Conservation Success Index: Great Lakes Brook Trout

SALVELINUS FONTINALIS

Rev. 1.1 - 8/2011

SPECIES SUMMARY

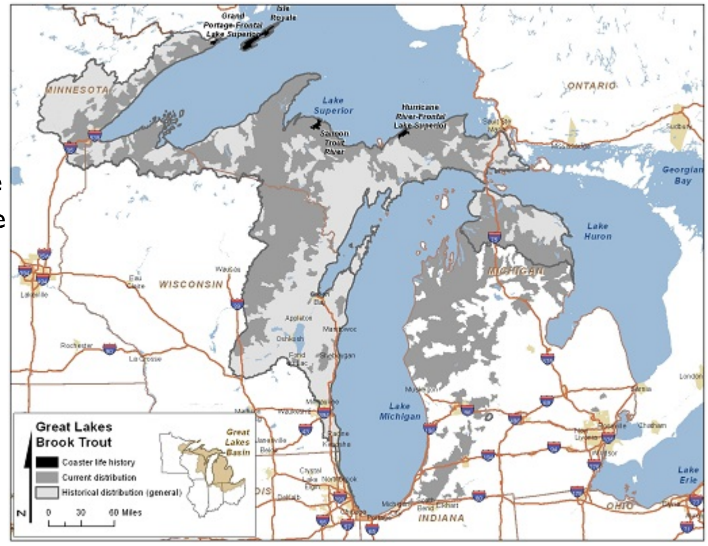
The native range of brook trout extends west to the western Great Lakes and upper Mississippi River Basin. While native to the Great Lakes, the exact native range of brook trout in the Great Lakes is uncertain. For example, some notable trout experts suggest brook trout were native to the northern-most portion of Michigan's Lower Peninsula. However, others have suggested that brook trout did not invade the Lower Peninsula until Arctic grayling began to decline there around the mid-1800's. Regardless, most experts agree that brook trout did not naturally occur as far south as some of Michigan's most famous trout streams, such as the Manistee and Muskegon rivers, or even the Au Sable River on the banks of which Trout Unlimited was founded. Why brook trout never inhabited these southern tributaries of Lake Michigan and Lake Huron is not clear, however.

Coaster brook trout from the Salmon Trout River, Michigan. Photo by D. Kramer.

Despite the uncertainty regarding the historical range of brook trout, one thing is for certain: the Great Lakes are home to the famed coaster brook trout, also known simply as 'coasters.' Coasters represent a unique life history (ecotype) of brook trout that are adfluvial or lacustrine. Adfluvial forms spawn in tributary streams, and lacustrine forms spawn in near-shore areas. Both forms spend the remainder of their lives in the Great Lakes to feed and grow. Coasters are not a unique genetic strain, but rather some brook trout populations appear to have the ability to produce coaster life histories depending on their natural environments. The highly productive Great Lakes allow coasters to reach very large sizes (over 14 pounds) and presumably increase their reproductive capability. Coasters were once a prominent member of the near-shore fish community.

Like many freshwater fishes, brook trout in the Great Lakes have declined to some degree because of anthropogenic activities. Coasters, on the other hand, have declined drastically. Because of their large size coasters supported an active fishery of considerable acclaim. By the late 1800's some coaster streams were already claimed to have been fished out. Watershed degradation, barriers to migration, and competition with non-native salmonids further contributed declines that continued into the 20th Century. Coasters were known to have spawned in over 106 tributary streams in Lake Superior alone. Currently extant populations exist in the Nipigon River and Bay (Ontario), Grand Portage Bay (Minnesota), Isle Royale National Park, and the Salmon Trout River (Michigan), and recent research has suggested that they now occur in the Hurricane River in Pictured Rocks National Lakeshore in Michigan. Anecdotal evidence, such as angler reports, also suggests that coasters occur in many other streams, but additional information is needed to determine if these large brook trout are in fact coasters and if they are self-reproducing populations.

Context Map



A coaster brook trout netted off of the shore of Isle Royale. Photo credit: A. Carlson.

Rehabilitation of coaster brook trout is a high priority among agencies, environmentalists, and anglers. Numerous attempts have been made to rehabilitate populations, but early attempts failed when non-non-native strains were used for stocking. Current efforts include close coordination among state and federal agencies and private interests. Maintaining widely distributed, self-sustaining populations in as many of the original native habitats as practical is a goal of the Brook Trout Rehabilitation Plan for Lake Superior. Current projects include assessment of remaining populations and habitats, restoration of spawning and in-channel habitat, reintroductions, and research. Descriptions of ongoing projects can be found on Trout Unlimited's website.

Our CSI analysis was based on information from the Minnesota Department of Natural Resources, Wisconsin Department of Natural Resources, Michigan Department of Natural Resources and

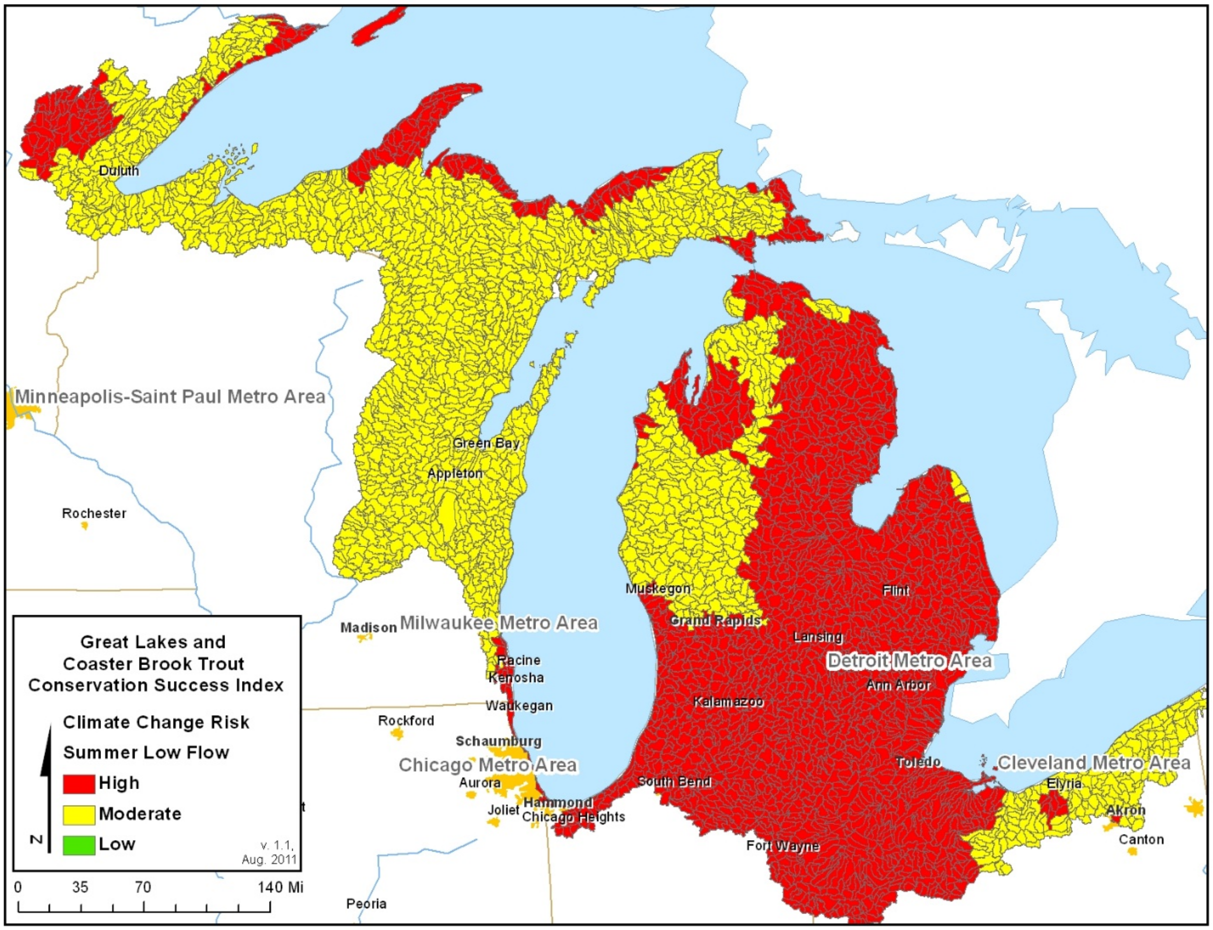
Environment, US. Fish and Wildlife Service, Forest Service, Menominee Indian Tribe of Wisconsin, and Trout Unlimited state councils. A complete list of data sources can be found under the Rule Sets and Data Sources link.

