Local Government Planning and Maintenance of Ecological Connectivity in a Fragmented Landscape

By

Margaret Grace Bakelaar

A thesis

presented to the University of Waterloo

in fulfillment of the

thesis requirement for the degree of

Doctor of Philosophy

in

Planning

Waterloo, Ontario, Canada, 2025

© Margaret Grace Bakelaar 2025

Examining Committee Membership

The following served on the Examining Committee for this thesis. The decision of the Examining Committee is by majority vote.

External Examiner	Carolyn DeLoyde Assistant Professor, Queens University
Supervisor(s)	Michael Drescher Associate Professor, University of Waterloo
Internal Member	Jeremy Pittman Associate Professor, University of Waterloo
Internal-external Member	Stephen Murphy Professor, University of Waterloo
Other Member(s)	Rob Feick, Associate professor, University of Waterloo

Author's Declaration

This thesis consists of material all of which I authored or co-authored: see Statement of Contributions included in the thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Statement of Contributions

Margaret Bakelaar was the sole author for Chapters 1, 2, and 6, which were written under the supervision of Dr. Michael Drescher and were not written for publication. Input and direction on these chapters was also provided by Dr. Stephen Murphy and Dr. Jeremy Pittman.

This thesis consists in part of three manuscripts written for publication. Exceptions to sole authorship of material are as follows:

Research presented in Chapters 3, 4 and 5:

This research was conducted at the University of Waterloo by Margaret Bakelaar under the supervision of Dr. Michael Drescher. Margaret Bakelaar designed the study with consultations from Dr. Michael Drescher, Dr. Stephen Murphy, and Dr. Jeremy Pittman, who contributed to the formulation of research questions, design of the study, analysis, interpretation, and writing.

Margaret Bakelaar wrote the draft manuscripts, and each co-author provided intellectual input on manuscript drafts. As lead author of these three chapters, I was responsible for contributing to conceptualizing study design, carrying out data collection and analysis, and drafting and submitting manuscripts. My co-authors provided guidance during each step of the research and provided feedback on draft manuscripts.

Abstract

With the continued loss of species and habitat together with the recognition that parks, and protected areas are insufficient to maintain biodiversity, the role of spatial planning to address land use change and account for ecological connectivity is becoming more significant. A well-connected system of natural areas is required to address the continued loss of biodiversity and to reduce threats to human well-being. The value of local governments in providing the spatial planning needed to reduce threats and protect natural areas and ecological connectivity is recognized. The need for a collaborative approach that engages multiple actors including all level of government and non-government organizations is required to implement policy direction on ecological connectivity effectively and efficiently.

This dissertation explores the role of local government land use planning in the protection and maintenance of ecological connectivity through the control of land use change. As ecological connectivity crosses political boundaries, the coordination of local plans across the larger landscape is necessary for effective management of ecological connectivity. This case study research is placed within the Carolinian ecoregion in southwestern Ontario Canada, a recognized area of high biodiversity and intense development.

My dissertation addressed three concerns, (1) the integration of ecological connectivity in local government land use plans; (2) factors that help or hinder the planning and maintaining ecological connectivity; and (3) how local governments interact with other actors in pursuit of ecological connectivity. This is done through three methods of investigation. First a qualitative content analysis of 16 Official Plans in the Carolinian ecoregion was undertaken. Second, 24 interviews were conducted with planning practitioners with thematic analysis applied to

identify influential factors to the planning and maintenance of ecological connectivity. Third intended social interactions were examined in Official Plan policy and past interactions identified from the interviews.

I found that ecological connectivity was consistently addressed in Official Plans through the identification of a natural heritage system, including linkages among natural areas. The policies were however inconsistently applied across the ecoregion with a notable variation between urban and rural areas in applying provincial direction. It was found that the integration of ecological connectivity in local government land use planning: is dependent upon clear and binding legislation from higher levels of government; benefits from an integrated policy framework; is addressed through site level development approvals and land stewardship initiatives; is less likely to be addressed across agricultural lands than urban areas; and lacks a coordinated approach across local government spatial boundaries. In the case study area, while some policy areas were readily integrated with ecological connectivity including water resources, parks and open space, and natural hazard lands, there was a lack of integration with climate change, green infrastructure and transportation polices.

Through interviews with planning practitioners, key factor theme areas were identified including the physical landscape, environmental governance, land use planning practices, sharing information, and resources. The results show that while ecological connectivity is supported by legislation, addressed in policy, with implementation mechanisms recognized and applied, local government still struggles with a natural features focus, cross border coordination, land use planning practice limitations, justification of the need for ecological connectivity, public and political resistance, and a lack of capacity and funding. Both the

interviews and Official Plan review contributed to the identification of actor interactions. I found that coordination across local government boundaries to accommodate the provincially legislated and delegated natural heritage system was not occurring. Planning practitioners interviewed did not see local government as leading but rather participating in collaborative actions. The main findings are a lack of provincial involvement, a large role to be played by Conservation Authorities, and a gap between policy and implementation.

Collectively, this research advances our understanding of the role of local government land use planning in establishing and maintaining ecological connectivity through the control of land use change and management of the whole landscape involving nature conservation but also sectoral policies. Spatial land use planning has the potential to address ecological connectivity through a comprehensive multisectoral and collaborative approach. There are many limitations to local government land use planning to address ecological connectivity that will need to be addressed and this research contributes to the identification of issues as well as possible solutions to address those limitations.

Acknowledgements

This thesis would not have been possible without the ongoing support and encouragement of many people. At times I questioned the wisdom of returning to school after working for (many) years as an environmental planner, but the rewards have been enormous.

First, I would like to thank my supervisor, Dr. Michael Drescher for believing in me and seeing my potential for academic research and writing. His continued assistance and encouragement supported me during this journey. I would also like to thank my committee members Dr. Stephen Murphy and Dr. Jeremy Pittman who encouraged my explorations, gave me much 'food for thought' and enough rope to dive into the fields of ecological connectivity and collaboration and then bring me back to reality.

This research would not have been possible without the participation of my interviewees. I am grateful for their time and insight. They provided a much-needed perspective on planning practice and the thoughtful comments on how to best address natural heritage systems were enlightening.

Finally, I would like to thank my family and friends for being there for me. I could not have finished without your understanding, support and sympathy as needed. Thank you for your faith in me.

Dedication

This dissertation is dedicated to my sisters, Jane, Joanne, Cathy, and Wilma - your love and care sustained me.

Table of Contents

Examining Committee Membership ii
Author's Declaration iii
Statement of Contributions iv
Abstract v
Acknowledgements viii
Dedication ix
List of Figures xiii
List of Tables xiv
List of Abbreviations xv
Chapter 1 : Introduction 1
1.1 Local government planning and maintenance of ecological connectivity 1
1.2 Ecological connectivity defined 3
1.3 A local government land use planning focus 4
1.4 Environmental governance to address ecological connectivity 6
1.5 A definition of environmental governance 7
1.6 The theory, practice, and politics of environmental planning 9
1.7 Research focus, objectives, and questions 11
1.8 Case study context 14
1.9 Dissertation structure 18
Chapter 2 : Literature review 21
2.1 Introduction 21
2.2 Environmental planning theory and practice 23
2.3 Environmental governance for ecological connectivity 27
2.4 Ecological Connectivity 31
2.5 Local government land use planning for ecological connectivity 39
2.6 The integration of ecological connectivity in local government land use planning 44
2.7 Factors that facilitate or hinder planning and maintenance of ecological connectivity 47
2.8 Collaboration for ecological connectivity 59
2.9 Conclusion 67
Chapter 3 - The integration of ecological connectivity in local government land use planning: a case study of the Carolinian ecoregion in southwestern Ontario Canada 69

3.1 Chapter summary 69
3.2 Introduction 70
3.3 Case study area 73
3.4 Methods 80
3.5 Results 87
3.6 Discussion 103
3.7 Conclusions 115
Chapter 4 : Factors that affect the planning and maintenance of ecological connectivity by local government in a highly fragmented landscape. 120
4.1 Chapter summary 120
4.2 Introduction 121
4.3 The role of local land use planning 124
4.4 Case study 127
4.5 Methods 131
4.6 Results 136
4.7 Discussion 158
4.8 Conclusions 172
Chapter 5 : Local government cross border collaboration for ecological connectivity: a case study of the Carolinian ecoregion in southwestern Ontario Canada 176
5.1 Chapter summary 176
5.2 Introduction 177
5.3 Local government land use planning and ecological connectivity 180
5.4 The Case Study 187
5.5 Methods 193
5.6 Results 197
5.7. Discussion 213
5.8 Conclusions 222
Chapter 6 – Synthesis 230
6.1 Introduction 230
6.2 Summary of findings and implications 232
6.3 Key findings 238
6.4 Contributions and future research 247
6.5 Conclusions 252

References **254**
Appendix A **278**
Interview Guide **278**
Appendix B **279**
Chapter 4: Theme areas: full results **279**
Appendix C **285**
Carolinian Ecoregion Local Government Official Plans Reviewed **285**
Appendix D **286**
Chapter 5: Tabulated results **286**

List of Figures

FIGURE 1-1 : THE ECOREGIONS OF ONTARIO 15
FIGURE 2-1 : RESEARCH CONCEPTUAL FRAMEWORK 22
FIGURE 3-1 : CAROLINIAN ECOREGION BOUNDARY MAP 74
FIGURE 3-2 : CONSISTENCY OF THE OFFICIAL PLANS REVIEWED AMONG VARIOUS APPROACHES TO IDENTIFY ECOLOGICAL CONNECTIVITY 90
FIGURE 3-3 : CONSISTENCY OF THE OFFICIAL PLANS REVIEWED FOR THE USE OF NATURAL FEATURES AND OTHER POLICY AREAS TO IDENTIFY ECOLOGICAL CONNECTIVITY 93
FIGURE 3-4 : CONSISTENCY OF THE OFFICIAL PLANS REVIEWED IN APPLYING REGULATORY TOOLS 96
FIGURE 3-5 : CONSISTENCY OF THE OFFICIAL PLANS REVIEWED IN APPLYING NON-REGULATORY PLANNING TOOLS 98
FIGURE 3-6 : CONSISTENCY OF THE OFFICIAL PLANS REVIEWED ON COLLABORATIVE EFFORTS TO PLAN AND MAINTAIN ECOLOGICAL CONNECTIVITY 100
FIGURE 3-7 : SAMPLE PORTIONS OF LOCAL GOVERNMENT MAPPING OF A NATURAL HERITAGE SYSTEM DEMONSTRATING INCONSISTENCY IN APPROACHES AND A LACK OF COORDINATION ACROSS LOCAL GOVERNMENT JURISDICTIONS 102
FIGURE 4-1 : CAROLINIAN ECOREGION BOUNDARY MAP 128
FIGURE 4-2 : THE FIVE IDENTIFIED THEME AREAS AND KEY FACTORS THAT INFLUENCES LOCAL GOVERNMENT PLANNING AND MAINTENANCE OF ECOLOGICAL CONNECTIVITY 160
FIGURE 5-1 : THE CAROLINIAN ECOREGION BOUNDARY GEOGRAPHIC LOCATION IN SOUTHWESTERN ONTARIO CANADA 189
FIGURE 5-2 : CONSISTENCY OF THE OFFICIAL PLANS REVIEWED ON COLLABORATIVE EFFORTS TO PLAN AND MAINTAIN ECOLOGICAL CONNECTIVITY 200
FIGURE 5-3 : FREQUENCY OF STUDY PARTICIPANT MENTIONS OF WHO THEY MOST CLOSELY WORKED WITH FOR NATURAL HERITAGE SYSTEMS PLANNING AND IMPLEMENTATION 202
FIGURE 5-4 : THE GOVERNANCE NETWORK WITH ASSOCIATED WEIGHT OF THE RELATIONSHIPS, COMBINING PLANNING AND IMPLEMENTATION STAKEHOLDERS. LOCAL GOVERNMENT (LG) AS THE FOCUS WITH A STRONG CONNECTION WITH CONSERVATION AUTHORITIES (CA) 208
FIGURE 5-5 : FREQUENCY OF STUDY PARTICIPANT MENTIONS OF WHO COULD FUNCTION AS A BRIDGING ORGANIZATION 210
FIGURE 5-6 : WHO ELSE SHOULD BE INVOLVED IN ECOLOGICAL CONNECTIVITY 212
FIGURE 6-1 : SUMMARY OF THE MAIN RESEARCH FINDINGS AND SPHERES OF INFLUENCE 237

List of Tables

TABLE 1-1 : AN OVERVIEW OF THE THREE MANUSCRIPTS IN THIS THESIS TO ADDRESS THE CENTRAL QUESTION OF HOW LOCAL GOVERNMENT LAND USE PLANNING CAN ADDRESS THE CONCEPT OF ECOLOGICAL CONNECTIVITY 19
TABLE 2-1 : VARIOUS FORMS OF GOVERNANCE RELEVANT TO ECOLOGICAL CONNECTIVITY 30
TABLE 2-2 : A SELECTED LISTING OF KEY CONNECTIVITY CONCEPTS AND TERMINOLOGIES 34
TABLE 2-3 : SUMMARY OF BARRIERS AND OPPORTUNITIES - PHYSICAL OR STRUCTURAL 51
TABLE 2-4 : SUMMARY OF BARRIERS AND OPPORTUNITIES - GOVERNANCE OR PROCESS 54
TABLE 2-5 : SUMMARY OF BARRIERS AND OPPORTUNITIES - FINANCIAL OR RESOURCES 56
TABLE 2-6 : SUMMARY OF BARRIERS AND OPPORTUNITIES - KNOWLEDGE OR LEARNING 58
TABLE 2-7 : THE CHALLENGES OF INSTITUTIONAL FIT IN A SOCIAL ECOLOGICAL SYSTEM 67
TABLE 3-1 : CAROLINIAN ECOREGION LOCAL GOVERNMENT AND CONTEXT INFORMATION 80
TABLE 3-2 : CODING SCHEME FOR THE REVIEW OF OFFICIAL PLANS 85
TABLE 3-3 : OFFICIAL PLAN REVIEW OF PURPOSE FOR ECOLOGICAL CONNECTIVITY 89
TABLE 3-4 : OTHER OFFICIAL PLAN POLICY AREAS RELEVANT TO ECOLOGICAL CONNECTIVITY 95
TABLE 3-5 : MULTIPLE METHODS TO IDENTIFY ECOLOGICAL CONNECTIVITY THROUGH LOCAL GOVERNMENT LAND USE PLANNING 108
TABLE 4-1 : CAROLINIAN ECOREGION LOCAL GOVERNMENTS AND CONTEXT INFORMATION 130
TABLE 4-2 : FACTOR THEME AREAS AFFECTING THE PLANNING AND MAINTENANCE OF ECOLOGICAL CONNECTIVITY DEDUCED FROM THE LITERATURE 134
TABLE 4-3 : MAJOR THEME AREAS AND CATEGORIES OF FACTORS THAT HELP OR HINDER THE PLANNING AND MAINTENANCE OF ENVIRONMENTAL CONNECTIVITY 137
TABLE 4-4 : PHYSICAL LANDSCAPE THEME KEY FACTOR IDENTIFICATION 139
TABLE 4-5 : ENVIRONMENTAL GOVERNANCE THEME KEY FACTOR IDENTIFICATION 142
TABLE 4-6 : LAND USE PLANNING PRACTICE THEME KEY FACTOR IDENTIFICATION 147
TABLE 4-7 : INFORMATION SHARING THEME KEY FACTOR IDENTIFICATION 152
TABLE 4-8 : RESOURCES THEME KEY FACTOR IDENTIFICATION 156
TABLE 5-1 : A SUMMARY OF METHODS TO IMPLEMENT ECOLOGICAL CONNECTIVITY 187
TABLE 5-2 : EXAMPLES OF PLANNING FOR ECOLOGICAL CONNECTIVITY IN THE CAROLINIAN ECOREGION AT VARIOUS SCALES BY DIFFERENT ACTORS 191
TABLE 5-3 : EXAMPLES OF 'WORKING TOGETHER' FROM OFFICIAL PLANS IN THE CAROLINIAN ECOREGION 198
TABLE 6-1 : COMPARISON OF KEY FINDINGS CROSS CHAPTER 3 (PLANNING POLICY), CHAPTER 4 (PLANNING INFLUENCE) AND CHAPTER 5 (PLANNING PARTNERS) 236

List of Abbreviations

CA	Conservation Authority
FED	Federal
FN	First Nations
LG	Local Government
NGO	Non-government Organization
OMMAH	Ontario Ministry of Municipal Affairs and Housing
OMMA	Ontario Ministry of Municipal Affairs
OMNRF	Ontario Ministry of Natural Resources and Forestry
PROV	Provincial
UTRCA	Upper Thames River Conservation Authority

Chapter 1 : Introduction

1.1 Local government planning and maintenance of ecological connectivity

Ecological connectivity or a well-connected system of natural areas is needed to prevent further biodiversity loss and ecosystem decline (Lemieux et al., 2022). Ecological connectivity addresses the persistence of plants and animals but also the continuation of ecological processes which maintain the integrity of biological communities and maintenance of ecosystems services for human use and well-being (Beger et al., 2022; Butler et al., 2022; Fischer & Lindenmayer, 2007; Hilty et al., 2020; Palomo et al., 2014; Watson et al., 2017). Planning for the maintenance of ecological connectivity is critical in areas subject to intensive land use change with only remnant natural areas remaining (Bodin & Chen, 2023).

A fragmented landscape is both the cause and the consequences of an unconnected landscape. Urbanization, agriculture, industrial activity, and linear barriers such as roads are major contributors to fragmentation (Hardy et al., 2022; Keeley et al., 2019). This fragmentation of the landscape disrupts the flow of species, ecological processes, and services. The provision of ecosystem services, or benefits to people from ecological processes (Egerer & Anderson, 2020), are dependent on a connected landscape (Mitchell et al., 2013). For example, fragmentation arising from human land development which disrupts geophysical processes such as land drainage can increase the risk of flooding and impact the quality of drinking water (Hardy et al., 2022). Similarly, land development which affects land cover composition and configuration can promote or hinder ecological connectivity, for example, by separating natural

habitat from croplands and restricting the movement of pollinators and pest predators needed for agricultural production (Field & Parrott, 2022).

Spatial land use planning is a tool that can be applied to counter landscape fragmentation through the identification, protection, improvement or restoration of corridors, stepping-stones, or a permeable matrix, together with the mediation of threats to continued ecological connectivity (Hilty et al., 2020; Fischer & Lindenmayer, 2007). Land use planning guides land use decisions on future land use change and can address ecological connectivity by directing and mitigating development. There has been substantial research on the identification or modelling of ecological connectivity but less on how land use planning can reduce the ongoing threats to continued ecological connectivity. Maintaining ecological connectivity is much more than a scientific exercise to identify ecological corridors; it requires coordinated planning, across multiple scales recognizing various social and economic constraints and opportunities (Parrott et al., 2019).

Planning for ecological connectivity can be through conservation plans specifically focused on the protection of biodiversity and ecological connectivity (Keeley et al., 2019), or through strategic land use plans that address multiple land uses, including the conservation of ecological connectivity (Perrin et al., 2022). The focus of my research is on local government land use planning and the integration of multiple land uses to address future land use change and protection of ecological connectivity. The integration of ecological connectivity into the social context of a landscape is required as ecological problems stem from social problems. Social ecological systems theory acknowledges the inseparability of humans and nature, recognizing that societies and ecosystems are shaped by each other (Berkes & Folke, 1998).

This dissertation explores how local government land use planning can address the concept of ecological connectivity. This is done through: an investigation of the integration of ecological connectivity in local government land use planning; identifying obstacles to planning and maintaining ecological connectivity and means to address the obstacles; and exploring how local government land use planning contributes to collective action in pursuit of ecological connectivity. This chapter provides the context and background for my research, outlines my research objectives, and explains the dissertation structure.

1.2 Ecological connectivity defined

The concept of connectivity is nebulous and varies depending on one's viewpoint or discipline. Research on connectivity is extensive with a range of terminology employed leading to confusion over what is being connected and for what purpose (Beger et al., 2022). The more common terms used are habitat connectivity, landscape connectivity, ecological connectivity, and ecological networks. Other topic areas integrate the concept of connectivity such as ecological services (Mitchell et al., 2013), green infrastructure (Liquete, 2015), greenways (Lynch, 2019) and protected areas (Cumming & Allen, 2017). This mass of information related to connectivity has two common themes: species migration and persistence through linkages among isolated natural areas; and ecological processes and functions which support species, including humans.

The conceptual framework that best fits my research is ecological connectivity and ecological networks. Ecological connectivity is defined as the unimpeded movement of species and the flow of natural processes that sustain life on Earth (Convention on Migratory Species (CMS), 2020). The flow of natural processes (energy, materials, and organisms) such as nutrient

and water cycling, plant productivity and seed dispersal, can help maintain biodiversity, species movement and ecosystem services (Beger et al., 2022; Hilty e al., 2020). Ecological networks are a system of habitats, connected by ecological corridors or linkages, which is established, restored, and maintained to conserve biological diversity in systems that have been fragmented (Hilty et al., 2020). It should also be noted that ecosystem connectivity can create negative impacts such as nutrient pollution, introduction or movement of invasive species and disease, fire transmission, loss of genetic variants, and change in plant and animal community composition, (Aslan et al., 2021; Beger et al., 2022; Keeley et al., 2022; Zimmerer et al., 2022).

1.3 A local government land use planning focus

I am focusing on how local government land use planning can address ecological connectivity in practice. Factors that disrupt ecological connectivity such as land use change and development are addressed through local government land use decision (Brody, 2003, Bryant, 2006). Land development can contribute to the loss of ecological connectivity and understanding how this can be ameliorated through local government land use planning and policy implementation is an important step in conserving ecological connectivity.

Local government land use plans are prescriptive, proactive, long-term instruments that combines numerous policy areas, such as growth management, settlement areas, transportation, health and social services, agriculture, and the environment (Brody & Highfield, 2005). Ecological connectivity is a topic that has been addressed in local government land use plans. Local government land use plans and policies address land use change on parcels of private property, can mitigate the cumulative impact of development on the landscape, and protect natural areas when acquisition is not feasible (Kamal et al., 2015; Leibenath, 2011;

Opdam et al., 2006; Bergsten et al., 2014). The process of developing a land use plan and associated public consultation, can serve to raise the level of awareness of the need for ecological connectivity to the general populace as well as the political decision makers (Bergsten & Zetterberg, 2013; Spang et al., 2012; Leibenath, 2011).

The incorporation of ecological connectivity into local government land use planning expands ecological connectivity from a purely ecological concept to a matter for which planners as well as political decision makers are accountable (Perrin et al., 2022). The interactions among ecosystem processes and the social context are complex, with feedback loops, historical influences, power dynamics, and community beliefs, influencing outcomes (Cumming et al., 2020). There are recognized issues to local government land use planning for ecological connectivity including:

- A 'silo' approach of local government, affecting policy integration (Andersson et al., 2014, Bergsten et al., 2014; Sayes & Baggio, 2017),
- The risk of social and economic benefits being given a higher priority than environmental conservation (Lennon, 2015; Opdam et al, 2006),
- The political nature of local government decision making with a need to address trade-offs or negotiations among interests (Auerbach, 2012),
- Lack of political support for environmental issues if the environment is not well championed and economic prosperity is a priority (Millner & Olliver, 2016; DeCaro & Stokes, 2013),
- Lack of means to implement environmental policies (Huber et al., 2012; Watson et al., 2017),

- Limited ability to adapt to dynamic ecological processes and changing land uses (Leibenath, 2011; Perrin et al., 2022; Armitage et al., 2012),
- External factors such as level of expertise of the planners, and support by politicians and the public (Keeley et al., 2018, 2019; Opdam et al., 2006; Perrin et al., 2022).

The obstacles to local government planning and maintenance of ecological connectivity are considerable, however; the consequences of inaction are extreme and can lead to further land fragmentation, habitat loss and species extinction (Kamal et al., 2015). My research contributes to a greater understanding of strengths and weaknesses of local government land use planning for ecological connectivity. The results can inform planning practice and assist in future evaluation of land use plan outcomes.

1.4 Environmental governance to address ecological connectivity

Given the cumulative effects of human activities on the landscape, multiple uses and values, and complexity of social needs and ecological processes, no single organization can effectively address ecological connectivity (Armitage et al., 2012; Lemieux et al., 2021). Environmental planning and maintenance for ecological connectivity occurs at multiple scales, among a hierarchy or organization, across political boundaries and with overlapping jurisdictions (Wyborn & Bixler, 2013). Collective action to maintain ecological connectivity requires coordination across borders, jurisdictions, and land tenures (Aslan et al., 2021; Baggio et al., 2019; Bergsten et al., 2014).

The concept of 'fit' or matching the spatial scale of an ecological problem with the scale of environmental governance has been extensively documented (Bergsten et al., 2014;

Kininmonth et al., 2015; Keeley et al., 2022). A mismatch can result when the scale of management actions does not address the scale of the problem or when ecological processes transcend governance boundaries (Bergsten et al., 2014). Local government boundaries do not typically align with ecological boundaries such as watersheds or ecoregions and planning for ecological connectivity within local government boundaries may not take cross boundary ecosystem processes into account (Ekstrom & Young, 2009). From a social ecological systems perspective, the problem of fit goes beyond matching ecological processes to governance scales to matching multiple stakeholders at multiple levels to ecological issues (Bodin & Chen, 2023). A potential mismatch between higher level objectives and lower-level policy and implementation, or multiple stakeholders addressing the same problem can lead to ineffective implementation of collective actions (Holzhauer et al., 2019). A collaborative form of governance is proposed to connect actors and support collective action that match the scale of ecological processes (Guerrero et al. 2015, Sayles and Baggio 2017, McGlynn et al., 2023). My research contributes to the scholarship on environmental governance and social ecological fit by investigating how local government land use planning contributes to collective action in pursuit of ecological connectivity.

1.5 A definition of environmental governance

As with the term connectivity, governance can mean different things to different people. Government is an instrument of implementing societal needs while governance is seen as a process to collectively address societal problems (Armitage et al., 2009). Environmental governance involves a diversity of actors, both government and non -governmental agents, working collaboratively towards a common goal (Chaffin & Gunderson, 2016; Newig & Fritsch,

2009; Sternlieb et al., 2013). Environmental governance has been defined as the institutions, structure, social processes, and values, that guide decision-making on matters related to complex ecological issues (Lockwood, 2010; Lemos & Agrawal, 2006). The term institution has been defined as "the formal and informal rules, norms, and conventions that societies use to structure interactions and increase predictability in situations of interdependent choice (Epstein et al, 2015, p. 34). Institutions can either enable or constrain management actions (Bennett & Satterfield, 2018). The term structure refers to formalized decision-making arrangements or organizations and informal network of actors that enable management actions while governance processes are the means to produce rules and implement decisions (Bennett & Satterfield, 2018). For my research, the term environmental governance refers to government and non-government actors involved through formal and informal decision-making structures and processes to enable environmental management and collective action for ecological connectivity.

A fragmented environmental governance system occurs when multiple or overlapping jurisdictions who are jointly responsible for land management do not collaborate on a common environmental issue (Hamilton et al., 2021). Ecological connectivity as a complex environmental problem, requires a collaborative form of environmental governance for effective outcomes (Bodin, 2017; Kininmonth et al., 2015; Sayles and Baggio, 2017; Ekstrom and Young, 2009; Bixler et al., 2016; Scarlett & McKinney, 2016). Yet collaboration may not always work in all situations as collaboration is dependent upon the diversity and capacity of participants, the ability to reach a common ground, and aligning the governance structure with the underlying biophysical system (Bodin et al., 2017). While collaborative governance is seen

as an appropriate means to address a fragmented decision-making process and there has been much research on specific factors that improve collaboration, there is less research on local government collaboration with higher levels of government and non -government organizations in conservation efforts. The intent of my research is not to identify better ways to collaborate but to understand social network interactions and potential weak links, gaps or overlaps in the system, and potential conflicts in direction or objectives that hamper the ability to preserve a connected landscape.

1.6 The theory, practice, and politics of environmental planning

The influences of human values, behaviours and power relationships on the planning and maintenance of ecological connectivity need to be considered. Given the current political bent towards planning reforms for more efficient planning to encourage economic growth, understanding the social context of environmental planning is even more significant (Grant, 2022). The importance of social values in land use planning cannot be underestimated, and this is strongly supported in environmental planning theory. Environmental planning theory recognizes that environmental planning must not be addressed in isolation of social and economic priorities and must also address how humans live and interact with the environment and make decisions (White, 2015).

Land use planning theory tends to be anthropocentric and concentrate on human well-being rather than environmental integrity. There can be a separation between environmental and land use planning in practice. For example,

> environmental planners may be concerned with landscape scale connectivity's such as wildlife and riparian corridors or the range, occurrence, and dispersal of species [while]

> it is the economic drivers of landscape change that dominate the land use planning agenda (Houston et al., 2018, p. 195).

This apparent dichotomy between environmental planning and land use planning theory and practice is challenged by the conceptual framework of sustainability and social-ecological systems (Wilkinson, 2011).

Sustainability, from a planning theory perspective, involves the reconciliation of economic development, social equity, and environmental protection (Fainstein & DeFilippis, 2016). Sustainability segregates the three pillars of economics, society and the environment while recognizing interdependencies and the need to negotiate trade-offs (Reyers et al., 2018). The social-ecological systems concept does not separate social and ecological systems but offers a more integrated vision of humans in nature, recognizing that societies and ecosystems are shaped by each other (Anderies et al., 2004; Berkes & Folke, 1998; Reyers et al, 2018). It follows that planning theory will need to be better attuned to how humans are shaped by and affect ecological systems (Houston et al., 2018). The social – ecological systems concept regards the social and ecological systems as coupled with a need for planning to identify relations of the social and natural dimensions of a landscape (Löfgren, 2020).

The social and ecological system interconnectedness can extend beyond jurisdictional boundaries requiring collaboration across jurisdictions and among multiple interests (Bodin et al., 2016). This need for collaboration is supported in planning theory (Healy, 1998; Innes & Booher, 2004). The complex nature of environmental problems, uncertainty of cause-and-effect relationships and value conflicts led to a movement away from substantive rational planning theory to procedural communicative or collaborative planning theory (Löfgren, 2020).

Applying collaborative planning theory can "integrates diversity, build consensus, resolve conflicts, and balance scientific information with stakeholder participation" (Salazar et al., 2024, p. 3). Collaboration it is argued encourages decisions that include the diverse views of the community, more inclusive forms of deliberation, and building social networks (Campbell et al., 2016; Fainstein, 2000; Healey, 1998). Planners are also subject to political values and "externally imposed directives and constraints" (Filion, 2021, p. 257), that can lead to unexpected or undesirable decisions (Sturzaker & Hickman, 2024).

Decision making in local government land use planning entails trade-offs or negotiations among interests and where a political decision is required, the technical aspects are not all that must be considered (Auerbach, 2012). Science can provide the technical backing for decision making but the decision is still political and in economic transition times, the environment may not be well represented or championed. People's beliefs on environmental problems vary overtime, and politicians are unlikely to support environmental policy if the strongest voice heard is for economic prosperity (Millner & Olliver, 2016). This constant flux in times of change or crisis (political, economic, ecological), affect social norms and the degree or composition of participation (DeCaro & Stokes, 2013). In land use planning a 'problem' may not be solved and as values change the problem does not go away but another problem may displace it (Friedman, 1987). Planners have little control over the changing priorities in times of political and economic transition, but planners can respond by adapting and adjusting planning interventions to the evolving context (Filion, 2021).

1.7 Research focus, objectives, and questions

1.7.1 Research focus

Ecological connectivity crosses spatial political or administrative areas that do not match the ecological base. The coordination of local plans and policies across the larger landscape is necessary for effective management of ecological connectivity yet there has been little research directed "to show how local jurisdictions are playing a role in the management of large-scale natural systems" (Brody et al., 2004, p. 34). Local government is the emphasis as it is seen as the critical link. While there are policies and activities related to ecological connectivity at all levels of government as well as non-government approaches, the local level is mandated with land use planning and the decision-making ability to direct land use change. Given the global trend of rapid urban growth and impact on ecological connectivity and the need to incorporate private lands to connect protected areas (Kamal et al., 2015), there is a need to better understand how local governments can integrate ecological connectivity in land use planning, what factors inhibit or help effective planning and maintenance of ecological connectivity, and how local jurisdictions manage transboundary ecological systems.

1.7.2 Research objectives

The intent of my research is to explore, through a case study, how ecological connectivity is planned and maintained in a fragmented landscape at various scales by various actors. This is done by investigating how local government land use planning is conducted; factors that affect local government land use planning for ecological connectivity; and who local government collaborates with to achieve ecological connectivity. Overall, this research is important for four reasons: (a) it has a focus on local government which fills a gap in research; (b) it looks at a case study in an existing highly fragmented landscape, which makes connecting the landscape difficult, and can identify factors unique to this context; (c) it looks at how local

government fits or does not fit within a collaborative governance structure, again a gap in the research; and (d) by identifying barriers and opportunities for local government to address ecological connectivity, it can help focus efforts towards both the planning and maintenance of ecological connectivity. The results will highlight key problem areas and tools to help plan and maintain ecological connectivity and ultimately support the conservation of biodiversity and ecosystem services in highly fragmented human dominated landscapes.

1.7.3 Research questions

The goal of the research is to: determine if and how ecological connectivity is being planned for and maintained in a highly fragmented landscape and within a fragmented decision-making framework; analyze and explain factors that affect the planning and maintenance of ecological connectivity; and evaluate if and how ecological connectivity can be coordinated across jurisdictions through collaboration. This goal is pursued through findings to the following research questions:

(1) How does local governments address ecological connectivity through land use planning?
(2) Is the approach to address ecological connectivity consistently applied and coordinated across jurisdictional boundaries?
(3) What factors facilitate or impede local government land use planning and maintenance of ecological connectivity?
(4) How do local governments interact with other actors in pursuit of ecological connectivity?

1.7.3 Methods of analysis

Multiple methods of analysis are employed to address the research questions. Local government strategic land use plans called Official Plans from the case study area are reviewed and a qualitative content analysis conducted to describe the state of practice, provide baseline

data, and contribute to a greater understanding of strengths and weaknesses of local government land use planning for ecological connectivity. For qualitative content analysis, the data is reduced or synthesized through the process of coding the text to enable the description of themes or categories that manifest in the documents reviewed (Bowen, 2009; Escobedo Garcia & Ulibarri, 2023; Schreier, 2012). Interviews with planning practitioners in the case study area are carried out to identify factors that help or hinder the planning and maintenance of ecological connectivity by local government. Thematic analysis is used to explore planning practitioner perspectives, identify similarities and differences among respondents on influential factors, and to discern insights into why the factors were important (Nowell et al., 2017, Saldaña, 2016). Social network interactions are investigated to identify links, gaps or overlaps in the system that facilitate or hamper the ability to preserve a connected landscape.

1.8 Case study context

The province of Ontario, Canada and specifically the Carolinian ecoregion in southwestern Ontario was selected as the case study area to address the research questions noted above. The Carolinian ecoregion in southwestern Ontario Canada is an area heavily fragmented by urbanization and agriculture with lands that are primarily privately owned (Oldham, 2017). This ecoregion is bounded by Lake Ontario and Lake Erie to the south, the City of Toronto and Niagara River to the east, Lake St Clair and Lake Huron to the west, and follows climatic and geological parameters to define the northern boundary (Crins et al., 2009). This ecoregion is the southern-most region of Ontario (Figure 1.1), and the northern most portion of the Carolinian deciduous forest region, supporting many species that are not found anywhere

else in the country. It occupies less than 0.25% of Canada's landmass but is habitat to 40% of Canada's plant species and a large portion of its vertebrate and invertebrate fauna (Oldham, 2017).

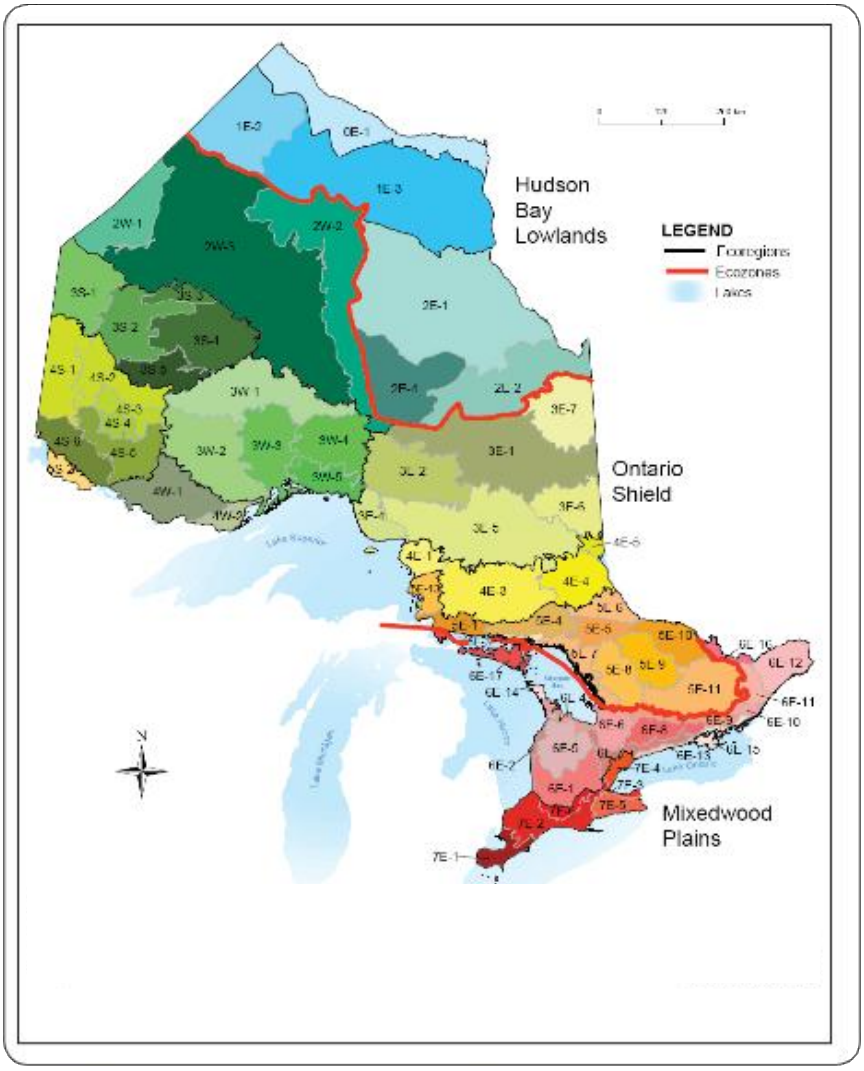


Figure 1-1 : The ecoregions of Ontario
Note: From The Ecosystems of Ontario. Part 1: Ecozones and Ecoregions (Crins et al., 2009). The Carolinian ecoregion includes 7E-1 to 7E-6

The Carolinian eco-region contains some of Canada's most valued and rare plant and animal species (Spang et al., 2012). The Carolinian ecoregion which covers approximately 21,850 km^2 has a mild climate, highly diverse flora and fauna, and is the most imperiled in Canada due to the substantial loss of natural habitat (Crins et al., 2009). A recent study evaluated 77 ecoregions in southern Canada, and the Carolinian ecoregion was identified as one of nine ecoregions considered to be a crisis ecoregion (higher biodiversity and higher threat) with the greatest need for immediate conservation action (Kraus & Hebb, 2020). Parks Canada, a federal government agency, through its National Program for Ecological Corridors, identified a part of the Carolinian ecoregion, the north shore of Lake Erie, as one of 23 priority areas in Canada where ecological corridors are most urgently needed and should be identified and created locally (Parks Canada, 2024).

There is a long history of conservation in the Carolinian ecoregion including national and provincial parks, biosphere reserves, conservation areas and other protected areas, resulting in the protection of remnant, biologically diverse areas. An ecoregional initiative called the Carolinian Canada Program started in 1984 comprised of government and non-government organizations (NGO) participants (Johnson, 2007) and evolved to the Carolinian Canada Coalition of today. Initially the Carolinian Canada Coalition identified 38 critical areas in need of protection and continued with the development of an ecological network of core areas and potential linkages, followed by the development of 14 Conservation Action Plans for biodiversity hotspots and most recently a means to monitor trends in the Carolinian ecoregion (Jalava et al., 2019).

The Carolinian ecoregion also has a complex governance structure with NGOs active in ecological connectivity and enabling provincial legislation to address ecological connectivity through local government land use planning. There are many agencies including federal, provincial, and local government, Conservation Authorities, NGOs, Universities, and landowners that are all involved in ecological connectivity on the same landscape at various scales (Spang et al.,2012).

Canada is a centralized federated government system with independent national and provincial (state) governments, shared political power, and discrete jurisdictional responsibilities (Richard, 2005). The Ontario provincial government has delegated many responsibilities for land use planning to local governments, though the province provides direction on matters of provincial interest to be addressed by local governments. The upper tier (regional, county, city) local governments are charged with decision making on future land use change and the built environment for lands within local government spatial boundaries. If there are lower tier municipalities (city, town, township), the lower tier municipalities in turn have been delegated responsibility for land use planning, following direction provided by the upper tier local governments. The focus in my dissertation is on land use planning through upper tier local governments as the upper tier local governments represent a broader scale and perspective for planning for ecological connectivity. There are 16 upper and single tier local governments that are part of this case study research.

The Carolinian ecoregion is also covered by Conservation Authorities which are stand-alone functioning semi-governmental organizations based on a watershed with a primary mandate to address natural hazards such as flooding and the conservation of natural resources. Of the 31

CAs in Ontario, 14 are located within the case study area. Given the different jurisdictional boundaries of local governments and Conservation Authorities, it is common for local governments to have multiple Conservation Authorities within their boundaries. Likewise, Conservation Authorities generally have multiple local governments within a watershed area.

This multi-scale multi actor forum to address ecological connectivity makes for a complex environmental governance system with various federal, provincial government, Conservation Authorities, NGO, university, and local government mandates and private landowner interests that apply to the environment and ecological connectivity. The Carolinian ecoregion is nationally recognized as a crisis region with high biodiversity and a high level of threat with a need for local action to address ecological connectivity. The long history of conservation efforts in the Carolinian ecoregion, active NGOs, multi-level government all addressing ecological connectivity, and the complex environmental governance system all combine to make the Carolinian ecoregion a good case study to investigate ecological connectivity and local level collaboration across jurisdictional boundaries and among different actors.

1.9 Dissertation structure

This dissertation is written in a manuscript format with three chapters intended as stand-alone manuscripts (chapters 3, 4 and 5). The other chapters set the context, discuss key concepts, theories, and methods, and contribute to a synthesis of overall findings. Chapter 2 is a literature review on the topics of environmental connectivity and governance. Chapters 6 offers a synthesis of the findings and conclusions as well as limitations of the research and

insight into future research. Each manuscript is guided by research questions though all chapters are directed by my central research question (Table 1.1).

Table 1-1 : An overview of the three manuscripts in this thesis to address the central question of how local government land use planning can address the concept of ecological connectivity

Chapter	Manuscript Title	Research questions	Approach
3	The integration of ecological connectivity in local government land use planning: a case study of the Carolinian ecoregion in southwestern Ontario Canada	How does local governments address ecological connectivity through land use planning? Is the approach to address ecological connectivity consistently applied and coordinated across jurisdictional boundaries?	Qualitative content analysis of 16 local government strategic land use plans (Official Plans) from the Carolinian ecoregion
4	Factors that affect the planning and maintenance of ecological connectivity by local governments in a highly fragmented landscape.	What factors facilitate or impede local government land use planning and maintenance of ecological connectivity?	Qualitative thematic analysis of 24 interviews with planning practitioners in the Carolinian ecoregion
5	Local government cross border collaboration for ecological connectivity: a case study of the Carolinian ecoregion in southwestern Ontario Canada	How do local governments interact with other actors in pursuit of ecological connectivity?	Combination of qualitative content analysis and thematic analysis of interviews

Chapter 3 (manuscript 1) addresses research questions (1) and (2); how does local governments address ecological connectivity through land use planning, and is the approach to address ecological connectivity consistently applied and coordinated across jurisdictional boundaries? A review of the local government Official Plans and the methods used to address connectivity is conducted to determine if and how connectivity was being tackled in the case

study area. The intent is to discover how local government could address a cross-jurisdictional issue in a policy document and to determine variances in approaches. Another objective was to investigate how connectivity lined up across the case study landscape or if there were connections made across jurisdictions.

Chapter 4 addresses research questions (3); what factors facilitate or impede local government land use planning and maintenance of ecological connectivity. While the literature provides a good summary of issues that may apply to help or hinder connectivity planning and maintenance, interviews were conducted to verify and expand upon context specific factors. The Carolinian ecoregion, while a highly fragmented human altered landscape, is comprised of local governments that are rural as well as urban and with some areas subject to higher level government oversight. Not all factors equally apply to all areas and distinctions were made based on location and attributes of the areas.

Chapter 5 addresses research question (4): how do local governments interact with other actors in pursuit of ecological connectivity? Governance structures appropriate for environmental conservation were reviewed in the literature. The importance of government, non-government and private land stewards' involvement, interaction or collaboration was supported in the literature with various structures suggested. The case study governance structure was determined based the interviews, and social network interactions investigated to identify links, gaps or overlaps in the system that facilitate or hamper the ability to preserve a connected landscape. The investigation includes a focus on 'how' but also considers the 'why'; namely why are interactions in the planning and maintenance of ecological connectivity succeeding or lacking?

Chapter 2 : Literature review

2.1 Introduction

In this chapter, key topics and concepts are reviewed to frame the research presented in subsequent chapters. My research is focused on the facilitators and challenges to the planning and maintenance of ecological connectivity. I concentrate on local government land use planning to address ecological connectivity as local government is where land use decisions are made that can fragment the land base, disrupt ecological connectivity, and affect a broader region. Though the scholarship on ecological connectivity is considerable, there are relatively fewer studies on local government land use planning for ecological connectivity, representing a gap in research. My research also investigates collaborative environmental governance as a model to address a fragmented landscape and decision-making process. The broad overview of ecological connectivity is thus refined by keying in on: the role and mechanisms for local governments to address ecological connectivity (Chapter 3); challenges and opportunities local government face to plan for and maintain ecological connectivity in a fragmented landscape (Chapter 4); and how local governments can collaborate to address the cross boundary and cross jurisdictional nature of ecological connectivity (Chapter 5).

Research on connectivity means different things to different people as highlighted by the various terminologies applied to the concept of a connected landscape. I explore the purpose of connectivity together with terminology applied to locate my research within this broader context. I investigate how past research has addressed ecological connectivity by looking at approaches, challenges, and environmental governance methods applied to large-scale or complex environmental issues, with a focus on local government. Investigating past

research will increase my understanding of local government land use planning for ecological connectivity, specifically as related to local government practices, factors that help or hinder local government planning for ecological connectivity, and cross border coordination.

This chapter is organized by specific subject areas. How the subjects come together to inform my research is outlined in Figure 2.1. Environmental planning theory and practice frames the topic of my research, ecological connectivity, located within a contextual governance system. The focus is local government which is divide into three topics; land use planning for ecological connectivity, influential factors that affect planning for ecological connectivity and collaboration to address those factors.

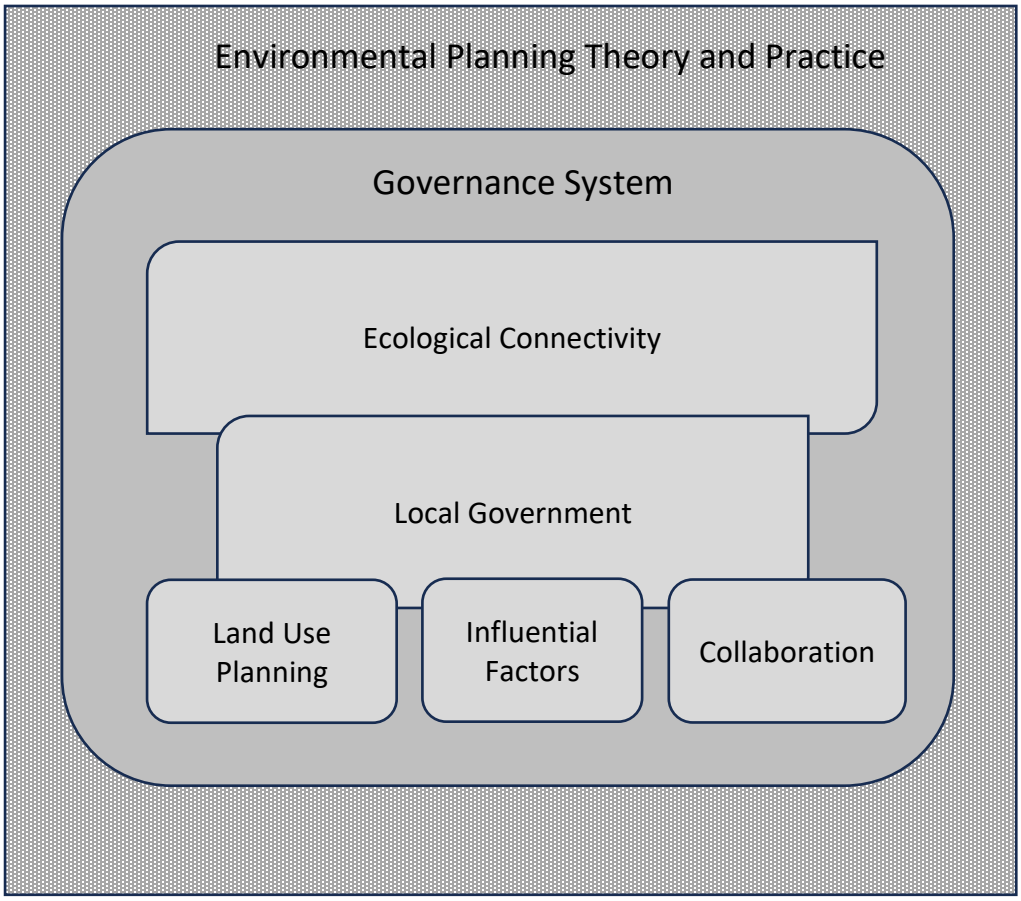


Figure 2-1 : Research conceptual framework

2.2 Environmental planning theory and practice

My research draws from both theory and practice. Planning theory informs and guides planning practice (Allmendinger, 2017). Planning theory can also 'learn' from practice by testing if a theory is relevant in planning practice (Richardson, 2005). In my research, I explore if planning practice works the way planning theory claims regarding the planning and maintenance of ecological connectivity.

Environmental planning theory recognizes that environmental problems are also social problems and environmental planning must address how humans live and interact with the environment and make decisions (White, 2015). Environmental planning practice is an interdisciplinary approach or methodology to integrate environmental matters into the planning process (Lein, 2003). Environmental planning and land use planning theory and practice, historically, progressed together. The normative land use planning theories (e.g., rational, advocacy, communicative-collaborative) and environmental planning theory (e.g., eco-humanism, social ecology, ecological planning, sustainability, social-ecological systems), do not always intersect. In this section I will provide a brief history of environmental planning and identify which theories apply to my research.

The historical basis for environmental planning theory and practice can be traced back to (at least) the environmental issues that arose from the industrial revolution. At this time an environmentalist movement arose with a central premise that human welfare depended on the physical environment and that planning was needed to address unchecked development causing environmental damage (Cohen, 2019a). Frederick Law Olmstead (1822-1903) with his

landscape planning projects (e.g., Central Park in New York), Ebenezer Howard (1850-1928) and his garden city concept, and Patrick Geddes (1854-1932) investigations of interactions between humans and their environment, all incorporating the environment into the planning of human settlements (Cohen, 2019a).

Concurrently, a new view arose recognizing the importance of conserving the environment through protecting and preserving natural resources (White, 2015). For example, Aldo Leopold identified a need for a land ethic in his book 'A Sand County Almanac' which he defined as "an ecological conscience, and this in turn reflects a conviction of individual responsibility for the health of the land" (Leopold, 1949, p. 258). Leopold was grounded in the utilitarian concept of conservation and nature protection of his time, but he also recognized the that human and natural systems were interconnected and that the social, economic, and political realities could not be separated from the ecological (Meine, 2020).

The mid twentieth century saw a rise in environmental advocacy to address the failing condition of the environment due to over exploitation of natural resources (Davidoff, 1965). At the same time there was a movement towards ecological humanism or the integration of social and ecological disciplines. For example, Murray Bookchin's 'social ecology' takes the perspective that "the social can no longer be separated from the ecological, any more than humanity can be separated from nature" (Bookchin, 1996, p.34) and that ecological problems stem from social problems. Lewis Mumford (1895-1990) advanced the concept of eco-humanism in planning, which was taken up by Ian McHarg (1920-2001) and expressed as ecological planning (Cohen, 2019a).

There are numerous planning theories which have evolved over time in response to changing social contexts. Both rational and communicative / collaborative planning theory intersect with environmental planning practice. Rational planning theory ascribes to the certainty that problems can be solved, consequences understood through perfect knowledge of the factors and influences of a given situation (Brooks, 2002). Argument against rational planning theory recognize the complexity of problems, uncertainty, and diffusion of solutions, given social, economic, and political influences on decision making. Yet in practice rational thinking is prevalent. For example, Ian McHarg's ecological planning theory applied a rational planning approach and the "persuasive power of data" to address both environmental and land use problems (Bryant & Turner, 2019, p. 334). His layer cake model and ecological inventory approach to determine land suitability was the basis for geographic information systems and a main tool in environmental planning practice today (Cohen, 2019b). A weakness of McHarg's theory and method of ecological planning was the lack of attention paid to social and political influences on decision making (Bryant & Turner, 2019). However, his ecological planning theory did contribute to countering the prevailing economic growth planning model of the time and recognizing the need to incorporate environmental matters into land use planning (Daniels, 2019; Yang & Li, 2016).

Communicative / collaborative planning theory also intersects with environmental planning theory. Communicative / collaborative planning theory arose from the recognition that a community is made up of diverse views with the need for planning to include more inclusive forms of deliberation (Campbell et al., 2016; Fainstein, 2000). As noted by Healey (1998):

> Collaborative approaches emphasize the importance of building new policy discourses about the quality of places, developing collaboration among stakeholders in policy development as well as delivery, widening stakeholder involvement beyond traditional power elites, recognizing different forms of local knowledge, and building rich social networks as a resource of institutional capital through which new initiatives can be taken rapidly and legitimately (p.1531).

In practice, public participation if not collaboration is an accepted and required component of environmental planning, serving to incorporate local knowledge, encourage collaborative learning, address conflicting values, and effectively address cross jurisdictional boundary issues (Salazar et al., 2024, Tang & Brody, 2009).

Today, environmental planning theory is geared towards sustainable development, sustainability, and social-ecological systems. Sustainable development, from a planning theory perspective, involves the reconciliation of economic development, social equity, and environmental protection (Fainstein & DeFilippis, 2016). Sustainable development depends on the three equally important pillars of economic, social and environment however, sustainability applies a reductionist approach which segregates the three pillars while recognizing interdependencies and the need to negotiate trade-offs (Reyers et al., 2018). This categorization of the environment, economy, and society as separate areas of concern does not recognize the interconnections, and this hinders effective cross-sectoral cooperation and can contribute to the marginalization of the environmental sector (Vasseur et al., 2017).

Sustainable development is not the same as sustainability. Sustainable development focuses on human well-being while sustainability is focused on desirable long-term conditions

of natural and social systems (Harrington, 2016). A systems perspective has been directly linked to sustainability of future social and ecological conditions through the integration of human, social, and biological systems (Bettencourt & Kaur, 2011). As noted by Harrington (2016), "emphasis on sustainability is driven in part by the many economic, social, and environmental stresses being felt in the world today and an orientation toward understanding human–environment relations and social-ecological systems" (p. 377).

The social-ecological systems concept does not separate social and ecological systems but offers a more integrated vision of humans in nature, recognizing that societies and ecosystems are shaped by each other (Anderies et al., 2004; Berkes & Folke, 1998; Reyers et al, 2018). Environmental planning employing a systems perspective will need to clarify the relationships among social and natural aspects of the landscape and address ongoing and predicted land use changes and the social and ecological processes involved (Löfgren, 2020). The concept of social -ecological systems can help explain the complex interrelationship of ecosystems and society (Fischer et al., 2015) and encompasses the theory of collaborative governance (Bodin et al., 2016). For my research, environmental planning theory takes a social - ecological systems perspective, with a need to integrate policy areas over multiple scales through environmental governance.

2.3 Environmental governance for ecological connectivity

2.3.1 Environmental governance defined

An appropriate definition of environmental governance for this research can be adapted from Pittman and Armitage (2016) and Bennett and Satterfield (2018) as the institutions and

rules, structure or arrangement of organizations, and social processes and values, that guide decision-making on matters related to ecological connectivity. There is a feedback loop as environmental governance in turn influences landscape pattern as well as human perceptions and societal responses (Brunckhorst, 2010). A fragmented environmental governance system occurs when multiple or overlapping jurisdictions who are jointly responsible for land management do not collaborate on a common environmental issue (Hamilton et al., 2021).

Governance is different from government. A major difference recognized in the literature is that government is a formal, hierarchical institution with a command-and-control structure and governance is a network involving both government and non -governmental agents (Chaffin & Gunderson, 2016; Newig & Fritsch, 2009). Government is an instrument of implementing societal needs while governance is seen as a process to collectively address societal problems (Armitage et al., 2009). Environmental management is also different from environmental governance. According to Armitage et al. (2012), management is related to operational decisions geared towards specific environmental outcomes while governance is related to the broader societal decision-making processes on matters pertaining to the environment. Within the framework of social-ecological systems, governance involves a diversity of actors and a collaborative structure (Sternlieb et al., 2013).

2.3.2 Models of environmental governance

There are numerous types, structures or forms to environmental governance found in the literature. Table 2.1 provides a summary of the various approaches together with relevant, though not exhaustive, sources of the information. The literature is replete with research on

various models of environmental governance, and I found substantial overlap among the models outlined in the literature. A common thread, however, is the need to collaborate, negotiate or communicate among many diverse interests and organizations, working at various scales, to address a common goal. Some models replace or supersede the existing government regulation while others see collaborative models working within an enabling government system to influence outcomes (Armitage et al., 2012). The limitations of government such as silos management, lack of flexibility, political boundaries, lack of shared learning, power dynamics, and economic priority (Armitage et al., 2012; Sayles & Baggio, 2017) are to be addressed through a collaborative environmental governance model to better address large scale environmental issues such as ecological connectivity.

Table 2-1 : Various forms of governance relevant to ecological connectivity

Form of Governance	Key Characteristics	Sample Source
Hierarchical government	Multiple levels and a top-down approach with sequential implementation to lower levels. Regulatory approach with 'silo' management	Newig & Fritsch, 2009; Armitage et al., 2012
Private–social partnerships	Applicable to land stewardship initiatives and payment for ecosystem services	Lemos & Agrawal 2006
Co-management	Co-operation of formal authority with stakeholders to address a specific context, resource, or problem	Scarlett & McKinney, 2016
Adaptive	Promotes collaborative learning and flexible governance to address complexity, uncertainty and change through iterative and mutual learning	Wyborn, 2015; Chaffin et al., 2014
Collaborative	Collaboration as a mechanism to address diverse policy and management, among a multiplicity of actors or jurisdictions at multiple levels and scales, to address collective in an interconnected social and ecological system	Guerrero et al., 2015; Bodin et al., 2016
Network	Informal arrangement of people or organizations collaborating to solve cross boundary (agency, jurisdiction, ownership) problems of mutual interest to gain legitimacy, knowledge integration, and responsiveness for collective action which integrates social and ecological systems	Scarlett & McKinney, 2016; Pittman & Armitage, 2017
Nested	Collective action through a hierarchy of scales and institutions to address cross scale complex environmental issues	Wyborn & Bixler, 2013
Polycentric	Involves decentralized, multiple, redundant or autonomous overlapping jurisdictions and centres of decision making at multiple scales with a common goal or shared rules situated within a social ecological system	Bennett & Satterfield, 2017

2.4 Ecological Connectivity

2.4.1 The importance of connectivity

The reason to address connectivity can be divided into three main categories: a) species-related b) ecosystem-related and c) human-related. All three categories can be addressed in research concurrently, but the focus varies among researchers. Species conservation as motivation recognizes that protected areas are insufficient to ensure the persistence of species, both plants and animals (Hilty et al., 2020). Protected areas may not be adequately sized to support populations, or the diversity of populations needed for survival (Hilty et al., 2020). Fragmentation of the landscape isolates species and separates areas and habitat needed for feeding and reproduction (Beger et al., 2022; Boulton et al., 2018). The identification of patches/core areas/nodes, and corridors/greenways or stepping- stones is identified as a viable option to connect the landscape for species movement (Lynch, 2019). If corridors are not an option given the existing condition of the landscape, a network of linkages including travel across the working landscape or matrix is considered a feasible option to connect core areas for species movement (Opdam et al., 2006).

