Achieving Co-benefits of Climate and Biodiversity Action in Canadian Municipalities

by

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COMMITTEE APPROVAL

The members of Carolyn Richman's Thesis Committee certify that they have read the thesis titled Achieving Co-benefits of Climate and Biodiversity Action in Canadian Municipalities and recommend that it be accepted as fulfilling the thesis requirements for the Degree of Master of Arts in Environment and Management:

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Abstract

The deeply interconnected climate and biodiversity crises are driving us to a critical global tipping point. Despite worldwide calls for integrated solutions by international agreements and researchers, climate change and biodiversity loss are too often addressed separately. Interest in and work on nature-based solutions (NbS) is expanding rapidly in response to the need for viable, integrated solutions. Recent research has shown that urban municipalities, at the forefront of addressing these challenges, have started incorporating NbS and integrated approaches. Awareness and interest in NbS have recently been increasing in Canada, but the overall use of NbS and integrated approaches by Canadian municipalities has been undocumented. This research investigated the extent to which large municipalities in Canada (>100,000 population) are implementing NbS to address both climate change and biodiversity loss. Through document analysis and interviews, results show that Canadian municipalities are using NbS to varying degrees with an increasing trend, but the NbS concept and the use of principles and standards is unclear in municipal plans. Some Canadian municipalities are integrating climate and biodiversity planning, but the use of NbS is not always an indicator of integrated practices. Recommendations include the need for common language, and development of a clear NbS concept and approaches in municipal plans. Canadian municipalities need to use principles and standards to guide NbS and ensure measurable biodiversity benefits. They would benefit from increasing forums to share information and experiences in order to increase understanding, address NbS barriers and respond to the urgent need for integrated solutions to climate change and biodiversity loss.

Table of Contents

List of Figures

List of Tables

List of Abbreviations

CAS	Climate Adaptation Services
EcoDRR	Ecosystem-based Disaster Risk Reduction
EP	Ecosystem Protection
ER	Ecological Restoration
FLR	Forest Landscape Restoration
GI	Green Infrastructure
IUCN	International Union for Conservation of Nature
LID	Low Impact Development (related to stormwater management)
NbS	Nature-based Solutions
NI	Natural Infrastructure

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Climate change, biodiversity loss and human well-being are "three central challenges of the Anthropocene" (Seddon, Chausson et al, 2020, p. 1) as life on the planet faces a critical tipping point (Steffen et al., 2015; Intergovernmental Panel on Climate Change [IPCC], 2022). Essential to these challenges is the global recognition of the mutually reinforcing nature of climate change and biodiversity loss (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services [IPBES], 2019; Pörtner et al., 2021). Despite the fact that they are "deeply interwoven and share many of the same drivers" (Seddon, Chausson et al., 2020, p. 1), biodiversity loss and climate change are too often addressed separately (Butt et al., 2018; Canadian Parks and Wilderness Society, 2018; Pettorelli et al., 2021). It has become clear that these critical challenges to life on earth cannot be effectively addressed without integrated solutions, raising global calls for synergistic approaches (IPBES, 2019; Secretariat of the Convention on Biological Diversity [CBD], 2009; The World Bank, 2019). In this context, nature-based solutions are an important tool for responding to these three central challenges at local to global levels.

The umbrella concept "nature-based solutions" (NbS) is a synergistic approach which has been increasing in interest and focus globally as a viable, integrated set of solutions to multiple imperatives such as climate change, biodiversity and human well-being (Cohen-Shacham et al., 2016; Frantzeskaki et al., 2019; Seddon, Chausson et al., 2020; United Nations [UN], 2019). NbS have been increasingly prioritized within international agreements (CBD, 2020; UN, 2019) and at local levels (Drever et al., 2021; European Commission [EC], n.d.). Along with the growing international interest in NbS, especially as a tool to address climate change and biodiversity loss, defining nature-based solutions (NbS) has been a key topic of research. (Castellar et al., 2021; Cohen-Shacham et al., 2016; Cohen-Shacham et al., 2019; Eggermont et

al., 2015). Since 2016, a widely used definition has been provided by the International Union for Conservation of Nature (IUCN): "Actions to protect, sustainably manage and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits" (Cohen-Shacham et al., 2016, p. 2). In a recent development in March 2022, the United Nations Environment Assembly (UNEA) formally adopted a definition of NbS during the UNEA Fifth Session (2022) that further refines this international definition as: "actions to protect, conserve, restore, sustainably use and manage natural or modified terrestrial, freshwater, coastal and marine ecosystems which address social, economic and environmental challenges effectively and adaptively, while simultaneously providing human well-being, ecosystem services, resilience and biodiversity benefits" (UNEP/EA.5/Res.5).

In Canada, interest and leadership in NbS have been growing. In recent years, Canada has hosted a number of key international conferences including: Cities and Climate Change Science Conference in Edmonton, 2018 (Frantzeskaki et al., 2019), and the Nature-based Climate Solutions Summit in Ottawa, 2020 (https://www.naturebasedclimatesolutions.ca/). Starting in 2018, Canada and Mexico co-led the two-year Nature-based Solutions Action Track for the Global Commission on Adaptation (Government of Canada, n.d.). The Government of Canada has made NbS a key pillar of their climate planning and have made a number of announcements about funding for NbS (e.g., Environment and Climate Change Canada, 2021; Global Affairs Canada, 2022).

Urban areas in Canada must be priorities for NbS approaches. Within global and national contexts, there has been significant recognition of the importance of local level action and urban planning addressing the climate and biodiversity crises (Seddon, Daniels, et al., 2020). Urban

areas are noted as being on the frontline of climate change and global responses (Federation of Canadian Municipalities, n.d.; Frantzeskaki et al., 2019). Cities are a major part of the problem, with greenhouse gas emissions estimated at about 75% of global emissions (United Nations Environment Program [UNEP], n.d.) and are highly vulnerable to the impacts of climate change (IPCC, 2022). The significance in Canada can be weighed against the fact that in 2021, 73.7% of Canadians were living in large urban centres of over 100,000 in population (Statistics Canada, 2022a). Along with the threat of climate change and "[d]espite underpinning the resilience of communities and economies, nature is rapidly being degraded" (Global Commission on Adaptation, 2019, p. 6). The importance placed on NbS in urban areas is rising and recent research on the use and integration of NbS in local government policies and practices, such as in Europe and South Africa, have provided valuable insights (Geneletti & Zardo, 2016; Pasquini & Cowling, 2015; Wamsler & Pauleit, 2016; Zölch et al., 2018; Zwierzchowska et al, 2019). Despite the increased recognition and urgency for NbS, including in Canada, the nature and extent of the use of NbS across Canadian municipalities has not been documented.

Research Objective and Question

The objective of this qualitative research is to explore current integrated climate and biodiversity approaches in large Canadian municipalities using a NbS typology. The research is guided by the question: to what extent are large municipalities in Canada implementing NbS to address both climate change and biodiversity loss? The aim of my research is to increase understanding of current integrated approaches in Canadian municipalities as well as barriers and opportunities to support future planning, informed decision-making and increased use of NbS for climate and biodiversity co-benefits.

Importance

This research is timely for Canadian municipalities as the critical challenges of climate change and biodiversity loss increase globally and locally. When I began this research in January 2021, I came across many colleagues and fellow students unfamiliar with the term "nature-based solutions". Since then, the term has quickly become a much more familiar topic in Canada with federal commitments and broader engagement across Canada. The municipal staff I interviewed were overall quite keen on the topic and expressed interest in what other municipalities are doing. I hope this work provides not only increased understanding of the current Canadian municipal practices, but also supports increased practices and policies that integrate climate and biodiversity solutions.

This scan and summary of NbS practices contributes the first broad empirical understanding of NbS in Canadian municipal practices, contributing to current academic research and dialogue as well as policy development and the potential to scale up municipal NbS practices, especially in Canada. This research is conducted within the unique Canadian context and hopefully provides insights for current and future planning and implementation in all sizes of municipalities. In addition, the findings could potentially serve as some level of baseline for future research.

Literature Review

This literature review provides background information on three key topics: (1) the importance and relevance of integrated approaches for climate change and biodiversity, (2) current definitions and standards for NbS and (3) current research findings related to municipal use of NbS for co-benefits. The objective of this literature review is to provide context for this research, and determine how my research relates to and builds on the results of previous relevant research as well as to provide an overview of the scope of the challenges being addressed.

Biodiversity and Climate Change Integration

Biodiversity loss and climate change are critical global threats that are fundamentally interconnected, requiring integrated strategies for effective solutions and to address escalating risks (CBD, 2009; De Lamo et al., 2020; Díaz et al, 2019; Mant et al., 2014; Pörtner et al., 2021). The global call for integrating climate and biodiversity approaches is gaining increased scientific and political importance (Chausson et al., 2020; Khan et al., 2021; Seddon, Daniels et al., 2020). The United Nations Framework Convention on Climate Change (UNFCCC), in the 2019 Decision 1/CP.25, "[u]nderlines the essential contribution of nature to addressing climate change and its impacts and the need to address biodiversity loss and climate change in an integrated manner" (1.CP/25, paragraph 15). The recent Kunming Declaration of the Conference of the Parties to the Convention on Biological Diversity commits to "[f]urther enhance collaboration and coordinate actions" with the UNFCCC and other related multilateral agreements (CBD/COP/15/5/Add.1). The Kunming Declaration emphasizes the critical role of "biodiversity and the ecosystem functions and services it provides" to "support all forms of life on Earth" and stresses the need for "urgent and integrated action… for transformative change", including increasing "ecosystem-based approaches to address biodiversity loss, restore degraded ecosystems, boost resilience, mitigate and adapt to climate change" (CBD/COP/15/5/Add.1). The IPCC (Intergovernmental Panel on Climate Change) and the IPBES (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services) held a historic collaboration of the two bodies in December 2020, followed by a peer-reviewed joint report (Pörtner et al., 2021). The report notes that "[i]t is the nature of complex systems that they have unexpected outcomes and thresholds, but also that the individual parts cannot be managed in isolation from one another" (Pörtner et al., 2021, p. 4). The authors go on to state that "[o]nly by considering

climate and biodiversity as parts of the same complex problem… can solutions be developed that avoid maladaptation and maximize the beneficial outcomes" (Pörtner et al., 2021, p. 5).

Climate change and biodiversity share many of the same drivers, "intertwined through mechanistic links and feedbacks" (Pörtner et al., 2021, p. 14). The destruction of ecosystems is a major driver of biodiversity loss and a critical source of greenhouse gas emissions (De Lamo, et al., 2020). The changing climate has already significantly impacted biodiversity and is anticipated to likely become the main driver of biodiversity loss globally by the end of the century (Millennium Ecosystem Assessment, 2005). If integrated policies and approaches are not used, climate change mitigation and adaptation efforts can also negatively impact biodiversity (IPCC, 2022). Biodiversity is increasingly understood as fundamental for climate resilience considering the important roles of biodiversity and ecosystems in mitigation and adaptation (IPCC, 2022; Seddon et al., 2019). Despite this, the current degradation and loss of ecosystems is impacting global carbon storage and reducing the resilience of nature and humans to cope with changing conditions (Pettorelli et al., 2021). "The mutual reinforcing of climate change and biodiversity loss means that satisfactorily resolving either issue requires consideration of the other" (Pörtner et al., 2021, p. 15).

Nature-based Solutions for Co-benefits

Evidence is growing that the life-support system of the planet is deteriorating to a critical point and urgent, large scale and integrated approaches are needed (Díaz et al, 2019; IPCC, 2022). It is within this context that the NbS umbrella concept is gaining importance as solutions that address climate adaptation, mitigation, biodiversity and other co-benefits (Cohen-Shacham et al., 2016; Dorst et al., 2019; Seddon, Chausson et al., 2020; UN, 2019). The NbS concept for co-benefits has been developing within the literature, government agencies and professional

networks (Chausson et al., 2020; Dorst et al., 2019; Eggermont et al., 2015; Nesshöver et al., 2017), with key definitions provided by the European Commission (EC, 2015), the IUCN (Cohen-Shacham et al, 2016) and most recently an international agreement for a definition through the United Nations Environment Programme (UNEP, 2022). The NbS umbrella concept builds on existing ideas and practices (such as ecosystem restoration and green infrastructure) while offering innovative approaches to current challenges, including the opportunity to bring together different bodies of knowledge for integrated solutions (Dorst et al., 2019).

Typologies of NbS within the literature have proposed definitions, descriptions and categories of different approaches within the NbS umbrella concept (Chausson et al., 2020; Eggermont et al., 2015; Nesshöver et al., 2017; Seddon, Chausson et al., 2020; Xing et al., 2017) as well as definitions and typologies from the IUCN (Cohen-Shacham et al., 2016) and the EU (EC, 2015). Typologies are also present in the literature regarding specific applications of NbS, such as for urban environments (Babi Almenar et al., 2019; Xing et al., 2017) and classifications through research on ecosystem-based adaptation (EbA) measures in urban areas (Geneletti & Zardo, 2016; Zölch et al., 2018). Different approaches for NbS categories have been proposed based on intervention types such as restoration, protection, management, creating ecosystems and combinations of these types (Chausson et al., 2020; Zölch et al., 2018). The IUCN definition of NbS is currently the most widely used (Seddon et al., 2021) and provides a framework of five NbS categories with different approaches or NbS types within those categories (Cohen-Shacham et al., 2016).

Although NbS have great potential for climate adaptation, mitigation and biodiversity co-benefits, there is also the risk of conflict without properly accounting for multiple objectives (Morecroft et al., 2019) and without following principles and standards of practice (Cohen-

Shacham et al., 2019; Seddon et al., 2021). As the use of NbS increases, the risk of potential adverse impacts from poorly designed NbS also increases, including over-emphasis on tree planting instead of broader ecosystem approaches (Donatti et al., 2022; Seddon et al., 2021) and tree planting in in-appropriate places (Morecroft et al., 2019), negative outcomes from lack of consent and engagement of Indigenous Peoples and local communities (Drever et al., 2021; Reed et al., 2022; Seddon et al., 2021), trade-offs with ecosystem services (Bush & Doyon, 2019; Donatti et al., 2022; Seddon et al., 2021; Smith et al., 2019) and failure to ensure biodiversity co-benefits (Bush & Doyon, 2019; Donatti et al., 2022; Drever et al., 2021; Morecroft et al., 2019; Seddon et al., 2021; Smith et al., 2019). In one example, despite having a "critical role in reversing damage to biodiversity, climate change, and land degradation" the Society for Ecological Restoration (SER) warns that "poorly designed and implemented restoration projects have the potential to be socially and ecologically harmful" (SER, n.d.). There are also concerns related to NbS used as a distraction away from the need for systemic change, especially the essential rapid phase out of fossil fuels, illustrated in examples provided by Seddon et al. (2021) of the use by high emitting industries as offsets for continued fossil fuel use and within related problematic corporate marketing. While poorly planned tree planting or afforestation may present challenges such as avoiding the restoration of healthy forests or protecting ecosystems and/or negative impacts from inappropriate locations, monocultures, inappropriate species, and trade offs with ecosystem services (Seddon et al., 2021), evidence is mounting that effectively implemented NbS ("conservation, restoration and improved land management") can provide significant and critical cost-effective mitigation towards global targets (Griscom et al., 2017, pp. 11646 & 11649). Despite disproportionate impacts of climate change on Indigenous communities and potential negative impacts of climate actions such as those replicating colonial

impacts (Townsend et al., 2020; Vogel et al., 2022), NbS designed and implemented with full consent and engagement with Indigenous Peoples and local communities (Seddon et al., 2021) and Indigenous-led NbS (Reed et al., 2022), has the potential to build equitable, successful solutions "supporting Indigenous reconciliation and climate leadership" (Vogel et al., 2022), tailored to the local context with effective adaptive management, "equitable distribution of benefits" (Seddon et al., 2021) and to "simultaneously advance decolonization and decarbonization" (Reed et al., 2022, p. 529). Evidence regarding the potential risks and the ultimate benefits underscores the importance of addressing NbS challenges moving forward.