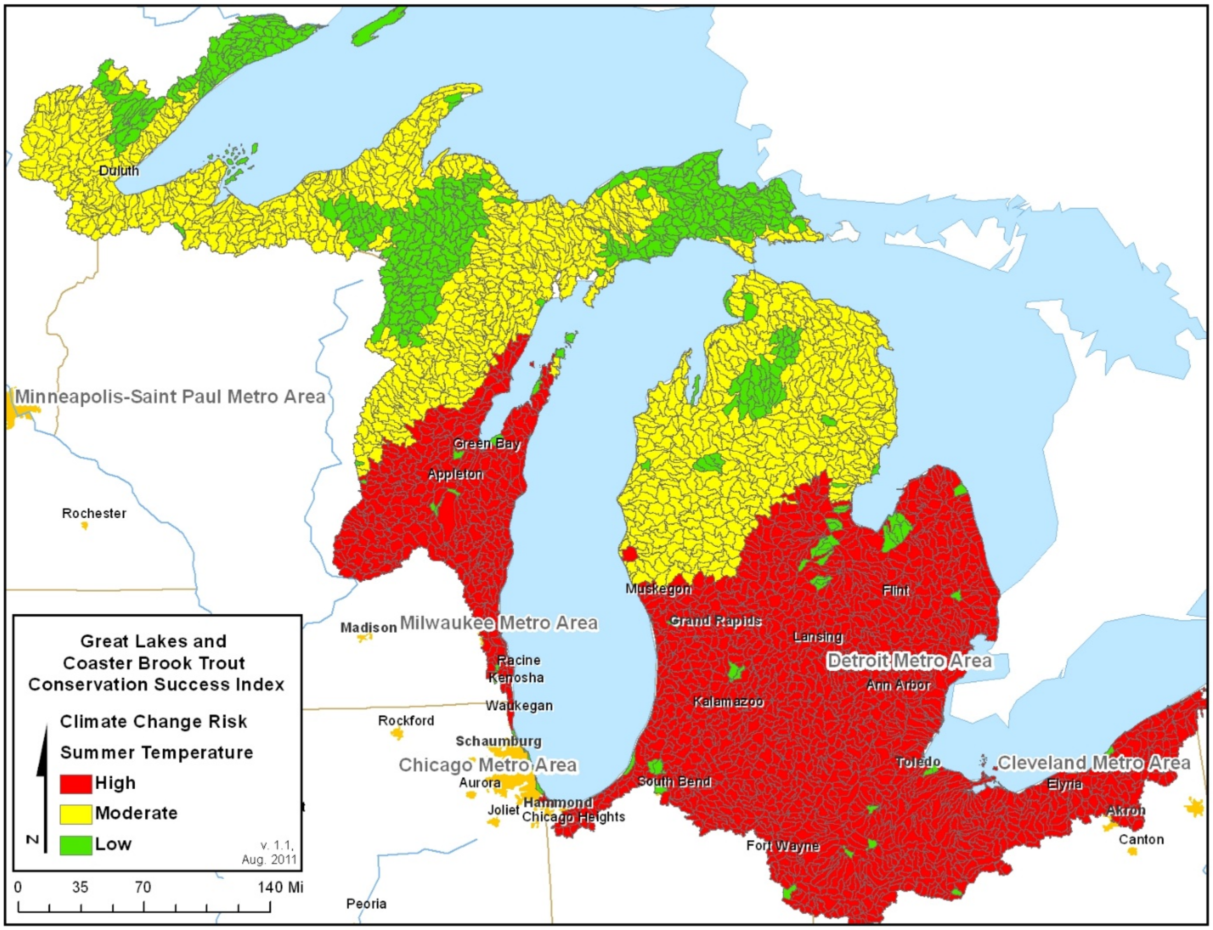
Key CSI Findings

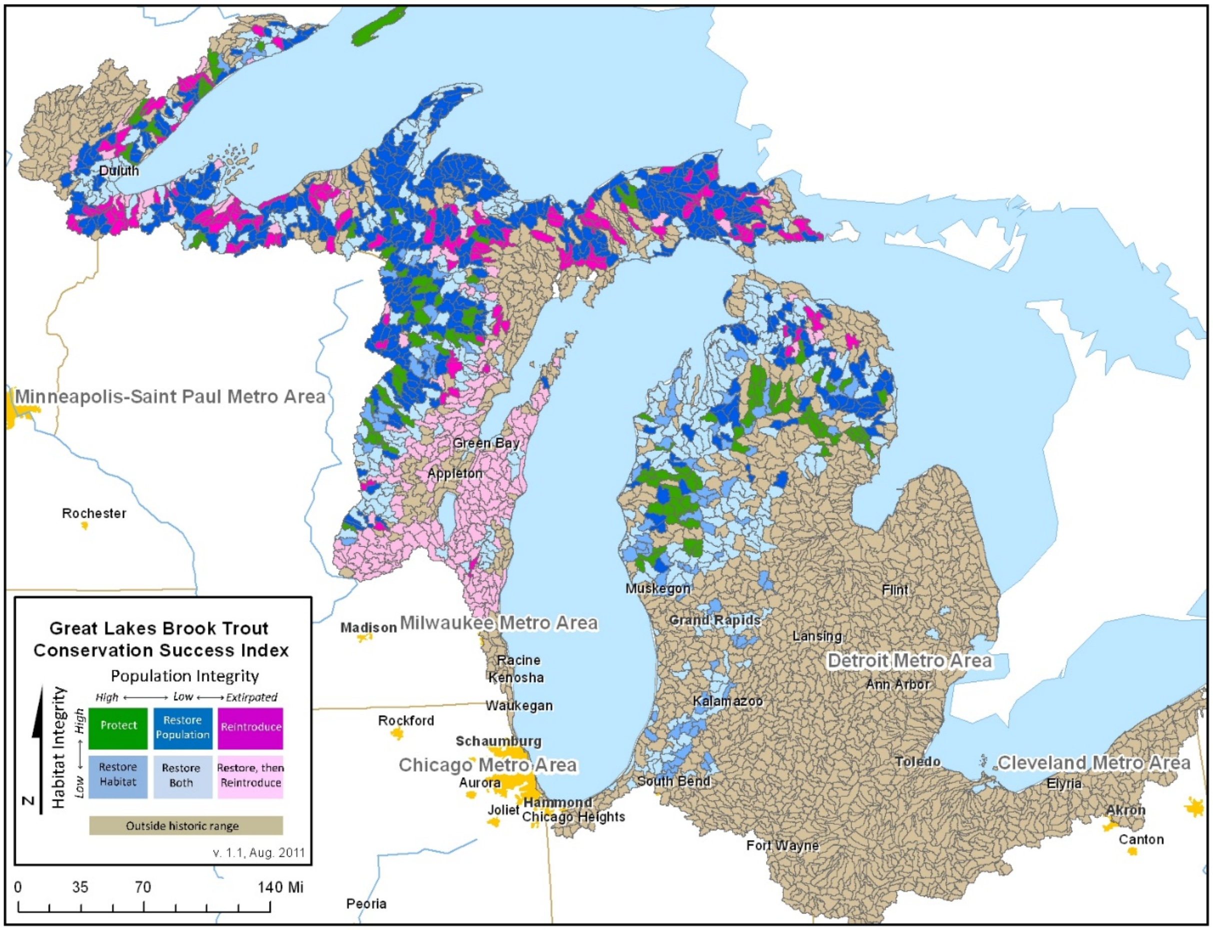
- Brook trout distribution is most retracted in western Lake Superior tributaries, although there is some uncertainty regarding the exact historical distribution of brook trout in Great Lakes tributaries.
- All historically occupied subbasins are currently occupied by brook trout
- Brook trout have been introduced into many streams outside of its native range in lower Michigan
- Self-reproducing populations of coaster brook trout occupy only four subwatersheds (Grand Portage Bay, Isle Royale, Salmon Trout River, Hurricane River). Reports of large brook trout from other streams suggests that coasters may be more widespread, but more detailed information is needed to determine whether these are self-reproducing populations rather than sporadic occurrences. These latter reports are not accounted for in CSI scoring.
- Several eastern brook trout strains have been stocked into Great Lakes tributaries over time. The broad-scale implications of these stockings on native brook trout genetics are unknown
- Population densities vary considerably across streams
- Many populations occupy short segments of headwater streams; however, some larger interconnected areas exists Minnesota, Wisconsin, and Michigan
- Viral Hemorrhagic Septicemia (VHS) occurs in the Great Lakes and poses a potential risk to inland trout populations
- Riparian condition is poor near urban areas and where agriculture is prominent, such as along the Michigan, Indiana, and Ohio border, resulting in low CSI scores
- Water quality is listed as impaired in about 1/3 of all subwatersheds, mainly in urban and agricultural areas
- Many brook trout populations are not at risk from future land conversion to urban or agricultural use, but extraction of forest resources does pose a potential future risk that is dependent on future economic needs
- Introduced species, particularly non-native salmonids, pose a risk to some existing brook trout and coaster populations and future rehabilitation efforts.

