Conservation Success Index: Atlantic Salmon

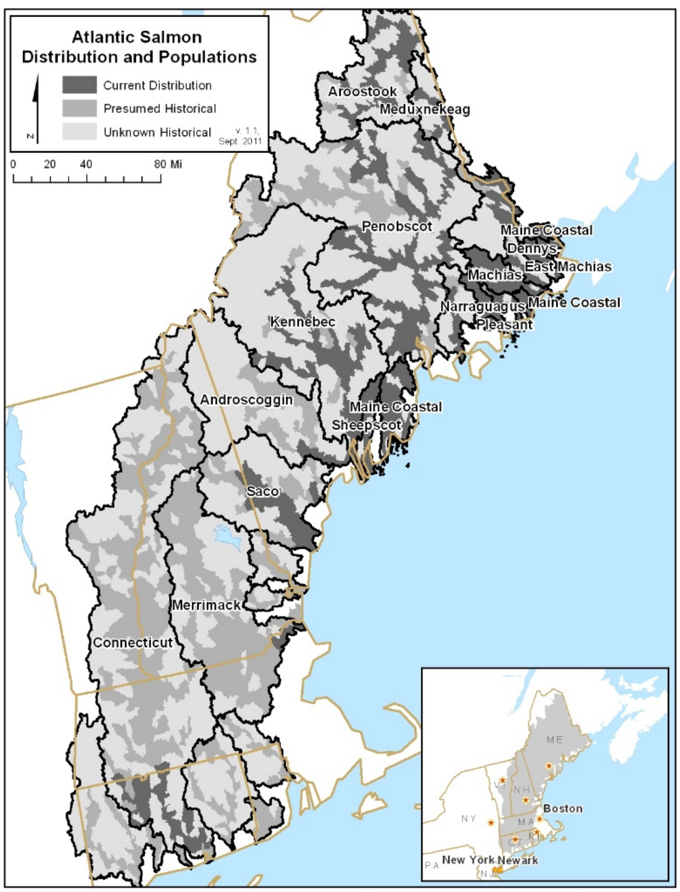
SALMO SALAR

Rev. 1.1 - 9/2011

SPECIES SUMMARY

The Atlantic salmon (*Salmo salar*) is native to drainages flowing into the North Atlantic Ocean. There are three generally recognized groups: European, Baltic, and North American. Historically, North American Atlantic salmon reproduced in nearly every major river north of the Hudson River in Long Island Sound to northern Quebec. Historical runs in the United States have been estimated between 300,000 and 500,000 fish, with the Connecticut, Merrimack, Androscoggin, Kennebec, and Penobscot rivers having the largest runs.

Context Map



While there are still Canadian populations that are self-sustaining and strong, by the early 19th century many Canadian and all United States populations had become severely depleted. Salmon runs disappeared from southern New England by the 1860's, and by the end of the century had been extirpated from three of the five rivers with the largest populations: Androscoggin, Merrimack, and Connecticut. Current populations of Atlantic salmon are divided into three Distinct Population Segments (DPS): Long Island Sound, Central New England, and Gulf of Maine. Stocks native to Long Island Sound and Central New England are considered extinct, and current populations are a result of stocking with fish from the Gulf of Maine DPS. In 2000, the Gulf of Maine DPS – from the Kennebec to the Dennys - was listed as Endangered under the Endangered Species Act. The 2006 Status Review has much background information on the current state of Atlantic salmon.

Many factors have been implicated in the demise of salmon populations and their endangered status. Land use change, water quality degradation, and poaching have all been cited. However, dams constructed for hydropower, mills, and other water uses have played a major role in declines because they prohibit adult fish from ascending rivers to spawn in tributary streams and can delay out-migration. Commercial fishing in Greenland and low marine survival, non-native predators, and aquaculture are seen as continual threats to Atlantic salmon persistence and recovery.

Restoration has a long history in New England. Atlantic salmon restoration began with limited success in the late 1800's due to impassible dams and inefficient fishways. Dam removal and use of fish ladders and fish lifts to pass fish over dams continue to be important restoration and recovery actions. Restoration of freshwater and marine habitats is also ongoing, as is protection of key freshwater habitats. Most New England populations are supplemented with hatchery salmon. Some returning adults are collected at dams for hatchery propagation, while others are released for natural spawning. Widespread stocking sustains most of the current distribution of Atlantic salmon across New England. Populations in the Gulf of Maine DPS are considered representative of historical stocks. The Connecticut and Merrimack populations were restored with fish from the Penobscot or Canadian rivers. Restoration and recovery actions follow recovery plans, especially for the Gulf of Maine DPS, developed by NOAA and US Fish and Wildlife Service.

Atlantic Salmon. Photo: William Hartley, USFWS

Our CSI analysis was based on information from multiple sources, including: the states of Maine, Massachusetts, New Hampshire, Rhode Island, and Connecticut; The Nature Conservancy; U.S. Atlantic Salmon Assessment Committee; U.S. Fish and Wildlife Service; and NOAA. A complete list of data sources can be found under the Rule Sets and Data Sources link.

Key CSI Findings

- Atlantic salmon occupy a small fraction of historical subbasins
- The fraction of historical subwatersheds currently occupied varies widely by river basin
- Adult returns are low; the Penobscot River has the largest runs numbering over 1,000
- Existing habitat for most populations is highly fragmented by dams

