

Rev. 1.0 - 12/2009

SPECIES SUMMARY

The Arctic grayling Thymallus arcticus ranges in distribution from northern Asia to northern North America, but within the lower 48 United States the Arctic grayling only occurred historically in Michigan and in Montana. The Arctic grayling was historically found in Otter Creek (Upper Peninsula) and Jordan River (Lower Peninsula) in Michigan but is now extinct (circa 1936). Historical accounts showed grayling to formerly occur in the Sun River, Smith River, Gallatin River, Madison River, Red Rock-Beaverhead-Jefferson Rivers, and Big Hole River drainages in Upper Missouri River above Great Falls in Montana. Montana populations were mainly fluvial (stream-dwelling), except for adfluvial populations (reside in lakes and spawn in streams) in Upper Red Rock Lake and Lower Red Rock Lake and possibly Elk Lake.

Arctic grayling in Michigan and Montana were separated from more northern populations during the last glacial period. Although no morphological differences exist among North American populations, extant populations of Arctic grayling in Montana exhibit unique genetics when compared to Alaskan and Canadian populations. Thus, Montana Arctic grayling are both geographically and biochemically identifiable from northern populations. Additional research has shown that the fluvial population in the Big Hole River is genetically different from populations in the Red Rock Lakes and other lakes where they have been introduced.



Context Map

Fluvial Arctic grayling in Montana were irregularly distributed but locally abundant in the upper Missouri River until the end of the 19th Century. By 1950 fluvial grayling had become rare throughout their distribution and today the only viable fluvial population that remains is in the Big Hole River. Overharvest, introductions of non-native fishes, and habitat degradation are common explanations for the decline of fluvial grayling in Montana. In contrast, Arctic grayling have been widely introduced into mountain lakes where they now have viable lacustrine populations. These lake populations sometimes exhibit adfluvial characteristics and grayling can be found sporadically in adjacent streams.

In response to the decline of fluvial grayling, several partners initiated the Arctic Grayling Recovery Program in 1987. The Program goals are to identify and offset threats to grayling and develop a fluvial brood stock for reintroduction efforts. Conservation efforts have improved dramatically, and efforts have been made to reintroduce fluvial grayling back into historical habitats such as the Ruby, Beaverhead, and Sun Rivers. A <u>Candidate Conservation Agreement with Assurances</u> (CCAA) has been developed to improve and protect grayling habitat in the Upper Big Hole River. The CCAA is an agreement with the U.S. Fish and Wildlife Service whereby property owners agree to manage their land to alleviate threats to fluvial arctic grayling. Property owners then receive assurances against additional regulatory requirements should the Arctic grayling be listed under the Endangered Species Act; a recent petition to list fluvial Arctic grayling was denied in 2007 by the U.S. Fish and Wildlife Service because fluvial Arctic grayling do not constitute a species, subspecies, or distinct population segment.



The Big Hole River north of Wisdom, Montana in April 2009. The Big Hole River contains the last remaining fluvial population of Arctic grayling in Montana. Photo: D. Dauwalter

Our CSI analysis incorporated key grayling data from the Montana Department of Fish, Wildlife and Parks, as well as various other sources. A complete list of data sources is provided in the 'Rule Sets and Data Sources' document.

Key CSI Findings

- Arctic grayling currently occur in all subbasins within their historic range in Montana
- Although grayling occupied few lakes historically, viable populations have been established in many mountain lakes where they sporadically enter tributary streams
- Introduced lake populations are often abundant whereas grayling are rare in riverine populations
- Arctic grayling have very low susceptibility to disease in the wild, including a low susceptibility to whirling disease
- The Big Hole River contains the last remnant fluvial population of Arctic grayling in Montana
- Most subwatersheds along mainstem rivers have poor watershed conditions
- Over half of all subwatersheds scored 1 for water quality conditions due to agricultural lands, roads along streams, and streams classified as impaired by the State of Montana
- There is wide range of future energy development threats within the historic range of grayling in Montana
- Seventy percent of subwatersheds have a moderately-high to high risk of being impacted by increased temperatures, winter flooding, wildfires, and drought due to climate warming
- Brown trout threaten existing stream populations of grayling as well as reintroduction efforts