Species persistence and diversity, however, is tied to the connectivity of ecological processes and functions which support species (Berger et al., 2022). The focus on ecosystem processes rather than specific species can address multiple species at various scales (Hobbs et al., 2014). Ecological processes as a focus for connectivity considers ecological structure such as types, sizes, conditions, and arrangements of ecosystems (Mitchell et al., 2015). For example, if a wetland is needed as a reproductive stage, a land connection to the wetland may be ineffective if the wetland size or condition cannot support the species needs. In this case the

hydrological connections needed for the wetland functions are as important as safe means for species movement across the landscape (Leibowitz et al., 2018).

The human perspective of connectivity is derived from the concept of ecosystem services, or benefits to people from ecological processes (Egerer & Anderson, 2020). The fragmentation of the landscape also disrupts ecological functions and services recognized as important for human survival, for example, for clean and abundant water, pollination of plants, and a connection to nature (Mitchell et al., 2013). Greenways and green infrastructure are two recognized means to address connectivity for species but also for human benefit (Lynch, 2019; Dupras et al., 2016). The human perspective also brings cities into the realm of connectivity, with it recognizing that addressing connectivity in heavily populated areas is important for human health (Hardy et al., 2022). The assumption generally supported in the literature is that connectivity is good; however, it should be recognized that there are potential negative aspects as well. Invasive species, human/animal encounters, as well as introduction of pests, disease and fire are all potentially unexpected consequences of implementing connectivity (Cumming & Allen, 2017).

Spatial land use planning can address all three perspectives on connectivity: species movement, ecosystem processes, and ecosystem services. Research on planning for connectivity will generally address species through the lens of landscape patterns and configuration or ecological structure (Correa Ayram et al., 2016). There is also a body of research focused on connectivity for ecosystem services. For example, Mitchell et al. (2015), investigated how changes to landscape structure and connectivity affected the provision of ecosystem services to inform land use planning and guide decision making. Other studies have

evaluated linkages among ecosystem services and connectivity for use in land use or landscape management (Field & Parrott, 2017; Mitchell et al., 2013). Many studies on connectivity focus on the spatial identification and mapping of connectivity through various modeling approaches (Kumar et al, 2022). My research does not evaluate modelling approaches, and other than relationships to land use planning, the literature review excludes papers specific to connectivity modelling.

2.4.2 Connectivity defined

There is a need to understand the various perspectives on connectivity as connectivity can be addressed for different purposes and at various scales. There is uncertainty or ambiguity in the literature on why a connected landscape is important and as well as what needs to be connected (Hannah, 2011; Beger et al., 2022) with many questions on the effectiveness of connectivity for a given purpose. For example, is a connected landscape needed for species movement, or ecological processes, or ecological services such as recreation, or human access to nature, or a combination of multiple factors? Is a continuous corridor needed of a certain width or can natural areas of various sizes in close proximity to each other enable species movement? Can various types of working landscapes such as agriculture and forestry provide connectivity? Can focal species be used to address all species movement or is it better to ensure the persistence of ecological functions which can consider multiple species? While the concept of a connected landscape seems simple, the various interpretations and research applications can cause much confusion and inconsistent treatments. Table 2.2 outlines terminology found in the literature association with connectivity and several main terms are further explored below.

Table 2-2 : A selected listing of key connectivity concepts and terminologies

Type	Description
Landscape connectivity	The ability of the landscape to facilitate or impede movement among habitat patches, support ecological flows and the long-term persistence of biodiversity (Ng et al., 2013). Structural and functional links between habitats, processes, and populations that enable movement of materials and organisms Where there are opportunities to preserve or create *structural and functional links* between habitat (Beller et al., 2019).
Structural connectivity	A measure of habitat permeability based on the physical features and arrangements of habitat patches, disturbances and other land, freshwater or seascape elements presumed to be important for organisms to move through their environment (Hilty et al., 2020).
Functional connectivity	A description of how well genes, gametes, propagules or individuals move through land, freshwater and seascape (Rudnick et al., 2012; Weeks, 2017).
Habitat connectivity	The ability of organisms and/or their genetic materials to move within populations and within potential habitats through connected, contiguous terrestrial or aquatic corridors or stepping stones (Hardy et al., 2022).
Ecosystem connectivity	The physical and functional links among and within ecosystems that support biodiversity, complexity, and resilience (Beller et al., 2019; Hardy et al., 2022).
Ecological connectivity	The unimpeded movement of species and the flow of natural processes that sustain life on Earth (CMS, 2020).
Ecological network	A system of core habitats, connected by ecological corridors, which is established, restored and maintained to conserve biological diversity in systems that have been fragmented (Hilty et al., 2020) or a set of ecosystems of one type, linked into a spatially coherent system through flows of organisms, and interacting with the landscape matrix in which it is embedded (Opdam et al., 2006).
Geophysical connectivity	Relates to matter and energy flows, natural processes, and landscape features (Butler et al., 2022).
Eco-social connectivity	Brings in the human dimension and recognizes the inter relationship of humans and nature and application of ecosystem services (Butler et al., 2022).
Green infrastructure connectivity	Network of green (land) and blue (water) natural and semi-natural areas designed to deliver a wide range of ecosystem services to improve environmental conditions, enhance biodiversity, human health and quality of life (Hilty et al., 2020).
Greenway connectivity	Linear landscape structures for multipurpose use, including nature conservation and aesthetics, and recreational and cultural purposes (Opdam et al., 2006).
Ecosystem services connectivity	The benefits people obtain from ecosystems. These include provisioning services such as food and water production; regulating services such as flood and disease control; cultural services such as spiritual, recreational and cultural benefits; and supporting services such as nutrient cycling that maintain the conditions for life on Earth (Millennium Ecosystem Assessment, 2005)
Corridor connectivity	Spaces that allow for movement of individuals of species and related ecological processes like energy movement, gene flow, and nutrient cycles (Beita et al., 2021).
Hydrological connectivity	The transfer of matter and organisms within or between water resources (Larsen et al., 2012).
Management or process connectivity	Flows of information and resources that enable active collaboration (Aslan et al., 2021). Quantifies not flows of mass but flows of information between physical and biological drivers affecting the evolution of environmental systems (Larsen et al, 2012).
Connectivity conservation	Seeks to protect, retain and rehabilitate natural connections among habitats within ecosystems at the landscape scale, promoting collaboration among diverse actors to ameliorate social, institutional and ecological fragmentation (Wyborn, 2015).

Habitat connectivity

The main reason behind connectivity is to allow for species persistence through uninterrupted movement across the landscape (Jennings et al., 2020). Biodiversity conservation, it is argued, will not be successful if conservation of critical habitat is not accompanied by linkages among those habitats or habitat connectivity (Fahrig, 2003; Oppler et al., 2021). Without adequate habitat connectivity and species dispersal, the ability to reproduce may be limited and community composition affected (Saura et al., 2014). Habitat connectivity connects populations at scales from small scales, for example to accommodate salamanders travelling to breeding ponds, to large scales, for example wide ranging species as the grizzly bear or salmon moving from the sea inland along rivers to spawn. A break in the habitat or fragmentation typical caused by anthropogenic activities such as land clearing or the building of roads and dams will stop species movement.

Landscape connectivity

Landscape connectivity is another term applied which can be defined as the degree to which a landscape facilitates or impedes the movement of species and matter (Mitchell et al., 2013). Landscape connectivity is typically separated into structural and functional connectivity. Structural connectivity is associated with the physical arrangement of the landscape while functional connectivity is related to the movement of species (Keeley et al., 2021). While structural connectivity may connect patches of natural areas it may not be functionally connected for all species which need to travel across non-habitat or the matrix (Keeley et al., 2021).

Ecological connectivity

Ecological connectivity has been defined as the unimpeded movement of species and the flow of natural processes that sustain life on Earth (Convention on Migratory Species, 2020). Ecological connectivity not only addresses the persistence of species but ecosystems and associated flows of energy and materials, and integrity of biological communities through habitat linkages (or interactions of species with the abiotic environment) (Beger et al., 2022). Ecological connectivity also brings the idea of natural processes, functions, and services for humans into the concept of connectivity. While species movement is still the main concern, it is not the sole purpose for connecting the landscape.

Ecosystem services

Ecosystem services can range from pollination to water quality and flood regulation, seed dispersal and recreation, all which can be disrupted with a fragmented landscape (Mitchell et al., 2013). The loss of connectivity can lead to not only a reduction in biodiversity but also a decline in the provision of ecosystem services (Field & Parrot, 2022). This direct connection between ecological connectivity and ecosystem services has been demonstrated in numerous studies (e.g., Field & Parrott 2017; Mitchel et al, 2015; Ng et al., 2013).

Ecological network

Ecological network is a term used to describe a system of intact natural areas or ecosystems linked by corridors, stepping stones, or a permeable matrix into a coherent system to conserve biodiversity, facilitate species movement and provide ecological services (Hilty et al., 2020). An ecological network is typically associated with an existing fragmented landscape

where restoration is needed to complete a linked system of protected areas. It is also associated with the concept of a multi-functional approach where multiple benefits are assumed in line with the concept of sustainability (Opdam et al., 2006). Unlike the protection of natural features or areas through formalized parks, public lands, or protection measures, linkages among natural areas are typically owned and used by multiple actors for various reasons other than nature conservation (Beunen & Hagens, 2009). Thus, the maintenance of linkages or the creation of an ecological network or system must consider the various priorities placed on the landscape.

Greenways

Greenways are open space corridors or multi-functional linear green spaces, used for recreation or leisure as well as nature conservation (Lynch, 2019). Greenways expand the concept of parks and open space as a place for recreation to include the movement of species, preservation of biodiversity and ecosystem services (Bryant, 2006; Meneguetti & Oliveira, 2020). Greenways depend on the linear structure of some landscape features with ecological processes being secondary (Opdam et al., 2006). Greenways can serve to connect urbanized areas to rural or more open landscapes which promotes animal and plant migration (von Haaren & Reich, 2006).

Green infrastructure

Green infrastructure is another term that integrates the concept of ecological connectivity (Liquete, 2015). Green infrastructure is typically related to more urbanized areas and can be a network of natural, semi natural or designed landscape components that links

hydrologic functions and vegetation systems to provide social and ecological benefits (Kukkala & Moilanen, 2017). The movement of species would be a secondary or consequential result of green infrastructure. As green infrastructure planning recognizes the need for future land development to accommodate places for people to live, work and play, it facilitates human-environmental interactions at various scales (Meneguetti & Oliveira, 2020).

Hydrological connectivity

Hydrological connectivity, or freshwater corridors, incorporates ecological connectivity by specifically addressing water resources both as a means for aquatic species movement and addressing ecological processes and services (Larsen et al., 2012; McCullough, 2022). As with terrestrial-based ecological connectivity, hydrological connectivity can be fragmented through human activity such as building of dams, and shoreline development (McCullough, 2022). Hydrological connectivity may be addressed inadvertently through the incorporation of riparian areas in terrestrial connectivity; however, aquatic species are not typically considered in terrestrial connectivity. Cross-environmental realm studies related to ecological connectivity do consider terrestrial, freshwater and marine environments, however such studies are relatively scarce (Pittman & Armitage, 2017; Beger et al., 2010; Tulloch et al, 2021).

Definition for my research

As noted above, connections or linkages can be through corridors, stepping-stones or a permeable matrix, which is used for conserving biological diversity, species movement and sustained ecological processes (Hilty et al., 2020). Species movement and biodiversity conservation, while varying in importance, is a consistent theme in connectivity. The

relationship to ecosystem processes is also consistently recognized. The human element is not consistently applied, however the importance of ecosystem services, green infrastructure and greenways to address connectivity in human dominated landscapes is well represented. A common thread among the various approaches to connectivity seems to be the movement of plants, animals, and ecosystem processes, functions, or services across a landscape through linkages among intact environments. In the current research, the term ecological connectivity is used as it best reflects the multi-functional, multi-benefit approach typically taken in spatial land use planning (Gurrutxaga et al., 2015).

Local government land use planning is one method among many to address ecological connectivity. Other methods include publicly owned parks, private land stewardship, non-government organization programs to either purchase land or protect private lands, incentives to promote better land management, agricultural programs, legislation protecting rare and endangered species, and community parks and recreational spaces, (Cumming & Allen, 2017). Land use planning can add to this collective 'toolbox', and the importance of local government actions and land use planning decision-making, though recognized (Brody et al., 2004), has not been extensively studied.

2.5 Local government land use planning for ecological connectivity

Incorporating ecological connectivity into land use planning is not a new idea (Huber et al., 2012). McHarg in his 1971 publication Design with Nature, stressed the importance of an environmental perspective in land use planning, and the need for land use planners to address the maintenance of corridors or linkages among natural habitat for species dispersal has been

considered for decades (Soule, 1991). The scholarship on ecological connectivity is considerable; however there are relatively fewer studies which focus on local government as the instigator of planning for ecological connectivity.

Studies on local level spatial planning for ecological connectivity consider either modelling tools for identification of ecological connectivity (e.g., De Montis et al, 2016; Babí Almenar et al., 2019; Parrott et al., 2019; Huber et al., 2012; Park, 2015; Popescu et al., 2022; Puric-Mladenovic & Strobl, 2012; Scolozzia & Genelettib, 2012) or collaborative efforts of fragmented governance systems to address ecological connectivity (e.g., Kininmonth et al., 2015; Li et al. 2024; Parrott et al., 2019; Spang et al., 2012). There were few studies found that specifically addressed how local government land use planning can address ecological connectivity in practice. Additional research in case specific areas can further the knowledge on how land use planning can deal with the concept of ecological connectivity, how local government land use plans can contribute to collective action on ecosystem connectivity, and factors that influence how land use planning can take ecological connectivity into account (Leibenath, 2011).

Research specific to local government and environmental conservation was reviewed to gain an understanding of how past research related to my research. The studies generally recognized the importance of local government in addressing ecosystem related issues given their role in local land use decision-making. Opportunities and limitations were also recognized. Below is a summary of sample local government case study research related to ecological connectivity.

Brody et al. (2004) conducted research in Florida of a similar nature to my research on ecosystem or watershed management. The research recognized that ecosystem approaches typically applied a broad spatial scale, crossing local government boundaries, but also acknowledged that local land use plans and land use decisions contributed to the implementation of ecosystem management (Brody et al., 2004). The cumulative effects of local land use decisions were noted and collaboration across local government boundaries and among multiple organizations was recommended. The study also found that those areas most likely to consider a cross boundary approach were the area's most heavily impacted by development and with the greatest planning capacity.

Bergsten and Zetterberg (2013) studied the use of network analysis to address ecological connectivity in the practice of land use planning in Sweden. The case study results indicated that ecological connectivity was not well addressed in local government land use planning. A major benefit of spatially identifying ecological connectivity for land use planners was the ability to better communicate the meaning of connectivity and locate connectivity priorities within the broader regional landscape structure (Bergsten & Zetterberg, 2013). Bergsten et al. (2014) studied intermunicipal collaboration on ecological connectivity in Sweden and recognized the link between land use planning and controlling land fragmentation impacts on species persistence and ecosystem functioning.

Von Haaren and Reich (2006) and Leibenath (2011), studied ecological networks in spatial land use planning in Germany and identified benefits and limitations of the land use planning approach to ecological connectivity. Von Harren and Reich (2006) recognized that

transferring scientific information to practical land use planning at various scales was lacking, arguable due to the amount of private land and necessity to deal with many landowners when attempting to implement ecological connectivity. Given the need to allow ongoing intensive use of private lands for economic survival, it was suggested that ecological connectivity is more specifically geared towards land availability than individual species needs (Von Harren & Reich, 2006). This study also recognized that multifunctional landscapes focus on reconnecting remnant habitat typically through linear structures such as streams and floodplains with species conservation often being of secondary concern to other interests such as recreation and development interests (Von Harren & Reich, 2006).

Huber et al. (2012) undertook a study in California to investigate municipal and regional habitat connectivity planning. Though this was a modelling exercise it addressed the issue of regional versus local spatial scales. It was recognized that local governments could not operate outside of their sphere of influence, but as land use decisions are made at the local level, "regional conservation actions will often be the summed results of multiple local efforts" (Hubert et al., 2012, p. 25). It was also noted that planner interest contributed to the motivation for inclusion of policy on connectivity. The authors ended their article with a question, "how can connectivity planning for wildlife be integrated systematically across jurisdictional boundaries and under what mandates or policy frameworks?" (Hubert et al., 2012, p. 25)

Bryant (2006) undertook a study in Virginia and Washington D. C. on local multi-use greenways (recreation and ecological) and the role they played in biodiversity conservation. She

noted that since most land use decisions are made through local government, this was the most appropriate scale to successfully address biodiversity conservation. The results suggested that biodiversity could be increased by integrating politics, planning policy and stakeholder involvement, and applying regulatory and non-regulatory tools including "overlay zoning, stormwater ordinances, land acquisition, conservation easements, education programs, and others." (Byrant, 2006, p. 41).

Mancilla-Garcia et al. (2019) undertook a study on the role of local government in integrated watershed governance arrangements. The premise of the study was that water resources are interconnected and cross local and regional scales, requiring an integrated governance approach. The researchers argued that local governments were pivotal in a polycentric and multi-level watershed governance arrangement as local governments make the day-to-day decisions that affect their and downstream local governments.

Gurrutxaga et al. (2015) undertook an assessment of the integration of ecological networks in spatial land use planning in Spain and found that there was uneven integration as common guidelines were not used and there was a need for improvements to environmental assessments and training for planners. Opdam et al. (2006) investigated ecological networks in the Netherlands and proposed that multi-functional human dominated landscapes can apply the concept of ecological connectivity in land use planning and decision-making, given certain considerations and conditions, such as having all stakeholders involved in the design of an ecological network, the use of indicators to address multiple values, and the cooperation of administrative units across ecological scales. Perrin et al. (2022) studied implementation

challenges in spatial planning for ecological connectivity, including limitations of local governments in France to transpose higher level direction into land use planning documents. Other studies concentrated on urban areas or peri-urban areas, using greenways, green infrastructure, and ecosystem services as surrogates for ecological connectivity (e.g., Lynch, 2019; Mitchell et al., 2013; Field & Parrot, 2022; Gradinaru & Hesperger, 2019).

2.6 The integration of ecological connectivity in local government land use planning

The first topic area covered by this current research is how local government can address ecological connectivity in land use plans. Urban development and the associated infrastructure as well as intensive agriculture can fragment the land base, destroy habitat, and disrupt ecological connectivity (Dupras et al., 2016; Huber et al., 2012). Local government land use planning is geared towards controlling land use change and can be an effective tool in the maintenance of ecological connectivity (Jennings et al., 2020; Keeley et al., 2019; von Haaren & Reich, 2006). Privately owned lands can serve as a conduit, linking protected areas and when acquisition is not feasible, other methods to facilitate ecological connectivity are needed (Kamal et al., 2015). Spatial land use planning can restrict and focus development to protect habitat and support ecological connectivity (Brody & Highfield, 2005; Leibenath, 2011; Opdam, 2006).

Municipal or local government land use planning can play an essential role in the maintenance of biodiversity and ecological connectivity through the guidance of land use decisions on future land use change (Allred et al., 2021; Bergsten et al., 2014; Byrant, 2006). Local government strategic land use plans are prescriptive, proactive, long-term instruments which spatially allocate future land uses and integrate multiple issues such as future growth, agriculture, environmental protection, and public services such as parks and recreation (Brody

& Highfield, 2005). The identification of local scale connectivity or a network of greenspaces can help maintain ecological connectivity at a broader scale (Park, 2015). The process of developing a land use plan and associated public consultation, can serve to raise the level of awareness of the need for ecological connectivity to the general populace as well as the political decision makers (Bergsten & Zetterberg, 2013; Spang et al., 2012; Leibenath, 2011).

The incorporation of ecological connectivity into local government land use planning expands ecological connectivity from a purely ecological concept to a matter for which planners as well as political decision makers are accountable (Perrin et al., 2022). Land use planning can provide justification (e.g., ecosystem services), guidance, and information for connectivity efforts and keep habitat available for wildlife without the need to purchase the land (Keeley et al., 2018). Without local government land use plans and policies to address ecological connectivity, there are limited opportunities to mitigate the impact of development on the landscape (Kamal et al., 2015).

There are, however, limitations to the utilization of local government land use planning to address the protection and restoration of ecological connectivity. The first limitation stems from the lack of fit of local government boundaries and the extent of ecological connectivity. Local government land use planning can more easily address locally contained ecological processes than cross boundary processes with a need to coordinate land use planning across jurisdictional boundaries to maintain ecological connectivity (Bergsten et al., 2014). Local government jurisdiction is restricted to the area within the politically identified area with no formal responsibility to manage cross border ecological connectivity (Bergsten & Zetterberg, 2013; Brody et al., 2004). The local government boundaries do not necessarily encompass the

area necessary to manage larger scale ecological connectivity and at times this lack of fit makes the effectiveness of policies questionable (Huber at al., 2012; Keeley et al., 2022).

A second major concern with local government land use planning to address ecological connectivity is a lack of plan implementation and inability to determine the ecological effectiveness of the policies (Huber et al., 2012; Watson et al., 2017). Many connectivity plans exist; however, implementation has been slow, and this failure has been referred to as the research-implementation gap or planning- implementation gap (Keeley et al., 2018). This condition of planning for but not implementing ecosystem connectivity appears to be a continuing issue with numerous factors being identified that hinder plan implementation such as a lack of long-term leadership, no specific recommendations, absence of enabling legalisation (Keeley et al., 2019) or a lack of research on the success of conceptually delineation studies in creating functional connections (Lynch, 2019).

Other limitations specific to local government land use planning are related to instruments or methods to implement ecological connectivity as generalized here:

- There is a time lag between upper-level policy development (international /national/ federal or provincial/state) and incorporation into local government land use planning documents (Perrin et al., 2022).
- Local government land use planning has a limited ability to adapt to dynamic ecological processes and changing land uses given the static nature of land use policy once adopted (Leibenath, 2011; Perrin et al., 2022; Armitage et al., 2012).
- External factors influence plan quality or direction such as level of expertise of the planners, support by politicians and the public, and balancing of multiple values (Keeley et al., 2018, 2019; Opdam, 2006; Perrin et al., 2022).

- There can be a variability of regulatory methods to implement identified ecological connectivity among local governments and compromises on the spatial delimitation of ecological connectivity such as reduced corridor width, can impact ecosystem functioning (Perrin et al., 2022).
- It is difficult for land use planning to ensure functionality of ecological connectivity and land use planning is best combined with other approaches such as land acquisition, voluntary measures by landowners, project specific actions by non-government organizations (Donati et al., 2022; Leibenath, 2011).
- There is overlap among local government policy areas for ecological connectivity with a need to integrate with other policy areas such as green infrastructure, water management, and parks and open space planning (Perrin et al., 2022), and agricultural land permeability (Donald & Evans, 2006) and climate change (Boehnke et al., 2023)
- The site-specific nature of land use planning makes it difficult to address the broader landscape perspective with ecological connectivity potentially being addresses in isolated parcels (Kor, et al., 2022, Lemieux, 2021).
- The local perspective limits the spatial reach of local government with broad scale connectivity beyond the scope of a particular local government (Huber et al., 2012; Moss, 2012).
- Land use planning addresses numerous land uses with the need to balance values through negotiations and compromises, which implies that ecological connectivity can end up with less than optimal consideration (Opdam et al, 2006).

How environmental issues are incorporated within land use planning or used to support planning practice will have a bearing on how land use decisions are made (Albert et al., 2014).

2.7 Factors that facilitate or hinder planning and maintenance of ecological connectivity

The second topic area covered by this current research is the factors that influence the planning and maintenance of ecological connectivity, with a focus on local government land use

planning. Above I presented a review of case study research on local government land use planning for ecological connectivity together with generalized benefits and limitations. A broader investigation of the literature on what factors help or hinder planning and plan implementation for ecological connectivity is outlined here. The literature reviewed typically studied either the practice of planning for ecological connectivity (Perrin et al., 2022) or the implementation of conservation plan policies (Keeley et al., 2019). Literature on the incorporation of similar topics into land use planning such as ecosystem services, green infrastructure, biodiversity, and multipurpose greenways was also reviewed. The literature reviewed tended to lump factors affecting the practice of planning together with factors affecting the implementation of ecological connectivity, and distinguishing factors of planning or of implementation was not always possible. As the literature was reviewed, it became apparent that the noted factors could be placed in four general categories: (a) physical or structural; (b) governance or process; (c) financial or resources; and (d) knowledge or learning.

2.7.1 Physical or structural landscape factors

The physical or structural theme reflects how the landscape configuration and use affect species persistence and the planning and maintenance of ecological connectivity. Landscape connectivity is represented as structural connectivity (spatial configuration and physical relationship of habitat) and functional connectivity (movement of species across the landscape) (Hou et al., 2017; Tischendorf & Fahrig, 2000). Structural connectivity is the basis for identifying an ecological network composed of habitat patches, corridors or linkages among the patches, steppingstones (patches in close proximity that can be used for species movement), and a permeable matrix (which permits species dispersal) (Opdam et al., 2006). Functional

connectivity, while the goal of ecological connectivity, is rarely directly applied in land use planning given a lack of data on species movement or need to accommodate more than certain focal species (Keeley et al., 2021). Instead, functional connectivity is estimated as landscape features that facilitate or impede the movement of species between patches (Correa Ayram et al., 2016).

Table 2.3 outlines the main barriers and associated opportunities identified in the literature. The primary issue identified is continued fragmentation of the landscape from urban and rural development (Babi Almenar et al., 2019; Fischer & Lindenmayer, 2007; Scolozzi & Geneletti, 2012). One solution outlined is the use of local government land use planning to focus and restrict development or mitigate impacts on ecological connectivity (Brody & Highfield, 2005; Leibenath, 2011; Opdam, 2006). Another overarching barrier is the spatial method, data and scale used to identify ecological connectivity. Many models are outlined in the literature to spatially identify ecological connectivity (Kumar et al, 2022), and the debate on an appropriate modelling tool to guide local government land use planning is ongoing.

Other factors identified related to the physical landscape include:

- A focus on identifying natural features such as wetlands or woodlands rather than linkages among natural features (Puric-Mladenovic & Strobl, 2012; Spang et al., 2012),
- Physical barriers such as fences, rivers, roads/road density, land cover, dams, topography (Elton & Drescher, 2019; von Haaren & Reich, 2006; McRae et al., 2012)
- Limited availability of natural areas in a densely populated area to set aside for connectivity (von Haaren & Reich, 2006)
- Competing land uses, private land tenures and existing land use patterns could be prohibitive to successfully implementing connectivity on the ground (Beunen & Hagens, 2009; Keeley et al., 2018, 2019).

- Climate change has the potential to alter species range (Hannah, 2011; Saura et al., 2017).
- Harmful effects from connectivity (e.g., invasive species) (Aslan et al., 2021).
- Modern farming practices with larger farm equipment and farm consolidation remove hedgerows or riparian areas (Hauser et al., 2016; Raymundo et al., 2023).

In summary, physical or structural factors are related to the configuration of the landscape, including the existence and location of natural areas, human influences that impede or compete with species movement across the landscape, and external factors affecting the configuration of the landscape such as private land, and climate change. All these factors influence if or how ecological connectivity is identified and maintained into the future.

Table 2-3 : Summary of barriers and opportunities - physical or structural

Barriers	Opportunities
Physical barriers –fences, rivers, roads/road density, land cover, dams, topography (Elton & Drescher, 2019; von Haaren & Reich, 2006; McRae et al., 2012)	Use linear features (riparian areas), remove barriers, create connections (tunnels, green bridges, fish ladders) (Elton & Drescher, 2019; von Haaren & Reich, 2006; McRae et al., 2012)
Focus on features and not linkages (Puric-Mladenovic & Strobl, 2012; Spang et al., 2012)	Carry out a networked or systems approach Puric-Mladenovic & Strobl, 2012; Spang et al., 2012)
Existing and conflicting land use that prohibits connections (Keeley et al., 2018, 2019)	Private land stewardship (Hauser et al., 2016; Martin, 2016)
Climate change altering the spatial location of corridors (Hannah, 2011; Saura et al., 2017)	Incorporating climate change into land use planning (Schloss et al., 2022)
Continued fragmentation from urban and rural development (Brody & Highfield, 2005; Opdam, 2006; Perrin et al., 2022).	Identification of ecological connectivity in planning documents (Brody & Highfield, 2011; Opdam, 2006; Perrin et al., 2022).
Determining the spatial location and extent of a corridor/linkage/ecosystem network (Beunen & Hagens, 2009; Ford et al., 2020)	Application of models and spatial data; scenario building with local stakeholders (Kumar et al, 2022; Keeley et al., 2021; Mitchell et al., 2015)
Limited natural /vegetated land available for connectivity (von Haaren & Reich, 2006)	Planning will need to be guided by availability of land (von Haaren and Reich, 2006) and address restoration of hotspots (McRae et al, 2012)
Adverse effects of connectivity such as invasive species (Aslan et al., 2021)	Threat mitigation - conserving native plants (Miller et al., 2009); improving matrix quality (Donald & Evans, 2006)
Multiple privately owned parcels to cross (Beunen & Hagens, 2009; Pelosi et al., 2010); opportunity based (Kamal, et al., 2015)	Landscape-scale approach to private land stewardship (Cooke & Moon, 2015)
Modern farming practices, farm consolidation (Hauser et al., 2016; Raymundo et al., 2023)	Retain small parcels such as forest remnants, hedgerows, and riparian areas as corridors (Hou et al., 2017; Mitchell et al., 2015)

2.7.2 Governance or process factors

Environmental governance is a broad topic and factors in this theme area can apply to any environmental issue. An effort was made to focus on general and most relevant factors for local government land use planning for ecological connectivity. Two types of planning for ecological connectivity were identified: conservation plans focusing on the environment; and land use plans addressing multiple values (economic, social, environment) and multiple land uses in addition to environmental protection. Both types were reviewed to identify factors. The surrogate aspects of ecological connectivity were also used to identify factors such as green infrastructure, biodiversity, greenways, and ecosystem services.

The main topic under investigation in the governance and process theme area is a fragmented decision-making process. Specifically, the lack of coordination across spatial jurisdictional boundaries and the lack of integration of various stakeholders and levels of government who have a part to play in the planning and maintenance of ecological connectivity (Mancilla-Garcia et al., 2019; Williamson et al., 2023). Additional factors are noted below, and Table 2.4 summarizes the main factors applicable to this theme area.

- Enabling legislation encourages policy development and implementation and without a legal mandate, NGOs play a more prominent role to provide leadership and funding (Keeley et al., 2019)
- Specific plan recommendations (e.g., land purchase, easement, restoration) will lead to implementation (Keeley et al., 2019)
- Key government stakeholder participation and buy-in (Keeley et aal., 2019)

- Lack of cooperation and coordination across jurisdictional boundaries (Allred et al., 2021; Bergsten et al., 2014; Sprang et al., 2012); local governments are poorly coordinated (siloed), leading to ineffectual policy and decisions (Rincón, et al., 2021)
- Ineffective and inefficient cross border regulation or communication (Moss, 2012; Scarlett & McKinney, 2016)
- A need for collaboration for cross-border issues, (Aslan et al., 2021; Epstein et al, 2015; Moss, 2012; Parrott et al., 2019; Baggio et al., 2019; Bodin, 2017; Mancilla-Garcia et al. 2019)
- Lack of policy integration, overlapping jurisdictions, uncoordinated mandates at various scales (Perrin et al., 2022; Pittman & Armitage, 2019; Hamilton et al., 2021)
- Local government jurisdiction and geographical boundaries restrict actions (Hardy et al., 2022)
- Multiple land tenures to be coordinated (Kamal et al., 2015).
- Private lands pose a barrier due to the voluntary nature of private land stewardship, reluctance of landowners, inability to target specific areas, the inequity in private landowners providing benefits which extend beyond their property (Bennett et al., 2018; Donald & Evans, 2006; Drescher, 2014; Martin, 2016; Nebel et al., 2017; Olive & McCune, 2017)
- Ineffective planning tools, site specific nature of development restricts a landscape view (Kor, et al., 2022; Allred et al., 2021; Brody, 2003)
- Lack of trust among government levels and landowners (Armitage et al. 2012; Williamson et al., 2023)

In summary, governance or process factors relate to how local government identify and maintain ecological connectivity. Influential factors are associated with the fragmented nature of the governance and decision-making structure, making cooperation and coordination difficult. Legislative and regulatory tools are needed to enable political support, and trust is needed to ensure local buy-in and landowner action.

Table 2-4 : Summary of barriers and opportunities - governance or process

Barriers	Opportunities
Jurisdictional fragmentation (Allred et al., 2021; Bergsten et al., 2014; Sprang et al., 2012; Perrin et al., 2022; Pittman & Armitage, 2019; Hamilton et al., 2021)	Integrated policy at different scales, collaborative approaches, improve institutional capacity (Allred et al., 2021; Bergsten et al., 2014)
Lack of co-operation and cross border co-ordination (Moss, 2012; Scarlett & McKinney, 2016; Perrin et al., 2022)	Cross border collaboration (Aslan et al., 2021; Epstein et al, 2015; Parrott et al., 2019; Bodin, 2017)
No legal or mandated direction to conserve ecological connectivity (Keeley et al., 2019)	Enabling legislation or NGO leadership (Keeley et al., 2019).
Lack of political support (Khoshkar et al., 2020; Williamson et al., 2023)	Fostering shared learning (Alexander et al., 2016; Khoshkar et al., 2020; Williamson et al., 2023)
Lack of initial buy in from key government stakeholders (transportation, land use, regulatory) (Keeley et al., 2019)	Key stakeholder involvement in the planning will promote implementation (Keeley et al., 2019)
Lack of recommendations and identified actors to carry out the implementation (Keeley at al., 2019)	Clear recommendations and actions outlined in a plan (Keeley et al., 2019)
Ineffective planning tools, lack of authority, site specific nature of development (Kor, et al., 2022; Allred et al., 2021)	Toolkits or toolbox (Keeley et al., 2019); environmental impact assessments incorporate the wider landscape (Kor et al., 2022)
Local government boundaries restrict actions (Hardy et al., 2022)	Top-down or bottom-up collaboration (Guerrero et al., 2020; Li et al., 2024)
Voluntary nature of private land stewardship (Bennett et al., 2018; Drescher, 2014; Martin, 2016; Olive & McCune, 2017)	Conservation easements (Drescher, 2014); partner with NGOs (Kamal et al., 2015)
Lack of trust (Armitage et al. 2010; Ayambire et al., 2022)	Bridging organizations as intermediaries (Ayambire et al., 2022; Hamilton et al., 2021)

2.7.3 Financial or resources factors

The financial or resource theme is very focused on the capacity or ability of practitioners to incorporate ecological connectivity in land use plans and implement the policy direction (Table 2.5). Resources include capacity of staff, available time, adequate funding, expertise, and leadership. Barriers commonly raised in this theme area were a lack of resources: for the identification of ecological connectivity; the implementation of policy; and for collaboration with others for cross jurisdictional coordination (Allred et al., 2021; Brody, 2003). Staff may not have the expertise to address ecological connectivity or financial resources to undertake a mapping exercise (Keeley et al, 2019; Williamson et al., 2023).

Keeley et al., (2018, 2019) noted that a continuity of partners and leadership was needed to implement connectivity plans with staff turnover or the loss of a key champion leading to a lack of institutional memory or commitment to the vision or anticipated tasks. The cost of land acquisition was identified as a barrier in maintaining ecological connectivity (Brunckhorst, 2010; Kamal et al., 2015; Shilling & Girvetz, 2007) as was the costs to carry out stewardship programs (Martin, 2016) and construct wildlife crossing structures (Elton & Drescher, 2019). The opportunity to address these funding challenges was the use of incentives or other funding mechanisms to encourage landowners to participate in stewardship initiatives (Cerra, 2017). A perceived impact on private landowners' lifestyle or livelihood is a financial barrier to landowner participation in stewardship programs (Drescher, 2014) with education seen as a method to address these perceptions (Bennett et al., 2018; Drescher et al., 2017).

In summary, financial or resources factors relate to costs, capacity, and staff needed to identify and maintain ecological connectivity. There are costs to address physical barriers, acquire land, and implement programs which require sufficient funding or financial resources. Adequate capacity, time and training is needed to address the science behind ecological connectivity, to collaborate with stakeholders and to address local concerns or justify actions. Adequate and continual staffing is needed for leadership and for consistency to enable implementation of ecological connectivity into the future.

Table 2-5 : Summary of barriers and opportunities - financial or resources

Barriers	**Opportunities**
Cost of wildlife overpasses (Elton & Drescher, 2019; Hardy et al., 2022)	Address at time of construction and maintenance as retrofitting is cost prohibitive (Newell et al., 2022)
Staff expertise or capacity (Keeley et al., 2019; Williamson et al., 2023)	Training and funding (Miller et al., 2009)
Cost of land acquisition (Brunckhorst, 2010; Kamal et al., 2015; Shilling & Girvetz, 2007)	Access funding sources, securement strategy (Lemieux et al., 2021)
Staff turnover, lack of institutional memory or commitment (Keeley et al., 2019)	Continuity of staff and leadership (Keeley et al., 2019)
Cost, time, and expertise to manage stewardship lands (Martin, 2016)	Incentives, outreach (Cerra, 2017)
Lack of capacity to participate in collaborative processes (Moss 2012)	Provide support and capacity building (Alexander et al., 2016)
Perceived impact on lifestyle (Drescher, 2014)	Educational programs (Bennett et al., 2018; Drescher et al., 2017)

2.7.4 Knowledge or learning factors

The knowledge and learning theme is related to the need for shared learning to understanding why ecological connectivity is important and should be maintained (Table 2.6). A lack of knowledge of the benefits of ecological connectivity (Allred et al., 2021) can lead to a lack of public support and political buy-in with a need for education or public outreach to garner support (Keeley et al., 2019; Ruzow-Holland, 2022). There was an opportunity to assess economic benefits such as ecosystem services to clarify the advantages of connectivity planning (Cortinovisa & Geneletti, 2018; Bryant, 2006; Andersson et al., 2014). The use of charismatic or endangered focal species to identify ecological connectivity could be utilized to raise the level of awareness by non-ecologist stakeholders to build support and motivate implementation measures (Keeley et al., 2019).

A science based transparent and repeatable process to identify ecological connectivity was identified as a positive factor to aid in decision making (Keeley et al., 2019). A lack of data and information needed to plan for connectivity was noted as a barrier (Cummings & Allen, 2017; Brodie et al., 2016) with an opportunity to maintaining a central database to increasing data availability, data use and general awareness (Lemieux et al., 2022). Knowledge (e.g., species needs, movement patterns, biotic responses, data required) was also needed to address the challenge of monitoring plan implementation progress with the need for measurable indicators to show effectiveness (Watson et al., 2017; Keeley et al., 2021). A lack of a standardized approach such as definitions, objectives, targets, and assessment criteria to assess performance can be a barrier and result in a narrow interpretation of what ecological

connectivity is and how it is identified or inconsistency in monitoring the success of ecological connectivity (Rincón et al., 2021).

Shared learning was often noted as a prerequisite for successful collaboration which brings together multiple interests (Armitage et al., 2012; Alexander et al., 2016; Baggio et al., 2019; Reyers et al., 2010; Sternlieb et al., 2013). Meaningful stakeholder engagement was also noted to encourage shared learning and a shared vision (Duvall et al., 2017; Spang et al., 2012). The importance to incorporate local knowledge was also stressed as a means to better inform conservation decisions and to encourage local management actions (Kark et al., 2014; Khoshkar et al., 2020).

Table 2-6 : Summary of barriers and opportunities - knowledge or learning

Barriers	**Opportunities**
Lack of knowledge or interest (Allred et al., 2021)	Education, public outreach (Keeley et al., 2019) environmental planner on staff (Miller et al., 2009)
Lack of effective collaboration (Armitage et al., 2012; Alexander et al., 2016; Baggio et al., 2019; Reyers et al., 2010; Sternlieb et al., 2013).	Shared learning (Armitage et al., 2012; Alexander et al., 2016; Baggio et al., 2019; Reyers et al., 2010; Sternlieb et al., 2013); local knowledge (Khoshkar et al., 2020).
Lack of stakeholder, public and political awareness and buy-in (Keeley et al., 2019; Ruzow - Holland, 2022)	Apply economic benefits such as ecosystem services (Cortinovisa & Geneletti, 2018; Bryant, 2006; Andersson et al., 2014); stakeholder engagement (Duvall et al., 2017; Spang et al., 2012)
Lack and inconsistency of spatial data (Cummings & Allen, 2017, Brodie et al., 2016)	Maintain a central database (Lemieux et al., 2022).
Insufficient efforts in implementation and monitoring (Lemieux et al., 2022; Watson et al., 2017; Keeley et al., 2021)	Monitoring plan implementation with measurable, standardized indicators (Keeley et al., 2021; Rincón et al., 2021; Watson et al., 2017)

In summary, knowledge or learning factors relate to a need for scientifically defensible data, outreach, and shared learning to identify and implement ecological connectivity. A need to educate those who make the decisions or own the land is considered essential to ensure support and convince stakeholders of the importance of conserving ecological connectivity. This can be done through a scientifically transparent and defensible application of appropriate data and demonstration of social or economic benefits. Collaboration is stressed as the best means to encourage shared learning and incorporate local knowledge and ensure all values are considered in the decision making and implementation process.

2.8 Collaboration for ecological connectivity

A common theme among the four general categories factors that affect ecological connectivity is the fragmentation of the landscape through land use change and the need for a collaborative form of environmental governance for effective outcomes (Bodin, 2017; Kininmonth et al., 2015; Sayles and Baggio, 2017). The last topic area covered by this current research is local government collaboration for ecological connectivity. The literature is expansive on how collaboration is carried out, and the benefits and limitations of a collaborative approach. A collaborative initiative can be either directed (top down) or self-organized (bottom up), each having inherent characteristics (Guerrero et al., 2015). For example, self-organized collaboration can better align with the ecological extent of the environmental issue but can benefit from some centralized coordination, while directed collaboration may not include all stakeholders but can extend across broader scales (Guerrero et al., 2015). The research on collaborative environmental governance can be focused strictly

on the social and political processes (Bodin, 2017), or directed to interactions among the actors and components of an ecosystem (Guerrero et al., 2015). In the following sections, I am focusing on two main issues outlined in the literature for collaborative environmental governance: (1) encouraging multiple actors, government and non-government, to participate in decision-making or implementation, and (2) matching the level and scale of the environmental issue with the governance structure (Newig & Fritsch, 2009).

2.8.1. Multiple actors

The move from government to governance is characterized by the inclusion of non-government organizations in collaborative decision-making. This is the general premise of my research on ecological connectivity, namely that collaboration is needed and that it involves multiple actors. It has long been argued that the inclusion of multiple actors can lead to better and legitimate solutions while still recognizing the limitations of broad involvement such as cost, time, and inertia (Koontz & Johnson, 2004). This is perhaps more important for local government land use planning given the need to address multiple interests and land uses with negotiated trade-offs. Communicative planning theory acknowledges the move of the planner as expert to the planner as mediator in collaboration among multiple interests (Barry et al., 2018). There is however an ongoing tension with the suggestion of ecological connectivity needing a defensible scientific and repeatable process (planner as expert) and a collaborative integrated process (planner as mediator). Both roles are apparently needed to plan for and maintain ecological connectivity, but can both be accommodated through local government land use planning?

Three main actors are identified in the literature as integral to the planning and maintenance of ecological connectivity: government, NGOs, and landowners. Government is recognized in the literature as a major actor in the planning and maintenance of ecological connectivity, particularly those with a mandate for transportation, land use planning, or environmental regulation (Keeley et al., 2019). Higher levels of government (international, national, state) are responsible for legislation, addressing the broad scale and cross boundary nature of ecological connectivity, and carrying out or mandating collaboration. For example, the EU Habitats and Birds Directives are the legal framework for Natura 2000, a Europe-wide network pf protected sites to be implemented by member states (EU, 2019). Local government is recognized as the subsidiary level where more socially acceptable land use decisions are made, albeit within a broader state framework to ensure consistency, minimum standards, and consideration of priority issues (Vasseur et al., 2017). The principle of subsidiarity, the devolution of decision-making to the lowest institutional level capable of or with the capacity to carry them out (Cheok et al., 2019) can be applied to local government. Yet there is still the need to determine the capabilities of local government to effectively address ecological connectivity and address cross scale effects of ecological connectivity.

It has been suggested that environmental NGOs can serve as a bridge to coordinate actors or a broker to mediate among interests (Keeley et al., 2019). Environmental NGOs can also focus on the environment as an issue, provide expertise, lobby governments, raise funds, conduct landowner outreach, acquire or protect lands through conservation easements, and can be more resilient to changing government priorities (Keeley et al., 2019; Doucet et al.,

2024). Overall, NGOs as part of a collaborative process, can supplement local government resources and increase local government capacity (Doucet et al., 2024).

Landowners are relevant actors in ecological connectivity. The literature recognizes that private land conservation is needed to link protected areas (Drescher & Brenner, 2018). Collaborating with private landowners, while necessary, can be difficult given the need to work across multiple properties to realize ecological connectivity (Cooke & Moon, 2015) and landowner reluctance or lack of trust of government and regulation (Drescher & Brenner, 2018). Still without the active engagement of private landowners directly or through NGOs, the conservation of ecological connectivity will not be effective.

In theory, collaboration can facilitate coordination among mandates and across spatial jurisdictions or boundaries. Collaboration can be achieved through standardization where similar use of standards or criteria (e.g., minimum parcel size, width of corridors, distance between patches, species of importance), can lead to consistency across the landscape (Rincón et al., 2021). The use of criteria was well recognized in the literature through modelling to scientifically identify ecological connectivity. Modelling can take a broad scale approach to be applied at a more local scale (Puric-Mladenovic & Strobl, 2012), serve to create guides for land use decision making (Park, 2015; Parrott et al., 2019), provide a means to prioritize areas or identify bottlenecks to ecological connectivity (Klar et al., 2012), and assist in monitoring (Keeley et al., 2021; Watson et al., 2017). Yet as so succinctly noted by Parrott et al. (2019), a fragmented governance structure:

> is the single biggest challenge in achieving and coordinating planning for ecological connectivity. In our experience, demonstrating what needs to be done

> to preserve a species, ecosystem, or ecological function is often the easy part of a project; achieving that objective across scales of governance and within a context of complex social and economic constraints and opportunities is altogether different (p. 212).

2.8.2 Ecological connectivity scales and the concept of fit

Ecological connectivity has been addressed at global, international, national, provincial or state, regional, watershed, local and site-specific scales. Ecological connectivity can be shown at any spatial scale related to different species needs (Opdam, 2006). It is important to identify relevant scales and scaling relationships to address ecological connectivity (Cumming & Allen, 2017). A broad scale is needed to maintain connectivity among protected areas and accommodate certain ecological processes and broad ranging species dispersal patterns (Baldwin et al., 2009). Addressing climate change related shifting of species ranges also requires a broad scale (Hannah et al., 2011; Opdam et al., 2006; Watson et al., 2017). A local scale is needed to address incremental and cumulative effects of land use change (Baldwin et al., 2009) and ensure that local knowledge and small habitat areas are included in the analysis of ecological connectivity (Huber et al., 2012). The local scale is where broader landscape goals are implemented and land use decisions are made (Bryant, 2006). Actions at the local scale affect the broader landscape since ecological processes are connected and can even impact global concerns (Folke et al., 2007).

It has been argued that land use planning can best address ecological processes at a landscape scale (Albert et al., 2014), without however, defining what is meant by a landscape

scale or landscape planning. Since ecological connectivity occurs at all scales (Cheok et al., 2019; Cumming et al., 2015), to effectively manage ecological connectivity it is necessary to match the object for connectivity to the management unit (Bergsten et al., 2014). This can require a coarse-grained resolution for generalized connectivity mapping or fine grained resolution for site specific linkage design (Modica et al., 2021). It may also consider the broader land matrix rather than connections among remnant natural areas (Gippoliti & Battisti, 2017). Overall, ecological connectivity is a cross-scale dependent system (Keeley et al., 2022) and all scales need to be considered to effectively address ecological connectivity. Addressing cross-scale issues can be difficult if the scale of the governance system does not match the ecological processes.

The concept of matching the spatial scale of an ecological problem with governance processes has been extensively documented, including reference to local government (Bergsten et al., 2014; Kininmonth et al., 2015; Keeley et al., 2022). A mismatch can result in poor ecological management through a resolution mismatch (scale of management actions does not address the problem), or boundary mismatch (ecological processes transcends governance boundaries) (Bergsten et al., 2014). Local government boundaries do not typically align with ecological boundaries such as watersheds or ecoregions (Keeley et al., 2022), and planning for ecological connectivity within local government boundaries runs the risk of not taking cross boundary ecosystem processes into account (Ekstrom & Young, 2009). In addition, government organizations can be hierarchical covering different scales and with overlapping interests (Keeley et al., 2022), with a potential mismatch between higher level objectives and lower level policy and implementation (Holzhauer et al., 2019). The potential mismatch or lack of fit

among local government spatial boundaries, levels of jurisdictions and maintenance of ecological connectivity, presents local government land use planning as a good example to investigate how local government can address cross boundary ecological connectivity.

Various terms are used to describe the matching of governance with environmental issues including institutional fit (Epstein et al., 2015), social-ecological fit (Enqvist et al., 2020; Guerrero et al., 2015), spatial fit (Bergsten et al., 2014), and functional fit (Ekstrom & Young, 2009). For my research, I am using the term institutional fit. The term institution has been defined as "the formal and informal rules, norms, and conventions that societies use to structure inter-actions and increase predictability in situations of interdependent choice (Epstein et al, 2015, p. 34).

It might be possible for a formal governance structure to adapt to an ecological issue by adjusting the boundaries of authority, such as governance on a watershed basis (Garcia et al., 2019; Yoder et al., 2012), or the governance structure can consist of an informal network of actors collaborating or coordinating actions (Guerrerro et al., 2015). A lack of fit, when institutions do not take the functionality of the ecosystem into account, can lead to ineffective management of complex environmental issues such as ecological connectivity (Ekstrom & Young, 2009). The means to address a this is to encourage a collaborative form of governance. However, it is recognized that collaborative environmental governance is not the only solutions, and there is ongoing debate on the effectiveness of collaborative governance (Bodin, 2017; Yoder et al., 2012), even though collaboration is still seen as a viable option to address challenges related to institutional fit.

Three challenges of fit were identified by Guerrero at al. (2015) and echoed by other research on the problem of fit. These three challenges are summarized in Table 2.7 demonstrating the relationship of social and ecological systems. The first challenge is shared management of an interdependent biophysical system. If the biophysical components are linked, so should the actors. The second challenge arises from the interconnected nature of ecosystem processes. If ecological processes and functions cross jurisdictional boundaries, so should the governance structure. The third challenge is related to the need for cross scale management. If ecological processes occur at multiple scales, so should the planning.

Shared management or policy interdependence, where managers work in isolation on components of a complex environmental issue, can lead to overlapping or uncoordinated management (Bodin & Chen, 2023; Hamilton et al., 2021). The challenge is to integrate interests and concerns from multiple jurisdictions (Scarlet & Mckinney, 2015). For example, various level of government, watershed-based agencies, non-government organizations and landowners may all be working on ecological connectivity but without coordinated or collective action. The second challenge is the interconnected nature of the ecosystem. Ecological connectivity is a prime example, as the movement of species cross jurisdictional boundaries and uncoordinated action can lead to ineffective management or adverse effects beyond jurisdictional borders (Boden & Chen, 2023). Cross-scale management is the third challenge where conservation efforts occur at multiple scales and multiple ecological processes occur at various scales. Under these conditions the scale of the problem needs to match the scale of the planning (Parrott et al., 2019; Guerrero et al., 2015; Perrin et al., 2022). For example, broad scale planning for ecological connectivity may not address local needs (Huber et al., 2012) and

local planning for ecological connectivity may not address cumulative effects (Baldwin et al., 2009).

Table 2-7 : The challenges of institutional fit in a social ecological system

Challenges	Institutional fit	
	Social (prosperity)	Ecological (integrity)
Shared management of an Interdependent system: If the biophysical components are linked, so should be the actors	Balancing multiple actor interests	Biophysical components and ecosystem dynamics
Interconnected: If ecological processes and functions cross jurisdictional boundaries, so should the governance structure	Administrative boundaries	Ecological processes and functions
Multi scale: If ecological processes occur at multiple scales, so should the planning	Organizational levels and planning at various scales	Multiple processes at small to large scales

2.9 Conclusion

This literature review identified key topics and concepts to frame my research presented in the subsequent chapters. Understanding the importance of ecological connectivity, what is being connected, and for what purpose, is needed to plan and maintain ecological connectivity. For local government land use planning, ecological connectivity is part of a social-ecological system with ecological connectivity one of many values to be considered

in the decision-making process. A collaborative form of environmental governance is necessary to integrate mandates and address cross-border issues. Numerous factors affect the success of local government land use planning, and identification of those factors from a practitioner's perspective can contribute to the literature on means to protect ecological connectivity. The following three chapters address these topics through case study research in southwestern Ontario, Canada, by investigating local government land use planning for ecological connectivity, factors that affect the planning and maintenance of ecological connectivity, and local government collaboration to address ecological connectivity.

Chapter 3 - The integration of ecological connectivity in local government land use planning: a case study of the Carolinian ecoregion in southwestern Ontario Canada

3.1 Chapter summary

Land development is considered a main driver of land fragmentation and loss of ecological connectivity, yet little research has been directed to how ecological connectivity is being addressed by local government in their role as controller of land use change. A review of local government strategic land use plans was carried out in the Carolinian ecoregion, a highly fragmented and biologically significant landscape in southwestern Ontario Canada. The findings indicate that the integration of ecological connectivity in local government land use planning: is dependent upon clear and binding legislation from higher levels of government; benefits from an integrated policy framework; is addressed through site level development approvals and land stewardship initiatives; is less likely to be addressed across agricultural lands than urban areas; and lacks a coordinated approach across local government spatial boundaries. Only 63% of the land use plans reviewed mapping ecological connectivity. Instead, riverine and shoreline features (94%) and valley lands (63%) were used as surrogates for ecological connectivity, limiting the ability to identify upland corridors. Other policy areas were integrated with ecological connectivity including parks, open space (81%) and trails (50%), and natural hazard lands (75%), though there was a lack of integration with climate change (38%), green infrastructure (19%) and transportation polices (6%). Recommendations and future research needs are outlined on how local government land use planning in the Carolinian ecoregion

specifically and local government land use planning generally can contribute to collective action towards the maintenance of ecological connectivity.

3.2 Introduction

In human dominated landscapes, landscape fragmentation through land development and land use change is a major threat to ecological connectivity. Urban development and the associated infrastructure as well as intensive agriculture, fragment the landscape, destruct habitat, and disrupt ecological connectivity (Dupras et al., 2016; Huber et al., 2012). The loss or impairment of ecological connectivity has a lasting impact on biodiversity, species movement and ecosystem processes, functions, and services (Hilty et al., 2020; Staccione, et al., 2022). Controlling land use change through land use planning can be an effective tool in the maintenance of ecological connectivity (Allred et al., 2021; Brody et al., 2004; Jennings et al., 2020; Keeley et al., 2019; von Haaren & Reich, 2006).

Land use planning is typically delegated from national or state / provincial government to local government with local government being responsible for implementing policy direction from higher government levels (Perrin et al., 2022). The importance of local government actions and land use planning decision-making on ecological connectivity though recognized, has not been extensively studied. The scholarship on ecological connectivity is considerable, however, there are relatively fewer studies on local government land use planning for ecological connectivity, representing a gap in research. If land development is a major contributor to the loss of ecological connectivity, understanding how this can be ameliorated through local government land use planning and policy implementation is an important step in conserving ecological connectivity.

Ecological connectivity has been defined as the unimpeded movement of species and the flow of natural processes that sustain life on Earth (Convention on Migratory Species, 2020). This definition addresses the persistence of plants and animals but also the continuation of ecological processes which maintain the integrity of biological communities (Beger et al., 2022). The main purpose of ecological connectivity is species movement, however connecting natural areas can also maintain ecosystems services for human use and well-being (Hilty et al., 2020; Lam & Conway, 2018). The provision of ecosystem services, or benefits to people from ecological processes (Egerer & Anderson, 2020), are dependent on a connected landscape (Mitchell et al., 2013, 2015). For example, a disruption of geophysical processes such as land drainage can increase the risk of flooding and impact the quality of drinking water (Hardy et al., 2022).

While the concept of a connected landscape seems simple, the various interpretations and applications can cause much confusion and inconsistent treatment. In human dominated landscapes human actions and needs must be considered when planning for ecological connectivity. There are interdependencies between humans and nature with societies and ecosystems being shaped by each other in an intertwined social – ecological system (Anderies et al., 2004; Berkes & Folke, 1998; Bodin & Chen, 2023; Reyers et al, 2018). Maintaining ecological connectivity is much more than a scientific exercise to identify ecological corridors; it requires coordinated planning, across multiple scales recognizing various social and economic constraints and opportunities (Parrott et al., 2019).

Land use decisions are primarily made by local government giving local government an important role in conserving ecological connectivity and biodiversity (Leibenath, 2011; McLean

et al., 2024; Stokes et al., 2010). Local government land use planning can direct land development away from priority habitat connections or mitigate land development impacts on ecological connectivity (Kamal et al., 2015). The process of developing a land use plan and associated public consultation, can serve to raise the level of awareness of the need for ecological connectivity (Bergsten & Zetterberg, 2013; Spang et al., 2012; Leibenath, 2011). There are, however, factors that affect how local government land use planning can address ecological connectivity.

Local government boundaries do not typically align with ecological boundaries such as watersheds or ecoregions (Keeley et al., 2022), and planning for ecological connectivity within local government boundaries may not take cross boundary ecosystem processes into account (Ekstrom & Young, 2009; Epstein et al., 2015). Local government land use planning combines numerous policy areas, of which the environment is only one of many. There is a risk of social and economic benefits being given a higher priority than environmental conservation (Lennon, 2015). Decision making in local government land use planning is political, subject to political vagaries, and entails trade-offs or negotiations among interests which go beyond scientific rational decision making (Auerbach, 2012). If environmental issues are not well championed and economic prosperity is a priority, political support for the environment is unlikely (Millner & Olliver, 2016; DeCaro & Stokes, 2013).