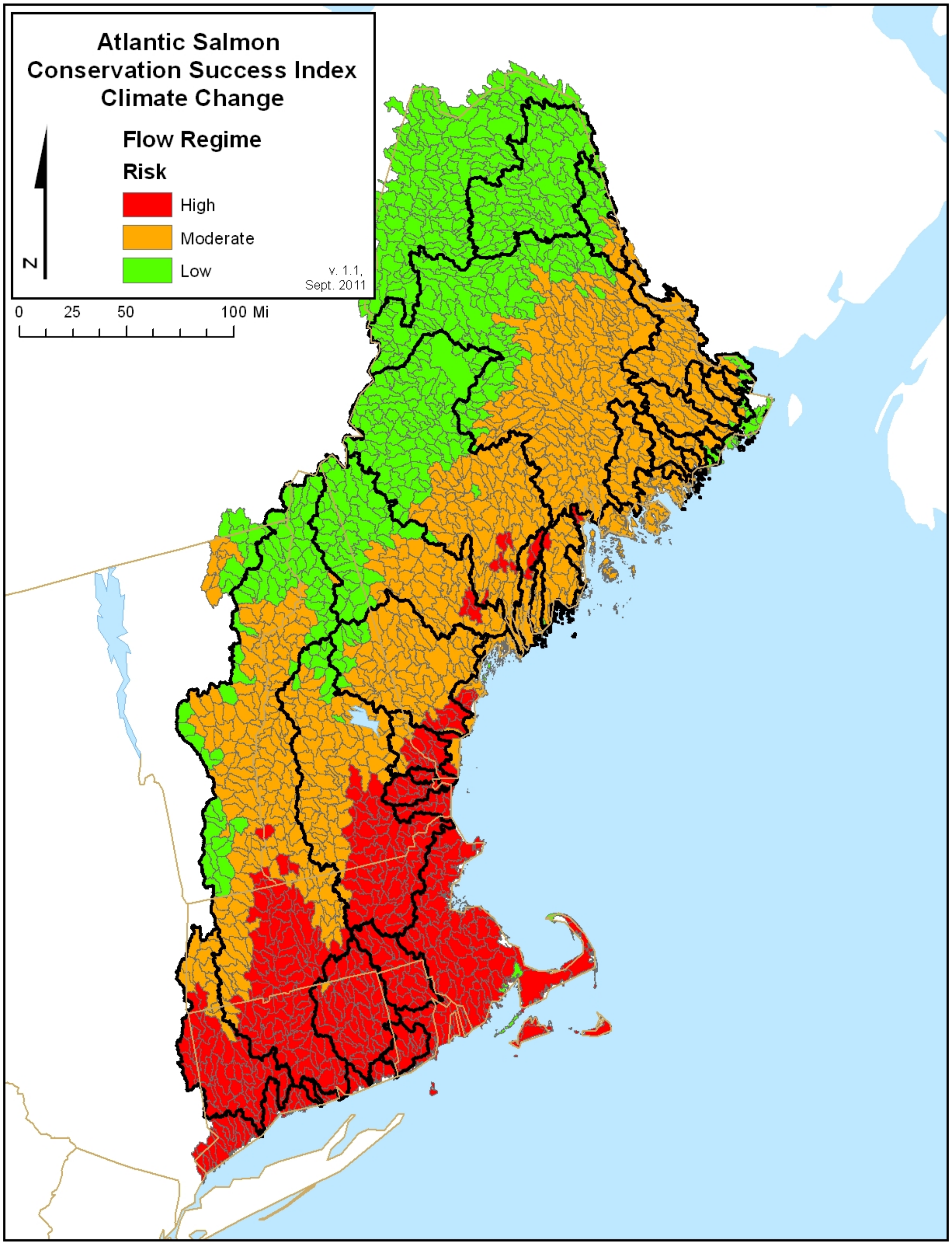
- Hatchery fish consistently represent a high number of adult returns.
- Despite low returns, returning wild fish often represent a good life history diversity in terms of sea-winter ages and repeat spawners
- Roads along streams and converted lands adjacent to streams threaten existing stream habitat, especially in southern New England
- Over 1/3 of subwatersheds scored 1 for connectivity due to high numbers of dams and road-stream crossings
- Watershed conditions are generally good owing to large amounts of forested land cover
- Large tracts of productive forests pose risks to the future security of populations and habitat
- Increased summer temperature and changes in precipitation due to climate change pose high risks to stream temperatures and flow regimes along the coast, especially in southern New England

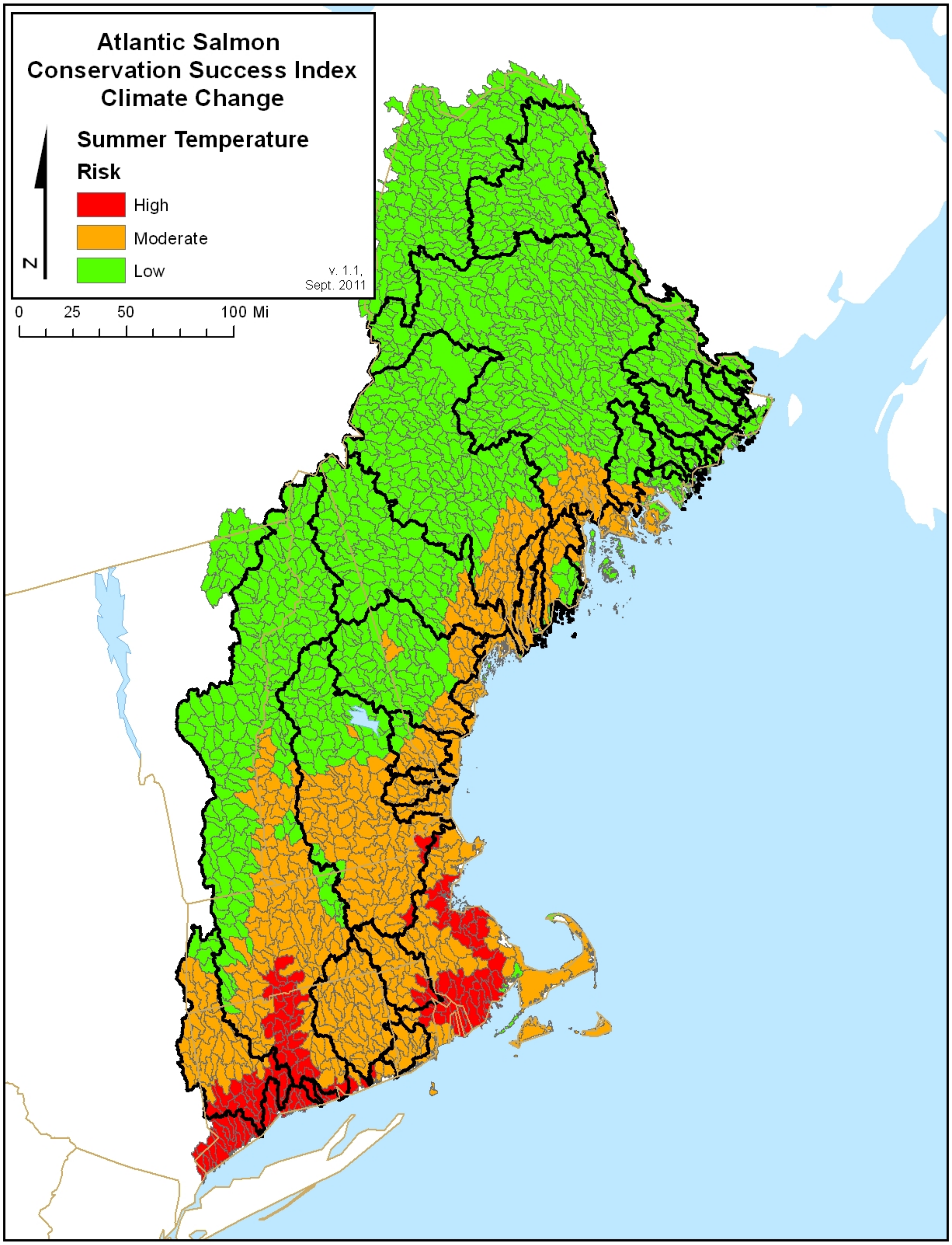
Prepared by Dan Dauwalter, September 2011

