Conservation Success Index: Driftless Area Brook Trout

SALVELINUS FONTINALIS

Rev. 1.3 - 8/2011

SPECIES SUMMARY

The Driftless Area in the midwestern United States is a distinct landscape in the Upper Mississippi River Basin that was left unglaciated during the last glacial period ending 10,000 years ago. The term "driftless" indicates a lack of glacial drift, which are sediments left behind by glaciers. The area is characterized by karst topography, with springs, caves and sinkholes. Coldwater streams and rivers cut steep canyons prior to joining the Mississippi River. The Driftless Area encompasses southwestern Wisconsin, southeastern Minnesota, northeastern Iowa, and northwestern Illinois.

Driftless Area Map

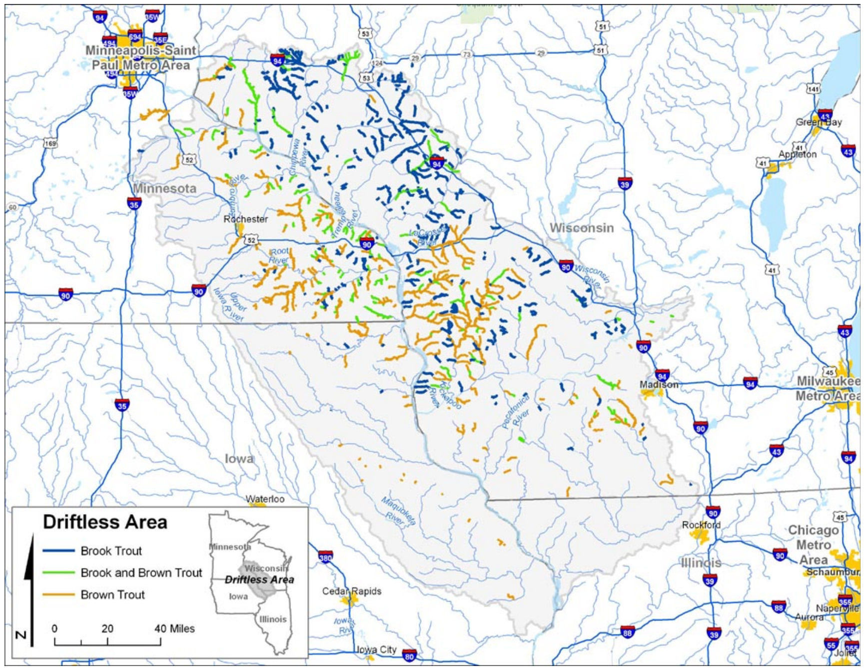


Photo: Driftless Area brook trout. Photo by L. Harris.

The brook trout *Salvelinus fontinalis* is the only trout native to the Driftless Area, and it was abundant in many streams prior to the 1850s. By 1900, brook trout were eliminated from many streams because of overexploitation and habitat degradation. Stream habitats were largely impacted when much of the natural prairie and forests were cleared for agriculture, fuels, and lumber. The reductions of natural land cover increased soil erosion and resulted in more frequent and larger floods. Upland soil erosion and flooding caused sediments to fill valley bottoms, which led to streams becoming wider and less connected with groundwater. When combined with a reduction in riparian vegetation and wood recruitment into streams, the wide, warm, and shallow streams were largely unable to sustain brook trout populations.

Beginning in the 1930's, efforts were made to improve farming practices and decrease soil erosion. In the second half of the 20th century, the U.S. Soil Conservation Service – today known as the Natural Resource Conservation Service – helped farmers implement conservation farming practices to reduce soil erosion and improve water quality. The Department's of Natural Resources of Minnesota, Wisconsin, and Illinois have partnered with local governments and organizations, including Trout Unlimited, to improve trout habitat in Driftless Area streams. In the past these efforts were not coordinated on a broad scale, but today several efforts are being made to strategically coordinate restoration efforts across the region. The Driftless Area Initiative is a multi-state partnership of federal agencies, state agencies, private organizations, and private individuals designed to restore and enhance the Driftless Area's ecology, economy, and cultural resources. The Driftless Area Restoration Effort is a Trout Unlimited effort aimed at restoring the coldwater streams and watersheds in the area.

Photo: Many Driftless Area streams were impacted and brook trout populations were extirpated as flooding and soil erosion increased when land was cleared between 1850 and 1900.

Photo: Many stream restoration projects have been undertaken as part of the Driftless Area Restoration Effort. Photo by J. Hastings.

Our CSI analysis incorporated data from the Wisconsin Department of Natural Resources, Minnesota Department of Natural Resources, Iowa Department of Natural Resources, Illinois Department of Natural Resources, and the Driftless Area Initiative. Their contributions were key to our understanding of brook trout in this area and development of the CSI. A complete list of data sources is provided at the bottom of the website.

Key CSI Findings

- Brook trout occupy variable amounts of their estimated historic range across the Driftless Area; however, their historic distribution in the Driftless Area is not precisely known
- Adult population densities are moderate, but many populations have limited extents
- The genetic purity of many populations is uncertain because of past stocking of eastern brook trout strains; however, current research is focused on understanding the genetic purity of populations across the Driftless Area
- Most subwatersheds scored moderate to poor because much of the Driftless Area has been converted for agriculture and has high erosion potential