To ensure synergistic, integrated solutions that address climate change, biodiversity and other co-benefits, there has been growing development of principles, standards and guidelines for effective, evidence-based NbS approaches (Cohen-Shacham et al., 2019; International Union for Conservation of Nature [IUCN], 2020; Seddon, 2021). Stronger policies and standards for integrated approaches (IPBES, 2019) and supporting well-designed NbS can help to ensure outcomes with multiple benefits, including climate, biodiversity, ecosystem services and human well-being (Seddon, Chausson, et al., 2020). The IUCN notes that "[i]nterventions can only be successful with the inclusion of different knowledge systems and participation of affected groups, including Indigenous people, local communities, women and youth" (IUCN, 2020). An important element of standards: effective monitoring and evaluation are needed in order to ensure the co-benefits intended, measure progress and to enable decision-making for evidence-based priorities and critical adaptive management approaches (Cohen-Shacham et al., 2019; Morecroft et al., 2019; Panfil & Harvey, 2015). As interest in and use of NbS approaches increases, effective standards and principles inform a common understanding of NbS, coordinated use, quality control and accountability, minimizing risks to nature, eliminating

detrimental actions to biodiversity being identified as NbS and the engagement of multiple sectors in the practice of NbS (IUCN, 2020).

Local Government Use of Nature-based Solutions

As the deeply interconnected crises of biodiversity loss and climate change need urgent action at global and local levels (Díaz et al, 2019), cities are at the front-line of global impacts and responses (Butt et al., 2018; Frantzeskaki et al., 2019). With climate change intensifying the environmental, social and economic challenges facing urban areas, the NbS concept is growing along with the importance of integrated approaches to address multiple societal challenges and increase resilience (Bush & Doyon, 2019; Dorst et al., 2019; IPBES, 2019). Integrated NbS approaches can address the fact that biodiversity can be at risk from climate adaptation and mitigation actions, identifying conflicts and synergies (Butt et al., 2018; Hobbie & Grim, 2020). While cities are well-poised to implement NbS and collaborative solutions, they face challenges, including the need for evidence to support decision-making (Bush & Doyon, 2019; Frantzeskaki et al., 2019; Hobbie & Grim, 2020) such as related to efficacy, trade-offs, long-term impacts and avoiding unintended consequences (Frantzeskaki et al., 2019). Sarabi et al. (2020, p. 4) identified 15 broad barriers for cites in adopting and implementing NbS, the top two being internal silo issues and the "lack of design standards and guidelines for maintenance and monitoring", followed by issues related to political will and commitment as well as "risk aversion and resistance to change". They identified important interrelationships of barriers in order to understand better how address them towards future success, highlighting political barriers as "underlying critical factors affecting all other barriers" (Sarabi et al., 2020, p. 8). Despite challenges such as these for implementing and scaling up NbS in cities, nature-based

approaches for co-benefits such as green infrastructure, urban forests and riparian restoration are increasingly becoming mainstreamed in urban planning and policies (Fastenrath et al., 2020).

Recent research on the use and integration of NbS within local government policies and practices is important to increase understanding of the current use of NbS by local governments, barriers that need to be addressed and what opportunities will support increasing best practices, scaling up and mainstreaming the use of NbS. Research in Europe and South Africa have provided valuable insights and recommendations for NbS implementation at the local level (Cousiño & Penha-Lopes, 2021; Geneletti & Zardo, 2016; Pasquini & Cowling, 2015; Wamsler et al., 2016; Wamsler & Pauleit, 2016; Zölch et al., 2018; Zwierzchowska et al, 2019). It should be noted that most of these studies focus on EbA associated NbS. Pasquini and Cowling (2015) found a lack of awareness of climate change and EbA and minimal use in eight South African local governments. Zwierzchowska et al. (2019) found NbS actions but no use of the NbS terminology and an explicit concept for the approach in their Poznań, Poland case study. Other case studies found general to considerable awareness of NbS in European municipalities and a range of use of ecosystem-based adaptation (EbA) from some implicit to more general use (Geneletti & Zardo, 2016; Wamsler & Pauleit, 2016; Zölch et al., 2018). Geneletti and Zardo (2016), in finding considerable awareness of EbA in their study of 14 European cities, also found the general approaches in the plans lack details and action planning, raising concerns regarding actual implementation. Zölch et al. (2018) found no comprehensive municipal integration of the EbA concept despite some implicit use and along with Geneletti and Zardo (2016) found a lack of consistent approaches across different municipalities. Cousiño & Penha-Lopes (2021) found that despite the encouragement of the EU to include EbA in climate adaptation planning, the concept and terminology has been generally used indirectly versus explicitly in municipal and

intermunicipal plans in Portugal and that the plans are primarily influenced by the backgrounds and interests of those involved in their development. A few studies found biodiversity to be the highest motivation for the use of EbA approaches within the case studies, including the study of 34 municipalities in Germany (Zölch et al., 2018) and a study of 4 Swedish municipalities (Wamsler et al., 2016). Pasquini and Cowling (2015 p., 1136) highlighted the importance of research like this on the use of NbS by municipal governments to serve as a baseline to measure progress or regression and to compare municipal approaches "within or between countries".

Methods

The challenge of understanding the extent of NbS in Canadian municipalities is a question best answered through a qualitative research approach, where depth is valued more than quantity in exploring social complexities (O'Leary, 2017, p. 142). A detailed environmental scan of larger municipalities (100,000+ population) was followed by matrix data analyses and purposive sampling interviews with staff from key municipalities. This is a similar approach used by other studies focused on EbA at the municipal level, such as Pasquini and Cowling (2015) and Wamsler and Pauleit (2016). Given there is little known in the literature about the overall use of NbS in Canadian municipalities, this type of exploratory research is designed to gain a deeper understanding (Creswell, 2008; Myers, 2000), allowing the research to be guided by emerging questions and information (Creswell, 2008) and aiming to explore and understand social complexities (Myers, 2000; O'Leary, 2017), including the complexity and context within each case (Creswell, 2008).

Typology

Identifying an organizing framework for typology development is critical for data collection and analysis (Ayres & Knafl, 2012). A review of typologies within NbS-related

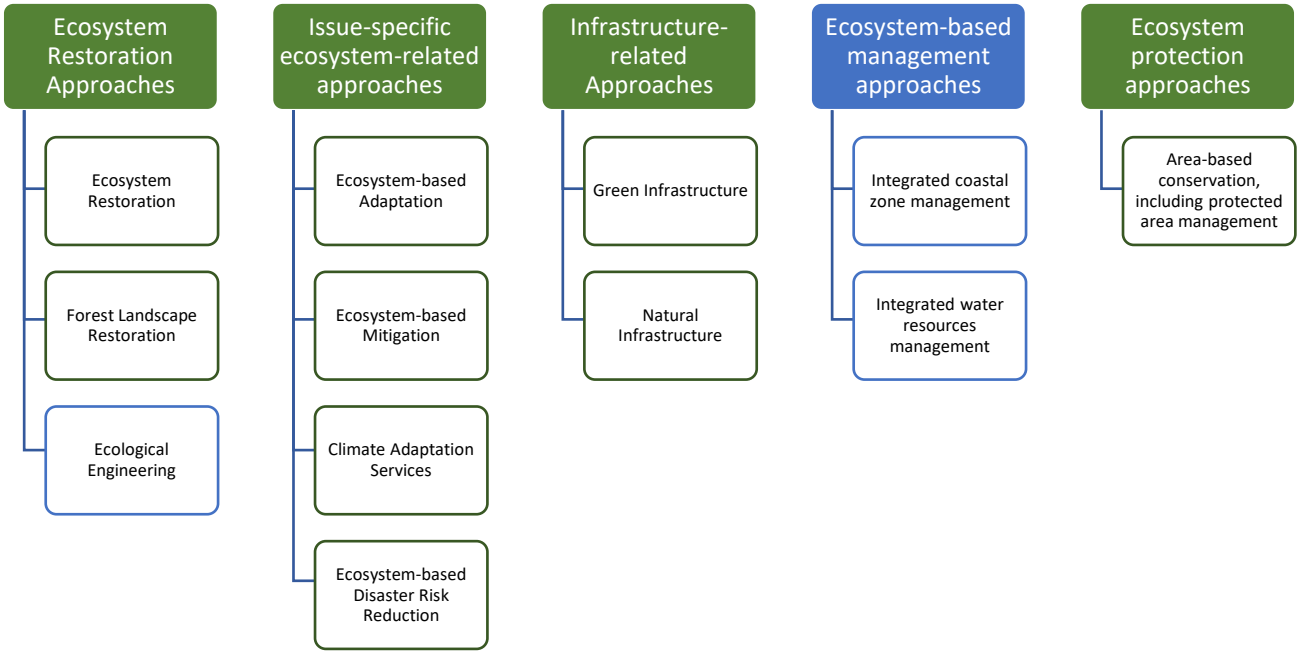
literature identified a variety of typology approaches, as noted in the literature review. I used the International Union for Conservation of Nature (IUCN) typology (Cohen-Shacham et al., 2016) as the guiding framework and terminology for this research as it is currently the most widely used (Seddon et al., 2021) and will potentially increase the comparative value of this research. This typology was developed through a "highly collaborative" process with experts in the field from within the "IUCN, its Commissions and Members, and other organizations including NGOs, research institutes, governmental bodies and private sector businesses" (Cohen-Shacham et al., 2016, p. ix). I also considered the typology a good fit to describe municipal approaches in Canada based on preliminary research and my own experiences.

The NbS categories selected for assessment in this study were chosen based on common municipal approaches, the clarity of categories in the plans being studied and the strongest links with biodiversity and climate change integration. Figure 1 provides an overview of the IUCN's NbS categories and identified approaches (Cohen-Shacham et al., 2016). Indicated in green are the categories included in this study. Other categories not included in this study (though present in at least a few plans) had lower relevance to biodiversity and climate change integration and were harder to assess in this context: Ecological Engineering and Ecosystem-based Management approaches. Initiatives within these categories generally overlapped with other NbS categories, so were not missed in the assessment. The categories chosen for the scan provide the strongest insight into the research question.

NbS initiatives may include or "qualify" as several types of NbS, the "terms are not mutually exclusive" (Seddon, Chausson et al., 2021, p. 1524). In the environmental scan, NbS-related initiatives were grouped and identified with the NbS categories based on the information

Figure 1

IUCN NbS Categories and Categories Assessed in the Environmental Scan (in Green).
(Based on Cohen-Shacham et al., 2016)



provided (and in some cases marked “unclear”). In addition to identifying NbS categories, data collected on the specific elements or initiatives identified within each NbS category, as well as other related information, provided insight into the extent of use and integration, the linkages with specific objectives or outcomes, as well as related documents and information. Following the initial environmental scan, reassessments of categories were conducted to clarify findings and especially to better identify NbS types harder to define and/or more interwoven. For example, this was an especially important process to better understand and distinguish GI and NI in these plans. In that case due to these challenges, a detailed coding exercise was conducted to refine the results, more accurately identify green infrastructure (GI) versus natural infrastructure (NI), and the elements and features. Matrix analyses were also used for some reassessments in order to increase data accuracy for NbS types.

Environmental Scan

I conducted an environmental scan to explore the strategic use of NbS in larger Canadian municipalities (>100,000 population), a total of 61 identified by Statistics Canada (2021) in January 2021. The target size of municipalities is in keeping with the Statistics Canada definition of large municipalities (Statistics Canada, 2022b). Cities are more likely to be advanced in climate planning including as "key sources of greenhouse gas emissions" and with large populations highly vulnerable to climate risks and impacts (Frantzeskaki et al., 2019, p. 455). The size of the municipalities scanned also takes into consideration other similar research that has focused on cities (Geneletti & Zardo, 2016) with one study specifically focused on larger urban centres with a population >100,000 (Zölch et al., 2018).

The environmental scan criteria I used focused on the most current and applicable climate change and biodiversity plans from each of these municipalities that were publicly available on municipal websites in English. The plans include climate plans, biodiversity plans and also broader plans in which the municipality has identified climate change and/or biodiversity as one of the purposes of the plan, such as sustainability and resiliency plans. The climate plans include a variety of broad climate plans and others specific to adaptation or mitigation. In the cases where I reviewed mitigation plans, it was likely because it was the only climate plan available in that municipality. In municipalities with multiple climate plans, I selected the most applicable plan to the study. Municipalities not represented in the scan lacked a plan that met the criteria, including most of the municipalities from the province of Quebec without plans available in English on their websites. Some municipalities identified on their websites that they were in the process of developing plans related to climate change and/or biodiversity, and a few reviewed and assessed other plans and reports that I determined did not meet the study criteria.

The IUCN typology was used to identify different categories of NbS use within the municipal plans as well as relevant details about the NbS-related initiatives (Cohen-Shacham et al., 2016). The data was organized into an excel database with standards set for all scan entries. Additional reassessments of individual categories were conducted after the initial scan was complete, including the detailed coding exercise for GI and NI previously mentioned and a matrix analysis approach for some categories more challenging to assess.

Matrix Analysis

Following the environmental scan, I used a matrix analysis method to reassess individual NbS categories within the plans and to gain broader insight across the plans. I especially used a detailed matrix analysis to analyze the integration of climate and biodiversity planning within the plans and across the different plans. I also used this analysis method for the municipal interview results. The matrix analysis approach for qualitative research allows for both an overview of data and more in-depth data analysis (Cassell & Nadin, 2011), in this case serving well as a relatively large study with multiple cases to be analyzed (King & Brooks, 2018).

Municipal Interviews

Following the environmental scan and document analysis, I used purposive sampling to select municipalities with one or more plans in this study to check the findings of the environmental scan and to gain insight into the nature and extent of the municipalities' use of NbS for climate and biodiversity planning beyond the document(s) analyzed. I used purposive sampling of municipalities for this qualitative research as it is designed to identify appropriate sources of information to best inform the study (Fossey et al., 2002). Similar studies effectively used purposive sampling to select municipal case studies and for interviews most relevant to the study (Geneletti & Zardo, 2016; Pasquini & Cowling, 2015; Wamsler, 2015; Wamsler & Pauleit,

2016; Zölch et al., 2018) and as noted by Wamsler (2015) and Wamsler and Pauleit (2016) due to the exploratory nature of the research. The interviews were conducted with municipal staff in some level of leadership position of planning and implementation within the subject areas, the key positions selected providing valuable data based on their experiences and perspectives (Harrison, 2009). Similar interviewee selection was used in related studies (Pasquini & Cowling, 2015; Wamsler & Pauleit, 2016). In a few cases within this study, I interviewed multiple staff, providing a broader view and reducing the impacts of individual participant bias (Harrison, 2009). This occurred in two municipalities in response to my invitation, when two staff were identified internally in key roles, accepting a joint interview.

I chose the municipalities identified for interviews based on the scan and analysis results. The choice of sample municipalities included a range of one or more factors: the highest results of NbS initiatives and integration of climate and biodiversity goals resulting from the scan and analysis, discrepancies between two assessed plans, evidence of increased NbS since the published plan(s), a range of provinces and one selection to gain insight from lower findings of NbS. Interviews were conducted with 8 municipal staff working for 6 selected municipalities from 5 different provinces: Calgary (Alberta), Mississauga (Ontario), Surrey (British Columbia), Halifax (Nova Scotia), Saskatoon (Saskatchewan) and Kelowna (British Columbia).