Table 1. CSI scoring result summary for Atlantic salmon

		Number of Subwatersheds Receiving Scores					**Total Subwatersheds Scored**
	CSI Indicator	**1**	**2**	**3**	**4**	**5**	
Range-wide Conditions	Percent historic stream habitat occupied	141	396	0	0	686	1223
	Percent subbasins (4th) occupied	1223	0	0	0	0	1223
	Percent subwatersheds (6th) occupied	510	21	42	186	464	1223
	Percent of historic rivers occupied	0	1223	0	0	0	1223
	Dam density in occupied habitat	1223	0	0	0	0	1223
Population Integrity	Population size	943	280	0	0	0	1223
	Habitat extent	291	475	183	12	262	1223
	Hatchery influence	507	400	4	312	0	1223
	Disease vulnerability	447	395	271	26	84	1223
	Life history diversity	33	0	285	551	354	1223
Habitat Integrity	Riparian condition	65	114	624	506	481	1790

	Watershed connectivity	562	353	317	281	277	1790
	Watershed conditions	73	50	141	246	1280	1790
	Water quality	560	58	75	220	877	1790
	Flow regime	345	238	181	235	791	1790
Future Security	Land conversion	338	488	506	309	149	1790
	Resource extraction	1357	307	75	28	23	1790
	Energy development	907	166	158	363	196	1790
	Climate change	112	330	203	563	582	1790
	Introduced species	0	219	810	761	0	1790


Atlantic Salmon
Conservation Success Index
Climate Change
Flow Regime
Risk
High
Moderate
Low
N
v. 1.1,
Sept. 2011
0
25
50
100 Mi