Prepared by Dan Dauwalter, September 2009

Table 1. CSI scoring result summary for Montana Arctic Grayin	Ta	able	۱ .	CSI	scoring	result	summary	/ for	Montana	Arctic	Gray	ling
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		Number of Subwatershed Receiving Scores					Total sSubwatersheds Scored
	CSI Indicator	I	2	3	4	5	
Range-wide Conditions	Percent historic stream habitat occupied	5	I	2	I	29	38
	Percent subbasins (4th) occupied	0	0	0	0	38	38
	Percent subwatersheds (6th) occupied	7	0	0	31	0	38
	Percent habitat by stream order occupied	П	0	0	0	27	38
	Percent historic lake area occupied	I	0	0	0	37	38
Population	Population Density	0	34	I	3	0	38
Integrity	Population Extent	12	Ι	0	0	25	38
	Genetic Purity	0	0	37	0	I	38
	Disease vulnerability	0	0	0	0	38	38
	Life history diversity	0	0	I	0	37	38
Habitat	Land Stewardship	473	I	103	0	193	770
Integrity	Watershed connectivity	44	38	50	133	505	770
	Watershed conditions	111	31	79	102	447	770
	Water quality	407	45	93	90	135	770
	Flow regime	64	52	77	137	440	770
Future	Land conversion	2	31	129	215	393	770
Security	Resource extraction	42	87	142	245	254	770
	Energy development	53	179	89	294	155	770
	Climate change	142	442	18	121	47	770

Introduced species

416 I 31 322 0 770





















Conservation Success Index: Montana Arctic Grayling Subwatershed Scoring and Rule Set

Introduction:

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



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

CSI Groups and Indicators

The CSI consists of four main groups of indicators:

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

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

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

Overview:

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

Indicator: 1. Percent historic stream habitat occupied.

Indicator Scoring:

Occupied stream	CSI Score
habitat	
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 arctic grayling in Montana is not precisely known and was based on the current distribution excluding streams occupied by grayling that were introduced into mountain lakes (Mussigbrod Creek, upper Miner Creek, Odell Creek, and upper Wise River), historical accounts summarized primarily by Kaya 1992¹ but also other sources²⁻⁵,

and a modeled historic distribution. Modeled historic distribution was based on identifying all stream segments connected to known historic distribution (from literature accounts) that were <1.5% gradient with mean annual flows >0.1 cfs, and then selecting from those streams those that were <1% in gradient but excluding stream segments above known barriers. The National Hydrography Dataset Plus⁶ served as the template for the historic distribution. The current distribution was determined using Montana Department of Fish, Wildlife and Parks MFISH database⁷ (http://fwp.mt.gov/fishing/mfish/ ; Accessed May 2009) for streams and lakes but including only populations that were listed as being common or abundant.

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.⁸

Data Sources: See description for indicator 1.

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: See description for indicator 1.

Indicator: 4. Habitat by stream order occupied.

Indicator Scoring:

Occupied 2 nd order streams	CSI Score
and higher	
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: See description for indicator 1. Stream order for an occupied stream was determined using the National Hydrography Dataset Plus⁶.

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.¹⁰

Data Sources: The current distribution of arctic grayling in lakes was determined using Montana Department of Fish, Wildlife and Parks MFISH database⁷ (<u>http://fwp.mt.gov/fishing/mfish/</u>; Accessed May 2009) for lakes but including only populations that were listed as being common or abundant; grayling were considered native to Pintler Lake, Elk Lake, Lower Red Rock Lake and Upper Red Rock Lake, and they have been introduced into Boot Lake, Grayling Lake, Hamby Lake, Lake Agnes, Lower Miner Lakes, Mussigbrod Lake, Odell Lake, Schwinegar Lake, and Twin Lakes.

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:

MFISH Class	CSI Score
	COLDCOLC
	1
Common	2
	3
Abundant	4
	5

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

Rationale: Small populations are more vulnerable to extirpation.^{11;12}

Data Sources: Abundance for each occupied stream was primarily determined using Montana Department of Fish, Wildlife and Parks MFISH database⁷ (<u>http://fwp.mt.gov/fishing/mfish/</u>; Accessed May 2009) for streams but only using populations that were listed as common or abundant. However, some abundance classes from MFISH were modified based on suggestions from P. Lamothe, Arctic grayling habitat biologist, Montana Fish Wildlife and Parks (May 2009).

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 extirpation¹³ as a result of small, localized disturbances.

Data Sources: Score based on extent of connected habitat for the contiguous population(s) using Montana Department of Fish, Wildlife and Parks MFISH database⁷

(<u>http://fwp.mt.gov/fishing/mfish/</u>; Accessed May 2009) for streams (populations listed as common or abundant) and barriers to fish movement based on data from the Geographic Names Information System¹⁴ (waterfalls), the National Inventory of Dams,¹⁵ and barrier database associated with the westslope cutthroat trout recovery team database.¹⁶

Indicator: 3. Genetic integrity.