For this current research, a social – ecological system perspective is applied, recognizing that the planning and maintenance of ecological connectivity is a social construct placed within a political context (Cumming & Allen, 2017). The integration of ecological connectivity into local government land use planning practice is explored through the following research

questions; (a) how does local governments address ecological connectivity through land use planning, and (b) is the approach to address ecological connectivity consistently applied and coordinated across jurisdictional boundaries? Economic agendas are becoming more prevalent and relevant in land use planning and to advance ecological connectivity as a concept, there is a need to understand how to integrate ecological connectivity in land use planning (Hersperger et al., 2020). This current study was conducted through the review of local government strategic land use plans called Official Plans, in a highly fragmented and human dominated landscape in southwestern Ontario, Canada. This Official Plan review describes the state of practice, provides baseline data, and contributes to a greater understanding of strengths and weaknesses of local government land use planning for ecological connectivity. The results can inform planning practice and assist in future evaluation of land use plan outcomes.

3.3 Case study area

3.3.1 Ecological context

The study area is the Carolinian ecoregion in southwestern Ontario, Canada, an area that is heavily fragmented by urbanization and agriculture, with lands that are primarily privately owned (Oldham, 2017). This region contains some of Canada's most valued and rare plant and animal species (Spang et al., 2012). The Carolinian ecoregion is bounded by Lake Ontario and Lake Erie to the south, the City of Toronto and Niagara River to the east, Lake St Clair and Lake Huron to the west, and follows climatic and geological parameters to define the northern boundary (Figure 3.1).

The Carolinian ecoregion, which covers approximately 21,850 km^2 has a mild climate, highly diverse flora and fauna, and is one of the most imperiled in Canada due to the

substantial loss of natural habitat (Crins et al., 2009). According to Crins et al. (2009), around 78% of the ecoregion has been cleared of the original land cover and converted to agriculture, while another 7% has been converted to urban type uses. This includes a loss of 94% of upland forests, more than 70% of the wetlands, and 99% of prairies and savannahs (Oldham, 2017). This loss of natural features in the study area has severely compromised ecological processes (Jalava et al., 2015).



Figure 3-1 : Carolinian ecoregion boundary map

From Candidate Natural Heritage Site Inventory Update for the City of Windsor (Essex Region Conservation Authority, 2008)

The study area is also densely populated, with large urban centres and an extensive transportation network. A recent study evaluated 77 ecoregions in southern Canada, and the Carolinian ecoregion was identified as one of nine ecoregions considered to be a crisis ecoregion (higher biodiversity and higher threat) with the greatest need for immediate conservation action (Kraus & Hebb, 2020). Parks Canada, a federal government agency, through its National Program for Ecological Corridors, identified a part of the Carolinian ecoregion, the north shore of Lake Erie, as one of 23 priority areas in Canada where ecological corridors are most urgently needed and should be identified and created locally (Parks Canada, 2024).

3.3.2 Governance system

The governance system in the case study area is fragmented. As noted by Spang et al. (2012), in southern Ontario there are many agencies including provincial and local government, watershed-based Conservation Authorities and non-government organizations that are all involved in land use planning on the same landscape at various scales. In Ontario, the provincial government is responsible for providing guidance on matters of provincial interest to be addressed in a consistent manner through local government land use planning. The main tool to address guidance on ecological connectivity is through the legislated Planning Act (R.S.O. 1990, c. P.13) and corresponding Provincial Policy Statement (OMMAH, 2020a). In 2024, an updated Provincial Policy Statement replaced the 2020 version. The natural heritage policy direction in the 2024 version remained largely unchanged. The Provincial Policy Statement (hereafter called provincial direction) outlines a range of matters to be addressed by local government land use planning and development, including conservation of the environment.

At the time the current research was conducted, the provincial direction specifically requires local government to develop a natural heritage system. A natural heritage system is defined as:

> a system made up of natural heritage features and areas and linkages intended to provide connectivity (at the regional or site level) and support natural processes which are necessary to maintain biological and geological diversity, natural functions, viable populations of indigenous species, and ecosystems. These systems can include natural heritage features and areas, federal and provincial parks and conservation reserves, other natural heritage features, lands that have been restored or have the potential to be restored to a natural state, areas that support hydrologic functions, and working landscapes that enable ecological functions to continue. The Province has a recommended approach for identifying natural heritage systems, but municipal approaches that achieve or exceed the same objective may also be used (OMMAH, 2020a, p.47).

Mandatory requirements are outlined for the protection of natural features. For example, provincial direction notes that development and site alteration shall not be permitted in specific natural areas such as 'significant wetlands' as defined in the Provincial Policy Statement. However, protection of linkages among natural features is not specifically referenced in the provincial direction.

Local governments incorporate provincial direction into strategic land use plans called Official Plans. The Official Plans guide local government decision making on the protection of a natural heritage system through control over future land uses. As provincial interests change,

local government policies also change to reflect provincial interests. Recent changes approved through the current elected government focus on the provision of housing and streamlining the approval process to encourage greater residential development. However, provincial direction on natural heritage systems has not substantially changed since 2005.

In the Province of Ontario several large-scale land use plans have been prepared by the provincial government which extend across several local governments. These provincial land use plans geographically focus on the more heavily populated areas radiating outward from the City of Toronto. Local governments are also required to implement provincial land use planning direction. At the time of the current research, there were three of these provincial land use plans which expand beyond and partially cover the Carolinian ecoregion:

- A Place to Grow: Growth Plan for the Greater Golden Horseshoe (OMMAH, 2020b)
- Greenbelt Plan (OMMA, 2017)
- Niagara Escarpment Plan (OMNRF, 2017)

A fourth provincial land use plan, the Oak Ridges Moraine Conservation Plan, while an excellent example of landform related connectivity planning (Whitelaw & Eagles, 2007), is outside of the case study area. The provincial land use plans have been created under separate legislation but are required to abide by provincial direction and the natural heritage system requirements.

Local governments in Ontario consists of upper tier (regional, county, single tier), and lower tier municipalities. Regional and county governments provide services to lower tier municipalities, including direction on natural heritage systems. A lower tier municipality can be a city, a town, a township, or a village, and mostly conduct their own land use planning under the direction of an upper tier government. Lower tier municipalities must be in conformity with upper tier land use planning; however, the lower tier municipality can identify locally important

visions and values and plan at a smaller scale than regional direction provided by upper tier local governments. Single tier governments are cities or counties which do not have lower tier municipalities. In this current research, only upper tier and single tier local governments were investigated.

Conservation Authorities are watershed-based semi-governmental agencies legislated through the Conservation Authorities Act (R.S.O. 1990, c.27) with a core mandate for natural hazards, source water protection, and conservation of lands owned by the conservation authority. Other programs and service may be provided to local government through a memorandum of understanding. Conservation Authorities may conduct watershed planning, prepare natural heritage studies and inventories, and offer educational, stewardship and monitoring programs. As Conservation Authority boundaries are based on watersheds, Conservation Authorities do not align with local government boundaries.

The Federal government has minimal jurisdictional association with local government. There are a few specific areas however where federal government may be involved in ecological connectivity. Parks Canada operates a National Program for Ecological Corridors which has identified national priority areas for ecological connectivity and fund on the ground projects for ecological corridors. The federal government is also responsible for international conventions or treaties such as the Convention on Biological Diversity (UNEP, 1992).

Non-government organizations that address environmental conservation are numerous in the Carolinian ecoregion. Some non-government organizations are directly involved in the identification of ecological connectivity at broad scales such as the Carolinian Canada Coalition or for portions of the ecoregion such as the Cootes to Escarpment EcoPark System at the west

point of Lake Ontario. Other non-government organizations (e.g., land trusts) are involved in ecological connectivity through promotion of land stewardship, conservation easements, land acquisition, education, and input on provincial policy.

3.3.3 Context information

The local governments part of the current study and context information for the Carolinian ecoregion are outlined in Table 3.1. The 2021 population density of the local governments in the Carolinian ecoregion range from 27 people/km^{-2} (County of Middlesex) to 4,435 people/ km^{-2} (City of Toronto). The local governments with higher population densities are located in the area covered by the Provincial Growth Plan (OMMAH, 2020b). The Growth Plan is intended to reduce negative impacts from unchecked growth by setting growth boundaries, addressing transportation and transit networks, and setting minimum density thresholds, population and job targets for local governments in the plan area (Fillion, 2021; MMAH, 2021). Of the 16 local governments in the Carolinian ecoregion covered by the current study, seven have provincial plans covering portions of their land base and nine do not. There are 14 Conservation Authorities located in the Carolinian ecoregion. Multiple Conservation Authorities cover the regional, county and city local governments in the ecoregion, except for the City of Toronto and City of Windsor which have one Conservation Authority covering the entire local government boundaries. There are 60 lower tier local governments in the ecoregion but not part of the current investigation.

Table 3-1 : Carolinian ecoregion local government and context information

Local government	Type	Lower tier	Population density /km2	Provincial plans	Number of Conservation Authorities	Official Plan Year
Niagara	Region – upper tier	12	243	Yes	2	2022
Peel	Region – upper tier	3	1153	Yes	3	2022
Halton	Region – upper tier	4	642	Yes	3	2022*
Toronto	City – single tier		4435	Yes	1	2022
Hamilton	City – single tier		572	Yes	4	2019/22
London	City – single tier		1004	No	3	2023
Windsor	City – single tier		1562	No	1	2013*
Brant	County – single tier		47	Yes	2	2023
Haldimand	County – single tier		39	Yes	3	2022
Norfolk	County – single tier		42	No	2	2023*
Chatham Kent	County – single tier		42	No	2	2024*
Middlesex	County - upper tier	8	27	No	5	2023
Oxford	County - upper tier	8	60	No	3	2023*
Elgin	County - upper tier	7	28	No	4	2024
Essex	County - upper tier	7	116	No	2	2014*
Lambton	County - upper tier	11	43	No	2	2020

*Update to natural heritage system policies not included in Official Plan and material also obtained from discussion papers, reports and studies on the Official Plan update

3.4 Methods

This qualitative exploratory research provides an in-depth analysis of a real-life contemporary case study bounded by time and place (Cresswell & Poth, 2018). Specifically, local government land use planning for ecological connectivity and methods to implement the plan policies are explored within the context of the Carolinian ecoregion in southwestern Ontario, Canada. In Ontario, an Official Plan expresses a local governments' vision on how land should be used and addresses this through directing and managing physical change on the landscape, while taking the social, economic, and environmental effects into consideration (Lam & Conway, 2018). It is expected that an Official Plan will influence the future use of the

landscape through decision-making about local land development that reflects the Official Plan goals and policies (Norton, 2008).

This current investigation is a point in time, based on the most up to date versions of the Official Plans found on the local government websites. The Official Plans are not static, and amendments are incorporated in Official Plans by planning staff on a regular basis and the most up to data consolidated versions were reviewed. During this research, all local governments were planning to or in the process of conducting a comprehensive update of the Official Plan policies to ensure compliance with new provincial direction. The Official Plan updates include updating policy to be in conformity with the 2020 version of the Provincial Policy Statement. Where local governments were in the process of updating the Official Plans, draft and approved amendments were utilized or planning discussion papers and staff reports. This ensured the most up to date data was collected. However, the results still represent a point in time with policies being in flux given the unsettled nature of the current provincial government policy direction.

3.4.1 Official Plan selection

The boundaries of the local governments in the case study area do not exactly reflect the Carolinian ecoregional boundaries. In the ecoregion, there are 22 upper tier or single tier local governments. Some of these upper tier local governments are located entirely within the ecoregion while others are only partially located within the ecoregion. Three upper tier local governments were excluded as their area of jurisdiction only marginally overlaps with the ecoregion (Regional Municipality of Waterloo, Huron County and Wellington County). Three single tier local governments were also excluded from the Official Plan review (City of

Brantford, City of St. Thomas, and the Township of Pelee) given their small size or inability to locate their Official Plans. A total of 16 local government Official Plans were reviewed to identify mentions or references to ecological connectivity. Of the 16 local governments, 12 had conducted natural heritage system studies to identify, evaluate, and map the natural heritage system components. These studies were reviewed to provide background information. Finally, the four provincial plans were also reviewed, though the results presented here are focused on the local government consideration of the provincial plan direction on natural heritage systems.

3.4.2 Official Plan review and qualitative content analysis

The document review and analysis was conducted to develop understanding and insight into the use of local government land use planning to address the conservation of ecological connectivity. Past studies have investigated the integration of ecological connectivity in spatial planning (e.g., Huber et al., 2012; Leibenath, 2011; Perrin et al., 2019, 2022), however these studies did not conduct detailed analysis of local government land use plans. Local government land use plans have been studied on related topics such the integration of biodiversity and open space planning (McLean et al., 2024) ecosystem services (Cortinovis & Geneletti, 2018, Lam & Conway, 2018), green infrastructure (Di Marino et al., 2019; Le & Tran, 2023) climate change (Baker et al., 2012) and water management, watershed or ecological system protection (Berke et al., 2013; Brody et al., 2004; Garcia & Ulibarri, 2023; Termorshuizen et al., 2007). These studies typically applied a deductive approach using a predeveloped framework, criteria or codes and rating individual plan quality.

Given the lack of existing studies on evaluation criteria for ecological connectivity policies in local government land use plans, in the current study a more exploratory inductive

approach was used. Pre-selected and standardized measurements were not applied, rather the categories and codes were data driven and emerged from the document review (Schreier, 2012). Therefore, my analysis of Official Plans looked at the breadth or the extent to which ecological connectivity was addressed across the collection of reviewed Official Plans (Tang et al., 2010), not the quality of the plans or how effectively ecological connectivity was addressed in any individual plan.

An iterative approach was used which involved a first read of the Official Plans to identify overall policy areas followed by a more thorough examination which yielded data such as excerpts containing reference to ecological connectivity. A key word search of the Official Plans was finally conducted to ensure all ecological connectivity related policy was gathered. Key words used were ecological, connectivity, linkages, corridor, natural, heritage, wildlife, collaboration, and work with. Each occurrence needed to be reviewed as the use of the key words were not always in relation to ecological connectivity such as transportation network connectivity or corridor.

For qualitative inductive content analysis, themes and subthemes were identified through the process of coding the text to enable the description of themes or categories that manifest in the documents reviewed (Bowen, 2009; Garcia & Ulibarri, 2023; Schreier, 2012). Table 3.2 outlines the categories and the associated codes that arose from the document review. The codes were grouped into six categories: (a) purpose or goal of ecological connectivity (b) approaches to identify ecological connectivity; (c) natural features providing ecological connectivity; (d) policy areas related to ecological connectivity; (e) methods to implement policies on ecological connectivity; and (f) collaboration among agencies.

The information on ecological connectivity from individual Official Plans was measured by reviewing each Official Plan against the codes identified in Table 3.2. A binary system was applied with a 0 if there was no mention and a 1 if there was a mention. Similar to the methodology applied by Termorshuizen et al. (2007), the code results across the Official Plans were combined and expressed in percentages. The degree of consistency among Official Plans was based on the percent of Official Plans that mentioned the same code and an ordinal rating scale applied to describe the degree of consistency among the Official Plans. The local government Official Plans were compared to higher level provincial legislation and land use plan direction to see if local government Official Plan policies on ecological connectivity were consistent with provincial legislation. For cross border coordination, consistency of spatially mapped linkages (or connecting elements such as natural hazards) of spatially adjacent or neighbouring plans was investigated.

Table 3-2 : Coding scheme for the review of Official Plans

Category	Code	Description
Purpose of ecological connectivity	Biodiversity	Preserve and enhance biological diversity.
	Species	Address species persistence and movement
	Process/function	Support and provide ecosystem processes and functions
	Human benefit	Provision of ecosystem services and contribute towards human health and well being
Identification of ecological connectivity	Mapping	Mapping as part of the Official Plan that specifically identifies connectivity
	Separate studies	Natural heritage systems studies that identify natural areas, features, and linkages.
	Future studies	Watershed, secondary, and lower tier official plans to identify linkages at a finer scale
	Impact assessment	Site specific assessment as part of a development proposal to identify connectivity
	Criteria	Standards applied to evaluate ecological connectivity
	Priority	Degree of protection to natural features versus ecological connectivity
Natural features providing ecological connectivity	Valley Land	Valleys, ravines or other landform depressions that has water flowing or standing
	Surface water	Water features such as rivers, stream channels, shorelines, and associated riparian lands
	Woodlands	*Woodlands* include treed areas, woodlots or forested areas
Other policy areas referencing ecological connectivity	Natural hazards	Naturally occurring hazards that could make lands unsafe for development and are used for ecological connectivity
	Water resources	Protection of surface water and associated riparian areas to address water quality and quantity and enable ecological and hydrological connectivity
	Parks & open space	A linked system of public parks and private open space areas used to address ecological connectivity
	Agriculture	Lands being used for the growing of crops or raising livestock which also accommodates ecological connectivity
	Trails	Creating a comprehensive network of recreational trails associated which also provide for ecological connectivity
	Tourism	Ecological connectivity as a source for eco-tourism

Table 3.2: Coding scheme for the review of Official Plans (continued)

Category	Code	Description
	Transportation	Recognition of impacts of roads on the movement of species
	Green infrastructure	Natural and human-made elements that provide ecological and hydrological functions and processes such as stormwater management systems, natural channels, and urban forests
	Climate change	Recognition of the contribution of ecological connectivity to the impacts from climate change
	Aggregate resources	Addressing ecological connectivity impacts from the removal of gravel, sand, or other material suitable for construction, and maintenance purposes
Planning tools to implement ecological connectivity	Avoid	Focus development away from identified connectivity (designations, overlays, zoning)
	Acquire	Secure land through purchase, dedication, easements
	Approvals	Site specific evaluation of connectivity at time of development application
	New lots	Avoid future land fragmentation (subdivision process)
	Funding	Provide funding for outside agencies
	Permitted uses	Restrict permitted uses, allow compatible uses
	Reduce threats	Address threats to connectivity (invasive species, bird friendly windows)
	Tree / woodlot Bylaws	By-laws to conserve trees and woodlands which can serve as linkages
Collaboration to address ecological connectivity	Stewardship	Programs that assist landowner to establish, maintain, improve connectivity
	Cross border	Coordination of connectivity across local government spatial boundaries
	Education	Education and outreach to promote and raise the level of awareness of the value of natural heritage conservation to residents.
	Committee	Use of an environmental committee to review development approvals
	Other stakeholders	Work with other stakeholders including conservation authorities, non-government organizations, other levels of government, landowners, and indigenous communities to maintain ecological connectivity

3.5 Results

3.5.1 Provincial direction and local government conformity

The provincial direction requires the protection of certain natural features but only suggests the inclusion of connectivity and linkages. The language in the provincial direction is either compulsory by utilization wording such as “shall” or “shall not” or enabling by utilizing wording such as “should,” “promote” and “encourage.” The provincial direction indicates that natural features and areas shall be protected, and development shall not be permitted in natural features and areas. In contrast, the connectivity of natural features should be maintained, restored, or improved. The use of the word ‘should’ in relation to ecological connectivity is not an actionable outcome as it has no legal force.

The provincial direction also notes that a natural heritage system shall be identified for the Carolinian ecoregion, creating a contradiction. A natural heritage system which includes linkages shall be identified but development is only restricted for natural features and areas. The enabling language for ecological connectivity allows for local government discretion and variation in the level of protection afforded to linkages.

Provincial direction does not define connectivity or linkages though the purpose can be derived from the definition of a natural heritage system as supporting natural processes and functions, maintaining biological and geological diversity, and maintaining viable populations of indigenous species, and ecosystems. Multiple purposes of ecological connectivity were outlined in the Official Plans with sample excerpts from Official Plans outlined in Table 3.3. The main purpose of connecting natural features identified in Official Plans was species persistence and

movement (88% of the Official Plans) and supporting the provision of ecosystem processes and functions (75% of the Official Plans). The role of ecosystem connectivity in conserving biodiversity and contributing to human health were less frequently mentioned (44% and 38% of the Official Plans).

All Official Plans reviewed identified a natural heritage system, and all but one Official Plan referenced ecological connectivity (linkages, connectivity, connected, corridors) as a component of the natural heritage system. Linkages were given less protection than natural features in all Official Plans, reflective of the provincial policy direction. Provincially significant natural features legally protected from development (e.g., wetlands) were given the highest protection. Natural features that require justification for development were also protected from development (e.g., woodlands, valley lands, wildlife habitat, areas of natural and scientific interest, fish habitat, habitat of endangered and threatened species, adjacent lands to the features, sensitive surface water and sensitive ground water). For these natural features, development shall not be permitted unless it is demonstrated that there are no negative impacts on the natural features or ecological functions or the functions will be protected, improved, or restored.

The information on ecological connectivity from individual Official Plans was measured by reviewing each Official Plan against the codes identified in Table 3.2. A binary system was applied with a 0 if there was no mention and a 1 if there was a mention. Similar to the methodology applied by Termorshuizen et al. (2007), the code results across the Official Plans were combined and expressed in percentages.

The degree of consistency among Official Plans was based on the percent of Official Plans that mentioned the same code and an ordinal rating scale applied to describe the degree of consistency among the Official Plans. The local government Official Plans were compared to higher level provincial legislation and land use plan direction to see if local government Official Plan policies on ecological connectivity were consistent with provincial legislation. For cross border coordination, consistency of spatially mapped linkages (or connecting elements such as natural hazards) of spatially adjacent or neighbouring plans was investigated.

Table 3-3 : Official Plan review of purpose for ecological connectivity

Purpose	**Sample Official Plan excerpt**
Species	"Ecological linkage means areas providing connectivity supporting a range of species, community, and ecosystem processes necessary to sustain natural plant and animal movement patterns between ecological features daily, seasonally, and over multiple generations" (Middlesex, 2023, p. A-5)
Process/function	"Corridors link isolated natural heritage features or enhance existing linkages, improve or enhance the ecological functions of designated natural heritage features, and strengthen the overall natural heritage system" (Essex, 2014, p. 68)
Biodiversity	"Linkages are necessary to maintain the long-term viability and diversity of plant and animal communities and entire ecosystems" (Haldimand, 2022, p. 97)*
Human benefit	"The Greenway System is based on the belief that the quality of life within Windsor will be enhanced by the establishment of a linked and continuous network of "green" land uses. This planned network of natural environment and recreational elements will provide a means to establish Windsor as a healthy and liveable city' (Windsor, 2013, p. 5-3)

*Page number in reference to the amendment document to the Official Plan

3.5.2 Identification of Ecological Connectivity in Official Plans

The identification of ecological connectivity or linkages in the Official Plans was through the incorporation of several means concurrently as outlined in Figure 3. Consistently referenced was the use of environmental assessments, watershed or sub watershed studies,

other policy areas and natural heritage studies. Low consistency was found with the use of criteria and mapping by Carolinian Canada Coalition.

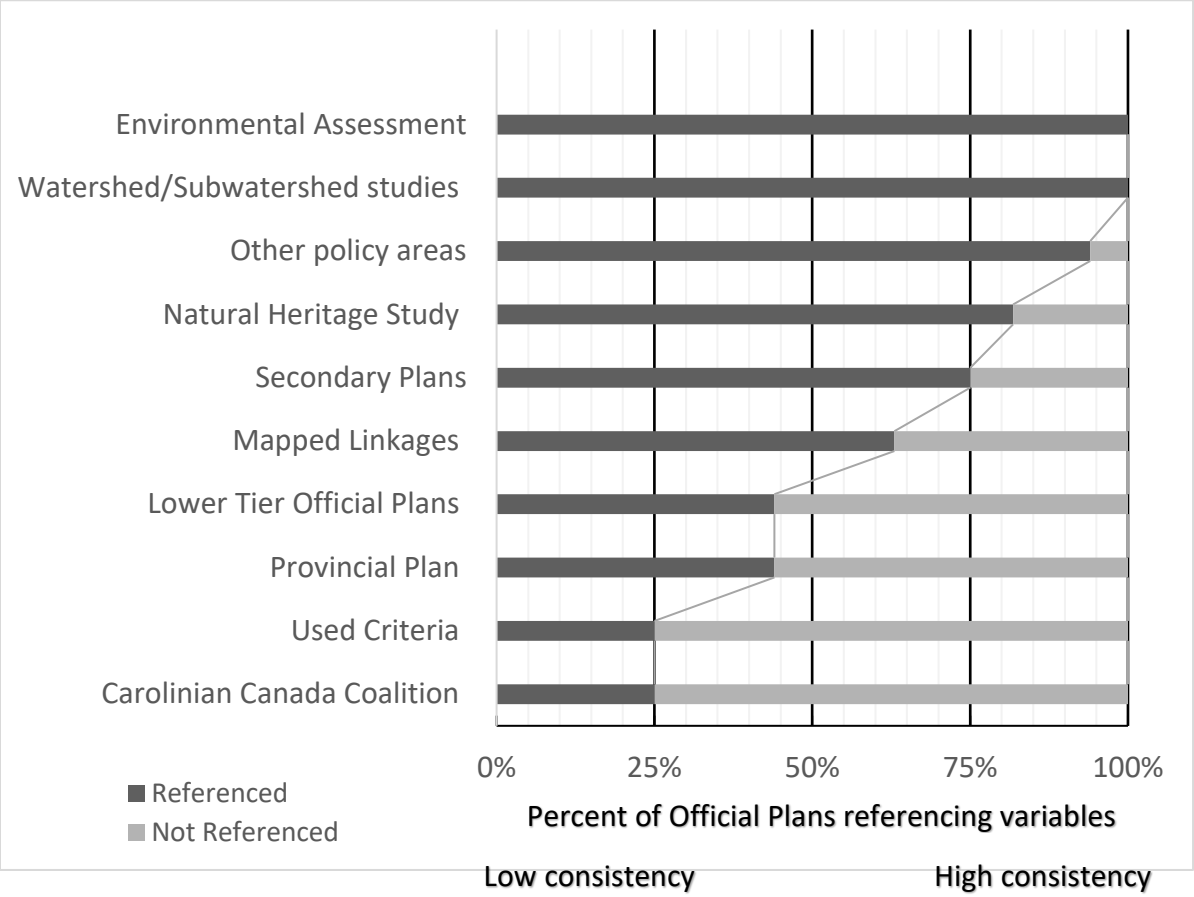


Figure 3-2 : Consistency of the Official Plans reviewed among various approaches to identify ecological connectivity

Note. The percentage value represents the number of Official Plans that indicated the code at least once divided by the total number of Official Plans review, n=16).

All Official Plans required environmental assessments to address site specific land development applications in proximity to the natural heritage system. For example, the City of Hamilton specifically required 'linkage studies' to assess the potential impacts on the viability and integrity of the linkage as a result of the development proposal; and make recommendations on how to protect, enhance or mitigate impacts on the linkage(s) and its functions through planning, design and construction practices" (Hamilton, 2022, p. F.3-5).

Provincial land use plan mapping or direction was refined through natural heritage studies or other investigations and applied by seven of the 16 Official Plans (44%). Outside of the provincial plan areas, all the remaining nine local governments utilized a natural heritage systems study to provide the technical information and mapping needed to identify a natural heritage system in the Official Plans.

The Carolinian Canada Big Picture Project (2001) was a collaborative initiative led by the Carolinian Canada Coalition which identified and mapped natural areas and potential habitat corridors across the ecoregion. The project was intended to provide a scientific context for local conservation initiatives and information to coordinate activities across jurisdictions. Few Official Plans (25%) recognized Carolinian Canada natural areas. Only one local government (City of London) referenced and utilized information from the Big Picture Project for the identification of corridors.

A total of ten of the 16 Official Plans (63%) mapped areas specifically noted as 'linkages'. Of those Official Plans that mapped linkages, the majority (70%) of plans were located within a provincial land use plan area which provided broad scale guidance on the mapping of linkages. However, all the Official Plans in Provincial Plan areas refined or added to the Provincial Plan mapping. Only three local governments (City of London, City of Windsor, County of Lambton) not covered by provincial land use plans specifically mapped linkages in Official Plans. The majority of Official Plans (81%) referenced Natural Heritage System Studies which served as the basis for the mapping of a natural heritage system. Most of the Natural Heritage System Studies (62%) however did not map ecological connectivity and/or the Official Plans did not incorporate ecological connectivity mapping. Priority areas for improvement or restoration of

linkages were also identified. For example, the City of London Official Plan (2023) identified potential naturalization areas with a priority given to “potential naturalization areas to restore, establish or replace connections between and within vegetation patches, riparian corridors and wildlife habitat” (p., 378).

3.5.3 Use of natural features and other policy areas

Natural features and other policy areas were used as surrogates for ecological connectivity. The consistency among official Plans on referencing these substitutions or supplements to ecological connectivity are highlighted in Figure 3.3. Natural heritage features whose protection is required (legally enforced) by provincial direction were used as a mechanism to address ecological connectivity, including surface water features, valley lands, and woodlands. The natural features either served as linkages or were recognized as part of the natural heritage system. Surface water features and shorelines were recognized as natural corridors by all but one of the Official Plans reviewed. Valley lands correspond to surface water features, and 63% of the Official Plans referred to valley lands as serving linkage functions. The Natural Heritage System Study for Oxford County (2023) states that “significant valley lands, which are identified in this study, form the backbone of the linkages/corridors of the natural heritage system” (p. 12). Woodlands arose as a natural feature which also added to connectivity. Official Plans identified priority woodlands based on the connectivity value (proximity) of woodlands to other woodlands or other natural features. Though not a linear feature, woodlands serve as stepping stones to facilitate species movement.

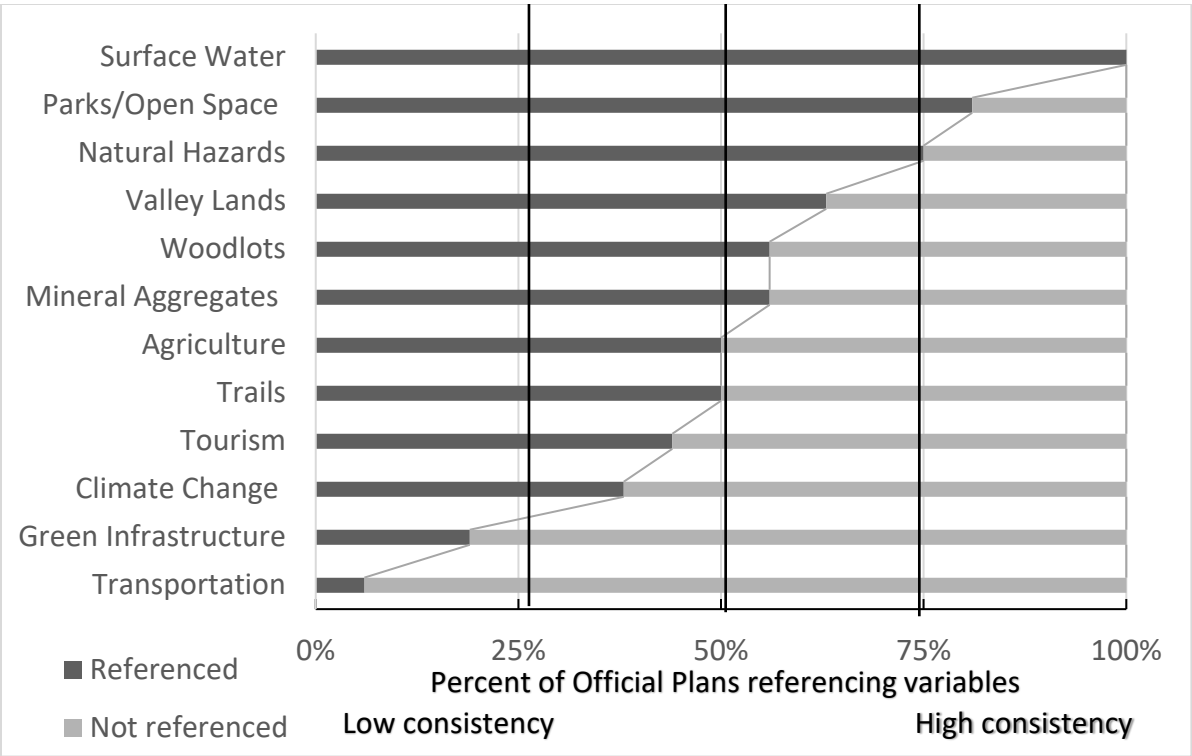


Figure 3-3 : Consistency of the Official Plans reviewed for the use of natural features and other policy areas to identify ecological connectivity

Note. The percentage value represents the number of Official Plans that indicated the code at least once divided by the total number of Official Plans review, n=16).

Other policy areas were referenced as being related to ecological connectivity and excerpts from the Official Plans on the various policy areas are shown in Table 3.4. Most of the Official Plans (81%) used a greenways approach, or linked parks and opens space system which combined linear parks and open spaces with a natural heritage system. The purpose of a linked parks and open space system included recreation or human benefits but also specifically noted the relationship to species movement. Related was the mention of an interconnected trail system (50%) which also functioned as linkages. Natural hazard lands are related to riverine and shoreline features and include floodplains and erosion prone or steep slopes. Natural hazard lands can implicitly through overlapping mapping or explicitly through policy, be

integrated into a natural heritage system. All Official Plans mapped natural hazards, but only 75% of the Official Plans explicitly referenced the ecological connectivity function of natural hazard lands. Half of the Official Plans suggest that agricultural lands can accommodate the movement of species with no need to specifically identify linkages. For example, the Middlesex Natural Heritage System Study (UTRCA, 2014), which serves as the basis of the Midddlesex County Official Plan natural heritage system policies notes:

> Given the complexity of defining linkages and sustainability in an agricultural landscape, where it could be argued that the majority of farm fields are part of the system, the [natural heritage system study] does not attempt to identify current or future linkages between patches or across agricultural fields or neighbourhoods or along unvegetated stretches of watercourses since the concern over loss of connectivity is not as great as it is for urban areas. Instead, Chapter 5 outlines recommendations for areas where there is a conversion of land use that affects the porosity of the landscape and the ability for species to move between features (p. 10).

Economic policy areas also demonstrated a relationship with ecological connectivity such as mineral aggregate resources (56%) and tourism (44%). Climate change (38%), green infrastructure (19%) and transportation policies rarely address ecological connectivity. Only one Official Plan (Brant County) explicitly noted the connection with transportation and wildlife movement.

Table 3-4 : Other Official Plan policy areas relevant to ecological connectivity

Policy area	Sample Official Plan excerpt
Water resources	"The Greenlands System and Water Resource System are interrelated and policies in both sections of the Plan dealing with these systems protect, improve or restore sensitive surface water features and sensitive ground water features and maintain linkages and hydrologic functions among features and areas" (Peel, 2022, p.70)
Natural hazards	"Land subject to environmental hazards or physical limitations such as poor drainage, organic soils, flood susceptibility, erosion, and steep slopes are protected to preserve and conserve the interconnected features of the natural environment and to avoid the potential for loss of life and economic investment" (Norfolk, 2023, p.5)
Parks and open space	"Planning for open space encourages physical activity, supports mental health, increases the use of active transportation, and provides linkages between natural heritage features" (Niagara, 2022, p. 165)
Agriculture	"All components of the Natural Heritage Systems are important to connectivity and enable ecological functions to continue and to thrive. It is important to recognize that agricultural and rural landscapes also contribute to and support the Natural Heritage Systems…"(Haldimand, 2023, p. 96)*.
Trails	"Trails are encouraged within and linking natural heritage features where public access is achievable and would not negatively impact the natural heritage feature or its function" (Lambton, 2020, p. 7-6)
Tourism	The County lakeshore… provides excellent tourism and recreational opportunities. While the County is in favour of further tourism and recreational development, the development pressures along the lakeshore need to be carefully managed to protect the area's natural attributes, ecological significance and importance through its connectivity to the natural features, which form the basis for much of the interest in the area" (Norfolk, 2023, p. 123)
Transportation	"Infrastructure, development and intensification shall be designed to reduce loss of wildlife from roadkill, and risks to human safety from road collisions with wildlife. New and replacement structures shall not impede wildlife passage through use of structures such as wildlife overpasses, wildlife tunnels, and open span culverts" (Brant, 2023, p. 5-69)
Green Infrastructure	"Contributing areas … provide opportunities for habitat connectivity and natural linkages across the city…these are areas where efforts should be made to protect and enhance ecological function and biodiversity by maintaining and enhancing existing tree canopy and soft landscaping, and encouraging other green infrastructure measures" (Toronto, 2022, p. 14)*
Climate change	"Connected natural spaces and a regional natural heritage system with thriving biodiversity are necessary components for our communities to adapt to and mitigate the impacts of climate change locally" (Toronto, 2023, p. 2)*
Aggregate resources	"The connectivity between key natural heritage features and key hydrologic features will be maintained before, during, and after extraction of mineral aggregate resources" (Brant, 2023, p. 5-77)

*Page number in reference to the amendment document to the Official Plan

3.5.4 Official Plan planning tools to implement ecological connectivity

Planning tools are divided into regulatory and non-regulatory tools. Regulatory tools (Figure 3.4) are planning tools specifically applied through measures outlined in the Planning Act or Municipal Act. Non-regulatory tools (Figure 3.5) can be applied through local government financing, formalized tax incentives, programs, initiatives, or voluntary means.

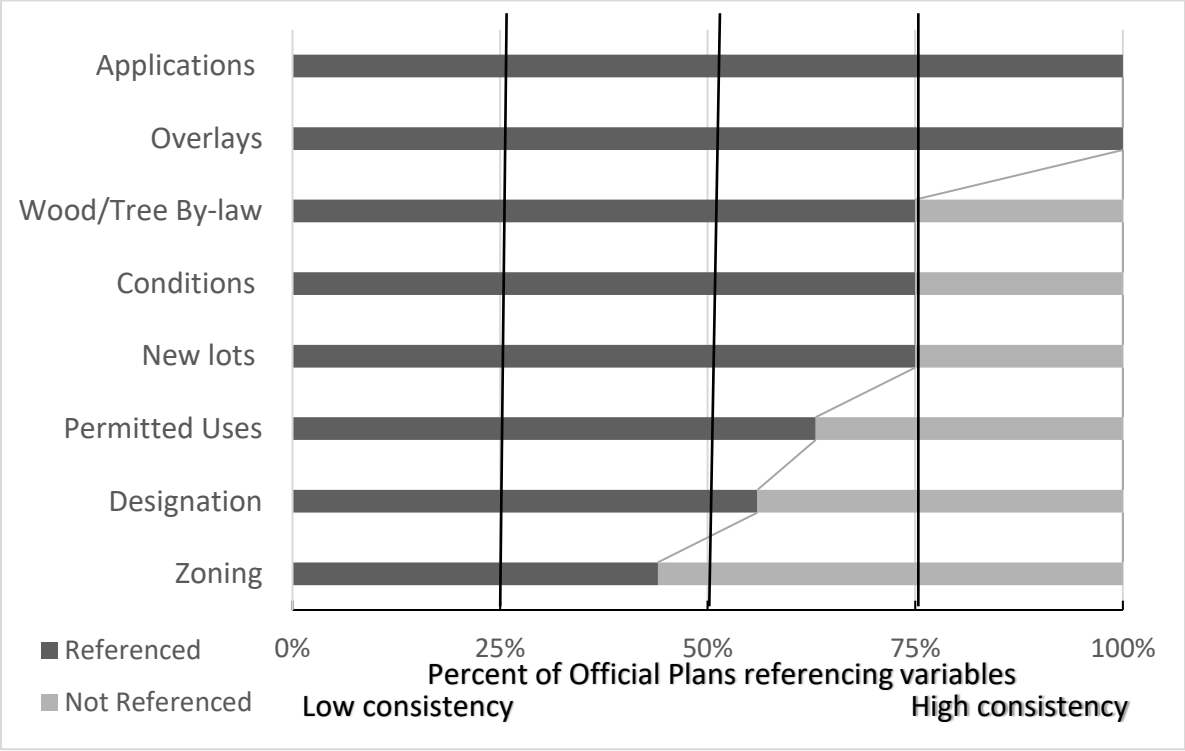


Figure 3-4 : Consistency of the Official Plans reviewed in applying regulatory tools

Note. The percentage value represents the number of Official Plans that indicated the code at least once divided by the total number of Official Plans review, n=16).

The main implementation method employed was through site specific land use development applications. All Official Plans indicated the natural heritage system was to be addressed at a site-specific level for proposed land use changes and required environmental assessments. The mapping of a natural heritage system can be through exclusive land use

designations (such as an environmental protection designation, or open space designation) or overlays which demonstrate where natural features and linkages are located as constraints to development while permitting the underlying land use designation to continue. All Official Plans used an overlay method to demonstrate natural heritage components while just over half (56%) used designations in combination with overlays.

The use of a woodland or tree conservation by-law (75%), setting conditions as part of development proposals (75%) and need to address land subdivision to reduce further land fragmentation in proximity to the natural heritage system (75%) were consistently applied. The application of a woodland conservation by-law was often noted as a tool to implement a natural heritage system by ensuring woodlots are effectively managed and trees that are cut are replaced. Restricting the type of permitted uses allowed in areas identified as natural heritage system was less consistently applied (63%) as was the use of land use zoning (44%) which more specifically spatially outlines and controls permitted uses and how those permitted uses are constructed.

Non regulatory means to address the implementation of a natural heritage system was well recognized in Official Plans. All Official plans identified and encouraged stewardship actions or actions by private landowners to protect and restore the natural heritage system. Actions such as conservation easements, tax incentives or other means of securing or encouraging conservation were identified as possible actions by 81% of the Official plans. Acquiring land through purchase, donation or land dedication as well as through conservation easement agreements with landowners was consistently referenced as a possible implementation measure by 81% of the Official Plans. For example, the City of London Official

Plan (2023) referenced that “upland corridors should be established through a variety of measures such as stewardship agreements or conservation easements with private property owners, planting programs, and acquisition by the City through purchase, dedication, donation and/or bequest” (p. 370).

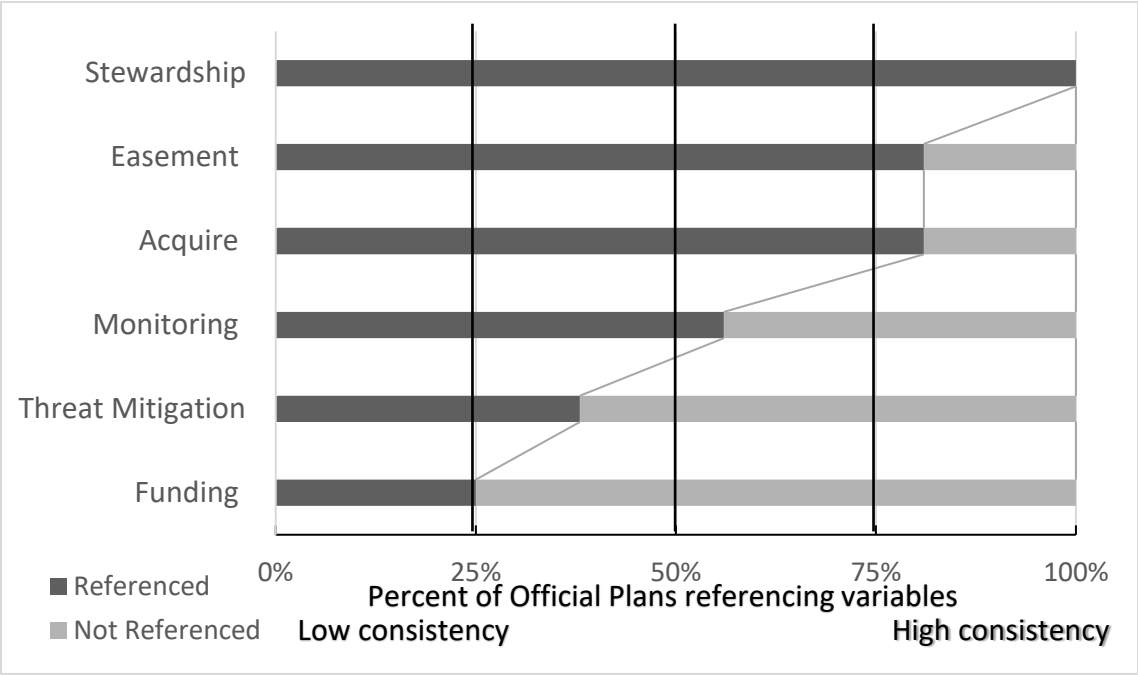


Figure 3-5 : Consistency of the Official Plans reviewed in applying non-regulatory planning tools

Note. The percentage value represents the number of Official Plans that indicated the code at least once divided by the total number of Official Plans review, n=16).

Monitoring is needed to see if Official Plan policies related to a natural heritage system are effective. Just over half of the Official Plans (56%) specifically indicated a need to monitor natural heritage system policies. Threat mitigation was sparsely indicated for ecological connectivity (38%) and included mitigating the effect from invasive species, road barriers and

migratory birds (bird friendly windows). Funding to outside agencies to maintain or restore ecological connectivity was the least consistent tool suggested (25%).

3.5.5 Cross border coordination or collaboration

There was good consistency among the Official Plans on references to collaborate or coordinate on planning and maintenance of ecological connectivity (Figure 3.6). As already noted, the use of stewardship initiatives which requires collaboration with the landowner and perhaps other levels of government and non-government agencies was consistently referenced as needed to address the natural heritage system. Working with other stakeholders was also consistently noted though the composition of those stakeholders varied. The Official Plans reviewed mentioned the need to collaborate to implement the natural heritage system with conservation authorities (100%), non-government organizations (75%), other levels of government (75%), landowners (44%) and Indigenous communities (38%). As noted by the Peel Region, an upper tier municipality, they will:

> work collaboratively with the local municipalities, conservation authorities, neighbouring municipalities, Indigenous communities, other government agencies, stakeholders and the public to develop a Regional Greenlands Strategy outlining tools, actions and resources to support the implementation of the Greenlands System policy framework and address future natural heritage systems planning needs in the Region. (p 249).

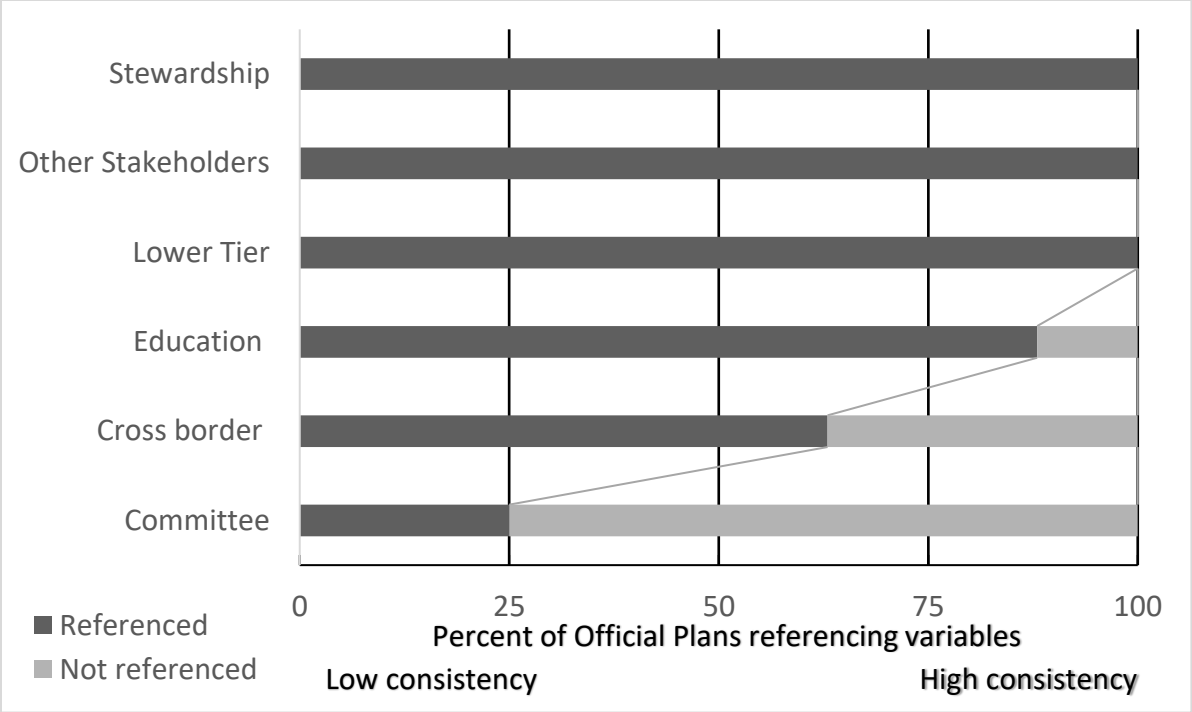


Figure 3-6 : Consistency of the Official Plans reviewed on collaborative efforts to plan and maintain ecological connectivity

Note. The percentage value represents the number of Official Plans that indicated the code at least once divided by the total number of Official Plans review, n=16).

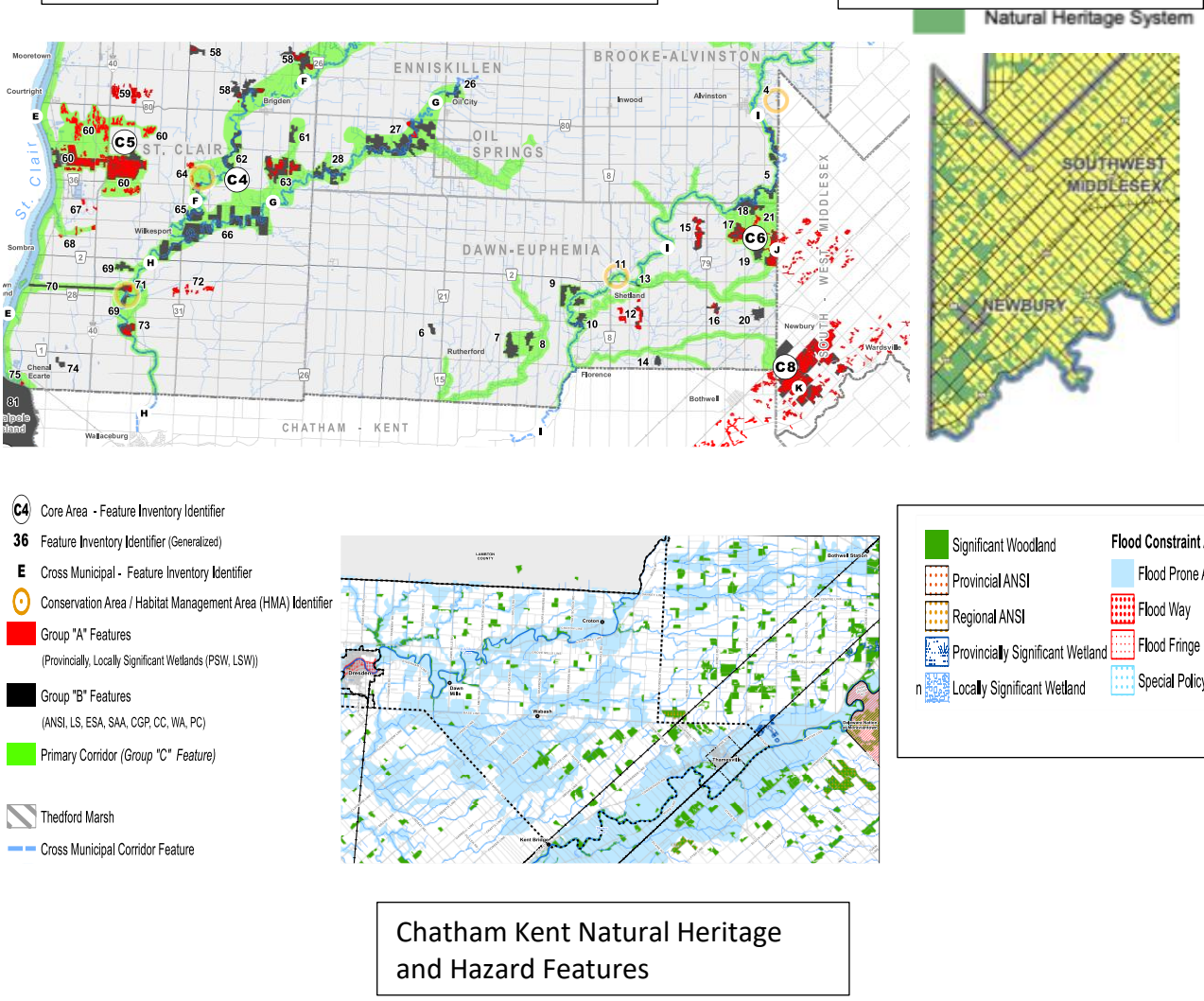
All upper tier local governments referenced the need to coordinate lower tier Official Plan content for planning for ecological connectivity. This specifically addressed the need for coordination among lower tier local governments located within upper tier regional or county local governments. Most Official Plans (88%) noted education of landowners, was needed to implement the natural heritage system. For example, the County of Middlesex Official Plan (2023) noted that as much of the natural heritage system is held in private ownership, the County would encourage private land management by "demonstrating sound environmental management of public land and through the distribution of information regarding the function and management of [the natural heritage system]" (p. 2-8).

Cross border coordination for ecological connectivity or a natural heritage system was not referenced consistently (63%) and the use of an environmental committee to assist in the maintenance of ecological connectivity was inconsistently applied (25%). While the mention of collaboration was made in the Official Plans, this appears to be specific to implementation of the natural heritage system, not the planning. Review of the mapping of ecological connectivity demonstrated a lack of cross border coordination with neighbouring upper and single tier local governments where natural features and ecological connectivity in one jurisdiction did not match up across political boundaries.

The lack of cross border coordination is a result of the different identification approaches utilized. For example, Lambton County is bordered by Middlesex County and Chatham-Kent. All three local governments take different approaches to the identification of ecological connectivity. Lambton County mapped primary corridors and provided guidance to lower-tier municipalities to refine linkages. Middlesex County identified multiple features through a natural heritage system study that includes linkage components such as valley lands and stream corridors but did not specifically map linkages. The Chatham-Kent Official Plan only identified features with linkages being identified in the future or through site specific development proposals. As seen in Figure 3.7, the County of Lambton identified primary corridors which follow stream corridors. These linear corridors are not specifically followed in the adjacent local governments though stream corridors are identified as valley lands and natural hazards.

Lambton County Natural Heritage System

Middlesex County Natural Heritage System



Chatham Kent Natural Heritage and Hazard Features

Figure 3-7 : Sample portions of local government mapping of a natural heritage system demonstrating inconsistency in approaches and a lack of coordination across local government jurisdictions

3.6 Discussion

In Canada, ecological connectivity is being addressed at federal, provincial, and local scales, with it being recognized that the local level of government can be effective and a crucial actor in planning and maintaining ecological connectivity through land use planning (Lemieux et al., 2021). A review and comparison of 16 regional, county and city local government strategic or comprehensive land use plans (Official Plans) in the Carolinian ecoregion in southwestern Ontario, Canada, was undertaken to better understand (a) how local governments address ecological connectivity through land use planning, and (b) is the approach to addressing ecological connectivity consistently applied and coordinated across borders. Consistency, a term used regularly in land use planning can be defined in numerous ways (Norton, 2008). In this current research, consistency is the coherence among local government land use plans on the integration of ecological connectivity within planning policy and coordination with neighbouring jurisdiction on the spatial identification of ecological connectivity.

The findings indicate that in the Carolinian ecoregion, land use planning is used through enabling legislation to address the identification and maintenance of ecological connectivity. This was attempted through application of numerous means but without policy consistency among Official Plans or spatial consistency across local government jurisdictional boundaries. There was, however, a strong awareness of the purpose of ecological connectivity to address the movement of species, ecological processes and functions, biodiversity, and to a lesser degree, human health and well-being. The findings point to five major issues of concern: a lack of clear and binding legislation, inconsistent identification of ecological connectivity, multiple policy areas which address ecological connectivity, a focus on site specific development

proposals and stewardship to implement ecological connectivity, and a lack of coordination across local government political boundaries. Each of these issues or further explored in this section.

First, the fact that ecological connectivity is being addressed through land use planning in the Carolinian Ecoregion is progressive. Ontario not only identifies ecological connectivity as a matter of provincial interest, but it has been identified as an area of concerns for over 20 years. That said, the effectiveness of local government land use planning for ecological connectivity cannot be said to be an outstanding success. Habitat is still being lost and fragmentation of the land base continues (Office of the Auditor General of Ontario, 2023; Ontario Biodiversity Council, 2020). The changing provincial political mandates and priorities, such as the current focus on providing more housing more quickly, greatly influences local government planning outputs and outcomes and can lead to unexpected or undesirable land use decisions (Filion, 2021). Simply having a land use plan in place with policies towards the conservation of ecological connectivity does not mean it will be realized in practice (Beunen & Hagens, 2009; Perrin et al., 2022). However, understanding how ecological connectivity can be integrated within the process and practical realities of local government land use planning is necessary to determine how local government land use planning can contribute to collective action on ecological connectivity.

3.6.1 Ambiguity in provincial legislation

There is a need for clear and binding legislation for government agencies to conduct planning for ecological connectivity (Keeley et al., 2018). The current study findings confirm that there is a greater chance of connectivity being protected when legislation clearly sets out

requirements to do so. The flexibility or vagueness in the Ontario provincial legislation to address ecological connectivity is reflected in the Official Plans reviewed in two ways. First, the provincial legislation has a 'features focus' (Spang et al., 2012) and while all Official Plans mapped the required natural features only 10 of the 16 Official Plans (63%) mapped areas noted specifically as linkages. Secondly, as linkages are not required to be protected from development and site alteration, linkages were consistently given less protection in Official Plans than natural features, reflective of the legislation direction. The wording in the Provincial Policy Statement enables the integration of ecological connectivity in local government land use plans, but this has no legal force, leaving the level of protection for ecological connectivity to the discretion of local governments. This ambiguity in the legislation provides flexibility for local governments to adjust to local conditions and interests, but it also reduces the chances of ecological connectivity being implemented (Beunen & Hagens, 2009).

In addition to the provincial direction, the legally binding provincial land use plans are to be implemented through local government Official Plans. The provincial land use plans provide guidance and a broad scale perspective on ecological connectivity by crossing local government political boundaries. Three large scale provincial land use plans cover portions of seven of the 16 local governments in the Carolinian ecoregion and all seven Official Plans under Provincial Plan guidance mapped linkages. In the areas outside of Provincial Plan boundaries, only three of the nine Official Plans mapped connectivity as a separate component of the natural heritage system. The provincial land use plans offer greater legal certainty for the incorporation of ecological connectivity in local government Official Plans. However, legal certainty is changeable. In Ontario as in other parts of the world, housing supply and affordability is of

prime concern with planning regulation and environmental scrutiny of projects seen as a constraint to the quick construction of housing (Grant, 2022). During the time of this current research, the Provincial government did pass legislation (Bill 23, More Homes Built Faster Act, 2022) and adjusted what land was to be protected by the Green Belt Plan area to allow for housing development.

I argue that ambiguity in legislation is a hindrance to local government integration of ecological connectivity in land use plans. It should also be noted that ambiguity can be good. As noted by Norton (2008), stringent and fixed policy direction is not reasonable or even desirable given ongoing policy uncertainty and changing political agendas and that "planning and development management benefit sometimes from a little bit of ambiguity" (p. 436). How that ambiguity is applied through land use planning is the question of concern. The current findings demonstrated that ecological connectivity is being considered in local government land use planning, without clear and binding legislation but this promulgated a variety of approaches on how ecological connectivity was incorporated in the Official Plans in the Carolinian ecoregion.

3.6.2 Inconsistent approaches in planning to maintain ecological connectivity

No two Official Plans reviewed in the Carolinian Ecoregion addressed ecological connectivity in the same manner, demonstrating a lack of consistency across the ecoregion. This lack of consistency or plethora of different approaches is comparable to that found by Perrin et al. (2019, 2022) and Leibenath (2011), where it was noted that the emphasis on legal latitude and a lack of a strict framework led to variation in planning practices. The current findings support both observations, both a lack of clear legislation and consistent standards has led to the multitude of approaches to identify and maintain ecological connectivity in land use

plans. This may be due in part to the need to address multiple land uses and resident values, of which ecological connectivity is one of many. Unlike the protection of natural features or areas through formalized parks, public lands, or protection measures, linkages among natural areas are typically owned and used by multiple actors for various reasons other than nature conservation (Beunen & Hagens, 2009; Drescher & Brenner, 2018). Land use planning must consider the various often divergent societal priorities and interests placed on the landscape (Perrin et al., 2019). Inconsistency in identification of ecological connectivity may also be due to the level of expertise of those responsible for the identification of the natural heritage system. For example, an environmental consultant, environmental planner, or urban land use planner in one local government may have greater expertise than those in an adjacent local government. Consequences of inconsistent ecological connectivity policy can include the potential inability to maintain functional connectivity across jurisdictional borders; variable levels of protection from external human impacts; and a dependency on political will and local government capacity to address ecological connectivity (Perrin et al., 2019). Alternatively, a variety of approaches may be needed to address the local context, local priorities, and landscape condition.

