FINDING COMMON GROUND: METHODS FOR SUSTAINING CITIZEN SCIENCE ENGAGEMENT THAT INCREASE INDIGENOUS PLANT BIODIVERSITY IN SOUTHWESTERN ONTARIO

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Abstract

Nature-based solutions to address biodiversity loss require supports that reach beyond government grants. The Conservation Impact Bond (CIB) developed by Southwestern Ontario regional conservation charity, Carolinian Canada Coalition, is an example of a novel financial tool to incentivize biodiversity conservation by supporting citizen science.

My research evaluated Carolinian Canada's *In The Zone* Tracker and its allied programs. A systematic review of the literature about Canadian citizen science projects provided context.

(1) The *ITZ* Program reversed plant biodiversity loss at a local level through planting projects that generated a self-reported increase in native species.

(2) Information about citizen science projects was difficult to discover. Academic research into citizen science projects published in peer-reviewed literature creates a more permanent record than web-based, grey literature.

(3) Citizen science projects do not necessarily improve science literacy. Rather, the *ITZ* tracker helped people to find common values and make positive, evidence-informed differences in their communities.

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CHAPTER 1: A Review of Biodiversity

1.0 - Statements of Purpose

The following questions are explored in **Chapter 1**:

1. What is biodiversity?
2. Why does biodiversity matter beyond ecology?
3. What policies currently exist to protect biodiversity?
4. How is biodiversity valued?
5. What types of environmental finance tools currently exist?
6. What is citizen science and social enterprise?
7. How might we motivate both businesses and local communities to invest in nature?

1.1 - Introduction

Biodiversity, defined as the variability among living organisms within and between species, is directly connected to the stability and resilience of ecosystems (The Convention on Biological Diversity 2006; Pimm 1984). The loss of species is occurring at an increasing rate as the human population continues to put strain on Earth's resources. In its 2019 Global Assessment report the United Nations' affiliated Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) stated that 25% of plant and animal species are threatened or endangered (IPBES 2019).

Biodiversity loss is occurring due to anthropogenic activities and the rates of loss will only accelerate as drivers of biodiversity loss put further strain on the planet (Cowie et al 2022). With species loss showing no sign of slowing down and the looming threat of an eventual sixth mass extinction event, citizen participation in monitoring biodiversity on a local level raises awareness and has the potential to mitigate losses (Danielsen et al 2024).

Citizen science activities, in subject areas ranging from biology (e.g. bioblitzes) to astronomy (e.g. Galaxy Zoo) and many in between, provide opportunities for non-scientists to collect and contribute data to ongoing research studies (Dickinson et al 2010; Ellwood et al 2023, Pollock et al 2015). While citizen science has long existed, participation has grown in popularity since the 1990s and 2000s (Fraisl et al 2022). Citizen science is characterized and defined by the presence, endorsement and some kind of oversight by professional scientists who work in partnership with non-experts or amateurs, to make observations, and collect and report data (Dickinson et al 2010; Ellwood et al 2023; Pollock et al 2015; Vohland 2021). In addition to providing expanded databases that leverage higher levels of participation, many citizen science projects provide some kind of training about the project and data collection, leading to a common perception amongst experts that citizen science is a means of increasing science literacy and awareness of research importance (Bazely and McPherson 2022).

Citizen science activities are documented in diverse places ranging from academic journals to government databases to webpages and social media, all of which are records with varying degrees of detail and permanence. Some of these projects have additional support from social enterprises; organizations or businesses aiming to pursue a social or environmental mission and continuously reinvesting in that mission (Haugh et al 2022).

A key principal of citizen science is that participation is open to anyone, regardless of expertise or experience, since guidance and training are assumed to be provided, as well as ways of reporting observations and data. In recent years, the term, *community science*, which is viewed as a more inclusive term for describing those who participate in "citizen science" who may be visitors and non-citizens, has grown in popularity (Lin Hunter et al 2023).

One social enterprise with an impact at a local level is the for-profit arm of Carolinian Canada Coalition (CCC), a regional ecosystem recovery network in southwestern. CCC is a non-governmental organization with charitable status that is also a social enterprise. The Carolinian Canada Coalition is funded through new and emerging environmental and climate finance tools such as the Conservation Impact Bond (CIB) which was designed to invest in healthy landscapes (Arjaliès and Aguanno 2021). Not only does the CIB aim to incentivize conservation efforts, but an additional goal is to incentivize and reverse biodiversity loss at a local level and improve the condition of existing land. The *In The Zone* Tracker, developed and run by the Carolinian Canada Coalition is a multidimensional citizen science tool for raising plant awareness. Plants are the ultimate regenerative tool and force in a circular economy, yet their importance is often overlooked (Stroud et al 2022).

This thesis aims to explore all of the above – the ongoing biodiversity crisis, the ever-evolving nature of citizen science, the importance of social enterprises in funding restoration efforts, new and emerging environmental finance tools, and multidimensional citizen science programs that seek to increase plant awareness and reverse biodiversity loss at a local level.

1.2 - Defining Biodiversity

What is Biodiversity?

In its simplest terms, biodiversity is the variety of all living things, determined by the amount and type of species in a given area (Maclaurin & Sterelny 2008). The Convention on Biological Diversity states that biodiversity is defined as:

> *'The variability among living organisms from all sources including,* inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems.'*

(The Convention on Biological Diversity, 1994)

When discussing the value of biodiversity, we must first understand how biodiversity is measured. Counting individuals of a species to determine species richness is the most common method ecologists use to measure biodiversity (Humphries et al 1995). There is alpha diversity, species richness of organisms in the same habitat. There is also beta and gamma diversity which inform biodiversity conservation in specific ways. Beta diversity indicates similarities and differences between two communities (Socolar et al 2016). Gamma diversity indicates diversity of habitats across an entire geographic region (Brummitt et al 2021). Knowing this information allows for understanding of biodiversity at various scales and can determine what kind of conservation action needs to be taken – local, regional, or global (Humphries et al 1995).

1.2.1 - Ways to Improve Biodiversity

Mechanisms to slow or reverse biodiversity loss can be split into two separate categories. First and most commonly, there are actions that mitigate the loss by restoring land to its original state. This includes practices such as bioremediation in contaminated environments or standard tree replanting programs (Ancona et al 2017; Brancalion and Holl 2020). Second, in contrast to mitigation which aims to restore balance and equilibrate any negative impact on the environment, regeneration aims to improve existing conditions.

Bioremediation aims to restore an area to its original state and is far less disruptive than excavating waste (Rigoletto et al 2020). Phytoremediation, or plant-based remediation, functions by utilizing plant metabolism to immobilize, extract, and degrade contaminants found in soil and water (Azubuike et al 2016; Yan et al 2020). Phytoremediation is particularly effective as it is: 1) economically feasible, 2) environmentally friendly, 3) can be applied to various sized land areas and 4) reduces the risk of contaminant spread (Yan et al 2020).

Enhancement of the environment through bioremediation is directly linked to combatting the effects of biodiversity loss and climate change. Increased biodiversity via bioremediation ensures a more stable climate and healthy functioning of an ecosystem. Healthy ecosystems yield nutrients and resources which benefit both nature and the economy (Thompson 2022).

The issue with biodiversity mitigation techniques such as bioremediation is they are widely perceived as a simple endpoint, with no further action required (Brancalion and Holl 2020). This may ultimately result in an ecosystem experiencing a decline in biodiversity. Citizen science activities that encourage the planting of native species are an example of regeneration. This thesis evaluates whether the Carolinian Canada Coalition *In The Zone* Tracker Program can be considered as an authentic example of biodiversity regeneration (**see Chapter 2**).

1.3 - Biodiversity Beyond Ecology

The ecological significance of biodiversity for ecosystem function and stability has been well-described and investigated for decades (Pimm 1984; UNEP 1994; Maclaurin and

Sterelny 2008). In contrast to the scholarly research into biodiversity in the field of biology, scholarship and understanding of biodiversity in other sectors, both academic and for human society at large, is variable. The benefits of biodiversity reach beyond the traditional ecological perceptions associated with environmentalism. Economics, government, education, recreation, tourism, and human health – both mental and physical – all depend on the benefits that biodiversity directly and indirectly provides (Karlsson-Vinkhuyzen et al 2017).

Biodiversity acts as a buffer in many aspects of life and its existence benefits society. From an economic and governmental perspective, biodiversity acts as a stream of revenue and a source of employment in primary, secondary, and tertiary economic sectors (Kenessey 1987). There are traditional primary sectors of business that rely on the biodiversity of the natural world, such as mining, fishing, agriculture, forestry, and hunting. In addition to this, there are careers specifically designed to protect these natural resources. These jobs can be referred to as 'green jobs,' which are positions that perform or provide an environmental service (Bowen 2012; Stanef-Puică et al 2017).

