# Evaluating Federal Climate Policies for Freshwater Ecosystem Protection in North America

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Abstract

Climate change poses a significant threat to freshwater ecosystems, which are vital for maintaining biodiversity, supporting human livelihoods, and providing essential ecosystems services. This paper evaluated the potential effectiveness of federal climate policies of Canada and the United States in protecting freshwater ecosystems amid a changing climate. By examining the National Adaptation Strategy Plan of Canada and the Office of Water Climate Change Adaptation Implementation Plan of the United States, this paper employed a formative evaluation approach to assess policy integration with current scientific knowledge and their potential effectiveness in managing freshwater ecosystems. The methodology included a selection of policies based on their relevance to climate change and freshwater ecosystems, followed by a rapid systematic literature review to gather data on climate impacts and scientific recommendations for climate policies. The analysis applied a formative evaluation approach to assess, a) the integration of current scientific knowledge in policy objectives, and b) to evaluate their potential effectiveness in protecting freshwater ecosystems. Key evaluation criteria included biodiversity conservation and protection, habitat management, stakeholder collaboration, and research and monitoring. The findings revealed that while both policies incorporated significant elements of climate adaptation and mitigation, there were notable gaps in some objectives from the Canadian and American policies regarding stakeholder collaboration. Additionally, the integration of scientific knowledge in policy objectives was fairly consistent, however there were other climate impacts that have not been acknowledged in the policies and could have possibly led to potential inefficiencies in addressing the multifaceted impacts of climate change on freshwater systems. This paper offered recommendations to enhance policy frameworks, emphasize the needs for stronger scientific integration, increased

stakeholder involvement and adaptive management strategies that focus on freshwater ecosystems. By addressing these gaps, federal climate policies can be better equipped to ensure the resilience and protection of freshwater ecosystems in North America.

## Foreword

This paper completed the requirements for the Master in Environmental Studies degree by fulfilling the major research component. It also aligned with the area of concentration outlined in the Plan of Study, which encompassed two critical sections: the impacts of climate change on freshwater ecosystems and the evaluation of conservation policies and practices. This paper accomplished the learning objectives of the first section by examining how climate change-related variables currently affect, and will continue to impact, freshwater ecosystems. By doing so, the paper provided a comprehensive understanding of the present and future challenges faced by freshwater environments in the context of climate change. The paper evaluated the current climate policies of Canada and the United States, which fulfills the learning objectives of the second component. This evaluation focused on identifying the strengths and limitations of these policies concerning the protection and conservation of freshwater ecosystems. By critically analyzing existing policies, the paper aimed to highlight areas where improvements are needed and to suggest potential pathways for enhancing policy effectiveness. Furthermore, this paper emphasized the crucial role of science in policy development. The analysis was grounded in current scientific knowledge, ensuring that the evaluation of climate policies was based on the latest research and data. This approach underscored the importance of integrating scientific insights into policy-making processes to develop effective and sustainable climate strategies for freshwater ecosystem protection.

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Introduction

Over the past few years, we have seen an increase in the frequency and severity of storms, droughts, and other extreme weather events in North America and globally (Bonar, 2021). Summers are getting warmer, and winters are becoming milder, though they can still feature short periods of intense cold. These observations are consistent with the phenomenon of climate change, which has brought about significant and lasting changes in the Earth's climate patterns. This phenomenon is primarily driven by human activities, such as the burning of fossil fuels and deforestation, leading to increased concentrations of greenhouse gases in the atmosphere, enhancing the natural greenhouse effect and leading to global warming (IPCC, 2023). According to the IPCC synthesis report on climate change of 2023, air temperature and global precipitation levels are and will continue to increase (IPCC, 2023). This warming is associated with a range of environmental impacts and increased climate variability, including rising sea levels, increased frequency, and severity of extreme weather events, and shifts in ecosystems and biodiversity (IPCC, 2023). The effects of climate change are widespread, influencing not just the atmosphere but also the hydrosphere, cryosphere, and biosphere, leading to complex and interrelated challenges for natural and human systems worldwide(IPCC, 2023) .

Freshwater ecosystems, encompassing rivers, lakes, streams, wetlands, and aquifers, are vital to both ecological and human health. They provide essential services, including supplying drinking water, supporting agriculture through irrigation, and sustaining a diverse array of plant and animal species (Carpenter et al., 2011). These ecosystems are hotspots of biodiversity, hosting species that are uniquely adapted to freshwater environments. Moreover, they play a crucial role in nutrient cycling, sediment transport, and water purification, acting as natural filters that improve water quality. Beyond their ecological importance, freshwater ecosystems also offer significant recreational, cultural, and economic benefits, serving as sites for fishing, boating, and tourism (Howarth et al., 2023). The health and functionality of freshwater ecosystems are therefore integral to maintaining environmental stability and supporting human livelihoods and well-being.

Despite their importance, freshwater ecosystems are increasingly threatened by climate change, which exacerbates existing environmental stressors and introduces new challenges. Alterations in temperature and precipitation patterns, coupled with extreme weather events, directly impact water quality and availability, posing risks to the flora and fauna that depend on these habitats. Extensive data on species imperilment in North America and the United States indicates that freshwater species face higher imperilment rates compared to terrestrial or marine species (Carpenter et al., 2011). The taxonomic groups most at risk are primarily freshwater organisms, with freshwater mussels leading the list (69% at risk or extinct), followed by crayfishes (51%), stoneflies (43%), freshwater fishes (37%), and amphibians (36%) (Carpenter, 2011). In contrast, high-profile terrestrial groups such as birds and mammals have lower imperilment rates, at 14% and 16% respectively (Carpenter et al, 2011). Recent assessments by the American Fisheries Society have confirmed the high rates of imperilment among North American freshwater fish species (Carpenter et al., 2011). As climate change accelerates, the need for effective policies to protect and restore freshwater ecosystems becomes more urgent.

This paper aimed to critically examine the current federal climate policies of Canada and the United States, assessing their effectiveness in protecting freshwater ecosystems amidst a changing climate. The research focused on analyzing the National Adaptation Strategy (2022) of Canada and the Office of Water Climate Change Adaptation Implementation Plan (2022) of the

United States. By evaluating these policies against scientific knowledge and their ability to address key aspects of freshwater ecosystem management, this paper sought to identify strengths, weaknesses, and areas for improvement. Through a comprehensive review of the literature and a formative evaluation of policies, the goal was to provide insights into how federal climate policies can be enhanced to ensure the resilience and protection of freshwater ecosystems in North America.

## Methodology

This paper has analyzed the current federal climate policies of Canada and the United States. A systematic approach was adopted to ensure a comprehensive and relevant selection of policies. The methodology began with a keyword-based search on Google, using terms such as "climate change policy/ies," "freshwater ecosystems," "United States," and "Canada." These keywords were chosen to capture a broad spectrum of policies that address climate change impacts, with a specific focus on those that include provisions or implications for freshwater ecosystems. The selection process prioritized policies that were published within the past five years to ensure the analysis reflected the most recent and relevant policy developments. Recent policies are also more likely to incorporate the latest scientific understanding and policy innovations regarding climate change and freshwater management. The selection process prioritized policies based on several criteria: 1) they needed to explicitly address climate change through either mitigation or adaptation strategies; 2) include provisions for the protection or management of freshwater ecosystems; and 3) have demonstrated a comprehensive scope and potential impact at the national level. Policies were evaluated for their relevance to water quality, biodiversity, ecosystem services, and the broader implications for climate resilience, ensuring that the chosen policies provide significant insights into the intersection of climate change and freshwater ecosystem management.

The method that was used to gather data regarding freshwater ecosystem responses to climate change and science-informed policymaking will primarily be through a rapid systematic literature review process (Johnson et al., 2010). Rapid systematic reviews are conducted within a shortened timeframe of 5 to 12 weeks, in contrast to traditional systematic reviews, which typically take about a year to complete and provide more comprehensive findings (Tricco et al., 2015). This method was selected for its efficiency in synthesizing a large body of literature within a constrained timeframe, which was crucial given the extensive and diverse nature of the topic. The review process has systematically collect, assess, and synthesize relevant studies and documents, focusing on the impacts of climate change on freshwater ecosystems in North America. As such, certain studies are selected through key databases that include Scopus, Web of Science, FiCli Database, and Google Scholar. The results were filtered based on geographical range and limited to Canada and America. The main question being targeted in this literature review is - what is the scientific state of knowledge on freshwater ecosystem responses to climate change in North America? The FiCli (USGS Fish and Climate Change) database was used to gather data specifically on freshwater fishes and climate change from the past 10 years. The remaining databases will be used to obtain results that focus on climate change impacts on freshwater habitats. The literature search was guided by specific key terms tailored to capture the breadth and depth of the topic. The primary search terms used in combination included "climate change," "freshwater habitats," "freshwater fisheries," and "North America." These terms were used to identify research articles, reviews, and reports that address the impacts of climate change on freshwater ecosystems within the specified geographical range of Canada and the United States. Google Scholar and Scopus were used to examine policy recommendations for freshwater ecosystems and explore case studies that focus on climate policy and freshwater ecosystems in North America. Key terms for this search include “scientific recommendations for freshwater ecosystems”, and “climate policy case studies and freshwater ecosystems”. This has helped in identifying policy documents, scientific recommendations, and case studies that offer insights into how climate policies are shaping the management and resilience of freshwater ecosystems.

