Conservation Success Index: Big Lost Mountain Whitefish

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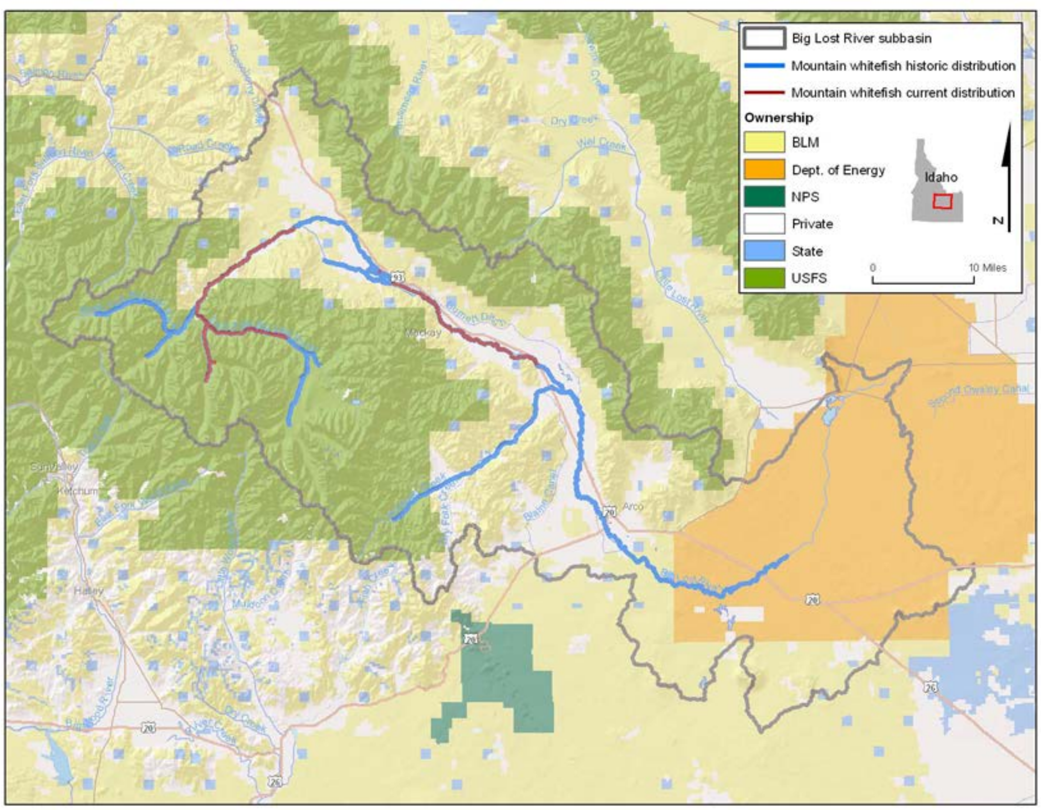
SPECIES SUMMARY

Idaho has several sinks river drainages that infiltrate completely into the porous volcanic geology of the northern Snake River Plain and, hence, are disconnected from other surface waters. The Big Lost River, the largest of the sinks drainages, has lacked a surface connection to other rivers for at least 10,000 years. Although the Big Lost River formally terminates at the Big Lost River Sinks, the river also loses water at several natural sinks that form a complex subsurface and groundwater system throughout the valley.

The mountain whitefish *Prosopium williamsoni* is native to western North America, including the Big Lost River in northeastern Idaho. It was first described by Charles Girard in 1891. Recent research at the University of Montana determined the mountain whitefish in the Big Lost River to be genetically divergent from other populations, including its parent population in the upper Snake River; genetic isolation times are estimated to be around 166,000 to 330,000 years.

Current Populations and Historic Range Map



The mountain whitefish in the Big Lost River has experienced drastic declines from its historical distribution and abundance. According to the 2005 Mountain Whitefish Conservation and Management Plan, it occupied only 24% of its historical range, and abundance was 1.5% of historical estimates. Although the mountain whitefish is considered to be a large river fish, little is known about its habitat requirements. As a result, it remains unknown whether the ecology of mountain whitefish in the Big Lost River differs from other populations. Because of its genetic uniqueness, contracted distribution, and decreased abundance, the Big Lost mountain whitefish was petitioned in 2006 to be listed as Endangered under the U.S. Endangered Species Act. The petition was denied by the U.S. Fish and Wildlife Service because insufficient information was presented to show that the mountain whitefish in the Big Lost River is a species, subspecies, or distinct population segment. However, in March 2009 the Idaho Federal District Court ordered the U.S. Fish and Wildlife Service to reconsider whether mountain whitefish in the Big Lost deserve protection under the Endangered Species Act.

There are many threats to mountain whitefish in the Big Lost River. The river is impounded by Mackay Dam (beginning in 1918) along the middle of its course. The dam prohibits upstream movement, but fish still pass through the spillway. Streamflow diversions and groundwater pumping for consumptive water uses cause several reaches of Big Lost River to go dry for much of the year. Water withdrawals have also caused stream temperatures to increase. Hundreds of stream miles in the Big Lost River Basin are listed as 303(d) impaired by the State of Idaho due to excessive nutrients, organic enrichment, siltation, flow modification, and thermal modification.

Our CSI analysis incorporated data from the U.S.D.A. Forest Service, Gregory Aquatics, and the 2005 Mountain Whitefish Conservation and Management Plan and 2007 fish surveys completed by the Idaho Department of Fish and Game. We are grateful for their contributions to our understanding of this species. A complete list of data sources is provided at the bottom of the website.

Key CSI Findings

- The current distribution of mountain whitefish has contracted and become fragmented compared to its historical distribution
- Two metapopulations of mountain whitefish persist - one above and one below Mackay Dam. These metapopulations are further fragmented by water diversion structures and dewatered stream reaches
- Population integrity is moderate. Mountain whitefish genetics and life history appear to be intact, but abundance is low and habitats are disconnected in some reaches in the lower basin
- Only the metapopulation in the upper Big Lost River is considered to be in good condition, but abundance is still below historical estimates
- Watershed conditions are low along the mainstem where land has been converted to agricultural fields and pastures are maintained by sprinkler irrigation
- The East Fork of the Big Lost River, Antelope Creek, Pass Creek, Sage Creek, and the mainstem Big Lost are major waters that are 303(d) listed because of sediment, nutrient, streamflow, and temperature problems
- The mountain whitefish are at low risk to the future threats of land conversion or introduced species

- Uncharacteristic wildfires associated with potential climate change and resource extraction represent the greatest additional future risk to mountain whitefish and aquatic habitat in the Big Lost Basin

Our CSI analysis showed that of the 26 subwatersheds historically occupied by mountain whitefish, only 11 are currently occupied. They are separated into two metapopulations - one above and one below Mackay Dam. There is no evidence that genetic differences exist between populations separated by Mackay Dam. All populations score highly for genetic purity, as there is no evidence of mountain whitefish from other populations being introduced into the Big Lost River.

Although the mountain whitefish in the Big Lost River appears to be genetically intact, population densities are low in some areas and the metapopulations are fragmented to some degree by diversions or dewatered stream segments during low flows. Population density scored high above the furthest upstream diversion (Neilson) where there is a large extent of connected habitat. The metapopulation downstream of Mackay Dam received a moderate score for extent of connected habitat, which reflects an increase in connectivity due to recent fish passage projects on water diversion structures. The moderate score for disease vulnerability reflects the presence of whirling disease in the basin but there is no evidence of mountain whitefish in the Big Lost River being susceptible to the disease. High scores for life history diversity reflect that there is no evidence that a life history strategy has been lost because they did not historically occupy any natural lakes within the basin.

Habitat integrity indicators scored high to moderate in upstream tributaries of the Big Lost River Basin but low along the mainstem. Tributary habitats are primarily managed by the U.S. Forest Service (Salmon-Challis National Forest), while the Bureau of Land Management is responsible for the lower elevation shrublands along larger streams. Watersheds of headwater tributary streams are largely protected as roadless areas except along stream corridors. Several tributaries are listed as 303(d) impaired by the State of Idaho because of temperature, sediments, nutrients, flow alteration, or habitat alteration. Watersheds along the mainstem Big Lost River scored low because they are privately owned, have extensive networks of canals that divert water, have water diversion structures that disconnect habitat, have land that has been converted to pasture and agricultural fields, and have streamflows that are disrupted by Mackay Reservoir. These conditions, as reflected by low habitat integrity scores, suggest that restoration, reconnection, and protection efforts should be focused on the area upstream of the confluence of Antelope Creek. Nonetheless, the absence of fine-scale instream habitat condition measurements limits our ability to precisely map habitat quality across the basin. As a result, some habitat integrity scores may not reflect conditions in larger streams: the protected uplands of the upper Big Lost River may inflate the habitat integrity scores of degraded subwatersheds in need of restoration from grazing impacts, such as the East Fork of the Big Lost River.

The lower Big Lost River below the Moore Diversion is dry most of the year because water is lost to sinks and is withdrawn for irrigation. Water users in the basin are increasingly switching from flood irrigation to sprinkler irrigation. Because return flows are less with sprinkler irrigation, surface and groundwater losses have increased with this transition.

The mountain whitefish historically occurred in larger tributaries and the mainstem of the Big Lost River. Use of tributaries likely fluctuated as habitat changed with natural precipitation and runoff cycles. However, construction of water diversion structures impassable to upstream movement has prohibited mountain whitefish from recolonizing tributary streams during favorable conditions. In the upper basin, the current drought cycle that peaked in 2005 may explain why mountain whitefish do not currently occupy all of the tributaries were they have been found historically; however, the exact reason for the current contracted distribution where habitat is intact remains unknown because 2007 surveys show recent recolonization of Wildhorse Creek and Fall Creek.

Most subwatersheds scored high for future security. There is low potential for existing unconverted lands to be converted for agriculture. Only one watershed scored low for resource extraction, and only two subwatersheds have been identified for future hydropower development. Risk to mountain whitefish from increased winter flooding and summer temperatures due to climate change was low throughout the basin; however, several mid-elevation subwatersheds were identified as having a high risk to future wildfires caused by climate change.

Trout Unlimited strongly supports current efforts by Idaho Department of Fish and Game to manage mountain whitefish as two metapopulations, one above and one below Mackay Dam and to provide fish passage across water diversion structures to maintain connected metapopulations. Since 2004, passage has been provided on or around six structures. Acquisitions of non-consumptive water rights are also encouraged to improve streamflows reconnecting stream segments and populations; Trout Unlimited recently acquired a 5 cubic feet per second water right for a fish ladder on the Chilly Diversion. Providing large interconnected habitats will increase the persistence of existing metapopulations in the face of both natural and anthropogenic disturbances. Ongoing habitat restoration on impaired streams should also improve mountain whitefish habitat.

Although the mountain whitefish in the Big Lost River has not been listed under the Endangered Species Act, several government and private organizations, including Trout Unlimited, realize that its genetic identity is unique, should be conserved, and cannot be replaced with individuals outside of Big Lost River Basin. Hence, conserving its existing genetic diversity and improving populations within the Big Lost River should remain a future priority.