In addition to yielding food and water, biodiversity is critical for the maintenance of ecosystem stability and the prevention of disease. In terms of genetic diversity, biodiversity lowers the probability of inbreeding. When a population is small and isolated its individuals may be forced to reproduce with close relatives of their species (Frankham et al 2012). This results in inbred individuals, who have lower genetic diversity hence reducing overall disease resistance, which impacts rate of survival (Frankham et al 2012).

Biodiversity is not only beneficial to ecosystem health but has a direct effect on human health. Loss of biodiversity contributes to the outbreak of pathogens, specifically ones causing zoonotic diseases (Lawler et al 2021). Human or anthropogenic factors such as land development can reduce overall land cover therefore increasing the possibility of exposure to pathogens via an animal or insect vector (Plowright et al 2017). Zoonotic spillover can also occur because of climate change, which may force an organism to migrate from their natural environment and come into contact with human populations, spreading disease (Mills et al 2010). These spillover events due to biodiversity loss have the potential to cause pandemics, which is why sustainable conservation practices must be considered (Waldron et al 2013).

1.4 - Biodiversity Policies and Politics

Understanding the importance of biodiversity is key for policy makers to work towards maintaining, enhancing, and protecting ecosystems and the benefits they provide. At each level of politics, there are policies that support the protection of species and encourage sustainable practices. On a provincial and sub-national level, the Ontario Biodiversity Council is responsible for maintaining Ontario's Biodiversity Strategy, which influences and guides conservation efforts across the province (Ontario Biodiversity Council 2023). This council reports on the state of Ontario's biodiversity every five years and tracks progress made towards achieving Ontario's 15 Biodiversity Targets. (Ontario Biodiversity Council 2020). These targets are split into four categories: 1) Engage People, 2) Reduce Threats, 3) Enhance Resilience and 4) Improve Knowledge (Ontario Biodiversity Council 2020). As of their 2020 report, only three of Ontario's biodiversity targets had been achieved; Making at least 50% of Ontarians aware of biodiversity, reducing greenhouse gas levels 6% to 1990s levels, and developing the Ontario Invasive Species Strategic Plan (2012) and the Invasive Species Act (2015) to reduce threats from invasive species.

On a national level, there is legislation in place such as the *Species At Risk Act (SARA)***,** a federal law passed in 2002 which was instilled to protect and recover at-risk species (Findlay et al 2009). SARA currently only applies to aquatic wildlife, migratory birds, and species found on federal land, with no automatic laws in place to protect at-risk species on non-federal land (SARA 2002). This is one of the main criticisms of SARA and its overall effectiveness (Turcotte et al 2021). The *Species At Risk Act* is also perceived by many as failing to seek Indigenous cooperation, having inadequate funding, and poor incentives to motivate landowners and industry to care about these species. As a result, the federal government has been slow to implement SARA on provincial and territorial crown land, allowing stakeholders to impact the rate of species recovery rather than scientific evidence (Turcotte et al 2021).

On the global scale, there are several committees and organizations dedicated to sustainability. The United Nations Convention on Biological Diversity (CBD) was established in 1992 and designed to promote biodiversity while encouraging sustainable resource use that is equitably distributed (Jørgensen 2013). There are also intergovernmental panels such as The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), designed to strengthen science-policy relationships and provide policymakers with the scientific evidence needed to create environmental policies (Díaz et al 2015).

1.5 - Indigenous Perspectives on Biodiversity

Indigenous communities have been considered the original stewards of the Earth and are committed to long-standing relationships with the land. Over 25% of terrestrial Earth is covered by formal and traditional Indigenous territory (Garnett et al 2018). With this comes the concept of Traditional Ecological Knowledge (TEK). The current Canadian educational system needs decolonization as it contributes to perpetuating bias and reinforcing assimilation (Battiste 2009). It does not teach non-Indigenous children of alternative knowledge systems to their own nor does it encourage understanding of Indigenous communities and neighbours (Battiste 2017).

TEK does share some similarities with restoration ecology: both encourage responsibility and stewardship of the land, but there are distinct differences that must be taken into consideration and recognized accordingly (Robinson et al 2021). To Indigenous communities, nature is an interconnected web of elements, all in relation and working together (Salmón 2000). TEK is far more spiritual than Western views of nature, which often views resources as disposable and unrelated. It is cumulative knowledge, passed down from generation to generation, often through storytelling and cultural practices (Robinson et al 2021). There is a sense of kinship, with the view that the land is an extension of humanity. In addition to this, there is a conscious awareness that humans impact the land, and the land impacts them in return (Salmón 2000). This is why Indigenous voices must be acknowledged and respected in the field of conservation ecology. For Indigenous communities, loss of land is a loss of culture, language, tradition, and self.

While not a substitution, many of the tenets of *One Planet, One Health* align with Traditional Indigenous Knowledge. It is a multidisciplinary and holistic approach that attempts to create a sense of unity, recognizing that environmental health is directly linked to human health (Naddeo 2021). The quality of our land has a direct effect on us, and we must treat land the way we wish to treat ourselves (Naddeo 2021).

Improper waste management disproportionately affects rural communities due to remote locations, small populations, and limited government attention (Government of Canada, 2017; Keske et al 2017). Indigenous communities are especially affected by this as they are particularly tied to the land, relying on it for food security including activities such as hunting and harvesting (Salmón 2000). Excess waste, decreasing biodiversity levels, and changing climates force Indigenous communities to purchase food, which is extremely expensive due to remote transportation costs (LaFortune 2021; Lam et al 2019). The effects of waste on remote and rural communities are not well understood as there is a lack of modern technological infrastructure. As well, in settler communities there is a lack of awareness of Indigenous ways of living and nature-based solutions as a method of resolution to environmental issues (Wildcat et al 2014).

1.6 - Valuing Biodiversity

Current social and economic systems have not properly accounted for the value of nature and the benefits nature provides are greatly overlooked. Nature provides an estimated $33 trillion in ecosystem services per year (Costanza et al 1997). An ecosystem service can be defined as something provided for you by nature that you do not pay a human for. An "ecosystem service" is not a novel concept but the term gained traction in 1997 with Costanza's publication. This publication became a foundational paper in anchoring and popularizing the term "ecosystem service."

Ecosystem services can be split into two categories: indirect and direct. Indirect services sustain and enrich the land that humans rely on, often without human awareness (Bolund & Hunhammar 1999). Examples of indirect ecosystem services include atmosphere, climate and water regulation; nutrient cycling; carbon sequestration; and pollination. All these processes contribute to the overall stability of an ecosystem, which yields nutrients and resources that benefit both nature and the economy, therefore adding inherent value to the environment (Thompson 2022). A majority of ecosystem services fall into this category.

Direct ecosystem services are ones that humans have more awareness of, as they are simpler to understand and provide recognizable, and tangible benefits. Examples of direct ecosystem services include food production, raw materials, recreational and cultural activities (Hermes et al 2018). Direct and indirect ecosystem services are both valuable; however, the public is biased towards protecting the direct services they encounter daily such as recreational green space (Hermes et al 2018).

1.7 - Current Environmental Finance Tools

Climate change finance helps to mitigate effects of climate change by directing funds towards insurance, loss and damage, and crisis management (Collier et al 2021, Thompson 2022). Enhancement of the environment and its services through restoration and bioremediation is directly linked to combatting the effects of climate change (Keske et al 2018). Sustainable, nature-based solutions for waste management require financial support that reaches beyond government grants, such as climate change insurance. This is all linked to the circular economy, an economic model which encourages sustainable reuse and regeneration (Geissdoerfer et al 2017).

Environmental finance tools can be broken down into four major categories. There are tools such as:

1) **carbon credits and greenhouse gas offsets** issued by the UNFCCC which balance out environmental activity. This forces individuals and corporations to pay for their environmental impact or allows individuals to purchase a carbon credit as compensation for committing a negative action elsewhere (Lovell and Liverman 2010).

2) Then there are **land trusts and easements**, which are legal agreements that request individuals or groups restrict or reduce their current environmental activity (Farmer et al 2015).

3) The third type of environmental finance tool includes **insurance funds** allocated to resolving the effects of climate-associated disasters, by providing relief and mitigation (Collier et al 2021).

4) The fourth category is financial mechanisms which are specifically designed to provide benefits to the environment or add something to the environment to improve its current state and value, such as **an investment bond** (Arjaliès and Aguanno 2021).

All such financial initiatives will be based on policy as enacted by local and global decision makers and stakeholders, whether they be private or governmental. These tools must be carefully monitored to ensure that the need to maximize stakeholder wealth does not negatively influence best land use practices. Environmental corporate social responsibility is key in motivating stakeholders to invest in biodiversity. Corporations and stakeholders cannot simply chase after profits, they must be an advocate for these causes (Lioui and Sharma 2012).