Atlantic Salmon
Conservation Success Index
Climate Change
Summer Temperature
Risk
High
Moderate
Low
N
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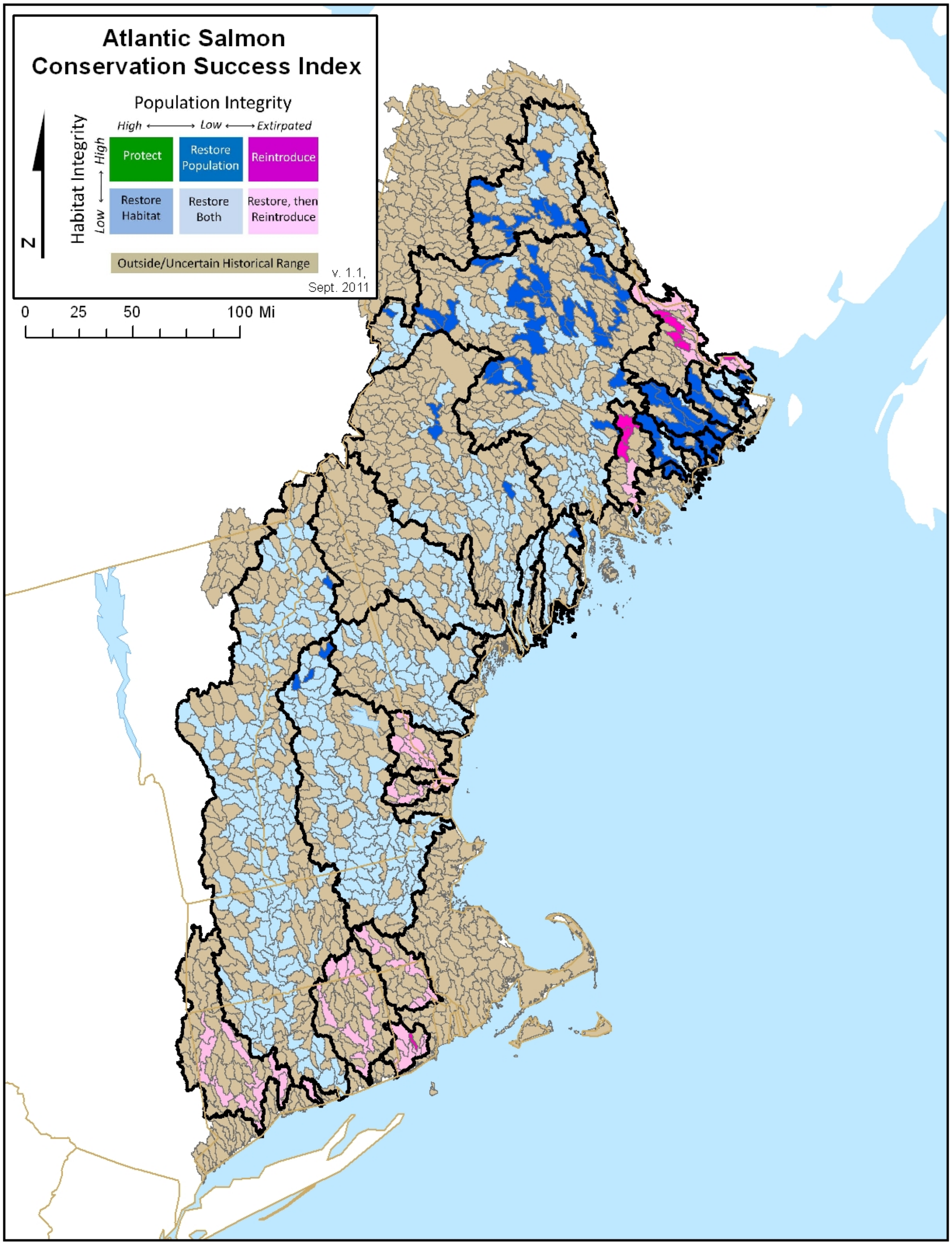