The formative evaluation method was used to analyze the American and Canadian climate policies. Formative evaluations are used while the policy is being implemented and rather than focusing on the outcomes, it focuses more on the policy and objectives itself. This analysis ensures that a program is feasible, appropriate, and acceptable before it is fully implemented and has been used in various fields including health care (Stuart et al., 2017). While there is no single definition or approach to formative evaluations, it can be further described as a rigorous assessment process that is designed to identify potential and actual influences on the progress and effectiveness of implementation efforts (Stetler et al., 2006). There are various potential uses of formative evaluation, and these uses range from understanding the nature of local implementation settings to modifying a proposed program or intervention as needed. This paper used formative evaluation to mainly assess whether the policy program integrates the findings of climate change science and recommendations to protect freshwater ecosystems.

To answer the research question, this paper evaluated existing climate change policies using two key criteria. The first criterion was whether these policies integrated the current state of knowledge on freshwater ecosystem responses to climate change. This step involved identifying if policies are informed by scientific literature and if they set goals or objectives accordingly. Policies that include such informed goals will be highlighted with specific examples. A comparative approach will be taken to assess how and where climate responses are incorporated into these policies. The second evaluation criterion examines the potential effectiveness of these climate policies in protecting freshwater ecosystems amidst a changing climate. To assess this, each policy will undergo a semi-quantitative evaluation process. Scientific recommendations from the scientific literature will be categorized for key aspects of freshwater ecosystem management. The following categories that will be used as policy evaluation criteria include:

- Biodiversity Conservation: The extent to which policies protect freshwater species and ecosystems.
- Habitat Management: Measures taken to maintain, restore, and manage freshwater habitats and their connectivity.
- Stakeholder Collaboration: Involvement of stakeholders in policy planning and implementation.
- Research and Monitoring: Implementation and the integration of scientific research and long-term monitoring into policy programs.

I have used a scale of 1-3 to assess how well each policy addresses recommendations/concerns attained from the specific categories in the scientific literature. A score of 3 indicates that the policy has potentially met the category recommendations effectively, while a score of 1 signifies that the policy has not met any of the category recommendations, deeming the policy potentially ineffective in achieving its goal. A theoretical example of this evaluation process is as follows, to preserve the ecological integrity of freshwater habitats, one of the recommendations in the scientific literature is that the habitat needs to be protected through a nature reserve or provincial park designation. The evaluation process involves cross-referencing this scientific recommendation with the stated goals and objectives outlined in the selected policies. If a policy explicitly includes a target aligning with this recommendation, it would receive a rating of 3, indicating potential effectiveness in addressing habitat preservation. If the policy does not meet the provided recommendation, it would be found potentially ineffective and be given a rating of 1. This evaluation has revealed how well current policies address various categories within freshwater ecosystem management, providing a clear picture of their overall potential effectiveness and areas needing improvement.

## Results

1. Climate Change Policies in North America

This section has summarized the selected federal climate policies of Canada and the United States with a focus on policy objectives/goals that refer to freshwater/aquatic ecosystems. The following are the most recent federal policies enacted by the Canadian and United States governments within the past five years, making them particularly relevant to current issues and contexts. Based on the criteria, the following policies were selected for analysis:

1. Canada: National Adaptation Strategy (2023)
2. United States: Office of Water Climate Change Adaptation Implementation Plan (2022)

These policies were chosen for their significant contributions to climate change mitigation and adaptation strategies, as well as their inclusion on freshwater ecosystems.

a. Canada

In 2022, the federal government of Canada published its federal climate policy, the National Adaptation Strategy, which covered a range of topics that centered on the theme of adaptation in a changing climate (ECCC, 2023). These interconnected system topics included disaster resilience, health and well-being, nature and biodiversity, infrastructure, and economy and workers. Each of these systems is outlined with specific goals, objectives, and targets. The policy is introduced by detailing the various ways in which climate change is impacting Canadians and explaining how each system is being affected. The policy further introduces the concept of climate change adaptation and outlines how Canada can pursue this approach to achieve climate resilience. The following diagram shows the general layout of the Canadian climate policy:

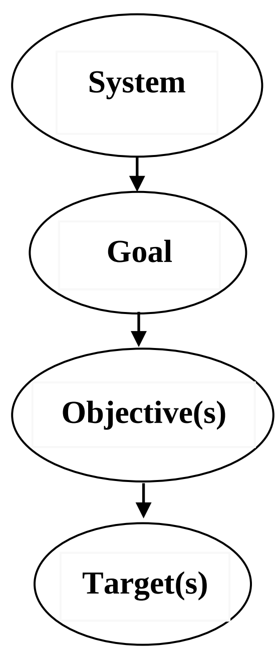


Figure 1. Flowchart presenting Canadian climate policy layout

I have focused on the topic of Nature and Biodiversity for this paper as it is the only system that explicitly includes freshwater ecosystems in its description (ECCC, 2023). In the original publication of this policy, the topic of nature and biodiversity was listed with the goal of halting and reversing biodiversity loss (ECCC, 2023). Apart from this, the goal includes the full recovery of nature that would allow for natural and human adaptation, where ecosystems and communities are thriving together in a changing climate (ECCC, 2023). There were four objectives listed for achieving this goal:

- "1. Human activities are transformed to halt and reverse biodiversity loss and enhance ecosystem connectivity and resilience" (ECCC, 2023, p. 25).
- "2. The ecosystems most affected by climate change are monitored, restored and managed to ensure their continued viability and adaptive capacity" (ECCC, 2023, p. 25).
- "3. First Nations, Inuit, and Métis governments, organizations, and communities have the opportunities and means to pursue self-determined priorities for ecosystem stewardship initiatives to adapt to climate change" (ECCC, 2023, p. 25).
- "4. The use of nature-based solutions is accelerated to increase resilience and maximize co-benefits such as reducing stress on grey infrastructure, increasing social benefits of nature, and climate change mitigation" (ECCC, 2023, p. 25).

The targets listed to meet the goal and objectives in the original publication of the policy were as follows:

- Target 1: “Conserve 25% of our lands and waters by 2025 and 30% of each by 2030, working to halt and reverse nature loss by 2030 in Canada” (ECCC, 2023, p. 25).
- Target 2: “Recognize and support at least 3 ecological corridors by 2025, to improve ecological connectivity between protected and conserved areas” (ECCC, 2023, p. 25).
- Target 3: “By 2026, support new and existing Guardians initiatives, establish new Indigenous Guardians Networks, and support Indigenous communities to build capacity to establish more Indigenous Protected and Conserved Areas” (ECCC, 2023, p. 25).
- Target 4: “Establish 15 new national urban parks by 2030 to conserve nature, connect people with nature, and advance reconciliation with Indigenous Peoples” (ECCC, 2023, p. 25).

According to the policy, this national adaption strategy is expected to change over time, with action plans developed and implemented on a five-year cycle (ECCC, 2023). The next update is scheduled for 2030. The National Adaptation Strategy will be executed through the Government of Canada Adaptation Action Plan and will involve collaboration with various levels of government to enhance climate change resilience (ECCC, 2023).

b. United States

In response to the Executive Order by President Joe Biden in 2021 with the topic of Tackling the Climate Crisis at Home and Abroad, the Environmental Protection Agency (EPA) launched the Climate Adaptation Implementation Plan to be conducted during the fiscal years from 2022-2026 (President Joseph Biden, 2021). This paper focused on the plan that is being implemented by the Office of Water under the EPA and has focused on the objectives and goals that are associated with aquatic ecosystems as freshwater ecosystems are not specified in the policy (EPA, 2022). The US policy states the climate vulnerabilities that are affecting water resources, communities, and any Office of Water Programs. Focusing on aquatic ecosystem health from the US policy, climate change will likely have wide-ranging effects on water chemistry, ecosystem health, habitat, and suitability for human use. The US policy also addresses the impacts of climate change on vulnerable communities and populations that generally have fewer resources to prepare for/cope with climate-related events. The policy is broken down so that each section has Priority Actions and each of these Priority Actions has a goal and subsequent objectives with extra details. Priority actions that benefit ecosystem protection and aquatic ecosystem health will be highlighted and summarized. The following diagram demonstrates the general layout of the American climate policy.