After the above review on current financial tools, the gaps are evident. Current ecological tools are not regenerative in nature. They aim to slow down or offset biodiversity loss and balance the effects of both natural disasters and negative human impacts such as pollution and habitat fragmentation. While current environmental finance tools may be restoring land to its original state, these tools do not generate a net increase in species biodiversity the way an investment bond aims to do. There is a lack of preventative tools that focus on regeneration and improvement as opposed to simple mitigation and balancing impact.

1.7.1 - The Conservation Impact Bond

One emerging environmental finance tool that addresses these gaps and fits the fourth category is the Deshkan Zibii Conservation Impact Bond (CIB). Established in 2020, this is an emerging financial tool designed to restore land in the Carolinian Life Zone and reconcile with Indigenous communities (Thompson 2022). The Conservation Impact Bond assists in determining the value of ecosystem services and puts a price tag on nature. Individuals or groups can invest a fixed amount of money for a fixed amount of time, and will receive return, or profits, upon certain environmental goals being reached (Arjaliès and Aguanno 2021).

The Conservation Impact Bond functions on a conditional basis and uses a "pay-for-success model" (Arjaliès and Aguanno 2021). If agreed-upon environmental outcomes are achieved, an investor's principal will be paid back; the initial sum of money invested. They will also receive a return, therefore profiting from investing in nature and encouraging further partnership (Arjaliès and Aguanno 2021). The Conservation Impact Bond pilot is in its first five years of action and its current impact investors include VERGE Capital; a social finance non-profit that provided a $130,000 loan for the pilot (Arjaliès and Aguanno 2021).

Unlike a stock, the amount of money invested into the Conservation Impact Bond is fixed and does not fluctuate. This differs from the high risk of investing in the stock market, where the value of a stock is variable and unpredictable due to supply and demand (Baulkaran 2019). Investors may receive a positive return on their stock, a capital gain, but there is also the risk of a stock's value decreasing. This can result in capital loss of part or all the principal investment. Bonds such as the Conservation Impact Bond are lower risk than stocks. Investors are aware of their expected payout and will generally receive their initial investment back

(Arjaliès and Aguanno 2021). Lowered risk and a monetary return help in accelerating action and gaining attention of investors (Baulkaran 2019; Arjaliès and Aguanno 2021).

The CIB is both regenerative and preventative, as it encourages native replanting to repair biodiversity loss while also improving the land and reducing the risk of future climate crises. The Conservation Impact Bond team aims to restore thousands of acres of land in the Carolinian Zone following the progression of the first few phases of establishing the CIB. In their 5-year action plan, they aimed to restore 150 acres of land in London, Ontario through native replanting with the *In The Zone* Tracker Program (Arjaliès and Aguanno 2021, Carolinian Canada Coalition 2023). Following a successful pilot that used $1.58 million to improve 269 hectares of land, the Conservation Impact Bond is entering a second phase. The Long Point Walsingham Forest Conservation Impact Bond (LCIB) will apply the piloted model of the Conservation Impact Bond (Deshkan Zibii CIB) to the Niagara region (Carolinian Canada Coalition 2023).

Through this funding, environmental finance tools such as the Conservation Impact Bond can support local citizen science initiatives that increase biodiversity. In the context of the Conservation Impact Bond, the Carolinian Canada Coalition functions as a project facilitator. The support of impact investors allows the Carolinian Canada Coalition to develop citizen science activities that encourage native planting, such as the *In The Zone* Tracker (Arjaliès and Aguanno 2021; Carolinian Canada Coalition 2023). Because the bond was developed by finance professionals, Carolinian Canada Coalition developed a website with a series of resources and interactive screens, to explain the Conservation Impact Bond to a layperson in plain language: https://caroliniancanada.ca/cib.

1.8 - Main Objectives and Research Questions

The main objective of this thesis was to investigate whether Carolinian Canada Coalition's citizen science projects, specifically the *In The Zone* Tracker, has the capacity to reverse the loss of native plant biodiversity in southwestern Ontario. This region of Canada is a highly settled landscape with low natural habitat cover compared with many other biomes of Canada, and it also contains a high number of rare and endangered species.

A second objective was to evaluate the extent to which information about citizen science projects across Canada is easily discoverable and documented in scholarly literature, and to place the *In The Zone* Tracker project in the context of past and current Canadian citizen science activities.

Specific research questions were:

- How might we give citizens the knowledge and resources they need to start a native planting journey? What are the best citizen science practices for increasing Indigenous Biodiversity?
- What does the *In The Zone* Tracker tell us about people in SW Ontario increasing indigenous biodiversity in rural and urban locations?
- How does the data from *In The Zone* Tracker support the hypothesis that planting native plant species increases biodiversity at a local level?
- Where in the landscape of Canadian citizen science activities does the *In The Zone* Tracker fall in terms of: its subject, longevity, level of participation, record-keeping, whether documented and analysed in the academic and scholarly record?

Hypotheses and Predictions:

- Planting native plant species increases biodiversity at a local level.
- Interactive citizen science programs increase local planting efforts
- If citizens are given access to engaging gardening programs, native planting increases.
- If ecological knowledge is made more accessible via citizen science planting programs, then biodiversity will increase.
- There are relatively few citizen science projects pertaining to vegetation and botany compared with those about more charismatic species such as birds and other fauna.

Internship Details:

The research for this thesis was supported by my internship with Carolinian Canada Coalition, a regional conservation non-governmental organization with charitable status that also includes a Social Enterprise arm. Through this internship, in which I was financially supported by the NSERC CREATE TABES program (**see Chapter 4**), a data-sharing agreement provided access to past *In The Zone* planting data, some of which was already in the public record in past annual reports by CCC. None of this information had been previously analyzed from a critical quantitative or qualitative perspective for trends and outcomes.

The social enterprise component of CCC involved developing the Conservation Impact Bond to fund projects that restore environments, including programs such as *In The Zone*. Because this is a social enterprise, NSERC CREATE agreed with our argument that Carolinian Canada Coalition met the criteria for the NSERC Industrial CREATE program internship placements, and after giving our request due consideration, they approved my internship placement.

In The Zone is a citizen science initiative designed to encourage native planting and transform an outdoor space (In The Zone, 2021). This program allows users to register planting projects of any size. *In The Zone* applicants can visit the website, take a baseline survey, and are then provided with a guide of suggested native plants for their chosen garden and living area (In The Zone, 2021). Participants can select between native planting for wildflower, woodland or wetland restoration. The *In The Zone* website aims to communicate science to the public and simplifies the benefits of investing in each type of land or garden space. Investing in wildflower spaces is beneficial, as healthy pollinator populations support food production. Woodland investments in shady trees can provide shade and moderate the temperature of your home. Wetland investments can reduce risk of flood or drought in your garden (In The Zone, 2021). By explaining this in relatable terms, *In The Zone* makes science accessible and encourages citizen participation.

Since Carolinian Canada Coalition is stationed in London, Ontario, the citizen science tool being analyzed will contain plants native to southwestern Ontario. Data gathered through *In The Zone* will provide insights on the value of nature's services, allowing for biodiversity to be quantified. From this internship, I will determine if native planting is a feasible solution to restoring land, and if native planting increases the biodiversity dividend. I also aim to explore the value of biodiversity as part of the circular economy and its connection to climate change finance. Ecology, economics, and ethics all play a role in sustainability and my work will explore the ability to commercialize nature through financial instruments that use funds to transform a natural space. The ultimate goal for a tool like the *In The Zone* Tracker is to encourage reconciliation, for both the environment and local Indigenous communities. These environmental finance tools can be implemented across Canada to restore habitats, improving the existing quality of the land.

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CHAPTER 2: The *In The Zone* Tracker: A Citizen Science Activity, Survey, and Educational Tool for Increasing Plant Awareness and Native Plant Biodiversity in Canada's Carolinian Life Zone

Acknowledgement of Co-Authorship

This chapter is co-authored and written in collaboration with past and present members of the Carolinian Canada Coalition: Tristan Bentley, Jennifer Nantais, Michelle Kanter, Jarmo Jalava, Stefan Weber, Sarah Winterton, Peter Ewins. It is a response to *Plants, People, Planet's* special issue call for papers that highlight methodologies investigating plant awareness, in which we wish to bring attention to the *In The Zone* Tracker Program as a multidimensional citizen science tool. The co-authors had a role in the development of the *In The Zone* Tracker and its subsequent modules - the Pawpaw Parade, cucumber magnolia, and seed orchard planting modules. These individuals did not contribute to writing the text for this chapter. I am the lead author and my supervisor Dr. Bazely is the corresponding author. This is currently a draft manuscript and has yet to be submitted to the journal for publication.