Indicator Scoring:

Genetic purity (introgression)	CSI Score
Hybridized or Unknown	1
	2
Not applicable	3
	4
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.¹⁷ Introgression with other subspecies can also cause a loss of genetic variation.

Data Sources: The Arctic grayling in Montana is not known to hybridize with other species and its genetic integrity¹⁸ is not known to be compromised from introduction of populations outside of Montana.

Indicator: 4. Disease vulnerability.

Indicator Scoring:

Disease Risk	CSI Score
Disease/pathogens present in target species	1
Disease/pathogens in habitat but not target fish	2
None present but proximity <10 km	3
None present but proximity >10 km	4
Not Vulnerable to Disease	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 salmonids and reduce their populations.

Data Sources: Arctic grayling are not susceptible to whirling disease nor any other disease in the wild.¹⁹ All subwatersheds were scored a 5.

Indicator: 5. Life history diversity.

Indicator Scoring:

Life History Diversity Lost	CSI Score
Two historical life histories were lost	1
One historical life history was lost	3
No historical life histories were lost	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.^{13;20;21}

Data Sources: There is no evidence of adfluvial or fluvial life histories being lost in native populations or Arctic grayling in Montana. All subwatersheds were scored a 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	Subwatershed	CSI Score
habitat	protection	
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.

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 areas²² and the U.S. Department of Agriculture, Forest Service's National Inventoried Roadless Areas dataset.²³ The current distribution was determined using Montana Department of Fish, Wildlife and Parks MFISH database⁷ (<u>http://fwp.mt.gov/fishing/mfish/</u>; Accessed May 2009) for streams and lakes but only populations listed as common or abundant.

Indicator: 2. Watershed connectivity.

Indicator Scoring:

Number of stream/canal intersections	CSI Score
GE 12	1
8 - 11	2
5 - 7	3
1 - 4	4
0	5

Explanation: The number of stream-canal intersections in the subwatershed.

Rationale: Increased hydrologic connectivity provides more habitat area and better supports multiple life histories, which increases the likelihood of persistence.¹³ Diversions, when they do not directly inhibit fish passage, can represent false movement corridors, cause fish entrainment, and act as population sinks.^{24;25}

Data Sources: The number of stream/canal intersections was determined using the National Hydrography Dataset Plus.⁶

Indicator: 3. Watershed condition.

Indicator Scoring:

Land	CSI
conversion	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 \geq 1.7 and <4.7 mi/square mile. If road density is \geq 4.7 mi/square mile it is downgraded 2 points.

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

Rationale: Habitat conditions are the primary determinant of persistence for most populations.²⁶ Converted lands are known to degrade aquatic habitats.^{27;28} Road density is computed for the subwatershed; roads are known to cause sediment-related impacts to stream habitat.²⁹⁻³¹ Lee et al.³⁰ recognized 6 road density classifications as they related to aquatic habitat integrity and noted densities of 1.7 and 4.7 mi/mi² as important thresholds.

Data Sources: Converted lands were determined using the National Land Cover Database³², with all Developed, Pasture/Hay, and Cultivated Crops land cover types considered to be converted lands. Road density was determined using the roads data from the Tele Atlas North America, Inc. / Geographic Data Technology, Inc.³³

Indicator: 4. Water quality.

Miles 303(d)	Agricultural Land	Number	Road mi/	Number	CSI
Streams		Active Mines	Stream mi	OG Wells	Score
>0	58-100%	≥10	0.5 - 1.0	\geq 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

Indicator Scoring:

	0-5%	0	0 - 0.04	0 - 49	5
Score for word and					

Score for worst case.

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

Rationale: Decreases in water quality, including reduced dissolved oxygen, increased turbidity, increased temperature, and the presence of pollutants, reduces habitat suitability for salmonids. Agricultural land can impact aquatic habitats by contributing nutrients and fine sediments, and deplete dissolved oxygen. Mining activity can deteriorate water quality through leachates and sediments. Oil and gas development is associated with road building, water withdrawals, and saline water discharge.^{34;35} Roads along streams can also contribute large amounts of fine sediments that smother benthic invertebrates, embed spawning substrates, and increase turbidity.^{36;37}

Data Sources: 303(d) impaired streams from USEPA³⁸. The National Land Cover Database³² 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 System³⁹. Road density within a 150 ft buffer was computed using roads data from the Tele Atlas North America, Inc. / Geographic Data Technology, Inc.³³ and the National Hydrography Dataset Plus⁶. Active oil and gas wells were determined using the Conservation assessment of Greater Sage-grouse and sagebrush habitats.⁴⁰

Indicator: 5. Flow regime.