The semi-structured interviews were approximately 1 hour in length, which I conducted using standard methodology and having received ethical approval from Royal Roads University (see Appendix D: Interview Questions). The semi-structured interview method provides structure to address the research question, while allowing the opportunity to explore the understanding of participants and their lived experience (Galletta, 2013) and being responsive to information and issues that unfolded in the interview (Harrison, 2009). I sent invitations to key contacts from the

selected municipalities with details of the research and the interview request. Those who agreed to participate were sent a consent form, all of which were returned by email. A check-in at the start of the interview included going over the processes and providing the opportunity for interviewees to ask questions and address any concerns prior to starting. Due to the geographic distance of interviewees and the current pandemic restrictions, virtual interviews were conducted via the Zoom platform. Agreements with each interviewee allowed for audio recording during the interviews to enable a full transcript, which was then sent to interviewees for further comment, editing and agreement prior to use within the research. Interviewees are identified in this research by letter for privacy purposes.

Data Analysis

Data analysis included the scan process of the municipal plans using the typology and a standardized process for data collection, followed by matrix analyses of the scan and staff interviews. I used a variety of research and analysis methods to increase data validity through the use of triangulation (Creswell & Miller, 2000) and data quality was enhanced through the multiple approaches of data collection and analysis (Fossey et al., 2002) and further reducing bias (Yin, 2009). The research was designed and data analyzed for consistency, to be well-documented and account for subjectivities (O'Leary, 2017).

Document analysis methods enabled richer descriptions of the scan and matrix analysis findings, the analysis identified questions for the interview process, provided context for interview data, and was then verified by interview data (Bowen, 2009). The analysis of related municipal plans is used in similar studies (Pasquini & Cowling, 2015; Wamsler, 2015; Wamsler & Pauleit, 2016), though these studies also analyzed additional documents to gain greater

understanding of mainstreaming. I scanned additional documents based on relevant information brought forward during the interviews for greater insight and data verification.

In conducting the data analysis, directed content analysis (Hsieh & Shannon, 2005) was used to gain insight in regards to the research question. For the typology, directed content analysis was used to extend or validate the theoretical framework (Hsieh & Shannon, 2005) using coding methods to assemble, validate and organize the information from the data (Pierce, 2008). This is an important consideration in my research considering the lack of literature and use of related terminology in the Canadian context. Standardized coding and descriptions were used in the environmental scan database, then used to guide further analysis of individual NbS categories due to challenges overlap of initiatives, terminology and, in some cases minimal details making assessment challenging.

The environmental scan and the matrix analysis included criteria and rankings providing results to describe the extent and types of NbS use in these municipalities and a ranking of the level of integration of biodiversity and climate change planning. Approaches within similar studies ranked related terms used (Cousiño & Penha-Lopes, 2021), scored EbA measures and context to evaluate plans (Geneletti & Zardo, 2016), identified results by EbA elements then described the top two municipalities (Pasquini & Cowling, 2015), while others ranked cities by percentage of EbA measures in relation to all measures found in the study (Zölch et al., 2018) or provided a comparison analysis of EbA characteristics (Wamsler, 2015; Wamsler & Pauleit, 2016). The challenge for this study included the broad scope of NbS categories, the large number of municipalities and plans and the wide variety of approaches used in terms of plan format, terminology, level of detail and other approaches. The data analysis elements were

developed in part based on what was found in the plans and to focus in on areas of insight regarding extent of use and indicators of integration.

Limitations

The sample size and criteria for the environmental scan are appropriate, but have both benefits and limitations. A large environmental scan limits the details and verification of findings, but serves to provide a broad overview of the subject. As the appropriate sample size depends on the research question and study purpose (Mocănașu, 2020), in this case the broader scan approach best answers the research question regarding the extent of NbS use for integration in large Canadian municipalities. This approach limits the more in-depth detail and data for verification that a case study with a small sample size would provide. The environmental scan best focused in on the most applicable climate and biodiversity related plans given the size of the study, thus additional document analysis had to be limited. In addition, while a small sample size of one or two interviewees from six municipalities provided additional data and different lenses to improve the results, the focus for interview selection was to gain insight across municipalities. This limits the variety of perspectives and experiences an in-depth case study approach could provide. In addition, the study was limited to English plans, thus may be missing some plans from Quebec. Aside from Montreal, municipal websites in Quebec were in French and though online translation was used, no plans in English were identified.

This study was not able to verify NbS within the municipal plans to the level of standards, such as provided by the IUCN (2019). Seddon et al., (2021) make an important case for how to properly identify NbS in relation to standards and loosely refer to unverified NbS as nature-based interventions. I have continued to use the term NbS here, with the caveat that this

study identifies potential but unverified NbS based on plans and descriptions and note that some do not appear to include monitoring biodiversity to ensure measurable benefits.

Results

The scan and analysis looking at NbS and integration of biodiversity and climate change are based on 50 climate and biodiversity plans (identified January 2021) that met the study criteria, representing 40 out of 61 Canadian municipalities (>100,000 population). The study includes 32 climate plans, 8 biodiversity strategies, and 10 broader plans. The broader plans include sustainability and resiliency plans, a green infrastructure strategy and plans from Ontario municipalities meeting natural heritage provincial planning requirements. Four out of the eight biodiversity strategies are focused on conservation planning and implementation: Toronto, Calgary, Edmonton and Vancouver. As the plans did not link with climate change objectives or co-benefits (or at least not in any significant way), NbS categories were not able to be identified in those plans. All plans are listed in the Appendices including: municipalities and the plans within the study (Appendix A) and a listing of a few specific plans that did not meet the criteria (Appendix B). As this research was very time-intensive, a scan of municipal websites was conducted at the end of the research to identify any newly published climate plans that met the criteria from municipalities without a plan in the study. Appendix C lists these plans and a general overview of the more recent plans is included in the results.

The results show NbS related initiatives are being employed or identified by the majority of municipal plans in the study, but this is not always an indicator of explicit biodiversity and climate change integration. The findings of the extent of NbS use ranged from low (such as only one type of NbS and/or a lack of integration of co-benefits or clarity regarding co-benefits) to a high level of use and integration. Moderate to higher levels of NbS inclusion in the plans is

more common. In some plans NbS are a significant overall focus. In general, the NbS category results were confirmed as generally accurate in the interviews (and clarified a few "unclear").

The following overall study results include findings related to the use of NbS as well as broader findings regarding the integration of biodiversity and climate change planning. Results for each NbS category are summarize elements, practices and how they relate to integration. A brief summary highlights federal and provincial support or leadership linked to NbS and/or integration. This is followed by the overall results of biodiversity and climate change integration, including findings regarding biodiversity monitoring.

Nature-based Solution (NbS) Category Results

Overall, the Canadian municipal plans reviewed commonly incorporate a fair number of NbS categories and the concept appears to be growing as an important approach for co-benefits. As shown in Table 1, the most commonly identified categories were: Forest Landscape Restoration (FLR) primarily for urban forest initiatives, Ecosystem Restoration (ER), Ecosystem Protection (EP), Green Infrastructure (GI) and Natural Infrastructure (NI) to a lesser degree. NbS are commonly used in these plans to address both climate adaptation and mitigation, which appears as the higher focus for all municipalities in this study. Biodiversity goals, if included, range from broad or unclear to specific and detailed. The NbS term is mentioned once in one plan and while NbS approaches were present, the closest the plans came to representing or describing the umbrella concept of NbS was through a broader approach and description of Green Infrastructure or Natural Infrastructure.

Ecological Restoration (ER)

Ecological Restoration is one of the most common NbS categories in these plans,

Table 1

Nature-based Solutions in Climate and Biodiversity Plans of Large Canadian Municipalities

NbS*	**Climate Plans** (32)	**Biodiversity Plans** (4 of 8 with NbS)	**Broad Plans** (10)	**Total**
ER	25 (2 unclear)	2 (1 unclear)	10	37 (3 unclear)
FLR	29	4	10	43
EcoDRR	8 (5 unclear)	0	3	11 (5 unclear)
CAS	3	(1 unclear)	(2 unclear)	3 (3 unclear)
GI &/or NI	25 (3 unclear)	1 (3 unclear)	8 (2 unclear NI)	34 (8 unclear)
EP	25 (2 unclear)	2	9	36 (2 unclear)

*ER (Ecological Restoration), FLR (Forest Landscape Restoration), EcoDRR (Ecosystem-based Disaster Risk Reduction), CAS (Climate Adaptation Services), GI (Green Infrastructure), NI (Natural Infrastructure), EP (Environmental Protection).

although not always well defined or clear. As shown in Table 1, 37 plans include ER with three plans unclear (possible). Of note, all 10 broader strategies include ER. Some plans include elements, terms or phrases that seem to implicitly include ER, while ER is clear and detailed in other plans. Table 2 lists 42 unique elements of ER that were identified and grouped into nine broader categories. One category for "possible or likely ER" includes terms in the plans that were difficult to assess for ER: "enhancing" or "active management" of natural areas or systems.

The most commonly identified ER elements in these plans, listed in Table 2, are related to Green Infrastructure (including expanding, improving and installing), naturalizing or greening built or highly disturbed areas and general plans to restore natural areas or ecosystems. The next highest elements found in the plans were ER related to watercourses, wetlands and/or riparian areas, ER to increase or expand biodiversity, expanding or enhancing natural infrastructure, ER for stormwater management and ER for the general description or goal of climate resilience.

Table 2

Elements of NbS Related Ecological Restoration (ER) in Large Canadian municipalities

Category	Elements
Area/Type of Restoration	Green infrastructure (expand, improve, install) Natural infrastructure (expand, enhance) Greening/ naturalizing (non-natural areas) Ecological restoration (detailed/ broad) Connectivity/ corridors Watershed restoration Watercourse/ riparian/ wetland Ocean/ shoreline
Policies & Strategies	ER related or specific strategies (linked to/ called for) ER policies (identified or called for) Development related (policies or targets) ER within the vision of the plan Investment for ER
Biodiversity Related Goals	Increase/ expand biodiversity (often species) Increase diversity of habitats Increase/ maintenance of genetic diversity Rare or important terrestrial ecosystems ER for pollinators
Climate/ Ecosystem Services	ER for resilience ER for ecosystem services (maintain/ increase) Increase carbon sequestration Species migration Incorporating climate adapted species EcoDRR such as flooding
Staffing/ Partnerships	ER related staff development/ expertise Municipal coordinated approaches Community volunteers Restoration partnerships
Data & Monitoring	ER data and monitoring System or source to identify priority sites for ER
ER Practices	Best management practices (e.g. development) Invasive species management Specific site recommendations Plant salvage for restoration Restoration for stormwater management
Case Studies	ER related case studies/ highlighted projects
Possible or Likely ER	“Enhancing” natural areas/ systems “Active management” of natural areas/ systems

Biodiversity and Climate Change Integration. ER results were fairly strongly linked with biodiversity and climate change integration, but limited by lower results for biodiversity monitoring. ER linked to both biodiversity and climate goals in these plans includes: restoring for increased biodiversity (often species), increasing the diversity of habitats, addressing genetic diversity, restoring rare or important terrestrial ecosystems and restoring for pollinators (or as an indicator of success). Ecological restoration is not frequently defined in the plans, so intentions are sometimes unclear. In some cases, there were indications that the use of the term may not meet ER definitions, such as outlined by the Society for Ecological Restoration (2021). ER elements that may be linked to biodiversity benefits also include species migration, invasive species management, plant savage and connectivity. Monitoring is included in some plans linked to ER, but not significantly overall.

Forest Landscape Restoration (FLR)

Forest Landscape Restoration (FLR) is the most common NbS category found in the plans, primarily focused on urban forests. FLR was identified in 43 plans, including all four biodiversity strategies with NbS (Surrey, Oakville, Sudbury and Delta) and all broader strategies. The three climate plans that were not identified with FLR (from Calgary, Edmonton and Red Deer) may include FLR elements (but not explicitly) within GI initiatives (as well as NI for Calgary and Red Deer) and Edmonton identifies researching urban forests with partners.

Table 3 provides an overview of initiatives or approaches identified under FLR, grouped into broad categories. Unique and remarkable FLR initiatives or elements were identified, some linking climate and biodiversity planning. Municipalities such as Surrey, Windsor and Sudbury include plans for assisted tree or species migration through FLR initiatives. Oakville's climate plan (2014, p. 42) identifies through urban forest planning to "[e]nsure, that when possible, the

Table 3

Elements of Forest Landscape Restoration (FLR) in large Canadian municipalities

Category	Element
Planning & Policies	Develop or update urban forest plan Update policies (e.g., Official Plan) Develop or update bylaws Mapping & inventory of trees/ tree canopy Equity & distribution/ cover planning Native species & at-risk tree policies
Strategies or Objectives	Urban forest canopy (protect or expand) Green & natural infrastructure planning Target areas (e.g., urban heat island mapping) Trees/forest for stormwater & erosion mgmt. Invasive management (forest protection)
Indicators & Targets	Tree canopy (e.g., % cover or target areas) Tree planting (e.g., target annual #) Reduction of heat island areas/ shade cover Mortality rate of public trees
Standards	Planting & protection standards Maintenance & monitoring standards Tree placement for energy efficiency (bldgs) Road designs for tree/ vegetation space Protection during utility management
Species Selection	Species selection for diversity (species & genetic) Climate resilient species selection Species selection for rainwater management Replacement of invasive trees
Research	Urban forest canopy related Urban forest health and planning Climate resilient species Assisted migration trials Carbon sequestration research
Initiatives	Boulevard trees & green streets Urban forest initiatives in Parks Equity planning for tree planting Forest naturalization/ restoration Afforestation areas and initiatives Special tree planting programs Urban forest protection initiatives Community stewardship programs Public tree planting funding programs Private land tree planting support & incentives Local tree nursery (native species) Food Forests

seed source is within the collection zone for Oakville as established by the Forest Gene Conservation Authority". Thunder Bay's climate plan (2015, p. 40) supports "the establishment of a local tree nursery which grows regionally-specific tree species". Winnipeg's climate plan (2018, p.52) identifies an initiative underway to use "Silva Cells and Strata Cells to assist with stormwater management along right-of-ways and simultaneously foster large tree growth for the benefits canopy cover provides to urban areas". Vancouver's climate plan (2018, p. 41) calls for updating "tree selection guidelines to reflect the City's goals for climate adaptation, rainwater management, food production, biodiversity and reconciliation".

Biodiversity and Climate Change Integration. FLR initiatives within the plans overall

Table 4

FLR Target Outcomes for Climate Change and Biodiversity in Large Canadian municipalities

Focus Area	FLR Target Outcomes
Climate Change	Carbon sink/storage and sequestration Increasing air quality or pollution filtration Stormwater management and erosion control Heat related outcomes (e.g., urban heat island effect) Energy efficiency re: tree placement & buildings (heating/ cooling) General targets (e.g., protecting/ increasing ecosystem services)
Biodiversity	Increase native tree species Tree seed sources (genetics) Address invasive tree species Protecting at-risk tree species Maintain and increase the diversity of tree species Targets for at-risk and sensitive ecosystems for FLR Increase broader forest diversity or overall biodiversity Maintain or increase biodiversity for specific forest sites Species &/or genetic diversity: monitoring and management Trials for new tree species (considering the changing climate) Increase public & private land diversity (trees/ overall biodiversity) Update policies/ standards re: tree species selection for biodiversity Increase diversity during development (tree retention/ replacement)

have a fairly broad range of clear target outcomes related to biodiversity, climate mitigation and adaptation, although substantial integration is lower than some of the other NbS categories. Table 4 identifies FLR climate and biodiversity related target outcomes, which are clearer than any other NbS category. Despite the common use of FLR and broad range of outcomes, overall biodiversity and climate change integration results are somewhat lower. While 27 plans include both climate and some level or element of biodiversity planning in FLR, there is a range of biodiversity inclusion: from simply aiming for "tree diversity" or "increase diversity" to a broad biodiversity goal along with specific biodiversity planning and initiatives. An additional 16 of the plans do not include biodiversity elements or integration with climate goals for FLR.

