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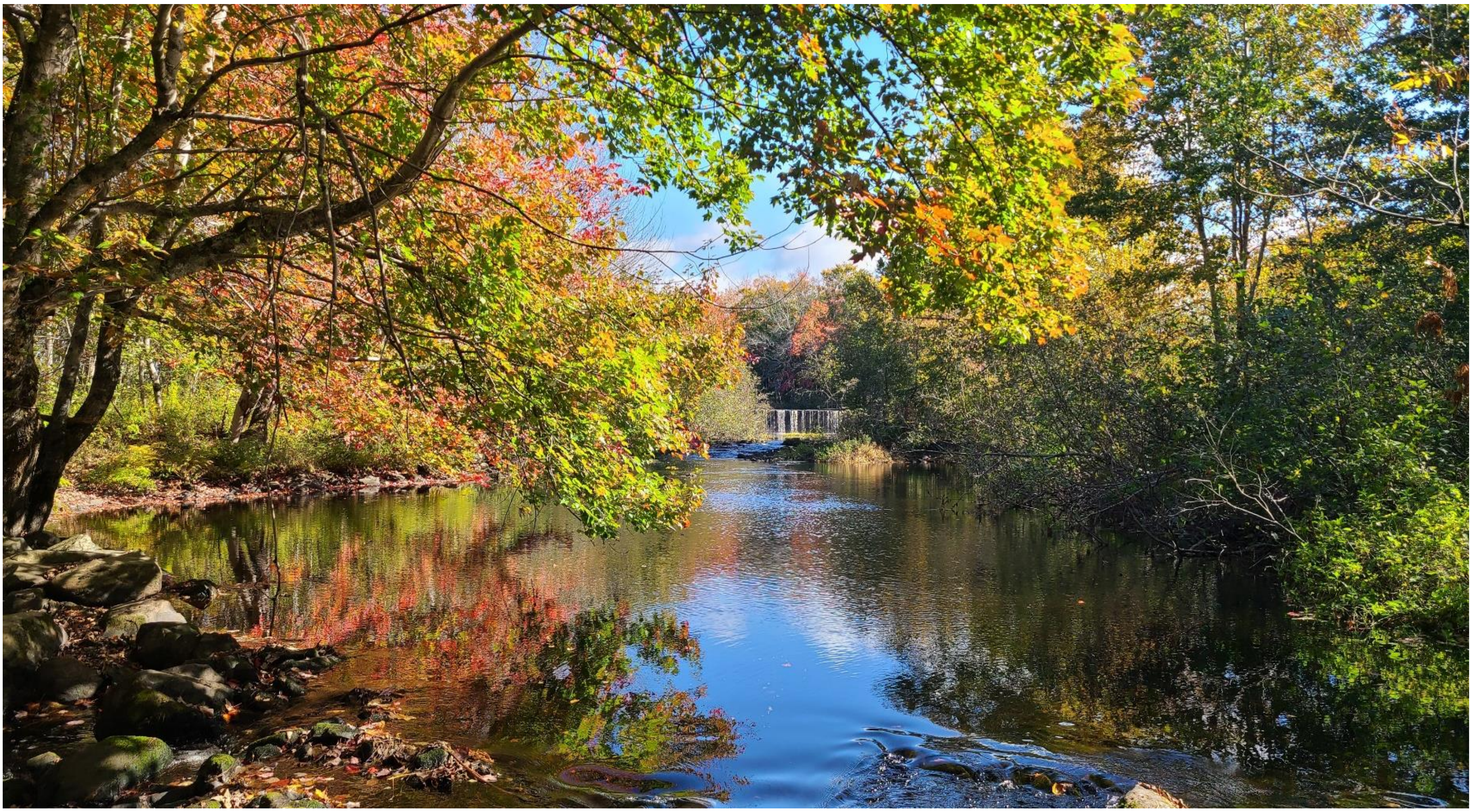

Evaluating river significance for wild Atlantic salmon (*Salmo salar*) in Nova Scotia: Significance Indicator Descriptions

Prepared By
Therese Wilson
Jenny Weitzman
Nicole Torrie
Kiersten Watson
Leah Lewis-McCrea
Gregor Reid

Date
July 8, 2025

Address
27 Parker Street
COVE
Dartmouth, NS
B2Y 4T5, Canada

Contact
P: 1-902-442-4660
E: info@cmar.ca
W: cmar.ca

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1 INTRODUCTION

The Centre for Marine Applied Research's (CMAR) Wild Salmon River Assessment evaluated the significance of 287 Nova Scotian rivers using a multi-criteria evaluation framework[1]. We collected and assessed data across five criteria, including: a river's habitat quality, population abundances, freshwater connectivity (e.g. barriers such as dams), existing stressors, and importance for conservation (**Figure 1**). For each criterion, we selected measurable indicators, such as the proportion of the summer period with water temperatures >20 °C. We then applied standardized scoring metrics and organized these indicators into relevant factors (e.g. temperature) under their respective criterion (e.g. habitat quality). The resulting indicator scores were then aggregated into a composite Significance Index score to provide an overall assessment. Finally, we categorized the Significance Index scores into distinct significance ratings to facilitate the interpretation of significance implications and assessment findings.

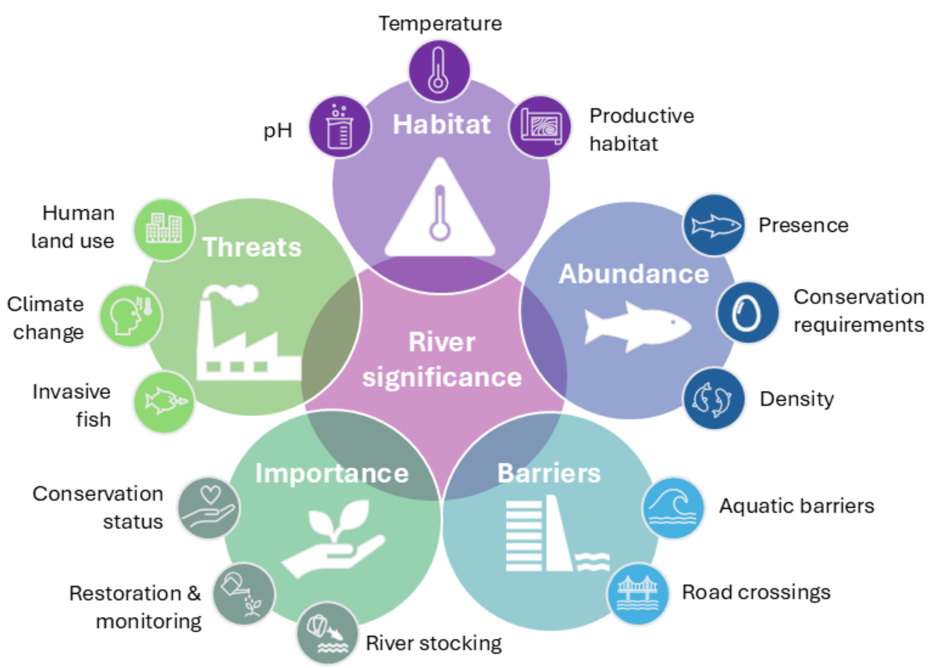

Figure 1. Calculation of river significance for wild Atlantic salmon, based on an assessment of five criteria: Habitat, Abundance, Barriers, Importance, and Threats and their respective factors.

[1] For more information about this project and to view the project summary report, visit Centre for Marine Applied Research | Assessing Wild Salmon Rivers in Nova Scotia

1.1 Purpose of Report

This report provides a summary review of the indicators included in the assessment. This report is structured to begin with brief descriptions of each criterion and their associated factors. Under each factor, the relevant indicators are listed and described, offering a clear overview of each metric contributing to the evaluation river significance for wild Atlantic salmon.

The description of data sources and processing applied is provided at a summary-level. Some indicators required more extensive data analysis or processing. More thorough description of these indicators and how they were developed will be provided in subsequent reports.

Indicators marked with an asterisk (*) may be classified as either primary or secondary depending on the scale or recency of the available data, while those shown in italics represent secondary indicators.