Four approaches to identify ecological connectivity in local government land use plans were ascertained in this current research: mapping linkages among natural areas, ecological connectivity recognized as a natural feature, addressing ecological connectivity through other policy areas, and relegating the identification of ecological connectivity to future studies. Typically, multiple approaches were used to identify ecological connectivity. No one approach is

judged to be better at providing guidance to decision makers though each approach has associated benefits and limitations (Table 3.5).

Table 3-5 : Multiple methods to identify ecological connectivity through local government land use planning

Method	Benefits	Limitations
Mapping of linkages in the Official Plans	Can proactively focus development away from identified areas	May not consider broad scale cross boarder connectivity
	Can ensure locally relevant connections are identified	Difficult to map, need appropriate data and scale
	Can serve as an educational tool on the need for ecological connectivity	Raises concerns over competing interests (farming and conservation)
As a natural feature	Strong legislation with experience and criteria on how to identify	Not managed for species movement
	Few remnant natural areas except linear riverine and shoreline features	Excludes upland corridors
	Already regulated and easily accepted – easy to map and visualize	Overlapping jurisdiction and confusion on who manages what
From other policy areas	Primarily related to human benefit	May not see relationship with connectivity
	Offers an integrated social -ecological approach	Lack of coordination among policy areas
	Good potential for future identification given under -utilized policy areas	May be identified based on human requirements
In future finer scale studies	Local context considered	May not consider broad scale cross border coordination
	Opportunity for future collaboration, input and education	Not incorporate cumulative effects or regional direction
	Better suited to operationalizing connectivity than a visionary Official Plan	Can sidestep or policy shift without internal consistency

Mapping of ecological connectivity was not always utilized and there was no consistent approach to the mapping of ecological connectivity or linkages in the Official Plans. Ten of the 16 Official Plans reviewed mapped regional, county, or city level ecological connectivity. The terms used varied and included linkages, small, medium, and large linkages, natural areas and corridors, linkages and enhancement areas, primary corridors, supporting or contributing areas, and upland corridors. There was a noticeable lack of mapping of linkages in the predominantly

agricultural areas of the Carolinian ecoregion. For example, Oxford, Middlesex and Elgin Counties did not map linkages as the predominant agricultural landscape would serve as a permeable matrix for the movement of species. The approach to use the land matrix in rural areas for ecological connectivity is supported as the concept of patches and corridors can neglect to account for the functionality of agricultural lands and the potential human impact on that functionality (Gippoliti & Battisti, 2017; Vimal et al., 2012). Alternatively, agricultural areas are not uniformly permeable or passable by all species, and without identified corridors or linkages (or steppingstones), the goal of species dispersal may not be realized (Raymundo et al., 2023).

The lack of mapped linkages across agricultural land in the Carolinian ecoregion may also be due to external factors such as a disinclination of the decision makers to address the perceived conflict between environmental conservation and farmers livelihoods (von Haaren & Reich, 2006; Beunen & Hagens, 2009). In the ecoregion, provincial direction clearly indicates that agricultural uses are exempt from the natural heritage systems policies or that the natural heritage system policies are not intended to limit the ability of agricultural uses to continue. Agricultural lands may enable ecological connectivity, but protective measures through land use policy is limited. Land use policy can direct new development and site alteration on agricultural land but cannot address agricultural land practices. For example, while new buildings can be directed away from environmentally sensitive areas, a change in farm practices such as from grazing to cropping, cannot be addressed through land use planning.

Local government Official Plans reviewed specifically recognized linear natural or human developed features and areas as a surrogate for ecological connectivity. The use of surface

water and shoreline features (94% of the Official Plans), linked parks and open space (81%) natural hazard lands (75%), valley lands (63% of the Official Plans) and a linked trail system (50% of the Official Plans) can all potentially address the same land area but be managed through different agencies or processes. This overlap or even confusion over jurisdictional responsibilities can lead to ineffective management of ecological connectivity.

A lack of fit or not matching the spatial scale of an ecological problem with governance processes has been extensively documented, including reference to local government (Bergsten et al., 2014; Kininmonth et al., 2015; Keeley et al., 2022). In this current research it was demonstrated that there is not only a boundary mismatch (across jurisdictional boundaries) but also a management mismatch for the maintenance of ecological connectivity through local government land use planning. Riverine features may be the only remnant areas remaining in a heavily populated area, however this reliance on water based linear natural features as surrogates for ecological connectivity reduces the ability or political will to address upland corridors.

3.6.3 Integrating multiple policy areas

The current findings demonstrate a multiple policy approach to address ecological connectivity. The review of the Official Plans demonstrated crossover among policies for ecological connectivity to greater or lesser degrees. The policy areas that were consistently integrated or associated with ecological connectivity were parks and open space (81%) and natural hazards (75%). Climate change (38%) green infrastructure (19%) and transportation (6%) were rarely associated with ecological connectivity, even though these areas are well recognized in the literature as related to, surrogates for, or impacting on ecological connectivity

(Boehnke et al., 2023; Donati et al., 2022; Field & Parrott, 2022; McRae, 2012; Newell et al., 2022; Elton & Drescher, 2019; Liquete et al, 2015; Zhang et al., 2019; Lam & Conway, 2018). For example, green infrastructure has been directly connected to ecological connectivity. Dupras et al (2015) defined green infrastructure as "a type of land use consisting of a network of natural areas and open spaces that optimizes biodiversity protection and generates other environmental and social benefit" (p. 355). Still, green infrastructure is commonly restricted to ecosystem services which benefit humans such as water quality, with the biodiversity aspects relegated to a secondary benefit (Donati et al., 2022). The application of green infrastructure to ecological connectivity will be context specific.

There is the potential for greater integration of other policy areas to address ecological connectivity. However, other policy areas are managed primarily for human health and safety and economic prosperity. Consequently, human benefits can be given a higher priority than environmental conservation with ecological connectivity not being effectively implemented (Lennon, 2015; Newell et al., 2022; Stokes et al., 2010). For example, natural hazards, while generally following surface water features and valley lands are managed for human health and safety (flooding, erosion, water quality) and regulated by Conservation Authorities. Still, policies not designed specifically for the movement of species can inadvertently contribute to ecological connectivity (Perrin et al., 2019). The current findings show that ecological connectivity is being addressed by default. This suggests the social and ecological relationships are not recognized, or that legislation encourages sectoral segregation, or that proactively planning for ecological connectivity could garner greater negative reaction than planning for human benefit.

3.6.4 Dependance on site specific planning tools and land stewardship initiatives

A major concern with planning for ecological connectivity is a lack of plan implementation and inability to determine the ecological effectiveness of the policies (Honeck et al., 2020; Huber et al., 2012; Jennings et al., 2020; Keeley et al., 2019; Watson et al., 2017). The question arises - is policy on ecological connectivity in Official Plans only rhetorical or are local governments active in maintaining ecological connectivity (Norton, 2008). Another concern is if land use planning regulatory tools can in fact influence the maintenance of ecological connectivity. It can be argued that land use plans can prevent land conversions that affect ecological connectivity but can land use planning protect the ecological functionality of the landscape (Leibenath, 2011; Perrin et al., 2019).

The current study findings identified a universal trend to relegate the identification and maintenance of ecological connectivity to a finer level of detail and site-specific development proposals. The lower-level land use plans are operational plans and more of a blueprint than a visionary document (Termorshuizen et al., 2007) with mapping at a scale more appropriate to land use decision making (McLean et al., 2024). Also, these lower-level planning documents encourage local participation offering the opportunity for the incorporation of local knowledge as well as resolution of conflicting interests. On the other hand, relegating the identification or refinement of linkages to future studies and site-specific development proposals, effectively side steps the need to connect natural features or areas identified in the Official Plans and is shifting the responsibility to other parties who may not be able to undertake evaluation of broad scale and cumulative effects of decision making.

In the current study environmental assessments were consistently used to identify areas to be set aside for ecological connectivity, and through conditions, require mitigation of impacts arising from the proposed development. Site-specific environmental assessments though effective on a localized scale, may not take the continuity across the landscape into consideration. Ecological connectivity addressed in isolated parcels can hinder the ability to address cumulative effects (Lemieux, 2021; Tarabon et al., 2019; Kor, et al., 2022; Allred et al., 2021). Conversely, considering a specific project within the context of the ecological network might help to mitigate large-scale impacts (Tarabon et al., 2019).

The Official Plans reviewed all acknowledged the need for land stewardship to address ecological connectivity on private property and agricultural lands. The non-regulatory tools recognized include land stewardship initiatives on private lands with the use of incentives, securing or acquiring lands, and increasing the level of awareness of the public and political decision makers through education. Past studies have recognized that that regulatory tools are not sufficient to ensure long term conservation due primarily to private land property rights (dos Santos et al., 2015), and stewardship initiatives can supplement regulation (Drescher et al., 2017, Keeley et al., 2019; Byrant, 2006). Land stewardship initiatives for ecological connectivity can be difficult due to the inability to target specific areas, need to address multiple properties, the inequity in private landowners providing benefits which extend beyond their property (Bennett et al., 2018; Drescher, 2014; Martin, 2016; Nebel et al., 2017; Olive & McCune, 2017; Cooke & Moon, 2015). Still without the active engagement of private landowners directly through local government or through partnerships with agencies, the conservation of ecological connectivity will not be effective.

3.6.5 Coordination across local government political boundaries

A major limitation of local government land use planning for ecological connectivity stems from the lack of fit of local government boundaries and the extent of ecological connectivity. The local government boundaries do not necessarily encompass the area necessary to manage larger scale ecological connectivity and at times this lack of fit makes the effectiveness of policies questionable (Bergsten et al., 2014; Huber at al., 2012; Keeley et al., 2022). Yet local government jurisdiction is restricted to the area within the politically identified territory with no formal responsibility to manage cross border ecological connectivity (Bergsten & Zetterberg, 2013; Brody et al., 2004). Uncoordinated planning and not taking cross boundary ecosystem processes into account can lead to disconnected implementation of policy and adverse effects beyond jurisdictional borders (Boden & Chen, 2023; Ekstrom & Young, 2009; Keeley et al., 2022).

The current study Official Plan review demonstrated that local governments are aware of the need to collaborate with other stakeholders (100%) and to a lesser degree across local government jurisdictional boundaries (63%). However, this does not mean collaboration is occurring. As noted, planning policies and mapping for ecological connectivity were not consistent across local government borders. The lack of cross-border coordination for ecological connectivity can be related to the application of varied methods to identify ecological connectivity, use of inconsistent criteria and data, and context-specific political compromises (Perrin et al., 2022). For example, as demonstrated in the results, three adjacent local governments took different approaches to identify ecological connectivity with no apparent lining up across the jurisdictional borders. In provincial plan areas, there was better

coordination across borders and scales, though still inconsistent means to address ecological connectivity as demonstrated through the various approaches to refine mapping in provincial plan areas.

A standard framework for local government to plan for ecological connectivity is not provided for the Carolinian ecoregion. Given the complexity of addressing ecosystem functioning, differing local context, interests, and political support, and difficulty in establishing universally acceptable criteria, it is difficult to establish a standard policy framework for ecological connectivity (Perrin et al., 2022). Still the provision of scientifically supported standards or criteria from higher levels of government on how to identify ecological connectivity can assist in a more consistent approach to identify ecological connectivity (Gurrutxaga et al., 2015) leading perhaps to better coordination across local government boundaries.

3.7 Conclusions

The purpose of ecological connectivity is to enable the movement of plants and animals and the flow of ecosystem processes, functions, or services through linkages among intact natural area. This rather ambitious concept is difficult to operationalize in local government land use planning. As noted by Vimal et al., (2012), “connectivity is not simply a measure of spatial separation based on patch size and distance, but a measure of the extent to which species, resources and ecological processes can move in a landscape” (p. 51). Species concerns and data were not specifically or notably addressed in local government land use plans for ecological connectivity in the Carolinian ecoregion. A landscape structure approach was utilized

where existing natural areas were linked, typically using proximity criteria to determine if a linkage should be identified.

The actual maintenance of functional ecological connectivity on the ground has not been proved through past research or this current research. This current research does provide insight into how local government land use planning can address ecological connectivity and contribute to collective action. Local government land use planning can identify 'pinch points' or priority areas for maintenance or restoration of ecological connectivity while still requiring finer detail investigation across the landscape through environmental assessments at the site level. Local government land use planning has the potential to integrate social and ecological policy areas to address ecological connectivity, in a way giving a redundancy to ecological connectivity. Local government can apply non regulatory tools to address ecological connectivity, including partnerships with agencies and landowners for stewardship initiatives. Finally, a strength of local government land use planning is in the planning process itself which has the potential to bring stakeholder together, raise the level of awareness, and encourage consideration in site specific applications. The integration of ecological connectivity into local government land use planning places ecological connectivity firmly on the political agenda. However, if the political agenda does not prioritize nature conservation but focuses on economic prosperity, increasing housing supply, and planning reform to increase efficiency, ecological connectivity will not be addressed, particularly with weak and vague legislation subject to interpretation and negotiation.

The current findings have indicated that ecological connectivity can be identified in local government land use plans and implemented through various tools. Several issues were

identified that may complicate local government planning and maintenance of ecological connectivity in the Carolinian ecoregion. First, the enabling legislation, though laudable, is vague with respect to the identification and protection of linkages and clearer language would assist in local government interpretation and incorporation into Official Plan. Second, policy integration into Official Plans is inconsistent across the Carolinian ecoregion for ecological connectivity with no standardized approach. Third, the primary land use planning tool identified to address ecological connectivity is site-specific and reactive to development applications, which limits local government ability to proactively target areas for maintenance or address cross jurisdictional ecological connectivity. Fourth, non-regulatory tools to address ecological connectivity such as land acquisitions, stewardship and incentives were recognized, however the ability to implement non regulatory tools is dependent on the capacity of the local governments and external agency assistance. A last issue is that while local governments did apply ecological connectivity concepts within their borders, cross border coordination was lacking as demonstrated by the inconsistency of approaches to identify ecological connectivity.

The following recommendations are suggested to address the identified issues:

- Recognize ecological connectivity as a significant natural feature with specific enforceable language. The Ontario *Planning Act* currently supports this option by recognizing that a local government zoning by-law can prohibit the use of land and construction of buildings within areas identified as 'significant natural corridors or shorelines'. An alternative would be to accept the language that a natural heritage system shall be identified and provide definitions and clearer and up to date guidance or a provincial framework on the identification of and implementation tools for ecological connectivity in Official Plans.
- Policy integration is a well-researched topic with continued recognition of the organizational 'disintegration or 'silo' approach of local government (Andersson et al., 2014,

Bergsten et al., 2014; Sayes & Baggio, 2017). While beyond the scope of this current research to offer suggestions on how policy integration can occur, this current research does suggest that greater attention should be paid to climate change, green infrastructure and particularly transportation policies to address ecological connectivity.

- Site level regulatory planning tools can be ineffective in addressing the main identified purposes of ecological connectivity in the Official Plans, namely species movement and ecosystem processes and functions. Direction on conducting connectivity analysis on a site level that addresses a broader scale should be incorporated into environmental assessment guidelines and brought into decision making process (e.g., Kor et al., 2022). Likewise, cumulative effects analysis should be incorporated into local government environmental assessments to better identify impacts to the natural heritage system.
- In the Carolinian ecoregion, Conservation Authorities have historically conducted stewardship initiatives and outreach activities for local governments. Recent legislative amendments intended to streamline the planning process have restricted Conservation Authority activities. However, local governments can still request, through a memorandum of understanding and funding arrangements, that Conservations Authorities conduct stewardship and outreach initiatives on behalf of a local government. Continued collaboration with Conservation Authorities is needed to address non regulatory tools to maintain ecological connectivity.
- The use of natural heritage system studies or watershed studies, typically conducted by Conservation Authorities, can take a broad scale viewpoint for local government consideration. However, local government is not obligated to incorporate the broad scale, technical based studies into the Official Plans. Continued study on a scientifically supported approach to identify ecological connectivity at various scales in the Carolinian ecoregion should be pursued.

I propose the following future research: (a) monitoring of Official plan policy direction related to ecological connectivity to determine effectiveness; (b) assess how local governments incorporate ecological connectivity into site specific land use planning decisions and verify the

impact of land use change on ecological connectivity (c) the use of agricultural lands in the Carolinian ecoregion as a permeable matrix for species movement, (d) the ability to integrate the concept of ecological connectivity into climate, change, green infrastructure and transportation policies (d) the use of environmental assessment guidelines to address both local and broad scale ecological connectivity, (e) if local governments are indeed collaborating with neighbouring local governments and other stakeholders to address ecological connectivity, and (f) evaluation of Official Plan quality in addressing ecological connectivity based on the initial criteria identified in this research.

The review and comparison of strategic land use plans within a defined area can describe the state of practice and provide baseline data for future monitoring and identify strengths and weaknesses in the planning process. While context specific, in general, strengths identified in the current study include enabling legislation, support for the protection of riverine and shoreline systems, and the integration of disparate though related policy areas. Weaknesses identified include the avoidance of identifying upland corridors, specifically across agricultural lands, a lack of integration of policy on ecological connectivity with policy related to green infrastructure, climate change, and transportation, a reliance on site specific measures and stewardship initiatives to maintain ecological connectivity, and the inability of policy to address ecological connectivity across jurisdictional boundaries. These strengths and weaknesses can inform planning practice and future evaluation of land use planning outcomes.

Chapter 4 : Factors that affect the planning and maintenance of ecological connectivity by local government in a highly fragmented landscape.

4.1 Chapter summary

Land use change is a major factor in the fragmentation of the landscape and the loss of ecological connectivity. Local government land use planning, through application of enabling legislation, can address this fragmentation and is a part of the environmental governance system needed to successfully address ecological connectivity. There is a gap in knowledge on how local government deals with ecological connectivity and this study addresses this by exploring factors that help or hinder the planning and maintenance of ecological connectivity by local government through a case study of the Carolinian ecoregion in southwestern Ontario, Canada. Through interviews with planning practitioners, key factor theme areas were identified including the physical landscape, environmental governance, land use planning practices, sharing information, and resources. The results show that while ecological connectivity is supported by legislation, addressed in policy, with implementation mechanisms recognized and applied, local government still struggles with a natural features focus, cross border coordination, land use planning practice limitations, justification of the need for ecological connectivity, public and political resistance, and a lack of capacity and funding. With a history of provincial legislation to protect natural heritage areas and water resources in the Carolinian ecoregion, there is the potential to construct a natural heritage system or ecological network that links natural features, parks, water resources, working landscapes, and ecological functions. The study concludes with the observation that local government land use planning,

while an important and necessary component of ecological connectivity identification, maintenance, improvement, and education, needs to be combined with other approaches such as watershed planning and land stewardship. Local government should be located within an identified broader decision-making framework to coordinate various and often disconnected activities that are addressing ecological connectivity at various scales among numerous agencies across the Carolinian ecoregion. The development of implementation guidelines and an inventory of existing actions could assist in this endeavour.

4.2 Introduction

Landscape fragmentation into isolated parcels through urbanization, agriculture, industrial activity, linear barriers, intensification of land uses, and other human land use change interrupts the movement of plants and animals, and ecosystem processes, functions, and services (Beger et al., 2022; Boulton et al., 2018; Hilty et al., 2020). This causes stress on the landscape with the associated reduction in resilience, limited ability of species and ecosystems to adapt to change (Cumming & Allen, 2017; Staccione et al., 2022), a decrease in biodiversity (Fischer & Lindenmayer, 2007; Mitchell et al., 2015; Perrin et al., 2021), and a reduction of ecosystem services, or benefits to people from ecological processes, such as crop pollination and clean water (Egerer & Anderson, 2020). In addition, political fragmentation of the land and regulatory authorities disrupts the flow of information and the ability to coordinate across borders, jurisdictions, and land tenures (Aslan et al., 2021; Baggio et al., 2019; Bergsten et al., 2014). Traditional conservation measures include protection of natural features, areas, or species and habitat of concern, by various government and non-government actors, but it is widely recognized that natural areas need to be connected across landscapes to safeguard

continued species survival, sustained ecosystem processes, biodiversity conservation, and human well-being (Butler et al., 2022; Hilty et al., 2020; Palomo et al., 2014). Connectivity is especially critical in areas subject to intensive land use change (Bodin & Chen, 2023).

Ecological connectivity has been defined as the unimpeded movement of species and the flow of natural processes that sustain life on Earth (Convention on Migratory Species, 2020). Ecological connectivity not only addresses the persistence of species but ecosystems and associated flows of energy and materials, and integrity of biological communities through habitat linkages or interactions of species with the abiotic environment (Beger et al., 2022). Ecological connectivity also brings the idea of natural processes, functions, and services for humans into the concept of connectivity. While species movement is still the main concern, it is not the sole purpose for connecting the landscape. The provision of ecosystem services is dependent on a connected landscape (Mitchell et al., 2013, 2015). For example, land development which affects land cover composition and configuration can promote or hinder ecological connectivity by separating natural habitat from croplands and restricting the movement of pollinators and pest predators needed for agricultural production (Field & Parrott, 2022). Here, I define ecological connectivity as connections or linkages among natural features to conserve biological diversity, species persistence and sustained ecosystem functions and services (Butler et al., 2022; Hilty et al., 2020; Palomo et al., 2014).

Land use planning can help address land use change and achieve a more connected landscape (Jennings et al., 2020; Keeley et al., 2019; von Haaren & Reich, 2006), yet how this is practically done by local government and what factors help or hinder local government

planning and plan implementation for connectivity has not been extensively studied. A few prior studies have identified factors that affect the implementation of connectivity (e.g., Keeley et al., 2018, 2019), but the study did not have a focus on local government. Many studies consider connectivity at a broad scale covering numerous local government jurisdictions with the assumption that the mapping and policy direction given by higher level governments will be integrated into local government land use plans (Jennings et al., 2020; Keeley et al., 2019; Rudnick et al., 2012), without recognizing the challenges to local government in addressing environmental issues that cross local government boundaries (Mancilla - Garcia et al., 2019).

There is as a gap in understanding of the issues that affect local government in the incorporation of connectivity in land use plans and implementation of the plan direction, to achieve a more connected landscape. This current research does not investigate the efficacy of the planning and implementation of policy for actual ecological connectivity. Rather, the goal of this paper is to identify factors that may help or hinder the planning and implementation of policy in support of connectivity. This inquiry is building on a series of interviews with local level planning practitioners followed by a synthesis of key influences that should be addressed to enable better planning and on the ground implementation of ecological connectivity policy. Specifically, the research question being addressed is what factors facilitate or impede local government land use planning and maintenance of ecological connectivity? This investigation contributes to the existing scholarship on conserving connectivity by focusing on the local level contribution to the maintenance and improvement of connectivity through local government land use planning.

4.3 The role of local land use planning

Ecological connectivity is or can be a large-scale natural phenomenon contingent upon the dispersal range of species. There is substantial scholarship on the need to match the scale of a social ecological system with the scale of governance for effective ecological management (Ekstrom & Young, 2009; Epstein et al., 2015; Bodin & Chen, 2023). A major limitation identified with local scale planning for ecological connectivity is the inability to address the needs of wide-ranging species or ecological processes or looking beyond jurisdictional boundaries (Cheok et al., 2019; Keeley et al., 2022). Local government political boundaries may not encompass the area necessary to manage larger scale ecological connectivity and at times this lack of fit makes the effectiveness of policies questionable (Huber at al., 2012; Keeley et al., 2022; Bergsten et al., 2014).

A top-down approach is suggested where higher levels of organizations conduct broad scale identification of ecological connectivity which is refined at a local level (Perrin et al., 2022). Two issues are identified for this top-down approach; (1) broad scale direction is lacking, and (2) a coarse grain identification of ecological connectivity misses small patches and local connectivity necessary for broad scale implementation of ecological connectivity (Belote et al., 2022; Fahrig, 2019; Hou et al., 2017; Huber et al., 2012). Alternatively, a collaborative governance approach is suggested where multiple stakeholders address ecological connectivity at various scales to collectively address species movement, the conservation of biodiversity and continuation of ecological processes (Guerrero et al., 2015; Newig & Fritsch, 2009; Scarlet & McKinney, 2015).

Local government is recognized as the subsidiary level where more socially acceptable land use decisions are made, albeit within a broader state framework to ensure consistency, minimum standards, and consideration of priority issues (Vasseur et al., 2017). Local level consideration of environmental conservation can be more legitimate or align with local values, but broad scale planning can better address ecological elements (Pittman, 2019; Newig et al., 2016; Cheok et al., 2019). Addressing this scaling down or scaling up issue for ecological connectivity (Cheok et al., 2019; Wyborn & Bixler, 2013) is outside the scope of this current research. Here it is accepted that planning for ecological connectivity is a cross scale issue and local level planning contributes to successful maintenance of ecological connectivity. Yet there is still the need to determine the capabilities of local government to effectively address cross scale effects of ecological connectivity.

It is recognized that local government will need to address ecological connectivity as most land use decisions are made at the local government level (Brody et al., 2004; Bryant, 2006; Huber et al., 2012). Land development is recognized as a major contributor to the loss of ecological connectivity and local government land use planning the culprit. Without local government land use plans and policies on ecological connectivity as guidance to decision making on land use change, there are limited opportunities to mitigate the impact of development on ecological connectivity (Kamal et al., 2015). On the other hand, land use planning addresses multiple land uses and community goals with the need to balance values through negotiations and compromises, and ecological connectivity can end up with less than optimal consideration (Opdam et al, 2006). External factors such as planner capacity and

political support also influence local government planning for ecological connectivity (Keeley et al., 2018, 2019; Opdam, 2006; Perrin et al., 2022).

Land use planning can be broadly viewed as interventions to improve the future condition for human health and prosperity and natural ecosystem integrity. Privately owned lands can serve as a conduit, linking protected areas and when acquisition is not feasible, land use planning can restrict and focus development to protect habitat and support ecological connectivity (Brody & Highfield, 2005; Huber et al., 2012; Leibenath, 2011; Opdam, 2006). Local government is responsible for land use planning within the boundaries of a political unit such as a region, county or city and regulates, among other matters, what land uses go where, standards that apply, studies that are required, how the land can be subdivided, and how the various publics are involved. Given this role, local government can spatially identify linkages among existing intact natural areas or areas where restoration is needed to maintain ecological connectivity, control land uses in proximity to identified linkages, retain the opportunity for ecological connectivity by reducing fragmentation and mitigating potential negative impacts from land use development, outline means to implement policy on ecological connectivity, and conduct public outreach on the importance of ecological connectivity. Given local governments' delegated role in administering higher level direction on land use change, infrastructure service delivery, and environmental protection, local government an important component of the environmental governance structure (Mancilla-Garcia et al., 2019). Understanding the factors that can help or hinder local government land use planning is necessary for successful maintenance of ecological connectivity.

4.4 Case study

The case study area is situated in southwestern Ontario, Canada, in the mixed wood plains ecozone and referred to as the Carolinian ecoregion. (Puric-Mladenovic & Strob, 2012; Waldron, 2003) (Figure 4.1). The Carolinian ecoregion is socially and ecologically complex. More than 90% of the land area is in private ownership and subject to intense growth pressures and intensive agriculture (Spang et al., 2012). The Carolinian ecoregion, which covers approximately 21,850 km^2 has a mild climate, highly diverse flora and fauna, and is the most imperiled in Canada due to the substantial loss of natural habitat (Crins et al., 2009). According to Crins et al. (2009), around 78% of the study area has been cleared of the original land cover and converted to agriculture, while another 7% has been converted to urban type uses. A recent study evaluated 77 ecoregions in southern Canada, and the Carolinian ecoregion was identified as one of nine ecoregions considered to be a crisis ecoregion (higher biodiversity and higher threat) with the greatest need for immediate conservation action (Kraus & Hebb, 2020). There is a strong legal framework for connectivity conservation in southwestern Ontario with legislation to direct the development of local government policies. Enabling legislation is as a critical component to for the implementation of ecological connectivity (Keeley, et al., 2019).



Figure 4-1 : Carolinian ecoregion boundary map

From Candidate Natural Heritage Site Inventory Update for the City of Windsor (Essex Region Conservation Authority, 2008

The Province of Ontario through the Provincial Policy Statement has mandated that local government shall identify a natural heritage system for the Carolinian ecoregion and suggests that:

> the diversity and connectivity of natural features in an area, and the long-term ecological function and biodiversity of natural heritage systems, should be maintained, restored or, where possible, improved, recognizing linkages between and among natural heritage features and areas, surface water features and ground water features (OMMAH, 2020, p.24).

The provincial direction further defines ecological functions as “the natural processes, products, or services that living and non-living environments provide or perform within or between

species, ecosystems, and landscapes. These may include biological, physical, and socio-economic interactions" (OMMAH, 2020, p.42). The need for local government to implement a natural heritage system in the Carolinian ecoregion manifests the concept of ecological connectivity being considered in this research.

The Carolinian ecoregion is comprised of various levels of local government: upper tier local governments (regions and counties) which contain lower tier municipalities (townships, smaller cities, and towns) within its borders, and single tier local government (typically counties and larger cities) (Table 4.1). There are also numerous Conservation Authorities (organized on a watershed basis) in the Carolinian ecoregion, having a core mandate for the protection of life and property against harm from natural hazards (flooding, steep slopes), regulation of water quality and quantity, and conservation of owned lands. Conservation Authorities are a local public sector agency that have been established by the province of Ontario under the Conservation Authorities Act. Conservation Authorities are governed by an appointed board of directors primarily made up of local government representatives in the watershed. Conservation Authority funding is dependent on the population of the member local governments with more funding being available for activities in larger populated areas. Some Conservation Authorities are large and spatially cover a large watershed area, while others are less extensive with smaller watersheds. Conservation Authority boundaries do not align with local government boundaries. In the Carolinian ecoregion, with multiple Conservation Authorities within the boundaries of one upper or single tier local government. Both local governments and Conservation Authorities are involved in ecological connectivity planning and implementation of policy.

Table 4-1 : Carolinian ecoregion local governments and context information

Local government	Type	Lower tier	Population density /km2 2021	Number of Conservation Authorities
Niagara	Region – upper tier	12	243	2
Peel	Region – upper tier	3	1153	3
Halton	Region – upper tier	4	642	3
Toronto	City – single tier		4435	1
Hamilton	City – single tier		572	4
London	City – single tier		1004	3
Windsor	City – single tier		1562	1
Brant	County – single tier		47	2
Haldimand	County – single tier		39	3
Norfolk	County – single tier		42	2
Chatham Kent	County – single tier		42	2
Middlesex	County - upper tier	8	27	5
Oxford	County - upper tier	8	60	3
Elgin	County - upper tier	7	28	4
Essex	County - upper tier	7	116	2
Lambton	County - upper tier	11	43	2

There are numerous environmental non-government organizations (NGO) that carry out conservation studies and activities, including planning and maintenance (or improvement and restoration) of ecological connectivity which may or may not be in concert with the province, local governments, or Conservation Authorities. Though the federal government is not typically involved in local government planning, in this case, there are federal initiatives on ecological connectivity and the federal government does have a role to play in ecological connectivity in the Carolinian ecoregion. Parks Canada, the federal agency in charge of the protection of significant natural heritage areas, is currently heading up a federal national program on ecological corridors to develop national criteria, identify priority areas, and provide substantial funding to NGOs. The federal government is also responsible for international conventions or treaties such as the Convention on Biological Diversity (UNEP, 1992). The

constellation and interactions of these varied actors make for a complex governance system with federal, provincial, local government, Conservation Authority and NGO mandates that all apply to the environment and ecological connectivity.

4.5 Methods

4.5.1 Data collection

A total of 16 local governments and 14 Conservation Authorities were identified as those with most of their land base falling within the Carolinian ecoregion. Maximum variation sampling was conducted for the local government and Conservation Authority key informant interviews to reflect different perspectives and physical locations within the case study area (Creswell, 2013). In addition, snowball sampling was used to assist in the identification of NGO, federal and provincial interviewees. A total of 24 interviews were conducted from February 2022 to August 2022, including ten from local governments, eight from Conservation Authorities, three from NGOs, one from Provincial, and two from Federal government. Interviews focused on three key areas: (a) general overview of issues, methods, and political support for connectivity; (b) identification of factors that helped or hindered planning for ecological connectivity and implementation of plan policies; and (c) collaboration in the process of planning and implementation (Appendix A). While the interviews covered a larger range of topics, the focus of the current inquiry were factors that helped or hindered planning and implementation of ecological connectivity. The interviews lasted from 40 to 90 minutes with the majority being approximately one hour in duration. The interviews were recorded, and the recordings transcribed verbatim in preparation for coding.

4.5.2 Coding and analysis

An abductive thematic analysis approach was used combining both deductive and inductive reasoning (Thompson, 2022). Abductive thematic analysis is a research approach that applies *a priori* coding scheme or framework and combines this with iteratively exploring the data to extend and refine the coding scheme and generate plausible explanations from the participant narratives (Lochmiller, 2021; Vila-Henninger et al., 2024; Timmermans & Tavory, 2012). In practice, this means one deduces provisional explanations from the comparative peer-reviewed literature that was refined based on the interview responses. While not as formalized, this is akin to an ecologist forming a hypothesis based on existing literature and testing it empirically. Deductive thematic analysis was used starting with the identification of initial themes developed from the literature (i.e., grounded in existing knowledge) followed with refinement through inductive coding (i.e., analyzing what emerged from the data) that resulted in identification of an additional theme and sub themes not distinct in the literature.

It is not uncommon to apply both deductive and Inductive approaches at different stages of thematic analysis. Application of the dual or tandem methodology of an abductive thematic analysis, while not common in the qualitative research literature (Thompson, 2022), has been used for past research on factors that affect the planning and maintenance of ecological connectivity. Keeley et al., (2019) conducted a comprehensive identification and assessment of factors influencing conservation connectivity planning and plan implementation using an abductive approach to qualitative thematic coding. Specifically, emergent themes were added to a deductively derived coding schema to identify factor themes or subthemes (Keeley et al., 2019).

Four broad theme areas of factors expected to facilitate or impede the planning and maintenance of ecological connectivity were identified from the literature, focusing on the integration of ecological connectivity into local government land use planning. The initial themes, derived from the literature, included (a) physical or structural; (b) governance or process; (c) financial or resources; and (d) knowledge or learning. (Table 4.2). Literature was reviewed on ecological connectivity or related topics such as green infrastructure and greenways, to identify common factors that affect the planning and maintenance of ecological connectivity. Theme areas discovered in past research were reflective of the research focus. For example, research related to landscape ecology noted the land pattern or structure as a factor which impacted the movement of species. Governance focused literature identified factors such as a need for a collaborative governance approach to address the cross jurisdictional dependency and multiple values or interests. Financial concerns such as adequate funding and resources was a common theme area that emerged. Finally, knowledge and learning factors for ecological connectivity emphasized the need for a scientific approach, appropriate data, and shared knowledge.

Table 4-2 : Factor theme areas affecting the planning and maintenance of ecological connectivity deduced from the literature

Factor theme	Topic	Select sources
Physical or structural	Continued land fragmentation, competing land uses, land availability, land tenure, climate change, barriers, adverse effects, functional connectivity	Keely et al. (2022); Beunen & Hagens, (2009); Huber et al., (2012); Jennings et al., (2020); Schloss et al., (2022); Elton & Drescher, (2019); von Haaren & Reich, (2006); McRae et al., (2012); Donald & Evans, (2006); Opdam, (2006)
Governance of process	Binding legislation, political support, diverse stakeholders, collaboration, multiple values, jurisdictional fragmentation, cross border dependency, stewardship	Keeley et al., (2018) ; Duvall et al., (2017) ; Aslan et al., (2021) ; Parrott et al., (2019) ; Bodin et al., (2017) ; Perrin et al., (2022) ; Cooke & Moon, (2015) ; Scarlett & McKinney, (2016) ; Hardy et al., (2022) ; Bergsten et al., (2014) ;
Financial or resources	Leadership, staff capacity, adequate funding, staff turnover, lack of time, use of incentives	Keeley et al., (2019) ; Martin, (2016) ; Allred et al., (2021) ; Spang et al., (2012) ;
Knowledge or learning	Scientific approach, public outreach, information exchange, measurable criteria, monitoring, adequate data, connectivity modeling, expert input, local knowledge	Keely et al., (2021) ; Khoshkar et al., (2020 ;) ; Sternlieb et al., (2013) ; Lemieux et al., (2022) ; Cummings & Allen, (2017), Brodie et al., (2016) ; Gurrutxaga et al. (2015); Bryant, (2006); Puric-Mladenovic & Strobl, (2012)

Note: sources typically identified multiple factors in several theme areas

Subthemes were inductively identified, reorganized, renamed, and otherwise categorized through an iterative approach. There are arguments both for and against an inductive approach to thematic coding. On one hand, an inductive approach may not be reliable, objective or accurate (Guest et al., 2012), and on the other, can provide an interpretive, subjective, and reflexive analysis that 'sculps' knowledge produced (Braun & Clarke, 2021). A lack of rigour is methodology is often a criticism of inductive approaches to thematic analysis and the provision of structure a means to provide rigour to the research (Nowell et al., 2017). The direction in Creswell and Poth (2018) on inductive coding was applied by following four steps: reading and memo emergent ideas; describing and classifying codes

into themes; developing and assessing interpretations; and representing and visualizing the data. I first read the transcripts to get an overall sense of the interviews followed by a memo approach to summarize and synthesize the meanings. The summarized text was labelled with a code that described the factor and fit within the themes identified in the literature. These initial codes were then revisited, and similar codes were categorized into related factors. Quotes were identified from the transcripts which represented the categories to support the findings. The quotes were used to improve 'trustworthiness' by demonstrating the accuracy of categories, independent of my personal opinions (Guest et al., 2012; Thompson, 2022).

Codes were applied to the data as 'summary markers' (Guest et al, 2014) and applied based on the explicit words used by respondents (i.e., 'lack of education' was coded 'education') or were derived from implicit comments (i.e., 'teach the decision makers and the public' was coded as 'education'). Categories were separated based on whether they covered factors that helped or hindered the planning of ecological connectivity and the implementation of policy. In most cases a factor could help if present and hinder if absent. For example, the analysis showed that education helped garner public and political support and the lack of education hindered the integration of ecological connectivity in decision making.

Based on the inductive coding, the governance and process theme was split into environmental governance and land use planning practice. The other themes were renamed as physical landscape, information sharing and resources to better reflect the reported factors. Given the topic of research and interviews with planning practitioner, the new theme area of land use planning practice is not unexpected. It must also be noted that I am a career planner and my insight into the planning profession may have been an impetus for identifying the

significance of the land use planning practice theme. Researchers not familiar with a specific perspective such as local government land use planning practice may not recognize the potential relevance to the broader topic, in this case the planning and maintenance of ecological connectivity (Timmermans & Tavory, 2012).

Thematic analysis was used to explore perspectives, identify similarities and differences among respondents on influential factors, and to discern insights into why the factors were important (Nowell et al., 2017, Saldana, 2016). A great deal of detail was derived from the interviews and the results presented here do not exhaustively cover all the factors raised but identify the most important areas. An effort was made to keep the themes distinct and non-overlapping. However, it needs to be recognized that the themes are interrelated and should be considered together rather than distinct areas of interest. Therefore, the themes identified are not necessarily fully mutually exclusive and there is some overlap.

4.6 Results

Factors that helped or hindered the planning and maintenance of ecological connectivity covered five themes: (1) physical landscape; (2) environmental governance; (3) land use planning practice; (4) information sharing, and (5) resources. Each theme contains information comprised of similar comments from those interviewed (Table 4.3; Appendix B).

Table 4-3 : Major theme areas and categories of factors that help or hinder the planning and maintenance of environmental connectivity

Theme	Description	Categories
Physical Landscape	The physical landscape aspects of connectivity including the land patterns, species movement, climate change and ecosystem functions and services. The location of private lands and lack of habitat affected connectivity. Land uses and cover that affect connectivity included agriculture, water, woodlands/trees, transportation, infrastructure, and other specific natural features or physical barriers to connectivity.	Structure and function Tenure Land availability Agriculture Barriers
Environmental Governance	How the existing governance structure and decision-making framework affects connectivity including international, national, provincial, Conservation Authority, local government and non-government actions. Cross border collaboration, planning on a watershed basis, and landowner stewardship actions on private lands are all part of the environmental governance structure.	Decision making framework Collaboration Watershed Stewardship
Land Use Planning Practices	Enabling legislation including provincial plans, and a focus on features versus linkages affected connectivity. Mapping utility and scale and policy used - including language, balancing needs, supporting studies, and planning system were considered. Land use planning process affected connectivity as did the use of science and monitoring outcomes.	Legislation Mapping Policy Planning system Science Outcomes
Information Sharing	A need for outreach, and shared learning to educate those who make the decisions or own the land and gain support on the importance of conserving ecological connectivity. This can be done through the planning process with leadership essential.	Education Planning process Knowledge Leadership
Resources	Resources recognized as needed for connectivity included capacity, expertise, funding, and incentives for private land stewardship. The cost, budgeting, tax base needed, and data management all affected connectivity.	Capacity Costs and budget Data management Funding and incentives

4.6.1 Physical Landscape.

The physical landscape theme reflects how the landscape configuration and use affect planning and maintenance of ecological connectivity. The coded interview results were clustered into five related categories: structure and function, tenure, land availability, agriculture and barriers (Table 4.4). The main factor identified that hindered the planning of ecological connectivity was a recognized focus on identifying natural features such as wetlands and woodlands, rather than linkages among natural features. Provincial legislation requires the protection of features but provides less direction on how linkages are to be considered, leading to ecological connectivity being less rigidly addressed. As noted by one interviewee, secondary corridors were removed from the planning update since "people were understanding of the whole primary corridor idea [along rivers] but they felt that secondary corridors [upland] might start to chip away at private property" (L-3). It was recognized by the interviewees that connectivity is difficult to explain as it is hard to 'see'. For example, an interviewee indicated that "everyone can see the feature but it's the landscape in between that people just can't seem to grasp or appreciate the need [for connectivity]" (P-1). A Conservation Authority interviewee indicated that it is an "issue of proving that it is needed - why give up part of the farm when it is not used by animals or ecological function or biodiversity" (C-3).

The potential porosity or permeability, of the working landscape (land matrix) was acknowledged as helpful in ecological connectivity. For example, a rural local government interviewee noted that the "agricultural landscape is porous, and animals travel through farm fields, so an active field doesn't necessarily break those linkages" (L-4). However, the tenure patterns, specifically the abundance of private land parcels and associated fragmentation, were

recognized as a constraint. A Conservation Authority interviewee noted that for agricultural lands there are "funding programs and initiatives currently out there to look at connectivity, but there are so many owners and a need to collaborative – so it is a big effort to get anything going" (C-7)

Table 4-4 : Physical landscape theme key factor identification

Category	Key Factors
Structure and function	• Focus on features, connectivity of secondary importance; corridors perceived as open for development • Exclude small features as stepping stones; mapping misses features • Permeability of the agricultural matrix; intensive agriculture • Lack of emphasis on species (functional connectivity) • Cannot target areas for implementation • Distance between features, no natural areas between • Only using proximity to identify corridors; no criteria used • Difficult to see connectivity or explain why needed
Tenure	• Abundance of private land parcels • Opportunity based and difficult to target landowners • Difficult to address multiple properties needed for connectivity • Loss of property rights and livelihoods • Political ramifications of property owner resistance
Land availability	• Lack of continuous corridors; just protect what is left • Competing interests; large population; emphasis on housing and urban growth • Connect woodlands; use woodland conservation by-laws • Use river systems as more readily accepted (water quality, already managed) • Upland corridors difficult to locate and protect
Agriculture	• Some farmers are ecologically minded; others maximize profit / yield • Protecting farmland, woodlots, wetlands a priority • No restoration can occur on active farmland; no marginal lands left • Modern farming practices larger equipment, amalgamation, modern farm practices, large machinery • Hedgerows, windbreaks, and riparian areas disappearing • Burdon of societal cost; no direct benefit for farmers or farming
Barriers	• Existing land uses, new uses and resource development restrict connectivity • Infrastructure, roads, transit are a priority in corridors • Tall buildings affect migratory birds • Marginal lands now economically feasible for housing development • Cost of overpasses, underpasses; cost of addressing wildlife passage after road construction

A challenge noted was land availability or the location of existing natural areas available to create continuous corridors. A local government interviewee noted, "it might be easier to simply protect natural lands that were left than figure out how to identify corridors" (L-8). The availability of river systems and natural hazard lands were seen as a help in the ability to plan for ecological connectivity as the use of shorelines, rivers or other linear water-related systems was more readily accepted than upland corridors. As noted by a local government interviewee, "upland corridors are a challenge as the [provincial direction] does not protect [upland corridors] …it is not black and white" (L-10). This was supported by a provincial government interviewee who noted "identifying upland corridors is a tough sell - riverine is easier than tableland" (P-1).

Protecting farmland was a priority and restoration on active farmland to improve connectivity was not seen as practical as even marginal lands were now being put into agricultural production. Modern farming practices with larger farm equipment and farm consolidation affect ecological connectivity with hedgerows, windbreaks, and riparian buffers disappearing. As noted by a local government interviewee, "the younger generation of farmers are more production oriented and not interested in protecting natural heritage" (L-10). Urban land uses, transportation routes, transit and infrastructure are given priority and create barriers to connectivity. A local government interviewee from a large city indicated that local government "will allow transit infrastructure in valley bottoms as it trumps everything" (L-8). Wildlife passages such as overpasses require funding, and while it may be relatively easy to address wildlife passages at the construction stage, addressing barriers after construction is cost prohibitive.

4.6.2. Environmental governance

The environmental governance theme refers to a multiplicity of government and non-government agencies and the level to which actors are working together in a coordinated manner to address ecological connectivity. The theme is comprised of the decision-making framework for ecological connectivity, collaboration for cross border issues, use of the watershed as a unit of planning, and coordinating with stewardship initiatives for implementation of ecological connectivity on private land (Table 4.5). There was a recognition of a need for an integrated decision-making framework to address ecological connectivity. As noted by a Conservation Authority interviewee, "most have identified lines on a map – they now need more guidance on how to integrate that into the other policy frameworks (C-7)". A rural local government interviewee noted that "I think there's an opportunity to add more clarity around linkages and connectivity and I think there is opportunity to integrate that into an implementation framework" (L-5).

A major issue raised was disconnects in the decision-making framework to address ecological connectivity. A disconnect was recognized by interviewees between local government and higher levels of government. Many local government interviewees noted that in the past they had a good relationship with the province, but they no longer received help to implement provincial natural heritage system legislation. A local government interviewee indicated "there's been so much staff turnover at the province, I would reach out [for help] and they just point me to the website with the mapping" (L-7). The province has implemented a one window contact process for land use planning through the Ministry of Municipal Affairs and

Housing to streamline provincial government input, but some local government interviewees pointed out that this only resulted in environmentally based provincial ministries being inaccessible to local government. This was confirmed by a provincial government interviewee who noted that "as soon as we started [the one window approach] the number of phone calls I used to get just dropped right off" (P-1).

Table 4-5 : Environmental governance theme key factor identification

Category	Key Factors
Decision making framework	• Wide range of policies apply; need implementation guidelines • How to work across jurisdictions • Disconnects among: LG functions, planning and implementation, science and planners • Balance public interests; political will
Collaboration	• Cross jurisdiction takes time and resources; already have a full plate • Need leadership, and staff to coordinate • Multi stakeholders collaboration is easier for area specific projects / studies
Watershed based governance	• Best scale to address ecological connectivity • Local government look inward within boundaries • Conservation Authority has a broader, ecological perspective and work with multiple local governments • Conservation Authorities have a mandate to regulate natural hazard lands • Water protection is readily accepted (water quality for human consumption) • Still local government is the decision maker, not a Conservation Authority
Stewardship	• A conflict with livelihood and private rights • Limited effectiveness (voluntary, transitory) • Need incentives; many available programs, incentives, funding opportunities • Local government is not active in stewardship but encourage • Woodlot and tree conservation and planting are stewardship related • Encourage native plants • Conservation Authorities are involved with stewardship / restoration / outreach, own land and are stewards themselves • Funding is site specific and not address multiple properties • Price of land is prohibitive, need stewardship

In some instances, local government interviewees perceived the province as detached without much knowledge of local government needs, resources, or capabilities and with little local trust. For example, a local government interviewee indicated "there was often a

perception that the province was the big bad province sitting out there in Toronto making all these rules … and people were more receptive to the local Conservation Authority" (L-3). A disconnect between federal and local government was raised when dealing with international plans. A Conservation Authority interviewee noted that it was expected that federal government plans such as remedial action plans would be implemented by Conservation Authorities, but that the Conservation Authority did not have the jurisdiction to address what was asked of them – "there's a disconnect and there's nothing in the provincial law that gives that protocol legal teeth" (C-2).

Local government participants noted that there was little coordination across local government borders. A local government interviewee indicated that each local government does their own planning and "we work in silos" (L-7). Within local government, there is a potential disconnect among local government functions. For example, woodland conservation by-laws are a major tool noted by interviewees for natural heritage systems implementation, yet tree conservation and tree planting programs are typically conducted by a different department than planning. Some Federal government employees noted an internal inability to address ecological connectivity. A federal government interviewee noted that connectivity work was primarily through Parks Canada, but other departments were "part of the problem with different priorities but not involved in the connectivity work though if others were involved it would water down recommendations" (F-1).

This separation of local government functions can lead to a separation of objectives, as noted by a Conservation Authority interviewee, "tree planting may be nowhere near identified [connectivity] restoration areas but where ecological benefits are minimal" (C-1). It was noted

that sometimes there is a disconnect between scientist who study ecological connectivity and planners who write ecological connectivity policy, which can result in incorrect interpretation of the science or ineffective policy. It was remarked that there is a separation between those developing the planning policy and those doing the implementation. As noted by a local government interviewee, "staff need to have a technical background or understanding of the purpose of the policy in order to implement [it] without a disconnect" (L-5).

Collaboration was needed but difficult because of the time and resources it takes to organize and meet with other stakeholders and smaller local governments and Conservation Authorities may not have the capacity. As noted by a local government interviewee, "everyone is so busy, applications increase but staff do not and there is no time to collaborate" (L-7). But collaboration was seen as needed to ensure cross border coordination. Local government with finite boundaries has a propensity to look inwards while Conservation Authorities were noted as being in a better position to address ecological connectivity given their watershed-based boundaries, their more holistic, ecological perspective, and their ability to work with multiple local governments. As noted by a Conservation Authority interviewee, a Conservation Authority "takes a more holistic point of view and works with multiple municipalities so they have a broader perspective than municipalities" (C-7). Collaboration is also needed to work with property owners. As noted by an NGO interviewee, "people do great things on their own property but if you're creating linkages that usually means multiple properties and talking to multiple groups like local governments and Conservation Authorities, so you need to talk to everyone who is involved" (NGO-1).

The watershed-based Conservation Authorities were viewed by both local government and Conservation Authorities as an appropriate agency to address ecological connectivity. Conservation Authorities are a large part of the local government planning system through the regulation of natural hazard lands (e.g., floodplains, steep slopes, river systems, wetlands) and through commenting on development applications, which inadvertently can contribute to ecological connectivity. As noted by a local government interviewee, "Conservation Authority regulation for natural hazard areas, or creek beds [offers a] double safety net because Conservation Authority polices discourage or limit development opportunities in those areas" (L-6). A Conservation Authority interviewee agreed noting "mandated riparian protection and hazard planning indirectly will address connectivity by restricting buildings and maintaining original [natural] features" (C-5).

In many areas, it was noted that the only natural lands left are riverine systems, ravines, valley lands, and portions of the waterfront onto the lakes, and these areas become the core of ecological connectivity planning. River corridors were more readily accepted as linear features and functioning as linkages, as riparian areas, and natural hazard lands were already regulated by the Conservation Authority. The watershed-based conservation authority was also recognized as the repository for data needed for natural heritage systems planning. While a watershed scale was noted as important, Conservation Authorities noted that it is still the authority of the local governments to make decisions on developments.

Stewardship, or the protection of ecological connectivity on private lands, through voluntary actions, was seen as needed to complement regulatory implementation means but difficult to implement. As noted by a rural local government interviewee, "we tried for policies

to encourage private land stewardship to follow policies for linkages and joining parcels, but it turned into an issue of 'how did you plan to implement linkages or did you at all?'" (L-3). Other local governments noted they were not involved in stewardship and depended on Conservation Authorities and NGOs to carry out this function. NGOs noted capacity issues in addressing stewardship as well as dependence on funding sources. As noted by an NGO interviewee, "funding programs do not typically look outside of one property, making it hard to deal with connectivity" (NGO-3). Conservation Authorities and NGOs raised the issue of the difficulty in targeting stewardship to address gaps in connectivity as stewardship was dependent on a willing landowner in the right location, leading to a matrix of sites, not a corridor.

4.6.3. Land use planning practice

The land use planning practice theme was well subscribed and includes the facilitators and challenges of provincial legislation, use of mapping, application of policy, shortcomings or assistance offered by the planning system, application of science and measuring outcomes (Table 4.6). It was recognized that the provincial legislation related to natural heritage systems planning is progressive and beneficial to local governments. However, many respondents also noted provincial legislation was vague with linkages suggested but not required. As noted by a Conservation Authority interviewee, "one of the issues is that it's easy for councils to approve things that are required by the province, but things that are [only] nice to do [are more difficult], I guess it's very site specific in that sense" (C-6)

Table 4-6 : Land use planning practice theme key factor identification

Category	Key Factors
Provincial legislation and plans	• Linkages suggested not required; provincial direction weak and vague • Politically difficult to exceed minimum standards • Provincial plan overlap with inconsistencies causing confusion
Local government planning system	• Only address ecological connectivity through development applications • Ecological connectivity addressed at the site level • Cannot address existing uses; can address permitted uses but hard to enforce • Implement at lower tier, a time lag, out of sync • Historical designations do not match the existing landscape • Developers see connectivity as positive (selling feature) or negative (profit)
Policy	• Connectivity not as high a priority as socio-economic human benefits • Purpose of Official Plan is growth management • Policy can maintain the opportunity for ecological connectivity • Language used in policy needs clarity; vague language interpreted differently • Need to outline means to implement policy • Guidance needed for environmental assessment to identify, maintain connectivity
Science and guidance	• Science needed to support decision making. • Need to understand technical aspects • Use of criteria and standards, need to be clear on background assumptions • Science is context specific • Old science used - outdated provincial guidance • Need implementation guidelines with examples
Mapping	• Need to spatially identify but can also be through policy • Connectivity considered a constraint to development • Extensive data collection, preparation, and refinement • Context specific • Mapping dated or incorrect • Validity and utility of mapping; only shows a point in time • Use of different scales / data • Connectivity does not line up across jurisdictions • Need to ground truth data but need owner permission to access property
Outcomes	• No monitoring on policies, outcomes unknown, need to be accountable • Outcomes due to activities outside of planning • How to monitor, who should monitor, what indicators to use • How to determine species movement

The provincial legislation does set minimum standards that local government can exceed, but there is a need for political will to go beyond the minimum required. A Conservation Authority interviewee noted that “a lot of the municipalities will do the bare

minimum based on what legislation and policies are out there and getting them to do anything beyond is pretty unlikely" (C-7)

Provincial plans were a useful tool for local government to address ecological connectivity. A regional local government interviewee indicated they had "no real issues as they have strong provincial protection with four overlapping plans, so they don't have the level of resistance as developers are aware of the provincial layers" (L-2). On the other hand, another local government indicated that they had "multiple provincial plans [applying within its area of jurisdiction], plans overlapping, not consistent" causing confusion to planners and developers (L-1). Provincial plans were seen as both good for providing certainty and bad as their scale does not take local context into consideration. As succinctly put by a local government interviewee, "provincial plans are good as they do definitely give additional strength to the whole concept [of ecological connectivity] and they can help provide greater direction or detail, but bad as they set lines that may not catch everything or missed some data" (L-5).

The mapping of connectivity on a broad scale is generally seen as a prerequisite to more specific ecological connectivity implementation. As noted by a local government interviewee, "establish what [linkages] you have and what you want to achieve on the macro scale – linkages present themselves at that scale" (L-10). Yet it was also noted that the mapping only shows a point in time and may not capture the dynamic nature of the environment. As noted by a Conservation Authority interviewee, "you can't spend 10 years on a study as you only see one point in time" (C-3). Scale was an issue also recognized by a federal government interviewee by noting that connectivity "depends on the species as [connectivity] could be a time corridor (seasonal), stepping stone corridors, connected patches, for birds and migration route, small

scale road crossing, butterfly corridors with gardeners in urban setting – it is very species specific and insight specific" (F-2). Implementation of the mapping was also a concern. As noted by an interviewee "you can draw a line on the map, but for the natural area connections and corridors, I would get push back as the mapping was considered to be just conceptual - not real" (C-7).

There are context specific approaches used by different local governments with varying baseline conditions leading to inconsistent mapping and ecological connectivity not lining up across local government boundaries. As noted by a Conservation Authority interviewee, "connectivity may not line up across borders if they have different criteria or one follows a creek and the other not" (C-6). A provincial interviewee noted that the "provincial policy statement says not to just stop at the [local government] border – you wouldn't stop a road at your border that doesn't connect to anything else, but that's not the case for connectivity" (P-1). A Conservation Authority interviewee suggested the application of consistent criteria and definitions "as to what is a connection, what is a system – what is meant by protection" (C-6).

Development is seen as a major contributor to fragmentation, yet the only time connectivity concerns of development can be addressed through the local government planning system is through a site-specific development application. Because of this site-specificity, it is difficult to take the broader context into account. As noted by a Conservation Authority interviewee, a natural heritage system "takes a broader scale approach to see connections between features and how they function together rather than a very site-specific perspective that does not consider the surrounding environment" (C-6). Another Conservation Authority interviewee agreed by saying that "microscale development does not look at the broad

landscape connectivity" (C-8). It was however also recognized that a site level assessment can see the broader view when the required expertise is present. For example, a local government interviewee noted that you need to "have an ecologist involved as it is easy to not see the broad scale in development review and you need to be aware of the larger goal" (L-10).

Environmental impact assessment at a site level can identify opportunities for retention and restoration of ecological connectivity or compensation for a loss of ecological connectivity. On the other hand, restoration is typically only on the property being developed, and it could be more valuable to restore areas off site. As noted by a local government interviewee, "this is a problem as in certain cases it could be more valuable to restore larger features and corridors than protecting small, isolated patches on every developed piece of land" (L-10). The land use planning system only addresses new development, but not existing uses that are already legally there, which is problematic when existing uses pose a barrier to ecological connectivity. As noted by a Conservation Authority interviewee, "you can say plan to connect [natural areas] in the future, but you cannot make existing uses illegal as per [the] Planning Act" (C-2).