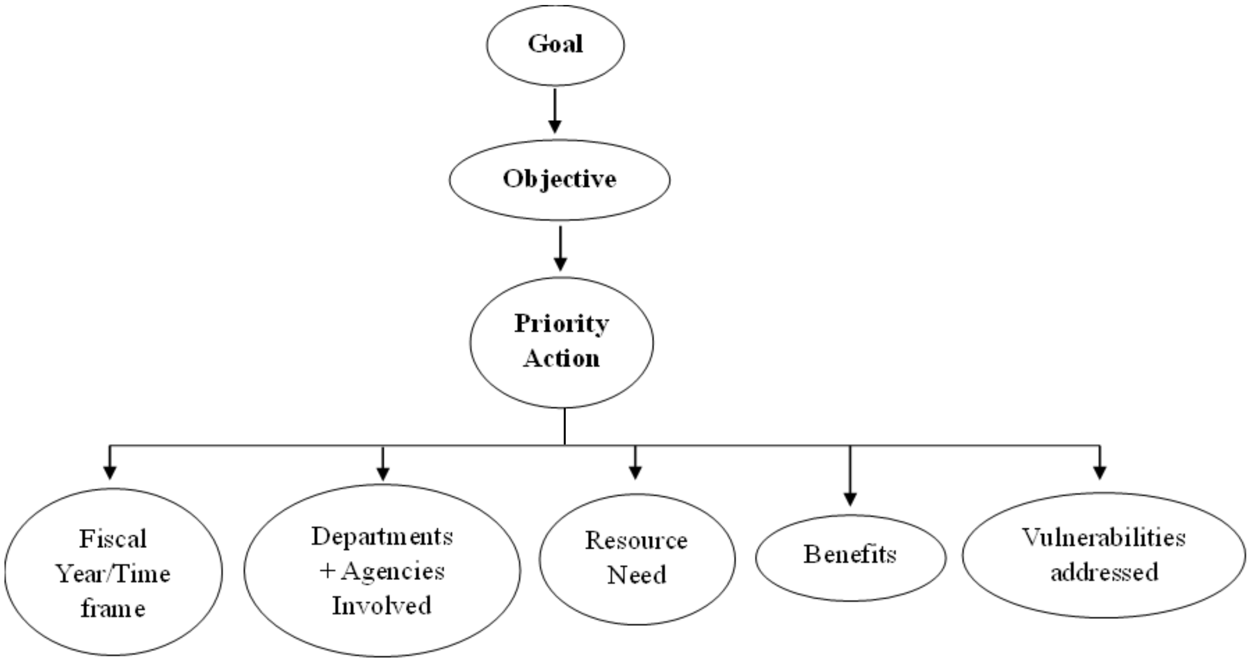


Figure 2. Flowchart presenting American climate policy layout

I have focused on the second and third goals outlined in the policy, as they pertain more to aquatic ecosystems compared to urban infrastructure which is the main focus of the first goal. The second goal listed in USA climate policy is to "protect the nation's waters from the impacts of a changing climate" (EPA, 2022, p. 29). The first objective (Objective 2.A) of this goal is to "integrate climate considerations into the Clean Water Act (CWA) and Safe Drinking Water Act (SDWA) actions and programs" (EPA, 2022, p. 29). This would be done by following priority actions:

- Priority Action 1: "Advancing a "Climate-Ready" National Pollutant Discharge Elimination System (NPDES) program" (EPA, 2022, p. 29).
    - Based on this action, the program would "establish nationwide permit limits, monitoring and reporting requirements on point sources that discharge pollutants into US water" (EPA, 2022, p. 29) as well as "incorporating climate data into multiple tools and models to account for

    - environmental measures" (EPA, 2022, p. 29). This would "permit writers with the latest information to support climate adaptation when developing pollutant limits and implementing permit-related activities" (EPA, 2022, p. 29).
- Priority Action 2: "Advance the adoption of nonpoint source water quality actions that provide climate resilience and adaption co-benefits under the CWA Section 319 Nonpoint Source Grant program" (EPA, 2022, p. 30).
    - This would allow for the improvement of "internal processes for tracking and documenting climate co-benefits of nonpoint source water quality actions" (EPA, 2022, p. 30) and would "identify opportunities for promoting greater adaptation of these practices through potential enhancements to the CWA section 319 Nonpoint Source Grant Program guidance" (EPA, 2022, p. 30).
- Priority Action 3: "Advance a "climate-ready" CWA section 303(d) assessment, listing, and Total Maximum Daily Loads (TMDL) program" (EPA, 2022, p. 31).
    - According to the policy, "under EPA's regulations and CWA section 303(d), states, territories, and authorized tribes identify waters that do not meet CWA water quality standards and develop TMDLs showing pollutant reductions needed to meet those standards" (EPA, 2022, p. 31). The integration of various climate change considerations in the reporting memorandum will "promote improved consideration of changing environmental conditions to produce water quality assessment and planning actions that are more resilient and adaptive" (EPA, 2022, p. 31).

The second objective (Objective 2.B) is to "invest in ecosystem protection and restoration" (EPA, 2022, p. 32). The following priority actions to achieve this objective include:

- Priority Action 1: "Leverage the BIL's historic funding of OW's Gulf Hypoxia Program, geographic programs, and the NEP to enhance ecosystem and community resilience to climate change" (EPA, 2022, p. 32).
    - The new funding of over $1.8 billion through the Bipartisan Infrastructure Law (BIL) program would allow grantees to identify and track climate resilience and adaptation projects (EPA, 2022, p. 32).
- Priority Action 2: "Release and implement a regional protocol that would identify, assess, and prioritize removing hard infrastructure that restricts tidal flow to restore natural habitats and strengthen ecosystem resilience" (EPA, 2022, p. 33).

The third objective (Objective 2.C) of this goal is to "leverage strategic research" (EPA, 2022, p. 34). This will be done through following priority actions that include:

- Priority Action 1: "Incorporating climate considerations into EPA's Water Quality Standards (WQS) program and handbook"(EPA, 2022, p. 34).
- Priority Action 2: "Develop a strategic plan to address HABs in fresh and coastal marine water that will include an objective to evaluate the impacts of climate change on their occurrence, magnitude, and spatial extent" (EPA, 2022, p. 35).
- Priority Action 3: "Develop CWA Water Quality Criteria recommendations that protect aquatic life from an imbalance of salts in water due to climate change" (EPA, 2022, p. 36).

The third goal written in America's climate policy is to "advance the adaptive capacity of the water sector and the climate knowledge of all communities and decision-makers" (EPA, 2022, p. 37). The first objective (Objective 3.A) is to "support the assessment of climate risks and climate-informed decision-making" (EPA, 2022, p. 38). The priority actions that will be fulfilled to achieve this objective include:

- Priority Action 1: "Support and integrate Traditional Ecological Knowledge (TEK) into decision-making tools" (EPA, 2022, p. 38)
- Priority Action 2: "Leverage the Urban Waters Federal Partnership to address climate adaptation in urban communities" (EPA, 2022, p. 39).

The second objective (Objective 3.B) is to "improve the availability of data and information to support climate-informed decisions" (EPA, 2022, p. 41). The following priority action include:

- Priority Action 1: Improving "accessibility and transparency of water and climate data through How's My Waterway" (EPA, 2022, p. 41).

Apart from the listed policy goals and their associated objectives/priority actions, the adaptation policy plan highlights the research and monitoring strategies to protect aquatic ecosystems and their services. These highlighted strategies include the expansion of continuous, long-term water quality monitoring networks that should focus on more vulnerable water resources such as lakes, wetlands, and smaller streams as they are often neglected in continuous, long-term monitoring networks (EPA, 2022). This type of monitoring would be able to reveal climate-driven trends and help water resource managers assess the relationship between "water quality and climate over finer scales and longer timeframes" (EPA, 2022, p. 47). Climate-related impacts should also be studied to see how they are "contributing to the rise of benthic HABs and share effective management interventions" (EPA, 2022, p. 47). The "impacts of altered hydrological flows and warming water temperatures" (EPA, 2022, p. 47) will also be researched on aquatic and terrestrial ecosystems with a focus on critical species (EPA, 2022). The "determination of how temperature and hydrologic changes will impact species ranges, tolerance, and survival due to ecosystem shifts and water quality alterations" (EPA, 2022, p. 47) should be examined as well. Wetland restoration strategies would be identified that "effectively account for climate impacts, such as extreme weather and warming waters, and performance standards to ensure successful restoration" (EPA, 2022, p. 47).