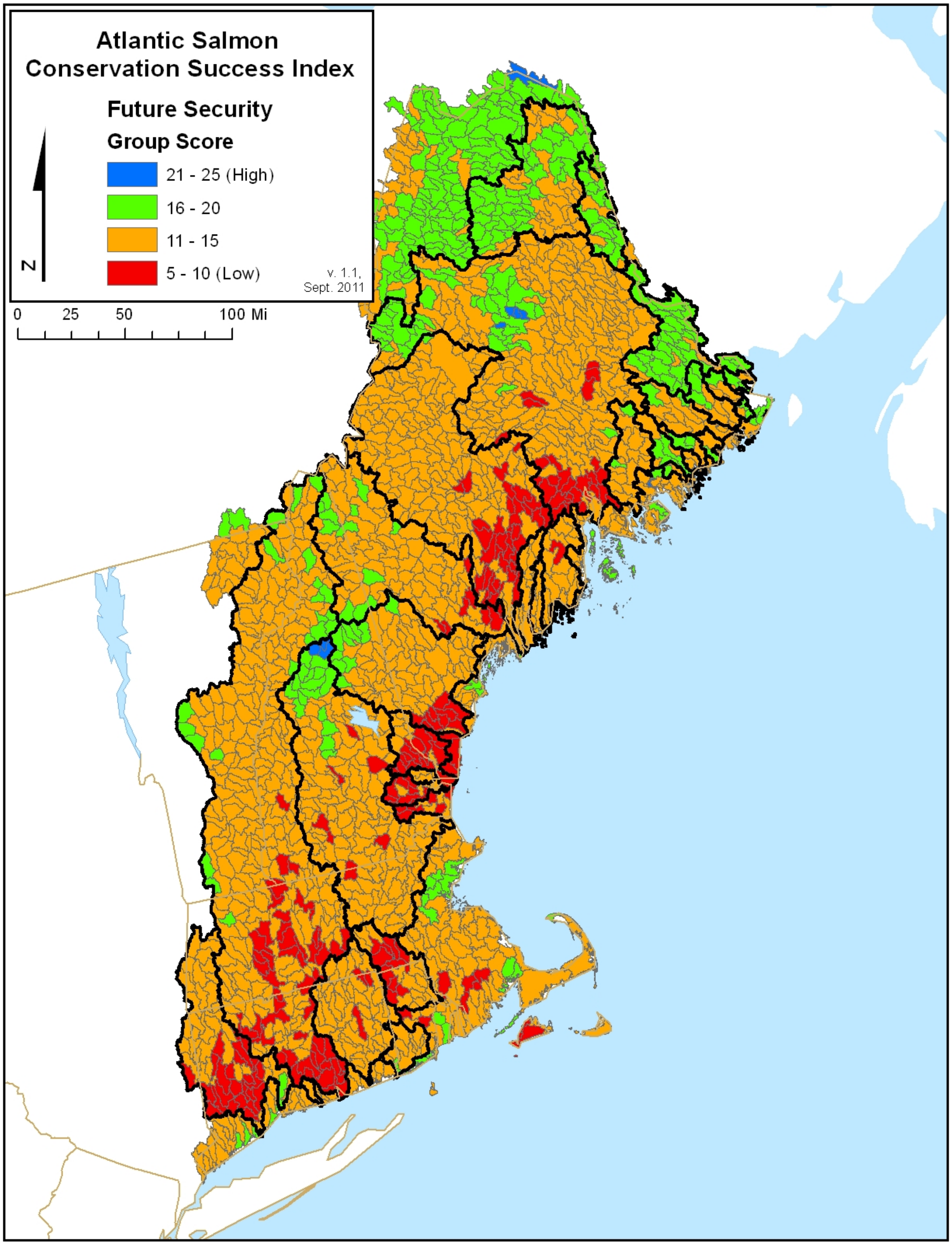
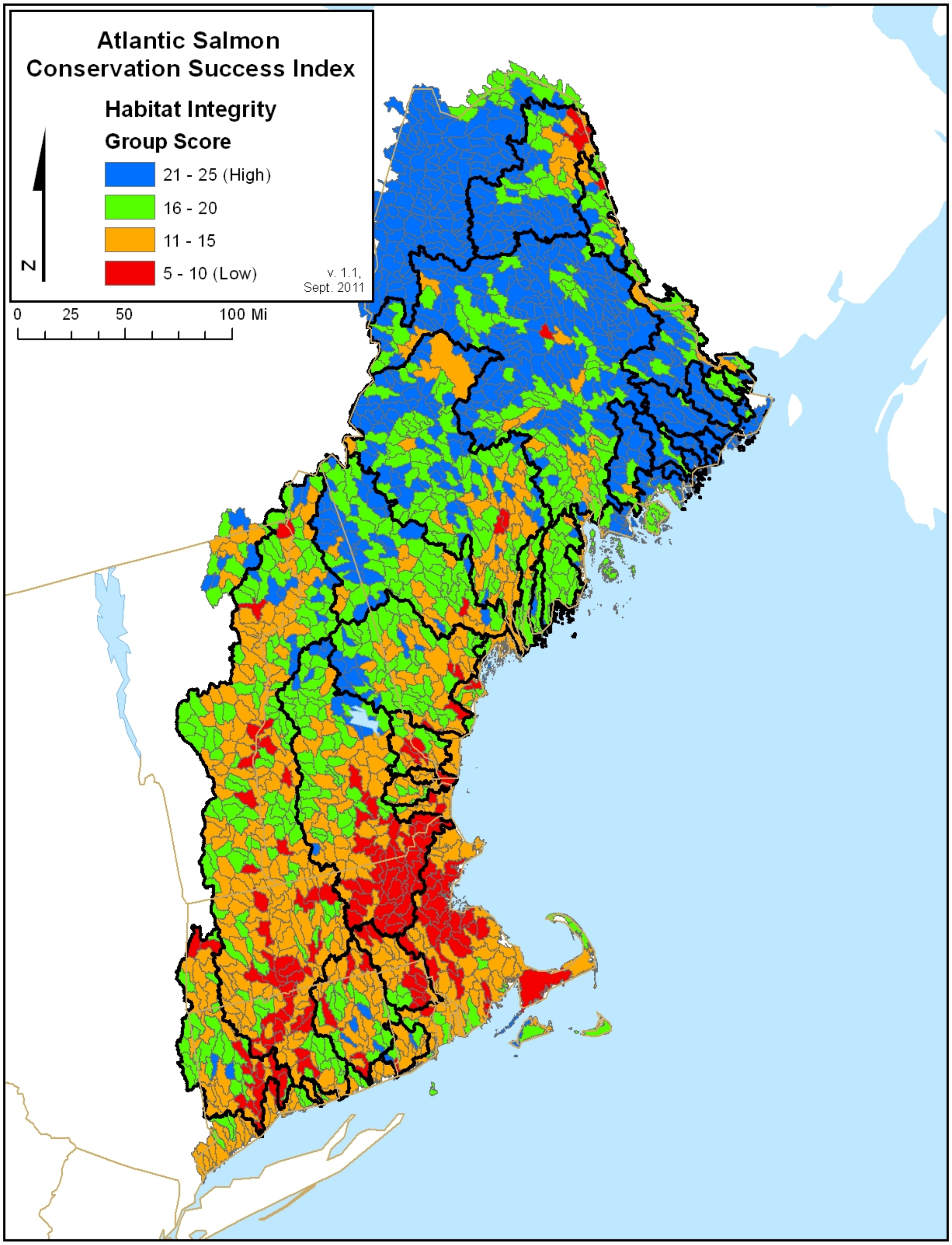
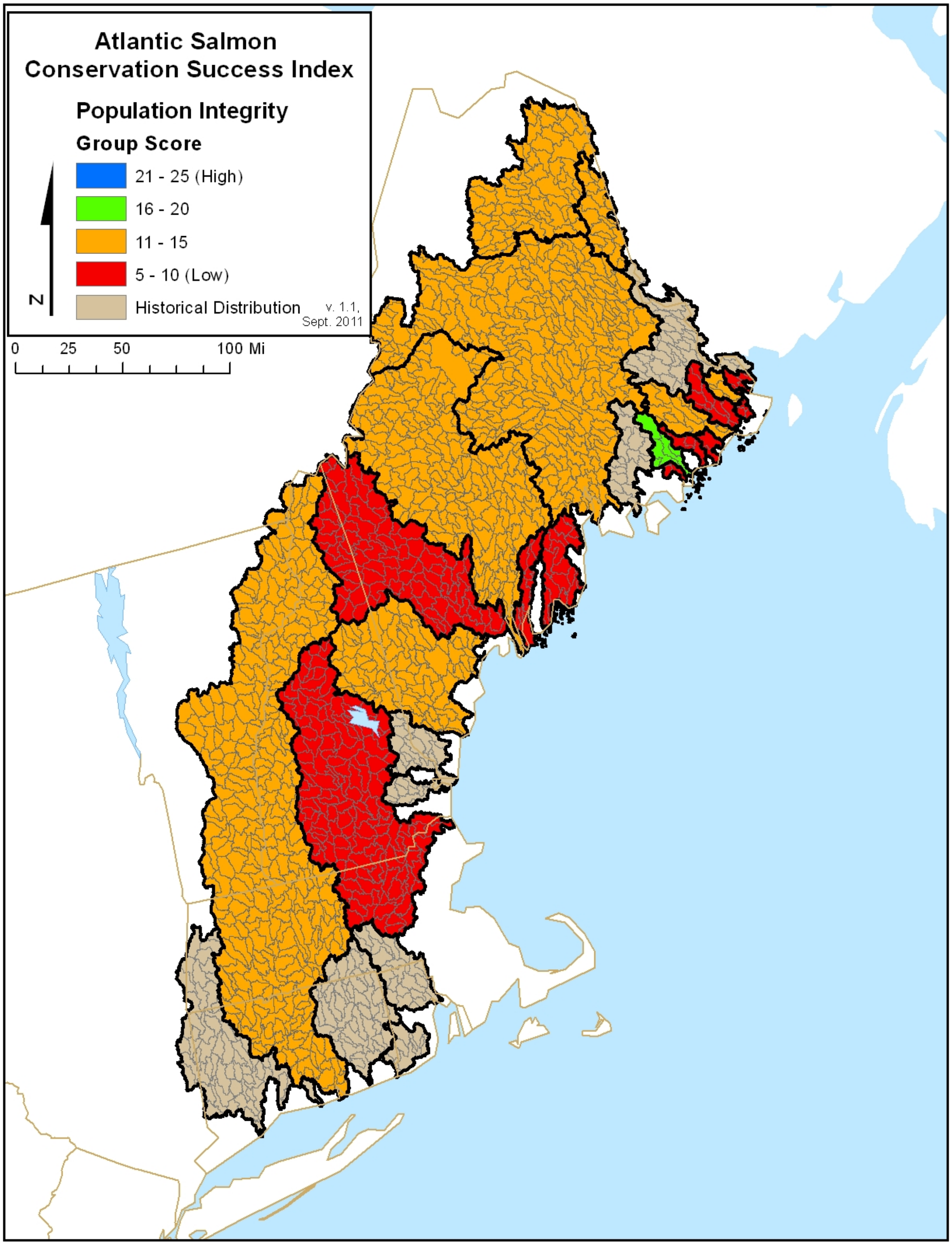
Sept. 2011
0 25 50 100 Mi