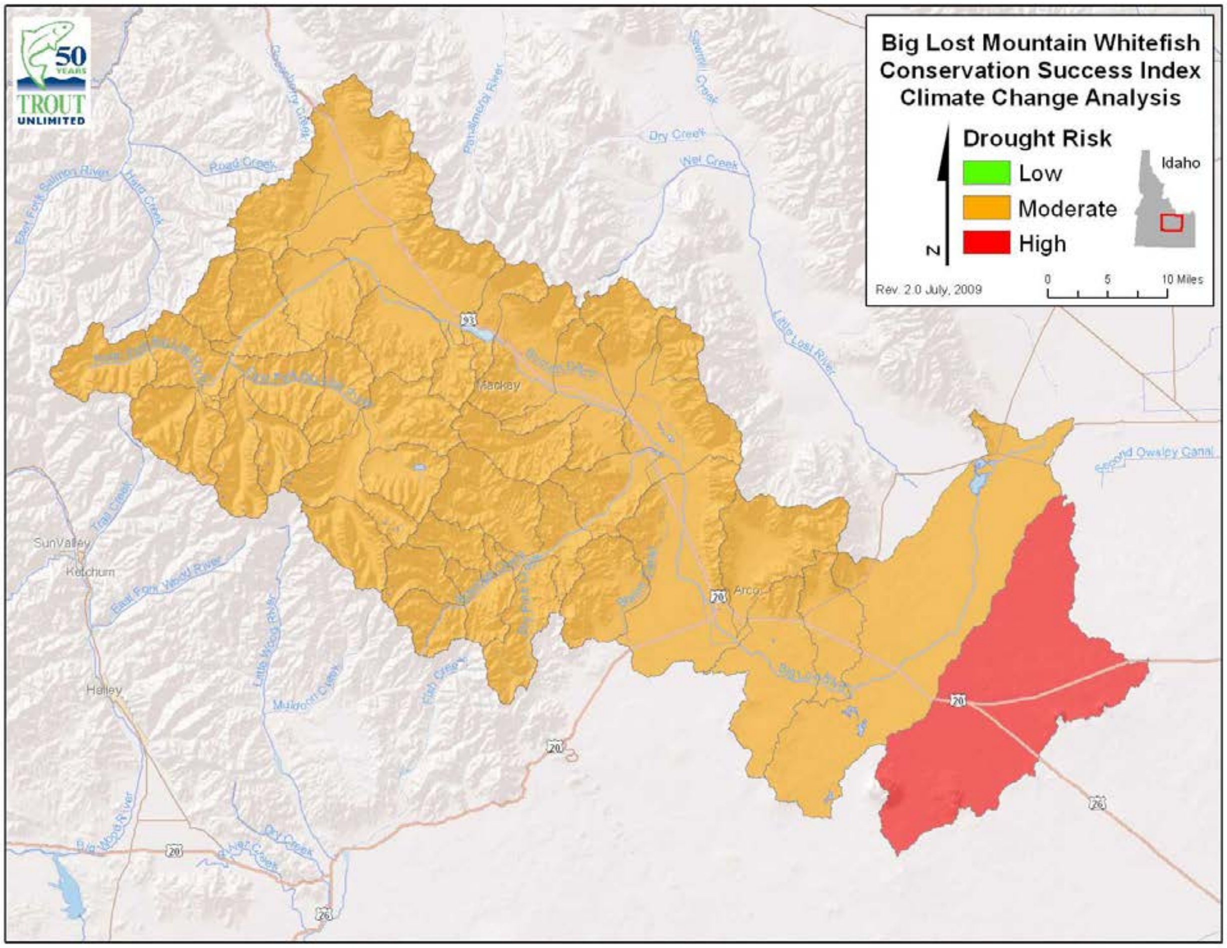
Prepared by Dan Dauwalter and Kurt Fesenmyer, TU, 2/23/2009

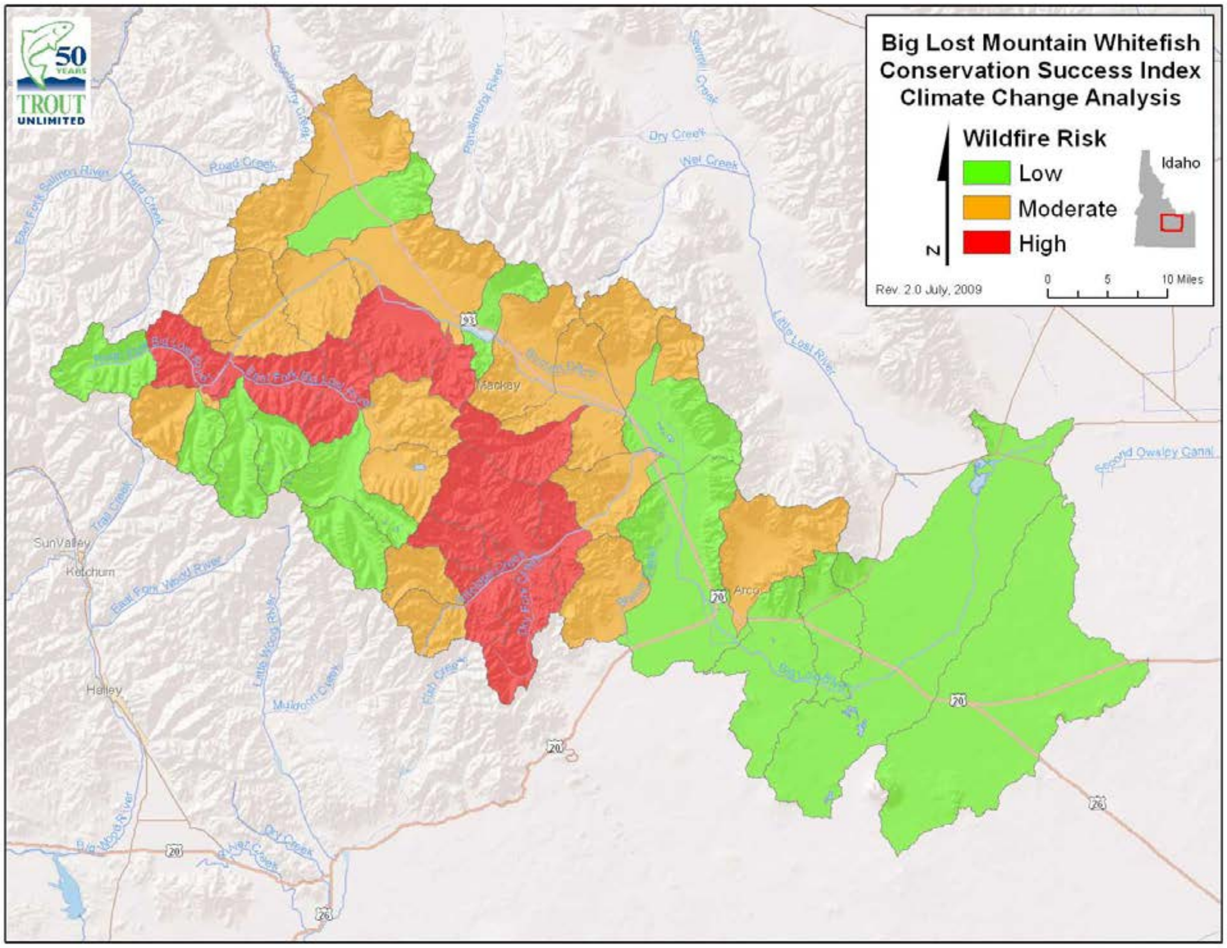
Blaine Diversion on the mainstem Big Lost River. Water diversions and dewatered stream segments have fragmented mountain whitefish populations in the Big Lost River. Providing passage over man-made structures has been a recent management emphasis in the basin.
Photo by D. Dauwalter.

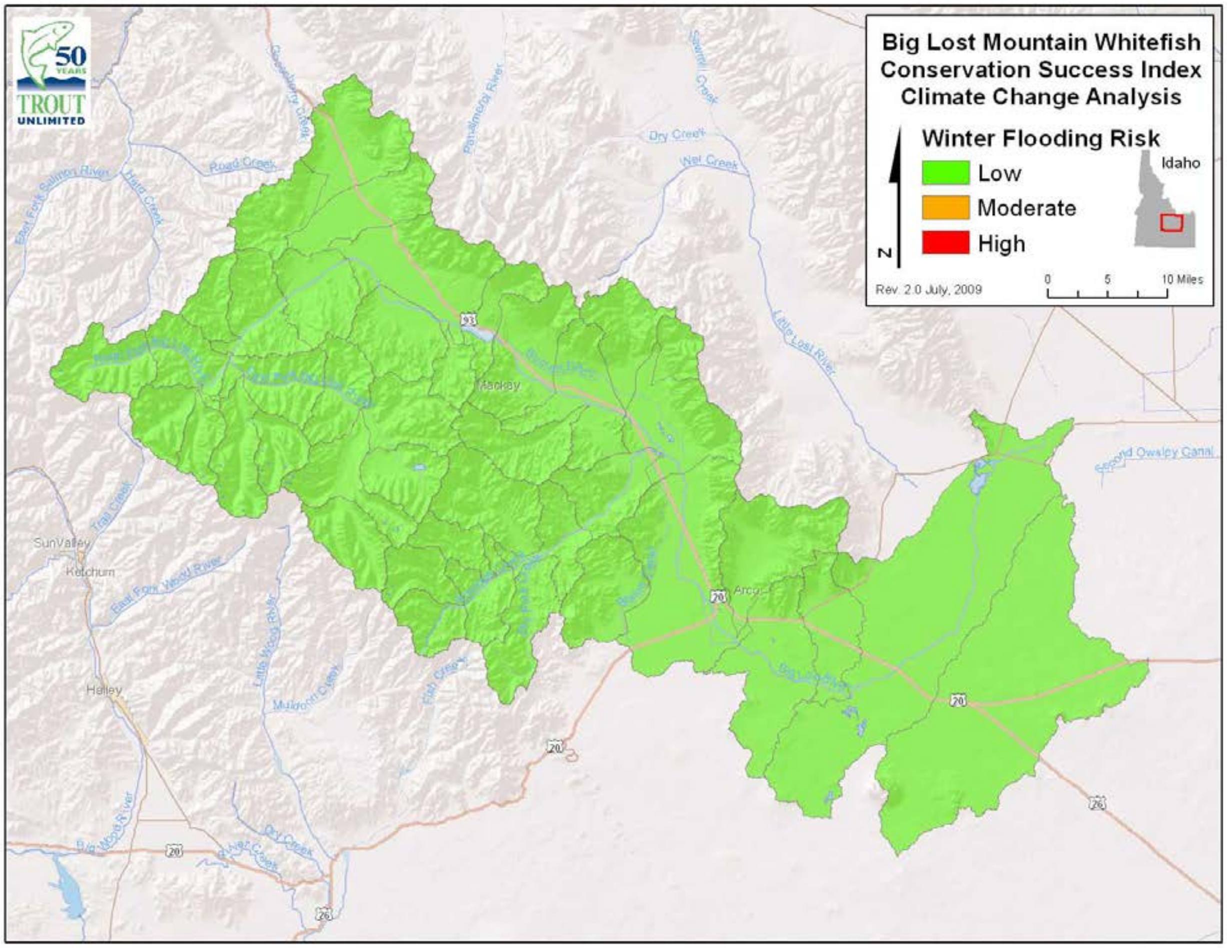
Table 1. CSI scoring results for mountain whitefish in the Big Lost River Basin. Rangewide conditions and population integrity indicators were scored only for currently occupied habitat (11 subwatersheds), while habitat integrity and future security indicators were scored for all 43 subwatersheds in the Big Lost Basin. All indicators are scored from 1 (poorest) to 5 (best): see detailed methods for scoring mountain whitefish.

