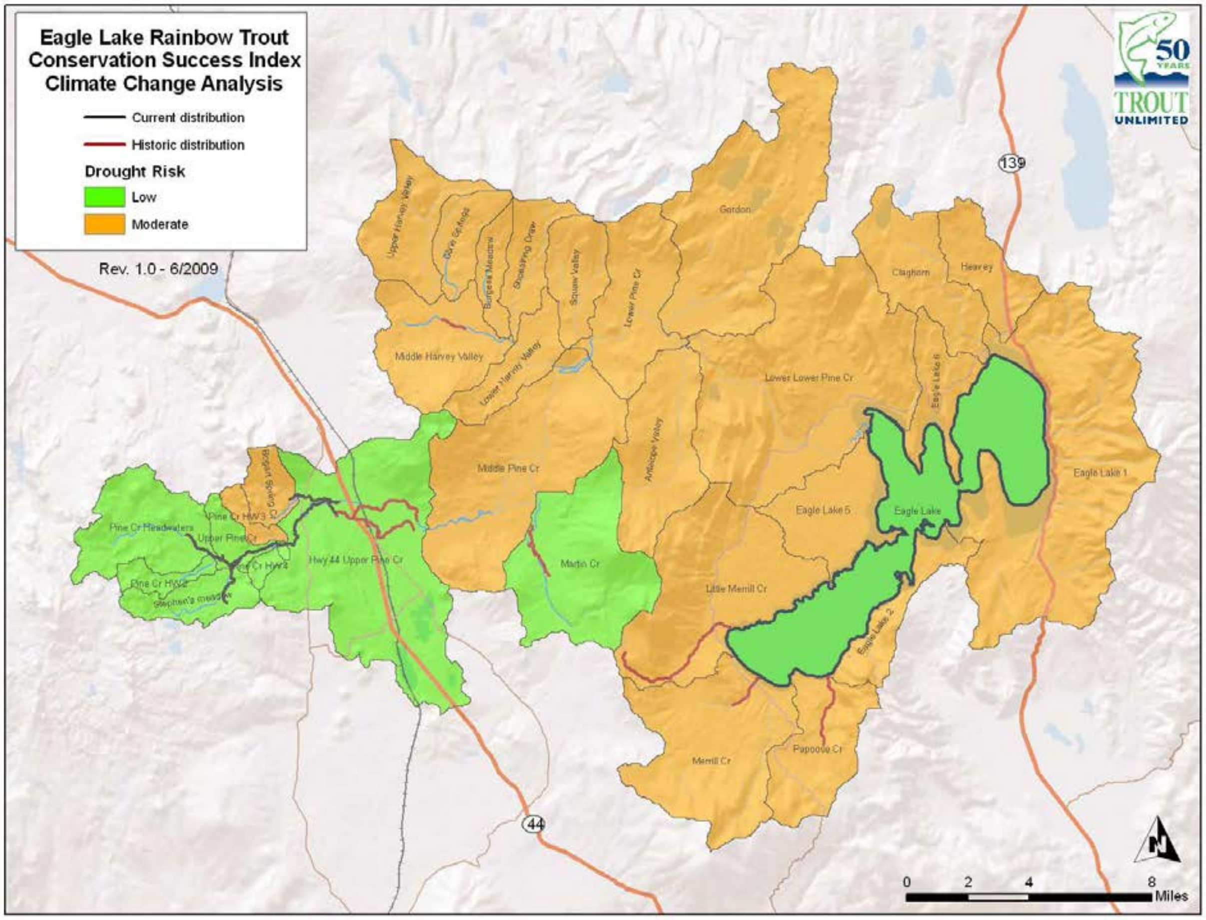
Moyle, Peter B., Israel, Joshua A., and Purdy, Sabra, E. Salmon, Steelhead, and Trout in California: Status of an Emblematic Fauna, a report commissioned by California Trout, 2008. UC Davis Center for Watershed Sciences, 2008.

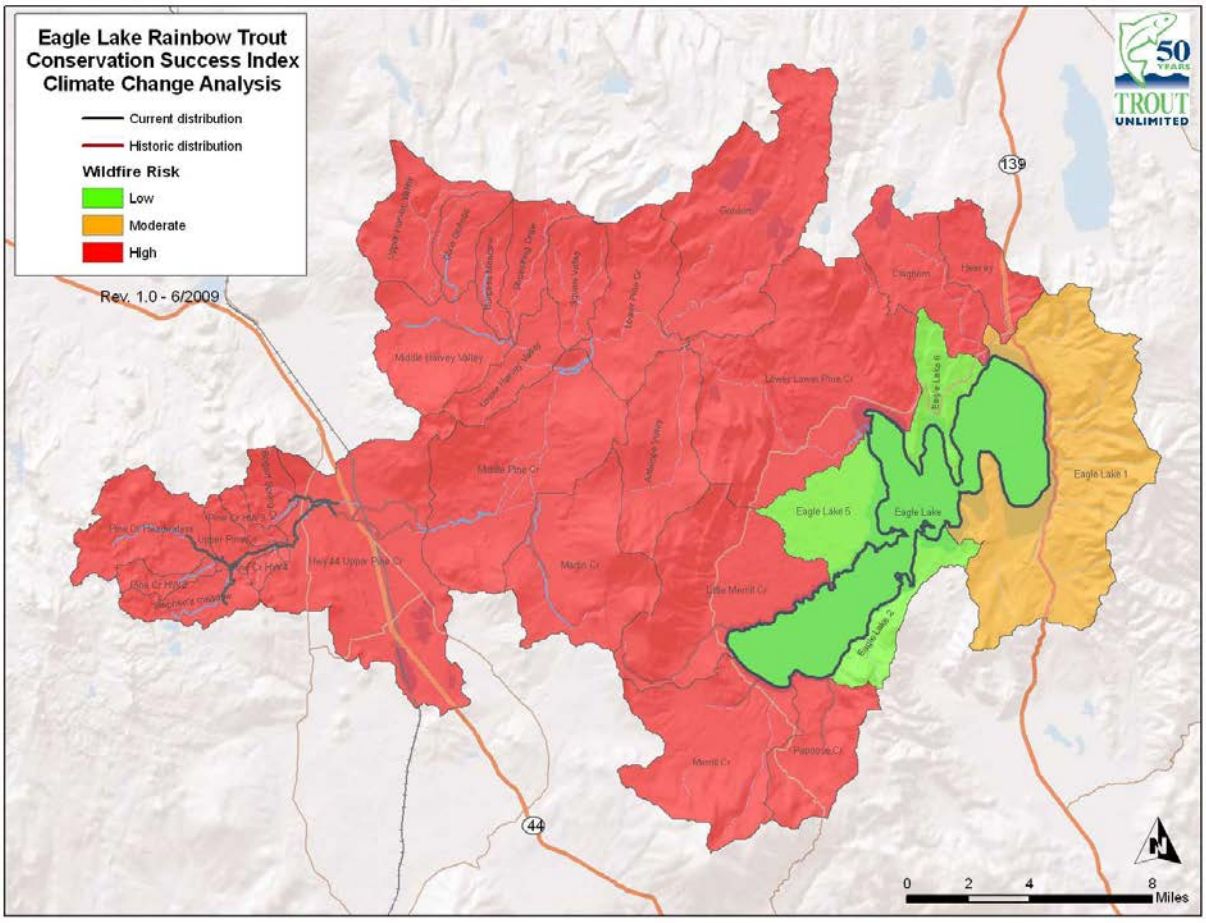
Pustejovsky, Teresa. A Conservation Plan for Pine Creek and Eagle Lake Rainbow Trout. Lassen County Resource Advisory Council, 2007.