Table 1. CSI scoring result summary for Great Lakes and Coaster Brook Trout

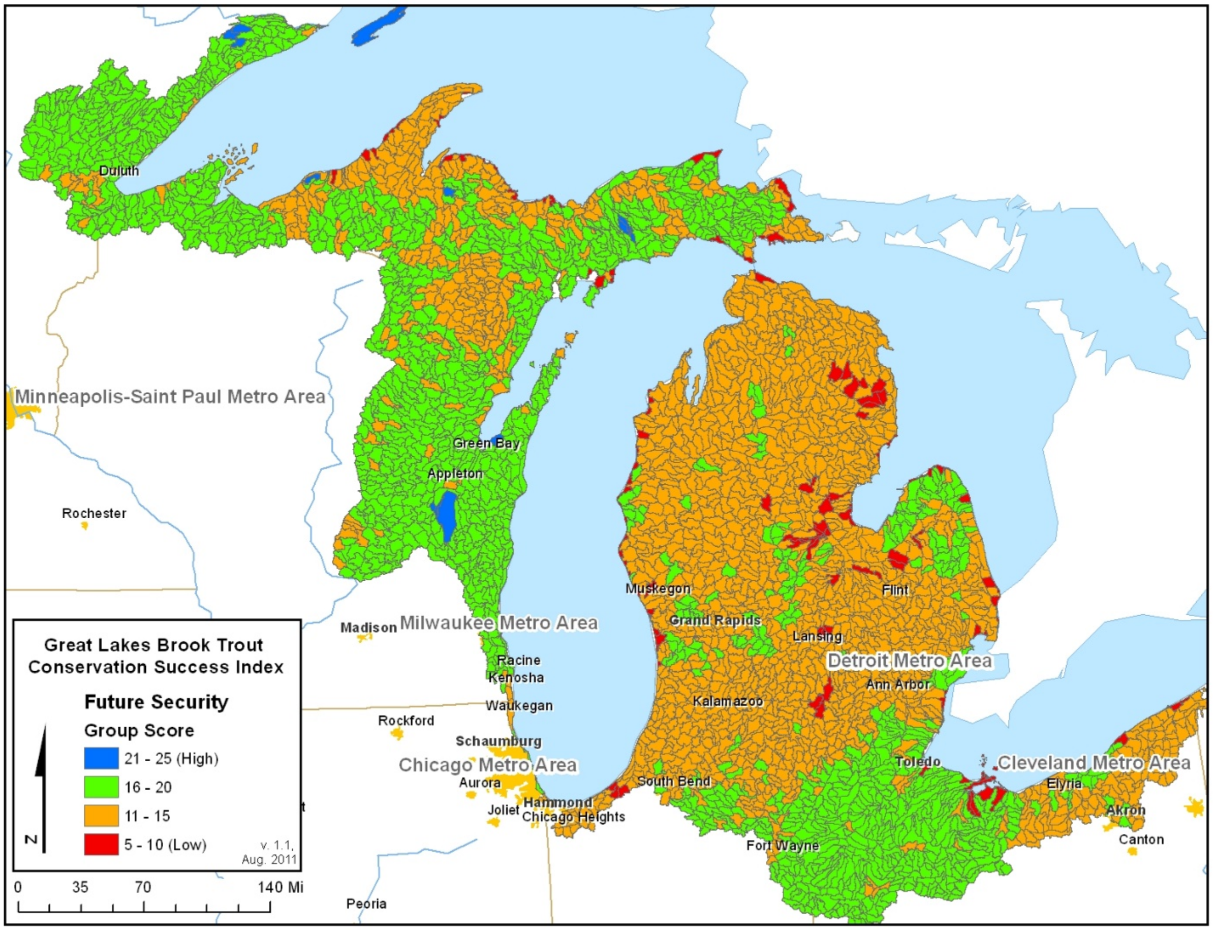
	CSI Indicator	Number of Subwatersheds Receiving Scores					Total Subwatersheds Scored
		1	2	3	4	5	
Range-wide Conditions	Percent historic stream habitat occupied	29	39	39	45	778	930
	Percent subbasins (4th) occupied	0	0	0	0	930	930
	Percent subwatersheds (6th) occupied	0	0	0	0	930	930
	Percent subbasins occupied by coasters	930	0	0	0	0	930
	Percent subwatersheds occupied by coasters within subbasin	231	31	0	0	668	930
Population Integrity	Population Density	104	73	556	95	102	930
	Population Extent	292	178	100	145	215	930
	Genetic Purity	112	435	0	0	383	930
	Disease vulnerability	0	4	80	201	645	930
	Life history diversity	45	15	0	158	712	930
Habitat Integrity	Riparian condition	371	492	844	802	592	3101
	Watershed connectivity	347	732	807	675	540	3101
	Watershed conditions	418	481	791	466	945	3101
	Water quality	961	86	199	476	1379	3101
	Flow regime	166	253	336	567	1779	3101
Future Security	Land conversion	61	138	478	972	1452	3101
	Resource extraction	688	754	681	726	252	3101
	Energy development	269	132	2204	201	295	3101
	Climate change	1195	820	765	321	0	3101
	Introduced species	0	253	2287	561	0	3101

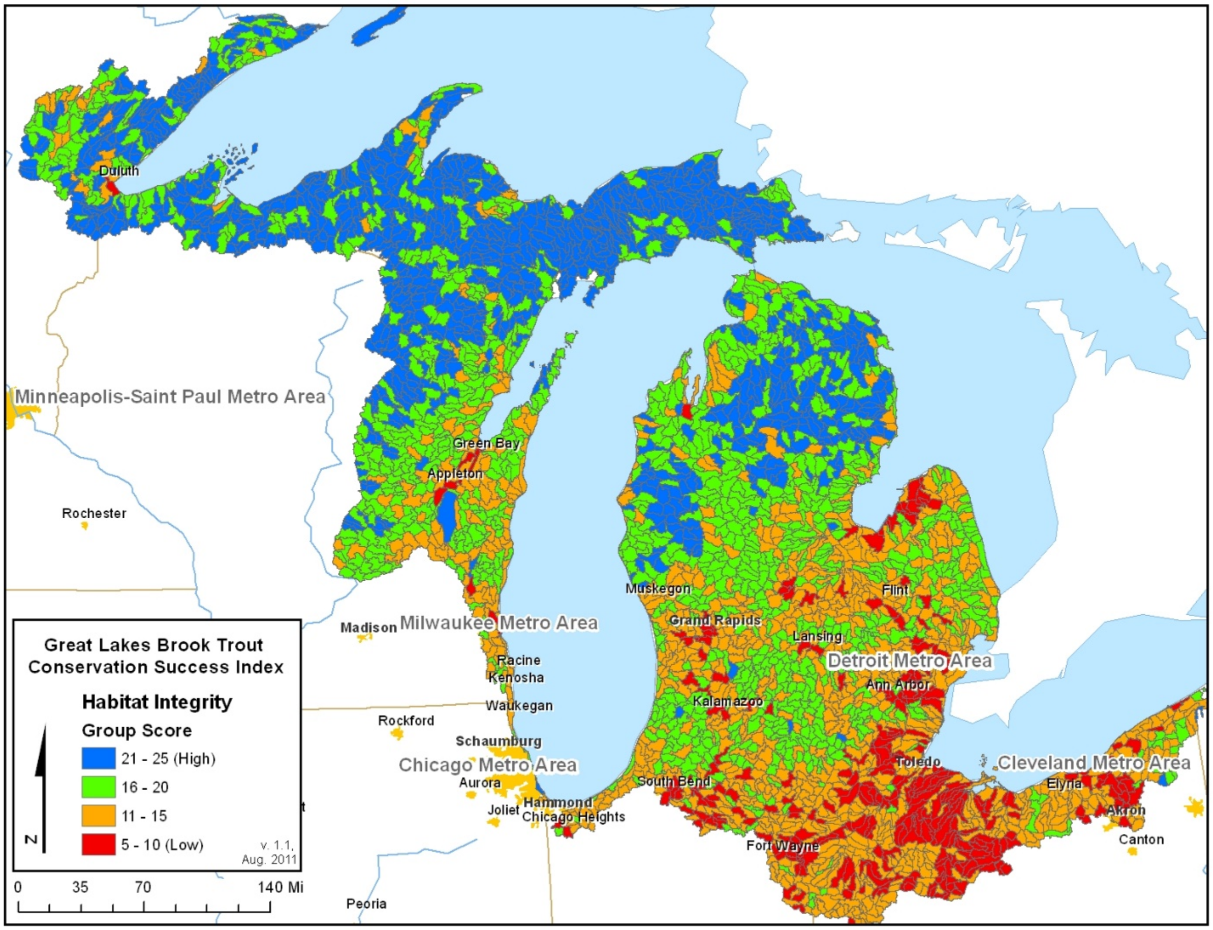

Great Lakes and
Coaster Brook Trout
Conservation Success Index
Climate Change Risk
Summer Low Flow
High
Moderate
Low
N
v. 1.1,
Aug. 2011
0
35
70
140 Mi
Duluth
Minneapolis-Saint Paul Metro Area
Rochester
Green Bay
Appleton
Madison
Milwaukee Metro Area
Racine
Kenosha
Waukegan
Rockford
Schaumburg
Chicago Metro Area
Aurora
Joliet
Hammond
Chicago Heights
Peoria
Muskegon
Grand Rapids
Lansing
Flint
Detroit Metro Area
Ann Arbor
Kalamazoo
South Bend
Toledo
Fort Wayne
Cleveland Metro Area
Elyria
Akron
Canton