The interviewed planners noted that having scientific evidence to support decision making is a positive factor. A local government interviewee noted "the Conservation Authority is instrumental in developing the model and maintaining background data and informing on the science - they are key" (L-5). But having scientific data is not enough; the science also needs to be understood. As noted by a Conservation Authority interviewee, "you need to have people who understand what's going on and most planners are not environmental planners - they don't have the training - so having partnerships with local government and Conservation Authorities is really important" (C-7). Other local governments depended on NGOs to bring the

science into decision making, noting that an “NGO can speak towards the science behind the policies” (L-5). NGO interviewees concurred with this perspective yet pointed to the complexity of the science for ecological connectivity. While scientific data are considered vital, it was noted by many interviewees that it is still a political decision on what is incorporated into policy. For example, a Conservation Authority planner indicated that “the experts can put the best science behind recommendations, but at the end of the day it is in the hands of politicians – I don't say that in a negative way, that's just [how] the planning system works” (C-2).

Another major factor raised as an issue for local government planning practice was a lack of monitoring of the policy direction and implemented policy tools to evaluate their effectiveness. Generally, no monitoring was being done and outcomes were unknown. For example, a provincial government interviewee noted when asked about policy outcomes “that's a good question and you know I don't know if I can say if it works, but maybe I can say it is not, not working” (P-1). Monitoring is a struggle as noted by a local government interviewee, “monitoring and adapting over time is a gap a municipality struggles with [given a lack of] resources and time and technical understanding” (L-5). It was recognized that it is hard to determine if the natural heritage system as designed is working if there is no monitoring. As noted by a provincial government interviewee, “it is hard to figure out how to monitor, if the system you have designed is actually working and allowing plants and animals to migrate back and forth … and that is resource intensive and hard to do for systems as they are huge” (P-1).

4.6.4 Information sharing

The information sharing theme reflects the need for human understanding of why ecological connectivity is important. This entails educating the public on the purpose of

ecological connectivity, use of the planning process as an educational tool, leadership to maintain ecological connectivity, and knowledge transfer from science to practice (Table 4.7). Public resistance to ecological connectivity was noted as a common factor hindering local government land use planning. There is a perceived loss of property rights and livelihoods together with associated political ramifications for the decision-making process. As noted by a local government interviewee, "private property owners see natural heritage mapped on their property as a loss of development rights or restriction on things they can do" (L-5). Education of landowners and the public was seen as imperative to gain support for ecological connectivity across private lands.

Table 4-7 : Information sharing theme key factor identification

Category	Key Factors
Education	• Public, political resistance • Well-educated population encourage buy-in • Easy to see a feature, hard to see ecological connectivity • Bring in more social – economic valuation (ecosystem services, human health, green infrastructure, natural assets) • Acton education – tree planting bird surveys
Planning process	• Learn from other local governments • Sample development sites to demonstrate policy • Planning process public participation and polices educate public and politicians
Leadership	• Provincial (legislation, provincial plans) • Indigenous (knowledge, land ownership) • Progressive environmentally minded council (political will) • Regional coordinator (cross border) • Planning staff (own the plan); need environmental planners • Community (active spokesperson)
Knowledge	• How to plan as a system instead of features • How to maintain, improve or restore ecological connectivity • Incorporation of local and indigenous knowledge • Understanding consequences of decisions • Transfer or translation of learning; science to practice

A specific lack of support from the farming community was noted as a barrier to incorporating ecological connectivity policy into planning documents. As noted by a local government interviewee, "the farming community have preconceived ideas that we need to get past as they [farmers] see [ecological connectivity] as more of a hassle" (L-10). Still, recognizing the needs of landowners is paramount. As noted by a Conservation Authority interviewee, "the system works through education – if you can barely put food on the table, they're not going to plant trees but support their family" (C-5). Overall, as noted by a NGO respondent, "outreach and education – ensuring that landowners know the benefits of protecting the habitats on their land – giving a voice to some of those species at risk, whether that's a Butternut tree or a Bobolink, can help motivate and inspire people" (NGO-3).

Political will was a factor noted by many as needed for the inclusion of ecological connectivity in policy. Politicians are fearful of negative public reaction to environmental initiatives, leading to low political support for ecological connectivity. There is a need to balance competing interests and without public support, political support may be lacking as well. Next to the public, politicians also need to be educated. Often, councils are more budget or growth oriented and, in these cases, using an economic or human benefit perspective to educate the decision makers may be useful. It was noted that there was a need to provide education about ecosystem services and human benefits instead of just the need to protect areas for intrinsic value. For example, it was noted that riparian areas can be used for ecological connectivity but also for flood control.

Using the planning process and public consultation as an educational tool was suggested with information provided to address misconceptions about ecological connectivity. As one

local government noted, questions from the community are a good means to turn "opposition into an opportunity" (L-3). It was suggested that there is a need to learn from other local governments with strong policies on ecological connectivity to set examples for others. As noted by a local government interviewee, where local governments have "stepped up with strong policies, they are seen as forerunners", making it easier for local governments with weaker policies to accept stronger measures to address ecological connectivity. (L-7). This same local government interviewee also suggested that having a sample site would help developers by showing how ecological connectivity can be incorporated into the development process.

Leadership was recognized as needed to both plan and maintain ecological connectivity. Provincial leadership is needed but this must be matched with local leadership. As noted by a Conservation Authority interviewee, "you need provincial leadership top-down, but also need the [local leadership] bottom-up perspective of the property owners who are willing to set some land aside to provide the connections" (C-7). An NGO interviewee noted that Indigenous leadership would also be beneficial both for their knowledge base as well as for land protection, because in some areas much of the remaining natural lands are located on Indigenous lands (NGO-1). Council leadership was also recognized as needed, with a progressive environmentally minded council being a strong factor of support. Planning leadership or motivated staff who understand the reason for the policy on ecological connectivity is needed for policy implementation. It was noted there are few local government environmental planners and there needs to be someone that understands the plan and will ensure the policies on ecological connectivity are incorporated into decision making. Lastly, community leadership is needed. As noted by a local government interviewee, there needs to be "an active spokespersons within

the community who will take the time and come out or send emails to counterbalance negative perspective that council usually hears" (L-5).

There was a recognized need for scientific knowledge to address ecological connectivity, but a lack of translating the science into planning practice. It was noted that research, conferences, and case studies on ecological connectivity are occurring but there appeared to be less transfer or translation of learning into how to build or design ecological connectivity. A local government interviewee noted there is a "need to have a technical background or understanding of the purpose of the policy in order to implement [it] without a disconnect [between policy and implementation]" (L-5). A Conservation Authority interviewee noted that a person may "lack the knowledge of how to implement or restore connectivity" leading to ineffective ecological connectivity on the ground (C-2). Knowledge also refers to understanding the consequences of decisions and what is working or not working. For example, as noted by a local government interviewee "if more islands are created as opposed to a connected system, then you need to understand what is not working in the policies and what needs to be changed" (L-5). An NGO did however remark that "one of the issues we identified 20 years ago was a lack of knowledge of how natural heritage systems need to work or why you should even have them" and "we don't need to convince anyone anymore; we just need the resources available so they can do what they need to do (NGO-1).

4.6.5. Resources

The resources theme is focused on the capacity or ability of practitioners to incorporate ecological connectivity in land use plans and implement the policy direction. Resources include capacity of staff, available time, adequate funding, expertise, and data (Table 4.8). It was

remarked by many interviewees that local government have no time to consider matters such as collaboration or restoration outside of their day-to-day work. As noted by a local government interviewee, “sometimes you’re so inundated with work from a development review perspective, you don’t necessarily have time to do the networking” (L-5). Similarly, a local government interviewee noted they had “no time or staff to address restoration work but leave that to property owners and NGOs” (L-7). Yet NGOs also indicated a lack of capacity to address land stewardship initiatives. It was also remarked that landowners themselves do not have the capacity, as noted by an NGO interviewee, “a lot of landowners simply don't have the time or resources to start to establish and work on linkages as it's time consuming just to take care of what you have” (NGO-2). With staff turnover as well as substantial reduction in staff, particularly at the Provincial government level, it was noted there was no continuity in policy direction and implementation to address environmental matters.

Table 4-8 : Resources theme key factor identification

Category	Key Factors
Capacity	• Local governments have no time or capacity • Staff turnover, particularly province • More difficult for smaller local governments (lack of staff, budget, expertise, time, tools, and tax base) • Need good GIS staff, dedicated staff • Conservation Authorities as support for local government
Data	• Obtaining, refining, updating data • Data on species movement, inventorying, and ground truthing
Funding and incentives	• Need incentives for landowners • Unable to take on opportunities; no funding available • Funding geared towards features and not ecological connectivity
Cost and budget	• Conservation Authority funding model based on population • No funding to help implement ecological connectivity • Local governments don’t or unable to allocate adequate budgets connectivity • No funding for monitoring • Lack of guaranteed funding for data management

Funding was lacking, primarily for implementation of ecological connectivity through stewardship initiatives and acquiring lands. As noted by a Conservation Authority interviewee, "from a developers' perspective, they may be willing to hand over property to the Conservation Authority to protect and add on to connectivity, but [the Conservation Authority] can't afford to, even if donated, as it is still a huge expense to monitor and manage" (C-7). The Conservation Authority funding model is based on population size in the Conservation Authority area of jurisdiction, with more funding going to the more urbanized areas with higher populations. Yet the need for ecological connectivity initiatives lies more so with the rural areas where there is habitat left and ability to address ecological connectivity. As noted by a Conservation Authority interviewee, "a larger Conservation Authority should help a smaller Conservation Authority that do not have the resources; the larger Conservation Authorities have funds but not space to use it" (C-4).

Many local governments do not, or are unable to, allocate adequate budgets to ecological connectivity and therefore are not engaged and restrict proactive action on ecological connectivity. It was recognized that "smaller municipalities have a harder time bringing Official Plan policies into compliance due to staffing and budgets" (L-1). An NGO addressed this issue by remarking that "you have some municipalities that have relatively adequate resources, but then you have others where they're just putting out fires and trying to stay afloat - and they can't actually do that proactive work" (NGO-2). It was suggested that the ecological connectivity policies need funding from a higher level of government for implementation. As noted by a local government, the province is "suggesting that there's

certain connectivity needs, but the only time you can implement that is through the planning process and those who want to do good things don't have resources" (L-4).

Resources were noted as lacking for ecological connectivity mapping and data needed to identify ecological connectivity. Guaranteed funding was needed as well as time for people to monitor and map ecological connectivity changes. As noted by a Conservation Authority interviewee, "having the right tools and resources makes it a lot easier - you do not want to use base mapping from 20 years ago" (C-7). Identification of ecological connectivity it was noted, includes extensive data collection, preparation, and refinement for mapping, as well as staff members who are knowledgeable in geographic information systems.

I will end the results section with a quote from an NGO which addresses the main issue, how can more be done to maintain ecological connectivity.

> The conservation community have all upped their game over the last 30 years. Really great tree planting programs, switched to native plants, the conservation programs are getting bigger and bigger, and doing great work. We've got all kinds of policies we didn't have 30 years ago like species at risk, natural heritage systems policies. All of that has increased in 30 years. Despite all that, despite our collective best efforts we are still losing habitat every year. So, we're not doing enough. It's all great stuff, but we have to do more. And so that is the big question for the conservation sector in the Carolinian zone. Is how do we do more? (NGO-1)

4.7 Discussion

Land use change is commonly cited as a major cause of fragmentation and loss of ecological connectivity, and land use or spatial planning is a key means to protect ecological

connectivity and implement ecological networks (Shafer, 2015, Perrin et al., 2022; Jennings et al., 2020; Keeley et al., 2019; Rudnick et al., 2012; Mancilla - Garcia et al., 2019). While spatial planning can occur at multiple scales, I focus on local government land use planning as this is the level where the development decisions are made that impact ecological connectivity and how higher-level direction is implemented. This current study investigates the issues that affect local government in the incorporation of connectivity in land use plans and implementation of the plan direction, to achieve a more connected landscape. Practical insight into factors that help or hinder that local government land use planning process are offered to identify how more can be done to maintain ecological connectivity.

Both the biophysical and social landscape influence ecological connectivity (Egerer & Anderson, 2020) and the current study findings highlight a need to address both landscape and social factors to facilitate ecological connectivity. Five themes (biophysical landscape, environmental governance, land use planning practice, resources, and information sharing) and key factors that affect ecosystem connectivity planning and implementation of policy were uncovered through the interviews with planning practitioners (Figure 4.2). Biophysical factors that influence how ecological connectivity planning and implementation is carried out include landscape patterns as well as land uses which promote or hinder ecological connectivity. The social factors identified in this study that facilitate ecological connectivity include an effective environmental governance structure and decision-making framework, a planning and implementation process that is enabled by legislation, sharing information about the benefits of ecological connectivity to encourage political will and public buy-in, and adequate resources to carry out the planning and implementation. Together these factors represent a social-

ecological system in a human-dominated and highly fragmented landscape with the potential for local government to plan and implement a network of natural features and linkages.

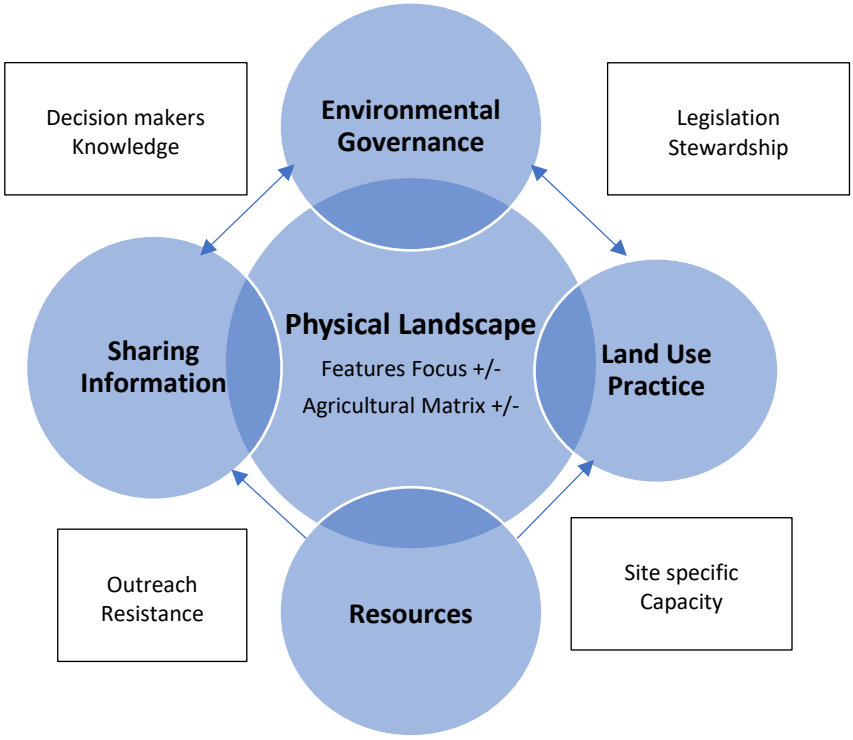


Figure 4-2 : The five identified theme areas and key factors that influences local government planning and maintenance of ecological connectivity

Most key factors noted could be either a positive influence or a negative constraint. In the Carolinian ecoregion, there was a focus on natural features which ensured key patches of natural areas were protected over time. However, linkages, though required to be identified, were afforded less protection. In rural areas, there was an emphasis placed on the importance of the agricultural matrix to enable ecological connectivity as it was seen to pose less of a barrier to species movement than urban development. The resistance of the farming community to land use planning for environmental protection and the inability of local government to protect ecological connectivity on agricultural land was a negative factor.

Environmental governance in the Carolinian ecoregion was influenced through provincial legislation, which provided a higher-level framework for local government land use planning practice. Planning practice, however, has a site-specific focus, which may not address ecological connectivity in a holistic manner. Both local government planning and implementation measures for ecological connectivity depend on resources and expertise as well as the ability to address resistance through outreach. Without adequate resources, and sharing of information, collaboration to address cross border issues is difficult.

4.7.1 The landscape - how does environmental connectivity fit?

Natural features continue to be the backbone to a system or network approach to ecological connectivity (Puric-Mladenovic & Strobl, 2012). But isolated natural areas may be too small, too few, or in the wrong locations to be effective in conservation of biodiversity and ecosystem functions or services (Rodrigues & Cazalis, 2020; Watson et al., 2017). Conversely, a well-connected system of natural areas has a greater chance of maintaining ecological integrity (Dupras et al., 2016, Staccione et al., 2022, Field & Parrott, 2017).

The fact that the Carolinian ecoregion has a history of planning for the protection of natural features and water resources with the benefit of enabling legislation encourages the maintenance or improvement of ecological connectivity. In Ontario, it was recognized in the 1990's that designating natural areas was "not sufficient to sustain ecologically sound and functioning natural areas and ecological process within southern Ontario's landscapes" (Puric-Mladenovic & Strobl, 2012, p. 723) and that a systems approach was needed identifying core areas and linkages among the natural areas. A systems approach to natural heritage planning was introduced in the 1997 Provincial Policy Statements, subsequently amended in 2005 (Puric-

Mladenovic & Strobl, 2012). Yet even with supporting legislation, this current research demonstrates the difficulty in implementing a systems approach given the existing landscape configuration.

The fragmented nature of the landscape, lack of available land to connect natural features, and the private land tenure pattern, were all noted by interviewees as contributors to the difficulty in identifying continuous corridors. While areas can be identified for restoration, interviewees stressed that implementation is more dependent on the availability of land and willing landowners. The findings of von Haaren, & Reich (2006) also identified that the implementation of ecological networks is more often guided by the availability of land than ecological requirements for species movement or ecological functions.

Land resources identified by interviewees as available for linking natural areas are river corridors, shorelines, floodplains, and steep slopes. The existing water-related corridors and associated riparian areas can function as buffers to address water quality and flooding, terrestrial corridors for the movement of plants and animals, and habitat for aquatic species (Environment Canada, 2013). In my study, riverine systems were identified by the respondents as part of a natural heritage system for three reasons: (1) the water resource system was recognized in legislation as part of the natural heritage system, (2) water resources and natural hazards were already regulated through Conservation Authorities, and (3) there was strong political support to address water resources. This inadvertent protection of ecological connectivity through the protection of the water resource system was considered to help facilitate ecological connectivity. Yet a concentration on water resources to address ecological connectivity is geared to the more anthropocentric concerns of water quality and human safety

rather than habitat and a movement corridor for species, still relegating ecological connectivity to a secondary priority (Donati et al., 2022). The use of riverine and lakeshore systems as linkages does not address upland linkages with it recognized by those interviewed that that upland corridors were a “tough sell”. The unpopularity of planning for upland corridors may be due to competing interests such as agriculture, or an assertion that the agricultural matrix was permeable to species movement.

Agriculture can fragment and isolate natural habitats and stop the movement of species, but these negative effects can be reduced by increasing the permeability or reducing the intensity of use of the agricultural matrix (Donald & Evans, 2006). The attributes offered by the agricultural matrix can be as important as the protection of natural areas (Environment Canada, 2013). However, factors such as field size and intensity of farming operations can affect linkages among habitat in the agricultural landscape (Hauser et al., 2016). The proximity of remnant woodlands or single trees can affect connectivity across the agricultural matrix (Von Thaden et al., 2022) as can the use of roadside verges (Raymundo et al., 2023). Regardless of the approach, interventions are needed to ensure the permeability of the agricultural matrix for connectivity (Raymundo et al., 2023). Interventions can include coordinating farm level actions to improve ecological connectivity across the landscape and increasing landscape heterogeneity (Leventon et al., 2017).

The inability of local government to address ecological connectivity on agricultural lands due to farmer resistance was identified in this current study as a major issue for local government land use planning. Farm woodlots and other vegetation patches on agricultural lands comprise a large portion of the remaining upland natural areas in the ecoregion. Most

rural local government interviewees in the ecoregion recognized the use of agricultural lands as part of the natural heritage system and acknowledged the abundance of farmland as a benefit for ecological connectivity but did not map linkages across agricultural lands. For example, a natural heritage system study conducted for Middlesex County claimed that the agricultural landscape is part of the natural heritage system, provides some linkage functions, and as such, ecological connectivity does not need to be mapped across farmland (Middlesex County, 2014). Instead, ecological connectivity was to be addressed if a land use change is proposed on agricultural lands with the potential impact on system linkages to be investigated at the time of development approval (Middlesex County, 2014). This lack of mapping on agricultural land, while politically supported, can make maintenance of ecological connectivity difficult with no direction provided for priority restoration areas or identification of gaps in corridors connecting natural features. Alternatively, refraining from identifying linkages across agricultural lands suggests the importance of the whole landscape for ecological connectivity, not just vegetated corridors. In the Carolinian ecoregion, a general lack of development applications in agricultural areas make land stewardship initiatives more relevant than regulatory means to address ecological connectivity. However, the farm scale of stewardship initiatives still needs to address the cross-tenure scale of ecological connectivity to be effective (Pelosi et al., 2010).

4.7.2 Environmental governance – decision making, regulation and stewardship

The need for a collaborative form of governance for large scale environmental problems with cross jurisdictional boundaries is well recognized (Aslan et al., 2021; Epstein et al, 2015; Moss, 2012; Parrott et al., 2019). For this study, the term environmental governance refers to the government and non-government institutions and actors involved in decision making and

collective action for complex environmental issues that are spatially connected across administrative jurisdictions (Newig et al., 2016; Pittman & Armitage, 2019). Two key factors for environmental governance highlighted in the current findings are: (1) the decision-making framework is fragmented, and (2) regulatory tools to implement Official Plan policies need to be supplemented with voluntary land stewardship initiatives by actors other than local government. For both issues, the watershed-based Conservation Authorities were recognized as an agency that could assist local government to address cross border matters and work with NGOs and landowners to maintain or improve ecological connectivity.

First, the fragmented decision-making process negatively affects the ability to coordinate among jurisdictions and across borders. Environmental collaborative governance is commonly promoted as a means to solve environmental problems spanning geographic scales and jurisdictional boundaries (Bodin, 2017). The current findings highlight a disconnect in the decision-making framework for planning for ecological connectivity and implementing planning policy on ecological connectivity. Various levels of government can be fragmented and not coordinated between and within institutions or across spatial scales (Perrin et al., 2022). As highlighted in this current study, a disconnect between provincial government and local government can lead to ineffective implementation of provincial direction and a lack of trust between the residents and provincial government. Within local government, a disconnect was noted by interviewees. For example, various departments within local government are responsible for the management of ecological connectivity, including functions related to land use planning, managing parks and open space, providing water services, implementing woodland by-laws, and transportation planning.

Local government functions can indirectly help maintain ecological connectivity, but local government departments will not necessarily communicate on issues outside of their mandate. As noted by Pittman and Armitage (2019), integration of mandates is difficult if actors cannot see the benefits to their individual mandate. For example, transportation planning is geared towards moving people, while ecological connectivity planning is geared towards moving species other than humans. The interface could be human safety and avoiding wildlife-related road accidents, yet this connection may not be clearly articulated in policy (Elton & Drescher, 2019). Respondents in the current study clearly articulated the connection between natural hazard planning and natural heritage systems planning, where river systems inadvertently served as linkages among natural features. The use of natural hazard planning to maintain ecological connectivity brought Conservation Authorities firmly into the decision-making framework. However, there are complications in the Carolinian ecoregion in instances where there are multiple Conservation Authorities within the political boundaries of a single local government.

The current findings also highlighted a disconnect across local government borders. Local governments in Ontario have been delegated the task of land use planning and each local government is responsible for a politically bounded area, which makes the management of ecological connectivity that crosses border difficult or conversely, makes governance of locally contained ecological connectivity easier (Bergsten et al., 2014). In the Carolinian ecoregion, the land use planning practice is to work in isolation without coordination or consideration of effects outside of local government boundaries (Sprang et al., 2012). The current study findings demonstrate that collaboration is perceived as important but perhaps not realistic for local

government. Local government jurisdiction and geographical boundaries restrict actions being taken outside of the political boundaries and restrict large-scale coordination (Hardy et al., 2022). The findings highlight that each local government is focused on undertaking their own planning, working 'in silos' with no need to collaborate with adjacent local governments. The watershed-based Conservation Authorities were again viewed as the best agency to address cross border linkages. Watershed-based planning is more ecologically based and in theory, can address complex environmental issues that are spatially connected across local government borders (Mancillia Garcia, et al., 2019).

Second, regulatory tools need to be supplemented with voluntary land stewardship initiatives. Environmental governance includes government and non-government actors operating within a complex institutional system, which can include collaborative arrangements, command-and-control regulation, and market-based policies directed to private lands (Lubell, 2015). Regulatory planning for ecological connectivity from an environmental perspective considers the existing natural landscape features and linkages among them, regardless of the land tenure pattern (Kamal et al., 2015). Implementing ecological connectivity policy, however, requires the participation of landowners as landowners are the decision makers for their own properties and form part of the governance system. In the Carolinian ecoregion, Conservation Authorities were viewed as a better agency to work with landowners on voluntary stewardship initiatives, rather than local government application of regulations for environmental conservation.

The current study findings confirmed that the abundance of private land in the landscape was a major hindrance to successful maintenance or improvement of ecological

connectivity. More specifically, the findings confirmed results from other studies that private lands pose a barrier to planning for and maintenance of EC for many reasons, including: (1) the need to address multiple properties, (2) the voluntary nature of private land stewardship and reluctance or inability to engage in stewardship actions, (3) inability to target or access specific areas where restoration may be required for cross border ecological connectivity, (4) the inequity in private landowners providing benefits which extend beyond their property, and (5) the resources needed to work with landowners and to provide incentives (Bennett et al., 2018; Donald & Evans, 2006; Drescher, 2014; Martin, 2016; Nebel et al., 2017; Olive & McCune, 2017). As government regulation is unlikely to achieve conservation goals without voluntary application of land stewardship (Drescher, 2014), coordination is required between regulatory approaches and land stewardship initiatives for effective ecological connectivity.

4.7.3 Land use planning practice challenges

Two highlighted challenges to plan and maintain ecological connectivity related directly to local government land use planning practice. Specifically, the quality of enabling provincial legislation and the site-specific nature of local government land use planning practice influenced the ability of local government to address ecological connectivity. The provincial legislation recognition of the need to identify, maintain or improve a natural heritage system is laudable and progressive. The system or network approach is typically comprised of core natural areas, corridors or stepping stones, and a permeable land matrix (Hilty et al., 2020). While the findings of the current study clearly demonstrated that a continued focus on natural features was not the preferred method, it was considered inevitable as protecting features was enabled in provincial legislation while protecting ecological connectivity was not required.

Planning for ecological connectivity through the identification of a natural heritage systems is required through legislation but implementing this policy direction for ecological connectivity without clearly required restrictions on development and site alteration, reduces the effectiveness of the legislation.

Legislated higher level plans, which cross local government boundaries, can be effective in coordinating cross border ecological connectivity (Perrin et al., 2022). However, the findings of the current study highlighted that higher level plans do not take small area features into account or do not utilize information that may only be available at a finer scale. Perhaps unique to the Carolinian ecoregion was the overlap of provincial plans, which in some instances caused confusion. Provincial plans in the Carolinian ecoregion were also spatially restricted with the mainly rural agricultural areas not benefiting from the greater certainty offered through the provincial plans. Changing the provincial legislation to be more enabling might assist ecological connectivity planning. However, in a highly fragmented landscape with the need for stewardship initiatives, achieving ecological connectivity may not be best achieved through strengthening legislation. Addressing the factors that inhibit operationalization of the current legislation may be a better approach than altering the existing legislation (Moss, 2012).

Land use planning policies are seen as a benefit to address ecological connectivity when the policies direct development away from identified core areas and linkages and preserve the potential for connectivity into the future (Keeley et al., 2019). The current findings demonstrate that the planning system itself inhibits the ability to maintain or improve ecological connectivity. While several impediments to land use planning practice addressing

ecological connectivity were raised by the interviewees, a key factor noted was the inability to proactively address ecological connectivity outside of the development application process. Site-specific development planning restricts implementation of ecological connectivity policy by simply being at a scale that encourages isolation and restricts the ability to work across multiple properties in private ownership (Kor, et al., 2022). The use of environmental assessments for development applications was highlighted in the current study as an important tool for local government in identification and protection of ecological connectivity. Methods to identify landscape scale ecological connectivity have progressed, but the use of environmental assessments for permitting and decisions are still made at the project scale, which may not address landscape scale effects of ecological connectivity or cumulative effects (Kor et al., 2022; Patterson et al., 2022) . Overall, interviewees highlighted that local government planning policies by themselves are not enough to conserve ecological connectivity, but that multiple means are needed. Though a myriad of methods to address ecological connectivity were mentioned by respondents, both in- and outside of land use planning practice, the lack of implementation guidelines with examples was identified as a major impediment to the implementation of ecological connectivity goals and objectives outlined in Official Plan policy and maps.

4.7.4 Information Sharing

The literature identifies public outreach as needed to build public and political support to plan and maintain ecological connectivity (Keeley et al., 2019; Ruzow - Holland, 2022). My findings indicate that public and agricultural landowner resistance continue to be major factors that hinder the local government planning process for ecological connectivity. This resistance

has led to many local governments doing the minimum required under legislation for ecological connectivity, i.e., doing what is required, not what is best practice. Without a progressive, environmentally focused council, or strong community support for a natural heritage system, local government planning for ecological connectivity was restrictive. Yet planners are stymied by how to prove the need for ecological connectivity to the public and politicians.

The use of more economic focused arguments and using surrogates to gain acceptance, such as ecosystem services, green infrastructure, greenways or trails for recreation and public health, and accounting for natural assets, may encourage greater political buy-in (Bryant, 2006, Andersson et al., 2014). Recognizing ecosystem services and green infrastructure benefits to human health and well-being arising from the protection of ecological connectivity such as water management, flood reduction, climate adaptation, and recreational space provision, supports a social-ecological systems approach to planning by reconciling environmental preservation with other social and economic interests (Honeck et al., 2020; Lennon, 2015). Likewise accounting for and managing natural assets (e.g., wetlands and riparian areas) which contribute to municipal servicing at a lower cost than engineered replacement (Drescher et al., 2018) can encourage public and political acceptance for ecological connectivity. Yet these terms can be even more nebulous to explain to politicians and the public, and difficult to visualize. Raising the level of public awareness on the importance of ecological connectivity appears to be a factor universally accepted as needed to maintain ecological connectivity, but without the ability to visualize the benefits or quantify monetized benefits, ecological connectivity will continue to be a “hard sell”.

4.7.5 Resources

A lack of capacity and funding is consistently noted as a factor affecting maintenance of ecological connectivity. Keeley et al. (2018, 2019) identified key resource-based factors that assist or challenge successful implementation of connectivity conservation plans, and these factors are supported by findings from the current study, including: (1) continuity of partners and leadership, with staff turnover a primary issue, (2) transparent and repeatable process embedded in science, and (3) adequate incentives and funding mechanisms. The findings of the current study highlight a need for long-term employed staff who have an interest and experience in ecological connectivity to facilitate plan implementation. Staff time and resources to collaborate as well as to conduct data management and mapping was also stressed as important factors by interviewees. In the Carolinian ecoregion, the disparity between funding and expertise between urban and rural areas was also demonstrated as a factor affecting continuous application of ecological connectivity across the landscape. Resources are and will continue to be a factor affecting ecological connectivity. However, greater attention should be paid to inequities in funding and resulting inconsistent expertise across the landscape.

4.8 Conclusions

Planning for ecological connectivity in a highly fragmented and human dominated landscape is constrained as well as facilitated by many factors. This study identified numerous individual factors through interviews with planning practitioners in the Carolinian ecoregion in southwestern Ontario Canada. A main constraint was the continued focus on natural features instead of linkages and the associated lack of attention paid to the agricultural matrix. This is

not unexpected given the focus of the legislation, but it does impact effective policy implementation. The fragmented nature of environmental governance and decision-making in the ecoregion greatly affected ecological connectivity planning by segregating potential land management actions that contribute to ecological connectivity maintenance.

The spatial fragmentation of governance into local government administrative boundaries, which do not reflect ecological processes, also constrain the planning of ecological connectivity. Local governments tend to look inward using local government boundaries as the unit of analysis for ecological connectivity, with a subsequent lack of attention paid to how decisions within one local government boundary affect adjacent local governments. This is not necessarily through active choice, but due to the hierarchical nature of local government land use planning and internal structure, which does not support work on environmental issues that cross spatial and jurisdictional boundaries (Mancilla-Garcia et al., 2019).

For example, local government does not have the authority to address management of habitat or ecological processes outside their borders that may impede the effectiveness of ecological connectivity within their borders. While collaboration is recognized as important to overcome sectoral and jurisdictional boundaries, this takes time, resources, expertise, and leadership, which are not necessarily available to local government. Having Conservation Authorities organized on a watershed basis, with a mandate for water resources, and available to assist local governments in natural heritage systems planning and cross border coordination, is a major asset to ecological connectivity in the Carolinian ecoregion.

A major finding specific to local government is that land use planning practice itself hinders ecological connectivity given the site-specific nature of local government planning. This

might be overcome to a certain degree through planning at the regional or county level, which then could provide the guidance for individual development applications. Still, this site-specific implementation of ecological connectivity can create isolated patches and further fragment the land unless the site level activities are cumulatively addressed, and gaps targeted for conservation and restoration. While planning and governing ecological connectivity at a broad ecoregional scale would ensure a holistic and spatially appropriate approach, there are also inherent drawbacks such as the risk of a lack of attention to local context and overgeneralization (Moss, 2012).

To address cross boundary landscape interconnections and broad-scale constraints and impacts, two options were identified by the interviewed planning practitioners: (1) the use of consistent criteria to address local government land use planning through higher level guidance, or (2) greater coordination through a collaborative network. While the second option is heavily supported in the literature (Bodin & Chen, 2022; Guerrero, et al., 2015, Aslan et al., 2021), the option of consistent criteria should also be considered, provided locally relevant ecological connectivity at finer scales can be retained.

A consistent shortcoming identified in the literature is the inability to move beyond planning for ecological connectivity to plan implementation. In the case study area, local government outcomes from the natural heritage systems planning were generally unknown, due in large part to a lack of ecological connectivity monitoring by local government. The lack of monitoring is a major gap in the determination of the effectiveness of local government policies and ability to recognize factors that may impede plan implementation. What might help are local government specific implementation guidelines with examples. A toolbox of

implementation measures which sets out possible means to implement ecological connectivity is useful, but more detailed implementation guidelines geared towards integrating a multi-modal approach to ecological connectivity with practical examples may be more relevant for local government staff, politicians, and the public.

A first step in developing an implementation guideline would be an inventory of what is already happening in the Carolinian ecoregion to address ecological connectivity. This could include actions taken by local government as well as other actors in the governance network. For example, guidelines for environmental impact assessments to identify, avoid or compensate for lost linkages; woodland conservation by-laws; park, open space and trail plans specifically accounting for ecological connectivity; threat mitigation measures such as site alteration by-laws; the location of conservation easements held by NGOs; funding or stewardship programs relevant to ecological connectivity; watershed plans conducted by Conservation Authorities; species recovery plans; or road closures for seasonal migration.

While this inventory and guidelines would only capture a moment in time and require periodic updating, it would demonstrate the breath of activities and allow land managers to collectively address ecological connectivity and enable better coordination of activities. Local government land use planning is necessary and a piece of the ecological connectivity puzzle, but without implementation of the plan, fragmentation will continue to affect biodiversity, species movement, and ecological functions and services. Implementation guidelines and an inventory of ecological connectivity actions in the Carolinian ecoregion are a practical next step for the continued maintenance and improvement of ecological connectivity in the Carolinian ecoregion.

Chapter 5 : Local government cross border collaboration for ecological connectivity: a case study of the Carolinian ecoregion in southwestern Ontario Canada

5.1 Chapter summary

Land use change through development can have a lasting impact on ecological connectivity by fragmenting the land base and disrupting connections among natural areas. Local government land use planning can direct development and mitigate impacts, contributing to collective action to maintain ecological connectivity. Planning for ecological connectivity needs to account for cross boundary dependency and the multiplicity of actors involved in managing components of an ecological network. Research on how local government land use planning fits within an environmental governance structure to address cross boundary environmental issues is limited. Through a case study of the Carolinian ecoregion in southwestern Ontario, Canada, this research explores how local governments intend to interact with other actors in pursuit of ecological connectivity. Social network interactions were investigated to identify links, gaps or overlaps in the governance system that facilitate or hamper the ability to preserve a connected landscape. The results indicate a series of intent and past interactions but not future action. It was found that coordination across local government boundaries to accommodate the provincially legislated and delegated natural heritage system was not occurring. While land use planning for ecological connectivity in the Carolinian ecoregion is a function of local government, and collaboration across jurisdictions and among stakeholders supported in land use plan policies, planning practitioners interviewed

did not see local government as leading but rather participating in collaborative actions. The main findings are (a) a lack of provincial involvement, (b) a large role to be played by Conservation Authorities, and (c) a gap between policy and implementation. These key results are both a political and a professional planning problem. The planning practitioners interviewed strongly supported the watershed-based Conservation Authorities as the most appropriate agency to address cross border linkages among natural areas and serve as a bridge with non-government organizations and landowners to maintain or restore ecological connectivity. However, the current political economy with a focus on building housing more quickly and planning reform will continue to negatively impact relationships with Conservation Authorities and leave individual projects on ecological connectivity isolated to their local areas. Recommendations on how to integrate local government land use planning into collective action for ecological connectivity in the Carolinian ecoregion are suggested, including collaborative watershed and sub watershed studies that specifically address ecological connectivity and local government use of environmental advisory committees. This current research is part of a larger study which investigated how ecological connectivity was addressed in local government strategic land use plans and through interviews, identified factors that affect the planning and maintenance of ecological connectivity.

5.2 Introduction

Urban development and the associated infrastructure, as well as intensive agriculture, can fragment the land base, destroy habitat, and disrupt ecological connectivity (Dupras et al., 2016; Huber et al., 2012). Ecological connectivity addresses the need to connect the fragmented landscape to allow for the movement of plants, animals, and ecosystem processes,

functions, or services across a landscape through linkages among intact environments (Beger et al., 2022). These connections, or linkages, can exist as corridors, stepping-stones, or a permeable matrix, which are supporting conservation of biological diversity, species movement and sustained ecological processes (Hilty et al., 2020; Lemieux et al, 2021; Fischer & Lindenmayer, 2007; Watson et al., 2017). The maintenance or restoration of ecological connectivity requires that natural areas with the connections among them be identified together with mediation of threats to continued ecological connectivity, including urban development and agriculture. There has been substantial research on the technical aspects or modelling of ecological connectivity but less so on how to reduce the ongoing threats to continued ecological connectivity. Maintaining ecological connectivity is much more than a scientific exercise to identify ecological corridors; it requires coordinated planning, across multiple scales, recognizing various social and economic constraints and opportunities (Parrott et al., 2019).

Planning for connectivity conservation is being generated by government agencies, non-government organizations (e.g., wildlife agencies, land trusts), transportation agencies, universities, or a coalition of numerous stakeholders (Keeley et al., 2019). Spatial land use planning through government agencies can play a role in establishing and maintaining ecological connectivity through the control of land use change and management of the whole landscape, involving nature conservation, but also sectoral policies such as transportation, housing, and agriculture (Gurrutxaga et al., 2015). Spatial land use planning has the potential to address ecological connectivity through a comprehensive multisectoral approach, and multi-scale perspective, in relation to spatially explicit land uses (Perrin et al., 2022). However,

numerous recognized challenges exist with government-based land use planning addressing ecological connectivity (Perrin et al., 2022). Of concern is how spatial land use planning can be coordinated across political boundaries and jurisdictional interests and retain ecological connectivity in the face of multiple, often conflicting interests and land uses.

The coordination of ecological connectivity across government political boundaries can be difficult as government boundaries do not typically align with ecological boundaries such as watersheds or ecoregions (Keeley et al., 2022). Species movement and ecological processes cross political administrative boundaries and uncoordinated action can lead to ineffective management or adverse effects beyond jurisdictional borders (Boden & Chen, 2023). Often management of components of ecological connectivity (e.g., park management, stewardship on agricultural lands) is shared between agencies, where individual agencies work in isolation, which can lead to overlap or gaps in management (Guerrero at al., 2015; Hamilton et al., 2021). For example, various level of government, watershed-based agencies, non-government organizations and landowners may all be working on ecological connectivity but without coordinated or collective action.

A substantial body of research exists that addresses the need to match the scale of an environmental issue with the scale of governance through the collaboration of multiple stakeholders (e.g., Guerrero at al., 2015; Bodin, 2017; Kininmonth et al., 2015; Sayles and Baggio, 2017). However, research on how local government land use planning fits within an environmental governance structure to address cross boundary environmental issues is limited. To help fill this gap, the current research explores how local governments interact with other actors in pursuit of ecological connectivity. Social network interactions were investigated to

identify links, gaps or overlaps in the identified governance system that facilitate or hamper the ability to preserve or restore a connected landscape. Through a case study it is explored how local government land use planning can contribute to collective action in pursuit of ecological connectivity. In the Carolinian ecoregion, local government strategic land use plans were reviewed, and interviews conducted to determine actor interactions. The results demonstrate a series of policy intent to collaborate and expressions of past relationships in planning and maintaining a natural heritage system. As such, this current research identifies intent but not action.

5.3 Local government land use planning and ecological connectivity

5.3.1 Research context

Research on local government land use planning and the conservation of ecological connectivity is primarily geared towards modelling of the existing landscape attributes and limitations to identify potential connections among natural areas. For example, there are studies on modelling ecological connectivity to incorporate mapping into local land use planning and decision making (e.g., Huber et al., 2012; De Montis et al., 2016; Parrott et al., 2019). Research has been conducted on the topic of comprehensive, land use, spatial or strategic plan evaluation in planning research with a focus on nature related aspects of planning (Hersperger et al., 2020). These studies have addressed the incorporation of ecological connectivity related topics into land use planning documents including green infrastructure, (Gradinaru & Hersperger, 2019; De Montis et al., 2022; Heim LaFrombois et al., 2023), ecosystem services (Lam et al., 2018), watershed protection (Berke et al., 2013), and biodiversity (Allred et al., 2022; Brody, 2004). These studies evaluated the quality of land use

plans and generally recognized the need for multiple stakeholder involvement and inter jurisdictional coordination.

Research has focused on land use planning at various scales to address ecological connectivity for multi-functional landscapes, values, and priorities. Planning practice is the focus for some of these studies. For example, Gurrutxaga et al. (2015) undertook an assessment of the integration of ecological networks in spatial land use planning in Spain and found that there was uneven integration as common guidelines were not used and there was a need for improvements to environmental assessments and training for planners. Perrin et al. (2022) studied implementation challenges in spatial planning for ecological connectivity, including limitations of local governments in France to transpose higher level direction into land use planning documents. For example, it was recognized that local government can have a limited ability to adapt to dynamic ecological processes and changing land uses given the static nature of land use policy once adopted (Perrin et al., 2022). Also, external factors can influence plan quality or direction such as level of expertise of the planners, support by politicians and the public, and balancing of multiple values (Perrin et al., 2022).

Von Haaren and Reich (2006) and Leibenath (2011) studied ecological networks in spatial land use planning in Germany and identified benefits and limitations of the land use planning approach to ecological connectivity. Local government land use planning can be an effective tool in the maintenance of ecological connectivity by controlling land use change and restricting or focusing development to protect habitat and support ecological connectivity (Leibenath, 2011; Von Haaren & Reich, 2006). On the other hand, it is difficult for land use planning to ensure functionality of ecological connectivity and land use planning is best

combined with other approaches such as land acquisition, voluntary measures by landowners, and project specific actions by non-government organizations (Leibenath, 2011). Also, in a multifunctional landscape, focus is on reconnecting remnant habitat typically through linear structures such as streams and floodplains with species conservation often being of secondary concern to other interests such as recreation and development interests (Von Harren & Reich, 2006).

Other studies specifically addressed the importance of local government land use planning in the broader landscape. Mancilla-Garcia et al. (2019) undertook a study on the role of local government in integrated watershed governance arrangements and argued that local governments were pivotal in a polycentric and multi-level watershed governance arrangement as local governments make the day-to-day decisions that affect themselves and downstream local governments. Bryant (2006) undertook a study in Virginia and Washington, DC, on local multi-use greenways with recreational and ecological functions and noted that since most land use decisions are made through local government, this was the most appropriate scale to successfully address biodiversity conservation. Huber et al. (2012) undertook a study in California to investigate municipal and regional habitat connectivity planning and suggested that "regional conservation actions will often be the summed results of multiple local efforts" (Huber et al., 2012, p. 25).

Finally, some studies specifically addressed collaboration among local governments in land use planning for ecological connectivity. Brody et al. (2004) conducted research in Florida on ecological systems planning and recognized that while an ecosystem approach crossed local government boundaries, it was mainly local land use plans and land use decisions that

contributed to the implementation of ecosystem management. Collaboration across local government boundaries and among multiple organizations was recommended (Brody et al., 2004). Opdam et al. (2006) investigated ecological networks in the Netherlands and proposed that multi-functional human dominated landscapes can apply the concept of ecological connectivity in land use planning and decision-making, provided stakeholders were involved in the design of an ecological network to address multiple values, and there was cooperation of administrative units across ecological scales. Bergsten et al. (2014) studied intermunicipal collaboration on ecological connectivity in Sweden, recognizing that land use planning and managing habitat fragmentation is challenging when ecological processes extend beyond the control of one manager, requiring multiple actors to coordinate activities at an appropriate scale.

5.3.2 Environmental governance structure for ecological connectivity

The term governance has a meaning that is quite different from the meaning of the term government where government is a formal, hierarchical institution with a command-and-control structure and governance is building on a network involving both government and non-governmental agents (Chaffin & Gunderson, 2016; Newig & Fritsch, 2009). While government can implement societal needs and values, governance is a process to collectively address societal problems, involving a diversity of actors and a collaborative structure (Armitage et al., 2009; Sternlieb et al., 2013). A collaborative governance structure includes both formalized decision-making arrangements and an informal network of actors (Bennett & Satterfield, 2018), which for this current research can enable environmental management and collective action for ecological connectivity.

In the current research, I focus on local government as the implementor of land use planning, and both a source of landscape fragmentation and manager of land use change (Belote et al., 2022; Haddad et al., 2015). The incorporation of ecological connectivity into local government land use planning expands ecological connectivity from a purely ecological concept to a matter for which planners as well as political decision makers are accountable (Perrin et al., 2022). Without local government land use plans and policies to address ecological connectivity, there are limited opportunities to mitigate the impact of development on the landscape (Kamal et al., 2015).

In Canada, spatial land use planning for private lands is a provincial government responsibility which has in turn been delegated to local government land use planning. Local government duties and direction for land use planning have been specifically outlined and legislated by the provinces. Local government can, however, be over-ridden by the provinces, given the constitutional delegation of powers. This hierarchical governance structure promotes internal regulation, restricting coordination across administrative and jurisdictional boundaries. Governing ecological connectivity will require intentional coordination beyond jurisdictional boundaries, between levels of government and among non-government organizations (Keeley et al., 2022; Huber at al., 2012; Bergsten & Zetterberg, 2013; Brody et al., 2004). In the absence of this, the corollary is a fragmented decision-making process that can lead to a lack of coordination across spatial jurisdictional boundaries and the lack of integration of various stakeholders and levels of government who have a part to play in the planning and maintenance of ecological connectivity (Hamilton et al., 2021; Mancilla-Garcia et al., 2019; Williamson et al., 2023).

5.3.3 Multiple scales, multiple interests of ecological connectivity

Ecological connectivity can be addressed at various scales to focus on different objectives. For example, the movement of large mammals may require an extensive and wide continuous corridor and multiple levels of government and non-government organizations (Shafer, 2015), while the movement of small amphibians to and from breeding ponds may be more dependent on seasonal connections in specific localized areas and a select number of participants in local conservation efforts (Hilty et al., 2020; Linton et al., 2018). Similarly, for connectivity of ecosystem functions and services the scale can be broad for cross boundary surface water movement and quality (Garcia et al., 2019), or more restricted such as for insect pollination and food production (Kovacs-Hostyanszki et al., 2017). Given the various ecological needs of different species and ecological functions and services, managing ecological connectivity requires cross scale consideration.

With ecological connectivity spanning spatial political or tenure boundaries, ecological interdependences exist where actions of one agency will affect actions of another (Hamilton et al., 2021; Peirson et al., 2015). While it is suggested that collaboration can support coordination across scales and interests, there remain significant knowledge gaps on how to achieve successful collaboration for these cross boundary environmental issues (Bodin, 2017). As the number of administrative areas and decision makers increase, the probability of retaining connectivity across the landscape decreases (Bergsten et al., 2019). While this puzzle is recognized as a possible issue for undeveloped landscapes (Aslan et al., 2021), it is an even more critical problem for developed landscapes with urban expansion, increased road density, agricultural lands, and multi scale governance regimes (Perrin et al., 2022). A fragmented

governance structure, when combined with a fragmented natural landscape, can make collaboration for ecological connectivity difficult and complex (Hardy et al., 2022; Parrott et al., 2019).

5.3.4 Planning and implementation of planning direction for ecological connectivity

Planning for ecological connectivity in this current study context refers to the use of maps, policies, and means to operationalize plans for ecological connectivity. For the case study, ecological connectivity is addressed through the identification of a natural heritage system with includes natural areas and linkages among those natural areas. Local government land use planning is a negotiated process involving social, economic, and environmental factors and stakeholder interests and the needed compromises may not adequately address a functioning ecological network (Perrin et al., 2022). However, the potential generation of co-benefits may encourage collaboration (Newel et al., 2022). A major benefit of the local government planning process is that stakeholder involvement raises the level of awareness of the importance of ecological connectivity and provides an opportunity to increase local public and political support (Perrin et al., 2022). If on the other hand, public sentiment is negative, a resulting lack of political support may reduce the priority of ecological connectivity.

Implementation of ecological connectivity as referenced in the current research, can be sought through application of a suite of mechanisms that can be categorized as a) regulatory, b) threat mitigation, c) voluntary land stewardship d) acquisitional, and e) educational (Table 5.1) (von Haaren & Reich, 2006; Keeley et al, 2018, 2019). Regulatory implementations include the use of government mechanisms such as the regulation of land use change through local government land use plans and zoning.

Table 5-1 : A summary of methods to implement ecological connectivity

Methods to implement	Description
Regulation	The application of legislation and direction on proactive protection of EC and reactive mitigation of land use change through political decision making
Acquisition or protection	Purchase of land or use of conservation easements or other tools to protect natural areas
Threat mitigation	Remove or mitigate threats such as roads (over or under passes), urban development (corridors or stepping stones), fences (use hedgerows), tall buildings (bird friendly windows), invasive species (plant native species) and intensive agriculture (cropping practices and timing of harvest)
Land stewardship	Active management of private lands to protect habitat and increase permeability across the land matrix, with or without the use of economic incentives
Education	Raising the level of awareness to encourage regulatory support and stewardship actions

Land can be purchased for long term management through public or private agencies. Threat mitigation includes means to overcome physical barriers such as roads through overpasses for wildlife. Voluntary implementations include land stewardship initiatives and voluntarily managing or restoring lands for ecological connectivity, with or without incentives. And finally, the use of education on the needs and benefits of ecological connectivity can increase public awareness and lead to greater support and political will.

5.4 The Case Study

5.4.1 Ecological Context

The Carolinian ecoregion in southwestern Ontario, Canada, is used as the case study area. The area is bounded by the Great Lakes to the west, south and east with the northern

boundary denoted due to climatic variability (Figure 5.1). The Great Lakes, dividing Canada and the United States, are some of the largest bodies of fresh water in the world and have a moderating climatic effect on the ecoregion with vegetation rarely found in other areas of Canada such as the Pawpaw tree and Kentucky Coffee tree (Johnson, 2007). Historically, this deciduous forest ecoregion supported a wide range of habitat, plants and animals. After arrival of the European settlers, southern Ontario was cleared and drained for farming and now supports some of the best farmland in Canada.

The changes in the Carolinian ecoregion are substantial with 95% of wetlands drained, 99% of the tallgrass prairie lost and 90% of upland forests cleared, leaving only remnant patches (Johnson, 2007). The Carolinian ecoregion currently supports significant biodiversity combined with a large and growing human population base. The area contains only one quarter of one percent of the land in Canada but contains more than half of the native tree species for all of Canada (Waldron, 2003) and contains some of the country's most valued and rare plant and animal species (Sprang et al., 2012). In addition, one quarter of Canada's population live or work in this area with 95% of the land base being privately owned (Jalava et al, 2019).

The history of conservation in the ecoregion is long, including national and provincial parks, biosphere reserves, conservation areas and other protected areas, resulting in the protection of remnant, biologically diverse areas. An ecoregional initiative called the Carolinian Canada Program started in 1984 comprised of government and NGO participants (Johnson, 2007) and evolved to the Carolinian Canada Coalition of today. Initially, the Carolinian Canada Coalition identified 38 critical areas in need of protection and continued with the development

of an ecological network of core areas and potential linkages, followed by the development of 14 Conservation Action Plans for biodiversity hotspots and most recently a means to monitor trends in the ecoregion (Jalava et al., 2019).



Figure 5-1 : The Carolinian ecoregion boundary geographic location in southwestern Ontario Canada

Note: From Candidate Natural Heritage Site Inventory Update for the City of Windsor (Essex Region Conservation Authority, 2008).

5.4.2 Governance Structure for Ecological Connectivity

Within the Carolinian ecoregion, the governance structure is complex with multiple government levels, non-government actors, watershed governance, and international lakes. Much work has been done in the Carolinian ecoregion by government and non-government

organizations to address biodiversity conservation and ecological connectivity. Provincial legislation is in place requiring local governments to maintain, restore and improve a natural heritage system which "recognizes linkages between and among natural heritage features and areas, surface water features and groundwater features" (OMMAH, 2020a, p. 24). In addition, many NGO initiatives exist at various scales that address ecological connectivity specifically or biodiversity and land stewardship generally. While NGOs have no legislative authority to address ecological connectivity, in the Carolinian ecoregion NGOs have been highly active and have assisted local governments by providing advice, local knowledge, lobbying higher levels of government, managing private lands, assisting landowners in stewardship initiatives, providing educational material, and receiving and utilizing funding to improve biodiversity and ecological connectivity. In the case study area, planning for ecological connectivity has occurred through collaborations, coalitions, partnerships or through government legislation at broad scales as well as project specific scales (Table 5.2).

The local level government addresses ecological connectivity through strategic land use plans called Official Plans. An Official Plan, similar for example to comprehensive plans in the United States (Le & Tran, 2023) and local urban plans in France (Perrin et al., 2022), is a decision-making tool, prepared by local government with public input to guide future development, encompassing policy on such topics as housing, transportation, resource use, and environmental protection (Lam & Conway, 2018). In the Carolinian ecoregion, local government is comprised of higher level, or upper tier municipalities (i.e., regions and counties), which oversee the planning of lower tier municipalities within their borders. There are also single tier municipalities without any lower tier including cities and counties. In the current research, I

investigated only the upper and single tier municipalities as the upper tier municipalities provided broad scale planning.

Table 5-2 : Examples of planning for ecological connectivity in the Carolinian ecoregion at various scales by different actors

Planning Approach	Led by	Initiative
Identify broad scale network of sites to sustain biodiversity	NGO and government	The Great Lakes Conservation Blueprint (Hensen et al., 2005)
Identify national priority areas for ecological connectivity and fund on the ground projects for ecological corridors.	Federal government	National Program for Ecological Corridors (Parks Canada, 2024)
Regional system of core natural areas and connecting corridors	NGO	Carolinian Canada Coalition – The Big Picture (Jalava et al., 2002)
Regional landform protection as a continuous natural environment	NGO and government	Oak Ridges Moraine (McCarthy et al., 2014) Niagara Escarpment (Moss & Milne, 1998)
Provincial (state) planning for ecological connectivity	Government	Greenbelt Plan (OMMA, 2017), Growth Plan (OMMAH, 2020b)
Decentralized land use planning for ecological connectivity through enabling legislation	Government	Natural Heritage System (Puric-Mladenovic & Strobl, 2012)
Project specific wildlife corridors	Collaboration	The Cootes to Escarpment EcoPark System (Apex Resource Management Solutions & Talbot & Associates, 2021)

Conservation Authorities are watershed-based local public sector organizations focused on water resources and natural hazards (e.g., flooding, water quality, hazard lands). Conservation Authorities were created under the Conservation Authorities Act (R.S.O. 1990, c.27) in 1946 in response to poor land practices such as land clearing leading to extensive soil

erosion and flooding (Conservation Ontario, 2024). Conservation Authorities, at the time of the current study, have permitting power, own and manage conservation lands, regulate natural hazards, and provide resources to local government in the form of advice, watershed planning, monitoring, and natural heritage studies.

Changes to the Conservation Authorities Act to accommodate more homes built faster and streamline approvals will delegate some permitting approvals to local governments and restrict the mandate of Conservation Authorities (OMMAH, 2023). Conservation Authorities are funded primarily through the local governments located within their watershed with a funding formula based on population – more people mean more funding. Typically, the Conservation Authority's watershed boundaries do not correspond to the local government political boundaries and it is common to find multiple local governments within one watershed and multiple watersheds within one local government. Even with, or because of, the overlapping jurisdictions, Conservation Authorities are key actors in cross jurisdictional planning (Drescher et al., 2018).

The Carolinian ecoregion has outstanding biodiversity value and a need to link the identified 'islands of green' to preserve biodiversity. The ecoregion also has a complex governance structure with NGOs active in ecological connectivity and enabling provincial legislation to address ecological connectivity through local government land use planning. A recent study evaluated 77 ecoregions in southern Canada, and the Carolinian ecoregion was identified as one of nine ecoregions considered to be a crisis ecoregion (higher biodiversity and higher threat) with the greatest need for immediate conservation action (Kraus & Hebb, 2020). Parks Canada, a federal government agency, through its National Program for Ecological

Corridors, identified a part of the Carolinian ecoregion, the north shore of Lake Erie, as one of 23 priority areas in Canada where ecological corridors are most urgently needed and should be identified and created locally (Parks Canada, 2024). Overall, the ecoregion represents a good case study to investigate ecological connectivity and local level collaboration across jurisdictional boundaries and among different actors.

5.5 Methods

An exploratory case study research design was used to investigate governance structures and interactions in pursuit of ecological connectivity. Two data collection methods were employed: document review and key informant interviews. For the document review, local government Official Plan documents in the Carolinian ecoregion were reviewed to assess if policy reflected a collaborative approach to ecological connectivity or natural heritage systems more generally. Interviews were held with planning practitioners during a time when many of the local government Official Plans were or had recently been updated to be consistent with provincial policy, including policies on natural heritage systems planning.

5.5.1 Official Plan Review

I reviewed a total of 16 Official Plans including eight upper tier (three regions, five counties) and eight single tier (four counties and four cities), to determine whether local governments had a mandate to collaborate across jurisdictional boundaries to address ecological connectivity. The most recent Official Plans were reviewed including some that were not yet formally approved (Appendix C). In the Carolinian ecoregion, a natural heritage system included water resources and hazard lands (e.g., flood prone areas and steep slopes), so even if

there was no direct reference to ecological connectivity, mentions of collaboration in relation to other ecological components were noted.

An iterative review approach was used which involved a first read of the Official Plans to identify the use of key words followed by a more thorough examination which yielded data such as excerpts containing reference to local government collaboration. The key terms *communicate*, *coordinate*, *cooperate*, *collaborate*, and *work with* were used to search and locate appropriate policy sections within the Official Plans. No assessment of the quality of the statements was conducted, rather the review was conducted to see if the intent to collaborate was identified in land use planning policy. As such, this expresses an intent but not necessarily action. The information on collaboration from individual Official Plans was measured against six variables (cross border, stakeholders, stewardship, lower tier, education, and committee). These variables were identified in previous research, which included a full review and qualitative content analysis of the same Official Plans on ecological connectivity policy integration into the Official Plans (Chapter 3). A binary system was applied with a 0 if there was no mention of collaboration and a 1 if there was a mention. Similar to the methodology applied by Termorshuizen et al. (2007), the results across the Official Plans were combined and expressed in percentages. The degree of consistency among Official Plans was based on the percent of Official Plans that mentioned the same code and an ordinal rating scale applied to describe the degree of consistency among the Official Plans. The degree of consistency among Official Plans ranged from low (0-25%) to high (75-100%). A total of 12 local governments had conducted or been part of natural heritage system studies, which were used as the basis for Official Plan policies and mapping, and these were also reviewed. I examined the broad

coordination between local governments through review of the Official Plan mapped representation of linkages. The information collected from the individual Official Plans was recorded in a spreadsheet by local government and compared to identify similarities and differences.