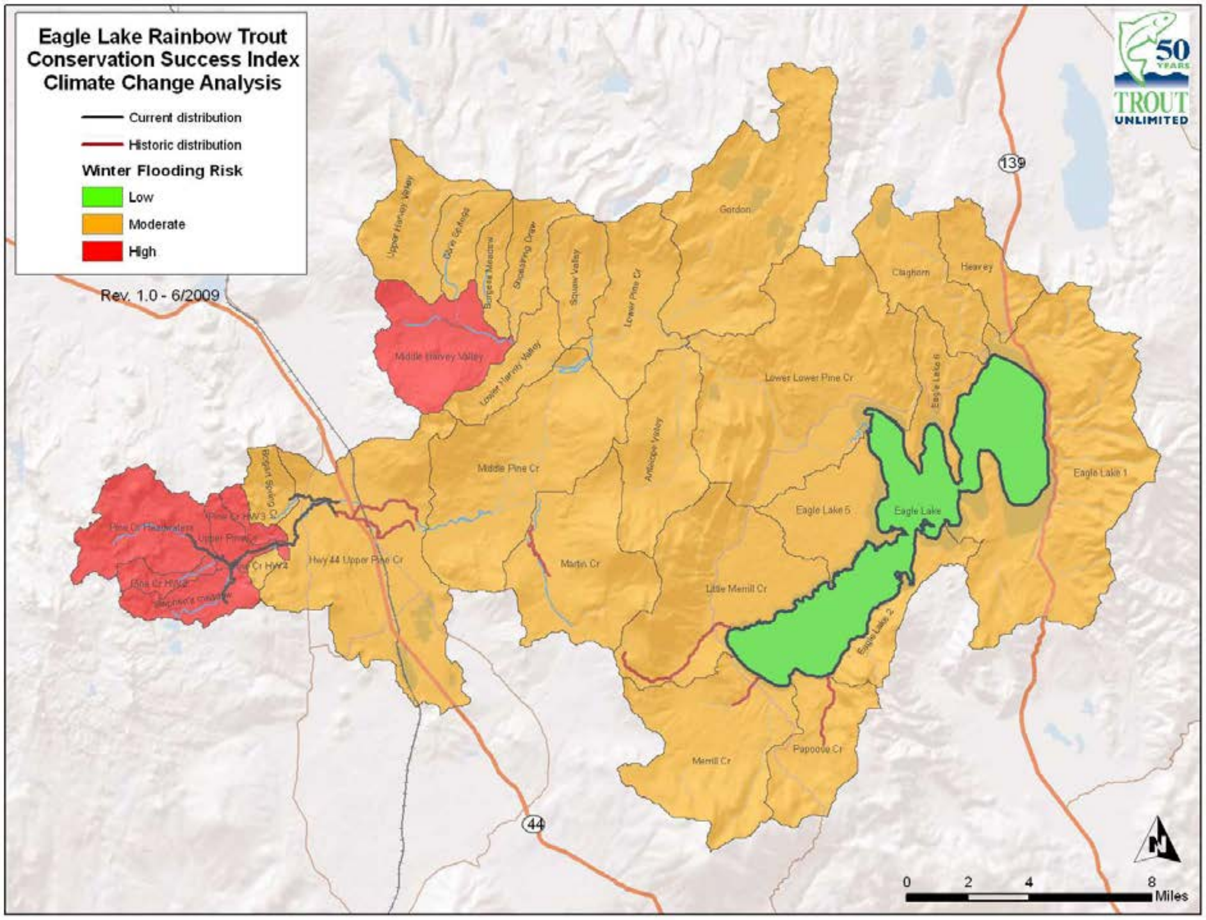
Table 1. CSI scoring results for Eagle Lake rainbow trout. All indicators are scored from 1 (poorest) to 5 (best): See framework documentation for details.