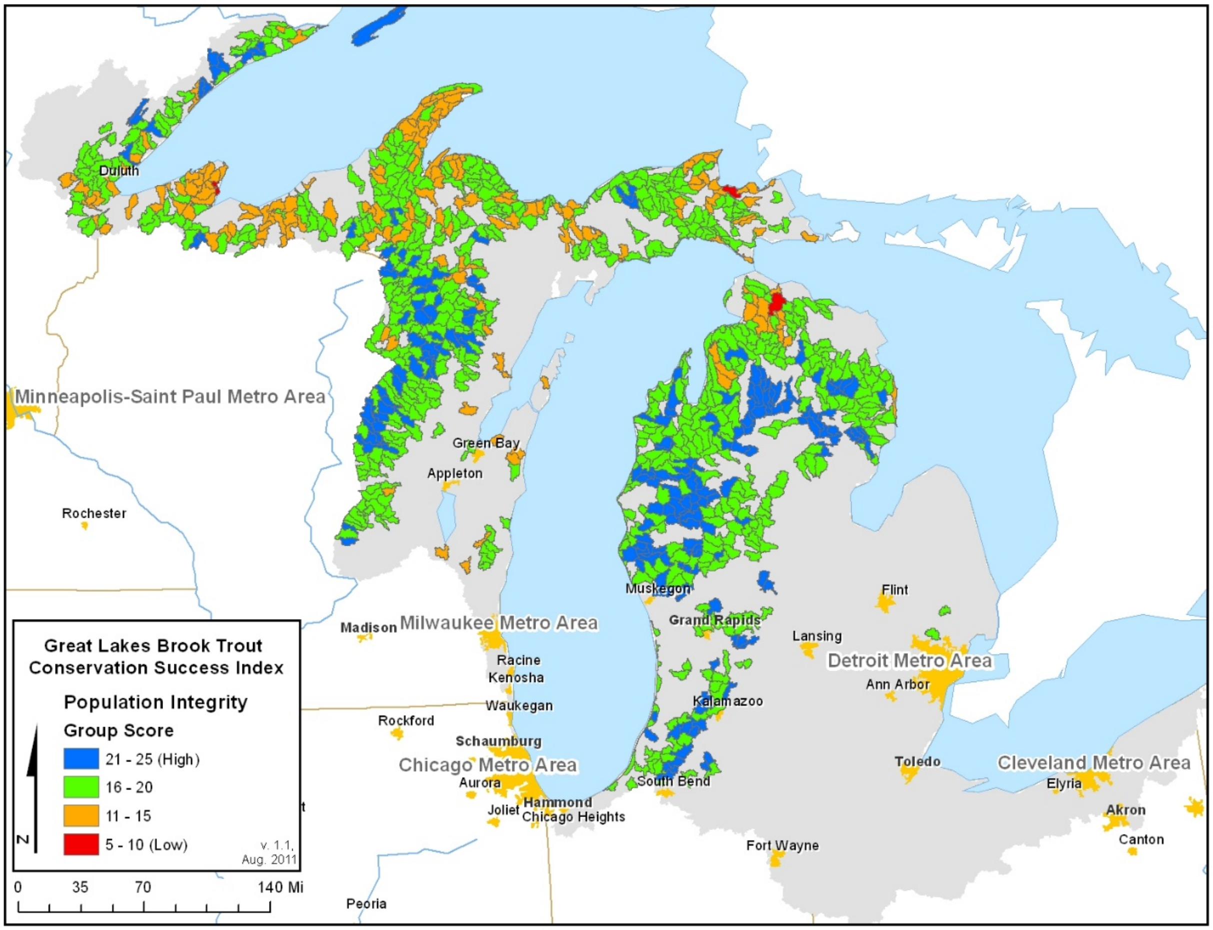

Great Lakes and
Coaster Brook Trout
Conservation Success Index
Climate Change Risk
Summer Temperature
High
Moderate
Low
N
v. 1.1,
Aug. 2011
0
35
70
140 Mi
Duluth
Minneapolis-Saint Paul Metro Area
Rochester
Green Bay
Appleton
Madison
Milwaukee Metro Area
Racine
Kenosha
Waukegan
Rockford
Schaumburg
Chicago Metro Area
Aurora
Joliet
Hammond
Chicago Heights
Peoria
Muskegon
Grand Rapids
Lansing
Flint
Detroit Metro Area
Ann Arbor
Kalamazoo
South Bend
Fort Wayne
Toledo
Cleveland Metro Area
Elyria
Akron
Canton



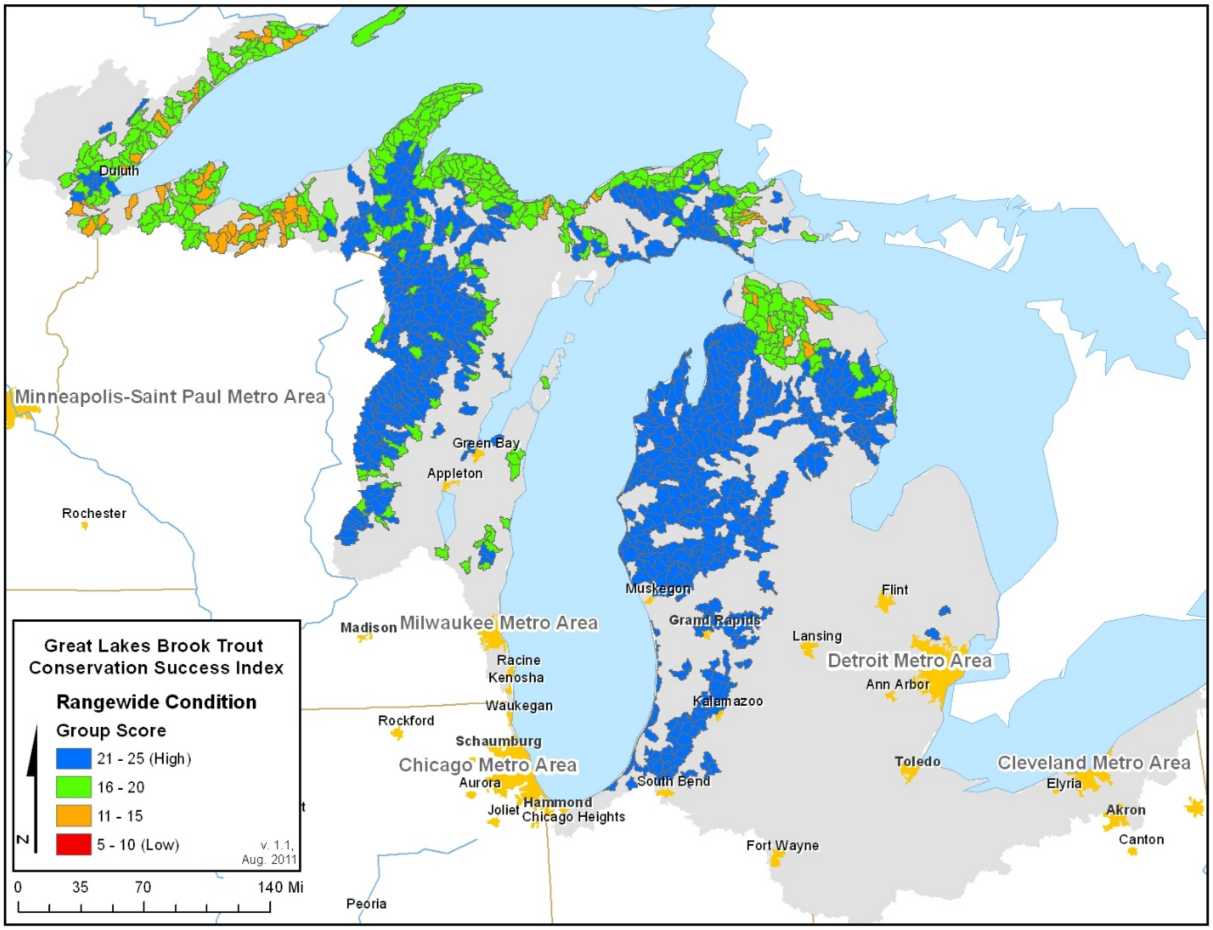
Great Lakes Brook Trout
Conservation Success Index
Population Integrity
High
Low
Extirpated
Habitat Integrity
High
Low
Protect
Restore Population
Reintroduce
Restore Habitat
Restore Both
Restore, then Reintroduce
Outside historic range
v. 1.1, Aug. 2011
N
0
35
70
140 Mi
Duluth
Minneapolis-Saint Paul Metro Area
Rochester
Green Bay
Appleton
Madison
Milwaukee Metro Area
Racine
Kenosha
Waukegan
Rockford
Schaumburg
Chicago Metro Area
Aurora
Joliet
Hammond
Chicago Heights
Peoria
Muskegon
Grand Rapids
Lansing
Flint
Detroit Metro Area
Ann Arbor
Kalamazoo
South Bend
Fort Wayne
Toledo
Cleveland Metro Area
Elyria
Akron
Canton