Atlantic Salmon
Conservation Success Index
Population Integrity
High Low Extirpated
Habitat Integrity
High Low
Protect
Restore Population
Reintroduce
Restore Habitat
Restore Both
Restore, then Reintroduce
Outside/Uncertain Historical Range
v. 1.1, Sept. 2011
N
0 25 50 100 Mi


Atlantic Salmon
Conservation Success Index
Future Security
Group Score
21 - 25 (High)
16 - 20
11 - 15
5 - 10 (Low)
v. 1.1,
Sept. 2011
N
0
25
50
100 Mi


Atlantic Salmon
Conservation Success Index
Habitat Integrity
Group Score
21 - 25 (High)
16 - 20
11 - 15
5 - 10 (Low)
v. 1.1,
Sept. 2011
N
0
25
50
100 Mi



Atlantic Salmon
Conservation Success Index
Population Integrity
Group Score
21 - 25 (High)
16 - 20
11 - 15
5 - 10 (Low)
Historical Distribution
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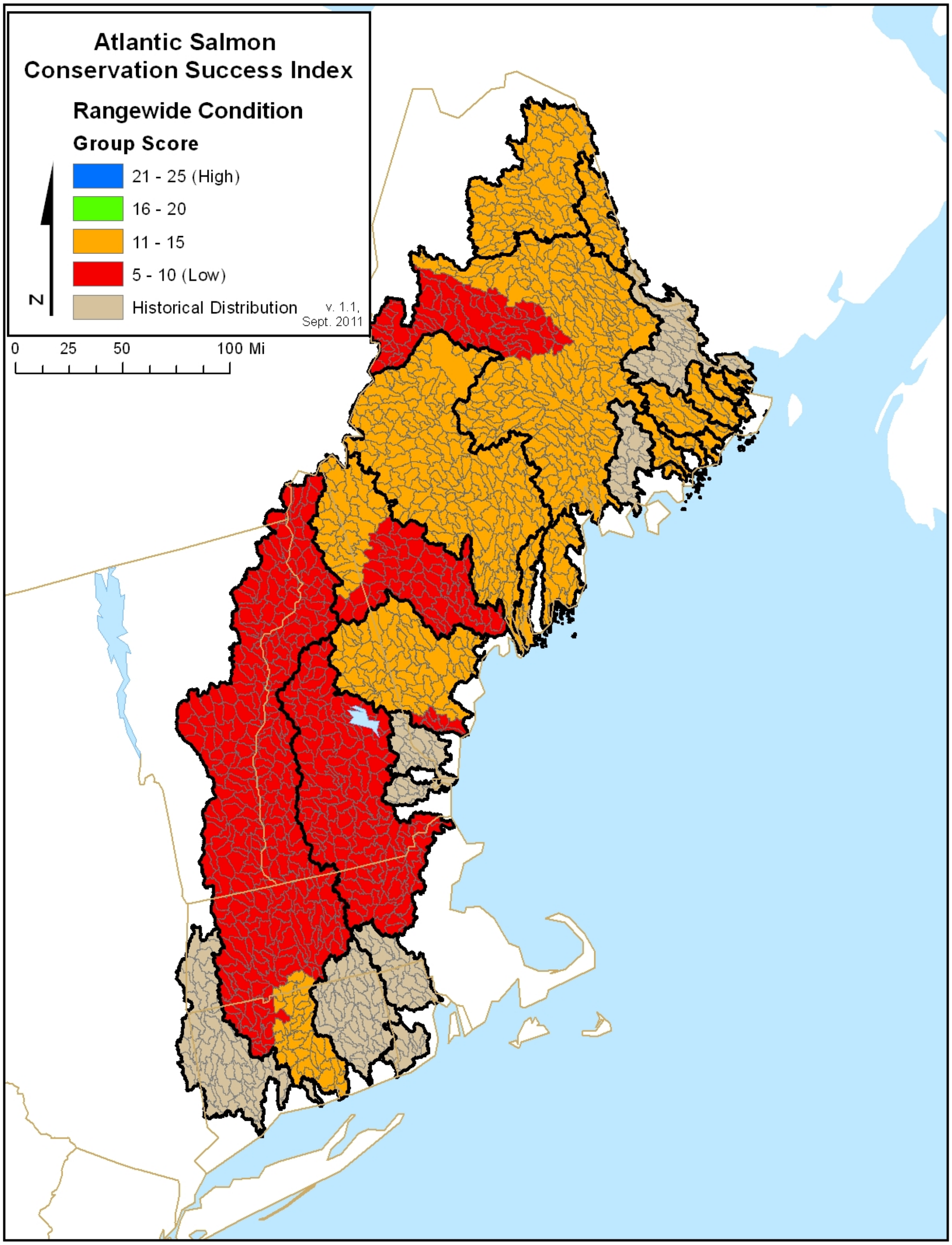
Sept. 2011
N
0 25 50 100 Mi



Atlantic Salmon
Conservation Success Index
Rangewide Condition
Group Score
21 - 25 (High)
16 - 20
11 - 15
5 - 10 (Low)
Historical Distribution
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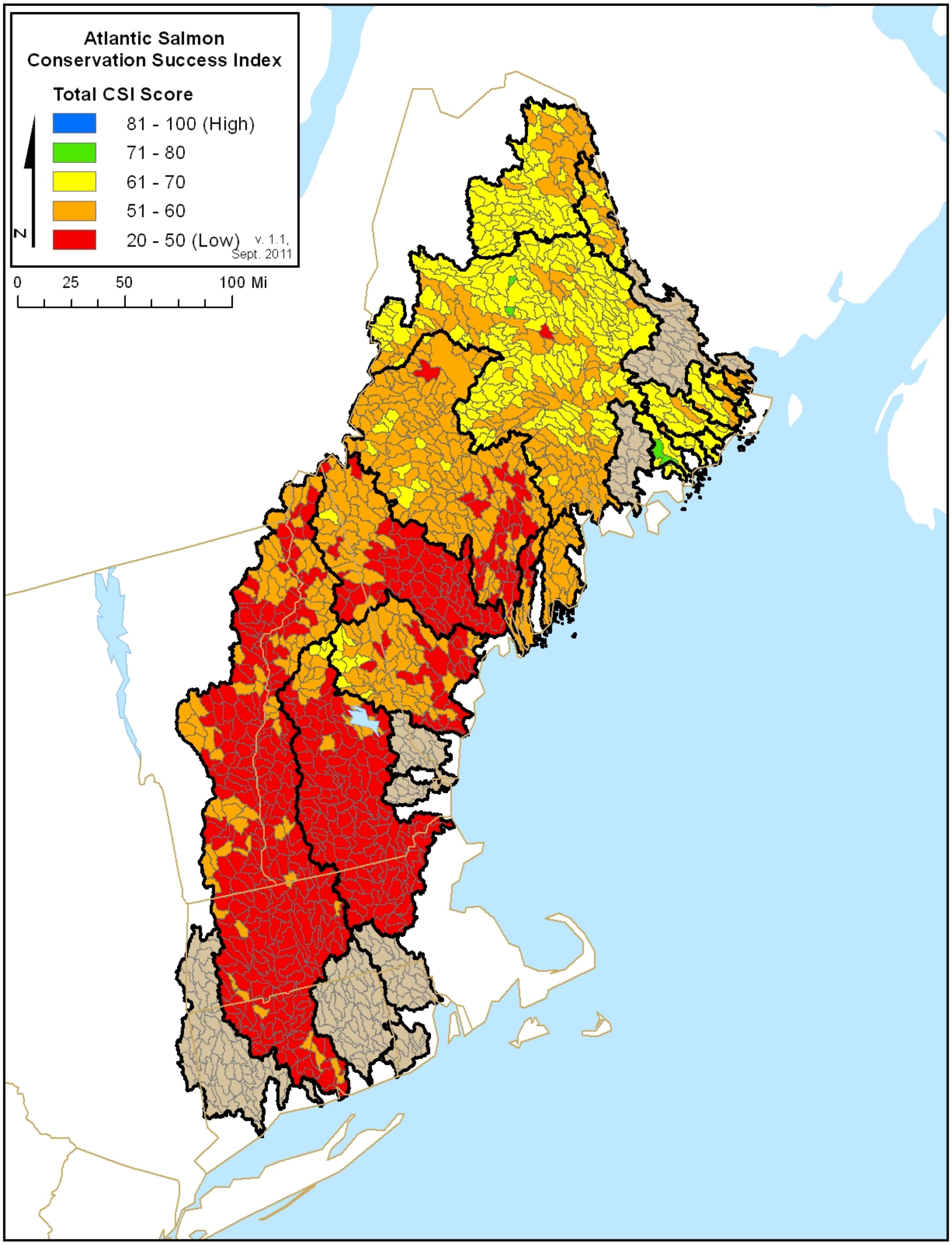
Sept. 2011
N
0
25
50
100 Mi



Atlantic Salmon
Conservation Success Index
Total CSI Score
81 - 100 (High)
71 - 80
61 - 70
51 - 60
20 - 50 (Low)
N
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Sept. 2011
0
25
50
100 Mi

v. 1.0 July. 2011

Conservation Success Index:
Atlantic Salmon:
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.