5.5.2 Key Informant Interviews

Key informant interviews were held with representatives of local governments, Conservation Authorities, NGOs, provincial government, and federal government. Local government and Conservation Authority planning managers or environmental planners identified on the agency websites were initially contacted to arrange interviews with those contacted or I was directed to planners specifically engaged in natural heritage planning. Local government and Conservation Authority interviewees were asked to identify contacts from NGO's, provincial and federal government the interviewees had worked with in the past on natural heritage planning and management.

An interview guide was developed outlining questions to be asked (Appendix A). The current study focused on the questions specifically related to collaboration. Maximum variation sampling was conducted for the local government and Conservation Authority key informant interviews to reflect different perspectives and physical locations within the case study area (Creswell & Poth, 2018). A total of 16 upper-level local governments and 14 Conservation Authorities covered the case study area and included a mix of urban and rural areas. Of 30 potential key informants contacted, ten local government and eight Conservation Authority planners were interviewed, representing a cross section of the different types of local governments, rural as well as urban areas, and a range of larger more well-funded Conservation

Authorities and smaller Conservation Authorities with less resources. A snowball sampling technique was used to assist in the identification of potential key informants from NGOs, federal, and provincial organizations. Of the 11 potential informants identified and contacted, six interviews were conducted: three with representatives of NGOs, one with provincial, and two with federal government employees. All of these non-local government organizations had a specific mandate or interest in ecological connectivity, though this tended to extend beyond the case study area.

A total of 24 telephone interviews of the 41 potential interviews (59%) were conducted from February 2022 to August 2022. The interviews lasted from 40 minutes to 90 minutes with the majority being approximately one hour in duration. The interviews were recorded, notes were taken, and as possible, word dictation was utilized. The recordings were transcribed and summarized. The summarized responses were recorded in a spreadsheet by question and interviewee and compared to identify similarities and differences. The responses were categorized by type of respondent (local government, Conservation Authority, NGO, federal and provincial government) to see if the organizations involved in collaboration varied by organizational type (Appendix D).

The social network was mapped using Gephi software to provide a visualization of the relationships and relative weight of those relationships. The nodes or categories of actors are a summary of those identified from the interviewees when asked – 'who do you work with for planning and implementation of the natural heritage system'. The weight of the ties or relationships were determined by the number of times the same relationship was mentioned.

Given the small sample size, minimal descriptive statistical analysis was conducted, specifically the average of the number of mentions of relevant topics across the interviews was calculated. In addition, notable quotes were identified and reported to help describe the reasoning behind the collaboration or lack of collaboration.

5.6 Results

5.6.1 Official Plan review

While all Official Plans noted the need to work across borders, this was primarily in connection with topics other than a natural heritage system, such as transportation and infrastructure. The concept of collaboration specifically related to natural heritage systems was less prevalent and terms utilized inter-changeably. The terms *collaboration*, *coordination*, *cooperation*, *communication*, *consultation*, *education*, *public participation*, *community involvement*, *partner with*, *work with*, and *participate* in were all used to describe situations where local government should work with other organizations (Table 5.3).

The results of the content analysis on terminology related to collaboration for natural heritage systems revealed ten variables or types of collaboration including working with or through: lower tier municipalities, Conservation Authorities, stewardship initiatives, education, government agencies, NGOs, adjacent local governments, property owners, Indigenous communities, and an environmental committee. The frequency of mentions among Official Plans is noted (Figure 5.2).

Table 5-3 : Examples of 'working together' from Official Plans in the Carolinian ecoregion

Excerpts from Official Plans	Location
"Work collaboratively with the local municipalities, Conservation Authorities, neighbouring municipalities, Indigenous communities, other government agencies, stakeholders and the public to develop a Regional Greenlands Strategy"	Region of Peel (2022, p. 249)
"As jurisdiction over environmental matters is divided among different levels of government, collaboration among a number of agencies such as the Federal and Provincial governments, Conservation Authorities, the County, non-profit agencies and the public is required".	Haldimand County (2022, p. 87)
The County recognizes the need to coordinate various matters addressed by this Official Plan with adjacent planning authorities, to ensure a coordinated, integrated, and comprehensive approach to cross-jurisdictional planning matters	County of Brant (2023, p.1-6)
"In conjunction with adjacent municipalities and other authorities, assist in coordinating and integrating planning activities with cross-jurisdictional implications, such as ecosystem, shoreline and watershed planning; natural heritage planning…."	Norfolk County (2023, p.2)
"Natural heritage system planning should occur at the regional, watershed, and subwatershed level with appropriate cross-jurisdictional co-operation and communication."	County of Lambton (2020, p. 8-4).
Encourage, through education and incentive programs, the cooperation of property owners in the maintenance of, or enhancement to, the naturalization of lands and the sustainable use of our Natural Heritage System.	City of London (2023, p. 360)

In the case of upper tier local governments, all noted the need to collaborate with the lower tier municipalities within their borders ensure lower tier Official Plan consistency with the regional or county Official Plan. All Official Plans indicated a connection with Conservation Authorities, either directly for assistance in mapping the natural heritage system, for implementation through permitting of natural hazards, through stewardship initiatives, or management of publicly owned conservation lands. Reference to either involvement or

coordination with stewardship initiatives and education of landowners to implement the natural heritage system was noted by 88% of the Official Plans. Most of the Official Plans (75%) noted the need to collaborate with other levels of government agencies and NGOs, through participation in initiatives (such as Ontario's Great Lakes Strategy and Great Lakes Protection Act), and implementation of Provincial Plans.

Cross border coordination with adjacent local governments for ecological connectivity or a natural heritage system was referenced in fewer Official Plans (63%). Some of the Official Plans reviewed specifically referred to working directly with property owners outside of stewardship initiatives (44%). Official Plans reviewed typically noted the need for engagement with Indigenous communities but only 38% of the Official Plans specifically referenced working with Indigenous communities for the natural heritage system. Lastly, the use of an environmental committee was rarely identified in the Official Plans (25%).

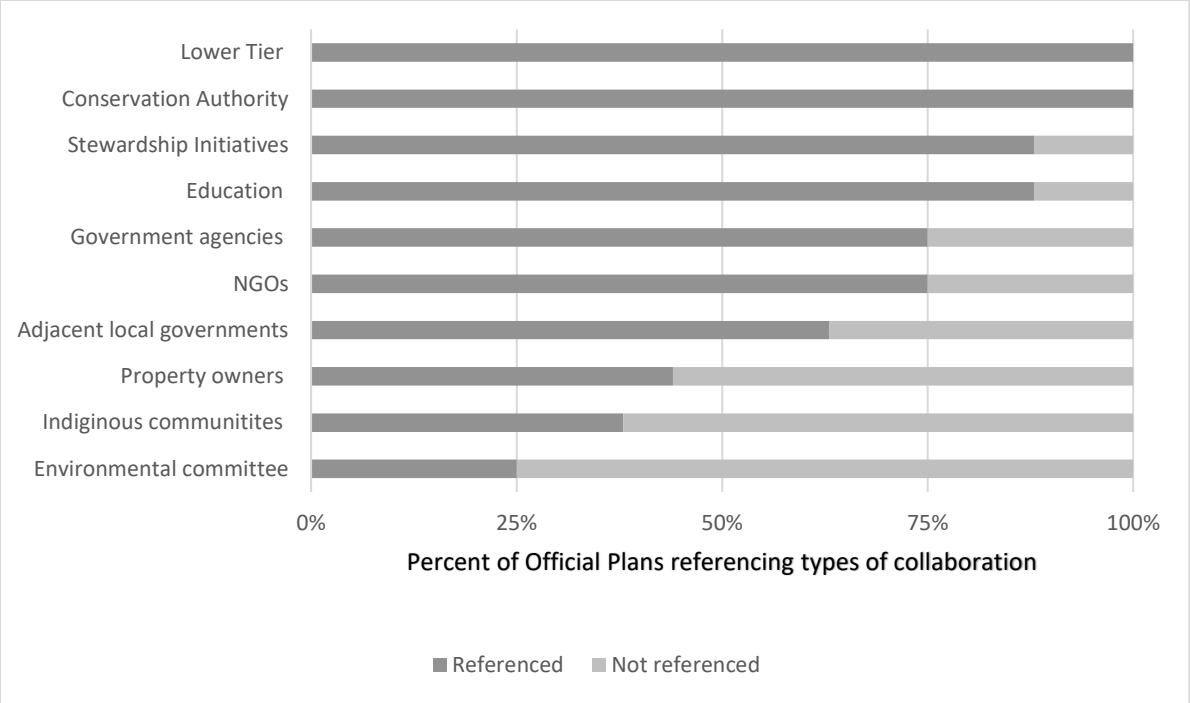


Figure 5-2 : Consistency of the Official Plans reviewed on collaborative efforts to plan and maintain ecological connectivity

5.6.2 Interview results – natural heritage system planning

In the case study area, local governments are required to identify and incorporate a natural heritage system within the Official Plan maps and policies. A natural heritage system is defined as **"**a system made up of natural heritage features and areas, and linkages intended to provide connectivity (at the regional or site level) and support natural processes which are necessary to maintain biological and geological diversity, natural functions, viable populations of indigenous species, and ecosystems." (OMMA, 2020, p. 47). Interviewees were asked who they worked with to plan a natural heritage system, which includes the linkages among natural areas or ecological connectivity.

The combined responses from all interviews show which agencies were part of the governance system for natural heritage system planning, and the relative degree of involvement according to the interview responses (Figure 5.3). The agencies noted by interviewees most often were Conservation Authorities, local government, and NGOs. When the results are broken down by organization type, it becomes evident that both local government and Conservation Authorities consistently indicated they worked with each other. An interviewee from a regional local government Indicated that they worked "mainly with the Conservation Authorities as they have the expertise not available at local government" (L-2). Though an interviewee from a single tier local government responded that "as they had an environmental planner on staff, they did not need the Conservation Authorities as much" (L-5).

A Conservation Authority interviewee remarked that it is important to work with local governments as "local governments have finite boundaries with a propensity to focus inward" (C-3). Conservation Authorities recognize a main role as providing information to local government planners to help identify the natural heritage system, yet this was also seen as problematic as "those doing the natural heritage system studies are not planners but more concerned with pure science and we don't do a lot of the planning" (L-6), raising the issue of a potential disconnect between Conservation Authority information and local government land use planning. It was also recognized by Conservation Authorities that while they provide the sound science and guidance, this still needs to be supported by local government who are the decision makers, and it is "hard to get them to do anything beyond what is required from a provincial perspective – not necessarily desire but capacity" (C-7).

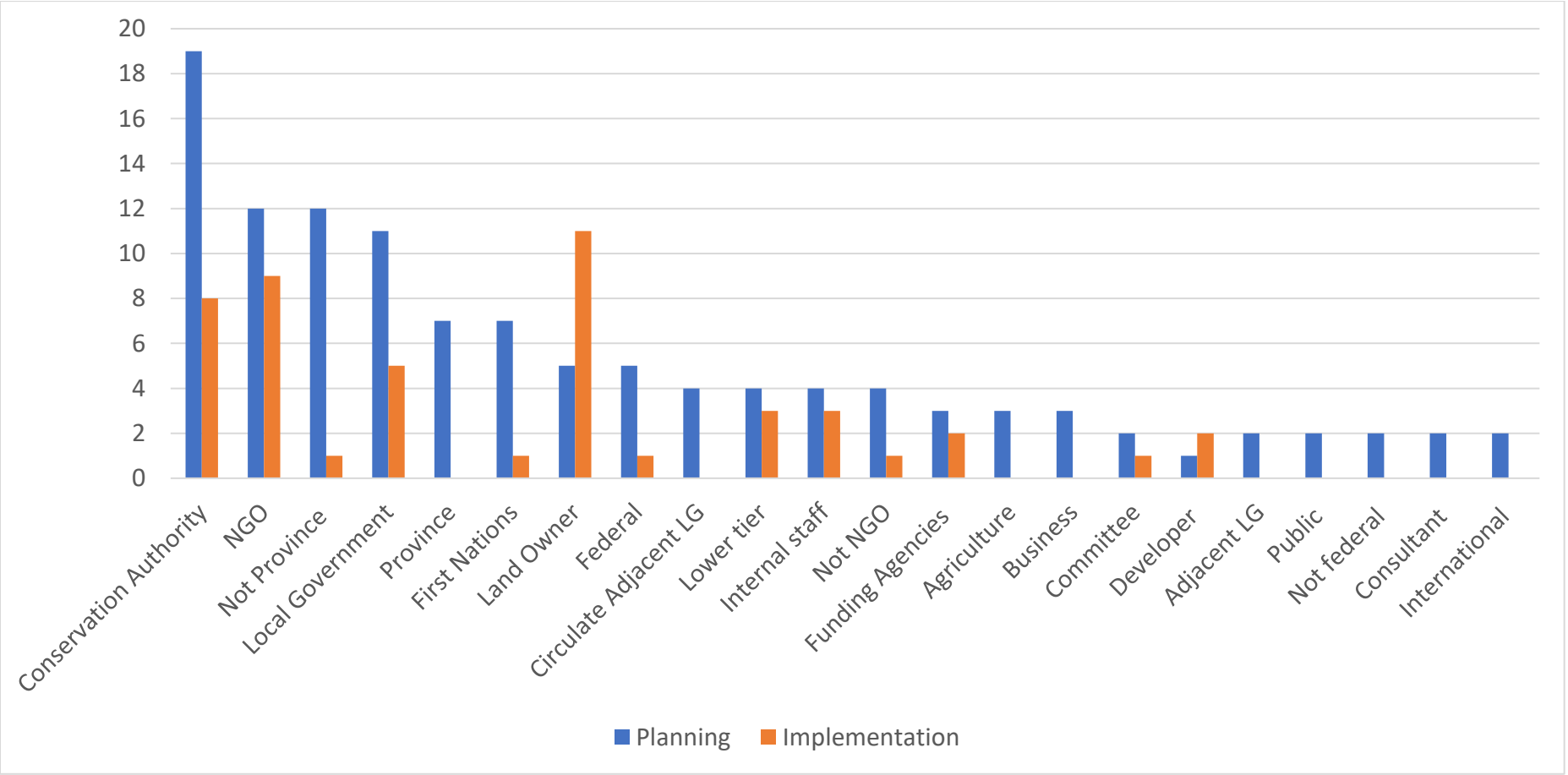


Figure 5-3 : Frequency of study participant mentions of who they most closely worked with for natural heritage systems planning and implementation

The province – the body that should be coordinating connectivity – is not top of mind according to the majority of those interviewed. In response to the question about who they worked with, "not the province" was the response from 80% of the local governments and 57% of the Conservation Authority interviewees. Of all those interviewed, only 13% indicated they would like to see the province more involved. However, the role of the province in providing funding was recognized. Of those local government interviewees that did mention working with the province (20%), it was through large scale provincial land use plans, or the one-window system implemented by the Ministry of Municipal Affairs and Housing, who then referred questions to other Ministries.

An upper tier local government interviewee indicated that they were "not sure how to contact the province – they used to have a good relationship, but it is not a strong connection now" (L-4). Another single tier local government interviewee expanded further and indicated "there's been so much staff turnover at the province, I would reach out [for help] and they just point me to the website with the mapping" (L-7). A local government interviewee noted that the province had little involvement in planning for natural heritage systems: "any feedback we get from them will be fairly high level and it'll be just aimed at ensuring that we're fulfilling the sort of obligations required under the provincial policy statement and ensuring we're meeting those provincial interests" (L-5). This view was supported by a local government interviewee who noted "The province itself has extracted themselves from natural heritage planning. So, except for specific provincial authority like species at risk and those sorts of things that are provincial responsibility, they basically have downloaded it to municipalities and Conservation Authorities" (L- 4).

It was recognized by local government and Conservation Authority interviewees that the province had helped with local government planning in the past, but they are not now. It was noted that the province had not updated guidelines and that they were working with "old science" (NGO-1). A local government interviewee noted it would help the planning if the province "updated provincial guidance and actually try to advance things based on current science as opposed to 20-year-old science" and that "some federal documents are more up to date than provincial" (L-5). A few interviewees (17%) perceived the province as detached without much knowledge of local government needs, resources, or capabilities and with little local trust. For example, an upper tier local government indicated "there was often a perception that the province was the big bad province sitting out there in Toronto making all these rules … and people were more receptive to the local Conservation Authority" (L-3).

A majority of local government interviewees (80%) indicated they did not work with adjacent municipalities. Some local government interviewees mentioned they circulated draft policy to adjacent municipalities (40%) but generally did not have direct or formal contact outside of the local government borders. As noted by a single tier local government, "We didn't [work with adjacent municipalities], I think we are all working in silos. But certainly, as part of the mapping, we would have taken anything within, I think, 500 meters of the boundary of an adjacent municipality into account." (L-7). As noted by a Conservation Authority "local governments have finite boundaries with a propensity to focus inward and without someone taking care of the system across boundaries issue can get lost" (C-3).

Only 20% of the local governments interviewed indicated they worked with NGOs. A total of 40% of the local government interviewees specifically noted they did not work with

NGOs for ecological connectivity, while others mentioned NGOs were involved through Conservation Authorities or the public consultation process. One local government noted they "have some NGOs knocking on the door about specific issues" (L-2). It was remarked by an upper tier local government that NGOs do not typically participate in planning processes, which has a negative effect as Councils do not hear the positive aspects of ecological connectivity (L-8). A Conservation Authority interviewee expressed that NGOs could help with connectivity planning and implementation: "NGO is a resource to tap into – promote science and help with implementation" (C-4). But another Conservation Authority interviewee voiced doubt about NGO influence, particularly with individual development applications where not all the facts are considered: "NGOs may have good intentions but can also be misinformed" (C-2).

Interviewees noted several disconnects and groups that were not involved but perhaps should be. A local government interviewee shared that more involvement of both provincial and federal government is needed "especially as they are doing different approaches and are both working on similar projects but not talking to each other" (L-5). Local government and Conservation Authority members stressed the importance of participation of the agricultural community and needing buy-in from the farming community. Most of those interviewed recognized the importance of incorporating Indigenous knowledge into planning. However, participation by the Indigenous community was lacking. Disconnects internal to organizations were also noted. A Conservation Authority interviewee noted "In our rural areas, we will get people who want to do wetland creations or stewardship activities, [but] I don't really know that side of the business. Need to talk to the other side of the building" (C-8). An NGO

interviewee indicated they "are approached by people wanting [them] to get involved in Official Plan or local government specific issues – but they do not have the capacity (NGO-3).

5.6.3 Interview results – natural heritage system implementation

The combined responses from all interviews show which agencies were part of the governance system of natural heritage system implementation and the relative degree of involvement according to the interview responses (Figure 5.3). Of all 24 interviews, 46% indicated that they worked most closely with private landowners followed by NGOs (38%) and Conservation Authorities (33%). Local government worked primarily with Conservation Authorities for implementation (70%), followed by working internally with other local government staff (30%), lower tier municipalities (20%) and developers (20%). An upper tier local government interviewee indicated they most closely worked with Conservation Authorities for implementation yet recognized that not all Conservation Authorities have the same staff expertise or capacity, and the various Conservation Authorities do things differently. A local government interviewee remarked on the importance of having "open communication and coordination with the local government departments involved [in ecological connectivity] (L-10). Local government interviewees also mentioned working with land developers and local government directed committees, but only one mentioned working directly with landowners for the implementation of the natural heritage system.

Conservation Authority interviewees indicated for implementation they worked mostly with private landowners (75%), followed by NGOs (63%), and local government (38%). Conservation Authority interviewees noted they worked with landowners for restoration, native plantings, agricultural land stewardship and education. As noted by a Conservation

Authority interviewee, “In rural area, there's no one stopping somebody from taking out a hedgerow, or upland vegetation so that comes down to education” (C-6)

NGO representatives indicated they worked with whoever was willing, but they recognized that for ecological connectivity, there was a need to work with multiple properties, making implementation more difficult. Still, it was acknowledged by an NGO interviewee that one landowner addressing conservation can lead to adjacent properties also participating as “Individuals who do good things on their land can show to neighbours and others what can be done” (NGO-1). An NGO interviewee suggested a lack of coordination on implementation with local governments by noting that local governments are unaware of the location of conservation easements: “There is a little bit of miscommunication between municipalities and [NGOs that] hold covenants […] a lot of [local governments] were surprised, which really amazed me that [this information about location of conservation easements] wasn't recognized” (NGO-3).

5.6.4 Combined planning and implementation network results

A generalized mapping of the network of stakeholders identified in the current study demonstrates the strong relationship between local government and Conservation Authorities but a disconnect with other stakeholders (Figure 5.6.). A common theme raised in the interviews was a disconnect among those involved in ecological connectivity. A major disconnect between the province and local government was noted but there was also a disconnect between local government and landowners. There was a good connection between Conservation Authorities and local government, and between Conservation Authorities, landowners and NGOs.

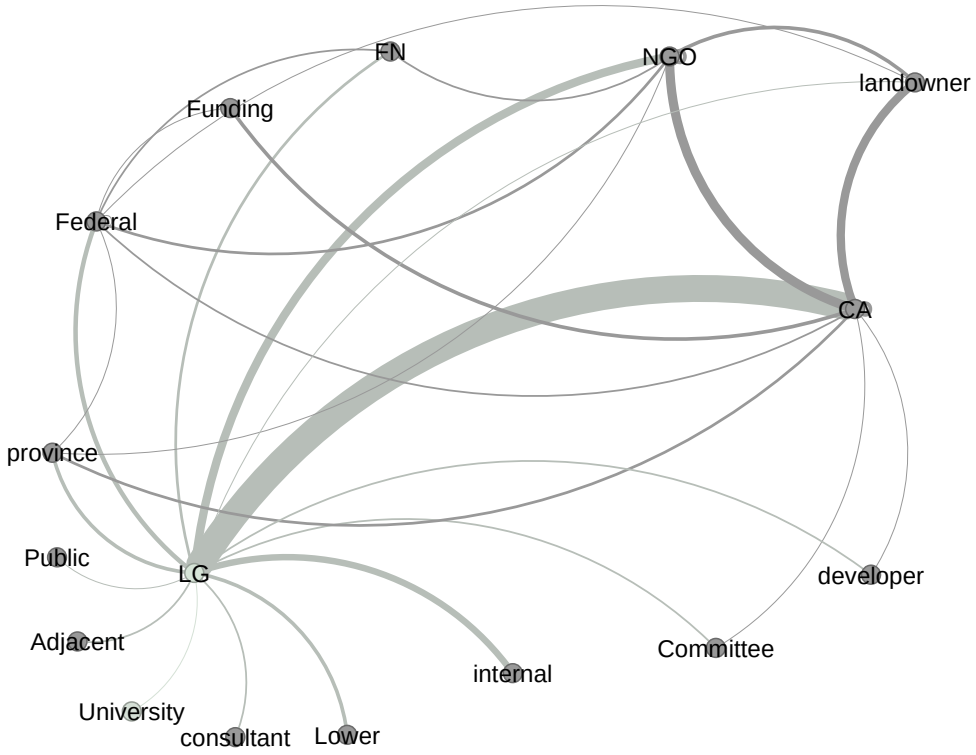


Figure 5-4 : The governance network with associated weight of the relationships, combining planning and implementation stakeholders. Local government (LG) as the focus with a strong connection with Conservation Authorities (CA)

5.6.4 Interview results - bridging to bring actors together

Interview participants strongly recommended the Conservation Authorities as the organization that best served as a bridge for planning and implementation of ecological connectivity (Figure 5.4). Conservation Authorities also were recommended as best suited to bring other groups together to support ecological connectivity. Both local government and Conservation Authority members recognized this as an important role for the watershed-based Conservation Authorities. A Conservation Authority interviewee noted "I think the broad sub-watershed framework in Ontario helps – we have the built-in planning mechanism to contemplate landscape scale analysis" (C-8). It was acknowledged by both local government and Conservation Authorities that the recent legislative changes on core mandates of Conservation Authorities may have an impact on Conservation Authority future involvement in natural heritage systems planning and implementation.

Two local governments and two Conservation Authorities specifically noted that the mandate of Conservation Authorities was in flux, however they also acknowledged that continued help was possible through a memorandum of understanding and continued good relationships. A Conservation Authority interviewee noted that the "change in Conservation Authority mandate doesn't change much of what we do – more so how we are funded – if you have a good relationship with the local government, then it is going to be alright" (C-6). Another Conservation Authority interviewee though indicated it was not within their mandate to address natural heritage systems and that "some conservation authorities had broadened their scope but changes to legislation has pulled everyone back to core mandate of flooding or natural hazards and wetlands" (C-5). However, it was also recognized that Conservation

Authorities could indirectly address natural heritage systems as they are “mandated [to conduct] riparian protection and natural hazard planning, which indirectly will address connectivity by restricting building and maintaining original features” (C-5).

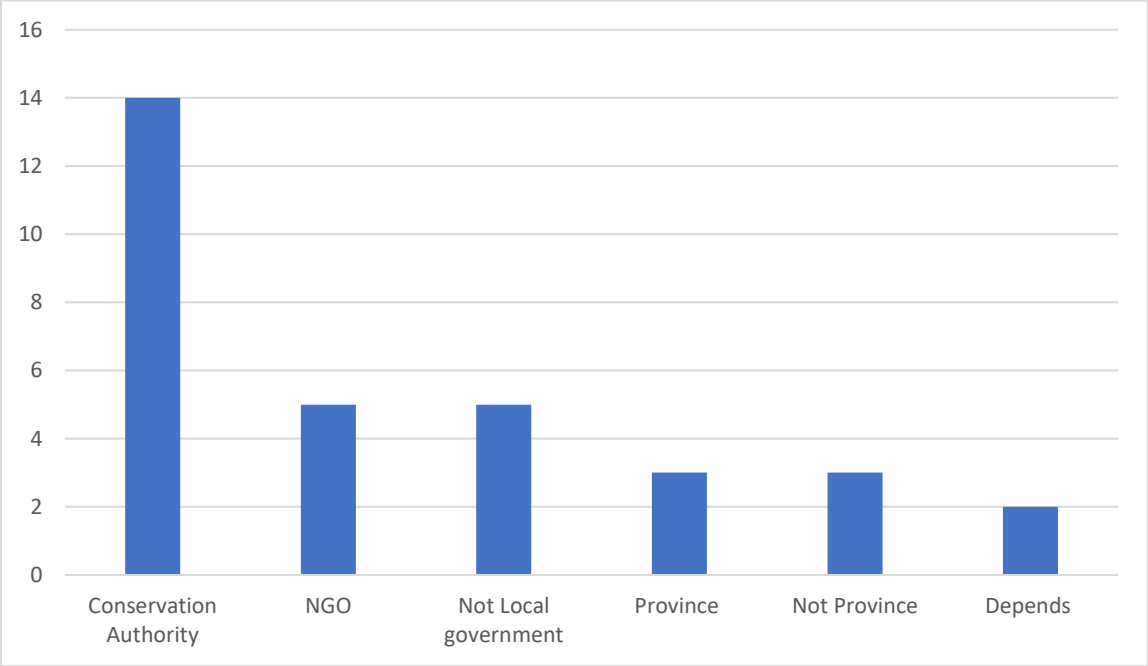


Figure 5-5 : Frequency of study participant mentions of who could function as a bridging organization

Local government members tended to agree with Conservation Authorities that local government did not function in a bridging capacity, as local governments were only responsible for what happened within their own narrow jurisdictional borders. A local government member succinctly demonstrated this sentiment by saying “no bridge – each municipality does their own planning” (L-6), while another local government interviewee shared: “no bridging–- we work in silos” (L-7).

Conservation Authorities and NGOs did note that NGOs also could function in a bridging capacity. A Conservation Authority interviewee noted that Carolinian Canada's Big Picture project was a good example of an NGO as a bridging agent, but that the project did not have local government and legislative policy support. However, the Conservation Authority interviewee did note that the "scale of a watershed is more practical for detail and focus; but this [Carolinian Canada] is an example of a partner bringing different jurisdictions together to look at planning at a higher-level scale" (C-1).

Another aspect that was mentioned as supporting bridging was the application of a more consistent methodology in planning. A Conservation Authority member noted that bridging could be accomplished more easily if one "[kept] natural heritage system criteria similar among counties, as science doesn't change but criteria can" (C-6). However, participants also noted that bridging would depend on several factors like scale and participants. For example, a provincial or ecoregional scale would require an agency with a broad mandate, while a smaller scale and ecological connectivity contained within a watershed would make a Conservation Authority a better bridge. Participants also mentioned that there could be several bridging functions working in parallel. An NGO interviewee noted that "many groups act as a bridge and when you map it all out like a network map, it's kind of messy" (NGO-1) with the potential of actors working on individual projects for different yet related purposes, but without connections among them.

5.6.5 Interview results – who is not involved but should be

The interviewees were asked who they would like to see involved but who typically was not part of the conversation on ecological connectivity (Figure 5.5). The public, First Nations

and NGOs were most often mentioned, as well as the agricultural or farming community. The province and business interests were also noted, but to a lower extent. A Conservation Authority participant suggested that "the province [should] take a leadership role not in local planning or guidance but in resources for implementation" (C-4). Another Conservation Authority member noted they "do not have a provincial contact - always changing - very confusing" (C-7). Both local government and Conservation Authorities would like more connection with the farming community and involvement of First Nations. A local government noted that "First Nations bring Indigenous knowledge and a different approach" (L-4) and "NGOs can speak towards the science behind the policies" (L-5).

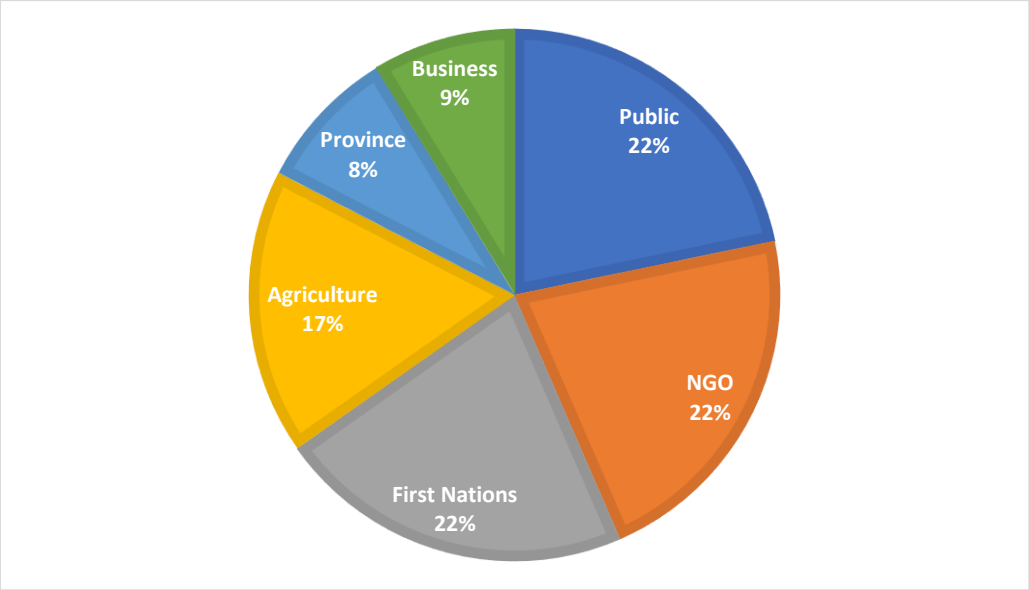


Figure 5-6 : Who else should be involved in ecological connectivity

The public was noted throughout the interviews, primarily related to the lack of understanding and support of the concepts of identifying and protecting ecological connectivity. As noted by an NGO, "I think having the public involved is generally important - I

don't think it should just be about the landowners that are involved. I think you need some representative from the local communities too" (NGO-2). There was a constant identification of the need for outreach and education to garner support from the public, which was suggested could increase political support. For planning, it was noted that "the more engagement in the process, the easier it is to implement [the policies] (L-2), though it was also noted that the public "are the ones to live with it". (L-6).

The need to explain why it is important to protect ecological connectivity was mentioned, so members of the public have more appreciation of their local natural environment and why there were efforts to protect natural areas. As noted by a Conservation Authority member: "Swans that are starting to migrate through right now and people will drive for hours to come and see the tundra swans. Yet the people who live here couldn't care less" (C-7). Members of the public want to see proof for the need for connectivity, but this is difficult produce as member of the public might say "we're not going to see wildlife, anyway, so why are we bothering?" (P-1). Local government typically recognized the important role that planners should play in educating about the value of ecological connectivity. As one local government interviewee stated: "The planning department has the responsibility to educate on the importance [of ecological connectivity] leading to less resistance" (L-9)

5.7. Discussion

The local level of government has a jurisdictional boundary focus, yet local governments are empowered to protect the environment and address cross boundary environmental issues. Given a local government role to protect the environment through land use planning, their contribution to large scale boundary spanning issues such as ecological connectivity must be

considered (Brody et al., 2004). The current case study looked at local government land use planning through review of Official Plans and interviews with planning practitioners to address the question of with whom local government interacts in pursuit of ecological connectivity. The findings indicate that regulatory cross border coordination by local governments is a challenge and generally does not occur without outside assistance, in this case mostly through Conservation Authorities who can serve as a bridge to bring stakeholder groups together. While the provincial government may seem to be the logical agent to coordinate across scales and borders, in practice their role in the Carolinian ecoregion is limited. The results indicate that the agencies involved in ecological connectivity planning differ from the agencies involved in implementation or on the ground maintenance of ecological connectivity. The separation between planning and implementation is a recognized phenomenon (Keeley et al, 2018) that is also demonstrated in the current study.

5.7.1 A lack of cross border coordination

The study results demonstrate that local government tend to work in isolation, concentrating just on their limited part of the puzzle. The Official Plan review demonstrated that local governments recognize the need to work with stakeholders, but the interviews with practitioners indicated a lack of collaboration and coordination across local government borders. When asked who they worked with to develop the natural heritage system policies and maps, only a few indicated some form of cross border coordination while more indicated that they circulated draft policies to adjacent local governments for comment. While this communication is laudable, it does not indicate coordination of policy or maps. As found through the review of the natural heritage system mapping in the Official Plans, each local a

government applied different approaches to identify the natural heritage system with no coordination across jurisdictional boundaries. Local government saw the benefit of collaboration but did not see themselves as doing the collaboration. This isolation of planning for ecological connectivity reflects the hierarchical government structure, where provincial government has delegated the duty of identifying a natural heritage system to local government but with limited assistance in cross boundary coordination.

The literature indicates a need to match the scale of an environmental problem with the scale of governance for effective management (e.g., Bergsten, 2014; Bodin, 2017). A social and ecological process scale mismatch can result from a fragmentation of the governance system (Baggio et al., 2019). The findings of the current study clearly indicate a fragmentation between provincial government and local government in addressing the delegated provincial direction of identifying a natural heritage system comprised of natural areas and linkages among them. "Not the province" was a common answer to the question of with whom local government and Conservation Authorities worked to plan ecological connectivity. The existing cross local boundary provincial plans were noted as beneficial in ensuring a broad scale perspective on ecological connectivity. But it was noted as well that the province has withdrawn from assisting local government on identifying a natural heritage system other than ensuring consistency in following general provincial policy direction. Indeed, there was an indication that local government had no wish to work with the province, except perhaps as a source of funding, given a lack of trust, conflicting higher-level direction, and outdated guidance materials.

A lack of involvement of local government in higher level decisions that affect local government together with a lack of trust, communication and understanding of both national and provincial government on what local government can do for cross border environmental issues, are recognized as ongoing issues (Leck & Simon, 2013). Adding to these issues is the formal hierarchical government structure that tends to compartmentalize functions. The intent of this approach was to maximize efficiency, but it also leads to organizational silos (Park et al., 2012). Local government tended to work in isolation within and between local governments, which was noted as a barrier to cross border coordination for ecological connectivity. Formal or mandated mechanisms for cross border collaboration have been suggested. However, it has been found that such mandated relationships tend to have lower productivity than shared interest relationships or 'genuine collaboration' (Sayles & Baggio, 2017).

Local land use planning can only influence a limited area and can only determine land uses inside the boundaries of a local government, but ecological connectivity occurs at a variety of spatial scales. The literature identified several means to address this scale mismatch to address ecological connectivity. Huber et al. (2012) noted that "effective local land use planning should ideally incorporate both local and regional ecological patterns within the local decision-making process" (p. 16). Huber et al. (2012) recommended local and regional planners must be part of the process of modelling both large scale and local scale ecological connectivity, which would allow local government integration into broad scale planning for species movement. Simply 'handing off' mapping does not guarantee inclusion of this information in land use planning decisions. The notion that providing information does not guarantee its use was supported in the current study as Conservation Authorities recognized that they could provide

scientifically defensible data and mapping for a natural heritage system, though it remained up to local government to decide to use it.

Bergsten et al. (2014) suggests intermunicipal collaboration to address scale mismatches inherent to planning for ecological connectivity. While recognizing the autonomy of local governments to plan within their boundaries for locally contained ecological processes, intermunicipal collaboration was suggested for ecological processes that transcended local government boundaries. However, Bergsten et al. (2014) recognized that local governments had not developed collaborative arrangements to effectively address cross boundary ecological connectivity and would rely instead on regional agencies for addressing boundary mismatches. Given the lack of provincial broad scale mapping over the Carolinian ecoregion and a lack of provincial assistance to address boundary mismatches, inter local government coordination is required. Local governments, while not undertaking coordination themselves, recognized that Conservation Authorities could serve as a bridge to address cross boundary ecological connectivity and bring stakeholders together.

5.7.2 A disconnect among ecological connectivity stakeholders

As identified by Sprang et al. (2012), in southern Ontario there is a lack of coordination in conservation efforts and natural heritage systems planning.

> Multiple agencies, including provincial ministries, Conservation Authorities, non-governmental organizations (NGOs), and municipalities, are involved in land use planning and natural heritage conservation on the same landscape, often at different scales. Planning decisions are made within political boundaries without coordination

> with neighbouring jurisdictions or without consideration for the effect on the broader ecosystem (p. 687).

The current research results confirm that this situation continues to exist in the Carolinian ecoregion. The interviews with planning practitioners indicated that local governments tend to work in isolation but consider the planning for natural heritage systems to be a shared responsibility with the watershed-based Conservation Authorities. Conservation Authorities are considered to be better placed or able to coordinate with other interests and consider ecological process effects outside of local government boundaries.

Still, there were connections noted at smaller scales. For example, a local government had a very good and working relationship with a 'friends of' NGO that took care of local environmentally sensitive natural areas on behalf of the local government. In another location, a local government had a good relationship with the federal government for a biosphere reserve. Overall, the specific relationships to address the planning and maintenance of ecological connectivity depends on context and scale and can create a 'messy' network with the potential of actors working on individual projects for different but related purposes with no connections among them.

5.7.3 The watershed-based Conservation Authorities as a bridging organization

In the current study, the watershed-based Conservation Authorities were seen as the primary means to integrate or coordinate across borders and interests. However, NGOs are recognized as important actors in a collaborative network as they can serve as a trusted conduit to private landowners for implementation of ecological connectivity (Keeley et al., 2019) and

this was supported by results from the current study. Nevertheless, local government planning practitioners recognized a strong tie with Conservation Authorities but not with NGOs. Good relational ties can contribute to better environmental governance and can help to coordinate actions (Bodin & Crona, 2009), but where there is a disconnect among actors as found in the current study, a bridging organization may be required to help encourage collective action.

A bridging organization is an organization with resources and staff that links diverse actors who would otherwise not be connected (Crona & Parker, 2012; Stewart & Tyler, 2019). Bridging organizations can serve as points of contact to engage divergent groups (Pittman and Armitage, 2019). Such a bridge can be, for example, across jurisdictions or administrative scales, and can facilitate the sharing of knowledge needed for cross border coordination (Alexander et al., 2016). Kininmonth et al. (2015) suggested that local government coordination on transboundary ecological issues could benefit from a facilitating third party coordinator. The current findings support this premise with the Conservation Authority acting as a bridge among local governments for planning of ecological connectivity but also as a bridge with NGOs and landowners for ecological connectivity implementation. The use of a watershed as a management unit can address cross border issues such as ecological connectivity better than a local government constricted by human defined political boundaries (Newig et al., 2016; Steward & Tyler, 2019). However, relationships between local governments and watershed governance can be disconnected or challenging with multiple decision makers operating at different scales (Mancillia-Garcia et al., 2019). Additional difficulty can arise from political institutions, such as local governments, being seen as more legitimate and accountable representation of various organizations (Newig et al., 2016).

In the Carolinian ecoregion, Conservation Authorities have been legislated through provincial acts and in place since 1946, with a clear framework on roles and responsibilities. Local governments have utilized, and perhaps have become dependent, on the expertise and resources of Conservation Authorities to address hydrological and ecological issues. Given that local governments do not have direct authority to address issues that originate or go beyond their borders, the resulting internal focus of local governments limits their ability to address cross border issues (Mancillia-Garcia et al., 2019). Hence, interviewees of both local government and Conservation Authorities suggested that a Conservation Authority was the best agent to address ecological connectivity. What is not know from this current study, however, is the ability of Conservation Authorities to take on this role successfully and whether Conservation Authorities can effectively facilitate an integrated approach to ecological connectivity planning and maintenance.

5.7.4 The Planning – Implementation Gap

The current research identified a gap between local government planning and local government implementation. Local government planning for ecological connectivity was primarily seen as involving Conservation Authorities, and NGOs. Implementation was clearly identified through landowners. The failure to translate policies into action can be referred to as the planning – implementation gap (Keeley et al., 2018). Local government planning for ecological connectivity tends to be centralized but implementation measures mainly are decentralized, through numerous local actors, potentially leading to different governance regimes (Newig et al., 2016). Planning practitioners indicated that while site specific

implementation of ecological connectivity can be addressed through development applications, targeted implementation of ecological connectivity was primarily through direct contact with landowners and voluntary rather than regulatory measures. Even with enabling legislation and a strong planning document, implementation can be lacking without public and landowner buy-in, as legislative authority through local government cannot obligate conservation actions on private land (Keeley et al., 2018; Tiemann & Siebert, 2009). The current research findings support the need for local government to partner with other actors to implement local government policies on ecological connectivity.

5.7.5 Research and strategic opportunities beyond the scope of my thesis

This research was an exploratory investigation into the planning and maintenance of ecological connectivity through local government land use planning and is context specific with a potential 'home grown' solution for collective action (Scarlett & McKinney, 2016). The results as such cannot be applied to other contexts, but certain aspects may be relevant, such as a recognition of local government barriers to cross border collaboration. As ecological connectivity is a complex environmental issue requiring cross scale collaboration, using an ecoregion as the basis for a case study for ecological connectivity made sense. The Carolinian ecoregion however may have different socioeconomic, cultural and political contexts than other areas. Also, a more detailed study separating the ecoregion into smaller regions would assist in refining the results. As this study is exploratory, identified themes could be studied in greater detail and at different scales and locations.

5.8 Conclusions

The intent of this research was not to identify better ways to collaborate but to understand social network interactions and potential weak links, gaps or overlaps in the system, and potential conflicts in direction or objectives that hamper the ability to preserve a connected landscape. The main findings in this research on collaboration for local government land use planning and maintenance of ecological connectivity has been (a) a lack of provincial involvement, (b) a large role to be played by Conservation Authorities, and (c) a gap between policy and implementation. These key results are both a political and a professional planning problem.

In the Carolinian ecoregion, a stronger and continued interaction among actors in the governance structure would assist the pursuit of broad as well as local scale ecological connectivity. The extent of provincial government removal from participation in local government natural heritage systems planning should not have been unexpected given the political economy prevalent in southwestern Ontario at the time of this research. As noted by Fillion (2021), "planning outcomes are the product of planners having to deal with resources and constraints originating from shifting institutional and political economy contexts…" (p. 263). In Ontario there has been a strong provincial government push to address housing supply and affordability, with new legislation introduced that impacts the local government and Conservation Authority mandates and priorities. This push for more housing built quicker supports private sector development with government regulations seen as an impediment to the provision of the needed housing supply (Grant, 2022). Land use planning is commonly seen as the cause of the problem with a call for policy reform to address planning constraints, an

unwieldy approval processes and high development charges (Joy, 2019). These planning reforms can be at the expense of social equity and environmental protection. While in the current research policy direction for the identification and protection of a natural heritage system has not changed, the provincial pressure to provide more housing built quicker can alter local values and decisions made. Planners have little control over the changing priorities in times of political and economic transition, but planners can respond by adapting and adjusting planning interventions to the evolving context (Fillion, 2021).

From a social – ecological systems perspective, different actors addressing different parts of an ecological network will not necessarily preclude collective action (Alexander et al., 2016; Bodin et al., 2017; Hedlund et al., 2023; Scarlett & McKinney, 2016). While my findings show that watershed-based Conservation Authorities were the most recognized bridge to assist local governments in planning and implementing plan policy for ecological connectivity, given the current political economy, additional research is needed to investigate if, how and why, or why not, Conservation Authorities in the case study area can function as a bridge for collective action on natural heritage systems planning and on the ground implementation. Without provincial oversight and assistance, or even with it, findings suggest that Conservation Authorities are the best option to address cross border connectivity scale issues.

Planning for ecological connectivity cannot be restricted by political borders and requires planning at a spatial scale that spans local government boundaries if it is to be effective in achieving conservation objectives. While the current research did not directly investigate any tangible outcomes of connectivity planning, it is apparent that large scale cross

boundary connectivity in the Carolinian ecoregion cannot be achieved through local government land use planning alone. However, as regional and county local governments in the Carolinian ecoregion range in size from 843 to 3000 square kilometers, this leaves plenty of room for smaller scale connectivity to be identified through local government land use planning at the regional scale, within their areas of jurisdiction. While local government land use planning has the potential to improve the identification and protection of ecological connectivity and reduce further land fragmentation, implementation will need more direct contact with landowners and private land stewardship initiatives. How landowners may respond to increased contact and stewardship initiatives by various network actors is an important consideration for further research. For example, in this current research, NGOs interviewed indicated they did not have enough resources to carry out all the landowner contact requested, while local governments identified a lack of support for ecological connectivity on private lands.

While it is recognized that various local governments must collaborate with each other, or at a minimum coordinate, to ensure cross border ecological connectivity, the current research did not find that strong connections were made among local governments or with outside agencies involved with ecological connectivity implementation. This disconnect of local government from the environmental governance structure impedes collective action and can result in overlap or, more likely, gaps in the maintenance of ecological connectivity. Without full disclosure on ecological connectivity planning and implementation actions by local governments and integration into actions by other actors, gaps in implementation are likely to continue. Local governments may not be the only 'game in town', but in the Carolinian

ecoregion, local governments are a major contributor to ecological connectivity planning and the mitigation of negative land development impacts and need to be fully integrated into the connectivity planning system.

Two approaches to coordinate across borders were suggested in the literature: (1) collaboration and (2) consistent application of criteria to identify ecological connectivity or a combination of both (Parrott et al., 2019; Rincón et al., 2021; Wyborn, 2015; Spang et al., 2012). This approach, a combination of the use of consistent criteria and collaboration and was conducted by Spang et al. (2012) for a portion of the Carolinian ecoregion and facilitated through the provincial government. Specifically, a multi-stakeholder process to identify a natural heritage system based on eco -district boundaries, was used on a project specific basis (Spang et al., 2012). Spang et al. (2012) identified that local governments that were not completely covered by the eco-district study boundaries did not have the same level of buy-in as those with full coverage (Spang et al. 2012). Therefore, if ecological connectivity is addressed on a watershed basis as suggested in the current research, the study area should include the entirety of a local government jurisdictional area to encourage buy-in. Local government will want to apply the same standards or constraints on development across the local government jurisdiction. To accomplish this and still address cross scale issues, separate Conservation Authorities will need to work together to cover watersheds as well as local government jurisdictions in their entirety.

Lastly a question arising from the current research is whether 'the public' is or should be a stakeholder in a collaborative governance structure for connectivity planning, recognizing there is not one public but a variety of groups with different interests. Planning theory informs

and guides planning practice (Allmendinger, 2017) and communicative or collaborative planning theory addresses this question, in theory. Collaborative planning theory arose from the recognition that a community is made up of diverse views with the need for planning to include more inclusive forms of deliberation (Campbell et al., 2016; Fainstein, 2000). As noted by Healey (1998):

> Collaborative approaches emphasize the importance of building new policy discourses about the quality of places, developing collaboration among stakeholders in policy development as well as delivery, widening stakeholder involvement beyond traditional power elites, recognizing different forms of local knowledge, and building rich social networks as a resource of institutional capital through which new initiatives can be taken rapidly and legitimately (p.1531).

Traditional government public participation can be described as democratic engagement, increasing public access to information, and ensuring citizens are heard (Fischer, 2012). It is true that shared decision-making through collaborative governance is not the same as public participation, but the two can be related and do coexist. Collaborative governance applies principals of communicative planning theory and governance approaches where decisions include the diverse views of the community, more inclusive forms of deliberation, and building of social networks (Campbell et al., 2016; Fainstein, 2000; Healey, 1998). This 'participatory governance' is described as a redistribution of political power with decentralization of decision making, knowledge exchange, collaborative partnerships, and inter-institutional dialogue (Fischer, 2012). While collaboration, decentralization, and local discretion is strongly supported by theory, the realty in times of planning reform is strong central direction and attending to developer interests (Allmendinger & Houghton, 2019).

The premise of my research is that a collaborative form of environmental governance is required to address the cross scale and multiple interests inherent with ecological connectivity. There is a need to match the scale of ecological connectivity with the scale of governance through collaboration or a networked governance structure. Also, as the planning for ecological connectivity through local government land use planning is legislated, cross border coordination through a collaborative governance structure is needed which integrates local government land use planning into collective action. The current research results indicate a lack of collaboration and cross border coordination through local government land use planning. The results do however point to possible steps forward to better coordinate land use planning across scales and among stakeholders:

- Conservation Authorities should lead collaborative studies to identify priority areas for ecological connectivity protection, improvement, or restoration and these studies should direct local government land use planning on natural heritage systems. As the Conservation Authority watershed boundaries do not correspond with local government boundaries, there would need to be cooperation among Conservation Authorities to ensure full coverage of local government jurisdiction. This has already been done in the Carolinian ecoregion by some Conservation Authorities. The Upper Thames River Conservation Authority is a good example of a Conservation Authority conducting a collaborative process to identify the natural heritage systems for the County of Middlesex, County of Oxford, and County of Elgin. While this is a commendable process, the study did not take a watershed perspective but was based on local government

boundaries and ecological connectivity was not identified. A study specifically geared towards ecological connectivity at a watershed scale is needed.

- Sub-watershed studies involving multiple stakeholders, should be the basis of finer scale identification of ecological connectivity to be incorporated in lower tier local governments or 'secondary' plans. While sub-watershed studies are a recognized process to identify a natural heritage system in finer detail if multiple stakeholders are involved and how ecological connectivity is addressed deserves future research.
- Local governments should create environmental advisory committees comprised of diverse members of the community to advise on land use planning, individual development proposals and environmental assessment guidelines to specifically incorporate ecological connectivity. Such committees should be facilitated and guided by a staff environmental planner to provide expertise and guidance on Official Plan policies. This would bring various stakeholders together, encourage shared learning, ensure consistent interpretation of Official Plan policies, and incorporate environmental issues such as ecological connectivity into decision- making.

Local government cross border collaboration or at a minimum coordination is needed for effective ecological connectivity. Yet there is little research which investigates the role of collaboration in promoting the effectiveness of local government Official Plan policies on ecological connectivity. Specifically, does the inclusion of local government actors and land use policies on ecological connectivity lead to the conservation of biological diversity, increase species movement and sustain ecological processes? What this current research confirms is

that cross border coordination for environmental issues is difficult for local governments, a bridging organization outside of local government can assist, and that greater landowner contact and environmental stewardship is a key component for the implementation of ecological connectivity. The 'messy' social network identified in this current research to plan for and maintain ecological connectivity gives greater flexibility to both identify areas functioning as linkages among natural areas and adapt to changing environmental conditions. However, without coordinated action and the pooling of knowledge and resources, the isolation of planning and maintenance of ecological connectivity is likely to continue. The Carolinian ecoregion is an area identified as a crisis ecoregion (higher biodiversity and higher threat) and a national priority area where locally identified and created ecological corridors are most urgently needed. Local government policies on ecological connectivity has the potential to focus development away from priority areas and mitigate impacts. Governing ecological connectivity will require intentional coordination among local government jurisdictions, between levels of government, and with non-government organizations to address ecological interdependencies. While political and resource constraints are recognized, reinforcing the strong existing relationships and addressing the weak linkages is needed to successfully address the movement of plants, animals, and ecosystem processes, functions, or services across the Carolinian ecoregion.

Chapter 6 – Synthesis

6.1 Introduction

The intent of this research was to explore the role of local government in planning for and maintaining ecological connectivity. As exploratory research, my results advance our understanding of the role of local government land use planning in establishing and maintaining ecological connectivity through the control of land use change and management of the whole landscape involving nature conservation but also sectoral policies such as transportation, housing, and agriculture (Gurrutxaga et al., 2015). Spatial land use planning has the potential to address ecological connectivity through a comprehensive multisectoral approach, and multi-scale perspective, in relation to spatially explicit land uses (Perrin et al., 2022). I identified benefits and limitations of integrating ecological connectivity into land use planning as one component of a social-ecological system.

This chapter outlines the key findings from chapters 3, 4 and 5 and identifies common trends and collective implications for local government land use planning for ecological connectivity. The findings from Chapter 3 (planning policy), Chapter 4 (planning influences) and Chapter 5 (planning partners) contribute not only to the body of knowledge on planning for ecological connectivity but also to the theory and practice of environmental planning in general. Limitations of the research are discussed together with possible directions for future research.

Chapter 3 explored if and how ecological connectivity is being planned for and implemented by local government in a highly fragmented landscape and within a fragmented decision-making framework. The following research questions were posed, (1) how does local

government address ecological connectivity through land use planning, and (2) is the approach to addressing ecological connectivity consistently applied and coordinated across borders. Through the review of 16 strategic land use plans (Official Plans) in the Carolinian ecoregion of southwestern Ontario, Canada, the benefits, and limitations of integrating ecological connectivity in local government land use plans were identified. This investigation contributes to the field of ecological connectivity by focusing on local government land use planning as the means to address land use change and maintain a connected landscape.

Chapter 4 investigated and explained factors that affect the planning and maintenance of ecological connectivity in a highly fragmented landscape at various scales and for various governance approaches. The research question was (3) what factors facilitate or impede planning and implementation of policy on ecological connectivity. The investigation was conducted through interviews with planning practitioners from the Carolinian ecoregion to obtain practical information and insight into factors that are facilitating or impeding to the integration of ecological connectivity in local government land use plans. This investigation contributes to the existing scholarship on ecological connectivity by identifying factors that can help and hinder local level planning practice in the protection and maintenance of ecological connectivity.

Chapter 5 explored how ecological connectivity can be coordinated across jurisdictions and through a collaborative governance structure. The research question was (4) how do actors (government, non -government organizations, private land stewardship) interact in pursuit of ecological connectivity? The question was addressed through the review of 16 Official Plans and through interviews with planning practitioners from the Carolinian ecoregion. This

investigation addressed the feasibility of collaboration across local government jurisdictional boundaries through local government land use planning for broad scale ecological connectivity.

6.2 Summary of findings and implications

The first research questions, addressed in my research was how does local government address ecological connectivity through land use planning? It was found that local governments in the Carolinian ecoregion, addressed ecological connectivity through the application of multiple policy areas. The main policy area was environmental, specifically the identification of a natural heritage system which includes linkages among natural areas. Other policy areas which integrated ecological connectivity were water resources, parks and open space, natural hazards, agriculture, trails, tourism, aggregate resources, climate change, green infrastructure, and transportation. The implementation of land use plan policies was through a combination of regulatory and non-regulatory means. The use of site-specific development applications was the main regulatory planning tool identified and land stewardship the main non-regulatory tool.

The second research question asked if the approach to address ecological connectivity was consistently applied and coordinated across borders. The short answer is no, there was no two Official Plans that applied the same approach to the identification, protection, and maintenance of ecological connectivity. There was some consistency in specific approaches with the proposed use of watershed and sub watershed studies and environmental assessments for proposed land development, consistency referenced to identify and mitigate impacts on ecological connectivity. There was no consistency on whether and how ecological connectivity was mapped or coordinated across local government borders.

The third research questions was what factors facilitate or impede planning and implementation of policy on ecological connectivity? A multitude of factors were identified, categorized as the physical landscape (e.g., existing land patterns); environmental governance (e.g., decision making framework); land use planning practice (e.g., legislation and planning system); information sharing (e.g., outreach and education); and resources (e.g., capacity and funding).

The last research question was how do actors (government, non -government organizations, private land stewardship) interact in pursuit of ecological connectivity? Regarding ecological connectivity, it was found that local governments are well connected with Conservation Authorities but not with other local governments, non-government organizations, and particularly not with the province. Non-government organizations were mostly connected with the landowner, Conservation Authorities, and the federal government. Conservation Authorities work with local governments non-government organizations, and landowners and function as a bridge to bring actors together and offer a holistic watershed view for ecological connectivity. Greater participation by First Nations and the agricultural community was noted as important.

There was overlap among the three research areas reflected in the empirical research chapters (Table 6.1). These key findings can be focused into the following points:

1. Generally, legislation affecting both planning policies and mapping as well as policy implementation on ecological connectivity is weak and vague. It is coupled with a withdrawal of the province from addressing the natural heritage system.
2. There are benefits as well as limitations of provincial plans related to their encouragement of local government political support and mapping of linkages.
3. There exist multiple policy areas that have bearing on ecological connectivity but limited coordination among policy areas, especially for transportation but also for climate change and green infrastructure.
4. Conservation Authorities are widely recognized as the organizations to address ecological connectivity through the regulation of water resources, provision of mapping and expertise, perceived ability to undertake collaborative studies, ability to bridge stakeholders and implement stewardship initiatives, based on a watershed scale.
5. The limitations of site level land use planning practice and a local government 'silo' approach is a severe limitation to planning for and maintaining ecological connectivity.
6. Agricultural lands and the use of the agricultural matrix to address ecological connectivity has a major influence on ecological connectivity planning.
7. There is a dependence on using existing natural areas for connectivity that are typically restricted to valleylands, riparian areas and shorelines, with little upland connectivity identified or politically acceptable.
8. Relevant policy has a focus on individual features (e.g., specific forests or wetlands) with ecological connectivity among them given a lower priority.

9. There is a disconnect with planning and plan implementation. Implementation needs to address landowners and stewardship initiatives to maintain ecological connectivity.
10. There are external factors that affect both the planning and maintenance of ecological connectivity including a fragmented decision-making framework, lack of resources, and need for education.

When arranged into spheres of influence (Figure 6.1) the importance of provincial direction on land use planning and the role of Conservation Authorities becomes apparent. Provincial policy direction for ecological connectivity directly influences provincial plans, local government land use planning, agricultural lands, and the natural features focus. The Conservation Authorities are the bridge with local government for agriculture, stewardship, rivers and shorelines, and natural features. There is an observed lack of direct connection of ecological connectivity through local government land use planning with agricultural lands and stewardship initiatives.