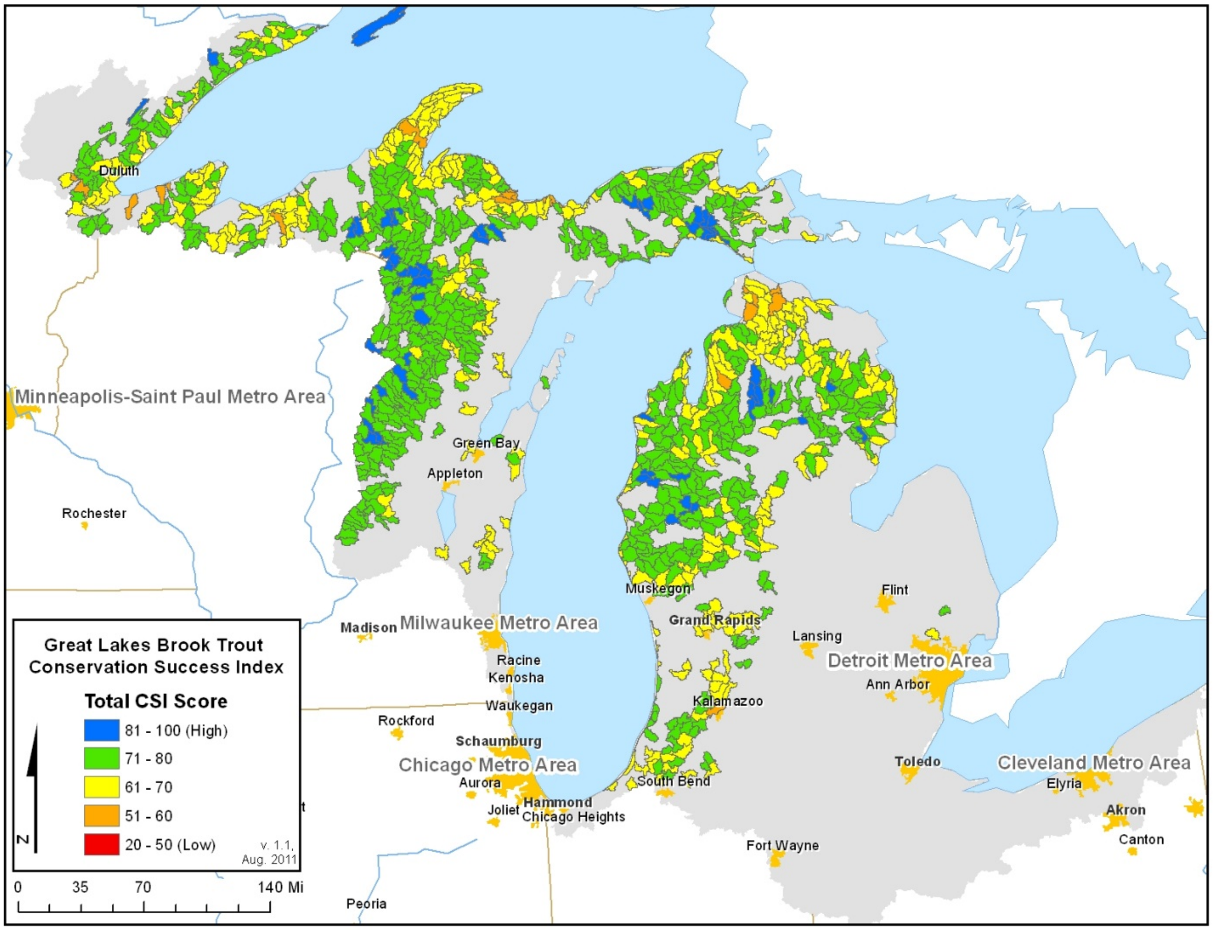

Great Lakes Brook Trout
Conservation Success Index
Future Security
Group Score
21 - 25 (High)
16 - 20
11 - 15
5 - 10 (Low)
v. 1.1,
Aug. 2011
N
0
35
70
140 Mi
Duluth
Minneapolis-Saint Paul Metro Area
Rochester
Green Bay
Appleton
Madison
Milwaukee Metro Area
Racine
Kenosha
Waukegan
Rockford
Schaumburg
Chicago Metro Area
Aurora
Joliet
Hammond
Chicago Heights
Peoria
South Bend
Fort Wayne
Muskegon
Grand Rapids
Lansing
Kalamazoo
Flint
Detroit Metro Area
Ann Arbor
Toledo
Cleveland Metro Area
Elyria
Akron
Canton


Great Lakes Brook Trout
Conservation Success Index
Habitat Integrity
Group Score
21 - 25 (High)
16 - 20
11 - 15
5 - 10 (Low)
v. 1.1,
Aug. 2011
N
0 35 70 140 Mi
Duluth
Minneapolis-Saint Paul Metro Area
Rochester
Green Bay
Appleton
Madison
Milwaukee Metro Area
Racine
Kenosha
Waukegan
Rockford
Schaumburg
Chicago Metro Area
Aurora
Joliet
Hammond
Chicago Heights
Peoria
Muskegon
Grand Rapids
Lansing
Flint
Detroit Metro Area
Ann Arbor
Kalamazoo
South Bend
Fort Wayne
Toledo
Cleveland Metro Area
Elyria
Akron
Canton



Great Lakes Brook Trout
Conservation Success Index
Population Integrity
Group Score
21 - 25 (High)
16 - 20
11 - 15
5 - 10 (Low)
v. 1.1,
Aug. 2011
0
35
70
140 Mi
N
Duluth
Minneapolis-Saint Paul Metro Area
Rochester
Green Bay
Appleton
Madison
Milwaukee Metro Area
Racine
Kenosha
Waukegan
Rockford
Schaumburg
Chicago Metro Area
Aurora
Joliet
Hammond
Chicago Heights
Peoria
Muskegon
Grand Rapids
Kalamazoo
South Bend
Lansing
Flint
Detroit Metro Area
Ann Arbor
Toledo
Fort Wayne
Cleveland Metro Area
Elyria
Akron
Canton


Great Lakes Brook Trout
Conservation Success Index
Rangewide Condition
Group Score
21 - 25 (High)
16 - 20
11 - 15
5 - 10 (Low)
v. 1.1,
Aug. 2011
N
0
35
70
140 Mi
Duluth
Minneapolis-Saint Paul Metro Area
Rochester
Green Bay
Appleton
Madison
Milwaukee Metro Area
Racine
Kenosha
Waukegan
Rockford
Schaumburg
Chicago Metro Area
Aurora
Joliet
Hammond
Chicago Heights
Peoria
Muskegon
Grand Rapids
Kalamazoo
South Bend
Fort Wayne
Lansing
Flint
Detroit Metro Area
Ann Arbor
Toledo
Cleveland Metro Area
Elyria
Akron
Canton



Great Lakes Brook Trout
Conservation Success Index
Total CSI Score
81 - 100 (High)
71 - 80
61 - 70
51 - 60
20 - 50 (Low)
v. 1.1,
Aug. 2011
N
0
35
70
140 Mi
Duluth
Minneapolis-Saint Paul Metro Area
Rochester
Green Bay
Appleton
Madison
Milwaukee Metro Area
Racine
Kenosha
Waukegan
Rockford
Schaumburg
Chicago Metro Area
Aurora
Joliet
Hammond
Chicago Heights
Peoria
Muskegon
Grand Rapids
Kalamazoo
South Bend
Fort Wayne
Lansing
Flint
Detroit Metro Area
Ann Arbor
Toledo
Cleveland Metro Area
Elyria
Akron
Canton

Conservation Success Index: Great Lakes and Coaster Brook Trout: Subwatershed Scoring and Rule Set

Introduction:

The CSI is an aggregate index comprised of four different component groups: Range-wide Condition; Population Integrity; Habitat Integrity; and Future Security. Each CSI group has five indicators that describe a specific component of each group. Each indicator is scored from 1 to 5 for each subwatershed, 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.