2. Climate Change Impacts on Freshwater Ecosystems in North America

As the climate continues to warm, freshwater systems such as rivers, lakes, streams, and wetlands are particularly vulnerable (Capon et al., 2021). The widespread changes due to climate change have profound implications for freshwater ecosystems. The intricate balance of these ecosystems is disrupted by alterations in temperature, precipitation patterns, and water levels (Nazari Sharabian et al., 2018). These changes affect water quality, availability, and the diverse species that depend on these habitats (Woolway et al., 2022). Warmer waters and shifting seasonal cycles are affecting aquatic species, leading to changes in species distribution and community composition (Ficke et al., 2007). These changes threaten the ecological integrity of freshwater habitats and have far-reaching consequences for human populations that rely on these resources for drinking water, agriculture, and recreation. Understanding the specific impacts of climate change on freshwater ecosystems is crucial, as these systems provide essential services that are vital for both ecological health and human well-being.

Out of the 2.5% freshwater on the Earth, only 0.26% of this is liquid freshwater and accessible through the surface, most of which is found in lakes, reservoirs, and rivers (Carpenter et al., 2011). Surface freshwaters are in rapid flux compared to other bodies of water on Earth. This flux is essential for the cycling and transport of nutrients and to ensure ecosystem health and productivity (Carpenter et al., 2011). As mentioned previously, the increase in temperature and variability of precipitation due to climate change directly affect freshwater systems. Increasing water temperatures reduce the solubility of oxygen in surface waters, leading to diminished oxygen availability for aquatic organisms (DFO, 2013). Combined with heavy precipitation levels, these factors also impairs the breakdown of organic matter and the processing of pollutants (Woolway et al., 2020). The warming of freshwater systems limits habitat space and reduces suitable thermal environments for coldwater species like Brook Trout and Arctic Grayling (Dove-Thompson et al., 2011; Murdoch et al., 2020). High-latitude lakes are sensitive to atmospheric temperature changes and can be described as sentinels of climate change (Hovel et al., 2017). In higher latitudes and elevated regions, the warming trend shortens the ice-covered season, increases the duration of thermal stratification, and accelerates the melting of glaciers and permafrost, which in turn alters the seasonal patterns, volume, and origins of hydrologic flows (Hovel et al., 2017). Lake variables and their interactions with each other act as an indicator of climate change based on their responses to the climate and these include lake ice, lake surface water temperatures, lake mixing regimes, and lake area and water (Woolway et al., 2020). Using lake ice as a climate indicator, lakes are experiencing less ice cover with the risk of more than 100,000 lakes having ice-free winters if air temperatures increase by 4°C. Ice duration has become 28 days shorter on average over the past 150 years for Northern Hemisphere lakes with higher rates of change in recent decades (Woolway et al., 2020). It was found that lakes in regions with colder winters are warming faster than lakes in regions with warmer winters (Woolway et al., 2020). LSWT leads to the early onset of thermal stratification, thereby extending the duration of the shallow upper mixed layer and resulting in increased surface water temperatures during the warm season (Woolway et al., 2020). Evaporation plays a substantial role in the influence of lake levels and extent and contributes to the local climate as well through the lake effect of clouds and precipitation of freshwater ecosystems (Woolway et al., 2022). These combined drivers have their effects exacerbated by climate change and observed changes include phytoplankton biomass and shifts in community composition which allude to changes in the water quality (Woolway et al., 2020, 2022). Rising temperatures will also alter planktonic communities, leading to an increase in cyanobacteria populations and heightened toxin production (Woolway et al., 2020). Another general shift observation is the shift towards lower food quality that will likely have consequences for lake food webs. Climate change will only amplify the negative effects of stressors such as eutrophication on freshwater ecosystems (Woolway et al., 2020).

Enhanced variability in precipitation patterns, both temporally and spatially, contributes to fluctuating hydrologic inputs to lakes and streams. Based on climate scenarios and future simulations, it is predicted that significant changes in the amplitude of river flow throughout the year, either increasing or decreasing, will affect 80% of the global land surface (Arnell & Gosling, 2013). Additionally, the month of maximum runoff is expected to shift earlier across much of North America (Arnell & Gosling, 2013). These climate models also project increases in the average annual runoff in Canada, but the rate of increase slows as temperature increases due to the changing influence of precipitation and temperature in high-latitude regions (Arnell & Gosling, 2013). Dramatic changes in precipitation patterns have already been observed, with wet regions becoming wetter and dry and arid regions becoming drier (Lynch et al., 2016a). As the temperature rises, potential evaporation increases and begins to moderate the effects of increased precipitation, leading to a slowdown of the increased rate of runoff. Additionally, rising sea levels extend the intrusion of saltwater into tidal rivers. This issue is compounded by reduced sediment deposition due to siltation in upstream reservoirs and lower runoff levels caused by irrigation practices (Carpenter et al., 2011). The balance of salt and water has been artificially altered in the hydrologic cycle leading to increased salinity in inland aquatic systems (Herbert et al., 2015). Increased salinity will lead to fundamental changes in the soil-water environment, leading to physiological stress in the freshwater biota and eventually resulting in large shifts in communities and their associated ecosystem functions (Herbert, 2015). Salt-tolerant species will be favoured in salinized landscapes; however, this is dependent on the incidence and dispersal ability of potential colonizers.

Furthermore, changes to the physical environment affect lake productivity and community composition as species interactions among primary producers and zooplankton are influenced (Hovel et al., 2017). Climate change is expected to further amplify many of the biodiversity concerns including invasive species, pathogens, and eutrophication (Reid et al., 2019). Changes in lake stratification are likely to magnify hypolimnetic hypoxia and affect lake productivity which would restrict available habitat for many species. Harmful algal blooms (HABs) are accumulated biomass of algal species and climate change is one of the reasons that opportunities for algal species to become ecologically prevalent have increased (Reid et al., 2019). HABs threaten freshwater biodiversity as these blooms reduce dissolved oxygen availability for other species or directly through toxin production (Reid et al., 2019).

Climate change is affecting inland fish populations by altering population dynamics through changes to abundance, growth, and recruitment as well as shifts in species' spatial distributions and the timing of key behaviours that include migrations, and spawning (Lynch et al., 2016a). Studies have demonstrated that inland fish assemblages increase spatial and temporal overlap among species, as well as competitive interactions, through the expansion of species' ranges and the emergence of novel interactions. (Lynch et al., 2016a). Species interactions, such as trophic interactions and competition, frequently serve as the primary catalysts for climate-induced changes in fish population dynamics and extirpation (Lynch et al., 2016a). The proportion of coolwater and warmwater species in fish assemblages is shifting from coldwater and coolwater assemblages to those dominated by coolwater and warmwater species (Poesch et al., 2016). This can be seen with the 13 km per decade range expansion of warmwater species, such as smallmouth bass (Alofs et al., 2014). This northern expansion has led to a southern contraction of small-bodied prey species of smallmouth bass (Alofs et al., 2014). Climate change has also led to a decrease in somatic growth and growth potential of some Lake Trout populations, due to the establishment of smallmouth bass populations (Lynch et al., 2016a). One of the case studies based in the Rio Grande, located in the United States and Mexico, studied the combined effects of climate change. It found that flow regulation has resulted in less surface water and greater aridity, promoting overcrowding among species and life stages that are normally separated in time or space, potentially leading to an increase in food competition (Lynch et al., 2016a). There is an overall reduction in fish habitat size, complexity, and lateral connectivity with floodplain habitats which has also reduced biotic richness and has led to earlier spawning across entire fish assemblages (Lynch et al., 2016a).

Having examined the overall effects of climate change on freshwater ecosystems, it becomes imperative to consider and apply the scientific recommendations from researchers that can guide effective policy development. These recommendations emphasize the need for ongoing research and conservation efforts to address the complex interactions between climate change and freshwater ecosystems. Accurately identifying and attributing biological responses to climate change is vital for the conservation and management of animal populations in a warming world (Tillotson & Quinn, 2016). To mitigate climate change impacts, global and national targets must focus on protecting and restoring carbon-dense ecosystems, including wetlands, which play a crucial role in sequestering carbon and reducing greenhouse gas emissions (Bonar, 2021).

a. Recommendations for Climate-Smart Policies for Freshwater Ecosystems

As seen in the study conducted by Reid et al., “global government commitments to reduce greenhouse gas (GHG) emissions, expand freshwater protected areas, and restore habitats to provide refugia for thermal adaptation are critical to mitigate the effects of climate change on freshwater biodiversity” (Reid et al., 2019, p. 854). Policies should, therefore, prioritize the restoration and protection of freshwater habitats as a primary defense against climate-induced changes in those ecosystems (Geist & Hawkins, 2016). Key recommendations include enhancing habitat connectivity to facilitate species migration and adaptation, establishing and expanding protected areas to safeguard critical habitats, and integrating climate projections into water management plans to anticipate and mitigate future risks (Geist & Hawkins, 2016; Piczak et al., 2022; Prowse et al., 2009). Additionally, there is a pressing need for policies that support adaptive management practices, allowing for flexible responses to emerging climate impacts (Geist & Hawkins, 2016). Adaptation strategies focus on managing or living with expected climate change impacts, recognizing that effective adaptation will vary regionally depending on the extent and rate of ecosystem changes.