2.0 - Summary

The Carolinian Life Zone in southwestern Ontario overlaps with the Lake Erie-Lake Ontario provincial ecoregion 7E (2,185,845 ha). More rare and endangered species are found here than in any similar sized region of Canada (Johnson 2007; Almas and Conway 2016). Native biodiversity has declined due to urbanization and agriculture. The management of invasive species in the remaining natural, protected areas has been a decades-long priority.

The *In The Zone* Garden Program was developed by a long-established regional conservation organization, Carolinian Canada Coalition, to educate the public about native

biodiversity and to reverse biodiversity loss. Launched in 2016, in partnership with World Wildlife Fund Canada, the program encourages residents of rural *and* urban areas in southwestern Ontario to grow native plants on their properties, from apartment balconies to farms. The *In The Zone* Survey is the component of the ITZ Garden Program that tracks the engagement of citizen science participants.

We summarize early results of the *In The Zone* Tracker survey. Three case studies illustrate how the ITZ Garden Program promoted public engagement with, and awareness of native plants. Case Study One, about the Pawpaw Parade, describes how the survey raised broad-scale awareness of this regionally endangered plant species. Case Study Two describes how the ITZ database provided fine-grained, local information to drive action on Cucumber Magnolia, a provincially and federally recognized endangered species. Case Study Three describes the Southern Ontario Seed Saver Tool, which assists in the selection of seed orchard locations. The *In The Zone* survey has evolved and adapted since 2016 to encourage increased community participation for expanding regional native plant biodiversity.

2.1 - An Introduction to the Carolinian Life Zone

Canada is one of the largest countries in the world, and is bordered to the north, west and east by oceans. The biomes covering the largest areas are tundra, boreal forest and prairie grasslands. Most of Canada has low human population density, and the highest densities occur in the south within a few hundred kilometres of the world’s longest undefended border with the USA. Canada’s deciduous forest biomes, which are much smaller in area than other biomes, occur in the southern part of the province of Ontario, where they overlap with high human population densities and areas with the highest numbers and concentrations of rare and endangered species (Allen et al. 1990). This is one of the ecoregions identified as having both high biodiversity and high number of threatened and endangered species (Krause and Hebbs 2020).

Colonial settlement dating back over 250 years (CIRNAC 2022), along with intensifying urbanization, agriculture, and industrialization over the last century, have transformed the landscapes in the southwestern portion of southern Ontario known as the Carolinian Life Zone (Allen et al.1990) (Figure 1). The *Living Planet Report* (WWF 2022) described how monitored wildlife species have decreased by 69% since 1970. Many examples of biodiversity decline can be found across Canada's Carolinian Life Zone which is the landmass spanning south from Toronto to Windsor/Detroit and Niagara, lying between Lake Huron, Lake Erie and Lake Ontario (Figure 1). This area largely overlaps with Lake Erie-Lake Ontario Ecoregion 7E in the Ontario Ministry of Natural Resources Ecological Land classification system (Allen et al. 1990; Crins et al. 2009; Krause and Hebbs 2020). The larger zone, of which this is the southern part of, is the Lake Erie Lowland Ecozone in the Mixedwood Plains Ecozone.

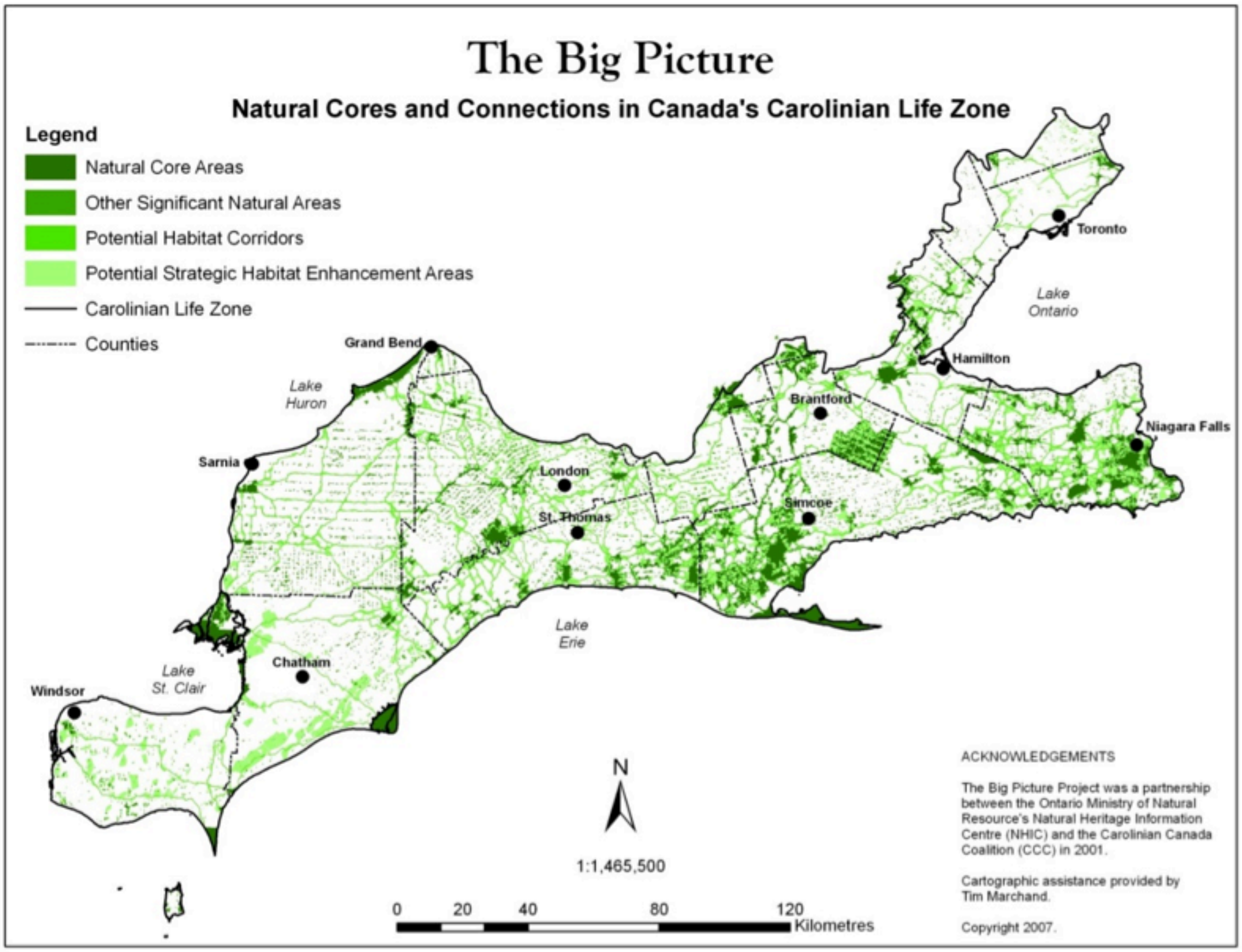

Figure 1. *Map of Canada's Carolinian Life Zone.* This big picture map shows Natural Core Areas and connections across Canada's Carolinian Life Zone.

The regional conservation group, Carolinian Canada Coalition (CCC), was established in 1984 by public and private groups, and conservation field work was funded by World Wildlife Fund Canada, in partnership with the Ontario Heritage Foundation, the Nature Conservancy of Canada and the Richard Ivey Foundation (Allen et al. 1990). CCC was incorporated as a charity that connects with many local naturalist groups, landowners and individuals. The membership of the board includes representatives from organizations such as Ontario's Conservation Authorities and Forests Ontario, as well as individual members. The *Big Picture Map* is one example of many Carolinian Canada Coalition partnerships and projects. This map, created in collaboration with the Nature Conservancy of Canada (2007) (Figure 1) shows the biodiversity hotspots.

[Unique challenge 1 to Carolinian Canada Coalition operations and work]: Most of northern Ontario is Crown land, as are natural habitats in the rest of Canada (Ontario Ministry of Natural Resources 2012). In contrast, only 2% of land in the Carolinian Ecozone is publicly owned, the majority being private (Environment Canada 1999; Ontario Ministry of Natural Resources and Forestry, 2018). Most of Canada's rare and endangered species are found here, where habitat fragmentation is high due to intensive agriculture, urbanisation and fragmentation. In 1997 the Carolinian Canada Conservation Strategy was established (Environment Canada 1999). Note the globally rare communities here that are at increased risk due to land use and urbanization, such as the Blanding's turtle (*Emydoidea blandingii*) and monarch butterfly (*Danaus plexippus*) (Ontario Biodiversity Council 2015; COSEWIC 2016; King et al 2021).