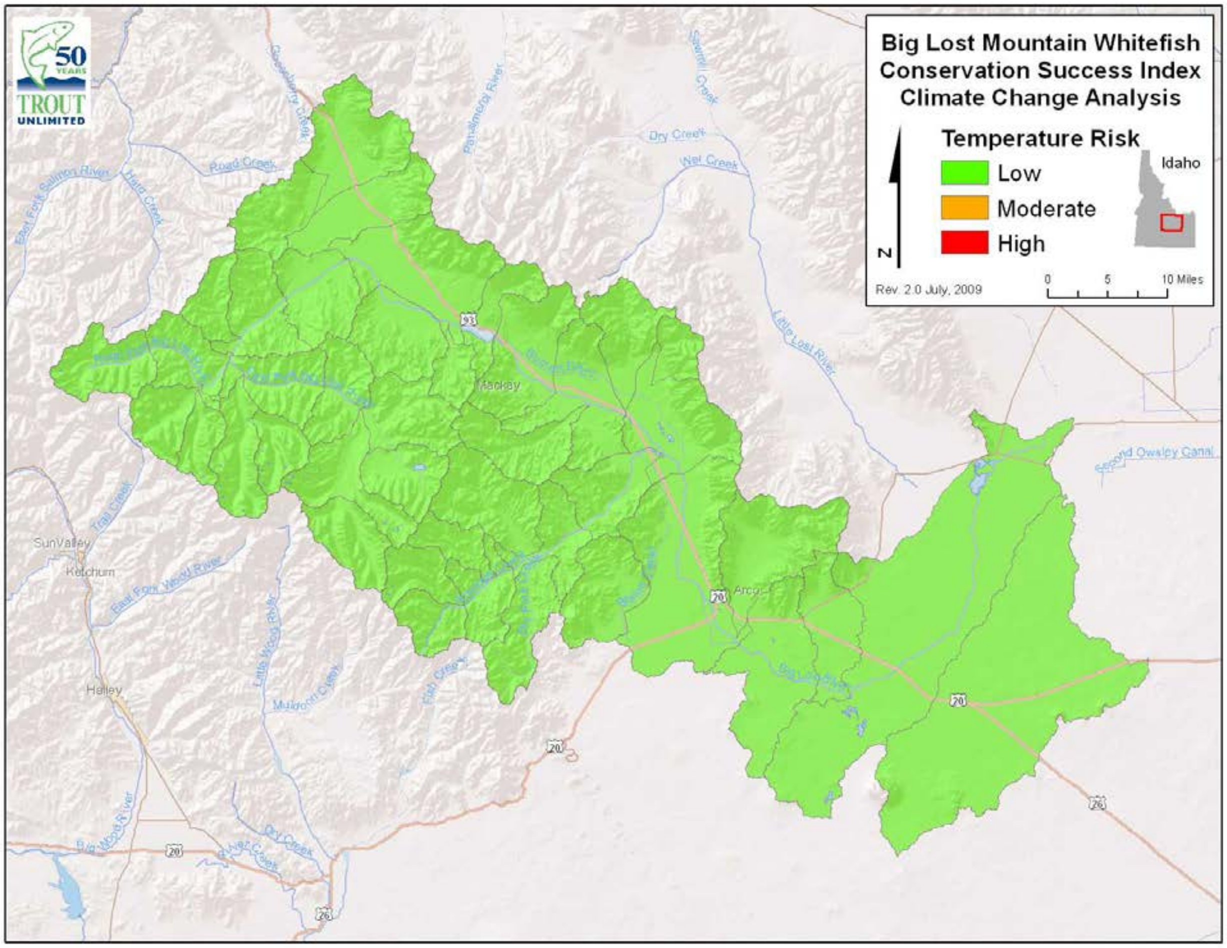
		Number of Subwatersheds Receiving Scores					**Total Subwatersheds Scored**
	CSI Indicator	**1**	**2**	**3**	**4**	**5**	
Range-wide Conditions	Percent historic stream habitat occupied	1	1	1	0	8	11
	Percent subbasins (4th) occupied	0	0	0	0	11	11
	Percent subwatersheds (6th) occupied	0	11	0	0	0	11
	Percent habitat by stream order occupied	0	0	0	0	11	11
	Percent historic lake area occupied	0	0	0	0	11	11
Population Integrity	Population Density	3	3	0	0	5	11
	Population Extent	2	1	3	0	5	11
	Genetic Purity	0	0	0	0	11	11
	Disease vulnerability	0	0	11	0	0	11
	Life history diversity	0	0	0	0	11	11
Habitat Integrity	Land Stewardship	5	4	0	5	29	43
	Watershed connectivity	7	1	7	28	0	43
	Watershed conditions	8	3	1	8	23	43
	Water quality	23	1	9	2	8	43
	Flow regime	9	3	2	7	22	43
Future Security	Land conversion	0	0	0	0	43	43
	Resource extraction	0	2	4	7	30	43
	Energy development	5	10	28	0	0	43

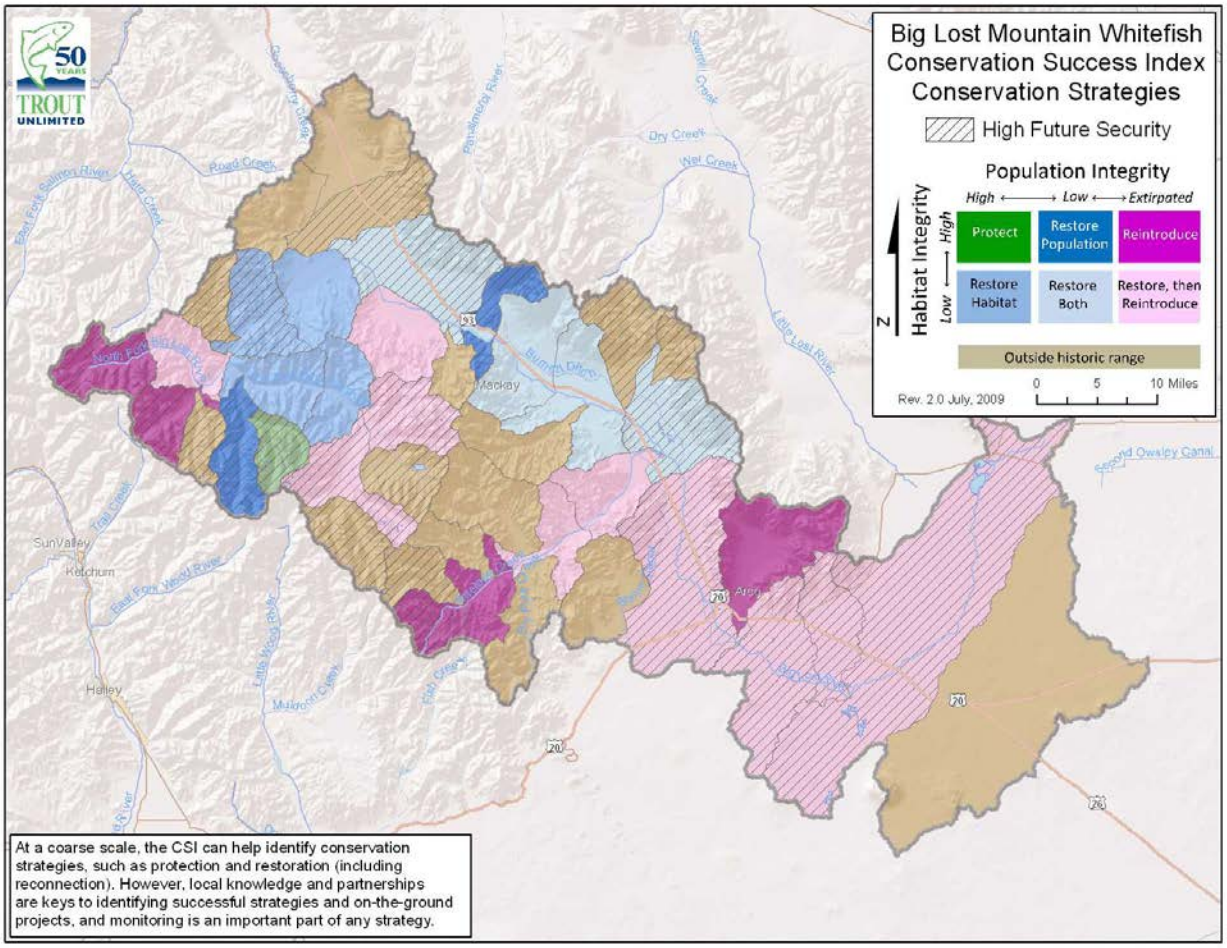
Climate change	0	12	0	18	13	43
Introduced species	0	0	0	0	43	43

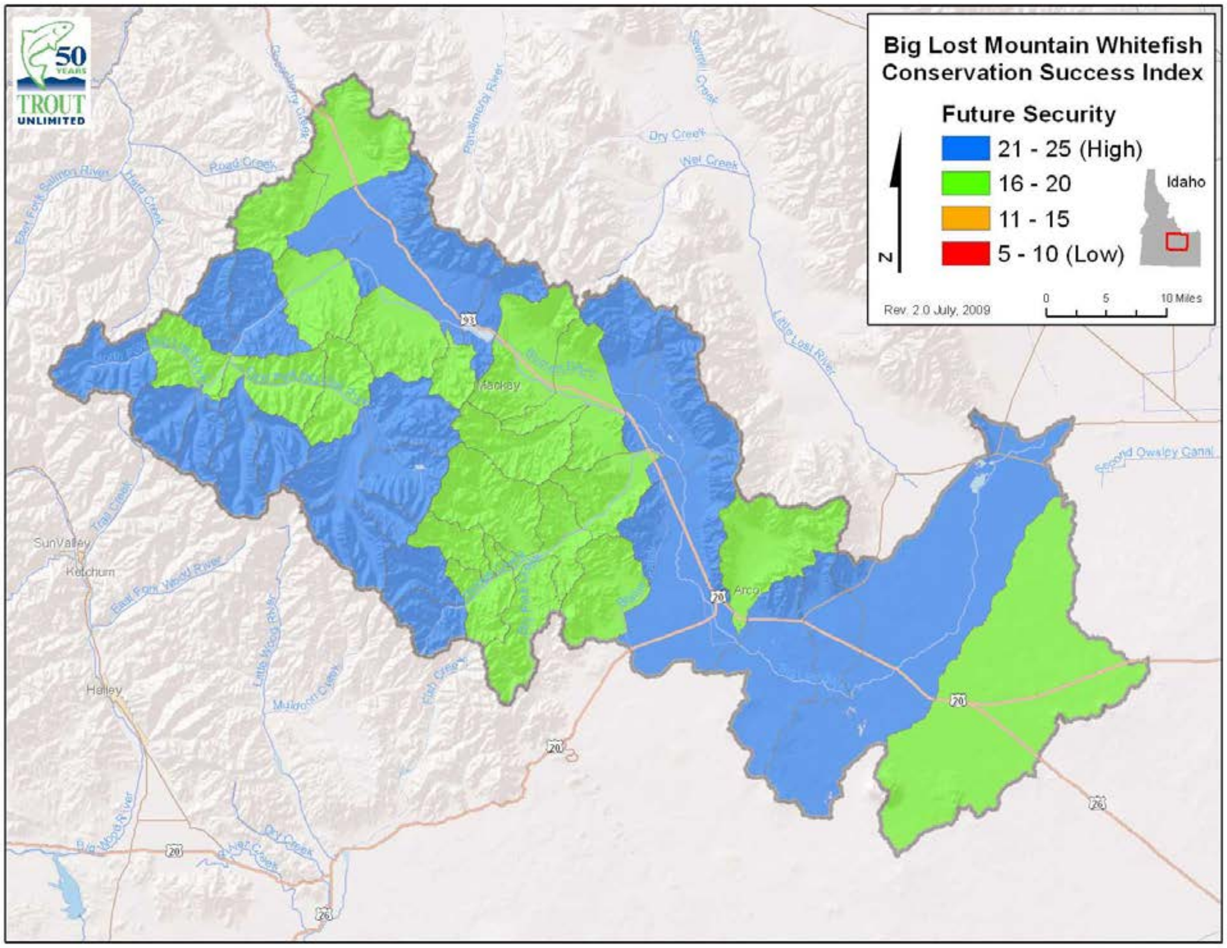

Big Lost Mountain Whitefish
Conservation Success Index
Climate Change Analysis
Drought Risk
Low
Moderate
High
Idaho
N
Rev. 2.0 July, 2009
0
5
10 Miles
TROUT UNLIMITED
Mackey
Arco
Sun Valley
Ketchum
Hailey
Little Lost River
Dry Creek
Wet Creek
Road Creek
Second Owsley Canal
Big Wood River
Little Wood River
Muldoon Creek
Fish Creek
Trail Creek
East Fork Wood River
Hard Creek
East Fork Salmon River
Pahsimeroi River
Sawmill Creek