Scientific concerns also highlight significant knowledge gaps that need to be addressed to improve policy effectiveness. Due to the complex nature of freshwater ecosystems, such as wetlands, "greater research emphasis should be placed on whole-ecosystem and landscape-scale studies" (Herbert et al., 2015, p. 29). In the context of flow regulation, practices such as water allocations (environmental flows) should be implemented to protect or restore ecosystems (Reid et al., 2019). The conservation of species may necessitate managed relocation (assisted migration) to areas where the likelihood of future persistence is high, even if the species has not previously been present in those locations (Reid et al., 2019). There is a pressing need for research to develop an in-depth understanding of technologies, policy instruments, and institutions that can sustain the provision of freshwater ecosystem services without compromising the natural capital that underpins these services (Carpenter et al., 2011). There is also a need for appropriate policy instruments and frameworks to restrict pollution levels by various chemicals to be within acceptable water quality margins (Carpenter et al., 2011). Long-term monitoring and scientific research would aid in assisting natural asset managers in any decision-making process (Dove-Thompson et al., 2011). After outlining these general actions, it is essential to engage in specific, targeted discussions on implementing strategies for different management areas (Dove-Thompson et al., 2011).

Apart from diverse climate change threats, the "complexity of working at the interface of people, fish, and habitat present a major challenge to inland research, management, and policy" (Lynch et al., 2017, p. 116). Key activities should include developing better partnerships across sectors to promote conservation and management, recognizing the role of natural infrastructure in freshwater resource management, increasing knowledge and capacity-building within sectors addressing freshwater conservation, improving policy frameworks, and learning lessons from successful water management practices (Darwall et al., 2018). Inland fisheries, for example, should adopt management strategies that are holistic, coordinated, and trans-jurisdictional, given that most fisheries are managed at local levels (Cooke & Murchie, 2015). Effective information management systems and standard sampling methods are essential to enable knowledge transfer and reduce inter-sectoral conflicts, allowing efforts to focus on addressing external threats (Cooke & Murchie, 2015).

There is a call for increased funding for comprehensive ecosystem monitoring programs to provide real-time data on climate impacts, enabling more informed decision-making (Capon et al., 2021). Fostering collaboration among governmental bodies, academic institutions, and local communities is crucial for developing and implementing policies that are comprehensive and locally relevant (Dove-Thompson et al., 2011). Incorporating these scientific insights into policy frameworks can enhance the resilience of freshwater ecosystems and ensure their sustainability in the face of ongoing climate change. Additional resources for data collection, mapping, and research are essential to better understand potential impacts and to equip natural resources agencies with the tools to mitigate these impacts. Rapid action is necessary to drastically curb greenhouse gas emissions and prevent the most detrimental consequences of human-caused climate change on ecosystems (Bonar, 2021). A coordinated call to action by public and private sectors, as well as citizens, is needed to improve our knowledge of freshwater biodiversity, overcome knowledge gaps, and work to reduce or reverse freshwater biodiversity declines (Darwall et al., 2018).

## Analysis

## 3. Canadian Climate Policy Evaluation

Canada's climate policy has limited policy objectives and goals that are associated with the protection of freshwater ecosystems. They lack specific details on the measures that will be implemented to restore, protect, and manage waterbodies in response to rising temperatures and significant changes in precipitation patterns, which are likely to have detrimental effects on these waterbodies. This policy evaluation will concentrate on Objectives 1 and 2 from the federal climate policy of Canada, as these objectives place greater emphasis on the protection of freshwater ecosystems compared to other objectives.

The first policy objective will respond to the global biodiversity crisis, threats to Canada's ecosystem and wildlife, and pressure for sustainable recovery and well-being of Canadians through Target 1 (ECCC, 2023). Protecting 25% of Canada's lands and freshwater by 2025 through provincial and territorial parks and protected areas, privately protected areas, Indigenous-led conservation areas, Other Effective area-based Conservation Measures (OECMs), as well as national wildlife areas and national parks would aid in the policy objective of reversing biodiversity loss (Environment and Climate Change Canada, 2024). Scientific research emphasizes that creating and managing protected areas is crucial for conserving biodiversity and maintaining ecosystem services. These areas would be able to act as refuges for species and help preserve genetic diversity, which is vital for ecosystem resilience in the face of climate change and this specific policy target incorporates what the science is telling us (Darwall et al., 2018). This initiative will also aid in strengthening the protection and recovery of species at risk and their habitats (Dove-Thompson et al., 2011). Climate change is a significant driver of biodiversity loss, particularly in freshwater ecosystems where temperature changes and altered precipitation patterns can disrupt habitats and food webs (Darwall et al., 2018). Protecting and restoring habitats is essential for mitigating these impacts and supporting species' survival (Reid et al., 2019).

One of the threats to freshwater ecosystems is habitat fragmentation as this threat will increase as the climate warms, leading to reduced availability of coldwater habitat (Thompson et., 2011). Policy Objective 1 also addresses the threat of habitat fragmentation to freshwater biodiversity in a warming climate through Target 2 that identify and recognize ecological corridors in key areas across Canada to help species and ecosystems adapt to climate (ECCC, 2023). Ecological corridors are areas of land and water that aim to maintain or restore ecological connectivity by allowing species to move and natural processes to flow freely across large landscapes. This connected network would preserve biodiversity, protect, and restore ecosystems, and contribute to the recovery of the species at risk (Geist & Hawkins, 2016).

Promoting and implementing better adaptive management strategies is crucial for protected areas, particularly in a rapidly changing climate (Juffe-Bignoli et al., 2016). Adopting an agile and adaptive approach helps address emerging issues effectively (Piczak et al., 2022). The second policy objective ensures the continued sustainability and adaptive capacity of climate-affected ecosystems through monitoring, restoration, and management efforts (ECCC, 2023). Although specific targets are not listed for Objective 2, the scientific basis is clear: monitoring ecosystems impacted by climate change allows for more accurate predictions of future changes. This, in turn, informs the development and implementation of effective conservation and adaptation strategies (Prowse et al., 2009).

The second phase of the policy evaluation of the Canadian federal climate policy involves assessing the alignment of the policy objectives with established scientific recommendations.

Table 1. Evaluation of the Canadian Climate Policy Objectives: Potential Effectiveness in Addressing Biodiversity Conservation and Protection

| Category #1: Biodiversity Conservation and Protection | | |
|---|---|---|
| Policy Objectives | Rating (1-3) | Reason |
| • 1. Human activities are transformed to halt and reverse biodiversity loss and enhance ecosystem connectivity. | **3** | • The reversal of biodiversity loss and connectivity enhancement policy strongly aligns with the scientific recommendation.<br>• Policies need to prioritize the protection of ecosystems which is emphasized in this objective and its associated action of conserving 25% of Canadian lands and water.<br>• The recognition of ecological corridors in Target 2 are critical for maintaining connectivity between fragmented habitats as they facilitate species' movement, support adaptation, and reduce extinction risks (Geist & Hawkins, 2016). |
| • 2. The ecosystems most affected by climate change are monitored, restored and managed to ensure their continued viability and adaptive capacity. | **2** | • This policy objective somewhat aligns with the scientific recommendation of biodiversity conservation and protection.<br>• This objective does not reflect the concept of biodiversity conservation or protection in its wording and there are not any targets to reflect any action this objective would undertake; however, it does state that affected ecosystems would be restored to ensure their continued viability and adaptive capacity.<br>• The monitoring of ecosystems allows for the identification of species and habitats that are most vulnerable to climate change. Restoration efforts can then be targeted towards these critical areas to enhance their resilience |

Table 2. Evaluation of the Canadian Climate Policy Objectives: Potential Effectiveness in Addressing Habitat Management

| Category #2: Habitat Management | | |
|---|---|---|
| Policy Objectives | Rating (1-3) | Reason |
| • 1. Human activities are transformed to halt and reverse biodiversity loss and enhance ecosystem connectivity. | **3** | • The reversal of biodiversity loss and connectivity enhancement policy strongly aligns with the scientific recommendation.<br>• The conservation of land and water provides multiple opportunities for comprehensive habitat management that include protection, restoration, and sustainable use, as well as incorporating adaptive management strategies.<br>• Managing protected habitats can help prevent degradation and restore ecosystems to maintain ecological function and biodiversity and the creation of ecological corridors involves effective habitat management to ensure ecological functionality and resilience. |
| • 2. The ecosystems most affected by climate change are monitored, restored and managed to ensure their continued viability and adaptive capacity. | **3** | • The monitoring, restoration and management of affected ecosystems strongly aligns with scientific recommendations.<br>• As mentioned previously, monitoring ecosystems provides valuable data that can inform management strategies, ensuring they are adaptive and responsive to changing environmental conditions. Restoration activities contribute to habitat improvement, making ecosystems more resilient to climate impacts. |