Table 6-1 : Comparison of key findings cross chapter 3 (planning policy), chapter 4 (Planning influence) and chapter 5 (planning partners)

Planning policy	**Planning influence**	**Planning partners**
Ambiguity in provincial legislation – enabling not requiring ecological connectivity	Ambiguity in provincial legislation – difficult to implement; need political support	Perceived provincial withdrawal on natural heritage systems planning
Use of provincial plans – limited to more heavily settled areas	Pros and cons of provincial plans – provides certainty; scale issues	Provincial Plans cross jurisdictions – scale issues
Inconsistent application of mapping – rural areas not mapped	Mapping as required by provincial plans; mapping through water resource management	CA's provide mapping resources
Inconsistent policy and approaches among Official Plans	Implementation guidance required	Inconsistencies across local government boundaries
Integration of multiple policy areas – little integration with transportation, green infrastructure, climate change	Integration framework required	Integrate for collective action
Dependence on site specific planning tools –environmental assessments	Dependence on site specific applications to apply mitigation – cannot target areas	Site specific nature of land use change does not address cumulative effects
Should collaborate with other stakeholders	Collaborating not realistic	Do not lead but participate in collaboration
Should coordination across boundaries – mapping not coordinated	Little coordination across boundaries – operate in silos	Little coordination across boundaries – CAs function as a bridge
Agricultura matrix used instead of recognizing linkages	Agricultural matrix permeability recognized – no support from agricultural sector	More involvement from agricultural sector needed
Riverine shoreline priority – water resource connection to linkages	Riverine shoreline priority – use of hazard lands as surrogate and by default	Watershed focus – CAs responsible
Focus on features – no guidance on linkages	Focus on features – no political support for linkages	Focus on features – science based - no need to collaborate
No apparent disconnect with planning and implementation policies	Disconnect with planning and implementation – few means to implement	Disconnect with planning and implementation – different actors
Dependence on stewardship initiatives to implement policy	Dependency on stewardship initiatives and outside agencies – better situated, more resources	Dependency on stewardship initiatives – NGO and CA - with little coordination
Political decisions based on policy guidance	Fragmented decision-making framework – sectoral decisions	Fragmented decision-making framework – isolation
Education encouraged	Information sharing required	Education a priority
Resources not specified	Planner lack of capacity and resources – rural emphasized	Lack of resources or leadership to collaborate

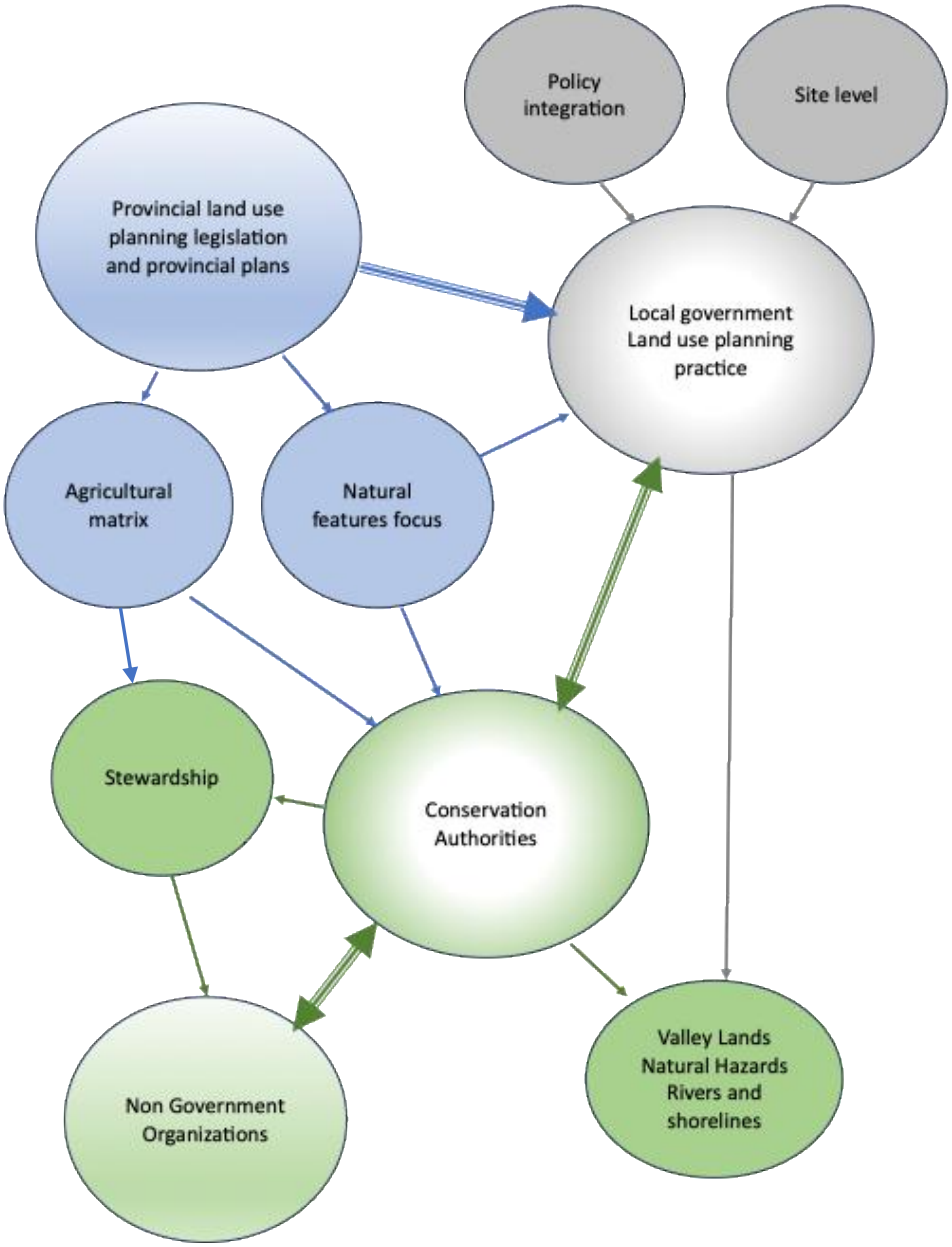


Figure 6-1 : Summary of the main research findings and spheres of influence

6.3 Key findings

6.3.1 Local government land use planning for ecological connectivity (planning policy)

Chapter 3 explored the potential for local government land use planning to address ecological connectivity. Of particular interest was if a consistent approach was used among the 16 Official Plans reviewed or if various means to address ecological connectivity were employed. The results conclusively demonstrated a lack of consistency among the Official Plans reviewed. The policies and mapping for ecological connectivity varied, demonstrating a lack of coordination across local government borders. However, there were also similarities demonstrated and both the similarities and differences were instructive.

All Official Plans identified a natural heritage system which, by definition, includes linkages. But all Official Plans gave ecological connectivity or linkages less protection from the impacts of development and site alteration than natural features. This is a direct reflection of the provincial legislation which has mandatory regulations for the protection of natural features and only suggested direction for linkages. Only the local governments covered by Provincial Plans were legally bound to be compliant with the Provincial Plans and these were the areas that created mapping for linkages. The results do implicate a deficiency in the provincial legislation. The vague wording and lack of legal backing did give ecological connectivity a lower priority for protection, making policy implementation more difficult or subject to local government interpretation. The lack of mapping across agricultural land was consistent across local governments, as was the identification in natural heritage system studies and policies that there was no need to do mapping across agricultural lands given a supposedly permeable

agricultural matrix and the permissiveness of provincial legislation which allows agricultural uses in the natural heritage system.

The use of other policy areas as surrogates for ecological connectivity was common, concentrating on valleylands, natural hazard lands, surface water (riverine and shorelines) and parks and open space. Natural hazards and surface water is strongly regulated and addressed through Conservation Authorities. Parks and open space were a readily accepted policy area given the benefits to the people living in the area. Many other policy areas were recognized as contributing to ecological connectivity. There was inconsistent integration of ecological connectivity with policies on climate change, green infrastructure, and transportation. The lack of integration of transportation policies with ecological connectivity was surprising. This may suggest that local governments are opting for 'safe' approaches to ecological connectivity, or local governments are not recognizing the overlapping ecological benefit of multiple policy areas.

There was an obvious use of criteria to identify natural features but a lack of criteria in Official Plans to address ecological connectivity. While natural heritage system studies did include detailed criteria, most did not identify linkages. Criteria or indicators will be needed for monitoring, however the need to monitor ecological connectivity or the natural heritage systems was rarely specified in the Official Plans. All Official Plans reviewed addressed ecological connectivity at a site level through the development approval process and environmental assessments. Site level application of policy can address ecological connectivity on isolated parcels with little ability to target areas for protection and maintenance and may

not address cumulative effects. With generally no broad context to place connectivity within, the effectiveness of site-specific measures to address ecological connectivity may be limited.

6.3.2 Factors that helped or hindered (planning influences)

Chapter 4 investigated planning practitioner practical experience and viewpoints on matters that help or hinder the planning and maintenance of ecological connectivity. Five theme areas were identified: the physical landscape, environmental governance, land use planning practice, resources, and information sharing. Based on the results, a land use planning practice theme was added to the initial literature review, indicating less emphasis in past research directed specifically towards planning practice factors that affect ecological connectivity. There were consistent views that stood out.

The continued focus on natural features with less on linkages, was consistently noted as detrimental to the acceptance of ecological connectivity as a priority. This may be due to the vagueness of the legislation in combination of a lack of support for ecological connectivity being mandated on private property. A lack of education for the public, agricultural sector, politicians and even planners was cited as a reason why ecological connectivity was less supported than natural features.

The prominent use of natural hazards and water resources to address ecological connectivity was noted by all local government and Conservation Authority respondents. Given the legislated mandate to address natural hazards and water quantity and quality, regulation through Conservation Authorities, and an emphasis on human safety, there was greater political and public support for the use of riverine and shorelines systems to function as

ecological connectivity – even if that was not the original purpose of the Conservation Authorities.

Farmer resistance to any component of the natural heritage system on agricultural land was consistently noted. Given the choice to address ecological connectivity through enabling legislation, a lack of political support was identified as the main factor in avoiding planning for ecological connectivity on agricultural land. The use of land stewardship initiatives and outside agencies were recognized as invaluable to address ecological connectivity on agricultural lands. The permeability of the land matrix was also noted as a reason why ecological connectivity did not need to be identified on agricultural lands, especially as the main planning tool to mitigate effects on connectivity was site specific development applications, of which there are few in rural areas.

A fragmented decision-making framework negatively affects the ability to coordinate among jurisdictions and across borders. While it was recognized that numerous policy areas as well as levels of government and non-government organizations could address ecological connectivity, there was no means to coordinate activities. Local governments tended to work in silos and land use planning did not always coordinate outside of the mandate to address land development applications. It was noted that while numerous initiatives addressed ecological connectivity, there was little discussion or coordination with local government land use planning.

Collaboration, while seen as important was difficult given staff capacity, and a lack of cross border and cross issue mandate. Conservation Authorities were consistently identified as better suited to address the broader scale and help coordinate across borders or serve as a

bridge to bring parties together. Related to this was a need to incorporate land stewardship initiatives to implement ecological connectivity, yet perhaps not through local government,

There was a general agreement that provincial assistance was absent. Provincial staff availability had declined with little assistance in addressing the natural heritage system other than ensuring consistency with Provincial legislation. Provincial land use plans were seen as both good by requiring the identification of ecological connectivity and bad given multiple overlapping plans and inconsistent application of connectivity. The scale of Provincial Plans was also an issue with small areas not being identified as important for connectivity.

The planning system itself was a focus for comment. The focus on the site level and individual development proposals inhibits the ability to maintain or improve ecological connectivity. The dependence on applications to address connectivity and inability to target areas or coordinate isolated parcels was noted as a hinderance to the maintenance of ecological connectivity. While policy was proactive and relevant, policy implementation was reactive and more dependent on land stewardship than the development process. This policy-implementation gap was recognized with a need for implementation guidelines.

Raising the level of public awareness on the importance of ecological connectivity was universally seen as important to garner public and political support. While this could be done through the planning process, outside agencies were also identified as pertinent in education and learning. The lack of participation by agents who supported ecological connectivity was a hinderance as only negative comments were received by the politicians.

A need for continuity in planning and with implementation was noted. The same people who wrote the plan were not necessarily responsible for implementation and the logic behind

the policy and anticipated actions could be lost in the translation. The experience of staff from Conservation Authorities and the province in natural heritage systems planning was invaluable yet the province had withdrawn, and Conservation Authority mandate was being restricted. Urban areas with more resources had less need to plan for connectivity while rural areas with less resources were unable to address the maintenance of ecological connectivity. There was reference to the golden horseshoe area of the Carolinian ecoregion being much different than the rest of southwestern Ontario, having strong well-funded Conservation Authorities, more support for environmental planning – "like comparing a Cadillac with a college car".

6.3.3 Local government cross border collaboration (planning partners)

Chapter 5 focused on the need for collaboration to address the cross-scale nature of ecological connectivity, and the multiple actors involved in planning and maintenance of ecological connectivity. A combination of Official Plan review and planning practitioner interviews were used to investigate local government collaboration. While the same data was used and analyzed as for Chapters 3 and 4, new insights were garnered from this more detailed look at who worked with who on ecological connectivity. Four main findings were highlighted: (a) no local government coordination was occurring across borders, (b) the province was absent from natural heritage planning except for high level policy guidance, and (c) Conservation Authorities were widely recognized as a bridge among local governments and with other stakeholders, including landowners, and (d) the people who planned for ecological connectivity differed from those who implemented connectivity plans.

As an environmental planner who has personal professional experience with initiating collaborative and cross boundary projects, with NGOs and through university assistance, I was

not prepared for the complete lack of willingness or recognition of a local government role in collaboration. Generally, planning practitioners from local government recognized the need for collaboration but planners saw this being done by someone else. Both local government and Conservation Authorities recognized the role of watershed-based Conservation Authorities as bridging across local government boundaries and among actors. In the geographic context of this research, the Carolinian ecoregion, it was found that Conservation Authorities have taken on a leadership role in environmental planning and collaboration. Given the current political economy in Ontario, which stresses planning reform to accommodate growth especially in affordable or other housing, the future influence of local governments and Conservation Authorities regarding natural heritage system conservation is uncertain.

6.3.4 Environmental planning theory and practice

The testing of environmental planning theory through the investigation of planning practice was not the primary goal of this current research, however, some observations can be made. A social-ecological systems perspective is the fundamental, underlying theory applied in my research with an integrated vision of humans in nature, recognizing that societies and ecosystems are shaped by each other (Berkes & Folke, 1998). Environmental planning theory recognizes the need to incorporate environmental matters in land use planning but also address the social system (including economics and politics), for effective policy development and implementation. My research revealed an awareness of the integration of social and ecological systems for effective planning and maintenance of ecological connectivity. In practice, the social system is prevalent with ecological systems that are not clearly perceived as pertinent to human well-being, given a lower priority.

Defining 'connectivity' as part of a social-ecological system was a first step in this research journey. Numerous and varying definitions are offered in the literature, but ecological connectivity is used as it best reflects the multi-functional, multi-benefit approach typically taken in spatial land use planning. The definition of ecological connectivity for my research is the movement of plants, animals, and ecosystem processes, functions, or services across a landscape through linkages among intact natural areas. This definition acknowledges the need to protect natural features and linkages for biodiversity conservation as well as provide for human well-being through application of the ecosystem services concept. My research demonstrated that in practice, ecological connectivity was defined from an ecological perspective with little reference to ecosystem services provided by ecological connectivity. This separation of the ecological from the social system may reflect the emphasis on rationality and scientific decision making as separate from societal values.

A major limitation of local government land use planning for ecological connectivity raised in the literature is the delimitation of jurisdictional boundaries that do not reflect ecological processes and functions. This limitation is addressed in the literature through the concept of institutional fit (Bergsten et al., 2014; Epstein et al., 2015) and a collaborative environmental governance structure (Armitage et al., 2012). Both these theories frame my research. The intent of my research was to understand social and ecological network interactions and potential opportunities or gaps in the system that help or hamper the ability to preserve a connected landscape. While my research demonstrated that collaboration was not a large part of local government planning, public participation was. The benefits of collaboration were recognized with an intention to collaborate, but the reality in practice was segregated

planning and a planning – implementation gap. Collaboration occurred consistently with Conservation Authorities on watershed-based projects and for land stewardship, but with little coordination with local government land use planning policy development and plan implementation.

Communicative or collaborative planning theory can help address a social-ecological systems approach. Collaborative planning theory arose from the recognition that a community is made up of diverse views with the need for planning to include more inclusive forms of deliberation (Campbell et al., 2016; Fainstein, 2000). Collaborative governance applies principals of communicative planning theory and governance approaches where decisions include the diverse views of the community, more inclusive forms of deliberation, and building social networks (Campbell et al., 2016; Fainstein, 2000; Healey, 1998). The incorporation of public views was noted in my research as very important in land use planning for ecological connectivity. Still, incorporating diverse viewed does not mean that the social and ecological views are given equal weight. While a lack of education was suggested as a factor against the acceptance of ecological connectivity, it was also recognized that land use decisions are political with no guarantee that raising the level of awareness of ecological matters influence political decisions. The political nature of decision making, enabling but not mandated legislation for ecological connectivity, and lack of awareness or acceptance of the importance of ecological connectivity, skewed decision making to the economic mandate currently prevalent in the study area.

In my opinion, the site-specific nature of land use planning practice has not been fully incorporated in planning theory. Land use planning practice is geared towards the isolation of land parcels or fragmentation of the landscape. Even with broad scale planning and identification of areas of ecological importance to protect, the concept of site-specific mitigation is employed as development applications are received with limited ability to address cumulative effects. While collaboration is a recognized solution to address ecological connectivity, planning practice is not geared towards collaborative decision making.

Environmental planning practice can adapt. As noted in the introduction to this dissertation, in land use planning a 'problem' may not be solved and as values change the problem does not go away but another problem may displace it (Friedman, 1987). Planners have little control over the changing priorities in times of political and economic transition, but planners can respond by adapting and adjusting planning interventions to the evolving context (Filion, 2021). Adaptations are suggested in this research.

6.4 Contributions and future research

My research provides insight into how local government land use planning can address ecological connectivity and contribute to collective action. This research did not address the effectiveness of land use planning in the provision of functional ecological connectivity as this was beyond the scope of my research. Opportunities identified can contribute to better planning and maintenance of ecological connectivity.

Land development is a major contributor to the loss of ecological connectivity, and my research furthers our understanding of how land use change can be ameliorated through local

government land use planning and policy implementation to conserve ecological connectivity. This dissertation describes the state of practice, provides baseline data, and contributes to a greater understanding of strengths and weaknesses of local government land use planning for ecological connectivity. The results can inform planning practice and assist in future evaluation of land use plan outcomes.

The main study limitation is the context specific nature of my research. The unique involvement of watershed-based Conservation Authorities in this research limits the ability to expressly export the findings to other areas that do not have separate watershed-based organizations. On the other hand, this research offers a unique perspective on the integration of local government with watershed-based organizations that can be applied to research on the concept of institutional fit.

A second limitation was the lack of similar research on qualitative content analysis of local government strategic plans specific to ecological connectivity. Though many studies tangential to ecological connectivity were located (e.g., green infrastructure, ecological services, greenways, general ecosystem, or watershed-based planning), no content analyses specific to ecological connectivity were found. As a result, I conducted an inductive content analysis being open to the concepts that arose from the documents themselves. The results can now be applied to future assessment of the quality of local government land use plans in addressing ecological connectivity.

Third, this research was conducted at a single point in time. I would argue it is a remarkably interesting point in time with the recent updates of Official Plans and need to accommodate changing political legislation, but still, it is just a point in time. Changes in

legislation and Conservation Authority mandates may impact the research-based recommendations put forward in this study.

Lastly, identifying policy and factors that help or hinder the planning and maintenance of ecological connectivity does not mean that the polices are implemented or factors addressed. This research was able to summarize issues but will need to be supported by further investigation into the effectiveness of the policies, mapping and approaches reviewed.

My research identified areas of future research to better address the topic of local government planning and maintenance of ecological connectivity in a fragmented landscape. The following future research is suggested to address the identified issues:

Provincial legislation and guidance

- Given a continued features focus of the provincial legislation, future research can address the benefits and limitations of provincial legislation in supporting local government planning and maintenance of ecological connectivity. Assuming the current state of political economy precludes amendments to strengthen legislation for ecological connectivity, future research would need to look at how the existing legislation could be better adapted to local government ability to plan for ecological connectivity and develop clearer and up to date guidance on the identification of and implementation tools for ecological connectivity through local government land use planning.

Multiple policy areas

- Greater attention should be paid to climate change, green infrastructure and particularly transportation policies to address ecological connectivity. Future research

should address the ability to integrate the concept of ecological connectivity into climate change, green infrastructure and transportation policies in land use planning.

Land use planning practice

- Sub-watershed studies involving multiple stakeholders can be the basis of finer scale identification of ecological connectivity to be incorporated in lower tier local governments, or 'secondary', plans. The use of sub watershed plans is a recognized implementation process in the Official Plans reviewed. How this is being done deserves future research to assess how local governments can incorporate ecological connectivity into smaller scale planning and site-specific land use planning decisions.
- The site level regulatory planning tools can be ineffective in addressing the main identified purposes of ecological connectivity in the Official Plans, namely species movement and ecosystem processes and functions. Direction on conducting connectivity analysis on a site level that addresses a broader scale should be incorporated into environmental assessment guidelines and brought into decision making processes (e.g., Kor et al., 2022). Future research should focus on the use of strategic environmental assessments or environmental assessment guidelines to address both local and broad scale ecological connectivity.
- Continued study on a scientifically supported consistent approach to identify ecological connectivity at various scales in the Carolinian ecoregion should be pursued and used as the basis for future monitoring of effectiveness of planning policies for ecological connectivity.

- For better incorporation of multiple views on the preservation of a natural heritage system, it was recommended that local governments should create and use standing environmental advisory committees comprised of diverse members of the community to advise on land use planning, individual development proposals and environmental assessment guidelines. Future research could evaluate the benefit and drawback of environmental advisory committees to address the multi-functional use approach applied in land use plans.
- Future research should evaluate Official Plans for their effectiveness in addressing ecological connectivity based on the initial criteria identified in this research.
- Future research should investigate and create an inventory of what is already happening in the Carolinian ecoregion to address ecological connectivity to demonstrate the breadth of activities, allow land managers to collectively address ecological connectivity and enable better coordination of activities.

Conservation Authorities

- Future research should address the role of Conservation Authorities as a bridging organization to identify priority areas for connectivity conservation, for voluntary stewardship measures on private lands and agricultural lands and to maintain or restore ecological connectivity.
- Conservation Authorities currently lead collaborative studies to identify a natural heritage system and these studies can direct local government land use planning. As the Conservation Authority watershed boundaries do not correspond with local government boundaries, there will need to be cooperation among Conservation Authorities to ensure

full coverage of local government jurisdiction. This has already been done in the Carolinian ecoregion by some Conservation Authorities. While a commendable process and results, there is still a focus on natural features. A study specifically geared towards ecological connectivity at a watershed scale is needed which also looks at upland corridors and the porosity of the agricultural matrix.

- Additional research is needed to investigate if, how, and why, or why not, Conservation Authorities in the case study area can function as a bridge for collective action on natural heritage systems planning and on the ground implementation.
- Future research should address the coordination of policy between local governments and Conservation Authorities on natural hazards, and water resource management to better address ecological connectivity.

6.5 Conclusions

This thesis has been first and foremost a learning experience. The wealth of literature on ecological connectivity and environmental governance was countered by the dearth of research on the integration of ecological connectivity in local government land use planning. But eventually enough literature on the topic was found to give substance to my research. My experience as a local government environmental planner who instigated a collaborative process to address ecological connectivity in British Columbia had to be harshly set aside to avoid naiveté.

My contribution to the field of environmental planning focuses on the opportunities and limitations of the land use planning process, and perhaps of land use planners, to address ecological connectivity. I do not foresee changes to the land use planning system soon. But

through greater attention paid to site level investigation in relation to protection of ecological connectivity, the integration of multiple policy areas, shared learning, and partnerships, better integration of ecological connectivity in local government land use planning seems possible.

References

Albert, C., Aronson, J., Fürst, C., & Opdam, P. (2014). Integrating ecosystem services in landscape planning: requirements, approaches, and impacts. *Landscape Ecology*, *29*(8), 1277–1285. https://doi.org/10.1007/s10980-014-0085-0

Alexander, S. M., Andrachuk, M., & Armitage, D. (2016). Navigating governance networks for community-based conservation. *Frontiers in Ecology and the Environment*, *14*(3), 155–164. https://doi.org/10.1002/fee.1251

Allmendinger, P. (2017). *Planning Theory: Planning, Environment, Cities (3rd Edition).* London, UK: Palgrave Macmillan Publishers Ltd.

Allmendinger, P., & Haughton, G. (2019). Opening up Planning? Planning Reform in an Era of "Open Government." *Planning, Practice & Research*, *34*(4), 438–453. https://doi.org/10.1080/02697459.2019.1630973

Allred, S., Stedman, R., Heady, L., & Strong, K. (2021). Incorporating biodiversity in municipal land-use planning: An assessment of technical assistance, policy capacity, and conservation outcomes in New York's Hudson Valley. *Land Use Policy*, *104*, 105344-. https://doi.org/10.1016/j.landusepol.2021.105344

Anderies, J. M., Janssen, M. A., & Ostrom, E. (2004). A Framework to Analyze the Robustness of Social-ecological Systems from an Institutional Perspective. *Ecology and Society*, *9*(1), 18–18. https://doi.org/10.5751/es-00610-090118

Andersson, E., Barthel, S., Borgström, S., Colding, J., Elmqvist, T., Folke, C., & Gren, Asa. (2014). Reconnecting Cities to the Biosphere: Stewardship of Green Infrastructure and Urban Ecosystem Services. *Ambio*, *43*(4), 445–453. https://doi.org/10.1007/s13280-014-0506-y

Ansell, C., & Gash, A. (2008). Collaborative Governance in Theory and Practice. *Journal of Public Administration Research and Theory*, *18*(4), 543–571. https://doi.org/10.1093/jopart/mum032

Apex Resource Management Solutions and C. Talbot & Associates, 2021. Wildlife Corridor Mapping in the Cootes to Escarpment EcoPark System. Report prepared for the Cootes to Escarpment EcoPark System

Armitage, D., de Loë, R., & Plummer, R. (2012). Environmental governance and its implications for conservation practice. *Conservation Letters*, *5*(4), 245–255. https://doi.org/10.1111/j.1755-263X.2012.00238.x

Armitage, D. R., Plummer, R., Berkes, F., Arthur, R. I., Charles, A. T., Davidson-Hunt, I. J., Diduck, A. P., Doubleday, N. C., Johnson, D. S., Marschke, M., McConney, P., Pinkerton, E. W., & Wollenberg, E. K. (2009). Adaptive Co-Management for Social-Ecological Complexity. *Frontiers in Ecology and the Environment*, *7*(2), 95–102. https://doi.org/10.1890/070089

Aslan, C. E., Brunson, M. W., Sikes, B. A., Epanchin-Niell, R. S., Veloz, S., Theobald, D. M., & Dickson, B. G. (2021). Coupled ecological and management connectivity across administrative boundaries in undeveloped landscapes. *Ecosphere (Washington, D.C)*, *12*(1). https://doi.org/10.1002/ecs2.3329

Auerbach, G. (2012). Urban planning: Politics vs. Planning and Politicians vs. Planners. *Horizons in Geography, 69-49,79/80* http://www.jstor.org/stable/23718581

Ayambire, R. A., Pittman, J., Drescher, M., Moreno-Cruz, J., & Olive, A. (2022). Governance of working landscapes: a conceptual framework. *Sustainability Science*, *17*(6), 2579–2596. https://doi.org/10.1007/s11625-022-01178-z

Babí Almenar, J., Bolowich, A., Elliot, T., Geneletti, D., Sonnemann, G., & Rugani, B. (2019). Assessing habitat loss, fragmentation and ecological connectivity in Luxembourg to support spatial planning. *Landscape and Urban Planning*, *189*, 335–351. https://doi.org/10.1016/j.landurbplan.2019.05.004

Baggio, J. A., Schoon, M. L., & Valury, S. (2019). Managing networked landscapes: conservation in a fragmented, regionally connected world. *Regional Environmental Change*, *19*(8), 2551–2562. https://doi.org/10.1007/s10113-019-01567-8

Baker, I., Peterson, A., Brown, G., & McAlpine, C. (2012). Local government response to the impacts of climate change: An evaluation of local climate adaptation plans. *Landscape and Urban Planning*, *107*(2), 127–136. https://doi.org/10.1016/j.landurbplan.2012.05.009

Baldwin, R. F., Trombulak, S. C., & Baldwin, E. D. (2009). Assessing risk of large-scale habitat conversion in lightly settled landscapes. *Landscape and Urban Planning*, *91*(4), 219–225. https://doi.org/10.1016/j.landurbplan.2009.01.004

Barry, J., Horst, M., Inch, A., Legacy, C., Rishi, S., Rivero, J. J., Taufen, A., Zanotto, J. M., & Zitcer, A. (2018). Unsettling planning theory. *Planning Theory (London, England)*, *17*(3), 418–438. https://doi.org/10.1177/1473095218763842

Beita, C. M., Murillo, L. F. S., & Alvarado, L. D. A. (2021). Ecological corridors in Costa Rica: An evaluation applying landscape structure, fragmentation-connectivity process, and climate adaptation. *Conservation Science and Practice*, *3*(8). https://doi.org/10.1111/csp2.475

Beger, M., Metaxas, A., Balbar, A. C., McGowan, J. A., Daigle, R., Kuempel, C. D., Treml, E. A., & Possingham, H. P. (2022). Demystifying ecological connectivity for actionable spatial conservation planning. *Trends in Ecology & Evolution (Amsterdam)*, *37*(12), 1079–1091. https://doi.org/10.1016/j.tree.2022.09.002

Beller, E. E., Spotswood, E. N., Robinson, A. H., Anderson, M. G., Higgs, E. S., Hobbs, R. J., Suding, K. N., Zavaleta, E. S., Grenier, J. L., & Grossinger, R. M. (2019). Building Ecological Resilience in Highly Modified Landscapes. *Bioscience*, *69*(1), 80–92. https://doi.org/10.1093/biosci/biy117

Belote, R. T., Barnett, K., Zeller, K., Brennan, A., & Gage, J. (2022). Examining local and regional ecological connectivity throughout North America. *Landscape Ecology*, *37*(12), 2977–2990. https://doi.org/10.1007/s10980-022-01530-9

Bennett, N. J., & Satterfield, T. (2018). Environmental governance: A practical framework to guide design, evaluation, and analysis. *Conservation Letters*, *11*(6). https://doi.org/10.1111/conl.12600

Bennett, N. J., Whitty, T. S., Finkbeiner, E., Pittman, J., Bassett, H., Gelcich, S., & Allison, E. H. (2018). Environmental Stewardship: A Conceptual Review and Analytical Framework. *Environmental Management (New York)*, *61*(4), 597–614. https://doi.org/10.1007/s00267-017-0993-2

Bergsten, Galafassi, D., & Bodin, Ö. (2014). The problem of spatial fit in social-ecological systems: detecting mismatches between ecological connectivity and land management in an urban region. *Ecology and Society*, *19*(4), 6–. https://doi.org/10.5751/ES-06931-190406

Bergsten, A., Jiren, T. S., Leventon, J., Dorresteijn, I., Schultner, J., & Fischer, J. (2019). Identifying governance gaps among interlinked sustainability challenges. *Environmental Science & Policy*, *91*, 27–38. https://doi.org/10.1016/j.envsci.2018.10.007

Bergsten, A., & Zetterberg, A. (2013). To model the landscape as a network: A practitioner's perspective. *Landscape and Urban Planning*, *119*, 35–43. https://doi.org/10.1016/j.landurbplan.2013.06.009

Berke, P., Spurlock, D., Hess, G., & Band, L. (2013). Local comprehensive plan quality and regional ecosystem protection: The case of the Jordan Lake watershed, North Carolina, U.S.A. *Land Use Policy*, *31*, 450–459. https://doi.org/10.1016/j.landusepol.2012.08.009

Berkes, F. & Folke, C. (1998) Linking Social and Ecological Systems for Resilience and Sustainability. In: Berkes, F., Folke, C. and Colding, J., Eds., Linking Social and Ecological Systems: Management Practices and Social Mechanisms for Building Resilience, Cambridge University Press

Bettencourt, L. M. A., & Kaur, J. (2011). Evolution and structure of sustainability science. *Proceedings of the National Academy of Sciences - PNAS*, *108*(49), 19540–19545. https://doi.org/10.1073/pnas.1102712108

Beunen, R., & Hagens, J. E. (2009). The use of the concept of ecological networks in nature conservation policies and planning practices. *Landscape Research*, *34*(5), 563–580. https://doi.org/10.1080/01426390903184280

Bixler, R. P., Wald, D. M., Ogden, L. A., Leong, K. M., Johnston, E. W., & Romolini, M. (2016). Network governance for large-scale natural resource conservation and the challenge of capture. *Frontiers in Ecology and the Environment*, *14*(3), 165–171. https://doi.org/10.1002/fee.1252

Boehnke, D., Jehling, M., & Vogt, J. (2023). What hinders climate adaptation? Approaching barriers in municipal land use planning through participant observation. *Land Use Policy*, *132*, 106786-. https://doi.org/10.1016/j.landusepol.2023.106786

Bodin, Ö. (2017). Collaborative environmental governance: Achieving collective action in social-ecological systems. *Science (American Association for the Advancement of Science)*, *357*(6352), 659–659. https://doi.org/10.1126/science.aan1114

Bodin, O., & Chen, H. (2023). A network perspective of human-nature interactions in dynamic and fast-changing landscapes. *National Science Review*, *10*(7). https://doi.org/10.1093/nsr/nwad01

Bodin, Ö., & Crona, B. I. (2009). The role of social networks in natural resource governance: What relational patterns make a difference? *Global Environmental Change*, *19*(3), 366–374. https://doi.org/10.1016/j.gloenvcha.2009.05.002

Bodin, Ö., Robins, G., McAllister, R. R. J., Guerrero, A. M., Crona, B., Tengö, M., & Lubell, M. (2016). Theorizing benefits and constraints in collaborative environmental governance: a transdisciplinary social-ecological network approach for empirical investigations. *Ecology and Society*, *21*(1), 40–40. https://doi.org/10.5751/ES-08368-210140

Boehnke, D., Jehling, M., & Vogt, J. (2023). What hinders climate adaptation? Approaching barriers in municipal land use planning through participant observation. *Land Use Policy*, *132*, 106786-. https://doi.org/10.1016/j.landusepol.2023.106786

Bookchin, M. (1996). *The Philosophy of Social Ecology.* Black Rose Books.

Boulton, Dedekorkut-Howes, A., & Byrne, J. (2018). Factors shaping urban greenspace provision: A systematic review of the literature. *Landscape and Urban Planning*, *178*, 82–101. https://doi.org/10.1016/j.landurbplan.2018.05.029

Boulton, C., Dedekorkut-Howes, A., & Byrne, J. (2020). Corrigendum to "Factors shaping urban greenspace provision: A systematic review of the literature" [Landscape Urban Plan. 178 (2018) 82–101]. *Landscape and Urban Planning*, *195*, 103713-. https://doi.org/10.1016/j.landurbplan.2019.103713

Bowen, G. A. (2009). Document Analysis as a Qualitative Research Method. *Qualitative Research Journal*, *9*(2), 27–40. https://doi.org/10.3316/QRJ0902027

Braun V, Clarke V. One size fits all? What counts as quality practice in (reflexive) thematic analysis? *Qualitative research in psychology*. 2021;18(3):328-352. doi:10.1080/14780887.2020.1769238

Brodie, J. F., Paxton, M., Nagulendran, K., Balamurugan, G., Clements, G. R., Reynolds, G., Jain, A., & Hon, J. (2016). Connecting science, policy, and implementation for landscape-scale habitat connectivity. *Conservation Biology*, *30*(5), 950–961. https://doi.org/10.1111/cobi.12667

Brody, S. D. (2003). Examining the Effects of Biodiversity on the Ability of Local Plans to Manage Ecological Systems. *Journal of Environmental Planning and Management*, *46*(6), 817–837. https://doi.org/10.1080/0964056032000157615

Brody, S. D., Highfield, W., & Carrasco, V. (2004). Measuring the collective planning capabilities of local jurisdictions to manage ecological systems in southern Florida. *Landscape and Urban Planning*, *69*(1), 33–50. https://doi.org/10.1016/j.landurbplan.2003.09.002

Brody, S. D., & Highfield, W. E. (2005). Does Planning Work?: Testing the Implementation of Local Environmental Planning in Florida. *Journal of the American Planning Association*, *71*(2), 159–175. https://doi.org/10.1080/01944360508976690

Brooks, M.P. (2002). *Planning theory for practitioners.* American Planning Association

Brunckhorst, D. J. (2010). Landscapes Shaped by People and Place Institutions Require a New Conservation Agenda. *Bioscience*, *60*(8), 569–570. https://doi.org/10.1525/bio.2010.60.8.2

Bryant, M. M. (2006). Urban landscape conservation and the role of ecological greenways at local and metropolitan scales. *Landscape and Urban Planning*, *76*(1), 23–44. https://doi.org/10.1016/j.landurbplan.2004.09.029

Bryant, M. M., & Turner, J. S. (2019). From thermodynamics to creativity: McHarg's ecological planning theory and its implications for resilience planning and adaptive design. *Socio-Ecological Practice Research*, *1*(3–4), 325–337. https://doi.org/10.1007/s42532-019-00027-1

Buijs, A., Hansen, R., Van der Jagt, S., Ambrose-Oji, B., Elands, B., Lorance Rall, E., Mattijssen, T., Pauleit, S., Runhaar, H., Stahl Olafsson, A., & Steen Møller, M. (2019). Mosaic governance for urban green infrastructure: Upscaling active citizenship from a local government perspective. *Urban Forestry & Urban Greening.*, *40*, 53–62. https://doi.org/10.1016/j.ufug.2018.06.011

Butler, E. P., Bliss-Ketchum, L. L., de Rivera, C. E., Dissanayake, S. T. M., Hardy, C. L., Horn, D. A., Huffine, B., Temple, A. M., Vermeulen, M. E., & Wallace, H. (2022). Habitat, geophysical, and eco-social connectivity: benefits of resilient socio–ecological landscapes. *Landscape Ecology*, *37*(1), 1–29. https://doi.org/10.1007/s10980-021-01339-y

Campbell, H., Tait, M., and Watkins, C. (2016). 'Is there Space for Better Planning in a Neoliberal World?'in S. S. Fainstein and J. DeFilippis (eds) *Readings in Planning Theory (4th Edition)*. Malden, MA:Wiley-Blackwell,

Cerra, J. F. (2017). Emerging strategies for voluntary urban ecological stewardship on private property. *Landscape and Urban Planning*, *157*, 586–597. https://doi.org/10.1016/j.landurbplan.2016.06.016

Chaffin, B. C., & Gunderson, L. H. (2016). Emergence, institutionalization and renewal: Rhythms of adaptive governance in complex social-ecological systems. *Journal of Environmental Management*, *165*, 81–87. https://doi.org/10.1016/j.jenvman.2015.09.003

Cheok, J., Weeks, R., & Pressey, R. L. (2019). Identifying the strengths and weaknesses of conservation planning at different scales: the Coral Triangle as a case study. *Ecology and Society*, *24*(4), 24-. https://doi.org/10.5751/ES-10919-240424

Cohen, P.J., Evans, L., & Mills, M. (2012). Social networks supporting governance of coastal ecosystems in Solomon Islands: Social networks for ecosystem governance. *Conservation Letters*, *5*, 376–386. https://doi.org/10.1111/j.1755-263x.2012.00255.x

Cohen, W. J. (2019a). *Ecohumanism and the ecological culture: The educational legacy of Lewis Mumford and Ian McHarg.* Temple University Press.

Cohen, W. J. (2019b). The legacy of Design with Nature: from practice to education. *Socio-Ecological Practice Research*, *1*(3–4), 339–345. https://doi.org/10.1007/s42532-019-00026-2

Conservation Authorities Act (1990). R.S.O. Chapter c.27. Retrieved from https://www.ontario.ca/laws/statute/90c27#BK1

Conservation Ontario (2024). Conservation Authorities. Available at https://conservationontario.ca

Convention on Migratory Species (CMS). 2020. Improving ways of addressing connectivity in the conservation of migratory species, resolution 12.26 (REV.COP13), Gandhinagar, India (17–22 February 2020). [online]: Available from https://www.cms.int/sites/default/files/document/cms_cop13_res.12.26_rev.cop13_e.pdf

Cooke, B., & Moon, K. (2015). Aligning 'public good' environmental stewardship with the landscape-scale: Adapting MBIs for private land conservation policy. *Ecological Economics*, 114: 152-158.

Correa Ayram, C. A., Mendoza, M. E., Etter, A., & Salicrup, D. R. P. (2016). Habitat connectivity in biodiversity conservation: A review of recent studies and applications. *Progress in Physical Geography*, *40*(1), 7–37. https://doi.org/10.1177/0309133315598713

Cortinovis, C., & Geneletti, D. (2018). Ecosystem services in urban plans: What is there, and what is still needed for better decisions. *Land Use Policy*, *70*, 298–312. https://doi.org/10.1016/j.landusepol.2017.10.017

Creswell, J.W. (2013). *Qualitative inquiry & research design: choosing among the five approaches.* Thousand Oaks, CA*:* Sage Publications*.*

Creswell, J.W. and Poth, C.N. (2018) Qualitative Inquiry and Research Design Choosing among Five Approaches. 4th Edition, SAGE Publications, Inc., Thousand Oaks

Crins, W.J., P.A. Gray, W.C. Uhlig and M.C. Wester. (2009). The ecosystems of Ontario, Part 1: Ecozones and Ecoregions. Inventory, Monitoring and Assessment Section, Ontario Ministry of Natural Resources, Peterborough, Ontario. Technical Report SIB TER IMA TR–01

Crona, B. I., & Parker, J. N. (2012). Learning in Support of Governance: Theories, Methods, and a Framework to Assess How Bridging Organizations Contribute to Adaptive Resource Governance. *Ecology and Society*, *17*(1), 32–32. https://doi.org/10.5751/ES-04534-170132

Cumming, G. S., & Allen, C. R. (2017). Protected areas as social-ecological systems: perspectives from resilience and social-ecological systems theory. *Ecological Applications*, *27*(6), 1709–1717. https://doi.org/10.1002/eap.1584

Cumming, G. S., Epstein, G., Anderies, J. M., Apetrei, C. I., Baggio, J., Bodin, Ö., Chawla, S., Clements, H. S., Cox, M., Egli, L., Gurney, G. G., Lubell, M., Magliocca, N., Morrison, T. H., Müller, B., Seppelt, R., Schlüter, M., Unnikrishnan, H., Villamayor-Tomas, S., & Weible, C. M. (2020). Advancing understanding of natural resource governance: a post-Ostrom research agenda. *Current Opinion in Environmental Sustainability*, *44*, 26–34. https://doi.org/10.1016/j.cosust.2020.02.005

Daniels, T. (2019). McHarg's theory and practice of regional ecological planning: retrospect and prospect. *Socio-Ecological Practice Research*, *1*(3–4), 197–208. https://doi.org/10.1007/s42532-019-00024-4

DeCaro, D. A., & Stokes, M. K. (2013). Public Participation and Institutional Fit: A Social–Psychological Perspective. *Ecology and Society*, *18*(4), 851–871. https://doi.org/10.5751/es-05837-180440

De Montis, A., Caschili, S., Mulas, M., Modica, G., Ganciu, A., Bardi, A., Ledda, A., Dessena, L., Laudari, L., & Fichera, C. R. (2016). Urban–rural ecological networks for landscape planning. *Land Use Policy*, *50*, 312–327. https://doi.org/10.1016/j.landusepol.2015.10.004

Di Marino, M., Tiitu, M., Lapintie, K., Viinikka, A., & Kopperoinen, L. (2019). Integrating green infrastructure and ecosystem services in land use planning. Results from two Finnish case studies. *Land Use Policy*, *82*, 643–656. https://doi.org/10.1016/j.landusepol.2019.01.007

Donald, P. F., & Evans, A. D. (2006). Habitat Connectivity and Matrix Restoration: The Wider Implications of Agri-Environment Schemes. *The Journal of Applied Ecology*, *43*(2), 209–218. https://doi.org/10.1111/j.1365-2664.2006.01146.x

Donati, G. F. A., Bolliger, J., Psomas, A., Maurer, M., & Bach, P. M. (2022). Reconciling cities with nature: Identifying local Blue-Green Infrastructure interventions for regional biodiversity enhancement. *Journal of Environmental Management*, *316*, 115254–115254. https://doi.org/10.1016/j.jenvman.2022.115254

dos Santos, R. F., Antunes, P., Ring, I., & Clemente, P. (2015). Engaging Local Private and Public Actors in Biodiversity Conservation: The role of Agri-Environmental schemes and Ecological fiscal transfers. *Environmental Policy and Governance*, *25*(2), 83–96. https://doi.org/10.1002/eet.1661

Doucet, T. C., Duinker, P. N., Charles, J. D., Steenberg, J. W. N., & Zurba, M. (2024). Characterizing Non-governmental Organizations and Local Government Collaborations In Urban Forest Management Across Canada. *Environmental Management (New York)*, *73*(1), 231–242. https://doi.org/10.1007/s00267-023-01889-8

Drescher, M. (2014). What is it like to take care of the land? Toward an understanding of private land conservation. *Rural Society*, *23*(2), 117–132. https://doi.org/10.5172/rsj.2014.23.2.117

Drescher, M., & Brenner, J. C. (2018). The practice and promise of private land conservation. *Ecology and Society*, *23*(2), 3-. https://doi.org/10.5751/ES-10020-230203

Drescher,M., Milligan,Z., Edwards, R.C. and Filion, P.2018. Identifying barriers and opportunities within professional planning practice in Ontario. University of Waterloo.

Drescher, M., Warriner, G. K., Farmer, J. R., & Larson, B. M. H. (2017). Private landowners and environmental conservation: a case study of social-psychological determinants of conservation program participation in Ontario. *Ecology and Society*, *22*(1), 44-. https://doi.org/10.5751/ES-09118-220144

Dupras, J., Drouin, C., André, P., & Gonzalez, A. (2015). Towards the Establishment of a Green Infrastructure in the Region of Montreal (Quebec, Canada). *Planning, Practice & Research*, *30*(4), 355–375. https://doi.org/10.1080/02697459.2015.1058073

Dupras, J., Marull, J., Parcerisas, L., Coll, F., Gonzalez, A., Girard, M., & Tello, E. (2016). The impacts of urban sprawl on ecological connectivity in the Montreal Metropolitan Region. *Environmental Science & Policy*, *58*, 61–73. https://doi.org/10.1016/j.envsci.2016.01.005

Duvall, A. L., Metcalf, A. L., & Coates, P. S. (2017). Conserving the Greater Sage-Grouse: A Social-Ecological Systems Case Study from the California-Nevada Region. *Rangeland Ecology & Management*, *70*(1), 129–140. https://doi.org/10.1016/j.rama.2016.08.001

Egerer, M., & Anderson, E. (2020). Social-ecological connectivity to understand ecosystem Service provision across networks in urban landscapes. *Land (Basel)*, *9*(12), 1–14. https://doi.org/10.3390/LAND9120530

Ekstrom, J.A. and O.R. Young. (2009). Evaluating functional fit between a set of institutions and an ecosystem. Ecology and Society 14(2): 16

Elton, K., & Drescher, M. (2019). Implementing wildlife-management strategies into road infrastructure in southern Ontario: a critical success factors approach. *Journal of Environmental Planning and Management*, *62*(5), 862–880. https://doi.org/10.1080/09640568.2018.1447445

Enqvist, J. P., Tengö, M., & Bodin, Ö. (2020). Are bottom-up approaches good for promoting social–ecological fit in urban landscapes? *Ambio*, *49*(1), 49–61. https://doi.org/10.1007/s13280-019-01163-4

Environment Canada (2013). *How much habitat is enough?* (3rd ed.). Canadian Wildlife Service.

Epstein, G., Pittman, J., Alexander, S. M., Berdej, S., Dyck, T., Kreitmair, U., Rathwell, K. J., Villamayor-Tomas, S., Vogt, J., & Armitage, D. (2015). Institutional fit and the sustainability of social–ecological systems. *Current Opinion in Environmental Sustainability*, *14*, 34–40. https://doi.org/10.1016/j.cosust.2015.03.005

Escobedo Garcia, N., & Ulibarri, N. (2023). Planning for effective water management: an evaluation of water management plans in California. *Journal of Environmental Planning and Management*, *66*(13), 2739–2759. https://doi.org/10.1080/09640568.2022.2082930

Essex Region Conservation Authority (2008). City of Windsor Update to the CNHS Inventory [online]. City of Windsor. Available at https://www.citywindsor.ca/residents/planning/plans-and-community-information/official-plan-review/documents/opr%20natural%20areas%20policy%20review.pdf

Fahrig, L. (2003). Effects of Habitat Fragmentation on Biodiveristy. *Annual Review of Ecology, Evolution, and Systematics*, *34*(1), 487–515. https://doi.org/10.1146/annurev.ecolsys.34.011802.132419

Fahrig, L. (2019). Habitat fragmentation: A long and tangled tale. *Global Ecology and Biogeography*, *28*(1), 33–41. https://doi.org/10.1111/geb.12839

Fainstein, S.S. (2000). New Directions in Planning Theory. *Urban Affairs Review.* 35(4), 451-478.

Fainstein, S.S. and DeFilippis, J. (2016). 'Introduction: The Structure and Debates of Planning Theory', in S. S. Fainstein and J. DeFilippis (eds) *Readings in Planning Theory (4th Edition)*. Malden, MA: Wiley-Blackwell, 1-18.

Field, R.D., & Parrott, L. (2017). Multi-ecosystem services networks: A new perspective for assessing landscape connectivity and resilience. Ecological Complexity, 32, 31–41. https://doi.org/10.1016/j.ecocom.2017.08.004

Field, R. D., & Parrott, L. (2022). Mapping the functional connectivity of ecosystem services supply across a regional landscape. *ELife*, *11*. https://doi.org/10.7554/eLife.69395

Filion, P. (2021). Creative or instrumental planners? Agency and structure in their institutional and political economy context. *Planning Theory (London, England)*, *20*(3), 255–274. https://doi.org/10.1177/1473095220980499

Fischer, F. (2012). 'Participatory Governance - From Theory to Practice'. S. S. Fainstein and J. DeFilippis (eds) *Readings in Planning Theory (4th Edition)*. Malden, MA:Wiley-Blackwell

Fischer, A. P. (2015). A boundary-spanning organization for transdisciplinary science on land stewardship: The Stewardship Network. *Ecology and Society*, *20*(4), 38-. https://doi.org/10.5751/ES-08121-200438

Fischer, J., & Lindenmayer, D. B. (2007). Landscape modification and habitat fragmentation: a synthesis. *Global Ecology and Biogeography*, *16*(3), 265–280. https://doi.org/10.1111/j.1466-8238.2007.00287.x

Folke, C., Pritchard, L., Berkes, F., Colding, J., & Svedin, U. (2007). The Problem of Fit between Ecosystems and Institutions: Ten Years Later. *Ecology and Society*, *12*(1), 30-. https://doi.org/10.5751/ES-02064-120130

Ford, A. T., Sunter, E. J., Fauvelle, C., Bradshaw, J. L., Ford, B., Hutchen, J., Phillipow, N., & Teichman, K. J. (2020). Effective corridor width: linking the spatial ecology of wildlife with land use policy. *European Journal of Wildlife Research*, *66*(4). https://doi.org/10.1007/s10344-020-01385-y

Friedmann, J. (1987). *Planning in the Public Domain: From Kmowledge to Action.* Princeton, NJ: Princeton University Press.

García, M., Hileman, J., Bodin, Ö., Nilsson, A., & Jacobi, P. R. (2019). The unique role of municipalities in integrated watershed governance arrangements: a new research frontier. *Ecology and Society*, *24*(1), 28-. https://doi.org/10.5751/ES-10793-240128

Gippoliti, S., & Battisti, C. (2017). More cool than tool: Equivoques, conceptual traps and weaknesses of ecological networks in environmental planning and conservation. *Land Use Policy*, *68*, 686–691. https://doi.org/10.1016/j.landusepol.2017.08.001

Gradinaru, S. R., & Hersperger, A. M. (2019). Green infrastructure in strategic spatial plans: Evidence from European urban regions. *Urban Forestry & Urban Greening*, *40*, 17–28. https://doi.org/10.1016/j.ufug.2018.04.018

Grant, J. L. (2022). When Politicians Call for "Better" Planning, it's Time to Worry. *Planning Theory & Practice*, *23*(4), 491–495. https://doi.org/10.1080/14649357.2022.2121582

Greenaway, G., Lee, T., & Kahal, N. (2019). Planning to connect: A guide to incorporating ecological connectivity into municipal planning. Miistakis Institute. https://www.rockies.ca/files/reports/planning_for_ecological_connectivity.pdf

Guerrero, A., Bodin, O., McAllister, R., & Wilson, K. (2015). Achieving social-ecological fit through bottom-up collaborative governance: an empirical investigation. Ecology and Society, 20(4):41. http://dx.doi.org/10.5751/ES-08035-200441.

Guest, G., MacQueen, K. M., & Namey, E. E. (2012). *Applied thematic analysis*. Sage Publications.

Gurrutxaga, M., Marull, J., Domene, E., & Urrea, J. (2015). Assessing the Integration of Landscape Connectivity into Comprehensive Spatial Planning in Spain. *Landscape Research*, *40*(7), 817–833. https://doi.org/10.1080/01426397.2015.1031096

Haddad, N. M., Brudvig, L. A., Clobert, J., Davies, K. F., Gonzalez, A., Holt, R. D., Lovejoy, T. E., Sexton, J. O., Austin, M. P., Collins, C. D., Cook, W. M., Damschen, E. I., Ewers, R. M., Foster, B. L., Jenkins, C. N., King, A. J., Laurance, W. F., Levey, D. J., Margules, C. R., Townshend, J. R. (2015). Habitat fragmentation and its lasting impact on Earth's ecosystems. *Science Advances*, *1*(2), e1500052–e1500052. https://doi.org/10.1126/sciadv.1500052

Hamilton, M., Fischer, A. P., & Jasny, L. (2021). Bridging collaboration gaps in fragmented environmental governance systems. *Environmental Science & Policy*, *124*, 461–470. https://doi.org/10.1016/j.envsci.2021.07.014

Hannah L. (2011). Climate Change, Connectivity, and Conservation Success: Climate Change and Connectivity. *Conservation Biology*, *25*(6), 1139–1142. https://doi.org/10.1111/j.1523-1739.2011.01788.x

Hardy, C., de Rivera, C., Bliss-Ketchum, L., Butler, E., Dissanayake, S., Horn, D., Huffine, B., Temple, A., Vermeulen, M., Wallace, H., & Karps, J. (2022). Ecosystem Connectivity for Livable Cities: a Connectivity Benefits Framework for Urban Planning. *Ecology and Society*, *27*(2), 36–. https://doi.org/10.5751/ES-13371-270236

Harrington, L. M. B. (2016). Sustainability Theory and Conceptual Considerations: A Review of Key Ideas for Sustainability, and the Rural Context. *Papers in Applied Geography*, *2*(4), 365–382. https://doi.org/10.1080/23754931.2016.1239222

Hauser, L. T., Van Der Sluis, T., & Giezen, M. (2016). The Role of Farm Management Characteristics in Understanding the Spatial Distribution of Landscape Elements: A Case Study in the Netherlands. *Rural Landscapes*, *3*(1), 7–7. https://doi.org/10.16993/rl.14

Healey, P. (1998). Building Institutional Capacity through Collaborative Approaches to Urban Planning. *Environment and Planning. A*, *30*(9), 1531–1546. https://doi.org/10.1068/a301531

Hedlund, J., Nohrstedt, D., Morrison, T., Moore, M.-L., & Bodin, Ö. (2023). Challenges for environmental governance: policy issue interdependencies might not lead to collaboration. *Sustainability Science*, *18*(1), 219–234. https://doi.org/10.1007/s11625-022-01145-8

Heim LaFrombois, M. E., LeBleu, C., Byahut, S., & Rogers, S. (2023). Planning for green infrastructure along the Gulf Coast: an evaluation of comprehensive plans and planning practices in the Mississippi-Alabama coastal region. *Journal of Environmental Planning and Management*, *66*(11), 2352–2372. https://doi.org/10.1080/09640568.2022.2074822

Henson B. L. Riley J. L. Brodribb K. E. & Nature Conservancy of Canada. (2005). *Great lakes conservation blueprint for terrestrial biodiversity*. Nature Conservancy of Canada

Hersperger, A. M., Bürgi, M., Wende, W., Bacău, S., & Grădinaru, S. R. (2020). Does landscape play a role in strategic spatial planning of European urban regions? *Landscape and Urban Planning*, *194*, 103702-. https://doi.org/10.1016/j.landurbplan.2019.103702

Hilty, J.A., Keeley, A.T.H., Lidicker Jr., W.Z, and Merenlender, A.M. (2019). Corridor Ecology: Linking Landscapes for Biodiversity Conservation and Climate Adaptation. 2nd ed. Washington, DC: Island Press

Hilty, J., Worboys, G.L., Keeley, A., Woodley, S., Lausche, B., Locke, H., Carr, M., Pulsford I., Pittock, J., White, J.W., Theobald, D.M., Levine, J., Reuling, M., Watson, J.E.M., Ament, R., & Tabor, G.M. (2020). *Guidelines for conserving connectivity through ecological networks and corridors.* Best Practice Protected Area Guidelines Series No. 30. Gland, Switzerland: IUCN.

Hobbs, R. J., Higgs, E., Hall, C. M., Bridgewater, P., Chapin, F. S., Ellis, E. C., Ewel, J. J., Hallett, L. M., Harris, J., Hulvey, K. B., Jackson, S. T., Kennedy, P. L., Kueffer, C., Lach, L., Lantz, T. C., Lugo, A. E., Mascaro, J., Murphy, S. D., Nelson, C. R., … Yung, L. (2014). Managing the whole landscape: historical, hybrid, and novel ecosystems. *Frontiers in Ecology and the Environment*, *12*(10), 557–564. https://doi.org/10.1890/130300

Holzhauer, S., Brown, C., & Rounsevell, M. (2019). Modelling dynamic effects of multi-scale institutions on land use change. *Regional Environmental Change*, *19*(3), 733–746. https://doi.org/10.1007/s10113-018-1424-5

Honeck, E., Moilanen, A., Guinaudeau, B., Wyler, N., Schlaepfer, M. A., Martin, P., Sanguet, A., Urbina, L., von Arx, B., Massy, J., Fischer, C., & Lehmann, A. (2020). Implementing Green Infrastructure for the Spatial Planning of Peri-Urban Areas in Geneva, Switzerland. *Sustainability*, *12*(4), Article 1387. https://doi.org/10.3390/su12041387

Hou, W., Neubert, M., & Walz, U. (2017). A simplified econet model for mapping and evaluating structural connectivity with particular attention of ecotones, small habitats, and barriers. *Landscape and Urban Planning*, *160*, 28–37. https://doi.org/10.1016/j.landurbplan.2016.11.008

Houston, D., Hillier, J., MacCallum, D., Steele, W., & Byrne, J. (2018). Make kin, not cities! Multispecies entanglements and 'becoming-world' in planning theory. *Planning Theory (London, England)*, *17*(2), 190–212. https://doi.org/10.1177/1473095216688042

Huber, P. R., Shilling, F., Thorne, J. H., & Greco, S. E. (2012). Municipal and regional habitat connectivity planning. *Landscape and Urban Planning*, *105*(1–2), 15–26. https://doi.org/10.1016/j.landurbplan.2011.11.019

Innes, J. E., & Booher, D. E. (2004). Reframing public participation: strategies for the 21st century. *Planning Theory & Practice*, *5*(4), 419–436. https://doi.org/10.1080/1464935042000293170

Jalava, J.V., P.J. Sorrill, J. Henson and K. Brodribb. 2002. The Big Picture Project: Developing a Natural Heritage Vision for Canada's Southernmost Ecological Region [online]. Available at http://www.carolinian.org/ConservationPrograms_BigPictureMethodology2.htm

Jalava, J.V., M. Kanter and K. Wysocki. 2019. *Big Picture Protected Areas Strategy for Ontario's Carolinian Zone, Version 1, February 2019*. Carolinian Canada Coalition, London, Ontario.