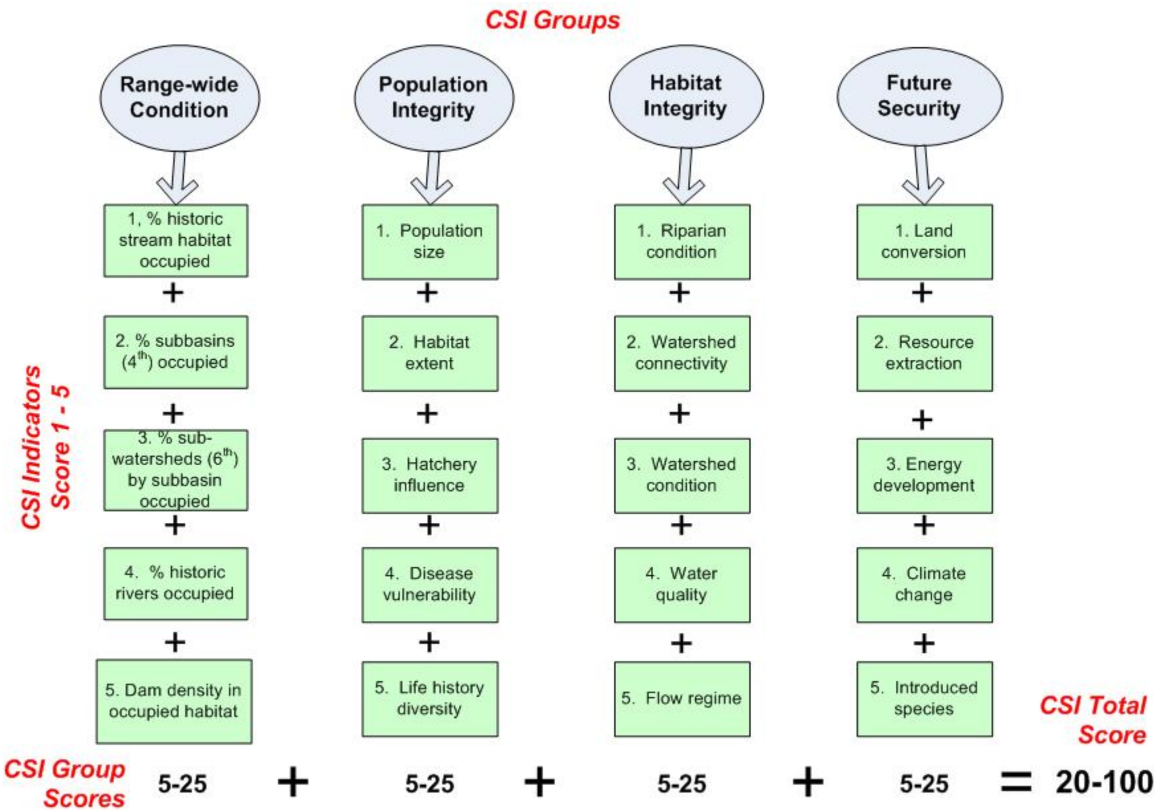

Figure 1. Each subwatershed is scored from 1 to 5 using 20 indicators within four main groups. Indicator scores are added per group to obtain an overall group score. Group scores are then added to obtain a composite CSI score for each subwatershed.

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 by population
2. Percent of subbasins (4th level HUC) occupied.
3. Percent of subwatersheds (6th level HUC) occupied within subbasin.
4. Percent of historic rivers occupied.
5. Dam density in occupied habitat by population.

Indicator: 1. Percent of historic stream habitat occupied by population.

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 historical range of the species. Lake centerlines included as habitat. Same value applied to entire population.

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

Data Sources: Current distribution data is from The Nature Conservancy, Northeast Aquatic Connectivity Project. Historical distribution data are from NOAA[1]and USASAC.[2] These data are derived from: Maine - Houston et al.[3]; New Hampshire - NHFGD[4]; Massachusetts - MassGIS[5]; Rhode Island - Alan Libby, RIDEM, pers. comm.; Connecticut - CTDEP[6]. Merrimack River distribution modified from U.S. Atlantic Salmon Assessment Committee.[2]

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 known 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 Geographic Management Units that may have distinct genetic or evolutionary legacies for the species.[7-9]

Data Sources: See description for indicator 1 for Atlantic salmon 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 Atlantic salmon distribution.

Indicator: 4. Percent of historic rivers occupied.

Indicator Scoring:

Percent historic rivers	CSI Score
1-49%	1
50-69%	2
70-79%	3
80-89%	4
90-100%	5

Explanation: Percent of historic rivers that are currently occupied.

Rationale: Larger river basins often correspond with populations that may have distinct genetic or evolutionary legacies for the species.[7-9]

Data Sources: See description for indicator 1 for Atlantic salmon distribution.

Indicator: 5. Dam density in occupied habitat by population.

Indicator Scoring:

Number dams / occupied stream mile	CSI Score
>0.075	1
0.050 – 0.075	2
0.025 – 0.050	3
0.01 – 0.025	4
<0.01	5

Explanation: Dam density (# / mile) within currently occupied habitat.

Rationale: Dams can either completely block or disrupt spawning migrations and delay outmigration.[10]

Data Sources: The Nature Conservancy dataset of dams on diadromous fish runs,[11] and The Nature Conservancy dataset on current habitat occupied by Atlantic salmon.[12]

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

Overview:

1. Population size
2. Habitat extent
3. Genetic purity

4. Disease vulnerability
5. Life history diversity

Indicator: 1. Population density.

Indicator Scoring:

Documented Adult Returns	% of Escapement Goal	CSI Score
0 - 1000	<25	1
1000 - 2500	25-50%	2
2500 - 5000	50-75%	3
5000 – 7500	75-100%	4
>7500	>100%	5

*Scored for specific river if data were available, otherwise scored by % escapement goal for DPS

Explanation: Five-year average (2006-10) number of documented adult returns within each river system and percent of spawner escapement goal met for DPS.