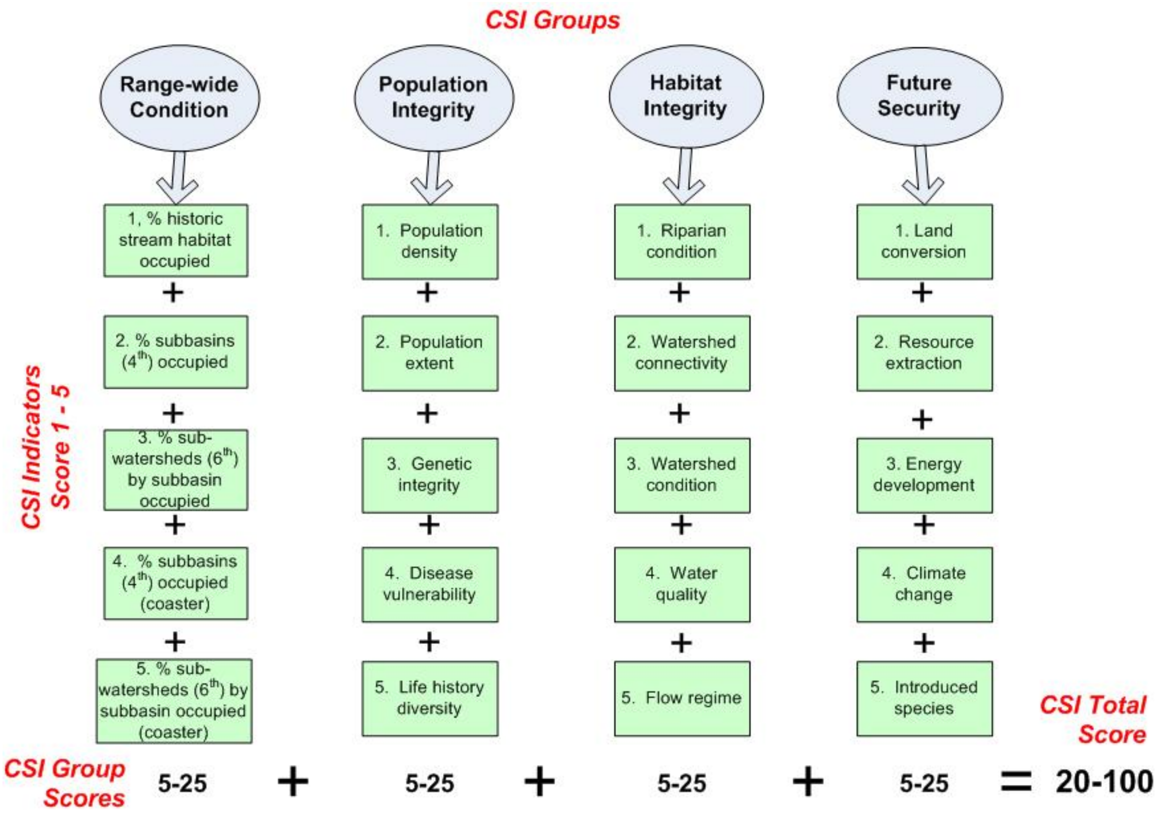


Figure 1. Each subwatershed is scored from 1 to 5 using 20 indicators within four main groups. Indicator scores are added per group to obtain an overall group score. Group scores are then added to obtain a composite CSI score for each subwatershed.

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 occupied within subbasin.
4. Percent subbasins occupied by coasters.
5. Percent subwatersheds occupied by coasters within subbasin.

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.

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

Data Sources: The historic distribution in Minnesota was defined by identifying all perennial streams (w/ connectors, artificial paths, and pipelines in NHDPlus) that were not upstream of natural barriers. Natural barriers were defined using GNIS Falls and barriers identified by Ward.[1] The historic distribution in Wisconsin was defined using a GAP model developed by John Lyons and others (J. Lyons, Wisconsin Department of Natural Resources, unpublished data), where brook trout were considered to be historically present if they had a presettlement probability of occurrence of 0.40 or greater and a presettlement predicted maximum daily mean temperature <=24.5 C. The historic distribution in Michigan was defined at a broad scale using Benke's[2] estimated historic distribution, and then using Michigan stream classifications within the broad-scale historic distribution: cold stream, cold small river, cold transitional stream, cold transitional small river. This was based on the assumption that the transitional streams have warmed over time due to human impacts, so they would have supported brook trout populations. The current distribution of brook trout in Minnesota was determined using sampling data compiled by Rebecca Reiche, Minnesota Department of Natural Resources. Current distribution in Wisconsin was defined by the Wisconsin Department of Natural Resources biologists in each county. In a few counties where maps were not returned (Douglas, Bayfield, Sheboygan, Fond du Lac, Washington counties), distributions were determined using survey data and stocking data from Wisconsin Department of Natural Resources databases as well as the Wisconsin Lake Superior brook trout plan.[3] Current distribution in Michigan was determined using cold stream and cold small river classifications from the Michigan Department of Natural Resources and Environment (T. Wills, Michigan Department of Natural Resources and Environment, pers. comm.).

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 in Minnesota was defined by identifying all perennial streams (w/ connectors, artificial paths, and pipelines in NHDPlus) that were not upstream of natural barriers. Natural barriers were defined using GNIS Falls and barriers identified by Ward.[1] The historic distribution in Wisconsin was defined using a GAP model developed by John Lyons and others (J. Lyons, Wisconsin Department of Natural Resources, unpublished data), where brook trout were considered to be historically present if they had a presettlement probability of occurrence of 0.40 or greater and a presettlement predicted maximum daily mean temperature <=24.5 C. The historic distribution in Michigan was defined at a broad scale using Benke's[2] estimated historic distribution, and then using Michigan stream classifications within the broad-scale historic distribution: cold stream, cold small river, cold transitional stream, cold transitional small river. This was based on the assumption that the transitional streams have warmed over time due to human impacts, so they would have supported brook trout populations. The current distribution of brook trout in Minnesota was determined using sampling data compiled by Rebecca Reiche, Minnesota Department of Natural Resources. Current distribution in Wisconsin was defined by the Wisconsin Department of Natural Resources biologists in each county. In a few counties where maps were not returned (Douglas, Bayfield, Sheboygan, Fond du Lac, Washington counties), distributions were determined using survey data and stocking data from Wisconsin Department of Natural Resources databases as well as the Wisconsin Lake Superior brook trout plan.[3] Current distribution in Michigan was determined using cold stream and cold small river classifications from the Michigan Department of Natural Resources and Environment (T. Wills, Michigan Department of Natural Resources and Environment, pers. comm.).

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 in Minnesota was defined by identifying all perennial streams (w/ connectors, artificial paths, and pipelines in NHDPlus) that were not upstream of natural barriers. Natural barriers were defined using GNIS Falls and barriers identified by Ward.[1] The historic distribution in Wisconsin was defined using a GAP model developed by John Lyons and others (J. Lyons, Wisconsin Department of Natural Resources, unpublished data), where brook trout were considered to be historically present if they had a presettlement probability of occurrence of 0.40 or greater and a presettlement predicted maximum daily mean temperature <=24.5 C. The historic distribution in Michigan was defined at a broad scale using Benke's[2] estimated historic distribution, and then using Michigan stream classifications within the broad-scale historic distribution: cold stream, cold small river, cold transitional stream, cold transitional small river. This was based on the assumption that the transitional streams have warmed over time due to human impacts, so they would have supported brook trout populations.

The current distribution of brook trout in Minnesota was determined using sampling data compiled by Rebecca Reiche, Minnesota Department of Natural Resources. Current distribution in Wisconsin was defined by the Wisconsin Department of Natural Resources biologists in each county. In a few counties were maps were not returned (Douglas, Bayfield, Sheboygan, Fond du Lac, Washington counties), distributions were determined using survey data and stocking data from Wisconsin Department of Natural Resources databases as well as the Wisconsin Lake Superior brook trout plan.[3] Current distribution in Michigan was determined using cold stream and cold small river classifications from the Michigan Department of Natural Resources and Environment (T. Wills, Michigan Department of Natural Resources and Environment, pers. comm.).

Indicator: 4. Percent subbasins occupied by coasters.

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 coaster brook trout that are currently occupied by coaster populations. The same percentage is applied to all subwatersheds scored.

Rationale: Life history forms, such as coaster brook trout, that occupy a larger proportion of their historic subwatersheds are likely to be more broadly distributed and have an increased likelihood of persistence. A broad distribution of self-sustaining coaster brook trout populations is a goal of management agencies.[5]

Data Sources: The historic and current distribution of coaster brook trout populations were based on the Lake Superior Rehabilitation Plan[6], the US Fish and Wildlife Service,[7;8] Schreiner et al.,[5] and Kusnierz et al.[9] The presence of a coaster population was not based on incidental or sporadic catches by anglers or during fishery surveys.

Indicator: 5. Percent subwatersheds occupied by coasters 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 coaster brook trout that are currently occupied by coaster populations within each subbasin. The percentage is the same for all subwatersheds within a subbasin.

Rationale: Life history forms, such as coaster brook trout, that occupy a larger proportion of their historic subwatersheds are likely to be more broadly distributed and have an increased likelihood of persistence. A broad distribution of self-sustaining coaster brook trout populations is a goal of management agencies.[5]

Data Sources: The historic and current distribution of coaster brook trout populations were based on the Lake Superior Rehabilitation Plan[6], the US Fish and Wildlife Service,[7;8] Schreiner et al.,[5] and Kusnierz et al.[9] The presence of a coaster population was not based on incidental or sporadic catches by anglers or during fishery surveys.

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:

Adult fish / mile	CSI Score
0	1
1 - 50	2
51 - 150	3
151 - 400	4
>400	5

Explanation: Population density within each subwatershed.
Rationale: Small populations, particularly those below an effective size of 500 individuals, are more vulnerable to extirpation.[10;11]

Data Sources: Population density data were from Minnesota Department of Natural Resources, Wisconsin Department of Natural Resources, and Michigan Department of Natural Resources and Environment fishery databases. Density represents the mean density at sites within a subwatershed. Density was determined by adjusting catch-per-effort data by a capture efficiency of 0.7. Scoring rules were based, in part, on May and Albeke[11] 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 extent is the amount of connected habitat available to the population.

Rationale: Populations with less available habitat are more vulnerable to extirpation[12] as a result of small, localized disturbances.

Data Sources: Population extent is determined by the amount of connected habitat for the contiguous populations as identified by the Minnesota Department of Natural Resources, the Wisconsin Department of Natural Resources, and using cold stream and cold small river classifications from the Michigan Department of Natural Resources and Environment (T. Wills, Michigan Department of Natural Resources and Environment, pers. comm.). Scoring rules were based, in part, on May and Albeke[11] and Williams et al.[4]

Indicator: 3. Genetic purity.