2 HABITAT

Habitat quality is a core criterion in assessing the significance of a river to wild Atlantic salmon, as it encompasses the physical, chemical, and biological characteristics essential for supporting all life stages of salmon. Favourable habitat characteristics may support salmon growth and population recovery. For this assessment, indicators that reflect the quality and availability of aquatic and riparian habitats are grouped into three separate factors: pH, temperature, and productive habitat.

2.1 pH

pH is a critical chemical property of freshwater systems that influences the overall health and suitability of aquatic habitats for wild Atlantic salmon. Waters that are too acidic (generally below pH 5.4) can impair respiration, ion regulation, and survival (Amiro, 2006; COSEWIC, 2010). Evaluating pH as a component of habitat quality assists in identifying rivers that are less likely to support salmon populations due to acidification, indicating lower significance for wild Atlantic salmon.

2.1.1 pH*

Atlantic salmon have narrow pH tolerances and are particularly sensitive to low pH conditions, which can result in reduced productivity or even local extirpation (COSEWIC, 2010). Low pH values can indicate the presence of acidification stressors in the river, which reduces habitat quality. Rivers with pH values below 4.7 are recognized as acidified and are unlikely to support salmon populations (COSEWIC, 2010). Those with pH between 4.8 and 5.0 are moderately impacted, with an increased mortality risk for fry and smolts (Farmer, 2000). Rivers with a pH above 5.4 are considered unimpacted and capable of supporting salmon populations (Amiro, 2006; COSEWIC, 2010). pH data were compiled from various data sources, including Department of Fisheries and

Oceans (DFO) reports[2], the Atlantic Data Stream platform[3], and the 2C1 Forest Atlas database[4]. For each river, data from each source were reviewed to identify the most recent year with available measurements. If multiple pH measurements were available within that year, they were averaged to produce a single indicator value. If only one measurement was available, that value was used. The data was spatially analyzed to calculate pH for each river based on values measured on a river scale within the last 15 years. The indicator was classified as secondary if pH calculations relied on data available only at the watershed scale (for example, Bowlby et al. (2013a)).

pH - Scoring	
Score	**pH value**
1	< 4.7
2	≥ 4.7 - < 5.4
3	≥ 5.4

2.1.2 Alkalinity

Alkalinity refers to a water body's ability to neutralize acids, essentially functioning as a buffer to counter changes in pH. Lower alkalinity suggests a reduced ability for an aquatic system to mitigate acidification (Fisheries and Oceans Canada, 2024), potentially indicating higher acidification threats and a reduced habitat quality. From The Nature Conservancy of Canada (NCC) Stream Classification[5] (Millar et al., 2019b), three classes of stream and river alkalinity were obtained, including: low alkalinity (≤ 20 mg/L of $CaCO_3$), moderate alkalinity (21-50 mg/L of $CaCO_3$), and high alkalinity (≥ 51 mg/L of $CaCO_3$). Alkalinity levels between 10 and 20 mg/L suggest sensitivity to acidic inputs, whereas values greater than 20 mg/L suggest a low sensitivity and a strong buffering capacity (Resources Information Standards Committee, 1997; Abell et al., 2017). River systems with a high proportion of their stream length characterized by low alkalinity (≤ 20 mg/L of $CaCO_3$) can be considered to have lower habitat quality, as they possess a higher sensitivity to the effects of acidification. Alkalinity data were acquired from the 2C1 Forest Atlas database, which provides mapped data from the NCC Stream Classification. The data was spatially analyzed to calculate the proportion of total stream length (km) with low alkalinity (≤2 0 mg/L of $CaCO_3$) for each river's secondary watershed[6].

Alkalinity - Scoring	
Score	**% of stream length (km) with low alkalinity**
1	> 75
2	75 – 50
3	< 50

[2] Examples of DFO reports from which data was sourced include Amiro (2000), Bowlby et al. (2013a), and MacDonald et al. (2023).
[3] The Atlantic Data Stream platform provides a wide range of mapped freshwater habitat data.
[4] The 2C1 Forest Atlas database provides mapped data from the Nature Conservancy of Canada (NCC) Watershed Health Assessment (Millar et al., 2019a).
[5] The NCC stream classification assessment developed and mapped a hierarchical classification of rivers and streams using five biophysical characteristics that affect the distribution of aquatic biodiversity: size, gradient, temperature, alkalinity, and tidal influence.
[6] Here, the secondary watershed was used as a general boundary to capture the main river and its primary tributaries.

2.1.3 Acid rock drainage (ARD) potential

Acid rock drainage (ARD) refers to the chemical process that occurs when sulphide minerals are exposed to water and oxygen, resulting in the release of acid and metal oxides into the surrounding environment (Fisheries and Oceans Canada, 2024). This runoff can be highly acidic and contain high concentrations of dissolved metals. Higher ARD potential can indicate a greater likelihood of acidification stressors and habitat degradation being present in the watershed. ARD data was acquired from the Nova Scotia Watershed Assessment Program (NSWAP) 2 Database, which provides a Nova Scotia-wide database of risks to the aquatic environment. In a watershed where ARD potential is 0, ARD is not considered a stressor. Conversely, as noted by Sterling et al. (2014), an ARD potential greater than 0.1 is indicative of high stress. This reflects that ARD can significantly increase acidity in some rivers, and when more than 10% of a watershed is identified as having ARD potential, it suggests a heightened risk of habitat degradation due to acidification stressors. The data were analyzed spatially to calculate the area of potentially exposed acid rock (km^2)/secondary watershed area (km^2) for each river's secondary watershed.

Acid Rock Drainage - Scoring	
Score	**km^2 of potentially exposed acid rock/ km^2 of watershed**
1	> 0.1
2	> 0 - 0.1
3	0

2.1.4 Acidification stressor rank

A watershed stressor is any physical, chemical, or biological agent within a watershed that can adversely affect watershed functions or health (U.S. Environmental Protection Agency, 2017; Millar et al., 2019b). Atlantic salmon have narrow pH tolerances and are particularly sensitive to acidification stressors, which can result in reduced productivity or even local extirpation (COSEWIC, 2010). As a part of the NCC Watershed Health Assessment (Millar et al., 2019a), designed to evaluate the relative health of aquatic systems across the study area (Northern Appalachian – Acadian Region of Canada), the NCC identified the top three stressors in each watershed[7]. When acidification ranks among the top three stressors, it signifies a heightened risk of poor habitat quality due to low pH levels. Stressor rank data for Nova Scotian watersheds were acquired from the 2C1 Forest Atlas database, which provides mapped data from the NCC Assessment. Data was only collected for half of the watersheds, based on the highest ranked (most stressed) watersheds in Nova Scotia. The data was analyzed to identify whether acidification was ranked as a top 3 stressor in the watershed.

[7] Watershed boundaries for this assessment were based on the Canadian Hydrographic Units (CHU).

Acidification Stressor Rank - Scoring	
Score	**Rank**
1	1, 2
2	3
3	No rank

2.2 Temperature

Water temperature is a key environmental property of freshwater systems that influences the overall health and suitability of aquatic habitats for wild Atlantic salmon. Optimal temperature ranges (16 – 20 °C) support effective feeding, growth, and immune function (Jonsson and Jonsson, 2009; Bernthal et al., 2023), while elevated water temperatures (>20 – 21 °C) can lead to physiological stress and alteration of behaviour (Breau et al., 2011; Millar et al., 2019a). Assessing temperature as a factor of habitat quality allows for the identification of rivers that are less likely to support salmon populations due to the presence of thermal stressors and are therefore less significant for wild Atlantic salmon.

2.1.5 Proportion of summer period >20 °C

Exposure to water temperatures above optimal levels (>20 °C) may cause thermal stress in Atlantic salmon, potentially leading to changes in behaviour and reduced growth (Bernthal et al., 2023). Larger proportions of the summer period where daily maximum water temperature exceeds 20 °C can indicate higher exposure to thermal stressors and lower habitat quality. The Nova Scotia Salmon Association W.A.T.E.R. Workshop classifies habitat quality metric scores based on the proportion of the summer period when daily maximum exceeds 20 °C into five classes: poor (> 60%), marginal (40 - 60%), OK (20 - 40%), good (10 – 20%) and excellent (< 10%). Temperature data were acquired from several repositories, including the Atlantic Data Stream platform[8], RivTemp database[9], and CMAR inland water quality data[10]. For this indicator, only datasets that recorded water temperature measurements at an hourly resolution or more frequently were included (i.e., at least 24 observations/day throughout the summer period). Data collected in lakes was not considered in this assessment. The data was analyzed spatially to calculate[11] the percentage of days in the summer period (June-September) where maximum temperatures exceeded 20 °C for each river, based on data collected since 2019. The indicator was classified as secondary if it was based on data collected prior to 2019.