		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	1	5	6
	Percent subbasins (4th) occupied	0	0	0	0	6	6
	Percent subwatersheds (6th) occupied	0	0	6	0	0	6
	Percent habitat by stream order occupied	0	0	0	0	6	6
	Percent historic lake area occupied	0	0	0	0	6	6
Population Integrity	Population Density	0	5	0	0	1	6
	Population Extent	0	0	5	0	1	6
	Genetic Purity	0	0	0	6	0	6
	Disease vulnerability	0	0	6	0	0	6
	Life history diversity	0	0	0	0	6	6

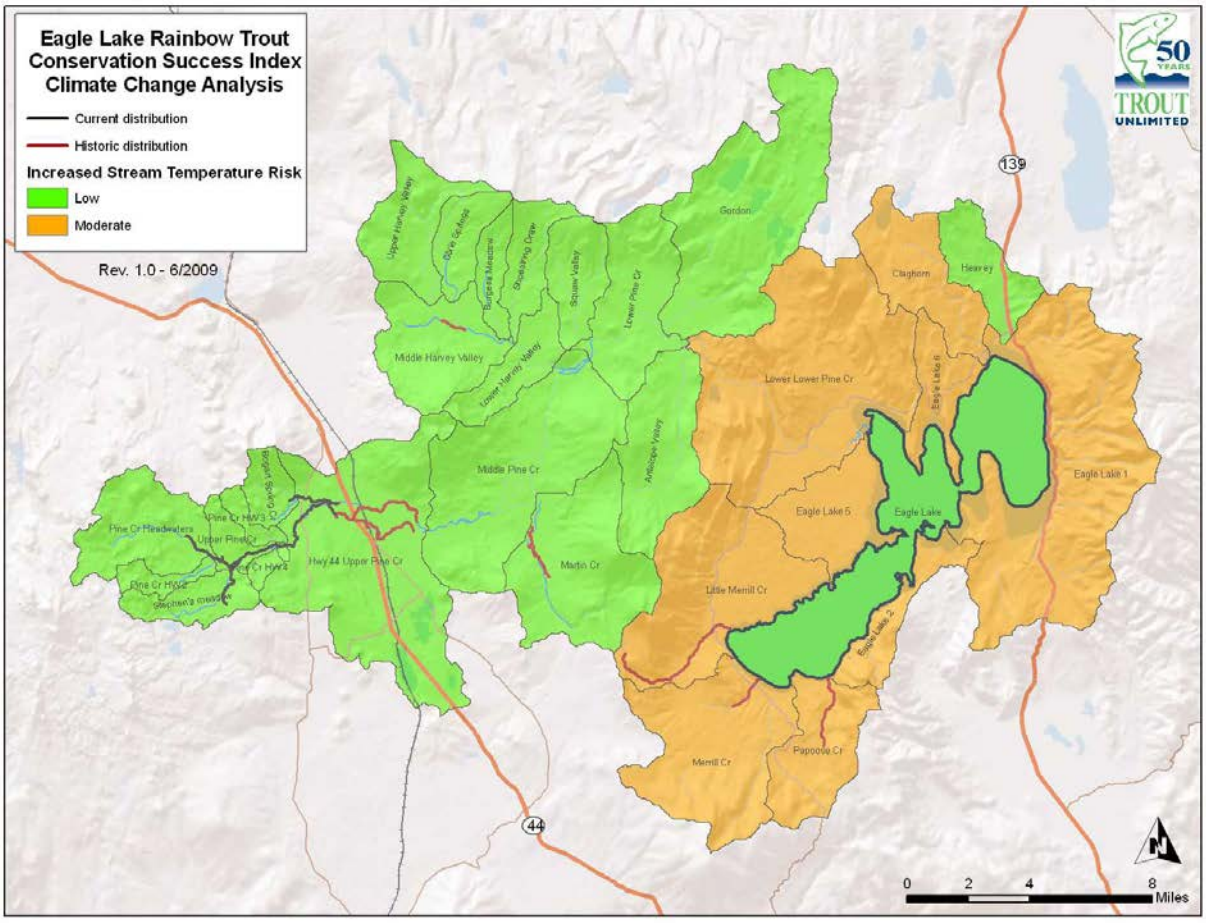
Habitat Integrity	Land Stewardship	29	0	1	0	1	31
	Watershed connectivity	0	0	1	3	27	31
	Watershed conditions	0	0	0	26	5	31
	Water quality	3	10	8	5	5	31
	Flow regime	0	0	0	0	31	31
Future Security	Land conversion	0	1	0	6	24	31
	Resource extraction	7	4	10	7	3	31
	Energy development	0	3	0	5	23	31
	Climate change	6	20	4	0	1	31
	Introduced species	31	0	0	0	0	31