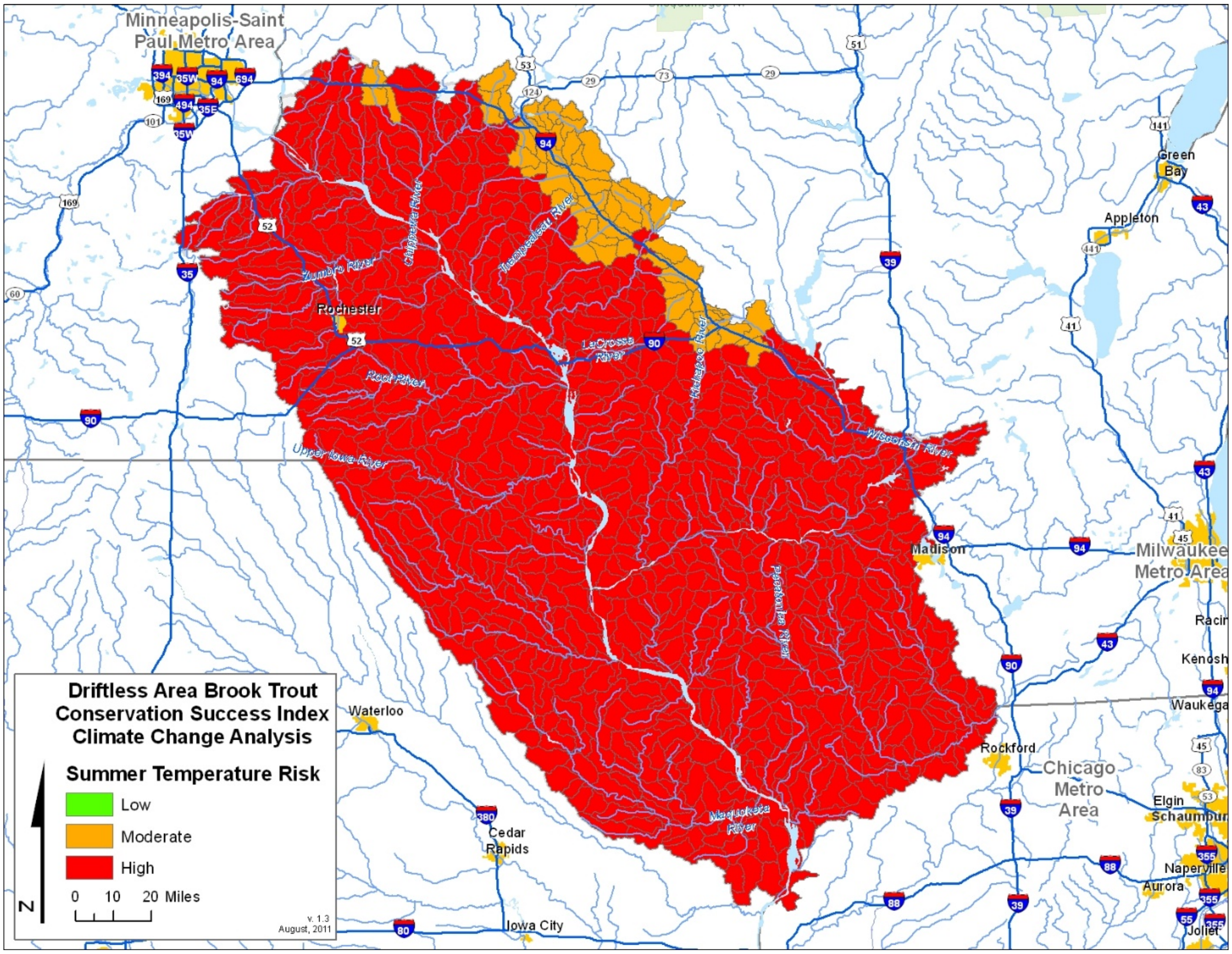
- Watershed connectivity in most subwatersheds has been disrupted by a high number of road crossings
- Water quality has been significantly impacted across the region due to an abundance of agricultural lands, high road densities along streams, and the presence of concentrated animal feeding operations. Many streams have been listed as 'impaired' during state water-quality assessments
- Dams and reservoir storage alter flow regimes in certain portions of the Driftless Area
- There is low risk of future land conversion because much of the landscape has already been converted for agriculture
- Only a few subwatersheds have high wind power development potential or have been identified for future hydropower development
- Increased stream temperatures due to climate warming pose a high future risk to stream habitats and brook trout populations across the Driftless Area
- Brown trout have been widely introduced and pose a risk to future brook trout restoration efforts