[8] The Atlantic Data Stream platform provides a wide range of mapped freshwater habitat data.

[9] The RivTemp database provides water temperature measurements taken at monitoring stations distributed in many salmon rivers across Québec and Atlantic provinces.

[10] The CMAR inland water quality dataset provides temperature measurements taken at various rivers throughout Nova Scotia and is currently in press/waiting for publication to the Nova Scotia Open Data Portal.

[11] The percentage of days in the summer period (June-September) where the maximum temperature exceeded 20 degrees Celsius, was calculated using the following equation: % days over 20 degrees = (count days over 20 degrees / number of days in dataset).

Proportion of summer period where maximum >20 °C – Scoring	
Score	**%**
1	> 75
2	25 - 75
3	< 25

2.1.6 Maximum temperature of warmest month

Higher maximum temperatures reported on a river can indicate higher exposure to thermal stressors and lower habitat quality. The temperature data used to assess this indicator were acquired from several repositories including the Atlantic Data Stream platform[12], RivTemp database[13], and CMAR inland water quality data[14]. For this indicator, only datasets collected since 2019, that included a minimum of two observations within the summer months (July-September) were included. Data collected in lakes was not considered in this analysis. Based on the acquired data, monthly averages were calculated for each summer month (July-September), and the month with the highest recorded temperature was identified for each river. From that month, the single highest recorded temperature was extracted and used as the indicator value.

Maximum temperature of warmest month - Scoring	
Score	**°C**
1	> 28
2	24 - 28
3	< 24

2.1.7 Average cool summer temperatures

Greater proportion of the river where average temperatures are within more optimal temperature ranges for salmon (i.e., < 21 °C) can indicate low exposure to thermal stressors and higher habitat quality. The NCC Stream Classification classifies average summer stream and river temperature into three classes: cold (≤ 18 °C), cool (19-21 °C), and warm (≥ 22 °C) (Millar et al., 2019b). River systems with fewer areas of cool (19-21 °C) or cold (< 18 °C) average summer temperatures may have a higher likelihood of thermal stressors for salmon. Average temperature class data was acquired from the 2C1 Forest Atlas database, which provides mapped data from the NCC Stream Classification (Millar et al., 2019b). The data was analyzed spatially to calculate the proportion of total stream length (km) with average temperatures less than 21°C ('cool' and 'cold') for each river's secondary watershed[15].

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[12] The Atlantic Data Stream platform provides a wide range of mapped freshwater habitat data.
[13] The RivTemp database provides water temperature measurements taken at monitoring stations distributed in many salmon rivers across Québec and Atlantic provinces.
[14] The CMAR inland water quality dataset provides temperature measurements taken at various rivers throughout Nova Scotia and is currently in press/waiting for publication on the Nova Scotia Open Data Portal.
[15] Here, the secondary watershed was used as a general boundary to capture the main river and its primary tributaries.

Average cool summer temperatures - Scoring	
Score	**% of stream length (km)**
1	< 50
2	50 - 75
3	> 75

2.3 Productive rearing habitat

River habitat quality for Atlantic salmon can be influenced by the availability and accessibility of productive freshwater habitats that are essential to supporting key life stages for wild Atlantic salmon, including spawning and rearing. These habitats include specific conditions, such as clear, cold, fast-moving water with a gravel bottom for spawning and rocky areas for juvenile fish rearing (Fisheries and Oceans Canada, 2018a). Evaluating this factor allows for the identification of rivers where the availability of productive habitat may constrain population productivity and long-term viability, that are therefore less likely to be significant for wild Atlantic salmon.

2.2.1 Stream gradient

Stream gradient refers to the slope or steepness of a stream channel, typically expressed as the change in elevation over a given distance. Atlantic salmon rivers and streams typically have a gradient of 0.2 to 1.5% (Fisheries and Oceans Canada, 2018b). Watersheds with more optimal stream gradients may support needed habitat for juvenile salmon. The NCC Stream Classification classifies stream and river gradient into three classes: low gradient (<0.1%), moderate gradient (≥ 0.1 % and < 2 %), and high gradient (≥ 2 %)(Millar et al., 2019b). River systems with a high proportion of their stream length within the optimal stream gradient range (i.e., low to moderate gradients) can be considered to have higher habitat quality, as they possess a greater availability of potentially productive habitat. Stream gradient data was acquired from 2C1 Forest Atlas database, which provides mapped data from the NCC Stream Classification (Millar et al., 2019b). The data was analyzed spatially to calculate the proportion of total stream length (in km) with gradients between 0.1% and 2% for each river's secondary watershed[16].

Stream gradient – scoring	
Score	**% of stream length (km)**
1	< 25
2	25 – 50
3	> 50

[16] Here, the secondary watershed was used as a general boundary to capture the main river and its primary tributaries.

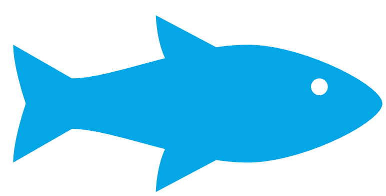
2.2.2 Rearing area

Based on DFO assessments, rearing area availability for juvenile Atlantic salmon within each secondary watershed is estimated by summing the number of habitat units (100 m^2) with gradients between 0.12 % and 25 % (Bowlby et al., 2013b). The amount of rearing area available in a watershed may indicate the productive habitat available for juvenile salmon. While there is no defined minimum watershed size for wild salmon occupancy, the smallest known rearing habitat in Nova Scotia that has historically supported salmon is the St. Esprit Brook, with an area of 333 habitat units (Gibson et al., 2014). Watersheds with less rearing habitat may be more susceptible to threats that may further decrease the availability of rearing areas, potentially constraining population growth and recovery. Therefore, we set generalized notions of 'small' rearing area being <500 habitat units to identify those that would be most susceptible to threats. As greater watershed size does not automatically presume higher habitat availability or quality, watershed with over 2000 habitat units can be considered less susceptible to threats. The rearing area data used within this assessment were acquired from three DFO reports (Bowlby et al., 2013a; Gibson and Claytor, 2013; Gibson et al., 2014) that provide assessment data on Atlantic salmon populations, habitat, and conservation requirements in Nova Scotia.

Rearing Area - Scoring	
Score	**Habitat units**
1	< 500
2	500 - 2000
3	> 2000

3 ABUNDANCE

Abundance is a key criterion in assessing the significance of a river for wild Atlantic salmon, as it reflects the capacity of a system to support and sustain viable populations. Measures of abundance are suggestive of the overall health and reproductive success of populations. Rivers with very low population sizes face more challenges for recovery and are more vulnerable to additional stressors, as small populations often have reduced genetic diversity, fewer age classes, and a lower intrinsic growth rate, resulting in increased susceptibility to environmental changes and local extinctions (Einum et al., 2003; Moore et al., 2010; Milner and de Leaniz, 2023). For this assessment, indicators that reflect the abundance of wild salmon populations are grouped into three separate factors: conservation requirement, density, and presence.



3.1 Conservation requirement

Conservation requirements (or conservation limits) provide a quantitative threshold for assessing whether Atlantic salmon populations are achieving the population size required to sustain populations (ASF, 2020). Poor attainment of conservation requirements can indicate a river may be incapable of supporting the spawning activities or the population levels necessary for long-term viability.

3.1.1 Conservation requirements*

In the Maritimes, status of salmon stocks is estimated through abundance monitoring and measured by comparing the estimated egg deposition (calculated from the estimated abundance and biological characteristics of salmon stocks) relative to a reference point known as the conservation egg requirement (Gibson and Claytor, 2013). The river-specific conservation egg requirement is based on an egg deposition of 2.4 eggs/m^2 (Fisheries and Oceans Canada, 2009) multiplied by the amount of accessible fluvial rearing habitat that is of suitable gradient. Gibson and Bowlby (2013) denotes three levels of attainment for egg deposition: exceeding the conservation requirement, meeting between 50% and 100% of the requirement, and falling below 50% of the requirement. Rivers exhibiting higher levels of attainment are considered to have abundances representing more stable salmon populations, resulting in higher significance scores. Conservation requirement data were acquired from several DFO reports (e.g. Levy and Gibson, 2014; Fisheries and Oceans Canada, 2018c; Raab et al., 2024), which provide assessment data on Atlantic salmon populations in Nova Scotia. Conservation requirement data was largely only available for rivers designated as index rivers. These data were analyzed spatially to identify the most recent percentage attainment of conservation egg requirements for each river, based on data collected over the last 10 years (2014 – 2024). The indicator was classified as secondary if percentage attainment calculations relied on data collected prior to 2014.