Indicator Scoring:

Stocking	CSI Score
Stocked with non-Great Lakes strain in subwatershed	1
Stocked with non-Great Lakes strain in subbasin	2
Stocked with other Great Lakes strain in subwatershed	3
Stocked with other Great Lakes strain in subbasin	4
No transbasin stockings in subbasin	5

Explanation: Genetic purity represents the probable genetic purity of populations.

Rationale: Hybridization or loss of the native genome via introgression with non-native species or strains are among the leading factors in the decline of native salmonids.[13] Introgression can also cause a loss of genetic variation. Since basin-wide genetics information was not available, stocking records were used as a surrogate for genetic integrity due to the potential of stocked fish to swamp wild population with low abundance.[14-16]

Data Sources: Stocking records were obtained from the Wisconsin Department of Natural Resources and Michigan Department of Natural Resources.

Strains listed in state databases were classified as follows:

Database	Strain	Native basin
Wisconsin DNR	Ash Creek – SW Feral	Mississippi
	Crystal Springs	Mississippi
	Domestic	local
	Feral	local
	Lake Superior Feral	Lake Superior
	Nipigon	Lake Superior
	St. Croix	Mississippi
	St. Croix/Chippewa Feral	Mississippi
Michigan DNR	Assinica	New York
	Assinica x Maine	Northeast
	Iron River	Lake Michigan
	Jumbo River	Lake Superior
	Michigan Domestic	local
	Nipigon	Lake Superior
	Owhi	Washington(Northeast)
	Rome	New York (Finger Lakes)
	Saint Croix Falls	Mississippi
	Siskowit	Lake Superior
	Temiscamie	Quebec (Lake Al-Banel)

Indicator: 4. Disease vulnerability.

Indicator Scoring:

Disease Vulnerability	CSI Score
Disease present in population	1
Disease within 1 km of habitat	2
Disease within 25 km of habitat	3
Disease within 50 km of habitat	4
Disease not within 50 km of habitat	5

Explanation: The risk of each population to relevant diseases.

Rationale: Viral Hemorrhagic Septicemia (VHS) can cause local to large-scale mortality of fishes, and has the potential to impact naive populations of native salmonids.[17-19]

Data Sources: Information on distribution of VHS was based the US Geological Survey.

Indicator: 5. Life history diversity.

Indicator Scoring:

Life History Diversity	CSI Score
Coasters lost from subwatershed and subbasin	1
Coasters lost from subwatershed but not subbasin	2
Coasters lost from subbasin, but did not historically occur in subwatershed	4
Coasters retained or did not exist historically in subbasin	5

Explanation: The presence of adfluvial coaster brook trout populations in historically occupied subwatersheds and subbasins.

Rationale: Loss of life history forms, particularly migratory forms, increases the risk of extirpation and may reduce genetic diversity.[12;20;21]

Data Sources: Life history information was based on the Lake Superior Rehabilitation Plan[6], the US Fish and Wildlife Service,[7;8] Schreiner et al.,[5] and Kusnierz et al.[9] The presence of a coaster population was not based on incidental or sporadic catches by anglers or during fishery surveys.

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

Overview:

1. Riparian condition
2. Watershed connectivity
3. Watershed condition
4. Water quality
5. Flow regime

Indicator: 1. Riparian condition.

Indicator Scoring:

% Riparian Buffer Converted	Buffer Road Density (Road miles / Stream mile)	CSI Score

75 - 100%	0.5 – 1.0	1
50 – 75%	0.25 – 0.49	2
25 – 50%	0.24 - 0.10	3
10 – 25%	0.05 – 0.09	4
0 – 10%	0 – 0.04	5

Explanation: Percent riparian buffer (300 ft. buffer) that is converted from natural land cover (forest or grass), and roads within 150 ft of perennial streams in the subwatershed.

Rationale: Percent riparian buffer that is converted from natural vegetation is a remotely sensed measure of riparian conditions[22] that is often related to aquatic habitat conditions[23], and 300 ft. is a useful buffer width in which to measure riparian condition.[24] Roads along streams can also contribute large amounts of fine sediments that smother benthic invertebrates, embed spawning substrates, and increase turbidity.[25;26]

Data Sources: Riparian vegetation was determined using the National Land Cover Database[27] using Developed, Pasture/Hay, and Cultivated Crops land cover classes. Road density within a 150 ft buffer was computed using ESRI Tele Atlas North America, Inc. roads[28] and the National Hydrography Dataset Plus.[29]

Indicator: 2. Watershed connectivity.

Indicator Scoring:

Current/historic connectivity in subwatershed	Road-Stream crossings	CSI Score
<50%	>50	1
50 – 74%	26-50	2
75 – 89%	11-25	3
90 – 94%	5-10	4
95 – 100%	<5	5

Score for worst case

Current/historic connectivity in subbasin:

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

Explanation: 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. The number road-stream crossings of class 4 and higher roads and 1st and 2nd order streams in the subwatershed.

Rationale: Increased hydrologic connectivity provides more habitat area and better supports multiple life histories, which increases the likelihood of population persistence.[12] Road-stream crossings on small streams can inhibit fish passage serve as an indication of stream connectivity, and the likelihood of fish passage problems increases with more road-stream crossings.

Data Sources: Stream network connectivity was based on the National Hydrography Dataset Plus[29] and several barriers datasets. Natural barriers were identified as 'Falls' within the GNIS dataset,[30] whereas man-made barriers were based on the National Inventory of Dams,[31] and information on water-control structures and known fish barriers from the Minnesota Department of Natural Resources (Lyn Bergquist, MDNR, pers. comm.). For road crossings, Strahler stream orders were based on the National Hydrography Dataset Plus.[29] Roads data was based on the ESRI Tele Atlas North America, Inc. roads[28], but only RTE_Class 4 and higher roads were used since major roads typically do not have fish passage problems.

Indicator: 3. Watershed condition.

Indicator Scoring:

% Row crop agriculture	% Impervious	CSI Score
75-100%	≥30%	1
50-75%	20 – 29%	2
20-50%	10 – 19%	3
5-20%	5 – 9%	4
0-5%	0 - 4%	5

Score for worst case

Explanation: The percentage of land converted to agriculture and percentage of land that is impervious/urban.

Rationale: Agricultural land can impact aquatic habitats by contributing nutrients and fine sediments, and deplete dissolved oxygen.[32] The amount of urban/impervious land cover has shown alter streamflows and degrade stream habitat and fish communities.[24;33]

Data Sources: The National Land Cover Database[27] was used to identify cultivated crop agricultural lands (the Cultivated Crops classification). Percent urban/impervious was determined using National Land Cover Data[34] and Low, Medium, and High Intensity Developed land classes.

Indicator: 4. Water quality.

Indicator Scoring:

Miles 303(d) Streams	Number Active Mines	NPDES Permits	CAFO Animal Units	CSI Score
>2	≥10	≥4	>10,000	1
1 – 2	7-9	3	5,000 – 10,000	2
0.5 - 1	4-6	2	1,000 – 5,000	3
0 – 0.5	1-3	1	>0 – 999	4
0	0	0	0	5

Score for worst case.

Explanation: The presence of 303(d) impaired streams, number of active mines, number of National Pollution Discharge Elimination System permits, and number of total animal units in registered concentrated (or confined) animal feeding operations (CAFOs).

Rationale: Decreases in water quality, including reduced dissolved oxygen, increased turbidity, increased temperature, and the presence of pollutants, reduces habitat suitability for salmonids. Mining activity can deteriorate water quality through leachates and sediments. NDPES permits indicate regulated point source discharges that can impair water quality.[35] Concentrated animal feeding operations indicate areas with high concentrations of livestock that can impair water quality.[36]

Data Sources: 303(d) impaired streams were obtained from the USEPA.[37] Active mines were identified by using the Mineral Resources Data System[38]. The number of NPDES permits (Permit Compliance System majors only) was determined using USEPA data.[39] The location of confined animal feeding operations and associated animal units were obtained from the Minnesota Pollution Control Agency,[40] Wisconsin Department of Natural Resources,[41] Michigan Department of Natural Resources and Environment (Mike Bitondo, MDNRE, pers. comm.).

Indicator: 5. Flow regime.

Indicator Scoring:

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

Score for worst case.

Explanation: Miles of canals and ditches, number of dams, acre-feet of reservoir storage per perennial stream mile.

Rationale: Natural flow regimes are critical to proper aquatic ecosystem function[42]. Canals, ditches, dams, and reservoirs alter streamflows. Reduced or altered flows reduce the capability of watersheds to support native biodiversity and salmonid populations.

Data Sources: The National Inventory of Dams[31] was the data source for dams and their storage capacity. Miles of canals and ditches is from the National Hydrography Dataset Plus[29], but some known errors in stream classification were corrected.

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[43].

Data Sources: Slope was computed from elevation data from the National Hydrography Dataset Plus[29]. Land cover was determined from the National Land Cover Database[27], 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[44], roads from Tele Atlas,[28] and land ownership was from Protected Areas Database of the United States.[45]

Indicator: 2. Resource extraction.

Indicator Scoring:

Forest management	CSI Score
51-100%	1
26 – 50%	2
11 – 25%	3
1 – 10%	4
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) 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 fishes[46].