Ecosystem-based Disaster Risk Reduction (EcoDRR)

Ecosystem-based disaster risk reduction (EcoDRR) is a less common NbS in these plans, found in seven of 32 climate plans (with six plans "unclear"), no biodiversity plans and three of 10 broader plans (with two plans "unclear"). EcoDRR was more challenging to identify in these plans so was reassessed individually after the full scan. In the analysis, EcoDRR elements were often identified woven in with other NbS types and initiatives, appearing less as a stand-alone and defined approach. EcoDRR was found to be linked most often alongside stormwater management, especially in the climate plans, going beyond basic stormwater management to include actions and/or outcomes related to flooding and disaster events. In a few cases simply addressing flooding (minor mention) without more details to indicate a disaster or event were marked "unclear". EcoDRR is also incorporated as smaller elements of larger emergency/ hazard/ disaster planning. The types of hazards identified that incorporate some element or reference to EcoDRR include major storms, flooding, heat related events, drought, coastal hazard events, storms that include high winds, and wildfires. Approaches identified for EcoDRR

primarily include protection, restoration and expansion of natural areas or GI (also described as ecosystem services) in relation to planning for disaster-type events, as well as replacing grey infrastructure with GI, increased tree planting and specifically riparian or shoreline restoration.

Biodiversity and Climate Change Integration. EcoDRR, of all the NbS in this study, resulted in the fewest details and elements, including indications of biodiversity and climate change integration. EcoDRR focused on addressing disasters related to climate change includes expanding ecosystems or natural areas, ecosystem protection and ecological restoration. Specific ecosystems often linked to EcoDRR include coastal shoreline, riparian ecosystems and urban forests. Primarily, benefits related to biodiversity and ecosystems were implicit in this category.

Climate Adaptation Services (CAS)

The Climate Adaptation Services (CAS) subcategory of "issue-specific ecosystem-related" NbS (Cohen-Shacham et al., 2016, p. 10), focused on "ecological mechanisms and processes that support adaptation services and their management" (Lavorel et al., 2015, p. 15), was also challenging to identify in many plans, less common and not extensive in approaches identified. CAS was identified in three climate plans (and 1 "unclear"), three broader plans (and 3 unclear) and two biodiversity plans were marked "unclear". In some cases where plans include one element without details, such as assisted tree migration, CAS was entered as possible ("unclear"). Some municipalities lean towards CAS with plans to study and use species adapted to the changing climate in urban forests, natural areas restoration and/or through GI development. Details are overall sparse regarding approaches. Assisted species migration, for example, is an element of four plans, but the plans do not include significant details for research, trials or other types of actions. Table 5 provides examples of CAS that were found in climate plans, a natural heritage and urban forest strategy and a green infrastructure strategy.

Table 5

Elements of Climate Adaptation Services in large Canadian municipalities

Element	Examples of Plans
Assisted species migration	Mississauga Natural Heritage & Urban Forest Strategy, 2014; Surrey Climate Adaptation Strategy 2013; Saanich Climate Plan, 2020 Sudbury Biodiversity Action Plan, 2018
Maximizing biodiversity (species & habitat types) for resilience to future climate shifts	Mississauga Natural Heritage & Urban Forest Strategy, 2014; Surrey Climate Adaptation Strategy 2013; Saanich Climate Plan, 2020
Planning for future ecosystem services: plant or tree diversity and species selection for future climates and stressors	Mississauga Natural Heritage & Urban Forest Strategy, 2014; Surrey Climate Adaptation Strategy 2013; Windsor Climate Change Adaptation Plan 2020
Natural area connectivity and restoration to facilitate the movement/ migration and adaptation of native species in changing climates	Mississauga Natural Heritage & Urban Forest Strategy, 2014; Surrey Climate Adaptation Strategy 2013; Saskatoon Green Infrastructure Strategy 2020; Saanich Climate Plan, 2020
Strategically acquiring diverse representative ecosystem types	Surrey Climate Adaptation Strategy 2013
Supporting ongoing ecosystem functions in future climates	Saskatoon Green Infrastructure Strategy 2020

*Note: plans listed include those with an element (or two) but listed as “unclear” overall for CAS

Biodiversity and Climate Change Integration. CAS focused on ecosystem resilience and ecosystem services for climate adaptation include explicit targets for biodiversity such as maximizing species and habitat types for resilience, species diversity for future ecosystem services and specifically acquiring diverse representative ecosystem types (overlapping with EP). Other elements of CAS could be tied to sustaining biodiversity (though not all plans explicitly describe or target biodiversity), including assisted species migration, improving connectivity,

increasing ER for species movement and supporting ecosystem functions in future climates. As CAS is usually not represented as a stand-alone initiative, it was unclear what monitoring may relate directly to CAS and directly support biodiversity and climate change integration.

Green Infrastructure (GI) and Natural Infrastructure (NI)

Of all types of NbS in the climate and biodiversity related plans, GI and NI are two of the most common NbS found and detailed in these plans. While including the richest information, these categories were difficult to definitively identify and categorize, requiring a lengthy plan reassessment with coding. Of the 32 climate plans, 25 include GI and/or NI and three are unclear. Of the four biodiversity plans with NbS, one includes both, one includes GI, one is unclear for GI and one is unclear for both. Of the 10 broader plans, eight include GI and/or NI while two are unclear for NI (no GI). These results show 70% of all plans explicitly include GI and/or NI and an overall total of 84% include or are "unclear" (possible). If only considering the plans that include NbS (eliminating four biodiversity plans from the calculation), a total of 91.3% of plans with NbS include or possibly include GI and NI.

GI and NI were reassessed after the scan as this was a challenging element due to issues with terminology and being often interwoven with other initiatives. The use of the term "infrastructure" was an important criterion used to identify GI and NI initiatives. One frequent approach in these municipal plans is to identify GI and NI as "natural assets". Many municipalities identify or plan to include natural assets in their corporate asset management systems (existing or under development). Commonly GI and NI include elements of stormwater management and urban forest planning, among many other elements and priorities. As GI and NI include broad and very integrated initiatives, there may be additional municipalities within the study with initiatives that fall into the GI or NI category, but were not identified in relation to

"infrastructure". Thus, elements of GI and NI may be even wider in use. Brantford's Corporate Climate Change Action Plan (Brantford, 2020) has no mention of infrastructure, natural assets or related language, but the plan includes green roofs, rain gardens and protecting wetlands as part of stormwater management. For Brantford, these are identified as NbS elements, but marked unclear related to GI and NI based on the assessment criteria. In my reassessment for GI and NI, I was careful not to infer GI or NI when that intention was unclear, but I did not want to miss GI or NI due to language limitations.

While GI and NI can be overlapping in planning and initiatives, the varying approaches described in the plans of this study could be seen as a spectrum of approaches and are referred to using a variety of terms. Table 6 summarizes the basic, general definitions used to identify and distinguish GI and NI within this study, based on the IUCN typology (Cohen-Shacham et al., 2016, p.21-22). As noted, the large Canadian municipalities in this study use a wide variety of terms to refer to GI and NI, though the plans that include GI and NI definitions tend to have many similarities. Table 7 lists many of the wide variety of GI and NI terms found within the municipal plans. A fair number of municipal plans use the term "natural assets" interchangeably

Table 6

IUCN Green Infrastructure and Natural Infrastructure Definitions

Nature-based Solution	Definitions
Natural Infrastructure	Restoration of ecosystems ("structure, function and composition") for the delivery of ecosystem services at a landscape scale. (Cohen-Shacham et al., 2016, p. 21)
Green Infrastructure	Enhancing aspects of ecosystems to deliver ecosystem services at both an urban and landscape scale. (Cohen-Shacham et al., 2016, p. 21-22)

Table 7

GI and NI Terms: Canadian Municipalities

GI & NI Terms	Municipalities
Blue and Green Infrastructure	Toronto, (many use "GI" term)
Constructed or Engineered Green Infrastructure	Windsor, Richmond Hill
Ecosystem Assets	Red Deer
Green Infrastructure Network (GIN)	Surrey
Green Network	Saskatoon
Green System or Greenway System	Mississauga, Richmond Hill
Natural Assets	Calgary, Brampton, Vancouver, Saskatoon, Saanich, Guelph, Nanaimo, Cambridge, Langley
Nature-based Green Infrastructure	Langley
Natural Capital Assets	Ajax
Natural Green Infrastructure	Windsor, Richmond Hill
Natural Infrastructure	Toronto, Montreal, Calgary, Richmond Hill, Ajax,

with GI and NI, or as an element of GI and NI initiatives. The municipalities listed in Table 7 as using the term "natural assets" are those using the term more extensively in describing GI and NI. In addition, Guelph and Saskatoon have three related GI and NI "asset" categories: natural assets, enhanced assets and engineered assets.

Biodiversity and Climate Integration. The climate plans and broader plans that were reviewed do not all specifically plan for biodiversity conservation or enhancement. Of the 25 climate plans that include GI and/or NI, 14 of the documents do not specifically include mention

of biodiversity planning in the GI and/or NI descriptions (although there are implicit elements like ecosystem protection that are biodiversity-related). Three additional climate plans with GI marked "unclear" also did not link biodiversity in the related description. In the interviews, GI and/or NI initiatives were described by interviewees in all six municipalities, but based on their descriptions, biodiversity was noted by staff from Kelowna and Mississauga (for GI) as being in earlier stages of consideration or integration and Halifax not yet explicitly factoring in biodiversity. Interviewees from Calgary and Surrey indicated integration of biodiversity goals with GI and/or NI and less clear in the interview, but likely, in Saskatoon.

Ecosystem Protection (EP)

The IUCN describes the NbS category Ecosystem Protection as simply "area-based conservation approaches including protected area management" and do not define this category, stating "these approaches are much more commonly seen and better known" (Cohen-Shacham et al., 2016, p.17). In the environmental scan, I identified elements of the plans that focus on ecosystem protection and management for co-benefits for climate change, biodiversity and more to indicate the use of this NbS. This is a very common NbS category in these plans with a wide range of approaches that can be categorized as "ecosystem protection", with elements that are unique and many that overlap with other categories. Out of 50 plans, 37 include EP as a nature-based solution for climate change and some explicitly integrate biodiversity goals. The protection and management of wetlands and riparian areas is a common focus in at least 17 of the plans. There are also many broad ecosystem protection approaches, such as in Surrey's climate plan (2013, p. 58-59), which calls for strategically acquiring "a diverse representation of ecosystem types", to "[r]educe habitat fragmentation by using and protecting a comprehensive network of corridors and larger natural areas" as well as increasing active management of

municipal natural areas and encouraging increased active management of natural areas on other public and private lands. An overview of the categories and elements found in the plans relating to EP is summarized in Table 8, which helps to describe the extent of use of EP as a nature-based solution, including a fair range of policies and bylaws, municipal planning, as well as protection practices ranging from incentives and funding mechanisms to protection methods and elements. EP related indicators and targets are identified in Table 9, which also helps to describe the extent of EP in the plans and in some cases the level of commitment to this NbS approach. The focus of these indicators and targets are primarily area-based (percentage or area of increased protected areas or managed natural areas) or specific management-related targets (such the number of conservation management plans developed or implemented). In addition, some species-related, policy goals, and budget-related targets or indicators were identified. Many plans identify indicators and targets are to be developed and a few interviewees noted their interest in learning about indicators and targets used by other municipalities.

Biodiversity and Climate Change Integration. EP was found to be very strongly linked to biodiversity outcomes along with climate change solutions. As a measure for climate change adaptation and/or mitigation, explicit integration can be seen in actions and goals to specifically protect biodiversity (and related terms) in general, planning for species and ecosystem at risk and biodiversity mapping related to EP. Biodiversity protection was identified in one case related to transportation planning. Targets and/or indicators for or related to biodiversity, as shown in Table 9, are strong elements found for EP throughout the plans.

Table 8

Ecosystem Protection NbS elements in Large Canadian Municipalities

Category	Elements
Protection Objectives	Natural areas and specific ecosystems Protection of biodiversity & ecosystem services (including CAS) Protection for features/ functions (e.g., sequestration, flooding) Rare and/or significant ecosystems & species Corridors for native species movement and adaptation
Policies & Bylaws	Development policies (natural areas & functions, species at risk) Increase no-build set-backs Update Official Community Plan/ Official Plan &/or Zoning Bylaw Remove policy barriers to wetland conservation Increase protection & conservation on private lands Reduce impervious surfaces in urban watersheds GI and Low Impact Development Guidelines/ Protocols General: develop policies & bylaws for increased protection Bylaws related to tree protection (including at-risk tree species) Bylaws to protect ecosystems at risk Development Permit Areas & guidelines (Streamside, Sea Level Rise)
Planning	Plans/ Strategies: environmental protection/ ecosystem services Plans/ Strategies: protecting & managing specific areas Planning for protection & management of natural assets, GI & NI Parks planning to protect/manage natural areas Transportation changes to increase greening/ biodiversity protection Watershed planning (resilience and ecosystem services) Natural asset and biodiversity mapping to inform decision-making ID areas of greatest risk to conserve/reclaim Land Acquisition planning or strategy Identify connectivity barriers
Protection Practices	Land acquisition for environmental protection* & natural parkland Incentives for conservation & GI (private, commercial, institutional) Protection of natural assets within asset management program Development Guidelines for various protection goals Funding mechanisms for protection and acquisition Protection partnerships: regional/ provincial/ federal gov’ts & others Monitoring for protection & management of ecosystems & species Monitoring for area-based conservation (e.g., coastal erosion) Conservation/protection of natural vegetation in corridors Improved/ science-based mgmt. (natural areas, ecosystem services) Invasive species management Soil preservation

*Plans reviewed include land acquisition for: natural area protection, protection of specific ecosystems and high priority habitats, protection of diverse ecosystem representation protection of corridors, ecological features, Green Infrastructure and Natural Infrastructure planning, and biodiversity protection.

Table 9

Ecosystem Protection Indicators and Targets used by Large Canadian Municipalities

Categories	Indicators and Targets
Area-based	Increase in protected natural areas/NI or GI (% or area) Increase in management of natural areas/NI or GI (% or area) Protected natural links/ corridors of natural vegetation (ha/km) Catchment areas of Low Impact Development sites (hectares) Percentage of natural cover in specific areas (e.g., riparian) Decrease in vulnerable areas
Management-related	Natural assets (increase or % included in asset mgmt. program) Natural area management/ enhancement initiatives (#) ID & classification highly-valued environmentally-sensitive areas Conservation Management Plans (#) Riparian Health Index; watercourses vegetated Biodiversity protection related indicators
Species-related	Decrease in species at risk Reduction of invasive species (or change in number)
Policy or bylaw-related	Protection policies or DPAs in place (# or %) Implementation of development bonuses for preservation
Budget-related	Budget or investment amount related to natural assets or GI Ratio of total investment in green and grey infrastructure Management costs of invasive species Dollar value of natural assets

Provincial Requirements and Leadership

One element of the matrix analysis looked at the explicit influence of provincial requirements or leadership in regards to NbS and integration of biodiversity and climate planning. Though it must be considered that the greatest number of plans in this study (a total of 28) come from Ontario, the provincial requirements and leadership outlined in the Ontario plans far exceeds that of any other province. Table 10 provides an outline of the provincial requirements or leadership by province mentioned in the plans (and identifies the number of plans within the study from that plan for context). The most significant contrast is between the provinces of Ontario and British Columbia.