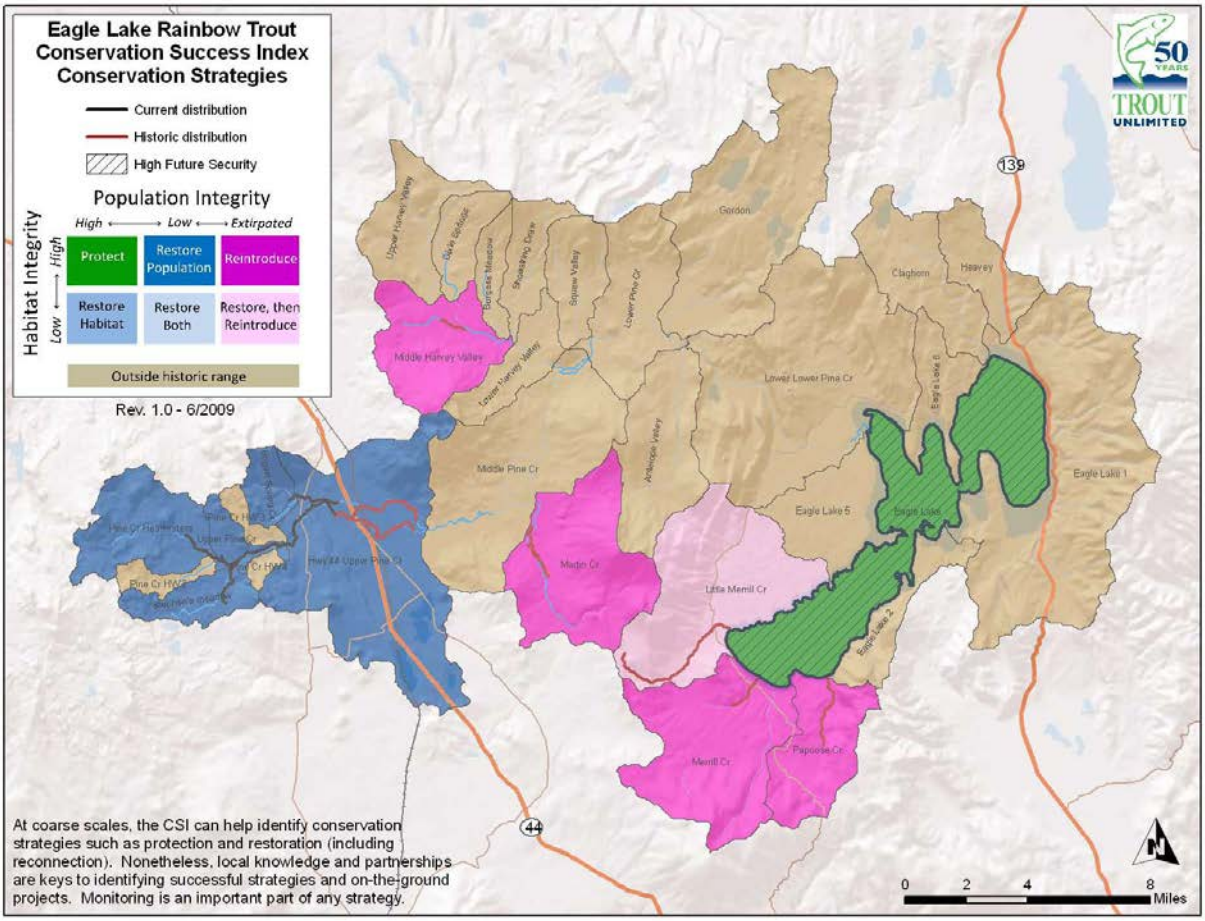

Eagle Lake Rainbow Trout
Conservation Success Index
Climate Change Analysis
Current distribution
Historic distribution
Drought Risk
Low
Moderate
Rev. 1.0 - 6/2009
50 YEARS
TROUT UNLIMITED
139
44
0 2 4 8 Miles


Eagle Lake Rainbow Trout
Conservation Success Index
Climate Change Analysis
Current distribution
Historic distribution
Wildfire Risk
Low
Moderate
High
Rev. 1.0 - 6/2009
50 YEARS
TROUT
UNLIMITED
139
44
Eagle Lake 5
Eagle Lake
Eagle Lake 1
Eagle Lake 6
Eagle Lake 2
Middle Harvey Valley
Lower Lower Pine Cr
Middle Pine Cr
Upper Pine Cr
Hwy 44 Upper Pine Cr
Maple Cr
Little Merrill Cr
Merrill Cr
Papoose Cr
Gordon
Elephant
Bear Ivy
0
2
4
8
Miles



Eagle Lake Rainbow Trout
Conservation Success Index
Climate Change Analysis
Current distribution
Historic distribution
Winter Flooding Risk
Low
Moderate
High
Rev. 1.0 - 6/2009
50 YEARS
TROUT UNLIMITED
Middle Harvey Valley
Gordon
Claghorn
Heavey
Lower Lower Pine Cr
Middle Pine Cr
Eagle Lake 1
Eagle Lake 5
Eagle Lake
Hwy 44 Upper Pine Cr
Martin Cr
Little Merrill Cr
Merrill Cr
Papoose Cr
139
44
0 2 4 8
Miles


Eagle Lake Rainbow Trout
Conservation Success Index
Climate Change Analysis
Current distribution
Historic distribution
Increased Stream Temperature Risk
Low
Moderate
Rev. 1.0 - 6/2009
50 YEARS
TROUT UNLIMITED
Gordon
Claghorn
Hearey
Lower Lower Pine Cr
Eagle Lake 6
Eagle Lake 1
Eagle Lake
Middle Pine Cr
Middle Harvey Valley
Lower Harvey Valley
Martin Cr
Little Merrill Cr
Merrill Cr
Papoose Cr
Pine Cr Headwaters
Upper Pine Cr
Hwy 44 Upper Pine Cr
Pine Cr HW3
Pine Cr HW2
Stephen's crossing
139
44
0 2 4 8
Miles