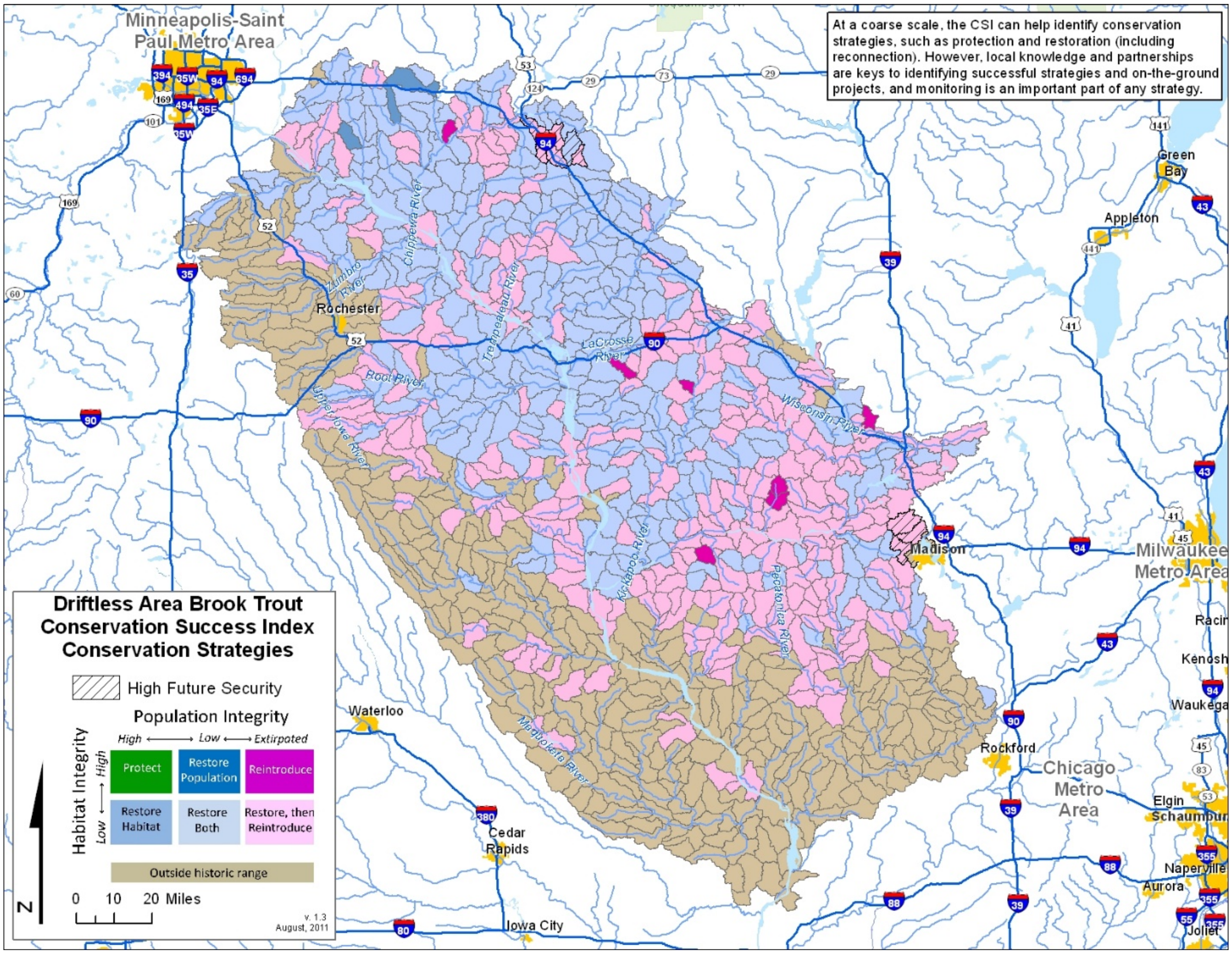
Prepared by Dan Dauwalter, 2/2011

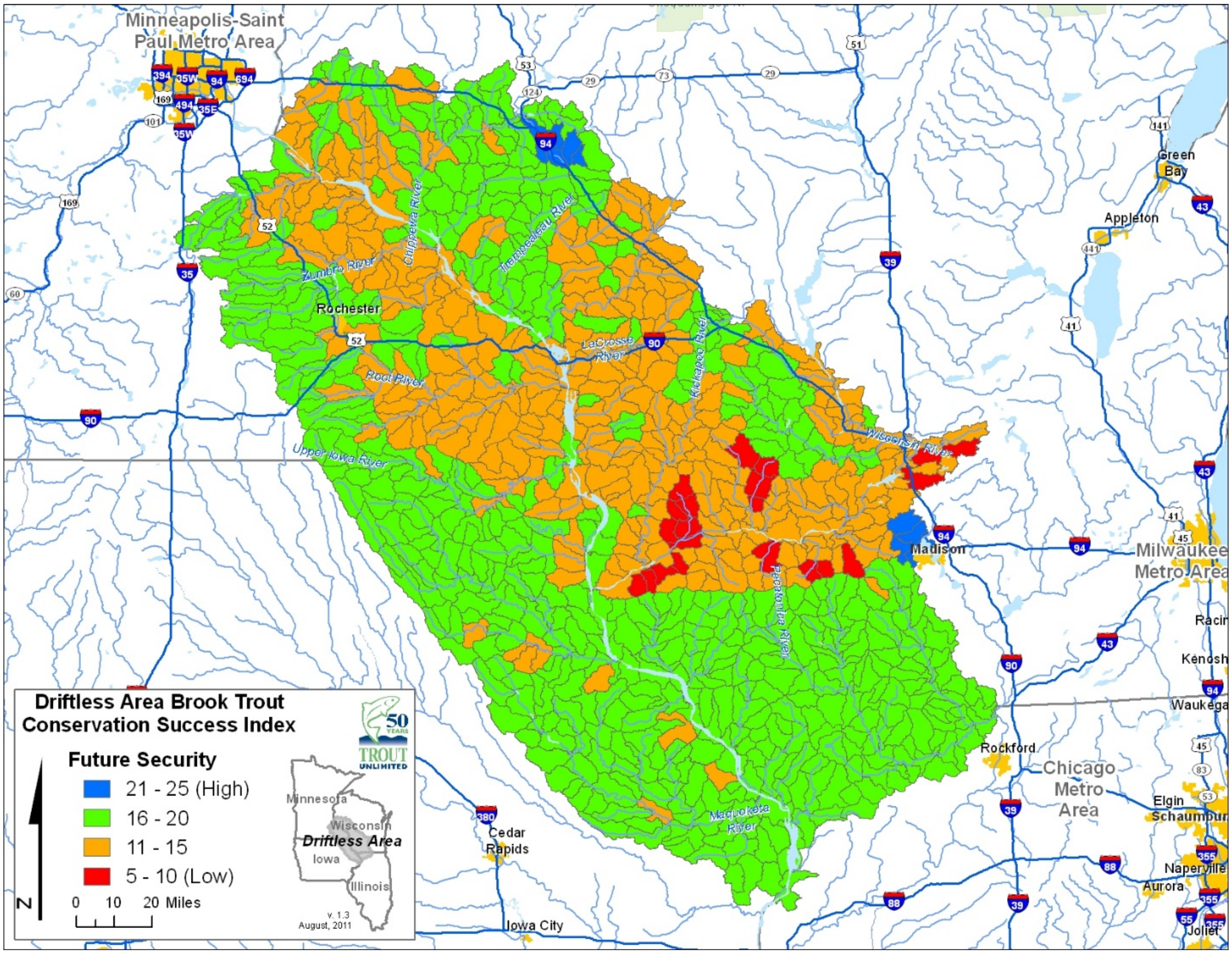
Table 1. CSI scoring results for Driftless Area brook trout. Rangewide Conditions and Population Integrity indicators were scored only for currently occupied habitat (262 subwatersheds), while Habitat Integrity and Future Security indicators were scored for all 819 subwatersheds in the Driftless Area. All indicators are scored from 1 (poorest) to 5 (best): see detailed methods for scoring Driftless Area brook trout.

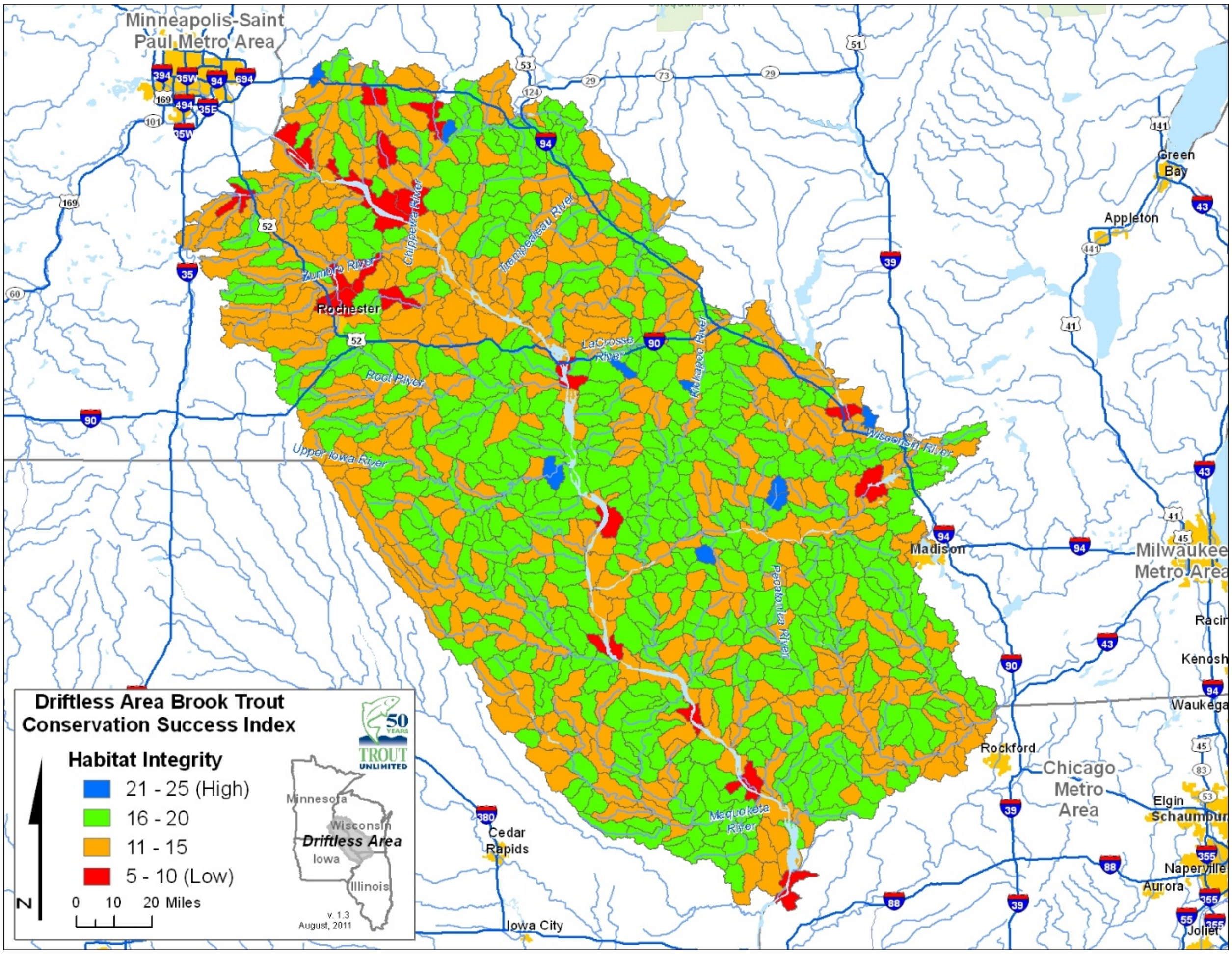
		Number of Subwatersheds Receiving Scores					**Total Subwatersheds Scored**
	CSI Indicator	**1**	**2**	**3**	**4**	**5**	
Range-wide Conditions	Percent historic stream habitat occupied	56	48	44	32	82	262
	Percent subbasins (4th) occupied	0	0	0	262	0	262
	Percent subwatersheds (6th) occupied	5	39	51	122	45	262
	Percent habitat by stream order occupied	15	1	1	5	240	262
	Percent historic lake area occupied	0	0	0	0	262	262
Population Integrity	Population Density	2	37	154	53	16	262
	Population Extent	152	53	16	19	22	262