Table 10

Provincial Requirements and Leadership: Nature-based Solutions and Integration

Province	Municipal Plans in Study	Requirements & Leadership Noted
British Columbia	12	/
Alberta	5	Provincial funding for GI development; Provincial partnership for river and ravine flooding resilience
Saskatchewan	2	Provincial policies and plans related to GI
Manitoba	1	Provincial funding related to NbS: Conservation Trust Fund and the Climate and Green Fund
Quebec	1	/
Nova Scotia	1	Possible link: new Coastal Protection Act
Ontario	28	Provincial Policy Statement (natural heritage protection, development compensation requirements, GI); Greenbelt Plan (protection requirements); Regulation 588/17 (asset management planning & Green Infrastructure); Provincial Growth Plan; Provincial stormwater management guidelines (LID & GI emphasis); Provincial funding for natural cover; habitat banking and restoration plans (for developments); 2010 Natural Heritage Manual (ID/mapping wildlife corridors & habitats); Provincial requirements for municipal plans and implementation (Natural Heritage Systems and Biodiversity Conservation Strategies), Oak Ridges Moraine Conservation Plan; Watershed planning guidance documents

The wide variety of provincial focus and leadership is evident in Table 10. The table provides only the highlights of the related regulations and leadership mentioned in the Ontario plans: the actual list and details is much broader. In plans from other provinces there are a few mentions of provincial regulations or leadership that can be linked to planning and implementing NbS. In Manitoba, the commitment to a $102 million-dollar Conservation Trust Fund is noted for “initiatives related to conserving ecosystems, green infrastructure (natural assets), water quality, and carbon sinks” and a $40 million Climate and Green Fund for mitigation and

adaptation such as wetland restoration (Winnipeg, 2018, p. 69). Saskatoon points to a list of Federal and Provincial policies and regulations to be considered for GI planning and management (Saskatoon, 2020, p. 46). Plans in Alberta note provincial funding (Calgary, 2018, p. 23) and a river and ravine flood resilience partnership (Edmonton, 2018, p. 31). In Nova Scotia the new Coastal Protection Act is mentioned in a section addressing coast, waterfront and shoreline areas (Halifax, 2020, p. 43) and is described on the provincial website as protecting natural ecosystems to address "sea level rise, coastal flooding and coastal erosion" (Province of Nova Scotia, n.d.).

Federal Leadership

Federal leadership is raised in a few plans in ways that could strengthen NbS in Canadian municipalities. Saskatoon highlights "recent federal investments in natural area protection and urban forestry" as potential opportunities for Saskatoon to "strengthen these areas" in relation to GI (Saskatoon, 2020, p. 120). Calgary's climate plan notes that Infrastructure Canada "has identified natural infrastructure as a critical element of climate adaptation and… [t]he Federal 2017 budget lays out the Government's plan to invest $12.9 Billion in natural infrastructure" (Calgary, 2018, p. 84). Saskatoon's Green Infrastructure Strategy points to the federal target "to protect 17% of Canada's natural areas by the end of 2020", and opportunity to align with this target in coordination with partners (Saskatoon, 2020, p. 85).

Integration of Climate Change and Biodiversity

Overall, the integration of climate change and biodiversity planning results in large Canadian Municipalities varied widely from no integration to extensive. Some municipal plans have moderate to strong use of NbS, but low to no evidence of explicit integration of biodiversity and climate planning. Interviews indicated that on-the-ground practices may differ from the

plans in either higher or lower biodiversity and climate change integration. Despite the extensive integration results for some municipalities, on-the-ground evidence beyond the municipal plans is not part of this study beyond insights for six municipalities from the interviews.

A rating system was used to describe levels of climate and biodiversity integration, factoring in many elements of analysis. Following the environmental scan, a matrix analysis improved data regarding integration such as the number of times and how the term biodiversity or a related term such as diversity (e.g., species or ecosystem) are used in the climate and broader plans or the number of times and how terms related to climate change are used in the biodiversity plans. The analysis factored in specific goals or objectives for biodiversity and climate change and links with specific NbS as well as implementation, monitoring and specific initiatives related to integration (and other related factors). Table 11 outlines the criteria used for ranking NbS use and biodiversity and climate change integration in the environmental scan and matrix analysis. Appendix E provides details of the matrix analysis elements resulting in the integration ranking.

The integration rating results of the plans are outlined in Table 12: none to very low (such as in cases where biodiversity was mentioned once or twice but not as an integrated issue), minor (one or a few areas of minor integration) and integrated. The "integrated" rating includes a range of integration but the usefulness of additional ratings would be limited without additional data. Table 12 shows a broad range of integration in climate plans with 14 plans ranked none to very low, five plans with minor integration and 13 plans ranked integrated. The ranking results of the biodiversity plans are similar and the broader plans were primarily ranked integrated.

Interview Results for Integration

Interview responses align with the findings in Table 12. A few interviewees noted less integration in older plans and higher integration in developing new plans. Considering this, I

Table 11

Climate Change and Biodiversity Integration Measures in Plans of Large Canadian municipalities

Environmental Scan		Matrix Analysis
Levels of NbS Use	**Indicators of Integration/ Mainstreaming**	**Ranking of Integration**
Low: Includes some NbS related activities, but significance within overall strategy appears fairly low. Low details within the plan of NbS related activities. No or low level of specific targeted outcomes within the plan to address co-benefits through NbS approaches.	**Low:** Some indications of integration/ mainstreaming of NbS concepts and approaches within policies and practices	**None to very low:** biodiversity was mentioned once or twice but not as an integrated issue
Moderate: NbS approaches are an integrated element of the strategy of moderate importance or significance. May include a number of different types of NbS approaches. Moderate in specifics regarding NbS targeted outcomes or in general have less developed targeted outcomes.	**Moderate:** Moderate number of elements identified to integrate/mainstream NbS concepts and approaches within policies and practices.	**Minor:** one or a few areas of minor integration
High: NbS approaches are an important part of the strategy. Incorporates different NbS approaches. Targeted climate change/ biodiversity co-benefit outcomes may be identified. Innovated practices may be included. Shows integration or intention to integrate within policies and practices. Clear communication of use and importance. Monitoring/ measuring outcomes included or under development.	**High:** High level of elements and description identified to integrate/mainstream NbS concepts and approaches within policies and practices.	**Integrated:** integration beyond minor integration (broad range)

compared the rankings with the dates of the plans, but overall, I found no broad correlation. Most interviews indicated varying levels of increasing integration including: happening actively since the plan, within a plan under development, facilitated by newer staff, occurring due to policy changes and as a result of new funding. Interviewees A and D indicated (despite NbS initiatives)

Table 12

Climate Change and Biodiversity Integration in Municipal Plans

Integration	**Municipal Climate Plans**
None to very low	Edmonton, Ottawa, Brampton, Hamilton, Burlington, Sudbury, Coquitlam, Kelowna, Cambridge, Kingston, Waterloo, Thunder Bay, Brantford, Red Deer
Minor	Calgary, Mississauga, Winnipeg, Vancouver, Kitchener
Integrated	Montreal, Surrey, Halifax, Saskatoon, Windsor, Oakville, Richmond Hill, Barrie, Langley, Ajax, Saanich, Clarington, Nanaimo
Integration	**Municipal Biodiversity Plans**
None to very low	Toronto, Calgary, Edmonton, Vancouver
Minor	Delta
Integrated	Surrey, Oakville, Sudbury
Integration	**Broader Plans (Addressing Climate &/or Biodiversity)**
None to very low	Burnaby, Kamloops
Minor	Vaughan
Integrated	Toronto, Mississauga, Brampton, Markham, Saskatoon, Guelph, Pickering

only implicit integration of biodiversity with climate change currently. Interviewee C described moderate levels of integration on the ground but increasing in a coming climate plan. Higher levels of increased integration were noted by the other interviewees from three municipalities. One of the clearest descriptions of integration was from Saskatoon: "… if you look at our strategic planning documents, green infrastructure is mentioned on par with greenhouse gas reductions and we have something called the triple bottom line policy where I'd say… we're trying to minimize trade offs between them, right, and instead maximize co-benefits…"

Extent of Integration

The municipalities that demonstrated the highest integration results from the combined data analysis results for NbS and overall climate and biodiversity co-benefits are: Surrey (British Columbia), Saskatoon (Saskatchewan), Saanich (British Columbia) and Markham (Ontario). It should be noted that interviews indicated the potential of higher or lower actual integration than the content of plans and the results for Saanich and Markham are based only on their plans. The interview results for Surrey and Saskatoon align with this integration result. Municipalities next highest in their extent of NbS use for climate and biodiversity co-benefits are all from the province of Ontario: Windsor, Richmond Hill, Mississauga, Brampton, Ajax, Guelph, Oakville and Barrie.

Inconsistencies between levels of NbS use and integration of biodiversity and climate change are highlighted in the findings for extent of integration. A number of municipalities were identified as having high use of NbS, but minimal to almost no mention biodiversity: Halifax (slightly higher), followed by (in order of size): Toronto, Vancouver, Thunder Bay, and Nanaimo. However, Barrie's climate plan is an example of a moderate (middle) NbS use, but in the second highest findings for integration. In addition, some climate plans have lower levels of NbS use and integration than another plan from the same municipality (e.g., broader sustainability plan) included in this study. Of the municipalities identified with indications of the highest levels of integration, this was the case for Saskatoon, Mississauga and Brampton.

Biodiversity Monitoring

In addition to the results for biodiversity and climate change integration, an additional key consideration is the inclusion or level of biodiversity monitoring. Biodiversity monitoring is an important factor in actual integration and the potential of international standards being met by

NbS initiatives. All plans in Table 12 listed as "integrated" were further assessed for monitoring as shown in Table 13. The strongest plans for biodiversity monitoring are Surrey's plans and broad plans from Brampton, Guelph and Pickering. Biodiversity monitoring identified overall includes: monitoring specific biodiversity elements, reporting indicators or targets, success or performance measures, establishing long-term monitoring baselines and a monitoring framework. "Included or prioritized" in Table 13 indicates active monitoring and monitoring prioritized for development.

Biodiversity monitoring descriptions from the interviews generally align with the results in Table 13. Biodiversity monitoring discussed fit the "none to very low" category in Halifax and wasn't mentioned for the Saskatoon climate plan. Interviews with Surrey and Saskatoon staff indicated biodiversity monitoring being developing and/or prioritized for both of Surrey's plans and for Saskatoon's Green Infrastructure Strategy. For Mississauga, the broader plan was not

Table 13

Biodiversity Monitoring in Plans rated as "Integrated" for Biodiversity and Climate Change

Indications of Monitoring	**Municipal Climate Plans**
None to very low	Montreal, Halifax, Saskatchewan, Richmond Hill, Langley, Ajax
Minor or not strong	Nanaimo
Included or prioritized	Surrey, Windsor, Oakville, Barrie, Saanich, Clarington
Indications of Monitoring	**Municipal Biodiversity Plans**
Included or prioritized	Surrey, Oakville, Sudbury
Indications of Monitoring	**Broader Plans (Addressing Climate &/or Biodiversity)**
None to very low	Toronto
Included or prioritized	Mississauga, Brampton, Markham, Saskatoon, Guelph, Pickering

able to be addressed in the interview. Kelowna and Calgary are not represented in Table 13, but in the Calgary interview, examples of partnerships for biodiversity monitoring were described.

Barriers and Opportunities

The interviews provided insights regarding what is actually occurring (beyond what is evident in the plans), integration barriers and opportunities. The overall results of the interviews could be summarized as including descriptions of ongoing increases in integration, planning for integration and integration occurring within specific projects. In general, the interviewees described a fairly equal balance of barriers and opportunities regarding biodiversity and climate change integration.

Municipal staff descriptions regarding what is actually happening "on-the-ground" were overall fairly in-line with their plans, with a few exceptions. In Halifax there may be a bit less explicit integration at this time than described in the plan, but the plan is fairly new. In Calgary, the integration is described as advanced from the 2018 plan which will be reflected in an upcoming new plan and is described as reflected in current projects, pilot projects and supported by new staff. Kelowna's climate plan identified only one NbS and does not integrate biodiversity and climate change, however, current initiatives and a newly developing plan in Kelowna were described as increasing NbS and beginning some integration. In Mississauga, the climate plan includes moderate levels of NbS and minor integration which was fairly in-line with the results of the interview. In Surrey, both plans are very strong for integration and though some challenges were reflected in the interviews, overall, the intention for integration seems strong and continuing to develop on-the-ground. Finally, Saskatoon interviews indicated NbS and biodiversity integration with climate change appears to be at a fairly high level, or developing, which is reflective of the plan analysis.

During the interviews, many challenges or barriers were highlighted in regards to integration and use of NbS, along with opportunities. Table 14 identifies challenges and the number of municipalities corresponding to challenges raised by municipal staff. Conflicting priorities were identified as challenges, such as described by Interviewee A, who noted: "I think we're still kind of stuck in this idea that in order to do nature-based things we're going to have to sacrifice… room for housing – is usually what it comes down to. There is this big housing crisis that looms over every discussion…". Challenges related to provincial policies were raised by three interviewees, with one flagging municipal conservation challenges due to provincial legislation, describing: "…it is easier for proponents to remove a wetland and pay compensation than to disturb a wetland and provide restoration or compensation". As noted in Table 14, staff capacity, buy-in and awareness was the most common challenge identified. Interviewee F

Table 14

Interviews: Challenges for NbS and Biodiversity/Climate Change Integration

# of Municipalities	Challenges
5	Staff capacity and awareness
3	Funding Provincial policies hampering municipal wetland preservation/ restoration Integration on-the-ground depending on other departments
2	Nature vs housing challenges The need for evidence-based examples or information Older plan not reflective of current/developing practices or politics Difficulties changing how staff have historically done their work
1	Political changes Lack of precedence and experience Biodiversity viewed as a provincial issue NbS are harder to measure for reporting Biodiversity integration limited by background of staff re: plan development Biodiversity is not necessarily an internal driver for the municipality Potential conflict of internal priorities with city acting as land developer

described internal decision-making where staff want more "tangible evidence" in regarding new NbS-related approaches and that "there's an expectation that somebody else is going to pay for it if it is not something they normally do… or maintain it". This interviewee also noted "it's normal in any institutional culture… that there's a bit of hesitancy in doing something differently just because its different". Interviewee H related similar experiences: "…combating that attitude of 'we've always done it this way, why do we need to change?' you know, because there's a lot of long-term people …and it's hard to change some of those attitudes sometimes".

Opportunities for integration (or increased) and NbS (or expansion) were also described by interviewees. Table 15 identifies the opportunities raised, indicating the number of municipalities represented as noted by staff. Interviewee B described NbS pilot projects "…have really demonstrated success" and "I think we've got some momentum building". Interviewee D noted regarding NbS: "I think it kind of links a lot of wins from different strategic focus areas and so its beneficial in the sense that you're not going to have… leadership turning down a lot of those like nature-based solutions because it does offer so many win-win-wins."