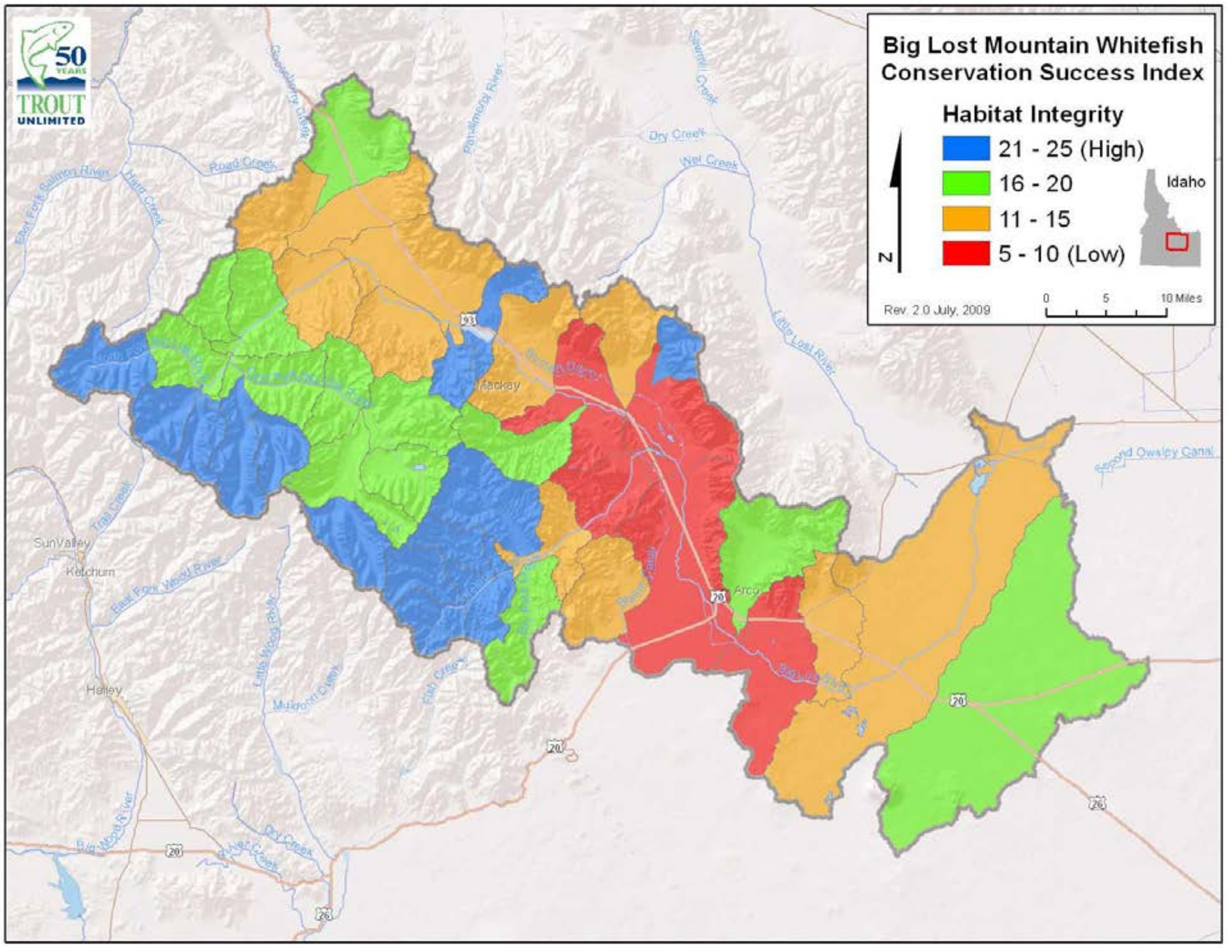

Big Lost Mountain Whitefish
Conservation Success Index
Climate Change Analysis
Wildfire Risk
Low
Moderate
High
Idaho
N
Rev. 2.0 July, 2009
0
5
10 Miles
TROUT UNLIMITED
50 YEARS
Mackay
Arco
Sun Valley
Ketchum
Hailey
Little Lost River
Second Owsley Canal
Big Lost River
Big Wood River
Dry Creek
Wet Creek
Road Creek
Muldoon Creek
Fish Creek
Little Wood River
Trail Creek
East Fork Wood River
Hard Creek
Pahsimeroi River

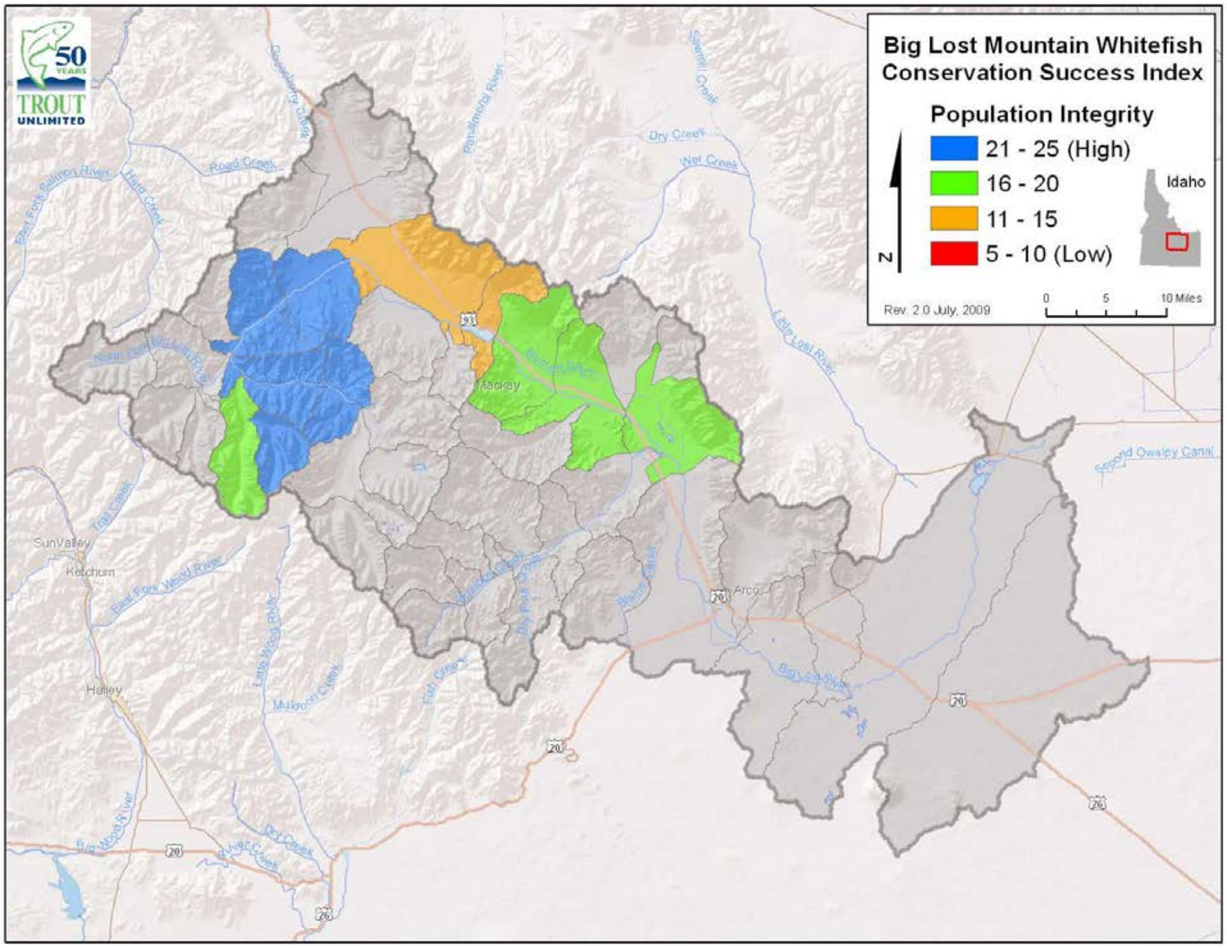

Big Lost Mountain Whitefish
Conservation Success Index
Climate Change Analysis
Winter Flooding Risk
Low
Moderate
High
Idaho
N
Rev. 2.0 July, 2009
0
5
10 Miles
TROUT UNLIMITED
Mackay
Arco
Ketchum
Hailey
Big Lost River
Little Lost River
Dry Creek
Wet Creek
Road Creek
Trail Creek
Little Wood River
Muldoon Creek
Fish Creek
Second Owsley Canal
Big Wood River