	Genetic Purity	262	0	0	0	0	262
	Disease vulnerability	0	0	0	0	262	262
	Life history diversity	0	0	0	0	262	262
Habitat Integrity	Riparian condition	19	114	395	243	48	819
	Watershed connectivity	45	320	369	77	8	819
	Watershed conditions	219	348	233	15	4	819
	Water quality	178	23	107	47	464	819
	Flow regime	40	52	67	137	523	819
Future Security	Land conversion	4	9	22	168	616	819
	Resource extraction	14	210	234	286	75	819
	Energy development	84	0	2	12	721	819
	Climate change	769	0	50	0	0	819
	Introduced species	265	7	494	34	19	819

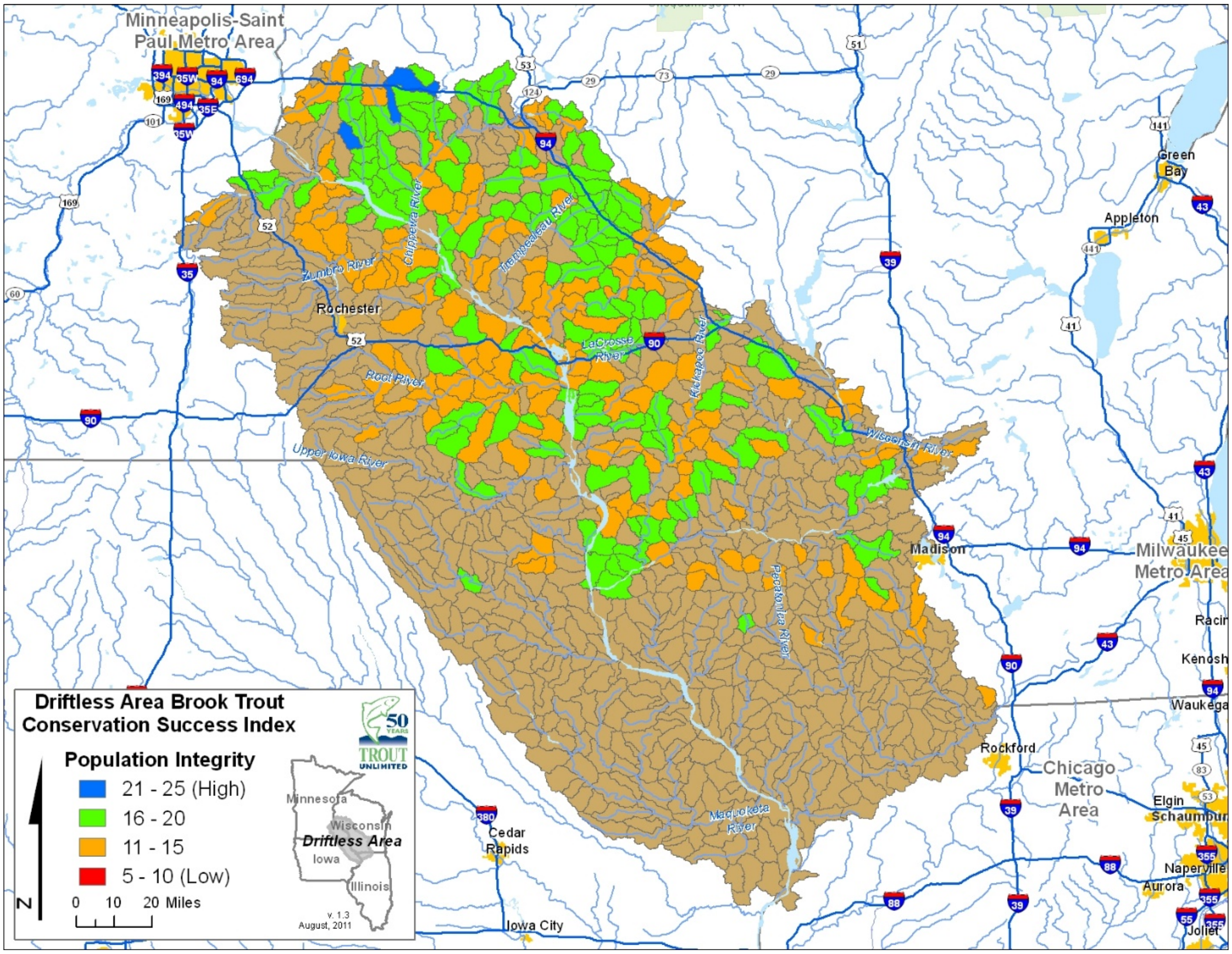

Driftless Area Brook Trout
Conservation Success Index
Climate Change Analysis
Summer Temperature Risk
Low
Moderate
High
N
0 10 20 Miles
v. 1.3
August, 2011
Minneapolis-Saint Paul Metro Area
Rochester
Madison
Milwaukee Metro Area
Chicago Metro Area
Rockford
Waterloo
Cedar Rapids
Iowa City
Green Bay
Appleton
Elgin
Naperville
Aurora
Joliet
Zumbro River
Chippewa River
Trempealeau River
Root River
Upper Iowa River
LaCrosse River
Kickapoo River
Wisconsin River
Pecatonica River
Maquoketa River