Rationale: Small populations are more vulnerable to extirpation.[13;14]

Data Sources: The five-year average (2006-10) of number of adult returns and DPS escapement goals were obtained from the U.S. Atlantic Salmon Assessment Committee.[2] Results were applied to entire river systems or DPS. The CSI score is the same for all subwatersheds currently occupied by a population. Where population-specific information was not available, a DPS-wide average was used.

Indicator: 2. Habitat extent.

Indicator Scoring:

Extent occupied habitat	CSI Score
< 50 mi	1
50 - 100 mi	2
100 -200 mi	3
200 - 300 mi	4
> 300 mi	5

Explanation: Habitat extent is the largest extent of interconnected habitat currently occupied by the population.

Rationale: Populations with less habitat are more vulnerable to extirpation[15].

Data Sources: Population extent was determined by current distribution of Atlantic salmon from The Nature Conservancy[12] broken into contiguous segments between dams; dams data from The

Nature Conservancy.[11] The CSI score is the same for all subwatersheds currently occupied by a population. Where population-specific information was not available, a DPS-wide average was used.

Indicator: 3. Hatchery influence.

Indicator Scoring:

% Natural Origin Spawners	CSI Score
0 – 24 %, Unknown	1
25 – 49 %	2
50 – 74 %	3
75 – 95 %	4
> 95 %	5

Explanation: Percent of adult returns over a 5-year period (2006-10) that were spawned in the wild.

Rationale: Hatchery fish exhibit less genetic diversity and reduced fitness relative to wild fish.[16]

Data Sources: The five-year average of number of adult returns over a 5-year period obtained from the U.S. Atlantic Salmon Assessment Committee.[2] Results were applied to entire river systems or DPS. The CSI score is the same for all subwatersheds currently occupied by a population. Where population-specific information was not available, a DPS-wide average was used.

Indicator: 4. Disease vulnerability.

Indicator Scoring:

Disease Vulnerability	CSI Score
Disease outbreak risk high (max August >21C)	1
Disease outbreak risk moderate-high (max August 20-21C)	2
Disease outbreak risk moderate (max August 19-20C)	3
Disease outbreak risk low-moderate (max August 18-19C)	4
Disease outbreak risk low (max August <18C)	5

Explanation: The risk of each population to furunculosis outbreak due to high summer temperatures.

Rationale: Furunculosis is the only disease known to result in mortality of wild Atlantic Salmon, and it can be a significant sources of mortality of water temperatures are high.[10;17]

Data Sources: Furunculosis is considered to be present in all Atlantic salmon waters.[10] Mean August air temperature based on PRISM data.[18]

Indicator: 5. Life history diversity.

Indicator Scoring:

Life History Diversity	CSI Score
Unknown (No adult returns documented)	1
1 life history present (1SW, 2SW, 3SW, Repeat)	2
2 life histories present (1SW, 2SW, 3SW, Repeat)	3
3 life histories present (1SW, 2SW, 3SW, Repeat)	4
4 life histories present (1SW, 2SW, 3SW, Repeat)	5

Explanation: The presence of different wild sea age and repeat adult returns in historically occupied subwatersheds.

Rationale: Life history diversity reduces the risk of extirpation and is suggestive of increased genetic diversity.[10;19;20]

Data Sources: Life history was determined using the number of sea-winter and repeat adult returns across a five-year period (2006-10) as a measure of life history diversity. Data were from U.S. Atlantic Salmon Assessment Committee.[2] The CSI score is the same for all subwatersheds currently occupied by a population. Where population-specific information was not available, a DPS-wide measure was used.

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

Data Sources: Riparian vegetation was determined using the National Land Cover Database[26] 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[27] and the National Hydrography Dataset Plus.[28]

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.[15] 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 historical distribution of Atlantic salmon[1;2] and TNC dams data.[11] For road crossings, Strahler stream orders were based on the National Hydrography Dataset Plus.[28] Roads data was based on the ESRI Tele Atlas North America, Inc. roads[27], 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.[29] The amount of urban/impervious land cover has shown alter streamflows and degrade stream habitat and fish communities.[23;30]

Data Sources: The National Land Cover Database[26] was used to identify cultivated crop agricultural lands (the Cultivated Crops classification). Percent urban/impervious was determined using National Land Cover Data[31] and Low, Medium, and High Intensity Developed land classes.

Indicator: 4. Water quality.

Indicator Scoring:

Miles 303(d) Streams	Number Active Mines	NPDES Permits	CSI Score
>2	≥10	≥4	1
1 – 2	7-9	3	2
0.5 - 1	4-6	2	3

0 – 0.5	1-3	1	4
0	0	0	5

Score for worst case.

Explanation: The presence of 303(d) impaired streams, number of active mines, and number of National Pollution Discharge Elimination System permits.

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.[32]

Data Sources: 303(d) impaired streams were obtained from the USEPA.[33] Active mines were identified by using the Mineral Resources Data System[34]. The number of NPDES permits (Permit Compliance System majors only) was determined using USEPA data.[35]

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[36]. 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[37] was the data source for dams and their storage capacity. Miles of canals and ditches is from the National Hydrography Dataset Plus[28], 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[38].

Data Sources: Slope was computed from elevation data from the National Hydrography Dataset Plus[28]. Land cover was determined from the National Land Cover Database[26], 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[39], roads from Tele Atlas,[27] and land ownership was from Protected Areas Database of the United States.[40]

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[41].

Data Sources: Timber management potential identifies productive forest types using the existing vegetation type in the Landfire dataset.[42] Protected areas data were compiled from the Protected Areas Database of the United States (GAP status 1 or 2).[40]

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.[43] 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) (Class 4 or higher).[44] Coal leases are mineable types from the Coal Fields of the United States dataset.[45] Potential dam sites are based on Idaho National

Laboratory (INL) hydropower potential data[46]. Protected areas data were compiled from the Protected Areas Database of the United States (GAP status 1 or 2).[40]

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[18] for perennial streams. These were then adjusted by the projected increase for August temperatures for 2050 under the A2 scenario,[47] 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 New England is likely to threaten most salmonid populations because of warmer water temperatures and changes in streamflow regimes, including extended low-flow periods.[48] Temperature increases have the potential to impact coldwater species occupying habitat at the edge of their thermal tolerance.[49] 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.[50]

Data Sources: Temperature and precipitation data were obtained from the PRISM Group.[18] The Baseflow Index data represents the fraction of streamflow that is comprised of baseflow rather than runoff.[51]

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.[52] 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.[53]

Data Sources: Roads were obtained from ESRI, Tele Atlas North American / Geographic Data Technology dataset on roads.[27]

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