New Plans

As this study was lengthy, a quick scan was conducted at the end of new climate-related plans in municipalities without climate plans identified in this study. Recent related plans were identified for Richmond (BC), St. Catharines (Ontario) and Strathcona County (Alberta), referenced in Appendix C. These plans appear to be consistent with the overall findings of this study. The NbS term was found once in Richmond's Climate Actions Program report (n.d.), one reference in St. Catharine's adaptation plan (2021) in a description of ICLEI (Local Governments for Sustainability) and in a number of locations in Strathcona's sustainability plan (Environmental Framework: Renewing Our Future, 2021), which includes climate and

Table 15

Interviews: Opportunities for NbS and Biodiversity/Climate Change Integration

# of Municipalities	Opportunities
5+	Natural Asset initiatives & municipal asset management system integration Pilot projects
4	Partnerships New funding A new plan coming that will increase NbS and/or integration
3	New staff Policy changes (e.g., Official Community Plan/ Municipal Development Plan)
2	GI planning New urban forest plans Increased or new focus on adaptation Increasing buy-in and training for staff increasingly incorporated in other city plans Future mainstreaming of NbS and integration The success of new initiatives that have integrated co-benefits Climate staff included in biodiversity planning initiatives or working group
1	Supportive political shift Triple Bottom Line policy Breaking down internal silos Validation due to new funding staff champion(s) in other department(s) New guidelines and designations in parks Zero-carbon resilience approach increasing NbS New biodiversity initiatives increasing integration Learning from other municipalities/ “peer pressure” (other municipal initiatives) Potential link to increase NbS through the Truth and Reconciliation lens

biodiversity planning. Richmond’s Climate Action Programs report (n.d.) states “[c]limate actions need to employ nature-based solutions, alongside a rapid phase-out of fossil fuel use, to reduce the scale and impacts of climate change, while providing positive benefits for biodiversity and other sustainable development goals”. (Richmond also has a new mitigation plan that was scanned.) Strathcona’s plan includes NbS and Nature Canada’s Nature-based Climate Solutions Programs under listings of strategic initiatives they are considering. Key terms were identified in

the new plans that indicate use (or potential use) of GI, ER, EP and urban forestry/ FLR and possibly other NbS approaches. The term biodiversity was found in all new documents, though ranging from one mention in Richmond's mitigation plan, two mentions in St. Catharine's climate plan to extensively in Strathcona County's sustainability plan.

Discussion

This study looks at the extent that large municipalities in Canada are implementing NbS to address both climate change and biodiversity loss. Extensive analysis was conducted to assess and summarize the different types of NbS being used in these municipalities, descriptions of the elements involved in each NbS (to help understand the extent and methods) and indications of explicit biodiversity and climate change integration overall. In addition, eight interviews provided further insight from six municipalities in five provinces. Overall, the results show NbS are being used in all large Canadian municipalities with plans assessed, to varying degrees and increasing. While four biodiversity plans were not assessed for NbS because of the lack of climate planning tied into the conservation plans, each of those municipalities had another plan (climate or broad) that included NbS. In general, the results show that specific biodiversity planning and monitoring is lower than the overall findings for NbS. This is significant when considering not only the urgent need for integrated solutions (De Lamo et al., 2020; Díaz et al, 2019; Pörtner et al., 2021) but also the international standards that consider this a baseline and important requirement for NbS (Cohen-Shacham et al., 2019; Seddon et al., 2021). The results indicate an increasing trend in the use of NbS and (to a lesser extent) broader integration of biodiversity and climate change in large Canadian municipalities has been occurring in recent years. Based on the interviews, this trend is anticipated to continue to increase with new plans, policies and initiatives currently unfolding. A critical question from these results is: does the

extent of integrated approaches and the rate of shift to integrated planning and practices align with the critical needs articulated internationally regarding these urgent interconnected crises?

Nature-based Solutions in Canadian Municipalities

The wide variety of results, approaches and terminology in the municipal plans of this study showed that NbS as a defined umbrella concept and approach has yet to become clearly established in the practices of Canadian municipalities. The term "nature-based solutions" was found in only one of the assessed plans: Toronto had a minor note that they participated in a NbS exchange with 8 cities hosted by Milan (Toronto, 2019). Saskatoon's adaptation strategy (2019, p. 3) also referred to the importance of "nature-based adaptation". The use of the IUCN typology as a commonly used framework to describe NbS was helpful in describing different types of NbS used by large Canadian municipalities using a common language, but it also highlighted the general lack of shared language in the plans. That said, the concepts are present and developing overall, along with the current use of individual types of nature-based solutions. Studies of municipal use of ecosystem-based adaptation as a NbS in climate plans found similar results, including Zölch et al. (2018) finding no use of the EbA term in 34 German municipalities and Cousiño and Penha-Lopes (2021) finding EbA was not an explicit objective of municipal plans in Portugal, though both studies noted most plans included indirect references to elements of the concept. In contrast to Cousiño and Penha-Lopes (2021), though this study did not find explicit descriptions of the NbS concept, NbS elements or categories are found as explicit objectives in some Canadian municipal plans. In addition, a few Canadian plans highlighted GI or NI as a larger concept that seemed to lean towards the umbrella NbS concept, describing a few NbS categories within their GI or NI approach or concept.

The lack of shared language can also be linked to the finding of a lack of references to principles and standards that would guide effective NbS practices. Considering that NbS principles and standards of practice can reduce the risk of negative impacts (Cohen-Shacham et al., 2019; IUCN, 2020; Seddon, 2021) and support well-designed NbS for co-benefits (Seddon, Chausson, et al., 2020), the missing links to principles and standards are a concern regarding increasing the use and effective practices of NbS in Canada. The IUCN describes that without the use of standards, "the application of NbS could result in inconsistent and ungrounded applications", while using standards increases credibility of the interventions, identifies gaps and solutions, provides a common framework and language and allows for adaptive management (IUCN, 2020, p. 2-3). It is possible or likely (but unclear) many of the Canadian municipalities in this study are using standards of practice specific to the individual categories identified, especially well-established practices such as for urban forests and ecological restoration. These individual standards, however, would not necessarily include the elements or criteria that make these approaches a NbS for addressing multiple societal challenges, including climate change and biodiversity loss. The use of standards, criteria and other best practices in NbS approaches are critical for success.

The importance of common language and standards can be illustrated by the ER findings and indicate an area for improvement in municipal plans. ER is one of the most common NbS categories found in all the municipal plans, yet it is rarely defined and not described linking to standards of practice. Reflecting on the quote from the Society for Ecological Restoration (above: Nature-based Solutions for Co-benefits), a lack of understanding of the definition and standards for ER could lead to social and ecological harm from "poorly designed and implemented restoration projects" (SER, n.d.). In some plans the term "naturalization" is used

and in some cases the projects or descriptions suggest ER, but are not explicit. Halifax's climate plan is an exception in including a definition of naturalization, which seems to be aligned with ER and provides some clarity about outcomes: "Naturalization is an ecological approach to landscape management that enhances biodiversity and improves ecosystem health and resilience in an urban environment" (Halifax, 2020, p. 41). The approach or definition of "naturalization" cannot be assumed. Interviewee H clarified the term "naturalization" used by their municipality, noting: "[w]hat we don't really have is a restoration style of naturalization yet and that's something that we'll be looking at expanding". It was also not clear from most of the plans what the targets or outcomes would be for ecological restoration, which may be included in other documents, but without indications in the guiding plan, this may be a limiting factor for effective NbS implementation. It has also been highlighted in the plans and by the interviewees that climate plans especially are implemented within various municipal departments and it raises the question: if elements like this are not defined in the plan, will they be understood in the same way, such as by those implementing the elements?

The NbS approaches identified in the municipal plans using the IUCN typology generally fell within the IUCN categories and descriptions (Cohen-Shacham et al., 2016). Of note, urban forest planning and initiatives may be a unique category considering that Forest Landscape Restoration (FLR) is described in a broader sense regarding deforested landscapes and restoring ecosystem services (Cohen-Shacham et al., 2016). Urban forest planning and initiatives fit within the general description and the IUCN notes that "[i]mplementation can involve different degrees of human intervention, ranging from planting trees to allowing natural processes of forest succession to occur" (Cohen-Shacham et al., 2016, p. 18). However, definitions of urban forests, such as in the Canadian Urban Forest Strategy 2019-2024, illustrate a specific focus:

"trees, forests, greenspace and related abiotic, biotic and cultural components in areas extending from the urban core to the urban-rural fringe." and are further described as addressing unique and varied issues within urban areas (Tree Canada, n.d., p. 6).

Forest Landscape Restoration: Role and Concerns

Forest Landscape Restoration (FLR), the most common category of nature-based solutions in all the plans, is clearly a valued approach in addressing climate change in these Canadian municipalities. FLR is not only the most common category, in 43 out of 50 plans, but detailed, clear planning and outcomes are often included. Mississauga notes in their Natural Heritage and Urban Forest Strategy (2014, p. 23) that "[s]ustaining natural areas, and trees in particular, is widely recognized as one of the most effective approaches to helping communities adapt to many of the impacts associated with climate change." Nanaimo describes, in their climate plan (2020, p. 23) that forests and other natural areas "help buffer the impacts of climate change", specifically "[u]rban forests improve stormwater management by absorbing and transpiring water, while also providing much-needed shade during hot summer days" and that "[p]rotecting and expanding these natural assets is key to improving Nanaimo's resilience". Pickering describes the urban forest in their sustainability plan (2017, p. 11) as including "all trees, shrubs, and understory plants that grow on public and private property in Pickering, as well as the soils that sustain them" and that a "healthy and resilient urban forest benefits the community, as trees absorb carbon dioxide, improve air quality, moderate climate, help control erosion, and provide recreational, health, and social benefits."

While the priority seen in Canadian municipalities for FLR use to address climate change is in line with international priorities and scientific community findings, the lower result for biodiversity integration in this category is a concern. An example of the importance of FLR as

an important and cost effective NbS for climate change is highlighted by the IUCN (2016): citing the New Climate Economy Report by the Global Commission on Economy and Climate. This report states: "[g]overnments, with the support of the international community, should commit to and start the restoration of at least 350 million hectares of lost or degraded forest landscapes through natural regeneration or assisted restoration by 2030", which they estimate will generate "US$170 billion per year in benefits from ecosystem services, and sequester 1-3 billion tonnes of CO2e per year" (New Climate Economy, 2014, p. 54). The Secretariat of the Convention for Biological Diversity identifies FLR initiatives as important for protecting biodiversity and stresses the importance of integrating and ensuring biodiversity planning in FLR approaches, especially in designing afforestation initiatives for biodiversity benefits versus impacts (CBD, 2009). Despite the value and widespread use of FLR, the lower result for biodiversity integration with FLR in Canadian municipalities is a concern considering this is a key element of NbS standards (Cohen-Shacham et al., 2019; IUCN, 2020) and concerns regarding the over-emphasis on tree planting instead of broader ecosystem approaches and failure to ensure biodiversity co-benefits (Seddon et al., 2021). This concern regarding the need to ensure biodiversity co-benefits also applies to all NbS (Cohen-Shacham et al., 2019; IUCN, 2020). The IUCN standards state that "[i]n order to inform the design, monitoring and assessment of an NbS, targets for enhancing key biodiversity values should be established" (IUCN, 2020 p. 10).

Biodiversity Monitoring

Monitoring, especially for biodiversity outcomes, is a critical missing element in most plans and is an indicator of the lack of use of NbS standards of practice. Monitoring is an important element of NbS to ensure co-benefits, to enable adaptive management and measure progress (Cohen-Shacham et al., 2019; Morecroft et al., 2019) and is essential in the standards of

practice developed by the IUCN (2020). One of the eight criteria in the IUCN standards of practice sets the baseline standard that "NbS result in a net gain to biodiversity and ecosystem integrity", describing monitoring for unintended consequences and that "[c]lear and measurable biodiversity conservation outcomes are identified, benchmarked and periodically assessed" (IUCN, 2020). Cohen-Shacham et al. (2019, p. 27) state that "monitoring programs must be institutionalized within organizations and stakeholder groups that manage a particular landscape, to achieve a broad range of social and environmental benefits". The results in Table 13 provide insight into the level of monitoring occurring or planned in municipalities that are integrating climate and biodiversity planning. Only six of these municipal climate plans include biodiversity monitoring with NbS in their plans, but it is unknown what is actually occurring. An illustration of both the challenges and the importance of monitoring was captured by the interviewee from Calgary in describing that "the measurement of the pollinators as that indicator of biodiversity improvement has been… staggering, like just unbelievable change", but noted it is "hard and expensive sometimes", noting that they can face trade-offs: a larger project and no monitoring or a smaller project with "really robust monitoring".

Monitoring has been described by municipalities as an area that requires building of internal capacity or is seen as requiring partnerships in order to accomplish. Comments by two interviewees seem to illustrate the current range of monitoring within these Canadian municipalities. Interviewee A described that "[a]s it stands right now, there is not really municipal capacity to do that kind of monitoring but there are a lot of local organizations that do that type of work". This interviewee also noted: "I would say there wouldn't be too many projects that deliberately aim to increase biodiversity" but that "there are definitely projects that do increase biodiversity as a side effect" and that the interviewee's role is to "increase

awareness". The last comment seemed to be in reference to the importance of biodiversity outcomes. Interviewee H reflected on the beginning of monitoring activities in that municipality, noting "all of that is work to be developed, but we're starting to get that expertise and build that capacity within the organization".

Along with biodiversity monitoring is the importance of identifying indicators and/or targets linked with both monitoring and reporting. The development of biodiversity indicators and targets can be a strong element of, or method used, to ensure integration of biodiversity benefits within climate-related initiatives. Frantzeskaki et al. (2019) identified indicators as one of three critical areas for NbS in urban contexts, providing valuable information, such as on trade-offs, which is important for policy decision-making. Panfil and Harvey (2015), in their review of 80 REDD+ (reducing emissions from deforestation and forest degradation) projects from 34 countries, found a lack (and need for) specific goals with quantitative targets and timeframes in order to guide successful implementation and to be able to demonstrate biodiversity benefits or success. In their study of 34 municipalities in Germany, Zölch et al. (2018) found that monitoring is crucial for strategic planning and implementation. Targets and indicators identified for FLR for climate change and biodiversity are included in Table 4 and for EP in Table 9. Other NbS categories include targets and indicators within the category element tables. As described by the IUCN standards, targets for biodiversity values inform design, monitoring and evaluation (IUCN, 2020). Monitoring, targets and indicators are a critical area needed for NbS development and success in these large Canadian municipalities.

Extent of NbS Use and Municipal Integration

The analysis of NbS and the integration of climate change and biodiversity resulted in a ranking of NbS categories used in municipal plans and ranking of municipalities to help describe

the extent of use, the range of practice and the overall levels of integration of climate change and biodiversity. The rankings of NbS category use provides one measure of the extent and types of NbS use in municipalities. The higher NbS results seems to correlate with well-established practices used for various municipal goals: forest landscape restoration (urban forests), ecological restoration, ecosystem protection and green/ natural infrastructure. Geneletti and Zardo (2016, p. 44) also found that the most common measures identified "rely on actions that are part of the standard portfolio that planners have been employing for decades" for a variety of purposes beyond climate change.