Conservation Requirement - Scoring	
Score	**%**
1	< 50
2	50 - 100
3	> 100

3.2 Density

To understand salmon stock status, density estimates (number of salmon per area) are often calculated to assess population abundance and trends (Gibson et al., 2003b; Bowlby et al., 2013a; Fisheries and Oceans Canada, 2015). Density estimates provide a standardized metric for evaluating population based on habitat area, allowing for meaningful comparisons across rivers of different sizes and to established reference values. Evaluating this factor allows for the identification of rivers with higher densities and potentially more stable populations, that are more likely to be significant for wild Atlantic salmon.

3.2.1 Juvenile density*

Juvenile density refers to the number of juvenile salmon per unit area of stream or river habitat and typically includes two age classes: fry (young-of-the-year, within their first year of life) and parr (older juveniles, age one year and older) (Fisheries and Oceans Canada, 2013). Higher juvenile densities can indicate reproductive success (Malcolm et al., 2019). Elson’s norm values[17], representing a normal index of abundance, have often been used as a reference for juvenile Atlantic salmon production (Gibson et al., 2011; Fisheries and Oceans Canada, 2013). In systems where Atlantic salmon populations are considered healthy or close to sustainable levels (i.e., conservation requirements), estimated juvenile densities across both fry and parr age groups often exceed these reference values (Fisheries and Oceans Canada, 2013). As such, total juvenile densities not meeting either fry (29 fish/100 m^2) or parr (38 fish/100 m^2) Elson’s norm are considered to be low significance. Total juvenile densities that reach or exceed at least one Elson’s norm value (i.e., fry or parr) but do not reach the combined Elson’s norm value are considered moderate and densities that meet or exceed combined fry and parr Elson’s norm values (i.e., 67 fish/100 m^2) are considered to be high significance. Juvenile density data were acquired from multiple sources including a dataset of compiled electrofishing data from Nova Scotian rivers and various DFO reports (e.g., Gibson et al., 2003a; Fisheries and Oceans Canada, 2010; Jones et al., 2018). Juvenile density was assessed using either directly reported total juvenile densities or by combining separately reported fry and parr densities. When only fry and parr values were available, they were collected and summed to calculate a total juvenile density. If total juvenile density was already provided in the data source, the value was directly used as the indicator value. The collected/calculated total juvenile density data were analyzed spatially to determine the average estimated juvenile salmon density per 100 m^2 for each river, based on data collected over the last 10 years. The indicator was classified as secondary, if juvenile density estimates relied on data collected prior to 2014.

[17] Elson (1967) examined the effects of DDT on juvenile Atlantic salmon and reported the typical juvenile densities of Atlantic salmon in untreated rivers. These baseline figures – now known as Elson’s norm values - have since been used as reference points for comparing juvenile salmon densities in other systems (Gibson et al., 2011).

Juvenile density – Scoring	
Score	**# /100 m^2**
1	< 29
2	29 – 66
3	> 66

3.3 Presence

Overall presence of Atlantic salmon detected in a river system can provide some foundational information on reported abundance of salmon. Presence/absence data indicate whether a species has been observed in a specific location or sampling unit, providing a basic, yet important, indication of habitat use and population distribution. This information can help to identify rivers of high significance where salmon populations are likely persisting.

3.3.1 Presence rating

Prior to this assessment, there were no up-to-date comprehensive assessments of general presence or absence of rivers in Nova Scotia. To assess the presence of Atlantic salmon across the area of analysis, CMAR collated and consolidated available information into a cohesive catalogue of calculated presence ratings for Nova Scotian rivers. This effort involved the development of a standardized rating system based on reported evidence and recency of salmon in a river. This system categorises observations into three presence ratings:

- **No reported observations** (documented absence of salmon or no evidence of salmon presence),
- **Historical presence** (evidence of salmon presence before 2014 but none since), and
- **Active presence** (evidence of salmon presence within the past 10 years).

Rivers unlikely to support salmon are those that have no evidence of previously supporting salmon and thus are scored as low significance. A river with a historical salmon population can be considered moderate significance for salmon, given the historical importance. Active rivers with recent abundance data are high significance, since there is evidence that they support an active salmon population.

Presence data compiled for this assessment were collected through several different methodologies, including electrofishing (Daigle, 2023), eDNA (Wringe et al., 2023), mark and recapture data (Fisheries and Oceans Canada, 2023a), fishway counts (Amiro et al., 2000), dive counts (Fisheries and Oceans Canada, 2020), and angling (Breau et al., 2009). Observations of salmon available through social media, local angling forums, or local and community-based knowledge were not included in this analysis. This exclusion was due to limitations in verifying these sources and resource limitations to comprehensively capture all relevant data for all rivers. Despite extensive efforts to compile data, it is also acknowledged that additional relevant sources likely exist beyond those captured in this assessment. The collected data were analyzed spatially to calculate a presence rating for each river, based on reported evidence (and recency) of salmon.

Score	Rating
1	No reported observations
2	Historical
3	Active

4 BARRIERS

Barriers are a critical criterion in assessing river significance for wild Atlantic salmon, as they directly affect the species' ability to access essential freshwater habitats. Physical barriers such as dams, culverts, and other obstacles can impede salmon migration and access to habitats, potentially affecting population connectivity (Angermeier et al., 2004; Fielding, 2011; Liermann et al., 2012; Millar et al., 2019a). Rivers with low number of barriers and higher connectivity are more likely to support healthy salmon populations. For this assessment, indicators that reflect the presence and severity of barriers to salmon movement are grouped into two separate factors: aquatic barriers and road crossings.

4.1 Aquatic barriers

Dams and other aquatic barriers are a major threat to freshwater biodiversity impacting sedimentation, flow, temperature regimes, and habitat connectivity (Angermeier et al., 2004; Fielding, 2011; Liermann et al., 2012; Millar et al., 2019a). These barriers can disrupt salmon migration, limit access to essential habitats, and fragment populations. Evaluating this factor allows for the identification of rivers with fewer aquatic barriers and higher connectivity, that may be more capable of supporting salmon populations and are therefore more likely to be significant for wild Atlantic salmon populations.

4.1.1 Proportion of river inaccessible*

Aquatic barriers without functional fish passageways can result in portions of the freshwater system becoming inaccessible to salmon. Larger portions of rivers being inaccessible to fish can indicate reduced habitat connectivity, reducing the ability of salmon to access ideal habitat or spawning areas. Mazany-Wright et al. (2021) classifies the extent of barriers into three classes: low extent (1 - 10 % of the habitat affected), medium extent (11 - 30 % of the habitat affected), and high extent (> 30 % of the habitat affected). Areas with a greater proportion of inaccessible river habitat, where barriers more significantly impede salmon passage, received lower significance scores. Proportion of river inaccessible data was acquired from the Nova Scotia Watershed Assessment Program (NSWAP) 2 Database, which provides data on the river length upstream of dams with no fish passage (km)/river length (km) for each river's secondary watershed. The indicator was classified as secondary, if proportion of river inaccessible estimates relied on data collected at the primary watershed scale.

Proportion of river inaccessible - Scoring	
Score	**%**
1	> 30
2	10 - 30
3	< 10

4.1.2 Aquatic barrier density

Aquatic barrier density refers to the number of in-stream barriers, such as dams or culverts, per unit length of river, providing a measure of habitat connectivity. A high density of aquatic barriers can contribute to habitat fragmentation, which can restrict salmon movement and limit access to critical habitats. Areas with higher density of barriers are considered to have a more substantial portion of habitat where salmon passage is impeded by barriers, resulting in lower significance scores. Aquatic barrier density data was acquired from the Nova Scotia Watershed Assessment Program (NSWAP) II Database, which provides data on the number of barriers per km of each river's secondary watershed. In watersheds where aquatic barrier density is 0, aquatic barriers are not considered a stressor. Conversely, aquatic barrier densities above 0.005 / km were scored as low significance as they indicate the highest aquatic barrier densities in Nova Scotia and are therefore assumed to be under the greatest habitat fragmentation risks.