Indicator Scoring:

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

Score for worst case.

Explanation: Number of dams and acre-feet of reservoir storage per perennial stream mile, and total streamflow (cfs) diverted.

Rationale: Natural flow regimes are critical to proper aquatic ecosystem function⁴¹. Dams, reservoirs, and canals alter flow regimes⁴². Reduced or altered flows reduce the capability of watersheds to support native biodiversity and salmonid populations.

Data Sources: The National Inventory of Dams¹⁵ was the data source for dams and their storage capacity. Data on canals were obtained from the National Hydrography Dataset Plus⁶. Total cubic feet per second of streamflow diverted was determined from the Montana Department of Natural Resources enrolled points of diversion.

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 availability⁴³.

Data Sources: Slope was computed from elevation data from the National Hydrography Dataset Plus⁶. Land cover was determined from the National Land Cover Database³², 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 data⁴⁴, Tele Atlas North America, Inc. / Geographic Data Technology, Inc.³³, and land ownership using USGS data on Land Ownership in Western North America⁴⁵.

Indicator: 2. Resource extraction.

Indicator Scoring:

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

Score for worst case.

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

Rationale: Productive forest types have a higher likelihood of being managed for timber production than unproductive types, and, hence, future logging poses a future risk to aquatic habitats and fishes²⁹. Areas with hard metal claims pose a future risk to mining impacts than areas without claims. Claims indicate areas with potential for hard mineral mining, and mining can impact aquatic habitats and fishes ⁴⁶.

Data Sources: Timber management potential identifies productive forest types using the existing vegetation type in the Landfire dataset.⁴⁷ The number of mining claims was determined using Bureau of Land Management data⁴⁸, 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 areas²² and the U.S. Department of Agriculture, Forest Service's National Inventoried Roadless Areas dataset²³.

Indicator: 3. Energy Development.

Indicator Scoring:

Leases or			CSI Score
reserves	New Dams 4 th	New Dams 6 th	
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.⁴⁹ 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).⁵⁰ Geothermal known and closed lease areas, coal leases, and oil and gas leases and agreements from BLM Geocommunicator.⁵¹ Potential dam sites are based on Idaho National Laboratory (INL) hydropower potential data⁵². Protected areas data were compiled from the ESRI, Tele Atlas North American / Geographic Data Technology dataset on protected areas²² and the U.S. Department of Agriculture, Forest Service's National Inventoried Roadless Areas dataset²³.

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



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.^{53;54} 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.⁵⁵ Drought is expected to reduce water availability^{56;57} and the availability of aquatic habitat. These risks are further discussed by Williams et al.⁵³

Data Sources: Temperature and precipitation data were obtained from the PRISM Group.⁵⁸ Elevation data was obtained from the National Elevation Dataset,⁵⁹ and LANDFIRE data for the Anderson Fire Behavior Fuel Model 13^{47} was used as input for wildfire risk. The Palmer Drought Severity Index was used for drought risk⁶⁰, but was adjusted for elevation (elevations above 2690 have lower risk⁵⁷) and the deviation from mean annual precipitation (areas with more precipitation on average have lower risk). Subwatersheds with a mean temperature >20.5 C was classified as 'High' risk, 19.0 – 20.5 C as 'Moderate' risk, and < 19.0 as 'Low' risk.

Indicator: 5. Introduced species.

Indicator Scoring:

Present in	Present in	Road	CSI Score
subbasin	subwatershed	Density	
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.¹⁷ 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.⁶¹

Data Sources: Brown trout were determined to be the only injurious non-native species to Arctic grayling⁶² (brook trout were not⁶³) and brown trout data were from Montana Department of Fish, Wildlife and Parks MFISH database⁷ (<u>http://fwp.mt.gov/fishing/mfish/</u>; Accessed May 2009) data for streams. Roads were obtained from ESRI, Tele Atlas North American / Geographic Data Technology dataset on roads.³³

Reference List

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2. C. L. Fuqua, "Restocking the famous Madison", Montana Wildlife 1, 10-11 (1929).

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