[Unique challenge 2 to Carolinian Canada Coalition operations and work – newcomers to Canada who don't know much about native plants]: While the urgency of protecting ecosystems has been recognized for decades, there has often been a lack of consideration about plant biodiversity and plant awareness (Balding and Williams 2016). Emotions, aesthetics, and media exposure play a substantial role in current conservation efforts (Castillo-Huitrón et al 2020). Humans will sympathise with familiar species that are 'charismatic' in appearance or behaviour. These charismatic species possess anthropomorphic characteristics such as front-facing eyes, fur, walking upright, intelligence, and friendliness (Thomas-Walters et al 2020). Individuals with minimal ecological exposure gravitate to familiar animals depicted in media such as the panda bear (*Ailuropoda melanoleuca*), polar bear (*Ursus maritimus*), or eastern chipmunk (*Tamias striatus*) (Root-Bernstein et al 2013). These species induce positive emotions hence motivating the public to care more strongly about their preservation. In contrast, the public may be repelled by species that evoke negative emotions such as fear or boredom (Gunnthorsdottir 2015).

An overemphasis on umbrella species, species chosen as representatives for an entire ecosystem when making conservation decisions, (Fleishman et al 2000) and charismatic species, species that are popular due to their physical appearance and depictions in media, in conservation biology, increases the likelihood of 'non-charismatic' species being overlooked. This is especially true for plants, fungi, and invertebrates (Barua et al 2012). While these less charismatic organisms may not be as visually appealing, they may have significant ecological value and are often keystone species which regulate ecosystem cycles and health. There is an identifiable and recognizable level of plant blindness amongst the public in conservation spaces and a need to educate about the benefits and services these plants provide (Balding and Williams, 2016; Jose et al 2019). Many people living in the Carolinian Life Zone are newcomers to Canada or to this part of the country (Krause and Hebbs, 2020; Ontario Ministry of Finance, 2020; Statistics Canada A, 2022), presenting an opportunity for people to learn about the region's natural history and native plant biodiversity.

This chapter was written in response to the *Plants, People, Planet's* special issue call for papers that highlight methodologies investigating plant awareness. It explains how a solution to the challenge of plant awareness in the Carolinian Life Zone was developed and implemented by Carolinian Canada Coalition. The *In The Zone* (ITZ) Tracker program is a citizen science project to monitor landscapes throughout the Carolinian Life Zone. The ITZ aligns with provincial policies to engage people in biodiversity action (Ontario Biodiversity Council 2015). This program collects citizen science data to monitor current environmental trends along with understanding the public’s level of plant awareness and overall perception of nature.

Uniquely, *In The Zone* Tracker Program allows its users to track their local gardening projects at small and large scale. Regardless of whether it be urban or rural, participants are encouraged to engage with nature and plant more native plant species on their property. The tracker was created with the intention of serving as:

1) A citizen science data collection which would provide a profile of the current state of the Carolinian Life Zone,

2) A method of outreach and engagement to connect participants with their community,

3) An educational resource to teach users what constitutes a healthy ecosystem.

This chapter introduces the *In The Zone* Tracker, specifically its survey questions and data usage. The survey consists of a series of questions, all pertaining to the participant’s current gardening habits, motivations and interests regarding connecting with nature, and the characteristics of the selected property. This section will also provide a timeline of the *In The Zone* program's history and its various iterations. Reports from CCC annual general meetings will show the tracker’s evolution along with the story of the cucumber magnolia case study, an imperative part of the tracker’s development.

2.2 - The *In The Zone* Tracker:

From 2014 to 2016, Michelle Kanter, Jarmo Jalava, and Tristan Bentley of the Carolinian Canada Coalition imagined developing a program that engaged with all the people living in the Carolinian Life Zone: from rural to urban and from landowners to renters. Realising that biodiversity in the region continued to decline despite provincial acts and management to protect biodiversity, CCC aimed to develop a program that increased plant biodiversity in the region, raised awareness of plants as nature-based solutions for climate change, and as an input to education.

The *In The Zone* Tracker is a multi-dimensional citizen science program, acting as a landscape survey, educational resource, and community outreach tool. It had both a soft and hard launch with further publicity from local expos such as London, Ontario's *Go Wild Grow Wild* green living show, as well as advertisements and booths outside southern Ontario IKEA stores. The tracker is easily accessible to individuals and groups online through Carolinian Canada coalition's website. It comprises a series of qualitative and quantitative questions regarding the characteristics of a selected property.

Questions are broken down into eleven main categories; Property Identification, Healthy Goals, Healthy Habitat, Habitat Area, Neighbourly Connection, Save Energy, Save Water, Wildlife, Community Connections, Green Economy, and My Green Life. In addition to these diagnostic questions, users have the option to tell their gardening story in an open-ended text box at the end of the survey. From these entries, future land leaders who are committed to developing healthy habitats can be identified for potential native planting sites. Once these questions are answered, a Healthy Garden Point score is generated for the submitted property. This is a score generated based on answers to these questions and indicates potential room for improvement for participants.

Not only does the *In The Zone* Tracker provide insights into current trends within the community in Southwestern Ontario but also notes the ecological gaps, offering further investigation and analysis with a critical eye. The full list of *In The Zone* Tracker survey questions can be found in **Appendix A** in the supplementary material.

2.3 - Results

Since 2017, the first full year of the *In The Zone* Garden Program, 6602 individuals and counting have logged their garden stories, sharing valuable information from over 6100 properties spanning 37,147 hectares (Carolinian Canada Coalition C). Data collected from the *In The Zone* Tracker has allowed for several outreach modules that educate and expand on current native plant knowledge (Figure 2). Information from a single property can be used to generate various data-driven programs. It has also led to the implementation of native plant tags at local plant nurseries to identify species and increase native plant sales.

Three case studies describe how data from the ITZ Tracker have been used. They demonstrate action and progress surrounding the topic of plant awareness. All three are ultimately a response to the research and field surveys carried out in the 1980s when the need to develop specific plans for protecting, conserving and restoring species and habitats in the Carolinian Life Zone emerged in an organised, data-driven fashion supported by government, universities and naturalist groups (Ambrose and Kevan 1990; Oldham 1990; Varga and Allen 1990).

The cucumber tree or cucumber magnolia, *Magnolia acuminata*, and the common pawpaw or custard apple, *Asimina triloba*, were included in a list of ten plant species in the Carolinian Life Zone needing seed ecology-related conservation research (Ambrose and Kevan 1990). Both species were on the list of 542 provincially rare plant species mapped in the Atlas of the Rare Vascular Plants of Ontario (Argus et al. 1982-87 cited in Oldham 1990). As of 2024, common pawpaw is not on the provincial endangered species list in any of the four categories: extirpated, endangered, threatened, or special concern.

Case Study One: The Pawpaw Parade

The Pawpaw Parade is a social story module that developed because of data collected by the ITZ Tracker. Common pawpaw, *A. triloba*, is a tree with edible fruit that is a native species in the Carolinian Life Zone. North America has a low number of native fruit trees in comparison to other regions such as Europe and Asia. (Hormaza 2014). In 1990, it was listed as one of Ontario's provincially rare species (Oldham 1990).

In September 2019, Ben Porchuk, an ecologist who frequently works with Carolinian Canada Coalition, became the champion of the Pawpaw Parade (Carolinian Canada Coalition F). The CCC was in possession of a hundred pawpaw trees that needed a place to thrive and be properly cared for by land stewards. Soon came the idea to create a Pop-up Pawpaw Parade, where Porchuk would drive and deliver trees to properties across the Carolinian Life Zone (Carolinian Canada Coalition F). Following a media release, the Carolinian Canada Coalition team was met with hundreds of requests for pawpaw trees.

Eligible candidates for the Pawpaw Parade were determined by property data; the same qualitative and quantitative characteristics that the *In The Zone* Tracker measures. There was a set of criteria that a property needed to meet in order to be chosen. Selecting the optimal properties for the trees would be instrumental to the restoration and recovery of pawpaw populations.

After considering the physiology of the tree, CCC's general criteria were: 1) The trees were to be planted in autumn, 2) Exposed to at least 50% sunlight, 3) Planted in pairs within 10 feet of each other for cross pollination, 4) Not impacted by nearby Black Walnut trees, 5) In moist, rich, and well-drained soil, 6) fenced off from grazing animals (due to their delicate trunks), 7) the soil must be compressed or mulch used to prevent uprooting, 8) the site must be able to accommodate tree growth of up to 15' in width and 5.5m in height and 9) trees must be watered daily for the first few months (Carolinian Canada Coalition B).