Aquatic barrier density - Scoring	
Score	**#/km**
1	> 0.005
2	> 0 - 0.005
3	0

4.1.3 Aquatic barriers stressor rank

A watershed stressor is any physical, chemical, or biological agent within a watershed that can adversely affect watershed functions or health (U.S. Environmental Protection Agency, 2017; Millar et al., 2019b). Aquatic barriers, such as dams and culverts, can act as watershed stressors by disrupting natural water flow, fragmenting habitats, and limiting the movement of species like Atlantic salmon throughout the river system (Angermeier et al., 2004; Fielding, 2011; Liermann et al., 2012; Millar et al., 2019a). As a part of the NCC Watershed Health Assessment (Millar et al., 2019a), designed to evaluate the relative health of aquatic systems across the study area (Northern Appalachian–Acadian Region of Canada), the NCC identifies the top three stressors in each watershed[18]. When aquatic barriers rank among the top three stressors, it can indicate a

[18] Watershed boundaries for this assessment were based on the Canadian Hydrographic Units (CHU).

heightened risk of poor habitat quality due to habitat fragmentation. Stressor rank data for Nova Scotian watersheds were acquired from the 2C1 Forest Atlas database, which provides mapped data from the NCC Assessment. Data were only collected for half of the watersheds, based on the highest ranked (most stressed) watersheds in Nova Scotia. The data was analyzed to identify whether aquatic barriers were ranked as a top 3 stressor in the watershed.

Aquatic barriers stressor rank - Scoring	
Score	**Rank**
1	1, 2
2	3
3	None

4.2 Watercourse crossings

Watercourse or road crossings are locations where roads intersect with streams or rivers, typically through the use of infrastructure such as culverts or bridges. These structures can act as a barrier to fish movement, leading to habitat fragmentation and impeding salmon access to important habitat. Evaluating this factor allows for the identification of rivers with low numbers of road crossings may have less habitat fragmentation and/or alteration, and greater ability to support populations.

4.2.1 Density of road crossings*

Density of road crossings refers to the number of intersections between a road and a stream per length of stream. Road crossings can significantly impact the freshwater habitat of Atlantic salmon, potentially acting as a barrier to fish movement, leading to habitat fragmentation and impeding salmon access to important habitat (Angermeier et al., 2004; Fielding, 2011; Bowlby et al., 2013b; Millar et al., 2019a). Higher densities of road crossings suggest a higher likelihood of habitat fragmentation and/or alteration. The Nova Scotia Salmon Association W.A.T.E.R. workshop classifies the habitat quality metric scores of road crossing densities into five classes: Poor (9.2 – 1.0 / km^2), marginal (1.0 – 0.4 / km^2), OK (0.4 – 0.2 / km^2), good (0.2 – 0.01 / km^2), and excellent (no road crossings). Areas with higher densities of road crossings are considered to have more barriers, resulting in lower significance scores. Several previous assessments calculate road density for the river's secondary watershed (Bowlby et al., 2013a; Gibson et al., 2014; Sterling et al., 2014). The indicator was classified as secondary, if density of road crossing estimates relied on data collected at the primary watershed scale.

Density of road crossings - Scoring	
Score	**#/km**
1	> 1.0
2	0.5 - 1.0
3	< 0.5

4.2.2 Crossings stressor rank

A watershed stressor is any physical, chemical, or biological agent within a watershed that can adversely affect watershed functions or health (U.S. Environmental Protection Agency, 2017; Millar et al., 2019b). Road crossings can significantly impact watershed health and functioning, potentially acting as a barrier to fish movement, leading to habitat fragmentation and impeding salmon access to important habitat (Angermeier et al., 2004; Fielding, 2011; Bowlby et al., 2013b; Millar et al., 2019a). As a part of the NCC Watershed Health Assessment (Millar et al., 2019a), designed to evaluate the relative health of aquatic systems across the study area (Northern Appalachian–Acadian Region of Canada), the NCC identifies the top three stressors in each watershed[19]. When road crossings rank among the top three stressors, it can indicate a heightened risk of poor habitat quality due to habitat fragmentation. Stressor rank data for Nova Scotian watersheds were acquired from the 2C1 Forest Atlas database, which provides mapped data from the NCC Assessment. Data were only collected for half of the watersheds, based on the highest ranked (most stressed) watersheds in Nova Scotia. The data was analyzed to identify whether road crossings were ranked as a top 3 stressor in the watershed.

Crossing stressor rank - Scoring	
Score	**Rank**
1	1, 2
2	3
3	None

5 IMPORTANCE

The importance criterion reflects the degree to which a river contributes to broader conservation objectives for wild Atlantic salmon. Rivers identified as priorities for monitoring, conservation, or restoration efforts are considered to contribute more significantly to conservation objectives. This includes rivers that currently sustain stable or genetically distinct populations, as well as those facing extensive threats where targeted conservation or restoration action could yield substantial recovery benefits. For this assessment, indicators that reflect the importance of rivers to achieving conservation objectives are grouped into three separate factors: conservation status, restoration and monitoring, and river stocking.

[19] Watershed boundaries for this assessment were based on the Canadian Hydrographic Units (CHU).

5.1 Conservation status

Conservation status refers to the formal classifications assigned to a species or population based on their risk of extinction or extirpation, as recognized under legislation or designated by scientific bodies. These designations indicate the urgency and level of conservation attention required for Atlantic salmon populations. Evaluating this factor allows for the identification of rivers that are formally recognized as requiring more urgent conservation measures, likely contributing more to conservation objectives, and are therefore more likely to be significant for wild Atlantic salmon populations.

5.1.1 SARA status

The Species at Risk Act (SARA) identify wildlife populations at risk of extinction or extirpation, triggering legal protections and recovery planning. SARA classifies species into one of several categories: Endangered (i.e., a wildlife species that is facing imminent extirpation or extinction), Threatened (i.e., a wildlife species that is likely to become endangered if nothing is done to reverse the factors leading to its extirpation or extinction), and Special concern (i.e., a wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats). Populations listed as threatened or endangered underscore the need for more urgent and intensive conservation efforts. In contrast, populations not listed under SARA (i.e., no status) are generally considered to face fewer immediate risks and represent less urgent conservation priorities. SARA status data were acquired from the Species at risk registry, which serves as the official list of wildlife species at risk. SARA status is assigned based on Designatable Units (DU)[20], which represent distinct Atlantic salmon population groups, such as the Inner Bay of Fundy population. The data was analyzed spatially to identify the SARA status of Atlantic salmon populations associated with each river's DU, or to confirm the absence of a current listing.

SARA Status - Scoring	
Score	**SARA Status**
1	No status
2	Special concern
3	Endangered or threatened

[20] COSEWIC defines a DU as "a unit of Canadian biodiversity that is discrete and evolutionarily significant, where discrete means that there is currently little transmission of heritable (cultural or genetic) information from other such units, and evolutionarily significant means that the unit harbours an evolutionary history or heritable adaptive traits not found elsewhere in Canada" (COSEWIC, 2023).

5.1.2 COSEWIC status

COSEWIC status refers to the assessment and designation of wildlife species by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), which exists to provide advice regarding the status of wildlife species that are nationally at risk of extinction or extirpation (COSEWIC, 2015). COSEWIC classifies species into one of several categories: Endangered (i.e., a wildlife species facing imminent extirpation or extinction), Threatened (i.e., a wildlife species that is likely to become an endangered if nothing is done to reverse the factors leading to its extirpation or extinction), Special Concern (i.e., a wildlife species that may become threatened or endangered because of a combination of biological characteristics and identified threats), and Not At Risk (i.e., a wildlife Species that has been evaluated and found to be not at risk of extinction given the current circumstances). Populations designated as 'threatened' or 'endangered' underscore the need for more urgent and intensive conservation efforts. In contrast, populations designated as 'not at risk' are generally considered to face fewer immediate risks and represent less urgent conservation priorities. COSEWIC status data were acquired from the Atlantic salmon (*Salmo salar*): COSEWIC assessment and status report. COSEWIC status is assigned based on Designatable Units (DUs), which represent distinct Atlantic salmon populations, such as the Inner Bay of Fundy population. The data was analyzed spatially to identify the COSEWIC status of Atlantic salmon populations associated with each rivers DU.