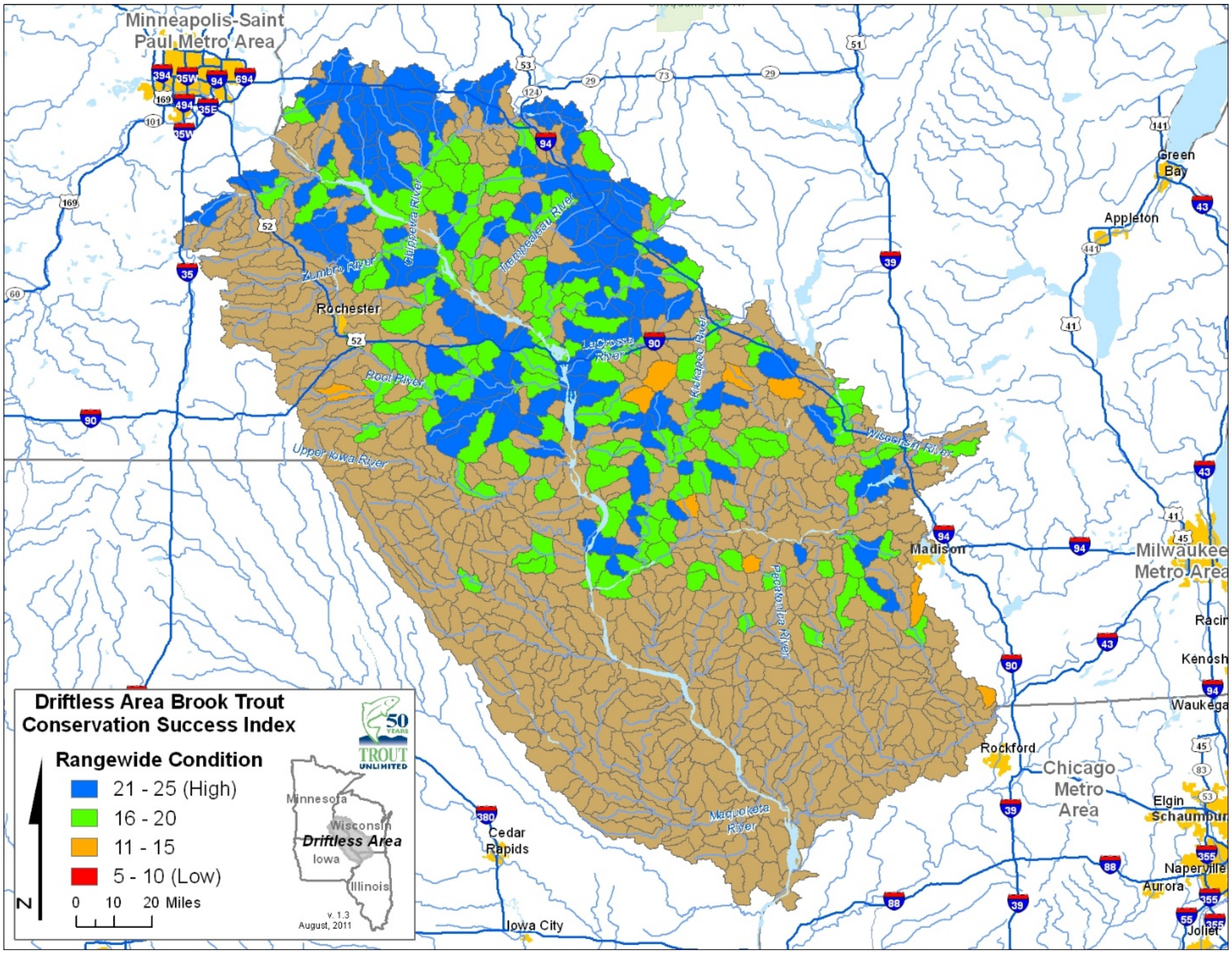

At a coarse scale, the CSI can help identify conservation strategies, such as protection and restoration (including reconnection). However, local knowledge and partnerships are keys to identifying successful strategies and on-the-ground projects, and monitoring is an important part of any strategy.
Driftless Area Brook Trout
Conservation Success Index
Conservation Strategies
High Future Security
Population Integrity
High
Low
Extirpated
Habitat Integrity
Protect
Restore Population
Reintroduce
Restore Habitat
Restore Both
Restore, then Reintroduce
Outside historic range
0 10 20 Miles
v. 1.3
August, 2011
Minneapolis-Saint Paul Metro Area
Rochester
Madison
Milwaukee Metro Area
Chicago Metro Area
Green Bay
Appleton
Waterloo
Cedar Rapids
Iowa City
Rockford
Elgin
Naperville
Aurora
Joliet
Zumbro River
Chippewa River
Trempealeau River
LaCrosse River
Root River
Upper Iowa River
Kickapoo River
Wisconsin River
Pecatonica River
Maquoketa River


Driftless Area Brook Trout
Conservation Success Index
Future Security
21 - 25 (High)
16 - 20
11 - 15
5 - 10 (Low)
0 10 20 Miles
N
Minnesota
Wisconsin
Driftless Area
Iowa
Illinois
v. 1.3
August, 2011
Minneapolis-Saint
Paul Metro Area
Rochester
Madison
Milwaukee
Metro Area
Chicago
Metro
Area
Rockford
Cedar
Rapids
Iowa City
Green
Bay
Appleton
Zumbro River
Chippewa River
Trempealeau River
LaCrosse
River
Kickapoo River
Root River
Upper Iowa River
Wisconsin River
Pecatonica River
Maquoketa
River
Elgin
Naperville
Aurora
Joliet
Kenosha
Waukegan