Once appropriate planting sites were determined based on submitted property data, the pawpaw trees were delivered in pairs. Recipients included: private gardens, restoration projects, seed banks, city gardens, green schoolyard projects, properties with existing pawpaws, properties seeking to improve bird populations, and food security programs. The Pawpaw Parade continues to be met with enthusiasm in the years following its debut. In 2022, 490 pawpaw trees and native plant kits were distributed across the zone with over 100 of these trees allocated to Indigenous groups (Carolinian Canada Coalition C). In 2023 the Parade surpassed this number, distributing 500 trees to 23 communities in southwestern Ontario (Carolinian Canada Coalition I). What distinguishes the Pawpaw Parade from other tree planting initiatives, is its focus on bringing people together in the practice of reconciliation. This replanting event was an opportunity for Carolinian Canada Coalition to connect with the Eshkiniigjik Naandwechigegamig, Aabiish Gaa Binjibaaying (ENAGB) Youth Agency and the Anishnawbe Wellness Collective, as a means of acknowledging the significance of Traditional Knowledge (Carolinian Canada Coalition K).

Pawpaw trees provide several ecosystem services, both direct and indirect. Directly, they produce nutritious fruits for humans and wildlife, high in fiber, minerals, and Vitamin C (Peterson 1991). In addition to the obvious and direct benefit of consuming its fruit, pawpaw trees provide an indirect ecosystem service. The pawpaw's self-pollination, long taproots, and affinity for wet soil assists in regulating the landscape and preventing soil erosion (Robles-Diaz-de-León and Nava-Tudela 1998). When comparing effectiveness of cultivated garden plants to indigenous plants such as the pawpaw, the presence of indigenous plants typically results in increased ecosystem integrity and resiliency (Almas and Conway 2016). Unlike non-native species typically seen in ornamental gardens, indigenous plants were present in the environment before major landscape changes and have evolved to survive over the years (Almas and Conway 2016). They are adapted to local conditions and preferred by local pollinators. Also, many indigenous plants are perennials which make them low-maintenance, reliable, and easy to care for (Shelef et al 2017).

Case Study Two: Identifying Habitats to Plant the Endangered Cucumber Magnolia

Citizen science programs offer at-risk species an opportunity to expand and restore population size. This can be seen through Carolinian Canada Coalition's work with the cucumber tree, *M. acuminata*. It was designated as an endangered species in 1984, and as of 2010 remains on the COSEWIC list of high priority species (Environment and Climate Change Canada, 2014).

About 200 wild trees remain in Canada, hence the need for ongoing projects to help restore the population (Carolinian Canada Coalition D). The cucumber magnolia module operated similarly to the Pawpaw Parade. Optimal habitats to plant the endangered cucumber tree were identified by analyzing citizen science data. As of 2020, there was no set number of cucumber magnolia plants to be distributed, as the project was still in active development and fundraising (Carolinian Canada Coalition D). Carolinian Canada Coalition continues to encourage native planting of high priority species and aims to raise awareness within the local community. In 2020, they distributed Pawpaw, Cucumber Magnolia, Tulip Tree, Blue Ash trees and Wild Garden Kits (Carolinian Canada Coalition J).

Case Study Three: Support for The Southern Ontario Seed Saver Tool

The *In The Zone* program data has supported other Carolinian Canada Coalition programs and initiatives such as the Southern Ontario Seed Strategy (SOSS), a collective focused on the preserving and expanding the commercial availability of native seeds. This includes the Southern Ontario Seed Saver Tool, which facilitates the creation of training videos and documents that explain how to collect native plant seeds and save them for planting in optimal locations. Ambrose and Kevan (1990) proposed that seed collection programs be developed. This was created to bring awareness to native seed sources across the region. This tool works in tandem with the *In The Zone* Tracker via citizen science data collection.

Participants create an online profile for the property, site, or project of interest. They then answer diagnostic questions which provide information about habitat characteristics. Following the completion of the Seed Saver Tool, participants will have access to resources, opportunities to connect with experts, and booklets with tips and best methods for the land (Carolinian Canada Coalition E; Carolinian Canada Coalition H). A Seed Savers Training Video Series was launched on the Carolinian Canada Coalition website as an educational resource for participants interested in protecting and expanding native seed sources. These videos were curated by experts and are in line with the two-eyed seeing approach, a traditional knowledge approach of best seed saving practices. The series includes: Stratification and Germination, Water Conservation, Soil Building, Grassland Seed Collection, Tree and Shrub Seed Collection, and Restoring Relationships to the Land (Carolinian Canada Coalition G).

Each of these distinct outcomes from the tracker data points to the same message: you do not need to be an expert to use the tracker. Anyone of any skill level can contribute stories about their property and garden. Regardless of a participant's prior experiences, the data collected generate a net increase in biodiversity and plant awareness. Figure 2 illustrates how *In The Zone* Tracker creates a flow of information that enables the creation of data-driven programming and conservation efforts.

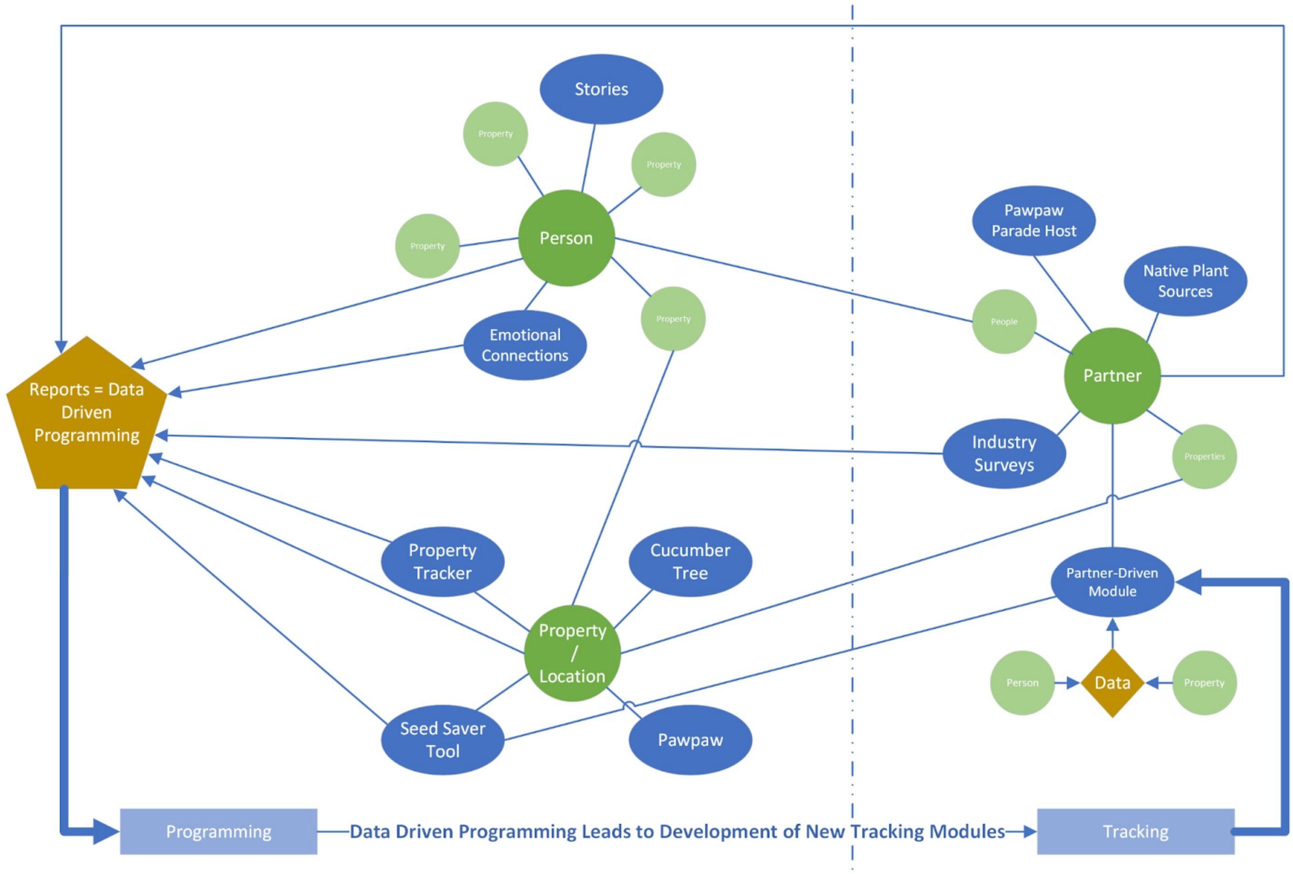

Figure 2. ***The* In The Zone *Tracker's Data-Driven Programming*.** This figure depicts the flow of information generated by the data collected from the *In The Zone* Tracker survey. It shows the potential of the data to be scaled from local to global. The flow chart shows the *In The Zone* Tracker architecture and how its survey data is used to inform plant awareness actions that support local biodiversity.