COSEWIC Status - Scoring	
Score	**COSEWIC Status**
1	Not at risk
2	Special concern
3	Threatened or Endangered

5.2 Restoration and monitoring

Across Nova Scotia, many organizations and individuals conduct activities on salmon rivers to help monitor and restore habitat for Atlantic salmon. Restoration or conservation efforts in river systems refer to targeted actions aimed at improving habitat quality, connectivity, or population health, such as barrier removals or liming. The presence of these efforts in river systems suggest the importance of the system to wild salmon conservation goals. Similarly, evidence of research and monitoring of salmon and salmon habitat – such as population assessments or water quality monitoring - provides an indication of a river's importance for advancing salmon-focused research.

5.2.1 Evidence of restoration/monitoring efforts*

At the time of this assessment, no comprehensive data was available that collates all previous restoration and monitoring efforts in Nova Scotia. To assess restoration and monitoring efforts across Nova Scotian rivers, CMAR collated and consolidated available information into a cohesive catalogue of ratings that reflect the strength of evidence for restoration and monitoring efforts. This effort involved the development of a standardized rating system based on the number or consistency of monitoring and restoration initiatives in a river. This system categorizes rivers into three rating categories:

- **None** - No evidence of activities or initiatives on the river, and no mention or reference to Atlantic salmon;
- **Some** - Some evidence, potentially indirect, or one-time initiatives, including a single activity on a river that is not associated with a river or watershed-specific program or initiative, or salmon is mentioned indirectly; and
- **Strong** - Multiple activities, or long-term programs that occurred over a minimum of two years, and clearly identified Atlantic salmon as a primary focus[21].

A river with strong evidence of restoration, conservation, and/or monitoring initiatives (through long-term programs or multiple activities) suggests a concerted effort to protect, conserve, and/or monitor the watershed or population, indicating a higher significance. Likewise, no evidence of recent conservation, restoration, or monitoring initiatives does not indicate low/no significance but illustrates the river may not be a priority.

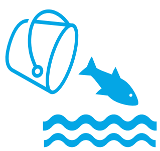
Evidence of restoration and monitoring efforts was gathered from the public websites of a wide range of organizations, including conservation and restoration organizations (e.g. the Nova Scotia Salmon Association, Clean Annapolis River Project, etc.), government agencies (e.g. the Department of Fisheries and Oceans, Parks Canada, etc.), and Indigenous organizations (e.g. the Mi'kmaw Conservation Group, Pictou Landing First Nation, etc.). The internet was scoured for evidence of funded initiatives to restore or conserve rivers since 2014. The initiative needed to be focused primarily on restoration, monitoring, or improving knowledge or understanding of salmon populations in a river system. Restoration initiatives included monitoring or restoration of habitat structure and function, such as stream restoration or alteration, and the monitoring or restoration of rivers to support fish passage, including barrier removal, fish passage installation, and culvert assessments. Monitoring initiatives included the monitoring of temperature and water quality, as well as acoustic monitoring efforts. Data were compiled from publicly available information on organizational websites at the time of data collection. It is recognized that these online sources may not capture the full extent of activities that have been completed or are currently underway, and that some relevant initiatives may not be publicly documented. Additionally, no organizations involved in river restoration or monitoring were contacted directly.

[21] Initiatives could include other species, but salmon had to be a central component.

While stocking efforts are often considered part of broader restoration or conservation strategies, they were excluded from this indicator to avoid redundancy, as stocking was assessed separately within the framework. Data was analyzed spatially to calculate a restoration and monitoring rating based on the number or consistency of monitoring and restoration initiatives, for each river. The indicator was classified as secondary if evidence of restoration and monitoring efforts were only available for efforts conducted prior to 2014.

Evidence of Restoration and Monitoring Efforts - Scoring	
Score	**Rating**
1	None
2	Some
3	Strong

5.3 River Stocking



River stocking is the practice of releasing hatchery-raised fish, such as Atlantic salmon, into a river system to support or enhance wild populations, often for conservation and recovery purposes. Evidence of river stocking can provide indication of the river's significance for wild salmon conservation and sustainability.

5.3.1 River stocking status

To assess river stocking efforts across the area of assessment, CMAR collated and consolidated available information into a cohesive catalogue of calculated river stocking status for Nova Scotian rivers. This effort involved the development of a standardized rating system based on reported evidence and recency of stocking efforts in a river. This system categorises observations into three stocking statuses:

- **No observations** (no evidence of river stocking efforts or reports of an absence of river stocking efforts);
- **Historical** (evidence of stocking efforts, but no efforts reported since 2014); and
- **Active** (evidence of recent river stocking efforts within the past 10 years).

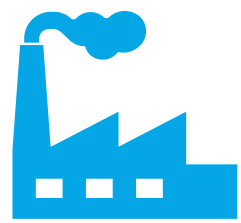
Rivers with no evidence of historic or current stocking, were scored as low significance. A river with evidence of historical stocking efforts, but no efforts reported since 2014 are considered "historical" and assigned a moderate rating. A river with active or recent (since 2014) stocking efforts can be considered "active" and high significance, as this effort may indicate the river's importance for wild salmon conservation and sustainability.

River stocking data was acquired from various sources, including DFO reports (e.g. Gibson et al., 2003a; Fisheries and Oceans Canada, 2010; Fisheries and Oceans Canada, 2018c) and the Nova

Scotia Fish Hatchery Stocking Records. Only publicly available online sources that provided formal records of river stocking efforts, such as government or non-government organization (NGO) reports and publicly accessible databases, were included in the assessment. This assessment only considered stocking records for Atlantic salmon; stocking of other species was not included. Data for this assessment were collected predominantly during the spring/summer of 2024; it is recognized that additional or updated data may have become available since that time. Despite extensive efforts to compile data, it is acknowledged that additional relevant sources likely exist beyond those captured in this assessment. The collected data were analyzed spatially to calculate a river stocking status for each river, based on reported evidence (and recency) of stocking efforts.

River stocking status - Scoring	
Score	**Rating**
1	No observations
2	Historical
3	Active

6 THREATS



The threats criterion reflects the myriad of threats Nova Scotia's wild salmon populations currently face, which pose significant challenges to their survival and proliferation (Dadswell et al., 2021). Here, threats refer to physical, chemical, or biological stressors – often driven by human activity – that degrade habitat quality or disrupt ecosystem functions, negatively impacting the health and sustainability of wild Atlantic salmon populations. Various human activities and industries, such as forestry, agriculture, and road construction, as well as anthropogenically induced climate change may introduce additional stressors to salmon populations and their habitats. High levels of cumulative stress may significantly impair a river's function as a productive salmon habitat, even if other ecological conditions are favourable. For this assessment, indicators that reflect the various threats faced by a river system are grouped into three separate factors: human land use, climate change, and aquatic invasive species.

6.1 Human Land Use

Human land use refers to the modification of natural landscapes for purposes such as agriculture, forestry, urban development, and infrastructure. These activities can impose additional stressors to salmon populations and their habitats by degrading water quality through eutrophication and contamination, increasing sedimentation, and altering temperature regimes (Cunjak, 1996; Blann et al., 2009; Millar et al., 2019a). Evaluating this factor allows for the identification of rivers with low levels of nearby human land use, which are less likely to experience high levels of anthropogenic stressors and are therefore more likely to be significant for wild Atlantic salmon populations.

6.1.1 Human population density*

Human population density refers to the number of people living within a given area, and is commonly used as an indicator of environmental stress, with higher densities generally linked to greater risks of environmental degradation (Millar et al., 2019a). Lower population density may suggest reduced environmental pressure and higher habitat quality, indicating higher significance. Data on estimated population per dwelling for each Statistics Canada Dissemination Area[22] was acquired from Statistics Canada Census (2021). To produce an estimate of human population per secondary watershed, the estimated population per dwelling was multiplied by the total number of dwellings within the secondary watershed, then divided by the watershed area. Data was analyzed spatially to identify the average number of people per km^2 within each river's secondary watershed. The indicator was classified as secondary if the population density was assessed at the primary watershed scale or relied on data collected prior to 2019. The scoring thresholds for human population density were selected to reflect the relatively low population densities typical of Nova Scotia. Although densities are low compared to many other regions, areas exceeding 50 people per km^2 are considered high density within the province and likely correspond to the rivers experiencing the greatest anthropogenic stressors.