Eagle Lake Rainbow Trout
Conservation Success Index
Conservation Strategies
Current distribution
Historic distribution
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
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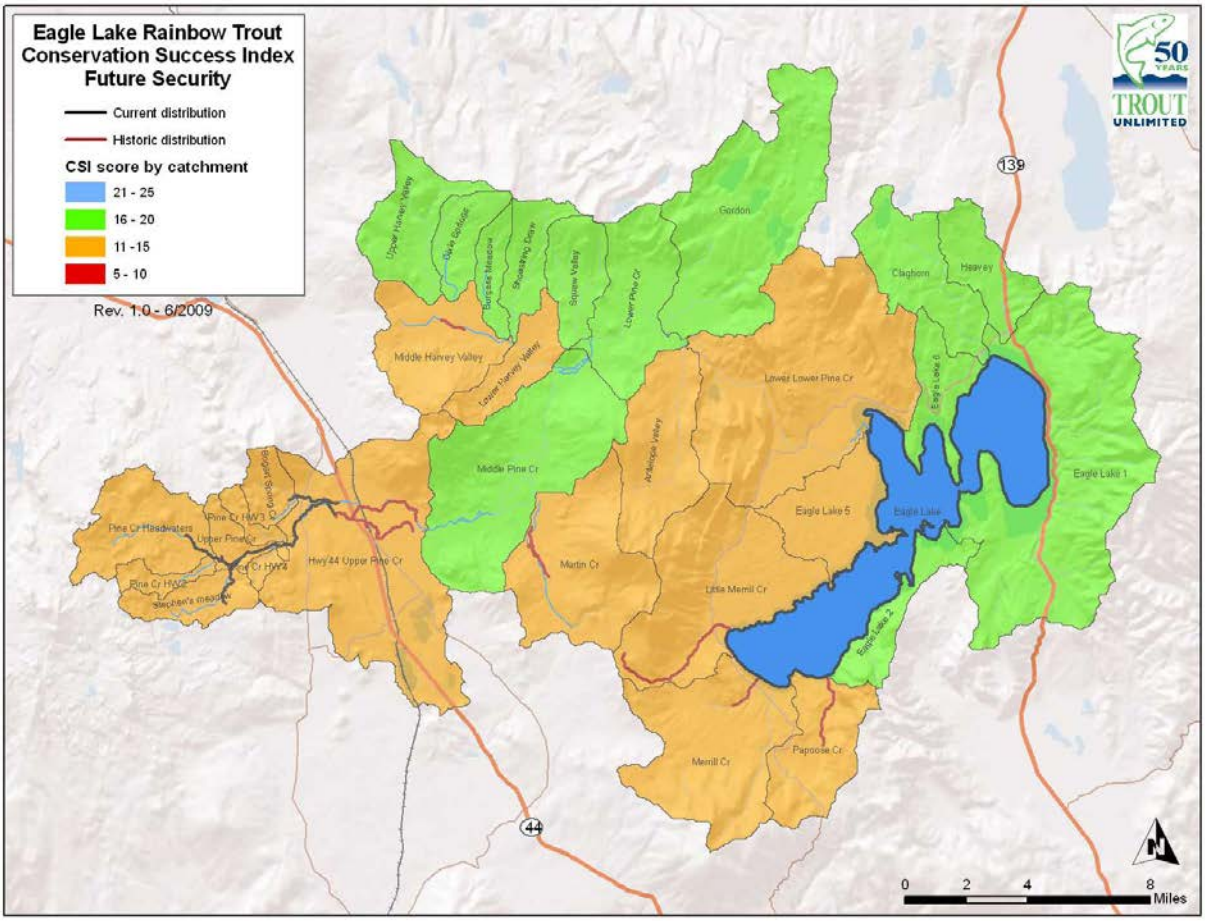
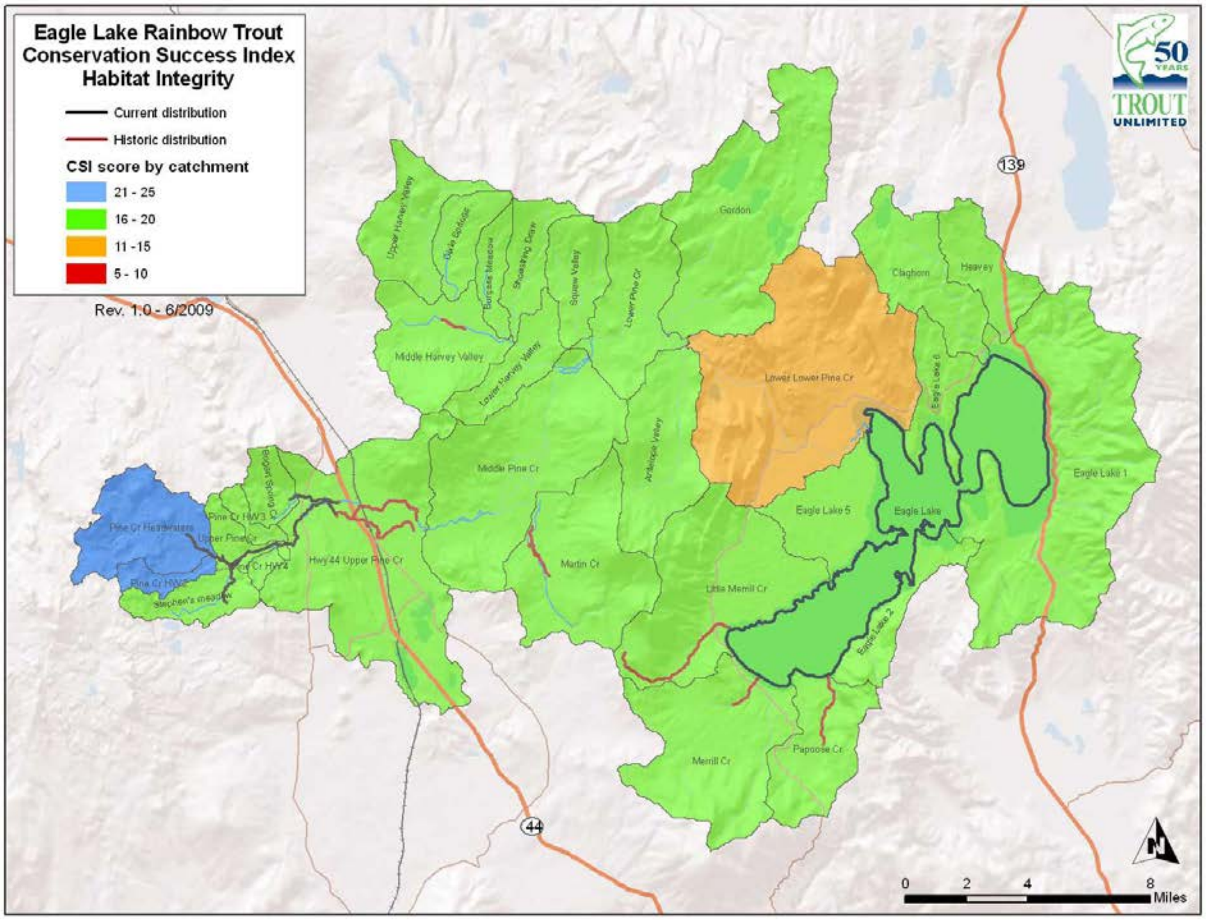
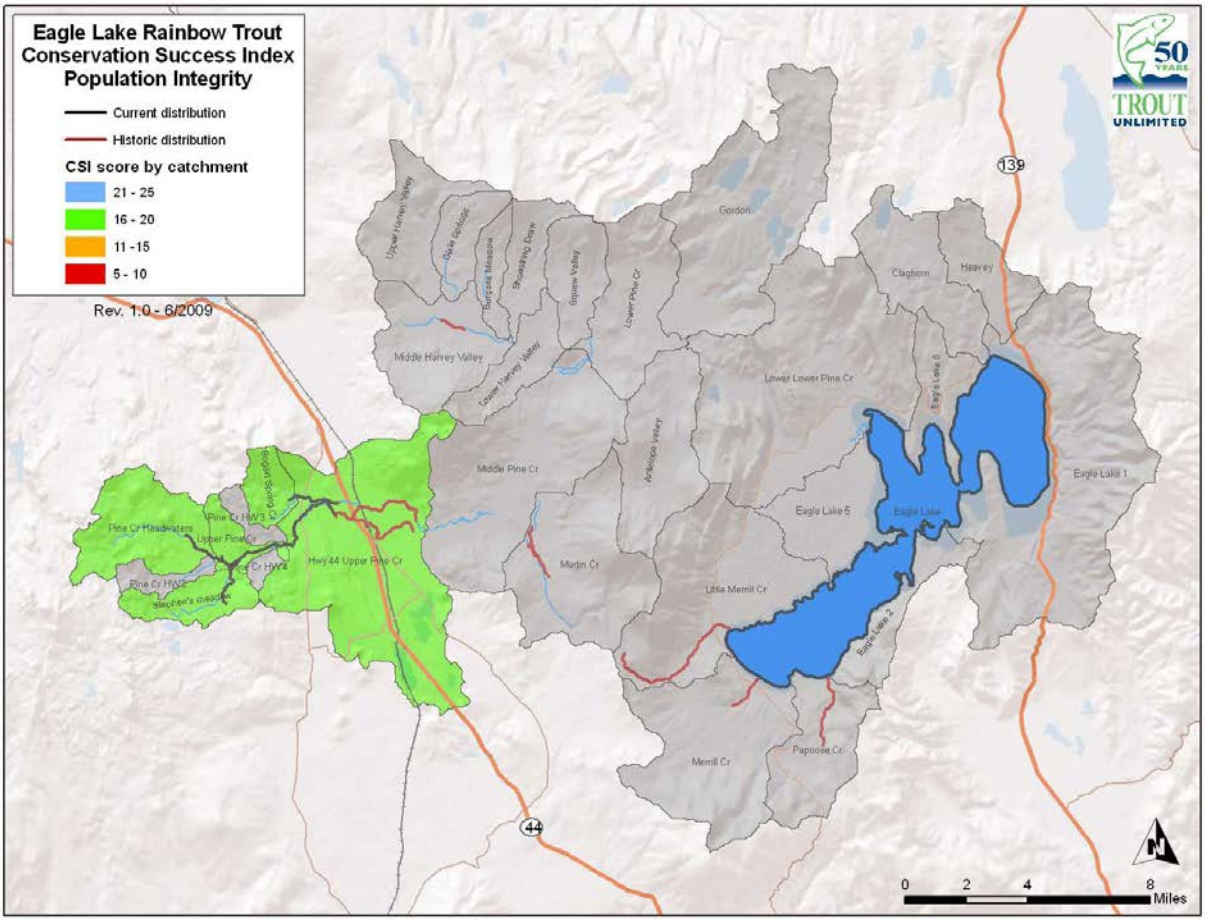
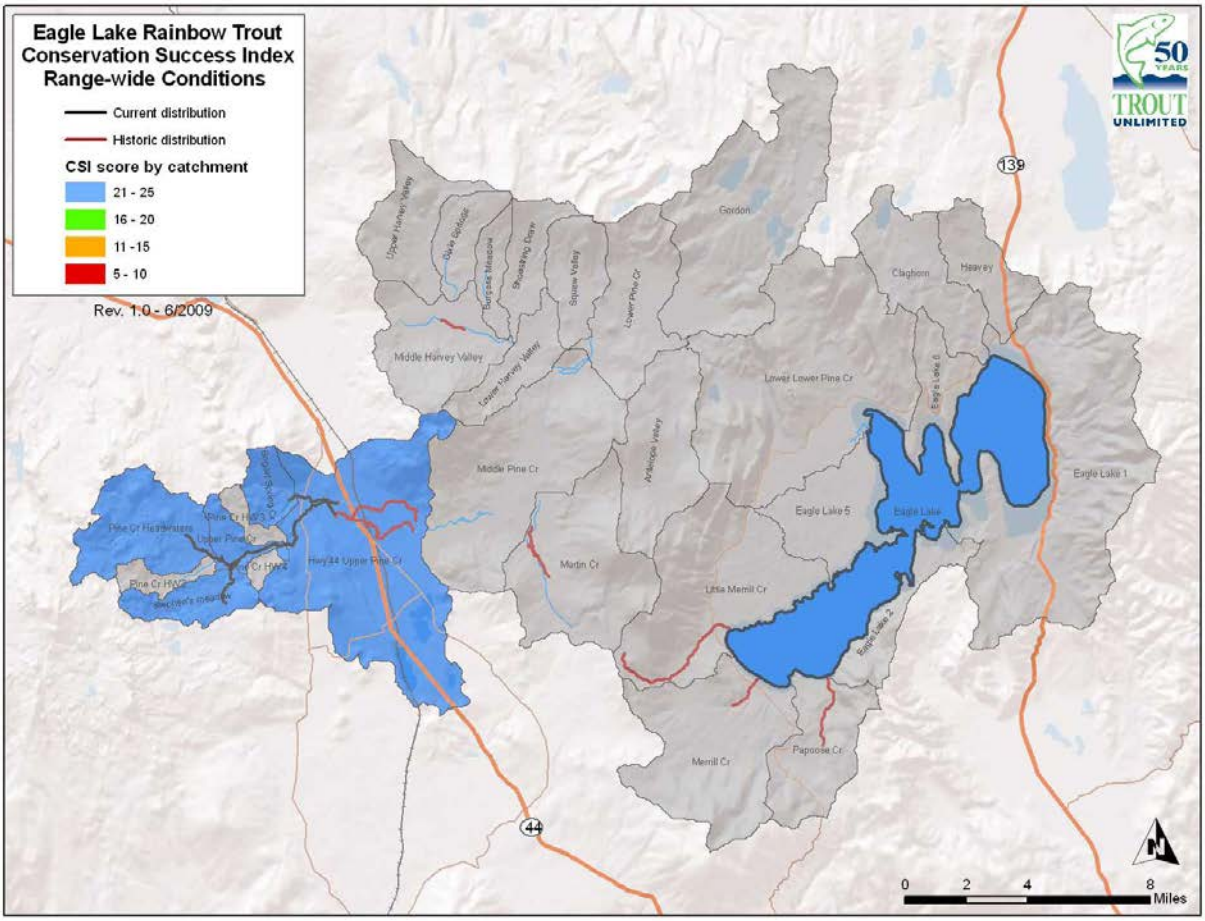
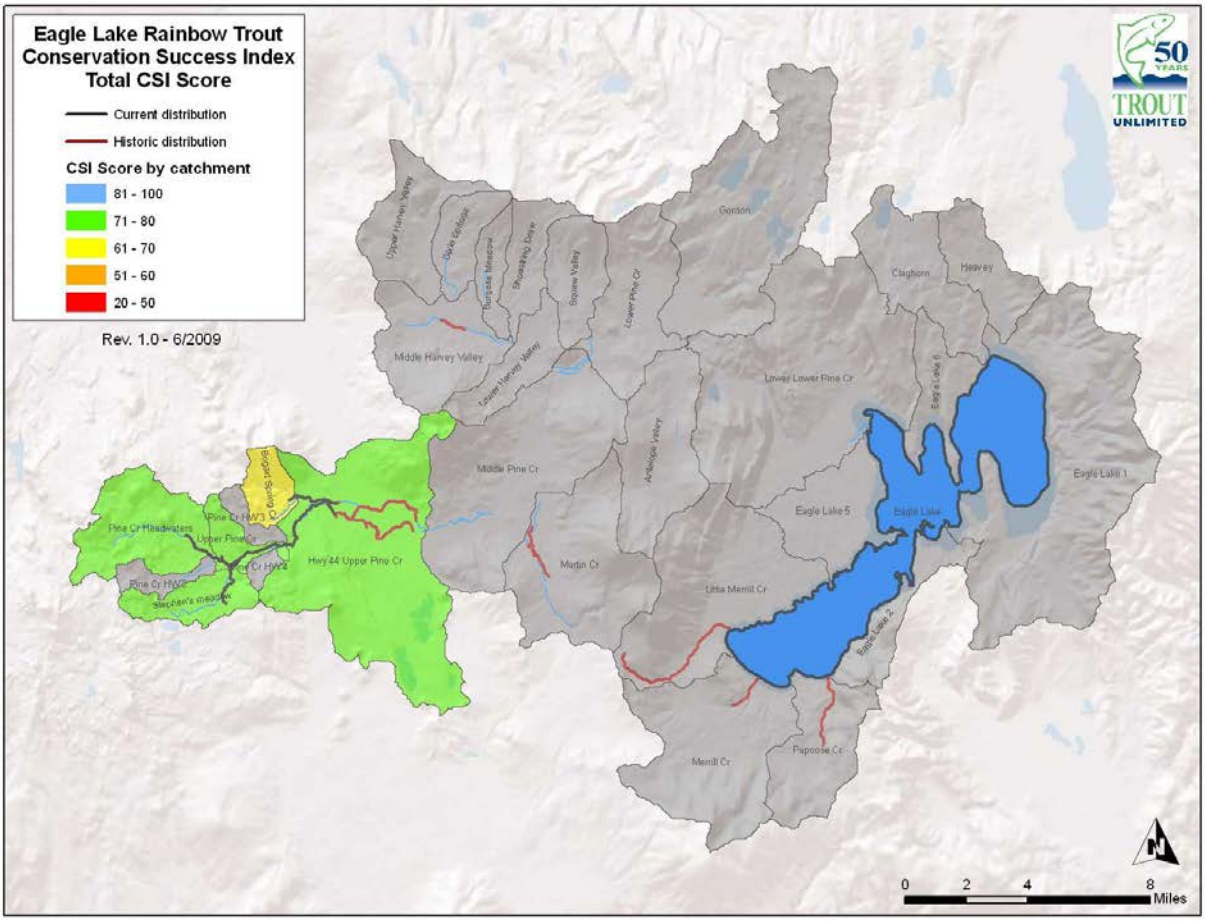
At coarse scales, the CSI can help identify conservation strategies such as protection and restoration (including reconnection). Nonetheless, local knowledge and partnerships are keys to identifying successful strategies and on-the-ground projects. Monitoring is an important part of any strategy.
50 YEARS
TROUT UNLIMITED
139
44
Gordon
Claghorn
Harvey
Middle Harvey Valley
Lower Lower Pine Cr
Middle Pine Cr
Eagle Lake 5
Eagle Lake
Eagle Lake 1
Madn Cr
Little Merrill Cr
Merrill Cr
Papoose Cr
0
2
4
8
Miles