The rankings of municipalities in terms of levels of NbS use and integration of biodiversity and climate change may be useful in describing the range of practices across municipalities as well as highlighting some municipalities to observe as potential or current front-runners in these practices. The ranking of municipalities in Table 12 (above: Integration of Climate Change and Biodiversity) helps to describe the overall extent of municipal integration, showing the wide variety of levels of integration across large municipalities. Table 13 (above: Integration of Climate Change and Biodiversity) provided an additional and important evaluation element of "integration", identifying which municipalities ranked as "integrated" have identified biodiversity monitoring (being conducted or as a priority to be developed). Biodiversity monitoring, as noted, is significant in that without it, the benefits of NbS initiatives for biodiversity will be generally unknown, as would unintended impacts. It may be that without monitoring for these outcomes and enabling adaptive management, true integration for biodiversity and climate change may not be able to be achieved. This is aligned with Zölch et al. (2018, p. 974) who found that assessment and monitoring are crucial for EbA mainstreaming and as a "key pathway to effective and sustainable climate change adaptation". The rankings

provided in this study may also serve as a baseline for future research to look closer at the actual implementation and outcomes. This is especially important considering that ranking is based on plan(s) and only two of the highest ranked municipalities (Surrey and Saskatoon) included some verification through the interviews.

Provincial and Federal Leadership

The indications of provincial and federal leadership related to NbS in these plans was generally minor, with the exception of Ontario. A few plans indicated opportunities of federal funding that could support future NbS initiatives in their municipality. The only mention of federal leadership that was explicit to the importance of NbS was from Calgary, noting federal identification of the importance of NI for climate adaptation and plans for NI investments. Considering a recent and distinct rise in federal leadership and investment in NbS in Canada, it would be interesting to see what influence this may have on future municipal plans and approaches. In terms of provincial leadership, no mention of provincial leadership from British Columbia (BC) was alongside the results that found both the lowest and highest use of NbS and integration within BC municipalities. Municipalities from Ontario identified many elements of provincial requirements and leadership in their plans, which may have resulted in increased use of NbS and certainly resulted in increased definitions for elements such as GI (provincially defined and required). In addition, a number of interviewees raised challenges between provincial approaches or regulations and municipal efforts to protect and/or restore wetlands.

In looking at the broad areas of provincial and federal leadership that influenced or were linked in these plans, it seems clear there is an important role to play at the provincial and federal levels to support and scale up this municipal level work. Leadership referenced in the municipal plans included: policies and legislation, funding, provincial planning, guidelines and resources as

well as provincial requirements for municipal practices. Most of these elements were found in the province of Ontario and many of the municipal plans reviewed from that province were more detailed and consistent in their NbS-related approaches and definitions. Considering the challenges that were raised or apparent in NbS-related municipal work, provincial and federal leadership could play important roles in defining and standardizing NbS concepts and approaches, in supporting and even requiring the conservation of biodiversity (and key measures such as monitoring), measures to aid in building staff capacity related to NbS, and providing or supporting professional forums for upscaling and improving NbS in Canada.

Barriers and Opportunities

Identifying and addressing barriers NbS in municipalities is critical for success and increased uptake (Sarabi et al, 2020), but it seems that identifying key opportunities for adoption and upscaling of NbS are also likely important to success. Barriers in this study generally aligned with the barriers identified by Sarabi et al. (2020). Barriers were not systematically identified and prioritized in this study, through the identification and perceptions of barriers by staff interviewed provides interesting insights. Results of the interviews also identified opportunities for increasing and improving the use of NbS, which in some cases aligned with the barriers. The barrier mentioned by the most interviewees was staff capacity and awareness. This issue linked with discussions related to the knowledge and skills of staff in adopting and implementing NbS, the internal capacity for monitoring initiatives, the background of staff who wrote the plans assessed (noted by a few related to lack of biodiversity and climate change integration), and the challenge of climate plans being implemented across different departments was raised as a barrier related to capacity and awareness. Overall, some interviewees described current actions to address barriers, while other barriers identified have yet to be addressed.

Opportunities raised in the interviews were closely related to or in response to barriers. Some of the opportunities identified by interviewees could be linked to the staff capacity and awareness barrier, including the ability to increase NbS use and success through partnerships, new staff, increasing buy-in and training for existing staff, the inclusion of climate staff in biodiversity-related planning, breaking down internal silos, identifying staff champion(s) in other department(s) and learning from other municipalities. Evidence-based examples were raised by two interviewees as barriers and aligned with the opportunities related to pilot projects (providing evidence-based examples and trials) raised in interviews from at least five municipalities. In connection with pilot projects, one interviewee discussed opportunities related to incorporating traditional knowledge and in exploring what role Indigenous Peoples might want to play in their Green Network, while another interviewee mentioned equity and Indigenous Peoples in a future project and a third interviewee highlighted increased relationships within a current project. Opportunities such as this can be further considered in alignment with international standards, such as those related to consent and engagement with Indigenous Peoples and local communities (Reed et al., 2022; Seddon et al., 2021).

One particular area of opportunity that was repeatedly raised in interviews and identified frequently in the document analysis was the use of and planning for natural asset management. All interviewees indicated that their municipality is working on some level of natural asset management approaches (or recently completed first steps such as an inventory). Many interviewees identified natural asset management as having a great potential for increasing integrated approaches and the use of NbS.

Political barriers and opportunities were raised in this study, but would benefit from further exploration. Sarabi et al. (2020) identify political barriers as critical and affecting all

other barriers in their study. The responses of the interviewees in this study included political barriers, but to a lesser degree. This may have been due to perceived sensitivities of staff not wanting to mention politics or just more of a focus on their own work. At any rate, barriers raised included nature vs housing issues that linked to politics, an older climate plan potentially in conflict with current politics and in general political changes reducing support. One interviewee raised opportunities for expanding NbS related to a supportive political shift. This is an important element related to challenges and opportunities for NbS and includes various levels of politics and the Canadian context.

Priorities in Canadian Municipalities

Climate change and biodiversity loss are not given equal importance in large Canadian municipalities. Considering the number of climate plans and level of climate planning and funding commitments indicated within the plans, as well as associated staff that are apparent within the plans and through the interviews: the challenge of biodiversity loss appears to be far less a priority overall for large Canadian municipalities. The majority of the municipalities have at least one climate plan and some had multiple plans, yet only eight biodiversity strategies were identified out of 61 municipalities and only four linked with climate planning (as well as some of the broader plans that include biodiversity as an objective). The stated goals and objectives of NbS in the municipal plans were by far more extensive and detailed for climate change than for biodiversity, if biodiversity was included at all. In these municipal plans, monitoring and reporting on climate change indicators and actions is a high priority, with biodiversity monitoring and reporting much less common. Of the municipalities that indicated higher climate and biodiversity integration as well as some level of biodiversity monitoring, many appear to be struggling or delayed in developing approaches for biodiversity monitoring based on the analysis

of the interviews along with the plans. It may be safe to assume that the different levels of importance between climate change and biodiversity loss in these municipalities includes significantly different allocations in funding and resources. This disparity in resources, planning and action for biodiversity is critical considering the broad and increasing agreement that

Canadian municipalities are on their way to incorporating the NbS concept and importance, which may be increasing and translating to integrated approaches. Halifax's climate plan (2020, p. 43) includes a sidebar feature titled "Conservation and Climate Action: The Perfect Pairing", which states that "[w]e will not succeed in addressing climate change if we do not protect and enhance the natural environment we depend on for survival". This feature goes on to note that "[n]atural areas like forests and wetlands produce oxygen, filter the air we breathe, clean our drinking water, hold flood waters, regulate climate and absorb carbon dioxide, a greenhouse gas" and notes the importance of assigning value for natural assets and their services helps with "cost benefit analyses and decision-making". Markham's sustainability plan (2011, p. 16) describes that "[w]hen a positive action is taken in one area of the system, such as protecting biodiversity through habitat conservation, the action ripples through the rest of the system to help conserve cultural landscapes, protect water resources, sequester carbon, clean the air and provide recreational amenities". Oakville's biodiversity strategy (2018, p. 27) is clear:

> "Biodiversity and climate change are closely interconnected. While climate change seriously threatens Oakville's biodiversity, healthy habitats that support biodiversity improve Oakville's resilience and adaptability to a changing climate through the ecosystem services they provide. Consequently, conserving and sustainably managing biodiversity is an important part of addressing climate change."

Conclusions and Recommendations

The question this study explored is timely: to what extent are large municipalities in Canada implementing nature-based solutions to address both climate change and biodiversity loss? The in-depth review of municipal climate and biodiversity-related plans as well as municipal staff interviews provides measures of the extent and detailed insights. The broad answer to this question is that Canadian municipalities are using NbS, but to greatly varying degrees and the larger umbrella concept and standards are still unclear in municipal planning and practices. Despite this, there appears to be an increasing trend in favour of NbS approaches along with integration of climate change and biodiversity planning.

The urgency of the twin crises of climate change and biodiversity is clear, as is the role and importance of NbS approaches in addressing the crises. While many Canadian municipalities have been historically using some of the practices within the NbS umbrella concept, the actual NbS concept and how it is applied within these practices needs to be clarified and standardized in municipal practices. There are also "newer" practices to incorporate, such as EcoDRR. Without clarifying and expanding these concepts and approaches, it is likely that municipalities could fall short of meeting the intended outcomes and avoiding unintended negative outcomes.

Overall, Canadian municipalities are not yet meeting the urgency of the international calls for action and standards related to NbS. Through this study, key recommendations were identified to address this. It is recommended that, overall, Canadian municipalities need to address the lack of focus and resources on addressing the biodiversity crisis, which also falls short of NbS standards and measures of success. Biodiversity monitoring is an important element currently missing in the majority of municipal approaches reviewed and is critical to enabling adaptive management and actually achieving this co-benefit. Increasing understanding of municipal barriers or challenges to NbS would be an important step forward, as well as

identifying and building on opportunities to pilot and scale up approaches. Political barriers have been identified as affecting all other barriers (Sarabi et al, 2020) and should be a priority to address towards future success. Indigenous leadership, knowledge, partnerships and reconciliation are important elements and principles of NbS to build on in Canada. In addition to these recommendations, municipalities need support and partnerships in order to quickly build capacity and scale up NbS practices, including from the federal government and provincial governments. Addressing these unprecedented global challenges requires unprecedented changes in municipal practices and policies.

Limitations and Future Research

While this study provides new insights and recommendations regarding NbS within Canadian municipal practices, the limitations of this study are important to consider and highlight opportunities for next steps and future research. One of the clearest limiting factors of this study was language. Within the plans that met the study criteria, the terminology used included variations in meaning and application, such as the terms green infrastructure and natural infrastructure. While the document analysis aimed to identify and describe the meanings and applications of terms, especially in plans where definitions are not included, some documents provided very limited or even no descriptions or applications of terms. This lack of common language impacted the analysis results but also indicated the lack of a developed NbS concept and related terminology in Canadian municipalities.

This broad environmental scan designed to gain understanding of the extent of NbS use and integration was limited in the depth of the information that was possible to review. A greater understanding of the current use and practices related to NbS in Canadian municipalities could be gained from future case study research to look deeper into other related documents,

implementation and perspectives of multiple staff per municipality. As this study can serve as a baseline of information, the municipalities that appear to be leading in NbS and integrated approaches would be an excellent start for in-depth research.

Within this study, the use of NbS principles and standards was not evident. This was a limiting factor for identifying the actual use of NbS approaches. Along with the case study recommendations above, further research on whether or not principles and standards are being used by municipalities for NbS would be helpful, along with what specific needs municipalities have in order to scale up the use of principles and standards. This information may be important for the development and clarity of the concept and practices in Canada.

While barriers and opportunities were identified through the document analysis and especially the interviews, a systematic assessment of barriers and/or opportunities was not part of this study and would be valuable for future research. Better understanding of barriers, as noted, is important for increasing uptake and success (Sarabi et al, 2020). Building on the understanding of barriers and opportunities within the Canadian context could be helpful to municipalities as the call for action and further development of NbS and integration increase.

Natural asset management was highlighted by all interviewees and is a current area of development in Canada. Natural asset management has been a more recent and quickly unfolding area of work for municipalities. Research to understand how this is being used and the outcomes (or potential) in relation to these approaches would be very helpful to municipalities as well as how it could effectively link with indicators and targets.

A critical part of this study was the identification of the challenges (and the need for) biodiversity monitoring, indicators and targets to ensure success and enable adaptive management in these integrated approaches. The depth of this study was limited in terms of the

level of understanding about what monitoring is actually occurring, how it is being done and whether or not the results are being used for planning and adaptive management. Indicators and targets are a critical linked element and the interest in sharing ideas and results of these approaches was highlighted in the interviews. Research on these practices in municipal settings related to biodiversity and NbS could be important in supporting the development of these critical practices.

The impacts of provincial and federal leadership and requirements linked with NbS was not an in-depth and systematic element of this study, but indications from the plans show that this likely has an effect on municipal use of integrated approaches and NbS. Results from Ontario indicated there may be higher levels of NbS use and common definitions, such as for green infrastructure, due to provincial requirements and leadership. Some plans indicated opportunities to engage in or increase NbS due to provincial or federal funding opportunities. Future research looking at provincial and federal leadership related to supporting and enabling municipalities regarding NbS and integration would be helpful in the efforts to scale-up NbS.

Recommendations for Municipalities

Municipalities facing urgent societal and environmental challenges cannot continue with business-as-usual in the face of crises such as climate change and biodiversity loss. As these and other challenges are interconnected, it is clear that integrated planning and approaches are required for success. As climate change has become a critical focus and area of funding for municipalities, the interconnected biodiversity crisis must also be a critical focus and funded priority.

As the use of NbS increases, effective practices and integrated approaches in Canadian municipalities requires common language, clearer concepts and the use of NbS principles and

standards. In line with recommendations from Geneletti and Zardo (2016), this study also shows that measures are needed to make NbS more explicit and detailed for implementation. Municipal plans need greater detail and definitions for NbS to clearly communicate and guide the processes implemented across sectors or departments. As interest in and use of NbS increases, employing NbS standards and principles can provide increased understanding of NbS, minimize risks to nature, eliminate actions detrimental to biodiversity being identified as "NbS" and increase effective integrated practices overall (IUCN, 2020). Included in the standards, measurable results for biodiversity are critical through effective monitoring and carefully developed indicators and targets. Currently many of the municipalities in this study are primarily assuming implicit benefits for biodiversity, if it is considered at all. Monitoring, indicators and targets are important for municipalities to use adaptive management for long-term success and ensuring co-benefits.

Along with the recommendation to increase the development of the NbS concept in Canadian municipalities, is the recommendation to increase the use of different NbS approaches, such as those found in this study to be under-utilized: CAS (Climate Adaptation Services) and EcoDRR (Ecosystem-based Disaster Risk Reduction). The importance of biodiversity outcomes in these and other NbS approaches is not only important, but also a basic principle and standard. Well-established municipal practices, such as urban forestry, will require incorporation of new planning and standards when used as a NbS, including the integration of biodiversity outcomes.

Overall Canadian municipalities are not (yet) responding at the level needed and being called for to effectively address climate change and biodiversity through integrated approaches. Despite this, a growing practice within the NbS concept is apparent and some municipalities are emerging as leaders. As noted, a systematic assessment of barriers to NbS and integration could increase practices and effective solutions in Canadian municipalities. Identifying and linking

barriers with key opportunities could help to bridge the gaps. As noted by Sarabi et al. (2020), barriers such as the critical political barriers they identified, along with 14 others and their interdependencies, need to be understood at deeper levels in order to be reduced. Municipalities can work together to address barriers and capitalize on opportunities. Issues such as staff capacity and awareness can be addressed through the active development of municipal practices related to NbS and integrated approaches. It seems clear from the interviews in this study that municipal staff are interested in learning from other municipalities as they develop their own practices. As urgency and calls for action increase in this area of work, municipalities would benefit from forums where they can learn from and support each other. This call must also be answered by elected officials, considering political barriers are found to affect all other barriers for uptake of NbS (Sarabi et al, 2020) and as a key factor in the lower focus on and resources for biodiversity action.