Jennings, M., Haeuser, E., Foote, D., Lewison, R., & Conlisk, E. (2020). Planning for Dynamic Connectivity: Operationalizing Robust Decision-Making and Prioritization Across Landscapes Experiencing Climate and Land-Use Change. *Land (Basel)*, *9*(10), 341-. https://doi.org/10.3390/land9100341

Johnson, L. (Ed.). (2007). *The natural treasures of Carolinian Canada: Discovering the rich natural diversity of Ontario's southwestern heartland.* James Lorimer and Company Ltd

Joy, R. (2019). Walk With Joy. *Building*, *69*(1), 30–30.

Kamal, S., Grodzinska-Jurczak, M., & Kaszynska, A. P. (2015). Challenges and opportunities in biodiversity conservation on private land: an institutional perspective from Central Europe and North America. *Biodiversity and Conservation*, *24*(5), 1271–1292. https://doi.org/10.1007/s10531-014-0857-5

Kark, S., Tulloch, A., Gordon, A., Mazor, T., Bunnefeld, N., & Levin, N. (2015). Cross-boundary collaboration: key to the conservation puzzle. *Current Opinion in Environmental Sustainability*, *12*, 12–24. https://doi.org/10.1016/j.cosust.2014.08.005

Keeley, A. T. H., Basson, G., Cameron, D. R., Heller, N. E., Huber, P. R., Schloss, C. A., Thorne, J. H., & Merenlender, A. M. (2018). Making habitat connectivity a reality. *Conservation Biology*, *32*(6), 1221–1232. https://doi.org/10.1111/cobi.13158

Keeley, A.T. H., Beier, P., Creech, T.G., Jones, K., Jongman, R.H., Stonecipher, G., & Tabor, G. (2019). Thirty years of connectivity conservation planning: an assessment of factors influencing plan implementation. *Environmental Research Letters, 14*.

Keeley, A. T. H., Beier, P., & Jenness, J. S. (2021). Connectivity metrics for conservation planning and monitoring. *Biological Conservation*, *255*, 109008-. https://doi.org/10.1016/j.biocon.2021.109008

Keeley, A. T. H., Fremier, A. K., Goertler, P. A. L., Huber, P. R., Sturrock, A. M., Bashevkin, S. M., Barbaree, B. A., Grenier, J. L., Dilts, T. E., Gogol-Prokurat, M., Colombano, D. D., Bush, E. E., Laws, A., Gallo, J. A., Kondolf, M., & Stahl, A. T. (2022). Governing Ecological Connectivity in Cross-Scale Dependent Systems. *Bioscience*, *72*(4), 372–386. https://doi.org/10.1093/biosci/biab140

Khoshkar, S., Hammer, M., Borgström, S., & Balfors, B. (2020). Ways forward for advancing ecosystem services in municipal planning—experiences from Stockholm county. *Land (Basel)*, *9*(9), 296-. https://doi.org/10.3390/land9090296

Kimberley, A., Hooftman, D., Bullock, J. M., Honnay, O., Krickl, P., Lindgren, J., Plue, J., Poschlod, P., Traveset, A., & Cousins, S. A. O. (2021). Functional rather than structural connectivity explains grassland plant diversity patterns following landscape scale habitat loss. *Landscape Ecology*, *36*(1), 265–280. https://doi.org/10.1007/s10980-020-01138-x

Kininmonth, s., Bergsten, A., & Bodin, Ö. (2015). Closing the collaborative gap: Aligning social and ecological connectivity for better management of interconnected wetlands. *Ambio*, *44*(Suppl 1), S138–S148. https://doi.org/10.1007/s13280-014-0605-9

Koontz, T. M., & Elizabeth Moore Johnson. (2004). One Size Does Not Fit All: Matching Breadth of Stakeholder Participation to Watershed Group Accomplishments. *Policy Sciences*, *37*(2), 185–204. https://doi.org/10.1023/B:OLIC.0000048532.94150.07

Kor, L., O'Hickey, B., Hanson, M., & Coroi, M. (2022). Assessing habitat connectivity in environmental impact assessment: a case-study in the UK context. *Impact Assessment and Project Appraisal*, *40*(6), 495–506. https://doi.org/10.1080/14615517.2022.2128557

Kovács-Hostyánszki, A., Espíndola, A., Vanbergen, A. J., Settele, J., Kremen, C., Dicks, L. V., & Irwin, R. (2017). Ecological intensification to mitigate impacts of conventional intensive land use on pollinators and pollination. *Ecology Letters*, *20*(5), 673–689. https://doi.org/10.1111/ele.12762

Kraus, D., & Hebb, A. (2020). Southern Canada's crisis ecoregions: identifying the most significant and threatened places for biodiversity conservation. *Biodiversity and Conservation*, *29*(13), 3573–3590. https://doi.org/10.1007/s10531-020-02038-x

Kukkala, A. S., & Moilanen, A. (2017). Ecosystem services and connectivity in spatial conservation prioritization. *Landscape Ecology*, *32*(1), 5–14. https://doi.org/10.1007/s10980-016-0446-y

Kumar, S., & Cushman, S. A. (2022). Connectivity modelling in conservation science: a comparative evaluation. *Scientific Reports*, *12*(1), 16680–16680. https://doi.org/10.1038/s41598-022-20370-w

Lam, S. T., & Conway, T. M. (2018). Ecosystem services in urban land use planning policies: A case study of Ontario municipalities. *Land Use Policy*, *77*, 641–651. https://doi.org/10.1016/j.landusepol.2018.06.020

Larsen, L. G., Choi, J., Nungesser, M. K., & Harvey, J. W. (2012). Directional connectivity in hydrology and ecology. *Ecological Applications*, *22*(8), 2204–2220. https://doi.org/10.1890/11-1948.1

Le, T., & Tran, T. (2023). An Evaluation of Local Comprehensive Plans Regarding Green Infrastructure in 52 Cities across the U.S. Gulf Coast Region. *Sustainability (Basel, Switzerland)*, *15*(10), 7939-. https://doi.org/10.3390/su15107939

Leck, H., & Simon, D. (2013). Fostering Multiscalar Collaboration and Co-operation for Effective Governance of Climate Change Adaptation. *Urban Studies (Edinburgh, Scotland)*, *50*(6), 1221–1238. https://doi.org/10.1177/0042098012461675

Leibenath, M. (2011). Exploring Substantive Interfaces between Spatial Planning and Ecological Networks in Germany. *Planning, Practice & Research*, *26*(3), 257–270. https://doi.org/10.1080/02697459.2011.580110

Lein, K.L., (2003). *Integrated Environmental Planning.* Blackwell Science Ltd.

Lemieux, C. J., Jacob, A.L., & Gray, P.A.. 2021. *Implementing Connectivity Conservation in Canada: Canadian Council on Ecological Areas (CCEA) Occasional Paper No. 22.* Canadian Council on Ecological Areas, Wilfrid Laurier University, Waterloo, Ontario, Canada.

Lemos, M. C., & Agrawal, A. (2006). Environmental governance. *Annual Review of Environment and Resources*, *31*(1), 297–325. https://doi.org/10.1146/annurev.energy.31.042605.135621

Lennon, M. (2015). Green infrastructure and planning policy: a critical assessment. *Local Environment*, *20*(8), 957–980. https://doi.org/10.1080/13549839.2014.880411

Leopold, A. (1949). *A Sand County Almanac.* Oxford University Press Inc.

Li, H., Wang, X., Mu, R., & Liu, L. (2024). Hierarchical interventions and environmental collaboration among municipal governments: a bottom-up analysis. *Journal of Environmental Planning and Management*, *67*(7), 1513–1535. https://doi.org/10.1080/09640568.2023.2174090

Linton, J, J. McCarter & Fotherby, H. (2018). *Recovery Strategy for the Jefferson Salamander (Ambystoma jeffersonianum) and Unisexual Ambystoma (Jefferson Salamander dependent population) (Ambystoma laterale–- (2) jeffersonianum) in Ontario.* Ontario Recovery Strategy Series. Ontario Ministry of Natural Resources and Forestry, Peterborough, Ontario.

Liquete, C., Kleeschulte, S., Dige, G., Maes, J., Grizzetti, B., Olah, B., & Zulian, G. (2015). Mapping green infrastructure based on ecosystem services and ecological networks: A Pan-European case study. *Environmental Science & Policy*, *54*, 268–280. https://doi.org/10.1016/j.envsci.2015.07.009

Leventon, J., Schaal, T., Velten, S., Dänhardt, J., Fischer, J., Abson, D. J., & Newig, J. (2017). Collaboration or fragmentation? Biodiversity management through the common agricultural policy. *Land Use Policy*, *64*, 1–12. https://doi.org/10.1016/j.landusepol.2017.02.009

Lochmiller, C. (2021). Conducting Thematic Analysis with Qualitative Data. *Qualitative Report*, *26*(6), 2029–2044. https://doi.org/10.46743/2160-3715/2021.5008

Lockwood, M. (2010). Good governance for terrestrial protected areas: A framework, principles and performance outcomes. *Journal of Environmental Management*, *91*(3), 754–766. https://doi.org/10.1016/j.jenvman.2009.10.005

Löfgren, S. (2020). Knowing the landscape: a theoretical discussion on the challenges in forming knowledge about landscapes. *Landscape Research*, *45*(8), 921–933. https://doi.org/10.1080/01426397.2020.1808962

Lubell, M. (2015). Collaborative partnerships in complex institutional systems. *Current Opinion in Environmental Sustainability*, *12*, 41–47. https://doi.org/10.1016/j.cosust.2014.08.011

Lynch, A. J. (2019). Creating Effective Urban Greenways and Stepping-stones: Four Critical Gaps in Habitat Connectivity Planning Research. *Journal of Planning Literature*, *34*(2), 131–155. https://doi.org/10.1177/0885412218798334

Mancilla García, M., Hileman, J., Bodin, Ö., Nilsson, A., & Jacobi, P. R. (2019). The unique role of municipalities in integrated watershed governance arrangements: a new research frontier. *Ecology and Society*, *24*(1), 28-. https://doi.org/10.5751/ES-10793-240128

Martin. (2016). Ecological restoration of rural landscapes: stewardship, governance, and fairness. *Restoration Ecology.*, *24*(5), 680–685. https://doi.org/10.1111/rec.12411

McCarthy, D. D. P., Whitelaw, G. S., Westley, F. R., Crandall, D. D., & Burnett, D. (2014). The Oak Ridges Moraine as a Social Innovation: Strategic Vision as a Social-Ecological Interaction. *Ecology and Society*, *19*(1), 48–12. https://doi.org/10.5751/ES-06212-190148

McLean, C. T., Roberts, D. C., & Slotow, R. (2024). The Evolution of Open Space Planning within a Developing, Biodiverse City (Durban, South Africa). *Sustainability*, *16*(7), 3073-. https://doi.org/10.3390/su16073073

McCullough, I. M., Hanly, P. J., King, K. B. S., & Wagner, T. (2022). Freshwater corridors in the conterminous United States: A coarse-filter approach based on lake-stream networks. *Ecosphere (Washington, D.C)*, *13*(12). https://doi.org/10.1002/ecs2.4326

McRae, B. H., Hall, S. A., Beier, P., & Theobald, D. M. (2012). Where to restore ecological connectivity? Detecting barriers and quantifying restoration benefits. *PloS One*, *7*(12), e52604-. https://doi.org/10.1371/journal.pone.0052604

Meine, C. (2020). From the land to socio-ecological systems: the continuing influence of Aldo Leopold. *Socio-Ecological Practice Research*, *2*(1), 31–38. https://doi.org/10.1007/s42532-020-00044-5

Meneguetti, K. S., & Oliveira, F. L. de. (2021). Reconsidering green belts, green wedges and greenways. *Acta Scientiarum. Technology*, *43*, e55196-. https://doi.org/10.4025/actascitechnol.v43i1.55196

Middlesex County. 2014. Middlesex County Natural Heritage Systems Study: A study to identify natural heritage systems in Middlesex County. Project management by Upper Thames River Conservation Authority in cooperation with Middlesex County Conservation Authorities.

Mills, Álvarez-Romero, J. G., Vance-Borland, K., Cohen, P., Pressey, R. L., Guerrero, A. M., & Ernstson, H. (2014). Linking regional planning and local action: Towards using social network analysis in systematic conservation planning. *Biological Conservation*, *169*, 6–13. https://doi.org/10.1016/j.biocon.2013.10.015

Millner, A., & Ollivier, H. (2016). Beliefs, Politics, and Environmental Policy. *Review of Environmental Economics and Policy*, *10*(2), 226–244. https://doi.org/10.1093/reep/rew010

Mitchell, M. G. E., Bennett, E. M., & Gonzalez, A. (2013). Linking Landscape Connectivity and Ecosystem Service Provision: Current Knowledge and Research Gaps. *Ecosystems (New York)*, *16*(5), 894–908. https://doi.org/10.1007/s10021-013-9647-2

Mitchell, M. G. E., Bennett, E. M., Gonzalez, A., Lechowicz, M. J., Rhemtulla, J. M., Cardille, J. A., Vanderheyden, K., Poirier-Ghys, G., Renard, D., Delmotte, S., Albert, C. H., Rayfield, B., Dumitru, M., Huang, H.-H., Larouche, M., Liss, K. N., Maguire, D. Y., Martins, K. T., Terrado, M., Ziter, c., Taliana, L., & Dancose, K. (2015). The Montérégie Connection: linking landscapes, biodiversity, and ecosystem services to improve decision making. *Ecology and Society*, *20*(4), 15-. https://doi.org/10.5751/ES-07927-200415

Modica, G., Praticò, S., Laudari, L., Ledda, A., Di Fazio, S., & De Montis, A. (2021). Implementation of multispecies ecological networks at the regional scale: analysis and multi-temporal assessment. *Journal of Environmental Management*, *289*, 112494–112494. https://doi.org/10.1016/j.jenvman.2021.112494

Moss, T. (2012). Spatial fit, from panacea to practice: implementing the EU Water Framework Directive. Ecology and Society 17(3): 2 http://dx.doi.org/10.5751/ES-04821-170302

Moss, M. R., & Milne, R. J. (1998). Biophysical processes and bioregional planning: The Niagara Escarpment of southern Ontario, Canada. *Landscape and Urban Planning*, *40*(4), 251–268. https://doi.org/10.1016/S0169-2046(97)00116-3

Nebel, S., Brick, J., Lantz, V. A., & Trenholm, R. (2017). Which Factors Contribute to Environmental Behaviour of Landowners in Southwestern Ontario, Canada? *Environmental Management (New York)*, *60*(3), 454–463. https://doi.org/10.1007/s00267-017-0849-9

Nel, J. L., Roux, D. J., Driver, A., Hill, L., Maherry, A. C., Snaddon, K., Petersen, C. R., Smith-Adao, L. B., Van Deventer, H., & Reyers, B. (2016). Knowledge co-production and boundary work to promote implementation of conservation plans. *Conservation Biology*, *30*(1), 176–188. https://doi.org/10.1111/cobi.12560

Newig, J., & Fritsch, O. (2009). Environmental governance: participatory, multi-level - and effective? *Environmental Policy and Governance*, *19*(3), 197–214. https://doi.org/10.1002/eet.509

Newig, J., Schulz, D., & Jager, N. W. (2016). Disentangling Puzzles of Spatial Scales and Participation in Environmental Governance—The Case of Governance Re-scaling Through the European Water Framework Directive. *Environmental Management (New York)*, *58*(6), 998–1014. https://doi.org/10.1007/s00267-016-0753-8

Newell, R., Dale, A., & Lister, N.-M. (2022). An integrated climate-biodiversity framework to improve planning and policy: an application to wildlife crossings and landscape connectivity. *Ecology and Society*, *27*(1), 23-. https://doi.org/10.5751/ES-12999-270123

Ng, C. N., Xie, Y. J., & Yu, X. J. (2013). Integrating landscape connectivity into the evaluation of ecosystem services for biodiversity conservation and its implications for landscape planning. *Applied Geography (Sevenoaks)*, *42*, 1–12. https://doi.org/10.1016/j.apgeog.2013.04.01

Norton, R. K. (2008). Using content analysis to evaluate local master plans and zoning codes. *Land Use Policy*, *25*(3), 432–454. https://doi.org/10.1016/j.landusepol.2007.10.006

Nowell, L. S., Norris, J. M., White, D. E., & Moules, N. J. (2017). Thematic Analysis: Striving to Meet the Trustworthiness Criteria. *International Journal of Qualitative Methods*, *16*(1), 1–13. https://doi.org/10.1177/1609406917733847

Oldham, Michael J. (2017). List of the Vascular Plants of Ontario's Carolinian Zone (Ecoregion 7E). Carolinian Canada and Ontario Ministry of Natural Resources and Forestry. Peterborough, ON

Olive, A., & McCune, J. L. (2017). Wonder, ignorance, and resistance: Landowners and the stewardship of endangered species. *Journal of Rural Studies*, *49*, 13–22. https://doi.org/10.1016/j.jrurstud.2016.11.014

Office of the Auditor General of Ontario (2023). The State of the Environment in Ontario Report. Available at https://auditor.on.ca/en/content/specialreports/specialreports/The_State_Of_The_Environment_EN.pdf

[OMMA] Ontario ministry of Municipal Affairs. (2017a). Greenbelt Plan [online]. Queen's Printer for Ontario. Available at https://files.ontario.ca/greenbelt-plan-2017-en.pdf

[OMMAH] Ontario Ministry of Municipal Affairs and Housing. (2020a). Provincial Policy Statement [online]. Queen's Printer for Ontario. Available at https://files.ontario.ca/mmah-provincial-policy-statement-2020-accessible-final-en-2020-02-14.pdf .

[OMMAH] Ontario Ministry of Municipal Affairs and Housing. (2020b). A Place to Grow: Growth Plan for the Greater Golden Horseshoe [online]. Queen's Printer for Ontario. Available at https://www.ontario.ca/document/place-grow-growth-plan-greater-golden-horseshoe

[OMMAH] Ontario Ministry of Municipal Affairs and Housing (2022). Bill 23, More Houses Built Faster Act [online]. Available at https://www.ola.org/sites/default/files/node-files/bill/document/pdf/2022/2022-11/b023ra_e.pdf

[OMMAH} Ontario Ministry of Municipal Affairs and Housing (2023). Value for Money Audit: Land Use Planning in the Greater Golden Horseshoe. Available at https://www.auditor.on.ca/en/content/annualreports/arreports/en23/1-10FU_land-use_en23.pdf

[OMNRF] Ontario Ministry of Natural Resources and Forestry. (2017). Niagara Escarpment Plan [online]. Queens Printer for Ontario. Available at https://escarpment.org/wp-content/uploads/2021/05/NEP-Consolidation-April-5-2021-FINAL.pdf

Ontario Biodiversity Council. (2020). State of Ontario's Biodiversity 2020 Summary. Available at https://sobr.ca/_biosite/wp-content/uploads/state-of-biodiversity-report-E-FINAL-aoda-with-links-and-correction-1.pdf

Ontario Planning Act (1990). R.S.O. Chapter P.13. https://www.ontario.ca/laws/statute/90p13

Opdam, P., Steingröver, E., & Rooij, S. van. (2006). Ecological networks: A spatial concept for multi-actor planning of sustainable landscapes. *Landscape and Urban Planning*, *75*(3), 322–332. https://doi.org/10.1016/j.landurbplan.2005.02.015

Oppler, G., Hilty, J. A., Laur, A. T., & Tabor, G. (2021). Connectivity conservation: The time is now. *Parks Stewardship Forum*, *37*(3), 448–455. https://doi.org/10.5070/P537354717

Parks Canada. (2024). National Program for Ecological corridors. Available at https://parks.canada.ca/nature/science/conservation/corridors-ecologiques-ecological-corridors

Park, S. (2015). Spatial assessment of landscape ecological connectivity in different urban gradient. *Environmental Monitoring and Assessment*, *187*(7), 425–425. https://doi.org/10.1007/s10661-015-4645-9

Palomo, I., Montes, C., Martin-Lopez, B., Gonzalez, J. A., Garcia-Llorente, M., Alcorlo, P., & Mora, M. R. G. (2014). Incorporating the Social–Ecological Approach in Protected Areas in the Anthropocene. *Bioscience*, *64*(3), 181–191. https://doi.org/10.1093/biosci/bit033

Parrott, L., Kyle, C., Hayot-Sasson, V., Bouchard, C., & Cardille, J. A. (2019). Planning for ecological connectivity across scales of governance in a multifunctional regional landscape. *Ecosystems and People (Abingdon, England)*, *15*(1), 204–213. https://doi.org/10.1080/26395916.2019.1649726

Patterson, C., Torres, A., Coroi, M., Cumming, K., Hanson, M., Noble, B., Tabor, G., Treweek, J., & Jaeger, J. A. G. (2022). Treatment of ecological connectivity in environmental assessment: A global survey of current practices and common issues. *Impact Assessment and Project Appraisal*, *40*(6), 460–474. https://doi.org/10.1080/14615517.2022.2099728

Peirson, W., Davey, E., Jones, A., Hadwen, W., Bishop, K., Beger, M., Capon, S., Fairweather, P., Creese, B., Smith, T. F., Gray, L., & Tomlinson, R. (2015). Opportunistic management of estuaries under climate change: A new adaptive decision-making framework and its practical application. *Journal of Environmental Management*, *163*, 214–223. https://doi.org/10.1016/j.jenvman.2015.08.021

Pelosi, C., Goulard, M., & Balent, G. (2010). The spatial scale mismatch between ecological processes and agricultural management: Do difficulties come from underlying theoretical frameworks? *Agriculture, Ecosystems & Environment*, *139*(4), 455–462. https://doi.org/10.1016/j.agee.2010.09.004

Perrin, M., Bertrand, N., Kohler, Y. (2019). PLACE Report: Spatial Planning & Ecological Connectivity - an analytical overview across the Alpine Convention area. French Ministry for the Ecological and Inclusive Transition (MTES)

Perrin, M., Bertrand, N., & Vanpeene, S. (2022). Ecological connectivity in spatial planning: from the EU framework to its territorial implementation in the French context. *Environmental Science & Policy*, *129*, 118–125. https://doi.org/10.1016/j.envsci.2021.12.011

Pittman, J., & Armitage, D. (2019). Network Governance of Land-Sea Social-Ecological Systems in the Lesser Antilles. *Ecological Economics*, *157*, 61–70. https://doi.org/10.1016/j.ecolecon.2018.10.013

Popescu, O.-C., Tache, A.-V., & Petrișor, A.-I. (2022). Methodology for Identifying Ecological Corridors: A Spatial Planning Perspective. *Land (Basel)*, *11*(7), 1013-. https://doi.org/10.3390/land11071013

Puric-Mladenovic, D., & Strobl, S. (2012). Designing natural heritage systems in southern Ontario using a systematic conservation planning approach. *Forestry Chronicle*, *88*(6), 722–735. https://doi.org/10.5558/tfc2012-138

Raymundo, M., Caballes, C. F., Mayfield, M. M., & Hock, K. (2023). Informed selection of corridors through network and graph analyses to enhance dispersal potential through an agricultural matrix. *Landscape Ecology*, *38*(2), 449–461. https://doi.org/10.1007/s10980-022-01563-0

Reyers, B., Folke, C., Moore, M.-L., Biggs, R., & Galaz, V. (2018). Social-Ecological Systems Insights for Navigating the Dynamics of the Anthropocene. *Annual Review of Environment and Resources*, *43*(1), 267–289. https://doi.org/10.1146/annurev-environ-110615-085349

Richard, J.D. (2005). Federalism in Canada, 44 Duq. L. Rev. 5. Available at: https://dsc.duq.edu/dlr/vol44/iss1/4

Richardson, T. (2005). Environmental assessment and planning theory: four short stories about power, multiple rationality, and ethics. *Environmental Impact Assessment Review*, *25*(4), 341–365. https://doi.org/10.1016/j.eiar.2004.09.006

Rincón, C. A. R., Santos, J., Volker, L., & Rouwenhorst, R. (2021). Identifying institutional barriers and enablers for sustainable urban planning from a municipal perspective. *Sustainability (Basel, Switzerland)*, *13*(20), 11231-. https://doi.org/10.3390/su132011231

Rodrigues, A. S. L., & Cazalis, V. (2020). The multifaceted challenge of evaluating protected area effectiveness. *Nature Communications*, *11*(1), 5147–5147. https://doi.org/10.1038/s41467-020-18989-2

Rudnick, D. A., Ryan, S. J., Beier, P., Cushman, S. A., Dieffenbach, F., Epps, C. W., Gerber, L. R., Hartter, J., Jenness, J. S., Kintsch, J., Merenlender, A. M., Perkl, R. M., Preziosi, D. V., & Trombulak, S. C. (2012). The role of landscape connectivity in planning and implementing conservation and restoration priorities. *Issues in Ecology*, *16*, 1–23

Ruzow Holland, A. H. (2022). If all planning is local, how are we going to save tomorrow? Ten pragmatic lessons from the field. *Journal of Environmental Studies and Sciences*, *12*(1), 177–192. https://doi.org/10.1007/s13412-021-00710-4

Salazar, K., Church, S. P., Prokopy, L., Ma, Z., Beaulieu, L., & Phillips, R. (2024). The need for proactive environmental planning in local government: Examining challenges and pathways forward in Indiana. *Community Development (Columbus, Ohio)*, 1–29. https://doi.org/10.1080/15575330.2024.2382207

Saldaña, J. (2016). *The coding manual for qualitative researchers* (Third edition.). SAGE.

Saura, S., Bodin, Ö., Fortin, M., & Frair, J. (2014). EDITOR'S CHOICE: Stepping stones are crucial for species' long-distance dispersal and range expansion through habitat networks. *The Journal of Applied Ecology*, *51*(1), 171–182. https://doi.org/10.1111/1365-2664.12179

Sayles, J. S., & Baggio, J. A. (2017). Who collaborates and why: Assessment and diagnostic of governance network integration for salmon restoration in Puget Sound, USA. *Journal of Environmental Management*, *186*(Pt 1), 64–78. https://doi.org/10.1016/j.jenvman.2016.09.085

Scarlett, L., & McKinney, M. (2016). Connecting people and places: the emerging role of network governance in large landscape conservation. *Frontiers in Ecology and the Environment* 14(3): 116-125.

Schloss, C. A., Cameron, D. R., McRae, B. H., Theobald, D. M., & Jones, A. (2022). “No-regrets” pathways for navigating climate change: planning for connectivity with land use, topography, and climate. *Ecological Applications*, *32*(1), e02468-n/a. https://doi.org/10.1002/eap.2468

Scolozzi, R., & Geneletti, D. (2012). Assessing habitat connectivity for land-use planning: a method integrating landscape graphs and Delphi survey. *Journal of Environmental Planning and Management*, *55*(6), 813–830. https://doi.org/10.1080/09640568.2011.628823

Schmitt, G., Franchomme, M., Hinnewinkel, C., & Laboureur, M. (2022). Towards an index of biodiversity potential: example in an anthropised and fragmented landscape matrix. *Cybergeo*. https://doi.org/10.4000/cybergeo.39205

Schreier, Margrit. 2012. “Qualitative Content Analysis in Practice.” Newbury Park, CA: SAGE.

Shafer, C. L. (2015). Land use planning: A potential force for retaining habitat connectivity in the Greater Yellowstone Ecosystem and Beyond. *Global Ecology and Conservation*, *3*(C), 256–278. https://doi.org/10.1016/j.gecco.2014.12.003

Shilling, F., & Girvetz, E. (2007). Physical and financial barriers to implementing a nature reserve network in the Sierra Nevada, California, USA. *Landscape and Urban Planning*, *80*(1), 165–172. https://doi.org/10.1016/j.landurbplan.2006.07.003

Soule, M. E. (1991). Land Use Planning and Wildlife Maintenance: Guidelines for Conserving Wildlife in an Urban Landscape. *Journal of the American Planning Association*, *57*(3), 313–323. https://doi.org/10.1080/01944369108975502

Spang, E., Lemieux, C. M., & Strobl, S. (2012). Stakeholder engagement: A foundation for natural heritage systems identification and conservation in southern Ontario. *Forestry Chronicle*, *88*(6), 686–696. https://doi.org/10.5558/tfc2012-13

Spencer L, Ritchie J, & O’Connor W. (2003). Analysis: Practices, principles and processes. In: Ritchie, J., & Lewis, J. (eds). *Qualitative research practice : a guide for social science students and researchers*. Sage Publications

Staccione, A., Candiago, S., & Mysiak, J. (2022). Mapping a Green Infrastructure Network: a framework for spatial connectivity applied in Northern Italy. *Environmental Science & Policy*, *131*, 57–67. https://doi.org/10.1016/j.envsci.2022.01.017

Sternlieb, F., Bixler, R. P., Huber-Stearns, H., & Huayhuaca, C. (2013). A question of fit: Reflections on boundaries, organizations and social–ecological systems. *Journal of Environmental Management*, *130*, 117–125. https://doi.org/10.1016/j.jenvman.2013.08.053

Stewart, J., & Tyler, M. E. (2019). Bridging organizations and strategic bridging functions in environmental governance and management. *International Journal of Water Resources Development*, *35*(1), 71–94. https://doi.org/10.1080/07900627.2017.1389697

Stokes, D. L., Hanson, M. F., Oak, D. D., Straub, J. E., & Ponio, A. V. (2010). Local Land-Use Planning to Conserve Biodiversity: Planners' Perspectives on What Works. *Conservation Biology*, *24*(2), 450–460. https://doi.org/10.1111/j.1523-1739.2009.01356.x n

Sturzaker, J., & Hickman, H. (2024). Planning's value, planners' values: defining and redefining for contemporary practice. *Planning, Practice & Research*, *39*(2), 157–170. https://doi.org/10.1080/02697459.2024.2316988

Tang, Z., & Brody, S. D. (2009). Linking Planning Theories with Factors Influencing Local Environmental-Plan Quality. *Environment and Planning. B, Planning & Design.*, *36*(3), 522–537. https://doi.org/10.1068/b34076

Tarabon, S., Bergès, L., Dutoit, T., & Isselin-Nondedeu, F. (2019). Environmental impact assessment of development projects improved by merging species distribution and habitat connectivity modelling. *Journal of Environmental Management*, *241*, 439–449. https://doi.org/10.1016/j.jenvman.2019.02.031

Termorshuizen, J. W., Opdam, P., & van den Brink, A. (2007). Incorporating ecological sustainability into landscape planning. *Landscape and Urban Planning*, *79*(3), 374–384. https://doi.org/10.1016/j.landurbplan.2006.04.005

Thompson, J. (2022). A Guide to Abductive Thematic Analysis. *The Qualitative Report*, 27(5), 1410-1421. https://doi.org/10.46743/2160-3715/2022.5340

Tiemann, S., & Siebert, R. (2009). Ecological networks implemented by participatory approaches as a response to landscape fragmentation: A review of German literature. *Outlook on Agriculture*, *38*(2), 205–212. https://doi.org/10.5367/000000009788632368

Timmermans, S., & Tavory, I. (2012). Theory Construction in Qualitative Research: From Grounded Theory to Abductive Analysis. *Sociological Theory*, *30*(3), 167–186. https://doi.org/10.1177/0735275112457914

Tischendorf, L., & Fahrig, L. (2000). On the usage and measurement of landscape connectivity [review]. *Oikos*, *90*(1), 7–19. https://doi.org/10.1034/j.1600-0706.2000.900102.x

Tulloch, V. J. D., Atkinson, S., Possingham, H. P., Peterson, N., Linke, S., Allan, J. R., Kaiye, A., Keako, M., Sabi, J., Suruman, B., & Adams, V. M. (2021). Minimizing cross-realm threats from land-use change: A national-scale conservation framework connecting land, freshwater and marine systems. *Biological Conservation*, *254*, 108954-. https://doi.org/10.1016/j.biocon.2021.108954

United Nations Environment Programme - UNEP (1992). *Convention on biological diversity, June 1992*. https://wedocs.unep.org/20.500.11822/8340

[UTRCA] Upper Thames River Conservation Authority (2014). Middlesex Natural Heritage Systems Study [online]. Middlesex County Administrative Offices. Available at https://www.middlesex.ca/sites/default/files/documents/misc/MNHSS%20Final%20Draft%206OCT14%20for%20County%20Council%20Approval.pdf

Vasseur, L., Horning, D., Thornbush, M., Cohen-Shacham, E., Andrade, A., Barrow, E., Edwards, S. R., Wit, P., & Jones, M. (2017). Complex problems and unchallenged solutions: Bringing ecosystem governance to the forefront of the UN sustainable development goals. *Ambio*, *46*(7), 731–742. https://doi.org/10.1007/s13280-017-0918-6

Vila-Henninger, L., Dupuy, C., Van Ingelgom, V., Caprioli, M., Teuber, F., Pennetreau, D., Bussi, M., & Le Gall, C. (2024). Abductive Coding: Theory Building and Qualitative (Re)Analysis. *Sociological Methods & Research*, *53*(2), 968–1001. https://doi.org/10.1177/00491241211067508

Vimal, R., Mathevet, R., & Thompson, J. D. (2012). The changing landscape of ecological networks. *Journal for Nature Conservation*, *20*(1), 49–55. https://doi.org/10.1016/j.jnc.2011.08.001

von Haaren, C., & Reich, M. (2006). The German way to greenways and habitat networks. *Landscape and Urban Planning*, *76*(1), 7–22. https://doi.org/10.1016/j.landurbplan.2004.09.041

Von Thaden, J., Salazar-Arteaga, H., Laborde, J., Estrada-Contreras, I., & Romero-Uribe, H. (2022). Arboreal elements of the agricultural matrix as structural connecting devices in fragmented landscapes – A case study in the Los Tuxtlas Biosphere Reserve. *Ecological Engineering*, *179*, 106633-. https://doi.org/10.1016/j.ecoleng.2022.106633

Waldron, G. 2003. Trees of the Carolinian forest: a guide to species, their ecology and uses. Boston Mills Press.

Watson, D. M., Doerr, V. A. J., Banks, S. C., Driscoll, D. A., van der Ree, R., Doerr, E. D., & Sunnucks, P. (2017). Monitoring ecological consequences of efforts to restore landscape-scale connectivity. *Biological Conservation*, *206*, 201–209. https://doi.org/10.1016/j.biocon.2016.12.032

Weeks, R. (2017). Incorporating seascape connectivity in conservation prioritisation. *PloS One*, *12*(7), e0182396–e0182396. https://doi.org/10.1371/journal.pone.0182396

White, I. (2015). *Environmental planning in context.* Palgrave Macmillan

Whitelaw, G. S., & Eagles, P. F. J. (2007). Conservation in Practice: Planning for Long, Wide Conservation Corridors on Private Lands in the Oak Ridges Moraine, Ontario, Canada. *Conservation Biology*, *21*(3), 675-. https://doi.org/10.1111/j.1523-1739.2007.00708.x

Wilkinson, C. (2012). Social-ecological resilience: Insights and issues for planning theory. *Planning Theory (London, England)*, *11*(2), 148–169. https://doi.org/10.1177/1473095211426274

Williams, K. J., Reeson, A. F., Drielsma, M. J., & Love, J. (2012). Optimised whole-landscape ecological metrics for effective delivery of connectivity-focused conservation incentive payments. *Ecological Economics*, *81*(1), 48–59. https://doi.org/10.1016/j.ecolecon.2012.07.005

Williamson, M. A., Parrott, L., Carter, N. H., & Ford, A. T. (2023). Implementation resistance and the human dimensions of connectivity planning. *People and Nature (Hoboken, N.J.)*, *5*(6), 1922–1936. https://doi.org/10.1002/pan3.10525

Wyborn, C. (2015). Cross-Scale Linkages in Connectivity Conservation: Adaptive governance challenges in spatially distributed networks. *Environmental Policy and Governance*, *25*(1), 1–15. https://doi.org/10.1002/eet.1657

Wyborn, C., & Bixler, R. P. (2013). Collaboration and nested environmental governance: Scale dependency, scale framing, and cross-scale interactions in collaborative conservation. *Journal of Environmental Management*, *123*, 58–67. https://doi.org/10.1016/j.jenvman.2013.03.014

Yang, B., & Li, S. (2016). Design with Nature: Ian McHarg's ecological wisdom as actionable and practical knowledge. *Landscape and Urban Planning*, *155*, 21–32. https://doi.org/10.1016/j.landurbplan.2016.04

Yoder, L., Ward, A. S., Spak, S., & Dalrymple, K. E. (2021). Local Government Perspectives on Collaborative Governance: A Comparative Analysis of Iowa's Watershed Management Authorities. *Policy Studies Journal*, *49*(4), 1087–1109. https://doi.org/10.1111/psj.12389

Zhang, Z., Meerow, S., Newell, J. P., & Lindquist, M. (2019). Enhancing landscape connectivity through multifunctional green infrastructure corridor modeling and design. *Urban Forestry & Urban Greening*, *38*, 305–317. https://doi.org/10.1016/j.ufug.2018.10.014

Zimmerer, K. S., Olivencia, Y. J., Rodríguez, L. P., López-Estébanez, N., Álvarez, F. A., Olmo, R. M., Ochoa, C. Y., Pulpón, Á. R. R., & García, Ó. J. (2022). Assessing social-ecological connectivity of agricultural landscapes in Spain: Resilience implications amid agricultural intensification trends and urbanization. *Agricultural Systems*, *203*, 103525-. https://doi.org/10.1016/j.agsy.2022.103525

Appendix A

Interview Guide

Questions

Overview:

My research is focused on connecting the landscape or linking together natural features and areas. I'd like to start with some general questions on the planning and implementation of natural heritage systems (NHS).

1. Why is connectivity or linkages important
2. What issues arose in the development of the policies and maps on connectivity
3. What do you think are the best methods or tools to implement connectivity / linkages?
4. How supportive is the local government of the NHS policies and maps in general? And for connectivity? The same or different?

Factors:

I'd like to move on now to some more specific questions about problems or help that you had in the development of the policies and in implementation. (Expand on the issues noted above).

5. What specific factors helped and hindered the planning of connectivity?
6. What about for implementation – are they different from the planning?
7. Are you aware of any outcomes or results from the NHS policies and maps?

Collaboration:

The last part of my interview is about collaboration.

8 Who did /do you work with to develop the natural heritage system *policies and maps?*
9 Was there any specific person or organization that made a big difference in getting the *policies and maps* in place?
10 Was there anyone/organization that served as a bridge to bring the other areas or people together so that the NHS could be connected?
11 Who would you like to see involved that were/are not?
12 Who do you most closely work with for the implementation?
13 Is it important that the public be consulted about NHS policies and maps – why or why not?

Wrap Up

14 Do you have any advice you would give to someone who is just starting the process of identifying areas/ linkages/ polices, implementation?

Appendix B

Chapter 4: Theme areas: full results

Theme	Category	Factor that Help	Factor that Hinder
Physical Landscape	Structure and function	water resource system, consistent criteria, agricultural land, woodlots	focus on features, provincial legislation requires feature protection but suggests linkages, cannot target areas for implementation, ignoring small parcels, mapping missing features, buffers, distance between features, use of proximity to identify corridors, agricultural lands, criteria used, hard to locate ecological functions / services, perceptions.
	Tenure	mosaic and permeable matrix	fragmented land ownership pattern, hard to target, stewardship opportunity based
	Land availability	protect what is left	lack of natural areas left, never be pristine, can only maintain status quo, 30% not politically supported or possible, no continuous corridors, competing interests
	Agriculture	Permeable, ecologically minded farmers, conserving woodlots and wetlands, controlling development on farmland, stewardship, incentives, education	Protecting farmland priority, not practical to restore on active farming, marginal lands put into active farming, modern farming practices, farm consolidation, amalgamation, larger farm machinery, maximize profit / yield, burden of cost, hard to convince if not see, farm practices not controlled or enforced, PPS not withstanding clause, cultivate to creek
	Barriers	Wildlife passage structures, new roads versus existing roads	Land uses, existing / established land uses, development adjacent to feature and linkages, lack of resilience, linear infrastructure, transportation, transit, tall buildings, aggregate removal, emphasis on growth and intensification, demand for housing and economic development, greenfield areas becoming viable for development, settlement in rural areas, subdivision and land severances
	Human health	EC use for recreation, multipurpose corridors or trails, mental health benefits, access to nature, health values contribute to EC	Multipurpose effects on species movement

Environmental Governance	Decision making Framework	OP scale (county, region) is good for EC, federal funding	Complicated decision making with multiple levels and rules, disconnects among the DMs/ LG functions /planning and implementation /among disciplines, need to convince decision makers, politicians are fearful of public reaction, need to work across jurisdictional boundaries, EC not line up across borders, lack of provincial guidance, lack of knowledge on how to incorporate EC in overall framework, lack of implementation guidelines, federal government lack of understanding of LG abilities, lack of participation from indigenous peoples, working with multiple landowners for implementation, rural areas more open to economic factors at the expenses of the environment, urban areas strong public support but not the areas needed for EC
	Collaboration	Use for crossing jurisdictions, use for studies with multi stakeholder approach, LG good collaboration with CA, partnerships for implementation	Takes time that planners do not have, smaller CAs less resources to collaborate, extra costs, extra staffing, need leadership, need for scientific information, need to balance public interest and have political will as well as the land base.
	Watershed	Watershed best scale, CAs already in place with regulatory functions, LG look inward - CAs broader scale and perspective / ecological mandate / multiple LG / see how things relate, using watershed and sub watershed plans, connecting NHS to water system - river corridor, lakeshore, steep valley systems all that is left and becomes core of NHS / easier to accept as a linear feature and already regulated, watershed plans take a systems approach and fill gaps in knowledge	LG hard to see the big picture, different watersheds have different challenges same legislation, multiple CAs within LG, CA funding model, CA changing mandate, still have LG as decision makers, not all areas have watershed or sub watershed plans
	Stewardship	Opportunity for implementation and raise level of awareness, Incentives, CA strong programming to help with stewardship, CA own land and stewards themselves, NGOs in better position for stewardship. land trusts and easements, external agency, funding, large tracts of land in one ownership	Affect property rights and livelihoods, voluntary and transitory, lack of incentives, burden of cost, LG generally not involved in stewardship, lack of ability to target areas for EC, NGO capacity, need to have the right partners, more accepted in urban areas but they do not own the land, not want to be told what to do on own property, funding programs discourage EC across multiple properties, capability of owners

Land use planning Practices	Legislation	PPS progressive by identifying need for EC, provides support for connectivity planning, sets minimum standards that can be exceeded by LG, provincial plans (PP) provide strong leadership and guidance, PP provide LG security to address EC, less resistance by developers with strong policy in PP on EC, PP provide clear direction and certainty, without PP may be too difficult to address at LG level, woodland conservation and tree cutting by laws through Municipal Act, legislation on species at risk and environmental assessment requirements	Difficult to exceed minimum standards of province (developers argue, decision makers leery), LG tend to do the bare minimum for EC, notwithstanding clauses which allows development should environmental impact shows no negative impact on EC, legislation and direction weak and vague, difficult to implement, multiple PPs with overlap and conflicting policy on EC, planners and developers confused with multiple plan direction, PP not being implemented, tree replacement requirements hard to implement, provincial policy can change based on current government
	Mapping	Need mapping for implementation – areas to protect need to be identified, mapped EC shown as a constraint to development and more certainty, NHS provide information needed for mapping EC	Extensive data collection, preparation and refinement needed to map EC, mapping considered as conceptual only, mapping considered to imply land cannot be used or will be acquired, current large scale EC mapping is dated, mapping at various scales and use of different data lead to inconsistent mapping, context specific approaches to mapping with differing baseline conditions, use of different standards and criteria for mapping, site level EC identification can be isolated and not incorporated into broader scale EC mapping, focus on mapping EC only along watercourses and not for upland areas, incorrect data uses (showing features not there or not showing features that are there) questioning validity of mapping, need to ground truth data but cannot get permission to access private land, studies a point in time and lack ability to keep data up to date
	Policy	Developers will typically accept clear policy and certainty of what they can do at the onset, *NHS help with knowledge of watershed to help plan how to spend money or identify opportunities,* secondary plans a strong tool to implement EC, OPs can provide linkage criteria and values to be used in secondary plans for more detailed mapping and policies, secondary plans better at setting expectations for EC	Language used needs to be clear and detailed with expectations noted and means to implement for developer adherence, developer appeal if policy is unclear or weak, vague language makes it difficult for other planners to implement, implementation depends on the quality of the policy, need guidance on what constitutes a negative impact on EC, difficult to interpret EAs from consultants on EC recommendations, EA from consultants typically demonstrate no negative impact on EC which negates options for restoration or compensation, vague language on how to how to identify EC or identify impacts on EC, other economic or social value take precedence, EC seen as conflicting with growth management objectives, competing interests, NHS may not be formally adopted or applied, even with policy ability to address land use change and restoration hampered
	Planning system	Policies dictate what can and cannot be done, upper-level LG a good scale (better attuned to EC planning),	Site specific applications take time and may be out of sync with EC policies, misunderstanding of intent of EC policies, historical

		CAs and water resources part of planning and inadvertently may create EC, positive developer attitude (increase property values, selling feature), appeals not allowed for new or updated OPs, apply aa mix of implementation tools as planned redundancy (each tool does different things to accomplish the same goal)	designations / zoning not match the current landscape / values and policies, disconnect with LG and CA policies, overlay maps used for EC not as strong as designations, wish to develop as per the underlying designation creates grey areas and negotiations, can only be applied through a planning act application (such as a building or subdivision), applications more prevalent in urban than rural areas, restoration or land acquisition opportunities for EC only available through the development process, not able to afford donations of land (costs to maintain), need for mechanisms to accept and afford donations, cash in lieu of donations typically directed to active parkland or recreation and not EC, existing uses are allowed and cannot be made illegal, zoning is permissive and cannot address site alterations, enforcement difficult with little monitoring as planning is reactive to complaints, negative developer attitude with EC as constraint (impact profit, maximize density), OLT more inclined to take advice of an ecologist hired by a developer over planner, tools not known or part of the planning process
	Science	Science supporting decision making, use of criteria easier to identify and implement EC, federal guidance documents more up to date than provincial, more guidance, environmental management guidelines to help with site specific implementation, more watershed based and local level information from CAs, information on how to incorporate EC into an overall framework, implementation guidelines with examples	Understanding technical aspects and varying directions, use of criteria varies as landscape varies, assumptions in methodology and criteria can have major implications (miss corridors, not account for porosity of matrix), lack of good definitions (how to define EC, significance, a system, protection), EC science outdated (based on old science, information, guidelines), need ecologically based guidelines, need more information on the matrix approach to EC, need strong methodology / science on requirements for maintaining linkages, holistic do over of the science underpinning the policies out of the scope of LG, don't know how sell the idea to the public and property owners
	Outcomes	Using EAs to identify EC or compensation at time of application for development, NGOs better suited to implement and monitor EC (acquisitions, active restoration, interagency collaboration, covenants, reward programs, standards and certification, education), while planning may have unavoidable losses, NGOS were countering by buying and naturalizing land, watershed planning used to set the baseline data to compare performance over time, need	Monitoring outcomes is not being done, difficult to know if actions resulted from policies (could be active / interested staff good at lobbying or getting funding), losses could be due to activities not controlled through the planning or under LG jurisdiction, larger LG and CA in urban areas better suited to implement EC and monitor results, need monitoring to adjust or adapt or discover changes to see if shifts or changes needed, not know how to monitor (review applications or air photos or track animal movement), monitoring may only show lines on a map around natural areas and not show improvements, resilience not taken into account or adaptive management (changes

		to achieve a net benefit at more than 1:1 with lands pre identified for EC	in land use intensity not taken into account), unclear who should undertake monitoring (province set consistent indicators for accountability of policy direction, or outside planning practice for stewardship, education, outreach, citizen science-based approaches), compensation only work with land available for restoration in locations needed for EC, compensation not monitored or not monitored consistently to see the before and after
Sharing information g	Education	well-educated population will encourage buy-in of EC, work incrementally by first putting the concept of EC forward, NGOs, public who support EC participate in planning processes, a technical advisory committee comprised of members of the public and local advocacy groups to advise council, design community engagement process to bring in divergent views, bring in social or economic benefits to educate decision makers ecosystem services, human heath, green infrastructure, natural assets, impact to budget or tax base how it helps growth), getting the public to help implement (plant trees, restore riparian areas, count birds)	A lack of public and political support caused by a lack of education, public resistance, agricultural community resistance, only those that disagree with EC participate in planning process (political support will reflect public sentiment), minimum required public consultation inadequate to get true picture of degree of public support for EC, no negative feedback does not mean political support at implementation, difficult to explain importance of EC as not as visible as features, social and economic benefits of EC are often nebulous and hard to demonstrate
	Knowledge	Need for scientific information to increase knowledge base, incorporation of local and Indigenous knowledge, NGOs assistance in raising the level of awareness of the public and property owners, need myth busting but also building the knowledge base	Lack of knowledge on a systems-based approach to EC, lack of understanding the consequences of decisions and what works or doesn't work in EC, disconnect between policy and implementation due to a lack of knowledge, lack of transfer of learning on how to identify, build or design EC, continually needing to reinvent methods in EC
	Leadership	Provincial leadership through provincial plans such as the Greenbelt plan, a progressive environmentally minded council, regional coordination through a well-respected or neutral leader, planning leadership to own the plan or perspective, active spokesperson in a community to counterbalance negative perspectives, Indigenous leadership for knowledge and protection of much of the remaining natural lands	Lack of leadership (provincial, council, for regional coordination, planning staff, active community spokesperson, Indigenous community)
	Planning process	Learn from other LG what they do for EC, LG with strong connectivity policies could set examples for others, sample sites to show developers how to incorporate EC	Lack of understand the planning process to integrate connectivity in the policy framework, lack of interest of planners in EC

Resources	Capacity	Larger LGs and CAs could help less resourced LG, having good GIS staff, LG staff dedicated to work on the NHS planning and available to answer questions, peer reviews, staff dedicated to stewardship, partnerships with CAs	Lack time to do more than day to day work, no capacity to follow up development proposal compliance, NGOs no capacity to work directly with landowners on site, staff turnover at provincial level, provincial reduction in staff to address environmental matters, LG lack expertise / tools, few LG environmental planners, ability to enforce policies, resource intensive to monitor species movement, LG planners do not have training
	Funding and incentives	Existing programs to help landowners protect the environment (significant features, ecosystem services, tax incentives, identify areas to protect), agricultural programs to financially help farmers (reduce burden of cost for ecological functions or service beyond property), funding for restoration	Funding and incentives for landowner to address EC (more geared to site specific and features), limited funding necessitates targeting areas which reduces opportunities from willing owners, funding criteria not geared towards EC and multiple adjacent landowners, tax implications if not focus on features such as significant wetlands, limits funding if EC is not identified as a feature
	Costs and budget	Use of environmental fees, cash in lieu or habitat banking	Costs to do OPs in house / hire consultants or experts or for appeals, CA funding model based on population of LG (less resources for rural areas, smaller population unable to do what Conservation Authorities in the more resourced municipalities already do), CA funding from LG reduces ability to work across borders, lack of funds to be proactive, lack of tax base, priority on jobs and housing, price of land, LG don't or are unable to allocate adequate budgets to EC and therefore are not engaged, addressing barriers after constructed is cost prohibitive (overpasses, underpasses, dams), lack of funding for monitoring
	Information and data	Good GIS staff, expertise on data availability, management and manipulation	Ability to obtain, refining and updating data, expertise on what data is for EC, lack of data on species movement, ability to inventory and ground truth data including getting permissions from land owners, using old data for monitoring, lack of guaranteed funding for data management and monitoring, inconsistent data across LG borders

Appendix C

Carolinian Ecoregion Local Government Official Plans Reviewed

Local government	Type	Lower tier	Population density /km2	Provincial plans	Number of Conservation Authorities	Official Plan Year
Niagara	Region – upper tier	12	243	Yes	2	2022
Peel	Region – upper tier	3	1153	Yes	3	2022
Halton	Region – upper tier	4	642	Yes	3	2022*
Toronto	City – single tier		4435	Yes	1	2022
Hamilton	City – single tier		572	Yes	4	2019/22
London	City – single tier		1004	No	3	2023
Windsor	City – single tier		1562	No	1	2013*
Brant	County – single tier		47	Yes	2	2023
Haldimand	County – single tier		39	Yes	3	2022
Norfolk	County – single tier		42	No	2	2023*
Chatham Kent	County – single tier		42	No	2	2024*
Middlesex	County - upper tier	8	27	No	5	2023
Oxford	County - upper tier	8	60	No	3	2023*
Elgin	County - upper tier	7	28	No	4	2024
Essex	County - upper tier	7	116	No	2	2014*
Lambton	County - upper tier	11	43	No	2	2020

*Update to natural heritage system policies not included in Official Plan and material also obtained from discussion papers, reports and studies on the Official Plan update

Appendix D

Chapter 5: Tabulated results

Summary of collaboration responses by LG (n = 10), CA (n = 8), NGO(n = 3), FED (n = 2), PROV (n = 1), with total number of responses in parentheses.						
	Who work with	Make big difference	Bridge	See involved	Implement	Total
Province	LG-2, CA-3, NGO-1, FED-1, PROV-0 (7)	LG-1, CA-0, NGO-0, FED-1, PROV-1 (3)	LG-1, CA-0, NGO-0, FED-0, PROV-0 (1)	LG-2, CA-1, NGO-0, FED-0, PROV-0 (3)		14
Not province	LG-8, CA-4, NGO-0, PROV-0, FED-0 (12)	LG-1, CA-0, NGO-0, FED-0, PROV-0 (1)	LG-1, CA-2, NGO-1, FED-0, PROV-0 (4)		LG-0, CA-1, NGO-0, FED-0, PROV-0 (1)	18
CA	LG-10, CA-6, NGO-3, FED-0, PROV-0 (19)	LG-5, CA-5, NGO-1, FED-0, PROV-0 (11)	LG-7, CA-6, NGO-1, FED-0, PROV-0 (14)	LG-0, CA-1, NGO-0, FED-0, PROV-0 (1)	LG-7, CA-1, NGO-0, FED-0, PROV-0 (8)	53
Agriculture	LG-1, CA-2, NGO-1, FED-0, PROV-0 (4)	LG-1, CA-0, NGO-0, FED-0, PROV-0 (1)	LG-1, CA-0, NGO-0, FED-0, PROV-0 (1)	LG-2, CA-1, NGO-1, FED-0, PROV-0 (4)		10
Consultants	LG-2, CA-0, NGO-0, FED-0, PROV-0 (2)	LG-1, CA-0, NGO-0, FED-0, PROV-0 (1)				3
NGOs	LG-5, CA-3, NGO-3, FED-1, PROV-0 (12)	LG-2, CA-1, NGO-1, FED-0, PROV-1 (5)	LG-0, CA-2, NGO-2, FED-0, PROV-1 (5)	LG-2, CA-2, NGO-1, FED-0, PROV-0 (5)	LG-2, CA-5, NGO-1, FED-1, PROV-0 (9)	36
Not NGO	LG-4, CA-0, NGO-0, FED-0, PROV-0 (4)			LG-0, CA-1, NGO-0,FED-0, PROV-0 (1)		5
University educational	LG-1, CA-0, NGO-0, FED-0, PROV-0 (1)					1
Adjacent – circulate	LG-4, CA-0, NGO-0, FED-0, PROV-0 (4)	LG-1, CA-0, NGO-0, FED-0, PROV-0 (1)				5
Adjacent	LG-2, CA-0, NGO-0, FED-0, PROV-0 (2)	LG-1, CA-0, NGO-0, FED-0, PROV-0 (1)				3
Public	LG-2, CA-0, NGO-0, FED-0, PROV-0 (2)	LG-0, CA-1, NGO-0, FED-0, PROV-0 (1)		LG-1, CA-3, NGO-0, FED-0, PROV-1 (5)		8

Feds	LG-2, CA-1, NGO-1, FED-1, PROV-0 (5)			LG-1, CA-1, NGO-0, FED-0, PROV-0 (2)	LG-1, CA-0, NGO-0, FED-0, PROV-0 (1)	8
Not feds	LG-1, CA-1, NGO-0, FED-0, PROV-0 (2)					2
FN	LG-3, CA-0, NGO-2, FED-2, PROV-0 (7)	LG-0, CA-0, NGO-0, FED-2, PROV-0 (2)		LG-2, CA-2, NGO-0, FED-1, PROV-0 (5)	LG-0, CA-0, NGO-1, FED-0, PROV-0-(1)	15
internal	LG-4, CA-0, NGO-0, FED-0, PROV-0 (4)	LG-1, CA-0, NGO-0, FED-0, PROV-0 (1)	LG-1, CA-0, NGO-0, FED-0, PROV-0 (1)		LG-3, CA-0, NGO-0, FED-0, PROV-0 (3)	9
landowner	LG-0, CA-4, NGO-1, FED-0, PROV-0 (5)	LG-0, CA-0, NGO-0, FED-1, PROV-0 (1)			LG-1, CA-6, NGO-3, FED-1, PROV-0 (11)	17
Funding agencies	LG-0, CA-3, NGO-0, FED-0, PROV-0 (3)	LG-0, CA-2, NGO-0, FED-0, PROV-0 (2)		LG-1, CA-0, NGO-0, FED-0, PROV-0 (1)	LG-0, CA-1, NGO-0, FED-1, PROV-0 (2)	8
LG	LG-2, CA-5, NGO-2, FED-1, PROV-1 (11)	LG-0, CA-3, NGO-1, FED-0, PROV-1 (5)	LG-1, CA-0, NGO-0, FED-0, PROV-0 (1)	LG-0, CA-0, NGO-1, FED-0, PROV-0 (1)	LG-0-3-0-1-1 (5)	23
Not LG	LG-0, CA-0, NGO-0, FED-1, PROV-0 (1)	LG-0, CA-1, NGO-0, FED-0, PROV-0 (1)	LG-5, CA-0, NGO-0, FED-0, PROV-0 (5)			7
Lower Tier	LG-2, CA-2, NGO-0, FED-0, PROV-0 (4)				LG-2, CA-1, NGO-0, FED-0, PROV-0 (3)	7
Developers	LG-0, CA-1, NGO-0, FED-0, PROV-0 (1)		LG-0, CA-1, NGO-0, FED-0, PROV-0 (1)		LG-2, CA-0, NGO-0, FED-0, PROV-0 (2)	4
international	LG-0, CA-1, NGO-1, FED-0, PROV-0 (2)		LG-0, CA-1, NGO-0, FED-0, PROV-0 (1)			3
Finance business industry	LG-0, CA-0, NGO-3, FED-0, PROV-0 (3)			LG-0, CA-0, NGO-1, FED-1, PROV-0 (2)		5
Steering committee	LG-1, CA-1, NGO-0, FED-0, PROV-0 (2)	LG-0, CA-1, NGO-0, FED-0, PROV-0 (1)			LG-1, CA-0, NGO-0, FED-0, PROV-0 (1)	4
Depends		LG-0, CA-2, NGO-0, FED-1, PROV-0 (2)	LG-0, CA-0, NGO-2, FED-0, PROV-0 (2)		LG-1, CA-0, NGO-0, FED-1, PROV-0(2)	6