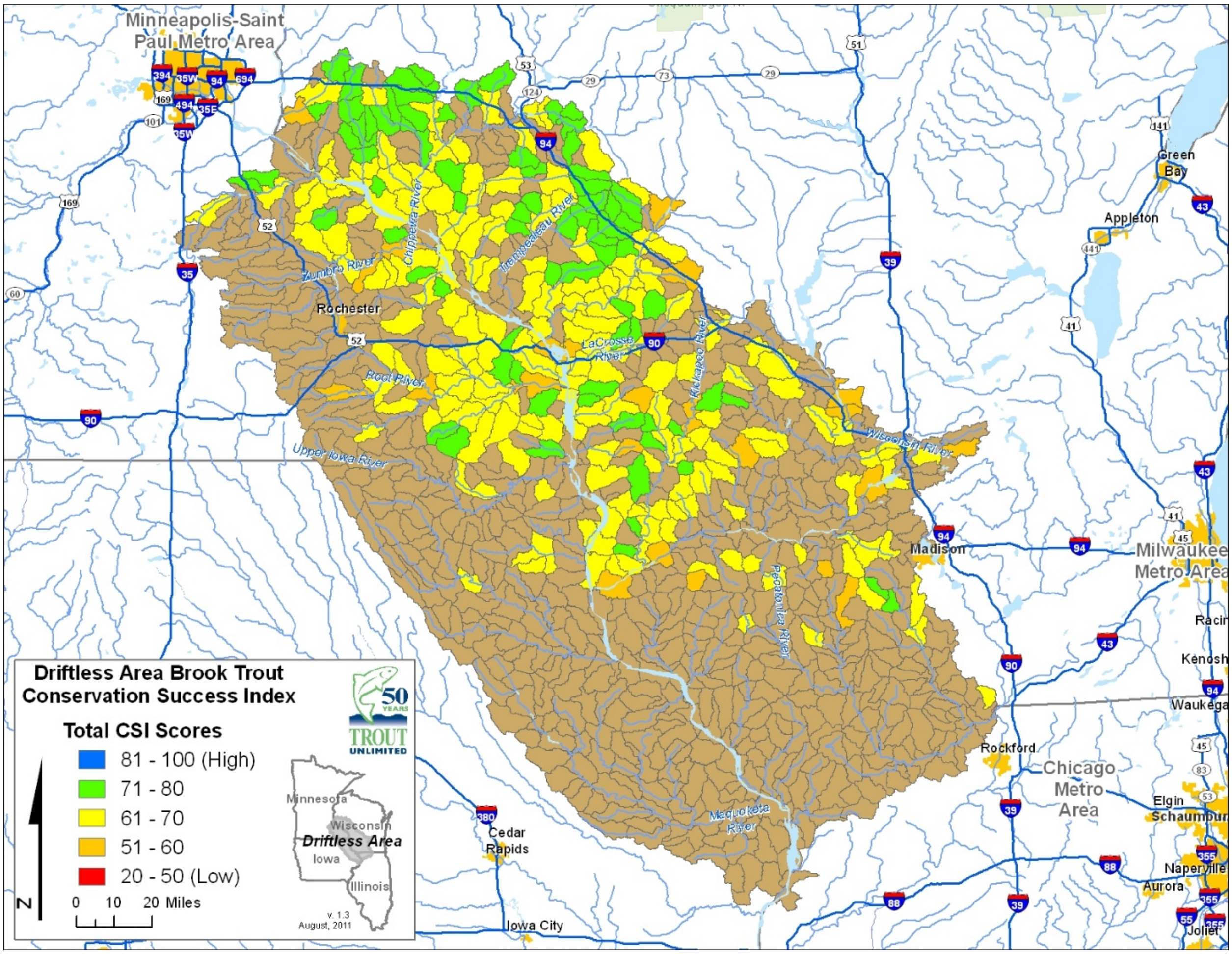


Driftless Area Brook Trout
Conservation Success Index
Habitat Integrity
21 - 25 (High)
16 - 20
11 - 15
5 - 10 (Low)
N
0 10 20 Miles
Minnesota
Wisconsin
Driftless Area
Iowa
Illinois
v. 1.3
August, 2011
Minneapolis-Saint Paul Metro Area
Rochester
Zumbro River
Chippewa River
Trempealeau River
LaCrosse River
Kickapoo River
Root River
Upper Iowa River
Wisconsin River
Pecatonica River
Maquoketa River
Madison
Milwaukee Metro Area
Green Bay
Appleton
Racine
Kenosha
Waukegan
Rockford
Chicago Metro Area
Elgin
Schaumburg
Naperville
Aurora
Joliet
Cedar Rapids
Iowa City


Driftless Area Brook Trout
Conservation Success Index
Population Integrity
21 - 25 (High)
16 - 20
11 - 15
5 - 10 (Low)
N
0 10 20 Miles
Minnesota
Wisconsin
Driftless Area
Iowa
Illinois
v. 1.3
August, 2011
TROUT UNLIMITED
50 YEARS
Minneapolis-Saint Paul Metro Area
Rochester
Madison
Milwaukee Metro Area
Chicago Metro Area
Green Bay
Appleton
Rockford
Cedar Rapids
Iowa City
Elgin
Schaumburg
Naperville
Aurora
Joliet
Kenosha
Waukegan
Zumbro River
Chippewa River
Trempealeau River
LaCrosse River
Kickapoo River
Root River
Upper Iowa River
Wisconsin River
Pecatonica River
Maquoketa River



Driftless Area Brook Trout
Conservation Success Index
Rangewide Condition
21 - 25 (High)
16 - 20
11 - 15
5 - 10 (Low)
0 10 20 Miles
N
Minnesota
Wisconsin
Driftless Area
Iowa
Illinois
v. 1.3
August, 2011
Minneapolis-Saint Paul Metro Area
Rochester
Zumbro River
Chippewa River
Trempealeau River
LaCrosse River
Kickapoo River
Root River
Upper Iowa River
Wisconsin River
Pecatonica River
Maquoketa River
Madison
Milwaukee Metro Area
Green Bay
Appleton
Rockford
Chicago Metro Area
Cedar Rapids
Iowa City
Elgin
Naperville
Aurora
Joliet


Driftless Area Brook Trout
Conservation Success Index
Total CSI Scores
81 - 100 (High)
71 - 80
61 - 70
51 - 60
20 - 50 (Low)
0 10 20 Miles
v. 1.3
August, 2011
Minneapolis-Saint Paul Metro Area
Rochester
Madison
Milwaukee Metro Area
Chicago Metro Area
Rockford
Cedar Rapids
Iowa City
Green Bay
Appleton
Minnesota
Wisconsin
Driftless Area
Iowa
Illinois

v. 1.2 February 2011

Conservation Success Index:
Driftless Area 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.

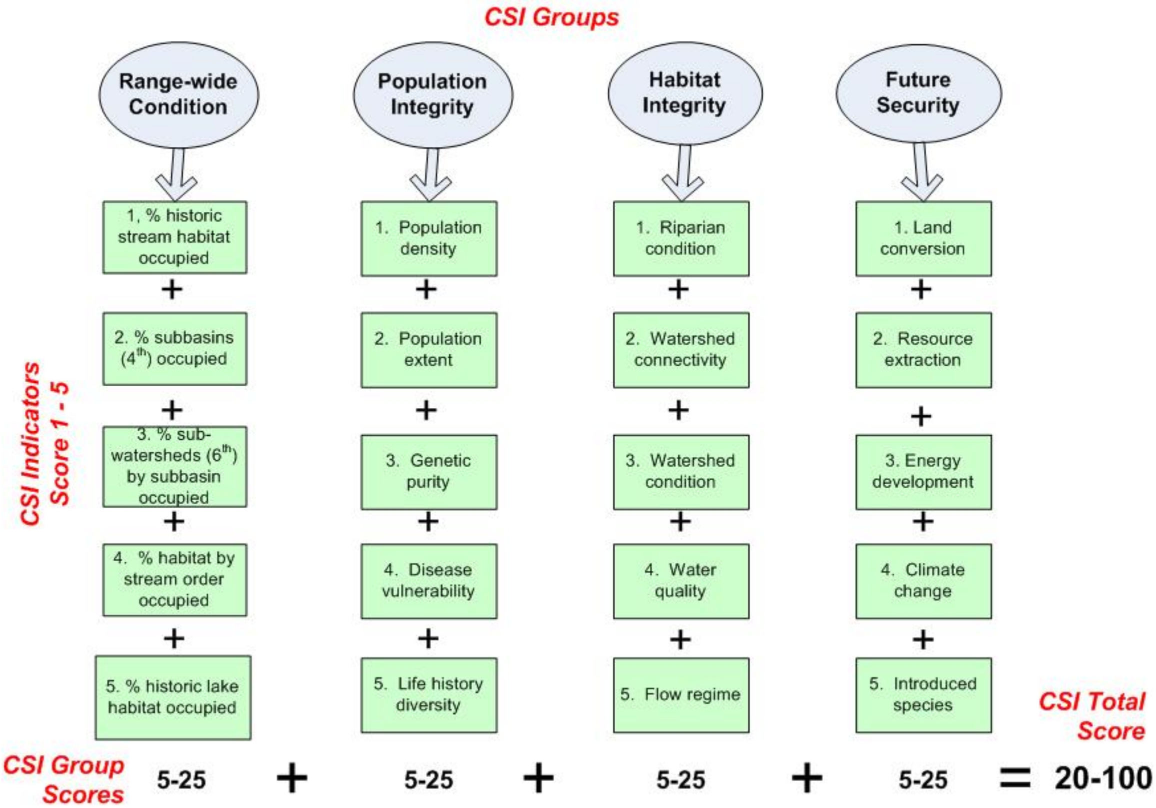


Figure 1. Each subwatershed is scored from 1 to 5 using 20 indicators within four main groups. Indicator scores are added per group to obtain an overall group score. Group scores are then added to obtain a composite CSI score for each subwatershed.

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 (4th level HUC) 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 habitat by surface area occupied.