2.4 - Discussion

Programs aimed at engaging citizens as scientists and reversing declines in native plant biodiversity of the highly settled landscapes of Southwestern Ontario, Canada, face a variety of key challenges that have been met by the *In The Zone* Tracker Program. The first challenge in this region is that, in contrast to much of the rest of Canada which is Crown Land with the government being the major landowner, only 2% of land in the Carolinian Life Zone is publicly owned (1999); most property is in private hands (Ontario Ministry of Natural Resources and Forestry, 2018). Secondly, the Carolinian Life Zone has some of the highest population densities in the country compared with much lower densities in most areas of Canada that are further than 200 to 300 km away from the Canada-US border (Statistics Canada B, 2022). A third challenge is that a high proportion of the human population in the Carolinian Life Zone has either recently immigrated from another country or have migrated internally to this region from other parts of Canada (Krause and Hebbs, 2020; Ontario Ministry of Finance, 2020; Statistics Canada A, 2022).

The *In The Zone* program engages with these challenges by providing easy entry activities and accessible educational resources for a large, diverse population ranging from private landowners to tenants, across rural and urban settings, who may be living on and in, or care-taking properties of greatly varying sizes. The data from the first few years of the *In The Zone* program, and the case studies presented here, show how many of the region's challenges are being met, and also how barriers to participation have been identified so as to inform future solutions. The latter is achieved by using the survey information to refine and develop new versions of the *In The Zone* program in nuanced ways that both address specific local and plant species needs, while also meeting interests and issues that are zone wide.

Notably, the *In The Zone Tracker* Program results support Staude's (2024) findings that gardens have untapped potential for driving native plant biodiversity because cultivated plants, in our case, local native species, do better than uncultivated plants. Data from the first version of the *In The Zone* survey confirmed that the initial goal of the tracker, to act at the local garden level, yielded a high level of engagement, while also revealing that many more issues were at play than only the topic of gardening with native plants. The tracker creates space for conversations about the relationship between native plants and biodiversity, how to undertake positive action against global warming, the topics of physical and mental health and wellbeing, topics of care work including caring for other people and caring for the environment, as well as truth and reconciliation and Indigenous perspectives.

Note that SOBR-2015 calls for all kinds of action on public engagement around biodiversity, and that the ITZ represents action from a non-government actor to make this happen. While current maps demonstrate a shrinkage in habitat cover, action is being taken at a citizen level to combat biodiversity loss and increase representation of native plant species. Getting public awareness for Canadian biodiversity poses numerous challenges including lack of time, resources, and knowledge gaps. SOBR-2015 has called for action on public engagement around biodiversity, but the *In The Zone* Tracker has been a primary non-government actor in making this happen.

Through citizen science planting programs comes a heightened awareness of native plant species and an improved relationship between the land and the people that inhabit it. With such citizen science programs, the aim is not to simply balance one's ecological impact, but to generate a net increase in biodiversity. The *In The Zone* Tracker offers insights into the current state of a community, highlighting both its ecological strengths and blind spots. The power of connecting with nature via citizen science is evident in the creation of data-driven programs. Participants with varying levels of experience - from novice to expert - are all able to contribute and make a difference, adding value to the habitat around them.

Carolinian Canada Coalition's mission has been to preserve, conserve, and restore biodiversity in the Carolinian Life Zone in the practice of Truth and Reconciliation. The ITZ Tracker Program will continue to be developed as a landscape survey, educational resource, and outreach tool. By partnering with local native plant retailers, environmental organizations, and conservation authorities, the ITZ Program will only improve through integration of new connected tools, ongoing refinements, and new community connection opportunities. Future directions for the *In The Zone* Tracker suggest the potential to be scaled from local to global, implemented across multiple ecoregions.

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CHAPTER 3: A Systematic Review to Evaluate the Current State of Canadian Citizen Science Activity

3.0 – Introduction: The Origins and Motivations Behind Citizen Science

The term "citizen science" was popularized in the mid to late 1990s in two independent instances, by American ornithologist Rick Bonney and British sociologist Alan Irwin (Riesch and Potter 2014). Irwin defines citizen science in a much broader sense, stating that its purpose is to develop scientific citizenship and expose the public to science policies and processes (Irwin 1995). Bonney's perspective is more specific, defining citizen science in simpler terms as a project where a non-scientist volunteers to collect scientific data (Bonney 1996; Bonney et al 2009).

It is important to note that in most instances citizen science activities are done in partnership with scholars and academics, in which the public is invited to volunteer in ongoing research (Dickinson et al 2010; Ellwood et al 2023). However, the concept of citizen science did not come into common science discourse in the 1990s. A common misconception today is that the public and non-scientists lack scientific understanding and skills (Bazely and McPherson 2022). Citizen or 'amateur' scientists have existed long throughout history and prior to the rise of industrialization and professionalization of science, science was conducted largely by 'amateurs' or those who were not paid (Bazely and McPherson 2022; Miller-Rushing et al 2020). These individuals conducted observations of natural history and the world around them simply because of an innate interest or curiosity.

This mindset persists today and fuels the growing citizen science movement. Recruiting and maintaining participants is one of the main challenges that all citizen science platforms face (Kao et al 2020). An effective citizen science program is one that can foster an individual's sense of social responsibility while making scientific concepts more accessible (Kao et al 2020). It relies on self-efficacy, satisfaction, and belief in science. Participants must be reminded that citizen science is a tool to enhance academic research, and that their contributions do make a difference (Hunter et al 2012). Self-regulated online projects without a community or group component can cause participants to feel less motivated or confident in their abilities and potentially deter them from contributing (Aristeidou and Herodotou 2020).

3.0.1 – Inequities and Inclusion in Citizen Science

Although the term ‘citizen science’ was popularized in the 1990s and persists in the scientific community, it is exclusionary and does not accurately represent all participants (Ellwood et al 2023). As the field continues to evolve, the terminology must also evolve to align with diverse identities of populations who engage in science. The word ‘citizen’ can be imposing for immigrants that are new to a country and for Indigenous communities who experienced colonialism, loss of land, and feel disconnected with an assigned national citizenship (Eitzel et al 2017; Ellwood et al 2023).

Also, the term ‘scientist’ refers to a highly qualified individual with academic or industrial training and could discourage participants (Liebenberg et al 2021). While people can gain awareness of ecological issues such as plant blindness, participating in a citizen science activity does not necessarily make someone a scientist. From an academic viewpoint, the term ‘science’ may be too specific and technical. This is especially true if the chosen activities do not meet the expectations of scholars such as Bonney and Irwin, who believe that scientific data must be collected, and a sense of scientific citizenship must be developed (Bonney 1996; Irwin 1995). Recent discussions have suggested more inclusive terms such as ‘community science’, 'tracking science', and 'public participation in science research (PPSR)' (Eitzel et al 2017; Ellwood et al 2023; Liebenberg et al 2021). There has yet to be a consensus within the scientific community to use a more inclusive term, and these terms often do not gain traction in the way that 'citizen science' has (Liebenberg et al 2021). Considering a more inclusive term going forward will welcome and encourage diversity in the scientific community and better define what it means to participate in science.

3.1 – Systematic Reviews in Ecology

By comparing the *In The Zone* Tracker with other citizen science projects and activities in Canada, its significance and impact can be contextualized and evaluated. In a rapidly changing world, evidence-based reviews are key in the transfer of knowledge and best practices to combat environmental challenges (Pullin and Stewart, 2006). Solutions to environmental issues are complex, requiring interdisciplinary collaboration and the support of both academics and non-academics (Hewitt et al 2011). This can be achieved through the creation of systematic reviews. A systematic review is a form of knowledge synthesis, whose purpose is to assess the current state of knowledge in a particular subject by evaluating scholarly articles from multiple databases (Smith et al 2012).

Research questions will vary but systematic reviews generally follow the same methods framework, which must be easily reproducible (Pollock and Berge 2018). A systematic review can be broken down into three stages: **1)** Developing questions and protocol, **2)** Collecting and extracting data, and **3)** Data synthesis and interpretation (Pullin and Stewart, 2006). To determine the current state of a topic, its respective literature must be collected and thoroughly investigated. Systematic reviews will commonly filter through academic databases and implement a set of search terms or keywords (Hewitt et al 2011). From this, the resulting articles are indexed using a set of research questions and classifications (Tanentzap et al 2009).

The origins of systematic reviews can be traced back to the medicine and healthcare field in the 1970s and 1980s (Munn et al 2018). In the last two decades, systematic reviews have risen in popularity and evolved to include a diverse range of research disciplines (Munn et al 2018). This method of data synthesis was taken from medical literature and employed to the field of ecology and evolution, where evidence-based reviews are especially important in informing conservation policy efforts.