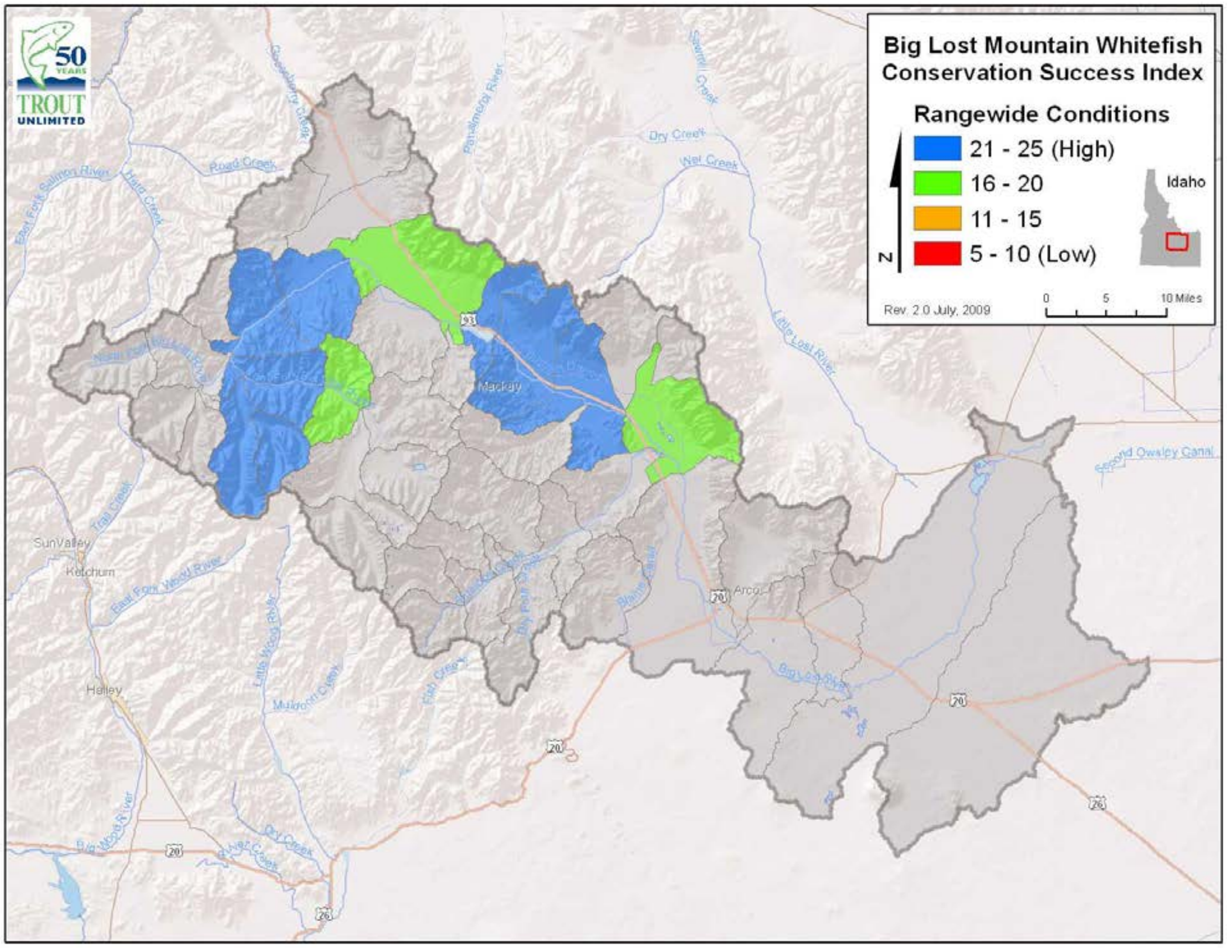

Big Lost Mountain Whitefish
Conservation Success Index
Climate Change Analysis
Temperature Risk
Low
Moderate
High
Idaho
N
Rev. 2.0 July, 2009
0
5
10 Miles
50 YEARS
TROUT UNLIMITED
Mackay
Arco
Sun Valley
Ketchum
Hailey
Dry Creek
Wet Creek
Road Creek
Little Lost River
Second Owsley Canal
Big Lost River
Big Wood River
East Fork Wood River
Little Wood River
Trail Creek
Hard Creek
Pahsimeroi River
93
20
26


Big Lost Mountain Whitefish
Conservation Success Index
Conservation Strategies
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
0 5 10 Miles
Rev. 2.0 July, 2009
50 YEARS
TROUT UNLIMITED
Mackay
Arco
Ketchum
Hailey
Sun Valley
Dry Creek
Wet Creek
Little Lost River
Second Owsley Canal
At a coarse scale, the CSI can help identify conservation strategies, such as protection and restoration (including reconnection). However, local knowledge and partnerships are keys to identifying successful strategies and on-the-ground projects, and monitoring is an important part of any strategy.

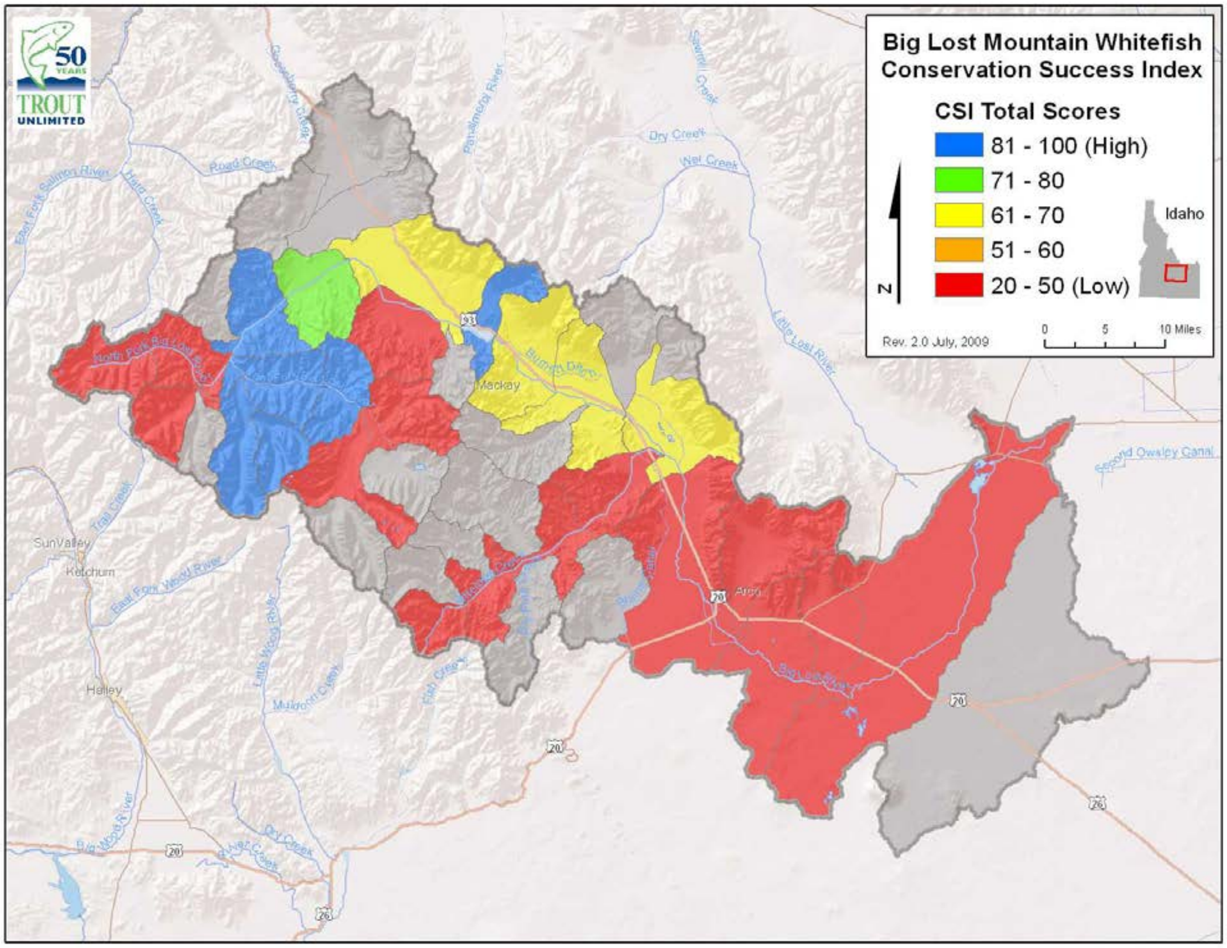

Big Lost Mountain Whitefish
Conservation Success Index
Future Security
21 - 25 (High)
16 - 20
11 - 15
5 - 10 (Low)
Idaho
N
Rev. 2.0 July, 2009
0
5
10 Miles
TROUT UNLIMITED
50 YEARS
Mackay
Arco
Sun Valley
Ketchum
Hailey
Little Lost River
Dry Creek
Wet Creek
Road Creek
Big Wood River
Little Wood River
Second Owsley Canal


Big Lost Mountain Whitefish
Conservation Success Index
Habitat Integrity
21 - 25 (High)
16 - 20
11 - 15
5 - 10 (Low)
Idaho
N
Rev. 2.0 July, 2009
0
5
10 Miles
50 YEARS
TROUT UNLIMITED
Mackey
Arco
Sun Valley
Ketchum
Hailey
Little Lost River
Second Owsley Canal
Dry Creek
Wet Creek
Pahsimeroi River
Road Creek
East Fork Salmon River
Trail Creek
East Fork Wood River
Little Wood River
Muldoon Creek
Fish Creek
Big Wood River
Big Lost River


Big Lost Mountain Whitefish
Conservation Success Index
Population Integrity
21 - 25 (High)
16 - 20
11 - 15
5 - 10 (Low)
Idaho
N
Rev. 2.0 July, 2009
0 5 10 Miles
50 YEARS
TROUT UNLIMITED



Big Lost Mountain Whitefish
Conservation Success Index
Rangewide Conditions
21 - 25 (High)
16 - 20
11 - 15
5 - 10 (Low)
Idaho
N
Rev. 2.0 July, 2009
0
5
10 Miles
50 YEARS
TROUT UNLIMITED
Mackay
Arco
Ketchum
Sun Valley
Hailey
Little Lost River
Big Lost River
Dry Creek
Wet Creek
Second Owsley Canal



Big Lost Mountain Whitefish Conservation Success Index
CSI Total Scores
81 - 100 (High)
71 - 80
61 - 70
51 - 60
20 - 50 (Low)
Idaho
N
Rev. 2.0 July, 2009
0
5
10 Miles
50 YEARS
TROUT UNLIMITED
Mackay
Arco
Sun Valley
Ketchum
Hailey
Big Lost River
Little Lost River
Second Owsley Canal
Dry Creek
Wet Creek
Road Creek
Hard Creek
Trail Creek
Big Wood River
Little Wood River
Muldoon Creek
Fish Creek
Pahsimeroi River
Sawmill Creek
93
20
26

Rev. 2.0 July 2009

Conservation Success Index:
Mountain whitefish *Prosopium williamsoni* and the Big Lost River basin:
Subwatershed Scoring and Rule Set

Introduction:

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

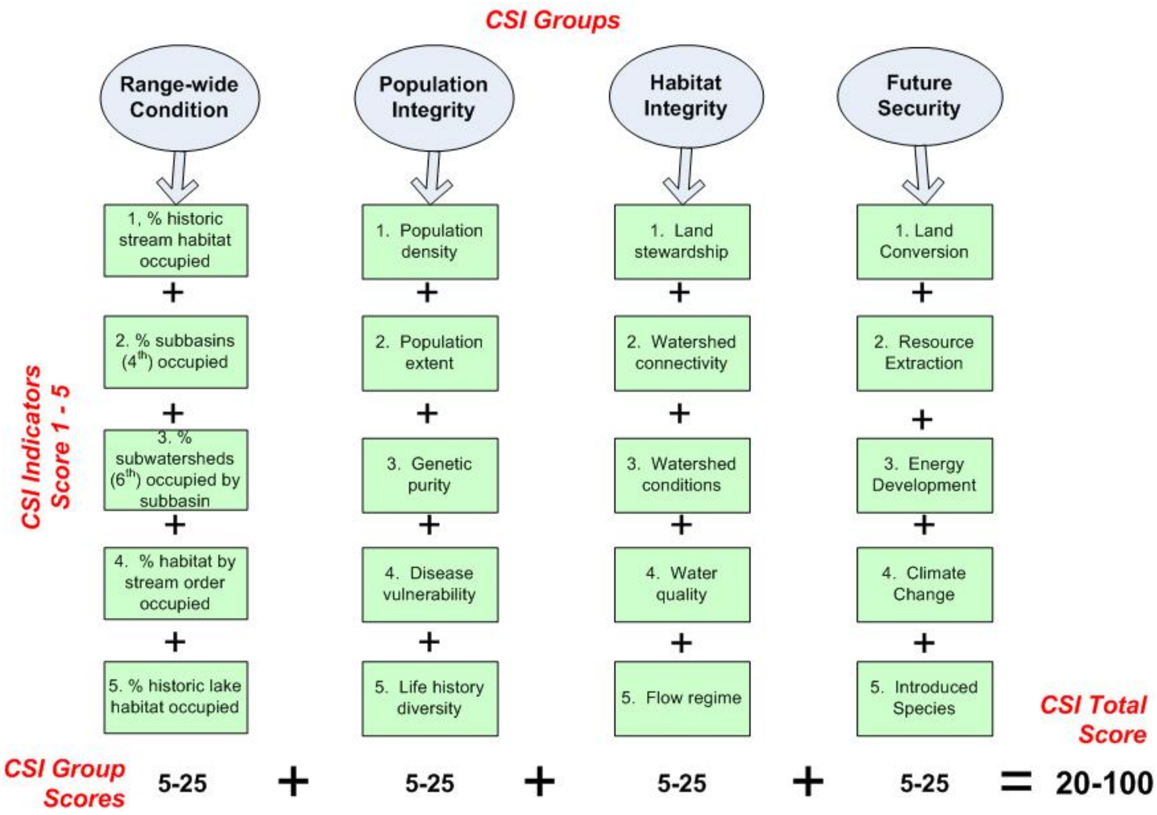


Figure 1. Each subwatershed is scored from 1 to 5 using 20 indicators within four main groups. Indicator scores are added per group to obtain an overall group score. Group scores are then added to obtain a composite CSI score for each subwatershed.