Recommendations for NbS Guidelines and Support

Considering the unique role and needs of local governments in the planning and implementation of NbS and the findings of this study regarding the need for clear and consistent concepts and standards, it seems that resources are needed that specifically guide and support local governments in this work. In addition, further development of categories or sub-categories such as related to urban forestry may serve to better guide this work. Building on all the excellent work through international agencies and the scientific community, local government-tailored resources and guidelines could help increase the use of common language and definitions as well as translate or enable guidelines, standards and other key information to be more accessible to the needs of local governments who face so many competing priorities.

In Canada, scaling up the use of NbS through municipal engagement and support could be facilitated by increases in federal and provincial level leadership. Integrated approaches and NbS at the municipal level can be guided and supported by federal and provincial policies and legislation, funding, guidelines and resources. A recommended priority is for the development of regional and national forums for sharing, learning and collaborative action.

Closing Summary

Considering the growing scientific consensus (IUCN, 2020) that "nature is essential for human existence and good quality of life" (IPBES, 2019, p. 10), and that biodiversity and climate change are "deeply interwoven" (Seddon, Chausson et al., 2020, p. 1) critical challenges that cannot be effectively addressed without integrated solutions (IPBES, 2019; The World Bank, 2019): NbS are essential for addressing these crises. Recent research has been increasing rapidly, supporting knowledge and implementation of NbS, including how implementation is vital and unfolding in urban areas. Despite the growing understanding of the importance of integrated strategies to address the critical and interconnected threats of biodiversity loss and climate change (CBD, 2009; De Lamo et al., 2020; Díaz et al, 2019; Mant et al., 2014; Pörtner et al., 2021), only 30% of Canadian municipalities with plans in this study are taking, or indicate they are planning to take, integrated approaches, including some level of biodiversity monitoring. Canadian municipalities are using (or starting to use) NbS, but the broader concepts and best practices are still emerging in municipal planning. The international call to action for integrated and effective climate change and biodiversity solutions must be answered.

There is a clear trend in Canadian municipalities leaning in to answer these challenges and the global NbS call to action: the question is how to get there quickly and effectively. This study has provided the first broad measure and description of the extent of nature-based solutions

being used by Canadian municipalities. The recommendations reflecting on current research and this new information include measures needed to clarify, standardize and upscale NbS in Canadian municipalities. Meeting these challenges calls for new integrated approaches, partnerships and innovative leadership as well as engagement at all levels: within communities, regions, provinces and at the national level. The great news is that nature-based solutions are especially effective because there are so many co-benefits - and hopefully that means making the "win-win-win" case will get easier and easier in Canadian communities. As the world faces critical global tipping points (IPCC, 2022), municipal leadership and action are essential.

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Appendix A: Municipalities & Plans Reviewed

Municipalities and Plans Reviewed January 2021 to January 2022

Municipality	Population 2020*	Document(s)
Toronto, Ontario	2,988,408	Toronto's First Resilience Strategy (2019); Wild, Connected & Diverse: A Biodiversity Strategy for Toronto, (2019)
Montreal, Quebec	1,821,070	Climate Plan 2020-2030
Calgary, Alberta	1,361,852	Climate Resilience Strategy: Mitigation & Adaptation Action Plans (2018); Our BiodiverCity: Calgary's 10-year biodiversity strategic plan (2015)
Edmonton, Alberta	1,047,003	Climate Resilient Edmonton: Adaptation Strategy and Action Plan (2018); Natural Connections Biodiversity Action Plan (2009)
Ottawa, Ontario	1,043,130	Climate Change Master Plan (2020)
Mississauga, Ontario	774,116	Climate Change Action Plan (2019); Natural Heritage & Urban Forest Strategy (2014)
Winnipeg, Manitoba	766,894	Climate Action Plan (2018)
Brampton, Ontario	713,463	Community Energy and Emissions Reduction Plan (2020); Natural Heritage & Environmental Management Strategy (2015)
Vancouver, British Columbia (BC)	697,266	Climate Change Adaptation Strategy: 2018 Update & Action Plan; Biodiversity Strategy (2016)
Surrey, BC	598,530	Climate Adaptation Strategy (2013); Biodiversity Conservation Strategy (2014)
Hamilton, Ontario	581,722	Corporate Air Quality & Climate Change Strategic Plan Phase II (2008)
Québec City, Quebec	550,326	(No plans available in English)
Halifax, Nova Scotia	448,231	HalifACT: Acting on Climate Together (2020)

Municipality	**Population 2020***	**Document(s)**
Laval, Quebec	442,648	(No plans available in English)
London, Ontario	430,828	(Climate plan under development)
Markham, Ontario	351,163	Greenprint Sustainability Plan (2011)
Vaughan, Ontario	331,572	Green Directions Vaughan (2019)
Gatineau, Quebec	290,239	(No plans available in English)
Saskatoon, Saskatchewan	280,174	Corporate Climate Adaptation Strategy: Local Actions (2019); Saskatoon's Green Infrastructure Strategy: Towards an Interconnected Green Network (2020)
Kitchener, Ontario	267,665	Kitchener Changing for Good: Our Corporate Climate Action Plan (2019?)
Burnaby, BC	257926	Burnaby's Environmental Sustainability Strategy: A Plan for Burnaby's Green Future (2016)
Longueuil, Quebec	252,828	(No plans available in English)
Regina, Saskatchewan	238,503	(No plans available meeting the criteria)
Windsor, Ontario	235,428	Climate Change Adaptation Plan (2020)
Oakville, Ontario	217,718	Climate Change Strategy - Technical Report (2014); Oakville Strategy for Biodiversity (2018)
Richmond, BC	216,046	(Climate Action Strategy planned)
Richmond Hill, Ontario	208,052	Climate Change Framework (2020)
Burlington, Ontario	193,668	Climate Action Plan (2020)
Oshawa, Ontario	178,893	(No plans available meeting the criteria)
Sherbrooke, Quebec	171,158	(No plans available in English)
Sudbury, Ontario	168,927	Greater Sudbury Community Energy and Emissions Plan (2019); Living Landscape: A Biodiversity Action Plan for Greater Sudbury (revised 2018)

Municipality	Population 2020*	Document(s)
Abbotsford, BC	161,581	(No plans available meeting the criteria)
Barrie, Ontario	153,411	City of Barrie Climate Change Adaptation Strategy (2017)
Coquitlam, BC	152,734	Climate Adaptation Strategic Plan (2020)
Lévis, Quebec	149,929	(No plans available in English)
Saguenay, Quebec	147,410	(No plans available in English)
Kelowna, BC	146,127	Our Kelowna as We Take Action: Kelowna's Community Climate Action Plan (2018)
Guelph, Ontario	145,379	(Climate plan under development) Natural Heritage Action Plan (2018)
Cambridge, Ontario	141,809	City of Cambridge Climate Adaptation Plan (2019)
St. Catharines, Ontario	141,490	(No plans available meeting the criteria at time of environmental scan, see Appendix C)
Whitby, Ontario	140,950	(Developing climate and sustainability plans)
Trois-Rivières, Quebec	140,420	(No plans available in English)
Kingston, Ontario	135,707	Kingston Climate Action Plan (2014)
Milton, Ontario	133,812	(Climate plan under development)
Langley, BC	133,302	Climate Action Strategy (2021) (Biodiversity plan under development)
Ajax, Ontario	132,251	Ajax Climate Risk and Resiliency Plan (2019)
Saanich, BC	125,107	Climate Plan: 100% Renewable and Resilient Saanich (2020); (Biodiversity plan under development)
Waterloo, Ontario	123,358	City of Waterloo Corporate Climate Change Adaptation Plan (2019)

Municipality	**Population 2020***	**Document(s)**
Terrebonne, Quebec	119450	(No plans available in English)
Thunder Bay, Ontario	112,602	Climate Ready City: Climate Adaptation Strategy (2015)
St. John's, Newfoundland and Labrador	111,663	(Climate plan under development)
Delta, B.C.	111,281	(Climate plan under development) Birds & Biodiversity Conservation Strategy (2018)
Brantford, Ontario	106,998	Corporate Climate Change Action Plan (2020)
Red Deer, Alberta	106,736	Climate Change Adaptation Plan: City of Red Deer (2014)
Chatham-Kent, Ontario	106,216	(Climate plan under development)
Strathcona County, Alberta	103,187	(No plans available that meet the criteria)
Clarington, Ontario	101,725	Corporate Climate Change Action Plan (2021)
Nanaimo, BC	101,336	Climate Change Resilience Strategy (2020)
Lethbridge, Ontario	101,324	(No plans available that meet the criteria)
Kamloops, BC	101,198	Sustainable Kamloops Plan (2010)
Pickering, Ontario	100,668	2017 Measuring Sustainability Report: Reporting on key indicators of sustainability in Pickering

*Statistics Canada, 2021

Appendix B: Municipal Plans Outside Criteria

Municipal Plans Assessed as Outside Criteria

Municipality	Document	Outside Criteria
Montreal, Quebec	Ville de Montreal Biodiversity Report (2013)	Report, not a plan
Ottawa, Ontario	Greenspace Master Plan: Strategies for Ottawa's Urban Greenspaces 2006	Biodiversity is more of a minor descriptor vs a key purpose or objective of this plan. No mention of climate change.
Halifax, Nova Scotia	Halifax Green Network Plan (2018)	Biodiversity is not a key purpose
Windsor, Ontario	Windsor Environmental Master Plan (2017)	Biodiversity is only mentioned 2x, not a key purpose
Richmond, British Columbia	Community Energy and Emissions Plan 2020-2050 Directions (2019)	Report to Council, not really a plan; previous 2014 plan has no NbS connections
Richmond, British Columbia	Ecological Network Management Strategy (2014)	Biodiversity is not a purpose
Oshawa, Ontario	Corporate Plan to Reduce Greenhouse Gas Emissions, Energy Consumption and Costs (Report to Council 2016)	Report to Council, not a plan
Thunder Bay, Ontario	Earthcare Sustainability Plan 2014-2020	Not a municipal plan, although supported, it is noted by the municipality to represent “ideas and concerns”.
Red Deer, Alberta	Environmental Management Plan (2019)	Biodiversity is not a purpose, but does call for a biodiversity plan
Chatham-Kent, Ontario	Natural Heritage Implementation Strategy (2014)	References to this strategy, but not available on the website

Municipality	Document	Outside Criteria
Strathcona County, Alberta	Strathcona County's Environmental Sustainability Framework (2009)	No mention of biodiversity or climate change
Strathcona County, Alberta	Conservation of Biological Diversity Policy	Not a plan: a very short policy with broad statements and goals
Lethbridge, Alberta	Environment and Historic Resources Strategy (undated: 2018 or 19?)	Not actually a plan with actions: background information and recommendations to update their Municipal Development Plan

Appendix C: New Municipal Plans

New Municipal Climate-related Plans (developed after Environmental Scan initiated)

Municipality	Document	Notes
Richmond, BC	Community Energy and Emissions Plan 2050 (2022)	Only current climate "plan" found
Richmond, BC	Climate Action Programs (n.d.)	Report (undated) on current climate action programs
St. Catharines, Ontario	Preparing for a Changing Future: Corporate Climate Change Adaptation Plan (2021)	
Strathcona County, Alberta	Environmental Framework: Renewing Our Future (2021)	Broader plan including Climate Change and Biodiversity

Appendix D: Interview Questions

Information Focus	Primary Interview Questions	Additional Probes
Understanding the role of the interviewee	1. Can you tell me about your position at the municipality? 2. Does your work include any direct work addressing biodiversity and/or climate change? [Talk about NbS, wide variety of terms used, and what was identified within their plan(s)] 3. Discuss NbS. What NbS related terms and initiatives used in your municipality (especially linked to climate planning and biodiversity)? 4. Are there sections or departments or specific positions identified to lead or implement NbS initiatives?	Length of time as staff with the municipality. Previous position(s) in the municipality? Is the section/ department you work in involved in any of these initiatives? What kind of role have you played in [NbS related] initiatives, such as with planning and implementation? Are there other key staff are involved in NbS related initiatives?
How are NbS initiatives used strategically?	5. Verify what I found related to NbS [general]: current climate action plan (or broader) and if there is a biodiversity conservation strategy 6. Comments about my findings of the types of NbS I found with their plan(s)? 7. What kind of benefits do the NbS initiatives aim to achieve? And how are biodiversity and climate goals integrated (if they are)? 8. Are the types of NbS your municipality is focused on guided by the plan(s) or are their other documents or planning for NbS beyond this/these plan(s)? Are there some planned but not yet implemented?	What was your involvement in these strategies? Are they part of any tracking related to biodiversity or climate change? Has the municipality developed any specific partnerships related to NbS? Have any policies been developed since the plan(s), related to or supporting NbS? How integrated are NbS within municipal processes? Are there any barriers to implementation that are being addressed?
Challenges	These questions need to build on what information has been provided. (I am interested in any challenges that have arose in planning or implementing NbS) 15. Have there been any internal challenges related to NbS such as	[Clarification and more information about whatever is raised] If so, have the challenges been addressed or are they ongoing?

	conflicting views, practices, policies or regulatory tools? 16. Have there been any challenges at the staff level in planning/ implementation? 17. Has there been any political support or inhibitions that have impacted the use of NbS for climate planning and biodiversity conservation? 18. Are there any other key challenges you face with these initiatives? 19. Are there any documents that might help me to better understand some of the challenges or complexities in the NbS initiatives?	If so, how has this supported or inhibited the planning or implementation? (potential: probes about staff knowledge, staffing capacity, conflicting views, etc.) [Depending on answer, another question on how they are or might be addressed]
Opportunities	20. What kind of success and new opportunities have you seen in what has been undertaken so far? 21. Have there been any changes in municipal practices or policies as a result of any of this work? 22. Have any of these initiatives led to increased integration in how biodiversity loss and climate change are addressed within the municipality? 23. Are there any other opportunities you see related to NbS within your municipal work in the future?	[Clarification/ more information as needed to understand] Do you anticipate any future changes? Has it led to any new staff relationships or integration of policies to address these issues together?
Additional Probes as needed	If public/communications were a barrier or resulted in NbS, probes: How have the public been involved in the NbS initiatives being part of your strategic plans? Has the municipality specifically communicated with the public to raise awareness of the NbS initiatives? Have any specific barriers or opportunities been identified related to public involvement?	

Appendix E: Matrix Analysis Elements

Matrix Analysis Criteria or Elements* Reviewed

Criteria/ Element	Description
Terms used	Biodiversity/related terms used in Climate or Broader Plan & Climate terms used in Biodiversity Plan
Specific Goals/ Objectives	Specific biodiversity goals & objectives in NbS within the plans and specific climate change goals & objectives in NbS within the plans. Included: identification of NbS without specific biodiversity or Climate change goals/ objectives
NbS Integration	NbS types in each plan explicitly integrating biodiversity and climate change
Co-benefits	Explicit mention/ descriptions of co-benefits related to NbS
Indicators/ targets	Indicators/ targets within the plan linked or related to NbS
Staffing	Mentions of staffing capacity, needs or plans related to NbS
Linked plans/ documents	Key plans or documents linked to NbS initiatives in the plans
Asset Management	Initiatives and descriptions of asset management linked to NbS
Opportunities	Specific opportunities related to NbS or the future potential of NbS initiatives
Additional Notes	Not captured in the other categories: other notes related to NbS and integration of biodiversity and climate change, including related plans and policies to be developed or updated
Senior Government Links	Provincial requirements or leadership related to NbS. Federal leadership or support related to NbS

*Some criteria or elements include multiple columns within the matrix analysis