Data Sources: Timber management potential identifies productive forest types using the existing vegetation type in the Landfire dataset.[47] Protected areas data were compiled from the ESRI, Tele Atlas North American / Geographic Data Technology dataset on protected areas[48] and the U.S. Department of Agriculture, Forest Service's National Inventoried Roadless Areas dataset[49].

Indicator: 3. Energy Development.

Indicator Scoring:

Wind development or coal reserves	New Dams 4th	New Dams 6th	CSI Score
51-100%	≥4	≥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 coal reserves and 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.[50] 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).[51] Coal leases are mineable types from the Coal Fields of the United States dataset.[52] Potential dam sites are based on Idaho National Laboratory (INL) hydropower potential data[53]. Protected areas data were compiled from the ESRI, Tele Atlas North American / Geographic Data Technology dataset on protected areas[48] and the U.S. Department of Agriculture, Forest Service's National Inventoried Roadless Areas dataset[49].

Indicator: 4. Climate change.

Indicator Scoring:

TU Climate Change Analysis	
Climate Risk Factors	**CSI Score**
High, High	1
High, Moderate	2
Moderate, Moderate; High, Low	3
Low, Moderate	4
Low, Low	5

Explanation: Climate change is based on risk to increase summer temperatures and increased frequency of summer low flows:

a. Increased Summer Temperature: increased air temperature will impact temperature sensitive salmonids. For each subwatershed, computed mean August air temperatures from PRISM normals[54] for perennial streams. These were then adjusted by the projected increase for August temperatures for 2050 under the A2 scenario,[55] but increases were adjusted based on the baseflow index since groundwater-dominated streams will better buffer stream temperatures against increases in air temperature: Temperature Risk = Mean August Temperature + (Projected Temperature Increase x (1.5 – Baseflow Index/100). Temperature risks were based on probable projected air temperature increase effects on stream temperatures.

Temperature Risk (C)	Temperature risk
> 22.5 C	High
< 22.5 C and > 20.5 C	Moderate

< 20.5 C	Low

b. Summer Low Flow: Summer low-flow periods will be most pronounced in areas with reduced August precipitation in areas where streamflows are mostly comprised of runoff (as opposed to baseflow). For each subwatershed, the percent change in August precipitation is multiplied by the Base-Flow Index (rescaled from 0 [100% groundwater] to 1 [100% runoff]): Low Flow Index = % Change in Precipitation x (1 – Baseflow Index / 100).

Summer Low Flow	Temperature risk
< -10%	High
< -5% and >-10%	Moderate
< -5%	Low

Rationale: Climate change in the Midwest is likely to threaten most salmonid populations because of warmer water temperatures and changes in streamflow regimes, including extended low-flow periods.[56] Temperature increases have the potential to impact coldwater species occupying habitat at the edge of their thermal tolerance.[57] Changes in summer precipitation can reduce baseflows during low-flow periods and limit habitat availability and exacerbate temperature changes. Some of these risks are discussed by Williams et al.[58]

Data Sources: Temperature and precipitation data were obtained from the PRISM Group.[54] The Baseflow Index data represents the fraction of streamflow that is comprised of baseflow rather than runoff.[59]

Indicator: 5. Introduced species.

Indicator Scoring:

Road Density	CSI Score
Any	1
> 4.7	2
1.7 – 4.7	3
<1.7	4
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.[13] 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.[60]

Data Sources: Roads were obtained from ESRI, Tele Atlas North American / Geographic Data Technology dataset on roads.[28]

Reference List

1. M. Ward, "Status of coaster brook trout in the Minnesota waters of Lake Superior" *Report No. F-29-R(P)-27* (Minnesota Department of Natural Resources, Fisheries Division, St. Paul, 2007).

2. R. J. Benke, Trout and salmon of North America (The Free Press, New York, 2002).

3. WDNR and USFWS, "Wisconsin Lake Superior Basin brook trout plan" (Wisconsin Department of Natural Resources and U.S. Fish and Wildlife Service, unpublished, 2005).

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. D. R. Schreiner et al., "Management perspectives on coaster brook trout rehabilitation in the Lake Superior Basin", *N.Am.J.Fish.Manage.* 28, 1350-1364 (2008).

6. L. E. Newman, R. B. DuBois, T. N. Halpern, "A brook trout rehabilitation plan for Lake Superior" *Report No. Miscellaneous Publication 2003-03* (Great Lakes Fisheries Commission, Ann Arbor, Michigan, 2003).

7. H. L. Enterline, "Coaster brook trout in Lake Huron" (U.S. Fish and Wildlife Service, Alpena, Michigan, 2000).

8. U.S.Fish and Wildlife Service, "12-month finding on petition to list coaster brook trout as endangered", *Federal Register* 74, 23376-23388 (2009).

9. P. C. Kusnierz, S. P. Stimmell, J. B. K. Leonard, "Movement and growth indicators in resident and adfluvial coaster brook trout (Salvelinus fontinalis) in the Hurricane River, Lake Superior, Michigan, USA", *Journal of Great Lakes Research* 35, 385-391 (2009).

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

11. 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).

12. 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).

13. 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).

14. M. K. Burnham-Curtis, "Genetic profiles of selected brook trout Salvelinus fontinalis populations from Lake Superior, Lake Huron and selected hatcheries" (Prepared by Great Lakes Science Center, U.S. Geological Survey for U.S. Department of the Interior Fish and Wildlife Service, Ann Arbor, Michigan, 2001).

15. B. L. Sloss, M. J. Jennings, R. Franckowiak, D. M. Pratt, "Genetic identity of brook trout in Lake Superior south shore streams: potential for genetic monitoring of stocking and rehabilitation efforts", *Trans.Amer.Fish.Soc.* 137, 1244-1251 (2008).

16. C. C. Wilson et al., "Conservation genetics of Lake Superior brook trout: issues, questions, and directions", *N.Am.J.Fish.Manage.* 28, 1307-1320 (2008).

17. N. Gagné et al., "Isolation of viral haemorrhagic septicaemia virus from mummichog, stickleback, striped bass and brown trout in eastern Canada", *Journal of Fish Diseases* 30, 213-223 (2007).

18. P. J. Walker and J. R. Winton, "Emerging viral diseases of fish and shrimp", *Veterinary Research* 41, 51 (2010).

19. M. B. Bain et al., "Distribution of an invasive aquatic pathogen (Viral Hemorrhagic Septicemia virus) in the Great Lakes and its relationship to shipping", *PLoS ONE* 5, 1-8 (2010).

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

21. 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).

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

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

24. L. Wang, J. Lyons, R. Gatti, "Influences of watershed land use on habitat quality and biotic integrity in Wisconsin streams", *Fisheries* 22(6), 6-12 (1997).

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

26. 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).

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

28. ESRI, "Roads" (Tele Atlas North America, Inc. / Geographic Data Technology, Inc., 2005).

29. 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/.

30. USGS. "Geographic names information system (GNIS)". 2008. U.S. Department of Interior, U.S. Geological Survey.

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

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

33. L. Wang, J. Lyons, P. Kanehl, R. Bannerman, "Impacts of urbanization on stream habitat and fish across multiple spatial scales", *Environ.Manag.* 28, 255-266 (2001).

34. USEPA. "National Landcover Dataset 2001". 2001. http://www.epa.gov/mrlc/nlcd-2001.html.

35. R. W. Adler, J. C. Landman, D. M. Cameron, The Clean Water Act 20 years later (Island Press, Washington, D.C., 1993).

36. J. Burkholder et al., "Impacts of water from Concentrated Animal Feeding Operations on water quality", *Environ.Health.Perspect.* 115, 308-312 (2007).

37. USEPA. "303(d) listed waters". (2002). 2002. Washington, DC, U.S. Environmental Protection Agency.

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

39. USEPA. "Facility and site information". 2009. United States Environmental Protection Agency. http://www.epa.gov/enviro/geo_data.html.

40. MPCA. "Feedlot Facilities". 7-22-2009. St. Paul, Minnesota, Minnesota Pollution Control Agency.

41. WDNR. "Concentrated Animal Feeding Operations". 2009. Madison, Wisconsin, Wisconsin Department of Natural Resources. http://dnr.wi.gov/runoff/ag/cafo.htm.

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

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

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

45. USGS. "Protected areas database of the United States (PAD-US) Version 1.1". 2010. Moscow, ID, USGS NBII.

46. 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).

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

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

49. 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.

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

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

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

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

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

55. E. Maurer, L. Brekke, T. Pruitt, P. Duffy, "Fine-resolution climate projections enhance regional climate change impact studies", *Eos Trans.AGU* 88, (2007).

56. K. A. Cherkauer and T. Sinha, "Hydrologic impacts of projected future climate change in the Lake Michigan region", *Journal of Great Lakes Research* in press, (2010).

57. J. Lyons, J. S. Stewart, M. Mitro, "Predicted effects of climate warming on the distribution of 50 stream fishes in Wisconsin, U.S.A.", *J.Fish Biol.* in press, (2010).

58. 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).

59. Wolock, D. M. "Base-flow index grid for the conterminous United States". Open-File Report 03-263. 2003. Reston, VA, US Geological Survey.

60. 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).