CSI Groups and Indicators

The CSI consists of four main groups of indicators:

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

Below is an overview of each CSI group and the indicators within each group. Each section contains the indicator scoring rules, the rational for the indicator, and the data sources used for the indicator.

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

Overview:

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

Indicator: 1. Percent historic stream habitat occupied.

Indicator Scoring:

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

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

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

Data Sources: The historic distribution of mountain whitefish was based on data in the Mountain Whitefish Conservation and Management Plan by Idaho Department of Fish and

Game,[1] and spatial data were provided by Bart Gamett, Salmon-Challis National Forest, Mackay, Idaho.[2] The current distribution of mountain whitefish in the Big Lost River was based on data from the 2007 fishery survey conducted by Idaho Department of Fish and Game.[3]

Indicator: 2. Percent subbasins occupied.

Indicator Scoring:

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

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

Rationale: Larger river basins often correspond with Distinct Population Segments or Geographic Management Units that may have distinct genetic or evolutionary legacies for the species.[4]

Data Sources: The historic distribution of mountain whitefish was based on data in the Mountain Whitefish Conservation and Management Plan by Idaho Department of Fish and Game,[1] and spatial data were provided by Bart Gamett, Salmon-Challis National Forest, Mackay, Idaho.[2] The current distribution of mountain whitefish in the Big Lost River was based on data from the 2007 fishery survey conducted by Idaho Department of Fish and Game.[3] Subwatersheds were based on Idaho Department of Water Resources data.[5]

Indicator: 3. Percent subwatersheds occupied within subbasin.

Indicator Scoring:

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

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

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

Data Sources: The historic distribution of mountain whitefish was based on data in the Mountain Whitefish Conservation and Management Plan by Idaho Department of Fish and Game,[1] and spatial data were provided by Bart Gamett, Salmon-Challis National Forest, Mackay, Idaho.[2] The current distribution of mountain whitefish in the Big Lost River was based on data from the 2007 fishery survey conducted by Idaho Department of Fish and Game.[3] Subwatersheds were based on Idaho Department of Water Resources data.[5]

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 not 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.[6]

Data Sources: The historic distribution of mountain whitefish was based on data in the Mountain Whitefish Conservation and Management Plan by Idaho Department of Fish and Game,[1] and spatial data were provided by Bart Gamett, Salmon-Challis National Forest, Mackay, Idaho.[2] The current distribution of mountain whitefish in the Big Lost River was based on data from the 2007 fishery survey conducted by Idaho Department of Fish and Game.[3] Stream order was determined using the National Hydrography Dataset Plus.[7]

Indicator: 5. Historic lake habitat occupied.

Indicator Scoring:

Occupied lake habitat	CSI Score
0 – 9%	1
10 – 19%	2
20 – 34%	3

35 – 49%	4
50 – 100%	5

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

Rationale: Lakes often harbor unique life histories and large populations that are important to long-term persistence of the species.[8]

Data Sources: The historic distribution of mountain whitefish was based on data in the Mountain Whitefish Conservation and Management Plan by Idaho Department of Fish and Game,[1] and spatial data were provided by Bart Gamett, Salmon-Challis National Forest, Mackay, Idaho.[2] The current distribution of mountain whitefish in the Big Lost River was based on data from the 2007 fishery survey conducted by Idaho Department of Fish and Game.[3] However, the historical distribution of mountain whitefish in the Big Lost River basin did not intersect any natural lakes in the National Hydrography Dataset Plus.[7]

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

Overview:

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

Indicator: 1. Population density.

Indicator Scoring:

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

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

Rationale: Small, low density populations, particularly those below an effective size of 500 individuals, are more vulnerable to extirpation.[9]

Data Sources: Population density for several stream segments in the Big Lost River is listed in Table 1 of the Mountain Whitefish Conservation and Management Plan for the Big Lost River.[1] Table 1 lists population densities for several stream segments, and the densities were based on data from extensive fishery surveys from 2002 to 2005. Idaho Department of Fish and Game conducted a fishery survey in 2007 at a select number of sites in the basin. Using this new data, correction factors for mountain whitefish densities were developed and applied to population density and size for populations within each stream segment. For example, several sites below Mackay Reservoir were resampled in 2007. These three sites had a median density that was 1.36 times higher than densities in 2002-03. Thus, the density for the mountain whitefish population below Mackay reservoir reported in the Conservation and Management Plan was multiplied by 1.36. When new populations were found in 2007 (e.g., Wildhorse Creek, Fall Creek), densities from 2007 surveys were used. In the case where a known fish barrier divided a population listed in Table 1 of the Conservation and Management Plan, the corrected densities were still applied but the total population size was computed by extrapolating the densities to the recalculated segment length. Population data were applied to the spatial data on mountain whitefish distribution provided by Bart Gamett, Salmon-Challis National Forest, Mackay, Idaho. Subwatersheds was based on Idaho Department of Water Resources data.[5] Scoring rules were based, in part, on May and Albeke[10] and Williams et al.[4]

Indicator: 2. Population extent.

Indicator Scoring:

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

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

Rationale: Populations with less available habitat are more vulnerable to extirpation[11] as a result of small, localized disturbances.

Data Sources: Scored based on extent of connected habitat for the contiguous populations using populations identified for population density (see above) and the barriers from the Big Lost Barriers Assessment[12] and Antelope Creek Barriers Assessment[13]; connectedness was determined using barriers identified as Complete, Partial, or Seasonal barriers to fish passage. The barriers information was updated to reflect all fish passage completed by the end of 2008 on the following barriers: Chilly Diversion; Darlington Diversion; Swauger Diversion; Blaine Diversion; 6X Diversion; and Antelope 2 Diversion (J. Gregory, Gregory Aquatics, pers. comm. 2008). Scoring rules were based, in part, on May and Albeke[10] and Williams et al.[4]

Indicator: 3. Genetic integrity.

Indicator Scoring:

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

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

Rationale: Hybridization and loss of the native genome via introgression with non-native salmonids are among the leading factors in the decline of native salmonids.[14] Introgression with other subspecies can also cause a loss of genetic variation.

Data Sources: There is low microsatellite variation between populations in the Big Lost River above and below Mackey reservoir and no evidence of introgression with other mountain whitefish sub-species.[1;15] All subwatersheds were scored a 5.

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
Disease/pathogens present, but no clinical signs in target species	3
None present but in close proximity <10 km	4
No diseases/pathogens present	5

Explanation: The risk of each population to disease.

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

Data Sources: Mountain whitefish are susceptible to whirling disease infection, can show clinical signs,[16;17] and have been found to be infected with *Myxobolus cerebralis* in the Salt River, Wyoming.[18] Whirling disease was first documented in the Big Lost River in 1987,[1] and it is still present.[19] Mountain whitefish in the Big Lost River do not appear to be affected currently by whirling disease even though is present in the Big Lost River basin;[1;19] however, environmental conditions may change and become favorable for whirling disease infection of mountain whitefish. For these reasons, all subwatersheds were given a score of 3.

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.[20-22]

Data Sources: Mountain whitefish in other populations can be fluvial and show some seasonal use of lakes and reservoirs,[1] but no natural lakes are within historical range of mountain whitefish in the Big Lost River drainage.[1] If an adfluvial life history was historically present in the genome, it likely still exists because whitefish are found in Mackey reservoir.[1] There is no evidence that a life history was lost. All subwatersheds were given a score of 5.

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

Overview:

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

Indicator: 1. Land stewardship.

Indicator Scoring:

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

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

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

Data Sources: Protected areas data were compiled from the ESRI, Tele Atlas North American / Geographic Data Technology dataset on protected areas[23] and the U.S. Department of Agriculture, Forest Service's National Inventoried Roadless Areas dataset.[24]

Indicator: 2. Watershed connectivity.

Indicator Scoring:

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

Score for worst case

Current/historic connectivity 4th:

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

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

Rationale: Increased hydrologic connectivity provides more habitat area and better supports multiple life histories (e.g., fluvial, adfluvial), which increases the likelihood of persistence[25].

Diversions, when they do not directly inhibit fish passage, can represent false movement corridors, cause fish entrainment, and act as population sinks.[26]

Data Sources: Connectivity was determined using the habitat historically occupied by mountain whitefish provided by Bart Gamett and reported in the Mountain Whitefish Conservation and Management Plan[1] and fish barrier assessments conducted in the Big Lost River basin by Jim Gregory, Gregory Aquatics. [12;13] The barriers information was updated to reflect fish passage that will have been provided by the end of 2008 on the following barriers: Chilly Diversion; Darlington Diversion; Swauger Diversion; Blaine Diversion; 6X Diversion; and Antelope 2 Diversion (J. Gregory, Gregory Aquatics, pers. comm. 2008).

Indicator: 3. Watershed condition.

Indicator Scoring:

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

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

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

Explanation: The percentage of converted lands in the subwatershed and the density of roads. Percent riparian vegetation along the stream is determined within a 300 ft. buffer.

Rationale: Habitat conditions are the primary determinant of persistence for most populations.[27] Converted lands are known to degrade aquatic habitats.[28;29] Road density is computed for the subwatershed; roads are known to cause sediment-related impacts to stream habitat[30-32]. Lee et al.[31] recognized 6 road density classifications as they related to aquatic habitat integrity and noted densities of 1.7 and 4.7 mi/mi^2 as important thresholds. Percent riparian vegetation is a remotely sensed measure of riparian conditions[33] that is often related to aquatic habitat conditions[34], and 300 ft. is a useful buffer width in which to measure riparian vegetation[34].

Data Sources: Converted lands were determined using the National Land Cover Database[35], with all Developed, Pasture/Hay, and Cultivated Crops land cover types considered to be converted lands. Road density was determined using Integrated Road Transportation of Idaho data[36]. Riparian vegetation was determined using the National Land Cover Database[35], using Woody Wetlands, Emergent Herbaceous Wetlands, Deciduous Forest, Evergreen Forest, and

Mixed Forest land cover classes. The National Hydrography Dataset Plus[37] was used to define the stream buffer.

Indicator: 4. Water quality.

Indicator Scoring:

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

Score for worst case.

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

Rationale: Decreases in water quality, including reduced dissolved oxygen, increased turbidity, increased temperature, and the presence of pollutants, reduces habitat suitability for salmonids. Agricultural land can impact aquatic habitats by contributing nutrients and fine sediments, and depleting 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.[38;39] Roads along streams can also contribute large amounts of fine sediments that smother benthic invertebrates, embed spawning substrates, and increase turbidity[40;41].

Data Sources: 303(d) impaired streams was determined using Idaho Department of Environmental Quality data[42]. The National Land Cover Database[35] 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[43]. Oil and gas wells were determined using oil and gas wells compiled by Finn[44] for the West. Road density within a 150 ft buffer was computed using Integrated Road Transportation of Idaho data[36] and the National Hydrography Dataset Plus[37].

Indicator: 5. Flow regime.

Indicator Scoring:

Number of dams	Percent of runoff	Storage (acre-ft)/stream mile	CSI Score

	diverted or withdrawn		
≥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

Score for worst case.