Table 3. Evaluation of the Canadian Climate Policy Objectives: Potential Effectiveness in Addressing Stakeholder Collaboration

| Category #3: Stakeholder Collaboration | | |
|---|---|---|
| Policy Objectives | Rating (1-3) | Reason |
| • 1. Human activities are transformed to halt and reverse biodiversity loss and enhance ecosystem connectivity. | **1** | • The reversal of biodiversity loss and connectivity enhancement policy somewhat aligns with the scientific recommendation.<br>• The transformation of human activities to protect biodiversity and ecosystem connectivity would require the extensive collaboration of multiple stakeholders and there are no clear mechanisms or targets in place to see how this would be achieved.<br>• This policy objective does have the potential to foster significant stakeholder collaboration, however, there needs to be a strong framework for the involvement of all parties that has not been established. |
| • 2. The ecosystems most affected by climate change are monitored, restored and managed to ensure their continued viability and adaptive capacity. | **1** | • The monitoring, restoration and management of affected ecosystems somewhat aligns with scientific recommendations.<br>• All three efforts outlined in this policy objective necessitate stakeholder collaboration. However, the objective lacks specific targets and does not mention engaging with stakeholders to achieve this goal.<br>• This policy objective also has the potential to foster significant stakeholder collaboration and contribution. |

Table 4. Evaluation of the Canadian Climate Policy Objectives: Potential Effectiveness in Addressing Research and Monitoring

| Category #4: Research and Monitoring | | |
|---|---|---|
| Policy Objectives | Rating (1-3) | Reason |
| • 1. Human activities are transformed to halt and reverse biodiversity loss and enhance ecosystem connectivity. | **1** | • The reversal of biodiversity loss and connectivity enhancement policy does not align with the scientific recommendation.<br>• Research and monitoring are crucial for understanding the impacts of human |

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| | | activities on biodiversity and ecosystem connectivity. However, no measures have been included to integrate research and monitoring into this objective. |
| • 2. The ecosystems most affected by climate change are monitored, restored and managed to ensure their continued viability and adaptive capacity. | **3** | • The monitoring, restoration and management of affected ecosystems strongly align with scientific recommendations.<br>• Continuous monitoring of ecosystems would provide critical data on the impacts of climate change, enabling timely interventions and adaptive management. Restoration and management efforts can be informed by the latest scientific research, ensuring that actions taken are evidence-based and effective (Geist & Hawkins, 2016). |

The Canadian federal climate policy somewhat aligns with the scientific recommendations across the four categories mentioned above. However, certain objectives either fail to acknowledge freshwater ecosystems or lack measures to meet the scientific recommendations in those specific areas. Minimal emphasis has been placed on stakeholder collaboration for freshwater ecosystem protection, which is concerning given that multiple researchers have strongly emphasized its importance.

## 4. American Climate Policy Evaluation

The second listed policy goal in America’s climate policy on water is concise and clear in its goal – to “protect America’s waters from the impacts of a changing climate” (EPA, 2022, p. 29). Climate change affects water temperatures, precipitation patterns, and the frequency and intensity of extreme weather events, which in turn influence pollutant loadings and dilution capacities of water bodies (Carpenter et al., 2011). By integrating climate considerations into the

CWA and SDWA through Objective 2.A, the following priority actions ensure that the regulatory framework is adaptive to changes in water quality and quantity (EPA, 2022). Research indicates that climate change leads to more extreme and variable weather patterns, altering the hydrological cycles and increasing the stress on freshwater ecosystems (Dove-Thompson et al., 2011). The priority actions clearly explain the measures that will be added to national programs such as "establishing nationwide permit limits, monitoring, and reporting requirements for pollutant discharge amounts", and how this will help to develop climate adaptation programs (EPA, 2022, p. 29). Increasing water temperatures due to climate change, lead to lower dissolved oxygen levels and negatively affect aquatic life (Ficke et al., 2007). Nonpoint source pollution is also intensified by climate change, as increased precipitation and storm events in certain regions lead to more nutrients and pollutants being washed into water bodies (Carpenter et al., 2011). Another priority action under Objective 2.A includes action that would support projects that provide climate adaptation and resilience co-benefits (EPA, 2022). These projects include topics such as "offset increases in water temperature, enhanced ecological flows, and groundwater recharge" and would be supported by the CWA Nonpoint Source Grant Program (EPA, 2022, p. 30).

The drivers of climate change are negatively impacting the health and function of freshwater ecosystems. Some detrimental effects include habitat degradation, altered water flow regimes, and increased stress on aquatic species (Darwall et al., 2018). Under Objective 2.B, the priority action of utilizing funding to enhance ecosystems and community resilience to climate change would lay the foundation for building adaptive capacity in ecosystems (EPA, 2022). This would help with buffering climate-induced disruptions, ensuring that freshwater ecosystems can continue to provide essential services and support biodiversity even as climate conditions change. Excessive nutrients, particularly nitrogen and phosphorus, from agricultural runoff and other sources, lead to eutrophication in freshwater systems, causing harmful algal blooms, oxygen depletion, and loss of aquatic life (Nazari Sharabian et al., 2018). Climate change exacerbates these issues by increasing rainfall and storm events, which can enhance nutrient runoff (Nazari Sharabian et al., 2018). This climate change effect is reflected in one of the measures to be undertaken in this priority action which is to identify nutrient reduction actions with climate benefits (EPA, 2022). Reducing nutrient inputs not only improves water quality and ecosystem health but also helps mitigate climate impacts by decreasing the likelihood of eutrophic conditions that are worsened by warmer temperatures and altered precipitation patterns.

As mentioned previously, climate change is affecting nutrient dynamics in freshwater ecosystems which would lead to degraded water quality and harmful algal blooms. By integrating climate-sensitive criteria for nutrients and hydrologic flow into the EPA's Water Quality Standards in Objective 2.C, the priority action for this objective acknowledges and addresses the complex interactions between climate change and water quality (EPA, 2022). Harmful algal blooms pose a significant risk to water quality, aquatic life, and human health. Developing an agency-wide strategic plan to address HABs that includes evaluating the impacts of climate change reflects a proactive approach grounded in scientific evidence (EPA, 2022). This plan will include the objective to "evaluate the impacts of climate change on their occurrence, magnitude, and spatial extent" (EPA, 2022, p. 35). Climate change can lead to higher salinity levels in freshwater systems due to sea level rise, saltwater intrusion, and altered hydrology (Herbert et al., 2015; Paukert et al., 2021). Increased salinity can disrupt the ionic balance in water, affecting aquatic organisms that are sensitive to salinity changes (Woolway et al., 2022). The priority action with recommendations to CWA's Water Quality Criteria will also be developed to protect aquatic life from an imbalance of salts in water due to climate change (EPA, 2022). This specific action emphasizes targeting and protecting freshwater biodiversity in response to climate change impacts, with a focus on mitigating the effects of increased salinity levels as indicated by scientific research.

Effective management of freshwater ecosystems under climate change requires a multi-stakeholder approach, as these systems are influenced by a variety of factors including land use, water management practices, and regional climatic changes (Higgins et al., 2021). Collaborative efforts ensure that diverse perspectives and expertise are integrated into decision-making processes, leading to more comprehensive and effective strategies (Piczak et al., 2022). The last goal of the policy pertains to collaboration between all stakeholders and tackling the climate risks and impacts by assessing them and aiding in making informed decisions about the actions national and local partners can take (EPA, 2022). The availability of high-quality data is crucial for understanding climate impacts and making informed decisions. Objective 3.A under this goal, supports the assessment of climate risks and climate-informed decision-making (EPA, 2022). Literature on climate impacts on freshwater ecosystems frequently calls for improved data collection and sharing to support better understanding and management of these impacts (Cooke & Murchie, 2015). Accurate data on climate variables and ecosystem responses is essential for developing predictive models and effective policy responses. The second objective of improving the availability of data and information to support climate-informed decisions will prioritize the improvement of data availability to support informed decision-making.

The second phase of the policy evaluation of the United States federal climate policy involves assessing the alignment of the policy objectives with established scientific recommendations.