Eagle Lake Rainbow Trout Conservation Success Index Future Security
Current distribution
Historic distribution
CSI score by catchment
21 - 25
16 - 20
11 - 15
5 - 10
Rev. 1.0 - 6/2009
50 YEARS
TROUT UNLIMITED
139
44
Gordon
Claghorn
Harvey
Middle Harvey Valley
Lower Harvey Valley
Squaw Valley
Lower Pine Cr
Lower Lower Pine Cr
Middle Pine Cr
Antelope Valley
Eagle Lake 6
Eagle Lake 1
Eagle Lake 5
Eagle Lake
Martin Cr
Little Merrill Cr
Merrill Cr
Papoose Cr
Pine Cr Headwaters
Upper Pine Cr
Pine Cr HWY 3
Pine Cr HWY 2
Hwy 44 Upper Pine Cr
0 2 4 8
Miles


Eagle Lake Rainbow Trout
Conservation Success Index
Habitat Integrity
Current distribution
Historic distribution
CSI score by catchment
21 - 25
16 - 20
11 - 15
5 - 10
Rev. 1.0 - 6/2009
TROUT UNLIMITED
50 YEARS
Gordon
Clagthorn
Heavey
Middle Harvey Valley
Lower Lower Pine Cr
Middle Pine Cr
Eagle Lake 1
Eagle Lake 5
Eagle Lake
Martin Cr
Hwy 44 Upper Pine Cr
Little Merrill Cr
Merrill Cr
Papoose Cr
139
44
0
2
4
8
Miles