Indicator: 1. Percent of 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 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 brook trout in the Driftless Area is not well defined and several data sources were used. For Wisconsin, historical (presettlement) predictions of brook trout presence (probability of presence >0) were modeled for a Great Lakes GAP project and were provided by John Lyons (Wisconsin Department of Natural Resources) and Jana

Stewart (U.S. Geological Survey); the model currently has no documentation, but is based on streamflow, land cover, air temperature, and lakes and reservoirs (J. Lyons, WDNR, pers. comm.). The historical distribution is poorly defined for Minnesota, Iowa, and Illinois. We used the presence of Class I and II trout streams identified as part of the Driftless Area Restoration Effort (DARE) Strategic Plan (N. Gillespie, Trout Unlimited, pers. comm.) and current distribution to define the historical distribution in these states, which was likely underestimated. The current distribution was defined by regional biologists of the Minnesota Department of Natural Resources, Wisconsin Department of Natural Resources, Iowa Department of Natural Resources, and Illinois Department of Natural Resources, and also brook trout data from the Wisconsin Department of Natural Resources and maps of brook trout distribution from the Minnesota Department of Natural Resources (http://www.dnr.state.mn.us/fishing/trout_streams/south_mn_maps.html).

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.[1]

Data Sources: See description for indicator 1 for brook trout distribution.

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 for brook trout distribution.

Indicator: 4. Habitat by stream order occupied.

Indicator Scoring:

Occupied 2nd order streams and higher	CSI Score
0 – 9%	1
10 – 14%	2
15 – 19%	3
20 – 24%	4
25 – 100%	5

Explanation: The percentage of currently occupied habitat that is first order streams.

Rationale: Species that occupy a broader range of stream sizes will have an increased likelihood of persistence. This is especially true because small, first order streams tend to have more variable environmental conditions and smaller populations than larger streams.[2]

Data Sources: See description for indicator 1 for brook trout distribution. Stream order was determined using the National Hydrography Dataset Plus[3].

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.[4]

Data Sources: There are no records that document historic brook trout occurrence in natural lakes in the Driftless Area. All occupied subwatersheds were scored a 5.

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	CSI Score
0	1
1 - 50	2
51 - 150, No recent data	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.[5;6]

Data Sources: Catch-per-effort data (N / mile) of adult brook trout were obtained from Minnesota DNR, Wisconsin DNR, and Iowa DNR for 2007 to 2008. Catch-per-effort was adjusted using an average sampling efficiency (p = 0.7) to obtain unbiased adult density estimates (N / mile). Densities for each stream reach where data were collected were averaged per subwatershed; densities were not weighted per population extent because of high variation across sites and streams and the uncertainty associated with extrapolating catch-per-effort beyond sample sites. Scoring rules were based, in part, on Williams et al.[1].

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[7] as a result of small, localized disturbances.

Data Sources: Scores were based on extent of connected habitat for the contiguous populations identified by regional biologists from the Minnesota DNR, Wisconsin DNR, and Iowa DNR, but also incorporating populations from state databases that were missed by the biologists or shown on public maps (e.g., Minnesota DNR maps of managed stream fisheries; http://www.dnr.state.mn.us/fishing/trout_streams/south_mn_maps.html). Scoring rules were based, in part, on Williams et al.[1]

Indicator: 3. Genetic purity.

Indicator Scoring:

Genetic purity (introgression)	CSI Score
< 80%, Unknown	1
80 – 89%	2
	3
90 – 99%	4
100%	5

Explanation: Genetic purity 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.[8] Introgression with other subspecies can also cause a loss of genetic variation.

Data Sources: There are no non-native species in Driftless Area with which native brook trout hybridize. However, recent genetics research in Minnesota shows that non-native strains of eastern brook trout have been stocked into Minnesota streams and populations show genetic characteristics similar to eastern brook trout (L. Miller, University of Minnesota, pers. comm.). However, there is no extensive information on brook trout genetics nor stocking history across the entire Driftless Area, and genetic research in Minnesota is preliminary (L. Miller, University of Minnesota, pers. comm.). The Minnesota Department of Natural Resources is currently conducting a distribution study of brook trout in the Driftless Area, and the study contains a genetic component (J. Hoxmeier, Minnesota DNR, pers. comm.) but the study is still in progress. The Iowa DNR is also in the process of determining the genetic status of brook trout populations (W. Stott and T. King, Iowa DNR via L. Miller, University of Minnesota, pers. comm.), and Brian Sloss, at the University of Wisconsin – Stevens Point is currently evaluating brook trout genetics in Wisconsin (L. Miller, University of Minnesota, pers. comm.). Because of the uncertainty associated with brook trout stocking histories and genetics, every population was scored a 1.

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.[9-11]

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

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.[7;12;13]

Data Sources: There is no evidence of adfluvial or fluvial life histories in Driftless Area brook trout. All populations and subwatersheds were scored a 5 since there is no evidence that a life history was lost.

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[14] that is often related to aquatic habitat conditions[15], and 300 ft. is a useful buffer width in which to measure riparian condition.[16] Roads along streams can also contribute large amounts of fine sediments that smother benthic invertebrates, embed spawning substrates, and increase turbidity.[17;18]

Data Sources: Riparian vegetation was determined using the National Land Cover Database[19] 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[20] and the National Hydrography Dataset Plus.[3]

Indicator: 2. Watershed connectivity.

Indicator Scoring:

Road-Stream crossings	CSI Score
>50	1
26-50	2
11-25	3
5-10	4
<5	5

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

Rationale: 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. Increased hydrologic connectivity provides more habitat area and better supports interactions with other populations, which increases the likelihood of persistence.[7]

Data Sources: Stream network and Strahler stream orders were based on the National Hydrography Dataset Plus.[3] Roads data was based on the ESRI Tele Atlas North America, Inc. roads[20], 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	Soil Erosion Risk	CSI Score
75-100%	≥30%	Highest (>4.5)	1
50-75%	20 – 29%	High (3.5 – 4.5)	2
20-50%	10 – 19%	Moderate (2.5 – 3.5)	3
5-20%	5 – 9%	Low (1.5 – 2.5)	4
0-5%	0 - 4%	Lowest (<1.5)	5

Score for worst case

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

Rationale: Agricultural land can impact aquatic habitats by contributing nutrients and fine sediments, and deplete dissolved oxygen.[21] The amount of urban/impervious land cover has shown alter streamflows and degrade stream habitat and fish communities.[16;22] Erosive soils also contribute sediment to streams,[21] and the Driftless Area has a long history of soil erosion problems.

Data Sources: The National Land Cover Database[19] was used to identify cultivated crop agricultural lands (the Cultivated Crops classification). Percent urban/impervious was determined using National Land Cover Data[23] and Low, Medium, and High Intensity Developed land classes. Soil erosion risk was based on Soil Erosion Risk analysis conducted for the Driftless Area Initiative,[24] and is based on a Revised Universal Soil Loss Equation. Soil Erosion Risk has five classes: lowest risk, low risk, moderate risk, high risk, and highest risk, which were reclassified as 5, 4, 3, 2, 1, respectively, and were summarized by subwatershed.

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.[25] Concentrated animal feeding operations indicate areas with high concentrations of livestock that can impair water quality.[26]

Data Sources: 303(d) impaired streams were obtained from the USEPA.[27] Active mines were identified by using the Mineral Resources Data System[28]. The number of NPDES permits (Permit Compliance System majors only) was determined using USEPA data.[29] The location of confined animal feeding operations and associated animal units were obtained from the Minnesota Pollution Control Agency,[30] Wisconsin Department of Natural Resources,[31] and Iowa Department of Natural Resources;[32] no data were available for Illinois.