Table 5. Evaluation of the United States Climate Policy Objectives: Potential Effectiveness in Addressing Biodiversity Conservation and Protection

| Category #1: Biodiversity Conservation and Protection | | |
|---|---|---|
| Policy Objective | Rating (1-3) | Reason |
| O2.A: Integrate Climate Considerations in CWA and SDWA Actions and Programs | **3** | • The integration of climate considerations in the CWA and SDWA aligns well with scientific recommendations for biodiversity conservation and protection.<br>• Incorporating climate change factors into water quality standards, pollution control measures and watershed management plans would ensure that aquatic ecosystems are better protected from the negative impacts of climate change. |
| O 2. B: Invest in Ecosystem Protection and Restoration | **2** | • The investment in ecosystem protection and restoration somewhat meets scientific recommendations.<br>• By focusing on protecting intact ecosystems and restoring degraded ones, this policy directly contributes to the maintenance of biodiversity.<br>• However, the priority actions under this objective focus more on coastal and marine ecosystems and do not have any specific actions for freshwater ecosystems. |
| O 2.C: Leverage Strategic Research | **3** | • The leveraging of strategic research strongly aligns with scientific recommendations for biodiversity conservation and protection.<br>• By focusing research efforts on understanding the impacts of climate change, pollution, and other stressors on |

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| | | freshwater biodiversity, policymakers can develop more effective conservation strategies (Lynch et al., 2016b). |
| O 3.A: Support Assessment of Climate Risks and Climate-Informed Decision-Making | **2** | • This policy objective aligns well with scientific recommendations regarding biodiversity conservation and protection, however, there is a greater focus on coastal and urban areas.<br>• By understanding and anticipating climate-related impacts on freshwater ecosystems, policymakers can implement proactive measures to protect vulnerable species.<br>• This approach would allow for the development of adaptive strategies that can mitigate the effects of climate change, such as temperature fluctuations, altered precipitation patterns, and extreme weather events, thereby safeguarding biodiversity (Lynch et al., 2016b). |
| O 3.B: Improve Availability of Data and Information to Support Climate-Informed Decisions | **1** | • This policy objective does not align with scientific recommendations regarding biodiversity conservation and protection as there is a focus on climate data, rather than biodiversity factors.<br>• Expanding the scope of data categories would allow for an expanded monitoring and research network and would support the identification of critical freshwater habitats and the development of targeted conservation strategies. |

Table 6. Evaluation of the United States Climate Policy Objectives: Potential Effectiveness in Addressing Habitat Management

| Category #2: Habitat Management | | |
|---|---|---|
| Policy Objective | Rating (1-3) | Reason |
| O2.A: Integrate Climate Considerations in CWA and SDWA Actions and Programs | **3** | • The integration of climate factors in these federal acts aligns with the scientific recommendations. |

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| | | • Effective habitat management requires addressing the impacts of climate change on water resources. Although this policy objective does not directly focus on freshwater resources, it does address aquatic ecosystems.<br>• The priority actions under this objective would ensure that water bodies maintain ecological flows, sediment transport, and other critical processes. These approaches would help in mitigating habitat degradation and promote adaptive management practices (Reid et al., 2019). |
| O 2.B: Invest in Ecosystem Protection and Restoration | **2** | • This policy objective meets the scientific recommendations but without including any actions regarding freshwater ecosystems.<br>• The priority actions include funding for climate resilience and adaptation projects which is assumed to cover freshwater habitat management and reducing coastal wetlands loss.<br>• This policy would help in creating more resilient and sustainable habitats capable of supporting diverse biological communities. |
| O 2.C: Leverage Strategic Research | **3** | • The strategic research aligns well with the scientific recommendations for habitat management.<br>• This includes the understanding of the effects of human activities on freshwater ecosystems and the development of various management practices to tackle these adverse effects.<br>• Strategic research can aid in the implementation of best practices for habitat management, ensuring that interventions are scientifically sound and created for the specific needs of different aquatic environments. |
| O 3.A: Support Assessment of Climate Risks and Climate-Informed Decision-Making | **2** | • This policy objective aligns well with scientific recommendations regarding habitat management, however, there is a greater focus on coastal and urban areas. |

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| | | • By incorporating climate risk assessments and climate-informed decision-making into policy objectives, it would ensure that habitat management plans are adaptive and resilient to the effects of climate change. |
| O 3.B: Improve Availability of Data and Information to Support Climate-Informed Decisions | **3** | • The improvement of data availability and information strongly aligns with scientific recommendations regarding habitat management.<br>• Improving data availability on water and climate impacts can guide habitat restoration projects and management plans. Additionally, it should support adaptive management by allowing for timely responses to changing environmental conditions and lead to the improvement of the overall resilience of freshwater habitats. |

Table 7. Evaluation of the United States Climate Policy Objectives: Potential Effectiveness in Addressing Stakeholder Collaboration

| Category #3: Stakeholder Collaboration | | |
|---|---|---|
| Policy Objective | Rating (1-3) | Reason |
| O2.A: Integrate Climate Considerations in CWA and SDWA Actions and Programs | **3** | • This policy objective strongly aligns with the scientific recommendation for stakeholder collaboration.<br>• The considerations incorporated into CWA and SDWA necessitate collaboration among various stakeholders that have been listed in the priority actions and include various government agencies, local communities, and Indigenous people. |
| O 2.B: Invest in Ecosystem Protection and Restoration | **2** | • This policy objective aligns with scientific recommendations for stakeholder collaboration.<br>• Investing in the ecosystem requires collaboration to identify and track |

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| | | projects as the EPA will be funding various projects associated with climate resilience and adaptation. |
| O 2.C: Leverage Strategic Research | **2** | • This policy objective aligns with the scientific recommendation for stakeholder collaboration.<br>• Strategic research involves various stakeholder collaborations that can benefit research initiatives and enhance the relevance and applicability of the findings.<br>• However, the extent to which stakeholder collaboration is integrated into strategic research can vary, and efforts must be made to ensure inclusive and effective partnerships. |
| O 3.A: Support Assessment of Climate Risks and Climate-Informed Decision-Making | **3** | • This policy objective aligns well with scientific recommendations regarding stakeholder collaboration.<br>• Effective stakeholder collaboration that has been emphasized under this objective ensures that diverse perspectives and expertise are incorporated into the decision-making process, and this includes the integration and application of Traditional Ecological Knowledge (Dove-Thompson et al., 2011). |
| O 3.B: Improve Availability of Data and Information to Support Climate-Informed Decisions | **3** | • The improvement of data availability and information strongly aligns with scientific recommendations regarding stakeholder collaboration.<br>• Improving access to reliable data and information could potentially foster better collaboration among stakeholders as it would promote trust and cooperation among the various parties. This collaborative approach is essential for developing and implementing effective climate-informed decisions (Darwall et al., 2018). |

Table 8. Evaluation of the United States Climate Policy Objectives: Potential Effectiveness in Addressing Research and Monitoring

| Category #4: Research and Monitoring | | |
|---|---|---|
| Policy Objective | Rating (1-3) | Reason |
| O2.A: Integrate Climate Considerations in CWA and SDWA Actions and Programs | **3** | • This policy objective strongly aligns with the scientific recommendation for research and monitoring.<br>• This objective underscores the importance of research and monitoring through the advancement of enhanced monitoring programs such as the NPDES program and these actions can inform adaptive management strategies and policy adjustments as highlighted by researchers (Lynch et al., 2016a). |
| O 2.B: Invest in Ecosystem Protection and Restoration | **1** | • This policy objective does not align with scientific recommendations for research and monitoring.<br>• There is little mention of research and monitoring plans as the focus of this objective is more on funding climate resilience and adaptation projects. |
| O 2.C: Leverage Strategic Research | **2** | • This policy objective aligns with the scientific recommendation research and monitoring.<br>• By prioritizing research that addresses key knowledge gaps and emerging challenges, this policy action ensures that ecosystem protection is based on the latest scientific evidence. Strategic research provides the foundation for a robust and adaptive management framework (Lynch et al., 2016a). |
| O 3.A: Support Assessment of Climate Risks and Climate-Informed Decision-Making | **3** | • This policy objective aligns well with scientific recommendations regarding research and monitoring.<br>• This objective relies heavily on robust research and continuous monitoring conducted by various agencies and would allow for the exchange of |

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| | | knowledge through multiple federal agencies and partners.<br>• The need for easily accessible data and continuous scientific monitoring has been emphasized greatly by multiple researchers (Lynch et al., 2016a; Prowse et al., 2009). |
| O 3.B: Improve Availability of Data and Information to Support Climate-Informed Decisions | **1** | • The improvement of data availability and information does not align with scientific recommendations regarding research and monitoring as there are no statements of measures written in this objective.<br>• If included, this policy objective does have the potential to enhance the capacity for scientific research and long-term monitoring, but it is not mentioned. |

The United States federal climate policy largely aligns with the scientific recommendations across the four categories mentioned above. However, certain objectives either fail to acknowledge freshwater ecosystems or lack measures to meet the scientific recommendations in those specific areas.