Human population density - Scoring	
Score	**# of people / km^2**
1	> 50
2	25 - 50
3	< 25

6.1.2 Total road density*

Total road density refers to the length of all roads within a watershed area, and is recognized as a useful indicator of human impacts, such as habitat conversion, degradation, and fragmentation,

[22] A dissemination area (DA) is a small, relatively stable geographic unit composed of one or more adjacent dissemination blocks with an average population of 400 to 700 persons based on data from the previous Census of Population Program.

on aquatic ecosystems and species, and consequently of overall habitat effectiveness (Trombulak and Frissell, 2000; Beazley et al., 2004). Roads are a well-documented stressor on aquatic ecosystems, and at high densities, may lead to habitat fragmentation and degradation (Trombulak and Frissell, 2000; Millar et al., 2019a). Areas with low total road density may be less likely to experience high levels of stressors and are therefore more likely to be significant for wild Atlantic salmon populations. Road density data were available from previous assessments, including Sterling et al. (2014), Bowlby et al. (2013a), and Gibson et al. (2014). Sterling et al. (2014) identifies road densities of less than 1 km / km as low stress. Conversely, densities above 2 km / km are recognized as high stress, reflecting higher habitat degradation and fragmentation risks. The indicator was classified as secondary if total road density was assessed at the primary watershed scale.

Total road density - Scoring	
Score	**km / km**
1	> 2.0
2	1.0 - 2.0
3	< 1.0

6.1.3 Impervious surfaces

Impervious surfaces (IS) refer to hard surfaces such as roads, buildings, and pavement, which prevent water infiltration and can be used to estimate the impacts of urbanization on freshwater systems, as they can alter habitat and water quality (Kim et al., 2016; Millar et al., 2019a). A widely used scale for the impacts of IS classifies watershed areas as 'stressed' if they contain 1 - 10 % IS area and 'impacted' if they contain 10 - 25 % IS area (Elvidge et al., 2007; Shin, 2023). As IS can drastically alter downstream hydrology, habitat structure, and water quality, areas with a higher percent of impervious surfaces are considered to be under more significant threats, resulting in lower significance scores (Kim et al., 2016; Millar et al., 2019a). Impervious surface data were acquired from the Nature Conservancy of Canada (NCC)'s Watershed Health Assessment (Millar et al 2019), which provided the percent area of impervious surfaces estimated within each river's CHU.

Impervious surfaces - Scoring	
Score	**% area**
1	> 10
2	1 - 10
3	< 1

6.1.4 Total riparian disturbance*

Total riparian disturbance refers to the proportion of the riparian (river) zone – the vegetated areas adjacent to rivers and streams – that has been altered or degraded by human activities, such as urbanization, agriculture, and forestry. Disturbance to riparian zones can impair key ecological functions, such as filtration, bank stability, and habitat provisioning (Bowlby et al., 2013b; Collison et al., 2022). Areas with higher percentages of riparian disturbance are more likely to experience high levels of stressors and are therefore less likely to be significant for wild Atlantic salmon populations. Nelitz et al. (2007) classified the functioning condition of riparian zones based on riparian disturbance into three classes: proper function (< 20 % disturbance), at risk (25 – 30 % disturbance), and non-functional (>30 %). Total riparian disturbance data were acquired from the Nova Scotia Watershed Assessment Program (NSWAP) 2 Database, which provided the combined percentage of human disturbances (i.e., urbanization, agricultural activity, or forest loss) within a 150-meter riparian zone surrounding aquatic features in each river's secondary watershed. The indicator was classified as secondary if total riparian disturbance was assessed at the primary watershed scale, such as by MacDonald et al. (2023).

Total riparian disturbance – Scoring	
Score	**%**
1	> 30
2	20 - 30
3	< 20

6.1.5 Total watershed disturbance

Total watershed disturbance refers to the area of land within a watershed that has been altered by human activities, such as urbanization, agriculture, and forestry, which can adversely influence habitat characteristics, such as water temperature and quality (Bowlby et al., 2013b; Collison et al., 2022). Areas with higher percentages of watershed disturbance are more likely to experience high levels of stressors and are therefore less likely to be significant for wild Atlantic salmon populations. The classification approach developed by Nelitz et al. (2007) for assessing riparian zone condition – categorizing areas as properly functioning (< 20 % disturbance), at risk (25 – 30 % disturbance), and non-functional (> 30 %) – is likely appropriate for evaluating overall watershed disturbance as well, as the underlying concept is similar. Just as excessive disturbance in riparian zones can impair key ecological functions and habitat provision, high levels of disturbance across an entire watershed can disrupt hydrological processes, increase pollutants, and degrade habitat quality. Total watershed disturbance data was acquired from the Nova Scotia Watershed Assessment Program (NSWAP) 2 Database, which calculates the total percentage of the watershed that has been altered or disturbed by human activities for each river's secondary watershed.

Total watershed disturbance - Scoring	
Score	**%**
1	> 30
2	20 - 30
3	< 20

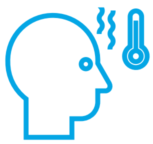
6.1.6 Human land use stressor rank

A watershed stressor is any physical, chemical, or biological agent within a watershed that can adversely effect watershed functions or health (U.S. Environmental Protection Agency, 2017; Millar et al., 2019b). Human land use, such as agriculture, forestry, urban development, and infrastructure, can impact habitat connectivity and adversely influence habitat characteristics, such as water temperature, and water quality (Bowlby et al., 2013b; Collison et al., 2022). As a part of the NCC Watershed Health Assessment (Millar et al., 2019a), designed to evaluate the relative health of aquatic systems across the study area (Northern Appalachian–Acadian Region of Canada), the NCC identifies the top three stressors in each watershed[23]. When human land uses rank among the top three stressors, it can indicate a heightened risk of poor habitat quality due to anthropogenic stressors. Stressor rank data for Nova Scotian watersheds was acquired from the 2C1 Forest Atlas database, which provides mapped data from the NCC Assessment. The NCC Assessment identifies multiple human activity-related stressors, including unpaved road density, clear-cutting, nitrogen and phosphorus leaching, impervious surfaces, pasture agriculture, and pesticide leaching. If any one of these stressors was identified by the NCC as a primary stressor in a watershed, it was used to represent the presence of a human land use stressor for this indicator. Data was only collected for half of the watersheds, based on the highest-ranked (most stressed) watersheds in Nova Scotia. The data was analyzed to identify whether human land use was ranked as a top 3 stressor in the watershed.

Human land use stressor rank – Scoring	
Score	**Stressor Rank**
1	1, 2
2	3
3	None

[23] Watershed boundaries for this assessment were based on the Canadian Hydrographic Units (CHU).

6.2 Climate change



Climate change may introduce additional stressors to salmon populations and their habitats, directly through habitat alterations, such as shifts in temperature and water flow, and indirectly by altering ecosystem functions, including food availability and predator-prey relationships (Angermeier et al., 2004; Millar et al., 2019a; Thorstad et al., 2021). For Atlantic salmon, these changes may disrupt critical life stages, such as spawning, rearing, and migration – by reducing habitat suitability. Evaluating this factor allows for the identification of rivers that are less impacted by climatic stressors and are therefore more likely to be significant for wild Atlantic salmon populations.