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[33]. 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[34] was the data source for dams and their storage capacity. Miles of canals and ditches is from the National Hydrography Dataset Plus[3], 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 was 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[35].

Data Sources: Slope was computed from elevation data from the National Hydrography Dataset Plus[3]. Land cover was determined from the National Land Cover Database[19], 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[36], roads from the ESRI Tele Atlas North American / Geographic Data Technology dataset on roads[20], and land ownership using ESRI Tele Atlas North American / Geographic Data Technology dataset for parks[37] and managed areas identified by the Driftless Area Initiative[38].

Indicator: 2. Resource extraction.

Indicator Scoring:

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

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, logging poses a future risk to aquatic habitats and fishes[39].

Data Sources: Timber management potential identifies productive forest types using the existing vegetation type in the Landfire dataset.[40] Protected areas data were compiled from the ESRI, Tele Atlas North American / Geographic Data Technology dataset on protected areas[41] and the U.S. Department of Agriculture, Forest Service's National Inventoried Roadless Areas dataset[42].

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 salmonids.[43] If lands are protected then the watersheds will be less likely to be developed.

Data Sources: Average annual wind speeds (Wind Power Class 4 or higher [>7.0 m/s at 50-m] were obtained from different sources for for Iowa,[44] Minnesota,[45] Wisconsin,[46] and Illinois.[47] Geothermal potential was determined from the Geothermal Education Office.[48] Potential dam sites are based on Idaho National Laboratory (INL) hydropower potential data[49]. Protected areas data were compiled from the ESRI, Tele Atlas North American / Geographic Data Technology dataset on protected areas[41] and the U.S. Department of Agriculture, Forest Service's National Inventoried Roadless Areas dataset[42].

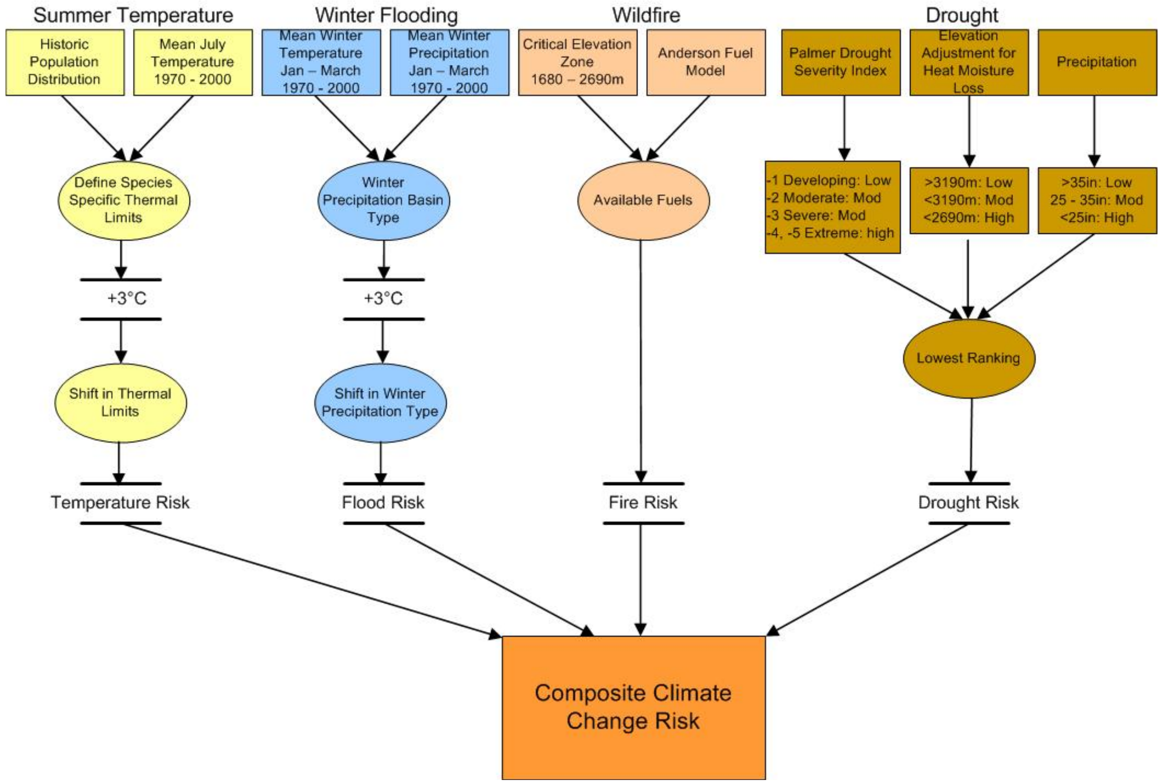
Indicator: 4. Climate change.

Indicator Scoring:

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

Explanation: Climate change is based on the temperature portion of the TU Climate Change analysis. Increased summer temperature impacts temperature sensitive species

TU Climate Change Analysis



Rationale: Climate change is likely to threaten most salmonid populations because of warmer water temperatures. A 3°C increase in summer temperature has the potential to impact coldwater species occupying habitat at the edge of their thermal tolerance.
Climate change risks are further discussed by Williams et al.[50]

Data Sources: Temperature data were obtained from the PRISM Group.[51] The historic distribution of brook trout in the Driftless area is not well defined and several data sources were used to obtain mean air temperatures for the historic range. For Wisconsin, historical predictions of brook trout presence were model for a Great Lakes GAP project and were provided by John Lyons (Wisconsin Department of Natural Resources) and Jana Stewart (U.S. Geological Survey); the model currently has no documentation, but is based on streamflow, land cover, air temperature, and lakes and reservoirs (J. Lyons, WDNR, pers. comm.). The historical distribution is poorly defined for Minnesota, Iowa, and Illinois. We used the presence of Class I and II trout streams identified as part of the Driftless Area Restoration Effort (DARE) Strategic Plan (N. Gillespie, Trout Unlimited, pers. comm.) and current distribution to define the historical distribution in these states, which was likely underestimated. The mean air temperature thresholds for determining temperature risk within the estimated historic range of brook trout are: Low Risk <22.5 C; Moderate Risk >22.5 and <24.5 C; High Risk >24.5 C. There is a large amount of uncertainty associated with the Driftless Area climate change risks.

Indicator: 5. Introduced species.

Indicator Scoring:

Present in subbasin	Present in subwatershed	Road Density (mi / mi^2)	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 in a subwatershed; also road density. Road density is the length of road per subwatershed area 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.[8] 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.[52]

Data Sources: Brown trout were the only introduced species currently considered to be potentially injurious to native brook trout; curlyleaf pondweed, New Zealand mud snail, Chinese mystery snail, Faucet snail, and zebra mussels were considered but their effects on native brook trout in the Driftless Area are unknown. The presence of brown trout was determined by regional biologists of the Minnesota Department of Natural Resources, Wisconsin Department of Natural Resources, Iowa Department of Natural Resources, and Illinois Department of Natural Resources, and also brown trout distribution from the Minnesota Department of Natural Resources (http://www.dnr.state.mn.us/fishing/trout_streams /south_mn_maps.html) . Roads were obtained from ESRI, Tele Atlas North American / Geographic Data Technology dataset on roads.[20]

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