## Discussion

Freshwater ecosystems are vital for biodiversity and human well-being and are increasingly threatened by climate change. As neighbouring, first-world countries that are supposed to be at the forefront of climate action, both Canada and the United States have developed federal climate policies with significant implications for freshwater ecosystem protection to address these challenges. The evaluation of the federal climate policies of Canada and the United States reveals both strengths and weaknesses in their approaches to protecting freshwater ecosystems. This section will discuss the analysis, compare the policies, highlight their strengths and limitations, and provide recommendations for improvement.

The analysis indicates that both the National Adaptation Strategy Plan of Canada and the Office of Water Climate Change Adaptation Implementation Plan of the United States incorporate significant elements of climate adaptation and mitigation. Both policies recognize the critical importance of freshwater ecosystems and include measure to address climate change impacts. However, there are notable differences in the comprehensive and implementation strategies of these policies.

Canada's federal climate policy emphasizes greatly upon the reversal of biodiversity loss, and management and restoration of ecosystems affected by climate change. Canada has increased the amount of protected land and water areas from 1.12 million $km^2$ in 2015 to 2.2 million $km^2$ in 2022 and these actions would help with the expected outcomes of contributing to 25% protection of Canada's lands and inland waters by 2025 (Environment and Climate Change Canada, 2024). Canada's policy principles, outlined in the introduction of the policy document, emphasized a strong commitment to respecting stakeholders. They particularly highlight the importance of engaging Indigenous communities and local governments in management decisions (ECCC, 2023). However, the analyzed objectives lacked detailed mechanisms for stakeholder engagement and collaboration, as well as specific guidelines for long-term monitoring and assessment.

The United States' Office of Water Climate Change Adaptation Implementation Plan, on the other hand, provides a more structured framework for policy implementation with clear objectives and timelines. It includes significant measures for water quality improvement through pollution control and habitat restoration, it is characterized by a broader focus on infrastructure development. Although the United States policy encompasses a broad range of water-related measures that include marine and aquatic ecosystems, it tends to treat freshwater ecosystems as part of broader environmental and climate initiatives. This difference in focus may affect the extent to which freshwater-specific issues are prioritized and addressed. The U.S. policy framework also recognizes the importance of stakeholder engagement with a greater focus on inter-agency collaboration and public-private partnerships. The policy objectives additionally include the incorporation of Traditional Ecological Knowledge (TEK) in federal decision-making through the collaboration between tribal officials and Office of Water staff.

Both countries recognize the importance of adaptability in policy frameworks to address the evolving challenges posed by climate change. Canada's commitment to incorporating climate monitoring ensures that its policies remain relevant and responsive to future risks. The U.S. approach, with significant investments in climate resilience and infrastructure, also aims to enhance the adaptability of its water management systems. The approach from both countries may benefit from more specific measures to integrate climate projections that specifically protect freshwater ecosystems into climate policy frameworks.

To improve its federal climate policy in terms of freshwater ecosystem protection, Canada can undertake multiple strategies that address the scientific and regulatory aspects. One of these approaches is to ensure that climate change mitigation and adaptation strategies including the reduction of greenhouse gas emissions, are directly aligned with freshwater management objectives. While acknowledging the termination of human activities is a step in the right direction to combat climate change and protect freshwater ecosystems, it should ensure stricter pollution controls, habitat protection mandates, and provisions for ecosystem-based water management that solely focus on freshwater ecosystems. This would call for increased investment in ecosystem restoration as well as promote nature-based solutions such as wetland restoration and the creation of riparian buffers to aid in improved water quality and flood mitigation (Piczak et al., 2022). There needs to be regulatory frameworks in place to ensure these actions are undertaken and implemented and address adaptive management with climate projections for freshwater ecosystems. Although the analyzed objectives are grounded in scientific knowledge, there is potential to expand these objectives to integrate and acknowledge a broader range of scientific insights. The policy goals for Canada make no mention of the management of invasive species which should be addressed as they do and will pose a big threat to native aquatic species (Piczak et al., 2022). With the climate warming rapidly, invasive species could expand their range and eventually dominate fragile environments, continuously outcompeting native species for resources and leading to a rapid decline in native populations. While stakeholder collaboration and research and monitoring are a major part of policymaking, a major point that should be included in the policy objectives is public awareness and education about the impacts on freshwater ecosystems in a changing climate. This would help build public support for policy measures and encourage community involvement in conservation efforts. Encouraging citizen science, for example, would involve the public in monitoring water quality and biodiversity and provide data that would support ecosystem management.

The United States climate policy has many comprehensive and specific approaches to address water quality, however, there is little emphasis on freshwater ecosystem protection. There is a greater importance on the infrastructure and protection of coastal, marine, and urban areas. The policy goals state that the two federal acts that relate to fresh water, SDWA and CWA, will have integrated climate considerations and tools, however, there is no mention of any adaptive management considerations in policy which has been recommended. The United States still has a federal responsibility to any major inland freshwater bodies that include lakes, rivers, and streams; however, it seems as though the focus of this policy is mostly on the protection of coastal, marine, and urban areas. It would be prudent to incorporate policy goals that target freshwater ecosystems, as the United States encompasses a vast region with a multitude of freshwater ecosystems. Some suggested strategies for freshwater ecosystem protection include the expansion of protected areas, habitat connectivity, inland wetland restoration, and species protection. The policy demonstrates a focused commitment to the protection and restoration of coastal and marine ecosystems, so it is only fair to extend a similar level of dedication and strategic vision to inland freshwater ecosystems. The U.S. policy would benefit from the inclusion of installing long-term research and monitoring networks, nationwide to provide critical feedback for adaptive management and help in the assessment of the effectiveness of conservation and restoration effects. Like Canada, there are no measures to address the management and prevention of invasive species in the local environment.

Although these are just recommendations to the written policies and their goals, future research can be conducted through an impact evaluation to observe whether targets are being implemented, action is being taken, and goals are being met. This research can also expand the categories that are being evaluated to include more topics about urban/human infrastructure, socio-economic needs, and more specific aspects of freshwater ecosystems. Future research and evaluation can undertake studying how designated protected areas and habitats are selected and if they are conserving biodiversity and ecosystem function effectively. The most significant barrier to conservation action is the translation of knowledge into action. Resources should be allocated towards protecting functional ecosystems with high species richness from all taxonomic groups to prevent taxonomic bias in conservation initiatives. There are also opportunities to embrace additional conservation approaches, such as citizen science, Indigenous knowledge systems, and emerging technologies like environmental DNA. The success of these climate policies depends on effective and efficient implementation by the federal government. Action needs to be taken now to reduce the negative impacts of climate change, rather than waiting for the perfect time to implement these measures. Delaying action in favor of bureaucratic procedures only exacerbates the urgency of the climate crisis and risks the effectiveness of these well-crafted policies. Immediate and decisive execution is crucial, as the window for meaningful intervention is rapidly closing. Federal governments must prioritize the implementation of these strategies, ensuring that the commitments outlined in the policies translate into tangible actions on the ground. This proactive approach will not only mitigate the detrimental effects of climate change but also demonstrate a firm commitment to safeguarding our environment for future generations.

## Conclusion

In conclusion, the comparative analysis of Canada's and the United States' federal climate policies reveals both strengths and gaps in their approaches to protecting and restoring freshwater ecosystems. Canada has shown a strong commitment to reversing biodiversity loss through the protection of Canadian lands and waters and the implementation of ecological corridors to enhance ecosystem connectivity. There is no firm commitment to freshwater ecosystem protection shown in Canada's National Adaption Strategy. Future action plans that would implement this strategy would benefit by directly addressing freshwater ecosystem protection, invasive species and enhancing public awareness and education on freshwater ecosystem impacts in a changing climate. On the other hand, the United States' climate policy, while comprehensive in addressing water quality and infrastructure, also lacks a focused approach to freshwater ecosystems. The emphasis on coastal and urban water management overshadows the specific needs of inland freshwater bodies. Integrating adaptive management strategies and addressing invasive species would strengthen the U.S. policy framework. Furthermore, enhancing public engagement and leveraging citizen science could provide valuable data and foster community involvement in conservation efforts. While this paper has been crafted through a Western science perspective, it is essential to acknowledge that there are alternative paradigms, including Indigenous knowledge systems, that offer valuable insights and approaches to policy evaluation, particularly in the context of environmental stewardship and the protection of natural resources.

Both countries can benefit from incorporating more specific measures to integrate climate projections into their policy frameworks, ensuring that they remain responsive to future risks. By addressing these gaps and building on their existing strengths, Canada and the United States can develop more effective and resilient strategies to protect and restore their freshwater ecosystems in the face of climate change.

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