Explanation: Number of dams, percent of natural runoff diverted or withdrawn, and acre-feet of reservoir storage per perennial stream mile.

Rationale: Natural flow regimes are critical to proper aquatic ecosystem function[45]. Dams, reservoirs, and canals alter flow regimes[46]. Reduced or altered flows reduce the capability of watersheds to support native biodiversity and salmonid populations.

Data Sources: The National Inventory of Dams[47] was the data source for dams and their storage capacity. Data on canals were obtained from the National Hydrography Dataset Plus[37]. The Idaho Department of Water Resources dam database did not have reservoir storage data and all dams not in the National Inventory of Dams database were on intermittent streams; hence, they were not used. Perennial streams were obtained from the National Hydrography Dataset Plus[37]. Percent runoff is calculated as the proportion of the predicted mean annual flow, estimated by Vogel et al.[48] and reported in the NHD Plus dataset[37], diverted by all upstream spring, stream, or groundwater diversions recorded in the Snake River Basin Adjudication[49].

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

Overview:

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

Indicator: 1. Land conversion.

Indicator Scoring:

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

0 – 20%	5

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

Rationale: Conversion of land from its natural condition will reduce aquatic habitat quality and availability[50].

Data Sources: Slope was computed from elevation data from the National Hydrography Dataset Plus[37]. Land cover was determined from the National Land Cover Database[35], and all land cover classes except developed areas, hay/pasture, and cultivated crops cover types were considered for potential conversion. Urban areas were determined using 2000 TIGER Census data[51], roads from Integrated Road Transportation of Idaho data[36], and land ownership using USGS data on Land Ownership in Western North America[52].

Indicator: 2. Resource extraction.

Indicator Scoring:

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

Score for worst case.

Explanation: Percentage of subwatershed available 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: Productive forest types have a higher likelihood of being managed for timber production than unproductive types, and, hence, future logging poses a future risk to aquatic habitats and fishes.[30] Areas with hard metal claims pose a higher future risk to mining impacts than areas without claims. Claims indicate areas with potential for hard mineral mining, and mining can impact aquatic habitats and fishes.[53]

Data Sources: Timber management potential identifies productive forest types using the existing vegetation type in the Landfire dataset.[54] The number of mining claims was determined using Bureau of Land Management data[55], and each claim was assumed to potentially impact 20 acres. Protected areas data were compiled from the ESRI, Tele Atlas North American / Geographic Data Technology dataset on protected areas[56] and the U.S. Department of Agriculture, Forest Service's National Inventoried Roadless Areas dataset[24].

Indicator: 3. Energy Development.

Indicator Scoring:

Leases or reserves	New Dams 4th	New Dams 6th	CSI Score
51-100%	≥0	≥1	1
26 – 50%	3		2
11 – 25%	2		3
1 – 10%	1		4
0%	0		5

Score for worst case

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

Rationale: Increased resource development will increase road densities, modify natural hydrology, and increase the likelihood of pollution to aquatic systems. Changes in natural flow regimes associated with dams are likely to reduce habitat suitability for native salmonids and increase the likelihood of invasion by non-native species.[57] If lands are protected then the watersheds will be less likely to be developed.

Data Sources: **Data Sources**: Wind resources ("Good" and better) from Wind Powering America/National Renewable Energy Lab (NREL).[58] Coal leases are mineable types from the Coal Fields of the United States dataset.[59] Geothermal known and closed lease areas and oil and gas leases and agreements from BLM Geocommunicator. [*60] Potential dam sites are based on

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

Lease: Parcel leased for oil and gas production.

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

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

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

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

Idaho National Laboratory (INL) hydropower potential data[61]. Protected areas data were compiled from the ESRI, Tele Atlas North American / Geographic Data Technology dataset on protected areas[56] and the U.S. Department of Agriculture, Forest Service's National Inventoried Roadless Areas dataset[24].

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: moisture loss under climate warming will overwhelm any gains in precipitation and lead to higher drought risk

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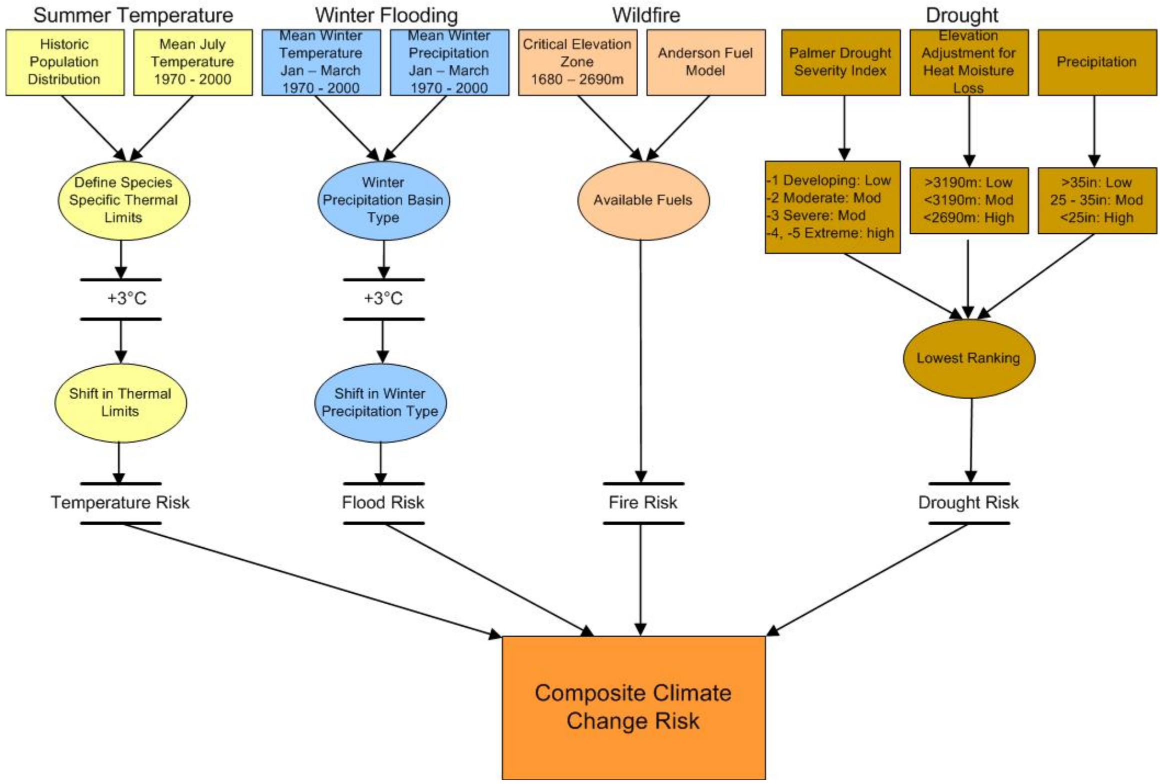
Lease Sale Parcel: Parcel slated for auction but not yet sold.

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. Drought risk is based on the Palmer Drought Severity Index, but was adjusted for elevation and precipitation.

Rationale: Climate change is likely to threaten most salmonid populations because of warmer water temperatures, changes in peak flows, and increased frequency and intensity of disturbances such as floods and wildfires.[62;63] 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.[64] Drought is expected to reduce water availability[65;66] and the availability of aquatic habitat. These risks are further discussed by Williams et al.[62]

Data Sources: Temperature and precipitation data were obtained from the PRISM Group.[67] Elevation data was obtained from the National Elevation Dataset,[68] and LANDFIRE data for the Anderson Fire Behavior Fuel Model 13[54] was used as input for wildfire risk. The Palmer Drought Severity Index was used for drought risk[69], but was adjusted for elevation (elevations above 2690 have lower risk[66]) and the deviation from mean annual precipitation (areas with more precipitation on average have lower risk).

Indicator: 5. Introduced species.

Indicator Scoring:

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

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

Rationale: Introduced species are likely to reduce native salmonid populations through predation, competition, hybridization, and the introduction of non-native parasites and pathogens[14]. 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: Data on non-native, injurious species were obtained from the Big Lost Mountain Whitefish Conservation and Management Plan[1]. Non-native trout were introduced into the Big Lost River basin around 1900, and there is no evidence that non-native trout have strong negative interactions with mountain whitefish[1]; therefore, non-native trout were not considered to be a future threat to the security of mountain whitefish. Roads were obtained from Integrated Road Transportation of Idaho data[71]. Road density risk includes the potential introduction of mountain whitefish from populations outside of the Big Lost River drainage that are genetically distinct[15].

References

1. IDFG, "Mountain whitefish conservation and management plan for the Big Lost River drainage, Idaho" (Idaho Department of Fish and Game, Boise, Idaho, 2007).

2. Gamett, B. "Big Lost Mountain Whitefish distribution". 2008. Mackay, ID, Gamett, Bart; USFS.

3. D. Garren, "Big Lost River" (Idaho Department of Fish and Game, Boise, Idaho, 2009).

4. J. E. Williams, A. L. Haak, N. G. Gillespie, W. T. Colyer, "The Conservation Success Index: synthesizing and communicating salmonid condition and management needs", *Fisheries* 32, 477-492 (2007).

5. IDWR. "Idaho watersheds 5th and 6th field units". 2003. Boise, Idaho. www.idwr.idaho.gov/watersheds, Idaho Department of Water Resources.

6. D. P. Peterson, B. E. Rieman, J. B. Dunham, K. D. Fausch, M. K. Young, "Analysis of trade-offs between threats of invasion by nonnative brook trout (*Salvelinus fontinalis*) and intentional isolation for native westslope cutthroat trout (*Oncorhynchus clarkii lewisi*)", *Can.J.Fish.Aquat.Sci.* 65, 557-573 (2008).

7. USEPA and USGS. "National Hydrography Dataset Plus - NHDPlus (1:100,000 scale)". 2005. Sioux Falls, South Dakota, U.S. Environmental Protection Agency and U.S. Geological Survey. http://www.horizon-systems.com/nhdplus/.

8. M. K. Young, "Conservation assessment for inland cutthroat trout" *Report No. General Technical Report RM-GTR-256* (U.S. Forest Service, Fort Collins, Colorado, 1995).

9. M. E. Soule, Where do we go from here? Viable populations for conservation (Cambridge University Press, Cambridge, England, 1987).

10. B. E. May and S. Albeke, "Range-wide status of Bonneville cutthroat trout (*Oncorhynchus clarki utah*): 2004" *Report No. Bonneville Cutthroat Trout Status Update Interagency Coordination Workgroup, Publication Number 05-02* (Utah Division of Wildlife Resources, Salt Lake City, Utah, 2005).

11. R. H. Hilderbrand and J. L. Kershner, "Conserving inland cutthroat trout in small streams: how much stream is enough?", *North American Journal of Fisheries Management* 20, 513-520 (2000).

12. J. Gregory, "Big Lost River fish barrier and entrainment survey" (Final report by Gregory Aquatics submitted to Trout Unlimited, Mackay, Idaho, 2004).

13. J. Gregory, "Antelope Creek and South Channel of Antelope Creek fish barrier survey" (Final report by Gregory Aquatics submitted to Trout Unlimited, Mackay, Idaho, 2008).

14. K. D. Fausch, B. E. Rieman, M. K. Young, J. B. Dunham, "Stategies for conserving native salmonid populations at risk from nonnative fish invasions: tradeoffs in using barriers to upstream movement" *Report No. General Technical Report RMRS-GTR-174* (U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, Colorado, 2006).

15. A. R. Whiteley, P. Spruell, F. W. Allendorf, "Can common species provide valuable information for conservation?", *Molecular Ecology* 15, 2767-2786 (2006).