6.2.1 Climate change velocity

Climate change velocity refers to how quickly and how far a species must move across the landscape to stay within its preferred climate conditions as temperatures and other climatic factors change. This metric is often used to estimate the rate at which climate change and changing environmental conditions are putting species using the area at risk (Carroll et al., 2015; Millar et al., 2019a). Greater climate change velocities are considered high stress, as it will require species to change ranges faster and farther to find suitable habitat. Climate change velocity data was collected from Shin (2023), which developed a Freshwater Climate Risk Index for Biodiversity. Shin (2023) modeled climate change velocity (or velocity of climate change (VOCC)) using the function gVoCC in the VoCC R package (García Molinos et al. 2019) to calculate the velocity of change (km yr-1) in average annual air temperature (-3°C to estimate water temperature), as in Boyce et al. (2022). This calculation was run for all 24 statistically downscaled climate simulations from CMIP5 and averaged for each watershed, for each RCP (2.6, 4.5, 8.5). Only data calculated for "worst case" climate scenario (RCP 8.5), was included within this assessment. Scores were based on low, medium, and high risk thresholds set by the distribution of global velocity values, following Shin (2023) and Boyce et al. (2022). Data was analyzed spatially to identify the mean velocity of change (km / yr) in average annual air temperature of the watershed, for each river's primary watershed.

Climate Change Velocity – Scoring	
Score	**Km / year**
1	> 15
2	6 - 15
3	< 6

6.2.2 Increased water temperature

Increased water temperature refers to a rise in river temperatures above the 'typical' or 'natural' baseline levels for that system (Millar et al., 2019a). Land use practices can remove forest cover and increase water temperatures, affecting freshwater communities and species, including salmon. Heat stress and warming temperatures negatively affect salmon populations (Elliott, 1991; Breau et al., 2011; Calado et al., 2021). Increased water temperature data were acquired from 2C1 Forest Atlas database, which provides mapped data from the NCC Watershed Health Assessment. The watershed health assessment assessed potential temperature increase by comparing current stream and river temperatures to predicted "natural" temperatures (Millar et al., 2019a). In Nova Scotia, some rivers have been predicted to increase in temperature (Millar et al., 2019), although most by less than 0.5 °C. When averaged across the watershed (CHU), the highest predicted average temperature increase was estimated at 0.061 °C. Scoring was based on the distribution of data within Nova Scotia, as reported through the NCC Watershed Health Assessment (Millar et al., 2019a). Areas with higher predicted temperature increases are considered to have greater threats, resulting in lower significance scores. Data was analyzed spatially to calculate the weighted average temperature increase (°C) of watershed for rivers predicted to have warmed due to land use change, for each river's CHU.

Increased Water Temperature - Scoring	
Score	**°C**
1	> 0.025
2	> 0 - 0.025
3	0

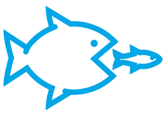
6.2.3 Temperature stressor rank

A watershed stressor is any physical, chemical, or biological agent within a watershed that can adversely affect watershed functions or health (U.S. Environmental Protection Agency, 2017; Millar et al., 2019b). Heat stress and warming temperatures are known to negatively affect salmon habitat and populations (Elliott, 1991; Breau et al., 2011; Calado et al., 2021). As a part of the NCC Watershed Health Assessment (Millar et al., 2019a), designed to evaluate the relative health of aquatic systems across the study area (Northern Appalachian–Acadian Region of Canada), the NCC identifies the top three stressors in each watershed[24]. When temperature ranks among the top three stressors, it can indicate a heightened risk of poor habitat quality due to thermal stressors. Stressor rank data for Nova Scotian watersheds were acquired from the 2C1 Forest Atlas database, which provides mapped data from the NCC Assessment. Data were only collected for half of the watersheds, based on the highest-ranked (most stressed) watersheds in Nova Scotia. The data was analyzed to identify whether temperature was ranked as a top 3 stressor in the watershed.

[24] Watershed boundaries for this assessment were based on the Canadian Hydrographic Units (CHU).

Temperature Stressor Rank – Scoring	
Score	**Rank**
1	1, 2
2	3
3	None

6.3 Aquatic Invasive Species (AIS)



Aquatic invasive species (AIS) are non-native organisms that have been introduced into the environment and have the potential to cause ecological harm. AIS can compete with native wild Atlantic salmon for habitat and resources, alter food webs, introduce disease, and degrade habitat quality (Fisheries and Oceans Canada, 2023b). Evaluating this factor allows for the identification of rivers where AIS pose a current or emerging threat and are therefore less likely to be significant for wild Atlantic salmon populations.

6.3.1 Presence of chain pickerel (*Esox niger*) and smallmouth bass (*Micropterus dolomieu*)

Smallmouth bass (SMB) and chain pickerel (CP) are highly predatory invasive species observed in various regions of Nova Scotia (Feener, 2018; Walsh, 2022). The presence of SMB or CP can reduce the availability of essential resources and increase predation of salmon populations. The Nova Scotia Salmon Association W.A.T.E.R. Workshop classifies the habitat quality metric scores of AIS presence into 5 classes: Poor (both CP and SMB present), Marginal (CP present), OK (SMB present), Good (neither CP or SMB present in the habitat but are in the watershed), and Excellent (neither CP or SMB are present anywhere within the watershed). To assess the presence of CP and SMB across the area of assessment, CMAR collated and consolidated available information into a cohesive catalogue of calculated presence ratings for Nova Scotian rivers. This effort involved the development of a standardized rating system based on reported evidence of CP and/or SMB in a river or watershed. This system categorises observations into three presence ratings:

- **No observation in river or watershed** (neither CP or SMB has been reported within the river or watershed),
- **Neither in river, but ≥1 in watershed** (neither CP or SMB has been reported within the river, but at least one has been reported within the watershed), and
- **Either or both in river** (either or both CP and SMB has been reported within the river). Areas with SMB and/or CP are more likely to experience high levels of AIS stressors and are therefore less likely to be significant for wild Atlantic salmon populations.

Data identifying reported evidence of CP and SMB within the assessed rivers or watersheds was acquired from various sources, the Atlantic Canada Chain Pickeral Database and various DFO (e.g. Bowlby et al., 2013b; MacDonald et al., 2023) and non-government organization (NGO) reports (e.g. Feener, 2018; Arany, 2019). We only included data from publicly accessible, published reports and sources. Observations from local anglers, fishers, or community members available in social media or fishing forums were not included. Despite extensive efforts to compile data, it is also acknowledged that additional relevant sources likely exist beyond those captured in this assessment. The collected data was analyzed spatially to identify the CP and/or SMB presence rating for each river.

Presence of chain pickerel or Smallmouth bass – Scoring	
Score	**Rating**
1	Either or both in river
2	Neither in river, but ≥1 in watershed
3	No observation in river or watershed

6.3.2 Number of non-native fish species

The number of non-native fish species refers to the total count of fish species present in a river or watershed system that are not native to the region (Millar et al., 2019a). Non-native and invasive aquatic species are considered the second-highest threat to freshwater fish in Canada (Millar et al., 2019a). Predatory non-native fish species, such as smallmouth bass and chain pickerel, can prey on salmon at various stages of their life cycle, and outcompete native species for food and suitable habitat (DFO, 2009; Feener, 2018). Rivers with a higher number of non-native fish species present, face an increased likelihood of competition, predation, and disease transmission, and are therefore less significant for wild Atlantic salmon populations. Non-native fish data were acquired from 2C1 Forest Atlas database, which identifies the total number of non-native fish species present within each river's CHU.

Number of non-native fish species – Scoring	
Score	**# Species**
1	> 1
2	1
3	0

6.3.3 Non-native fish species stressor rank

A watershed stressor is any physical, chemical, or biological agent within a watershed that can adversely effect watershed functions or health (U.S. Environmental Protection Agency, 2017; Millar et al., 2019b). Non-native fish species are a significant stressor for freshwater systems, as they can compete with native wild Atlantic salmon for habitat and resources, alter food webs, introduce disease, and degrade habitat quality (Fisheries and Oceans Canada, 2023b). As a part of the NCC Watershed Health Assessment (Millar et al., 2019a), designed to evaluate the relative health of aquatic systems across the study area (Northern Appalachian–Acadian Region of Canada), the

NCC identifies the top three stressors in each watershed[25]. When non-native fish species rank among the top three stressors, it can indicate a heightened risk of poor habitat quality due to AIS stressors. Stressor rank data for Nova Scotian watersheds were acquired from the 2C1 Forest Atlas database, which provides mapped data from the NCC Assessment. Data was only collected for half of the watersheds, based on the highest-ranked (most stressed) watersheds in Nova Scotia. The data was analyzed to identify whether non-native fish species was ranked as a top 3 stressor in the watershed.

Non-native fish species stressor rank – Scoring	
Score	**Rank**
1	1, 2
2	3
3	None

7 References

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