Eagle Lake Rainbow Trout Conservation Success Index Population Integrity
Current distribution
Historic distribution
CSI score by catchment
21 - 25
16 - 20
11 - 15
5 - 10
Rev. 1.0 - 6/2009
50 YEARS
TROUT UNLIMITED
139
44
Gordon
Claghorn
Heavey
Middle Harvey Valley
Lower Lower Pine Cr
Middle Pine Cr
Eagle Lake 5
Eagle Lake
Eagle Lake 1
Little Merrill Cr
Merrill Cr
Papoose Cr
Pine Cr Headwaters
Pine Cr HWY 3
Upper Pine Cr
Pine Cr HWY 4
Pine Cr HWY 5
Hwy 44 Upper Pine Cr
Stephen's shoulder
0 2 4 8
Miles


Eagle Lake Rainbow Trout Conservation Success Index Range-wide Conditions
Current distribution
Historic distribution
CSI score by catchment
21 - 25
16 - 20
11 - 15
5 - 10
Rev. 1.0 - 6/2009
50 YEARS
TROUT UNLIMITED
Gordon
Claghorn
Harvey
Middle Harvey Valley
Lower Lower Pine Cr
Middle Pine Cr
Eagle Lake 1
Eagle Lake 5
Eagle Lake
Little Merrill Cr
Merrill Cr
Papoose Cr
Pine Cr Headwaters
Upper Pine Cr
Hwy 44 Upper Pine Cr
139
44
0 2 4 8
Miles


Eagle Lake Rainbow Trout Conservation Success Index Total CSI Score
Current distribution
Historic distribution
CSI Score by catchment
81 - 100
71 - 80
61 - 70
51 - 60
20 - 50
Rev. 1.0 - 6/2009
50 YEARS
TROUT UNLIMITED
Gordon
Claghorn
Heavey
Middle Harvey Valley
Lower Lower Pine Cr
Middle Pine Cr
Eagle Lake 5
Eagle Lake
Eagle Lake 1
Marlin Cr
Little Merrill Cr
Merrill Cr
Papoose Cr
Pine Cr Headwaters
Pine Cr HWY 3
Upper Pine Cr
Pine Cr HWY 4
Pine Cr HWY 5
Hwy 44 Upper Pine Cr
0
2
4
8
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.

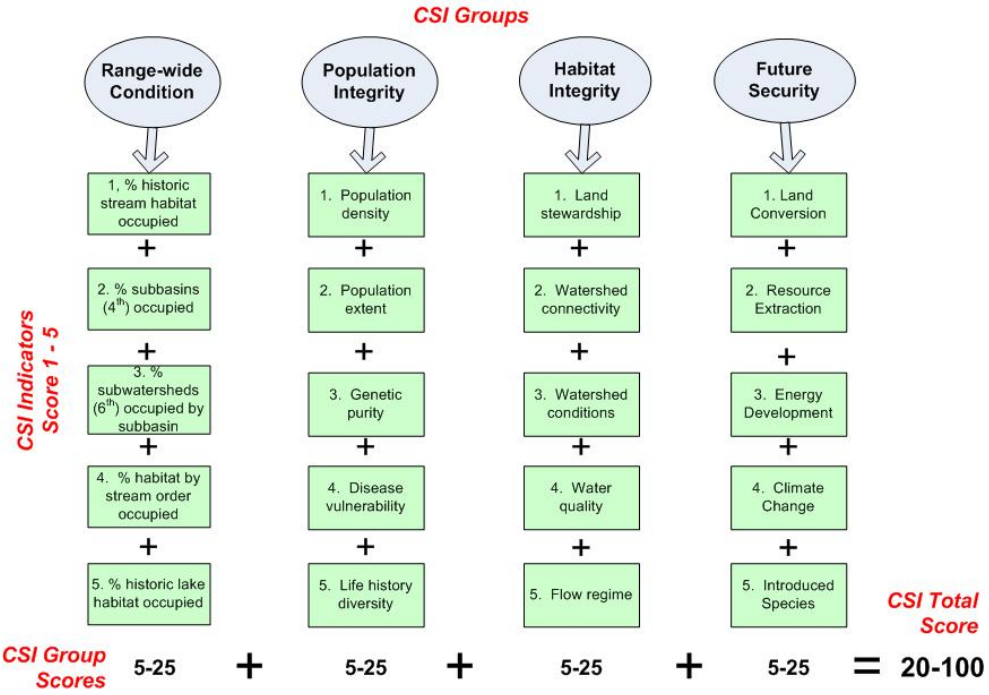


Figure 1. Each subwatershed or catchment is scored from 1 to 5 using 20 indicators within four main groups. Indicator scores are added per group to obtain an overall group score. Group scores are then added to obtain a composite CSI score for each subwatershed or catchment.

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.

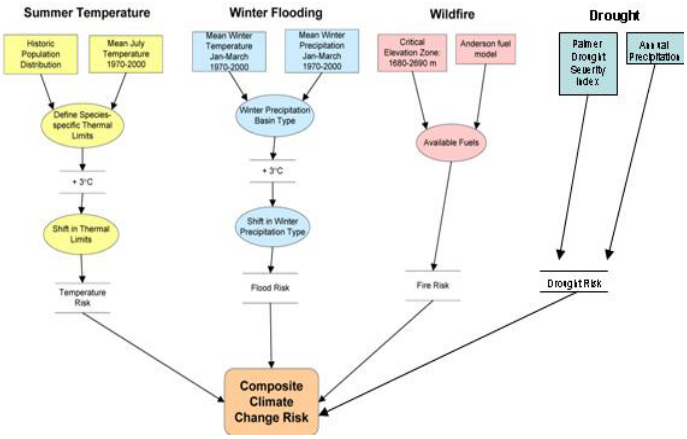
Communitization: Combining smaller federal tracts to meet the necessary minimum acreage required by the BLM (for spacing purposes).

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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