16. E. MacConnell and A. V. Zale, "Susceptibility of mountain whitefish, *Prosopium williamsoni*, to *Myxobolus cerebralis*" *Report No. Final report to Whirling Disease Initiative* Bozeman, Montana, 2000).

17. E. MacConnell and E. R. Vincent, "Review: the effects of *Myxobolus cerebralis* on the salmonid host" in *Whirling disease: reviews and current topics*, J. L. Bartholomew and J. C. Wilson, Eds. (American Fisheries Society, Symposium 29, Bethesda, Maryland, 2002).

18. K. Gelwicks and D. Zafft, "Effects of myxobolus cerebralis on salmonids in the mainstem Salt River, Wyoming" in *Whirling disease symposium: solutions to whirling disease: putting the pieces together*, Coeur d' Alene, Idaho, 2000).

19. D.-L. M. Szumylo, "Investigating whirling disease in the upper Big Lost River basin of Mackay, Idaho", thesis, Duke University, Durham, North Carolina (2007).

20. W. T. Colyer, J. L. Kershner, R. H. Hilderbrand, "Movements of fluvial Bonneville cutthroat trout in the Thomas Fork of the Bear River, Idaho-Wyoming", *North American Journal of Fisheries Management* 25, 954-963 (2005).

21. J. Bascompte, H. Possingham, J. Roughgarden, "Patchy populations in stochastic environments: critical number of patches for persistence", *The American Naturalist* 159, 128-137 (2002).

22. B. E. Rieman, D. C. Lee, J. D. McIntyre, K. Overton, R. Thurow, "Consideration of extinction risks for salmonids" *Report No. Fish habitat relationships technical bulletin, Number 14* (US Department of Agriculture, Forest Service, Logan, Utah, 1993).

23. ESRI. "Protected areas (1:100,000)". 2004. Redlands, California, U.S. Tele Atlas North America, Inc. / Geographic Data Technology, Inc., ESRI.

24. USDA Forest Service. "National inventoried roadless areas (IRAs)". 2008. Salt Lake City, Utah, Geospatial Service and Technology Center, U.S. Department of Agriculture, Forest Service. http://fsgeodata.fs.fed.us/clearinghouse/other_fs/other_fs.html.

25. W. T. Colyer, J. L. Kershner, R. H. Hilderbrand, "Movements of fluvial Bonneville cutthroat trout in the Thomas Fork of the Bear River, Idaho-Wyoming", *N.Am.J.Fish.Manage.* 25, 954-963 (2005).

26. J. J. Roberts and F. J. Rahel, "Irrigation canals as sink habitat for trout and other fishes in a Wyoming drainage", *Trans.Amer.Fish.Soc.* 137, 951-961 (2008).

27. A. L. Harig, K. D. Fausch, M. K. Young, "Factors influencing success of greenback cutthroat trout translocations", *North American Journal of Fisheries Management* 20, 994-1004 (2000).

28. B. B. Shepard, R. Spoon, L. Nelson, "A native westslope cutthroat trout population responds positively after brook trout removal and habitat restoration", *Intermountain Journal of Sciences* 8, 191-211 (2002).

29. S. M. White and F. J. Rahel, "Complementation of habitats for Bonneville cutthroat trout in watersheds influenced by beavers, livestock, and drought", *Transactions of the American Fisheries Society* 137, 881-894 (2008).

30. G. S. Eaglin and W. A. Hubert, "Effects of logging and roads on substrate and trout in streams of the Medicine Bow National Forest, Wyoming", *N.Am.J.Fish.Manage.* 13, 844-846 (1993).

31. D. C. Lee, J. R. Sedell, B. E. Rieman, R. F. Thurow, J. E. Williams, "Broadscale assessment of aquatic species and habitats" in *An assessment of ecosystem components in the Interior Columbia Basin and portions of the Klamath and Great Basins: Volume III*, T. M. Quigley and S. J. Arbelbide, Eds. (USDA Forest Service, General Technical Report PNW-GTR-405, Portland, Oregon, 1997).

32. T. F. Waters, Sediment in streams: sources, biological effects, and control (American Fisheries Society Monograph 7, Bethesda, Maryland, 1995).

33. S. J. Goetz, "Remote sensing of riparian buffers: past progress and future prospects", *J.Am.Water Resour.Assoc.* 42, 133-143 (2006).

34. J. Van Sickle et al., "Projecting the biological condition of streams under alternative scenarios of human land use", *Ecol.Appl.* 14, 368-380 (2004).

35. USGS. "National Land Cover Database". 2001. Sioux Falls, South Dakota, U.S. Geological Survey.

36. IGDC. "Integrated Road Transportation of Idaho". (2008-06-22). 2008. Moscow, Idaho, Idaho Geospatial Data Clearinghouse (INSIDE Idaho). http://insideidaho.org/asp/GeoData.asp.

37. USEPA and USGS. "National Hydrography Dataset Plus - NHDPlus (1:100,000 scale)". 2005. Sioux Falls, South Dakota, U.S. Environmental Protection Agency and U.S. Geological Survey. http://www.horizon-systems.com/nhdplus/.

38. G. D. Grossman, J. F. Dowd, M. Crawford, "Assemblage stability in stream fishes: a review", *Environmental Management* 14, 661-671 (1990).

39. C. Murray-Gulde, J. E. Heatley, T. Karanfil, J. H. Jr. Rodgers, J. E. Myers, "Performance of a hybrid reverse osmosis-constructed wetland treatment system for brackish oil field produced water", *Water Research* 37, 705-713 (2003).

40. D. S. Lloyd, "Turbidity as a water quality standard for salmonid habitats in Alaska", *N.Am.J.Fish.Manage.* 7, 34-45 (1987).

41. R. J. Davies-Colley and D. G. Smith, "Turbidity, suspended sediment, and water clarity: a review", *J.Am.Water Resour.Assoc.* 37, 1085-1101 (2001).

42. IDEQ. "Streams of Idaho: 305(b) & 303(d) integrated report - water quality - 2002". 2002. Boise, Idaho, Idaho Department of Environmental Quality. http://www.deq.state.id.us/water/data_reports/surface_water/monitoring/integrated_report.cfm.

43. USGS. "Mineral Resources Data System (MRDS) (Active)". (2005). 2008. Reston, Virginia, U.S. Geological Survey. http://tin.er.usgs.gov/mrds/.

44. Finn, S. P. "Oil and natural gas wells, western U.S.". 2004. Cheyenne, Wyoming, Conservation Assessment of Greater Sage-grouse and Sagebrush Habitats, Western Association of Fish and Wildlife Agencies.

45. N. L. Poff et al., "The natural flow regime", *BioScience* 47, 769-784 (1997).

46. A. C. Benke, "A perspective on America's vanishing streams", *J.N.Am.Benthol.Soc.* 9, 77-88 (1990).

47. USACE. "National Inventory of Dams". 2008. U.S. Army Corps of Engineers. http://crunch.tec.army.mil/nidpublic/webpages/nid.cfm.

48. R. M. Vogel, I. Wilson, C. Daly, "Regional regression models of annual streamflow for the United States", *Journal of Irrigation and Drainage Engineering* May/June, 148-167 (1999).

49. Idaho Department of Water Resources. "Idaho Water Right Point of Diversion". (August 2002 website addition, accessed 2008). 2002. http://www.idwr.idaho.gov/gisdata/new%20data%20download/water_rights.htm.

50. S. E. Stephens et al., "Predicting risk of habitat conversion in native temperate grasslands", *Conserv.Biol.* 22, 1320-1330 (2008).

51. ESRI. "US MapData Places (2000 TIGER)". (1998 - 2002). 2005. Redlands, CA, ESRI.

52. USGS. "Land Ownership in Western North America, 180 m". (1986-2003). 2004. Boise, Idaho, Sage-grouse rangewide conservation assessment, Snake River Field Station, U.S. Geological Survey. http://sagemap.wr.usgs.gov/FTP/regional/USGS/westna_ownership_sgca.zip.

53. P. H. Rahn, A. D. Davis, C. J. Webb, A. D. Nichols, "Water quality impacts from mining in the Black Hills, South Dakota, USA", *Environmental Geology* 27, 38-53 (1996).

54. USFS. "LANDFIRE". (Rapid Refresh). 2008. Wildland Fire Leadership Council and U.S. Forest Service. http://www.landfire.gov/.

55. Hyndman, P. C. and Campbell, H. W. "BLM mining claim recordation system: mining claim density". 1996. Fort Collins, Colorado, Open-File Report 99-325. Natural Resource Ecology Labaoratory, U.S. Geological Survey.

56. ESRI. "Protected areas (1:100,000)". 2004. Redlands, California, U.S. Tele Atlas North America, Inc. / Geographic Data Technology, Inc., ESRI.

57. K. D. Fausch, "A paradox of trout invasions in North America", *Biol.Invasions* 10, 685-701 (2008).

58. Wind Powering America and National Renewable Energy Laboratory. "Wind Resource Potential". 2003. National Renewable Energy Laboratory, USDOE.

59. USGS. "Coal Fields of the United States". 2009. Reston, VA, USGS Eastern Energy Team, National Atlas of the United States.

60. USBLM. "Geocommunicator". 2008. USBLM and USFS. http://www.geocommunicator.gov/GeoComm/index.shtm.

61. INL. "Hydropower Resource Assessment". 2004. Idaho Falls, Idaho, Idaho National Laboratory.

62. J. E. Williams, A. L. Haak, H. M. Neville, W. T. Colyer, "Potential consequences of climate change to persistence of cutthroat trout populations", *N.Am.J.Fish.Manage.* 29, 533-548 (2009).

63. J. E. Williams, A. L. Haak, H. M. Neville, W. T. Colyer, N. G. Gillespie, "Climate change and western trout: strategies for restoring resistance and resilience in native populations" in *Wild Trout IX: Sustaining wild trout in a changing world*, R. F. Carline and C. LoSapio, Eds. (Wild Trout Symposium, Bozeman, Montana, 2007).

64. J. B. Dunham, M. K. Young, R. E. Gresswell, B. E. Rieman, "Effects of fire on fish populations: landscape perspectives on persistence of native fishes and nonnative fish invasions", *Forest Ecology and Management* 178, 183-196 (2003).

65. M. P. Hoerling and J. Eischeid, "Past peak water in the Southwest", *Southwest Hydrology* 6, 18-19,35 (2007).

66. A. L. Westerling, H. G. Hidalso, D. R. Cayan, T. W. Swetnam, "Warming and earlier spring increases western U.S. forest wildfire activity", *Science* 313, 940-943 (2006).

67. PRISM Group. "PRISM 800m Normals (1971 - 2000)". (1972 - 2000). 2008. Corvallis, Oregon, Oregon State University. http://www.prism.oregonstate.edu/.

68. USGS. "National Elevation Dataset (30m) (1:24,000)". 2008. Sioux Falls, SD, USGS EROS Data Center. http://ned.usgs.gov/.

69. W. C. Palmer, "Meteorological drought" *Report No. Research Paper No. 45* (U.S. Weather Bureau, 1965).

70. F. J. Rahel, "Unauthorized fish introductions: fisheries management of the people, for the people, or by the people" in *Propagated fish in resource management*, M. J. Nickum, P. M. Mazik, J. G. Nickum, D. D. MacKinlay, Eds. (American Fisheries Society Symposium 44, Bethesda, Maryland, 2004).

71. IGDC. "Integrated Road Transportation of Idaho". (2008-06-22). 2008. Moscow, Idaho, Idaho Geospatial Data Clearinghouse (INSIDE Idaho). http://insideidaho.org/asp/GeoData.asp.