Systematic reviews, such as the one conducted in this chapter, are considered a form of new and original research. Although systematic reviews summarize existing research topics, they are creating new knowledge by interpreting data and identifying the trends and gaps within a particular field (Munn et al 2018). In the case of ecology, specifically conservation biology, tools such as systematic reviews are essential in adding value to the field and providing insights on best practices to solve current environmental crises (Alston 2019). In the case of my systematic review of citizen science activities in Canada, I made one important change by also including grey literature and literature from non-academic sources. The reason for this, is that when writing **Chapter 2**, I discovered that documentation of Carolinian Canada Coalition programs was not found in peer-reviewed journals. Therefore, I assumed that this would likely apply to other citizen science activities.

3.2. - A Structured Systematic Review of Existing Citizen Science Tools

Methods

This systematic review aims to evaluate the success of the *In The Zone* Tracker by placing it in the context of a systematic review of the current state of citizen science. The protocol used for this systematic review was as follows: Three independent Boolean searches were conducted with different key phrases in the publication titles. The first search pulled publications with "citizen science" in their titles, the second search filtered for "citizen science" AND "environment" in publication titles, and the third search filtered for "citizen science" AND "Canada" in publication titles. For the systematic review, the terms "citizen science" AND "Canada" were searched within Web of Science, SCOPUS, PubMed, and Google. Three scholarly portals and one non-academic portal were chosen to compare differences in reporting of citizen science tools. In a general web search, citizen science projects were extracted from an official Government of Canada ongoing citizen science portal. These were accessed on October 24th, 2024. Searches were limited to publications with key terms in their titles as a content analysis was then performed on the scholarly and grey literature.

Question of interest: What kinds of citizen science projects have run the longest and what can we discover about methods for sustaining citizen science engagement?

Predictions: The most common citizen science projects will be bird or insect-based and documented in grey literature.

After carrying out searches of databases and the internet, the following information was extracted by performing a content analysis of the search results returned by searches in both the peer-reviewed literature and the Government of Canada grey literature portal on citizen science:

1. What year did the citizen science project begin?
2. What year did the citizen science project conclude? If no conclusion date: Is the project still ongoing? When was the project last active? Is it unknown or not available?
3. How many participants did the project have?
4. How many total users does the citizen science platform have?
5. Where did the project occur and where is the tool available to use?
6. What topic(s) and subject(s) did the citizen science project cover?
7. How was the project reported? Was it peer-reviewed, grey literature, or documented in both?

Results

My systematic review searched for information in both academic and non-academic sources, to give as broad as possible insight into current trends in Canadian citizen science projects. The systematic search results using various keyword combinations returned relatively few citizen science projects across Canada when the initial global search results were narrowed down by country. Furthermore, none of the searches of either the scholarly literature or grey literature (Government of Canada portal about citizen science projects) returned any results, references or information about the *In The Zone* Tracker.

Tables 1-3 show search results after filtering with keywords “citizen science”, “environment”, and “Canada”. Table 1 gives the results of the first database and web searches for articles with the keyword “citizen science” in the title. Searches were conducted through three scholarly portals (Web of Science, SCOPUS, PubMed) and two Google web browsers, one academic (Google Scholar) and one that is non-academic, to pull both peer-reviewed literature and grey literature. There were between 1,000 and 200,00 results.

In Table 2 the Boolean search for articles with the keyword “citizen science” AND “environment” in the title. This search was conducted to determine how many citizen science projects pertained to ecology. Searches of the same scholarly portals and a non-academic web browser were carried out. There were many fewer results (10-842). Finally, in Table 3, which filtered the earlier results by adding the word “Canada” in the title, yielded three to 200 results depending on the database or web search.

Table 1. ***Results of searches for the term "Citizen Science" in publication titles***

Database	Publication Type	Results
Web of Science	Peer-reviewed literature	3,436
SCOPUS	Peer-reviewed literature	4,201
PubMed	Peer-reviewed literature	1,039
Google Scholar	Peer-reviewed and grey literature	14,400
Google web search	Grey literature	201,000

Table 2. ***Results of searches for the terms "Citizen Science" AND "Environment" in publication titles***

Database	Publication Type	Results
Web of Science	Peer-reviewed literature	33
SCOPUS	Peer-reviewed literature	54
PubMed	Peer-reviewed literature	10
Google Scholar	Peer-reviewed and grey literature	104
Google web search	Grey literature	842

Table 3. ***Results of searches for the terms "Citizen Science" AND "Canada" in publication titles***

Database	**Publication Type**	**Results**
Web of Science	Peer-reviewed literature	16
SCOPUS	Peer-reviewed literature	17
PubMed	Peer-reviewed literature	3
Google Scholar	Peer-reviewed and grey literature	46
Google web search	Grey literature	191

Information about Canadian citizen science studies discovered

Figures 3 and 4 show the topics (subjects) and geographic locations of the 17 Canadian citizen science projects discovered in the peer-reviewed scholarly literature. **Appendix B** gives detailed information in response to the seven questions posed about the 17 citizen science projects. The **standard deviation** is 17.233, indicating data points spread out over a wide range and therefore have high variability. Like the government citizen science portal, most of the citizen science platforms mentioned in these publications are still active. These studies had an average duration of 11.4 years and a median of 3 years.

Participation was highly variable between citizen science platforms, with a **standard deviation** of 31760.3. Again, this high variability is expected as the citizen science platforms being observed have a wide distribution of participation rates. The average peer-reviewed study monitored 1087.8 participants. The platforms being studied collected an average of 18,822 reported users or publicly available followers on their social media platforms. Smaller platforms such as GrizzTracker, RinkWatch, and Urban-Rural Biomonitoring and Assessment Network

(URBAN) had a few hundred participants, while large nation-wide platforms such as iNaturalist, eBird saw tens of thousands of users.

Seven out of 17 (41%) of these studies did not explicitly state how many participants or volunteers they had, and 5/17 (29.4%) of the citizen science tools did not provide the number of total or lifetime participants on the platform. It is unclear if these numbers were unknown, or just not publicly available. As seen in Figure 4, 5/17 (29.4%) of the projects extracted from the three scholarly databases are available nation-wide, again using online components for accessibility. Ontario was once again the region with the most projects available to its inhabitants.

The most frequent topic was water and water quality: 31% of projects were about water quality based, including the monitoring of harmful algae, water clarity, lakes, and wetlands. As anticipated, insects and birds were also somewhat popular within the peer-reviewed literature. Other topics of interest included climate, plants (n=1), bears, and human health.

Figures 5 and 6 show the topics (subjects) and geographic locations of the 57 citizen science projects listed in the official Government of Canada citizen science portal. Detailed tables in **Appendix C** summarize answers to questions 1-7 listed in the Methods about the specifics of these projects. These projects are currently ongoing and vary in length, with start dates ranging from the 1990s to 2024. The **standard deviation** is 12.9, indicating data points spread out over a wide range and therefore have high variability. The median of these values is 9 years, the typical duration for the citizen science projects in this portal.

The number of participants in each listed project was highly variable, with a **standard deviation** of 177070.9. This number is expected as participation in the listed projects varies drastically. There were local small-scale projects such as Stop-Carcasses or Cuscuta DNA

Barcoding via iNaturalist with groups as small as 20-30. In contrast, larger projects such as the North American Breeding Bird Survey (BBS) and the City Nature Challenge host thousands of Canadian participants to date, and FluWatch garnered over one million participants. The median of these values is 2753, indicating the average number of participants. Nine out of the 57 (15.7%) projects listed did not explicitly state the number of lifetime or yearly participants and these numbers were not publicly available.

Figure 6 shows that 34 out of 57 (59.6%) of the projects listed on the Government of Canada's citizen science portal occur nationally, many with online components that make them easily accessible. Ontario had the most citizen science projects available. Sixteen percent of these projects were dedicated to general nature observations, with no specific topics of interest. As expected, animals (fauna) were the subject of the most popular citizen science projects. Fifteen out of 57 (26.3%) of projects focused on birds and wildlife in general, while an additional eight projects were solely dedicated to insects, specifically monitoring for the presence of invasive species and pests. Plants were the topic of only four projects listed on the Government of Canada portal. Other topics of interest included climate, water, and human health. When comparing the number of peer-reviewed projects to non-academic projects, it was found that 29 out of 57 (50.9%) fell under solely grey literature. Roughly 40% of the projects were present in both academic and non-academic contexts (see Figure 5 and **Appendix C**).

There was, overall, more information about science articles discovered through non-academic web browsers than from scholarly databases. Although the Google web searches were filtered to return results with the selected keywords in the title, there was some repetition in the searches due to videos, conference proceedings and e-books. Including the Google web searches could create a large source of error by inaccurately overestimating the actual number of citizen science activities. For this reason, Google searches were excluded from further analysis in the systematic review.

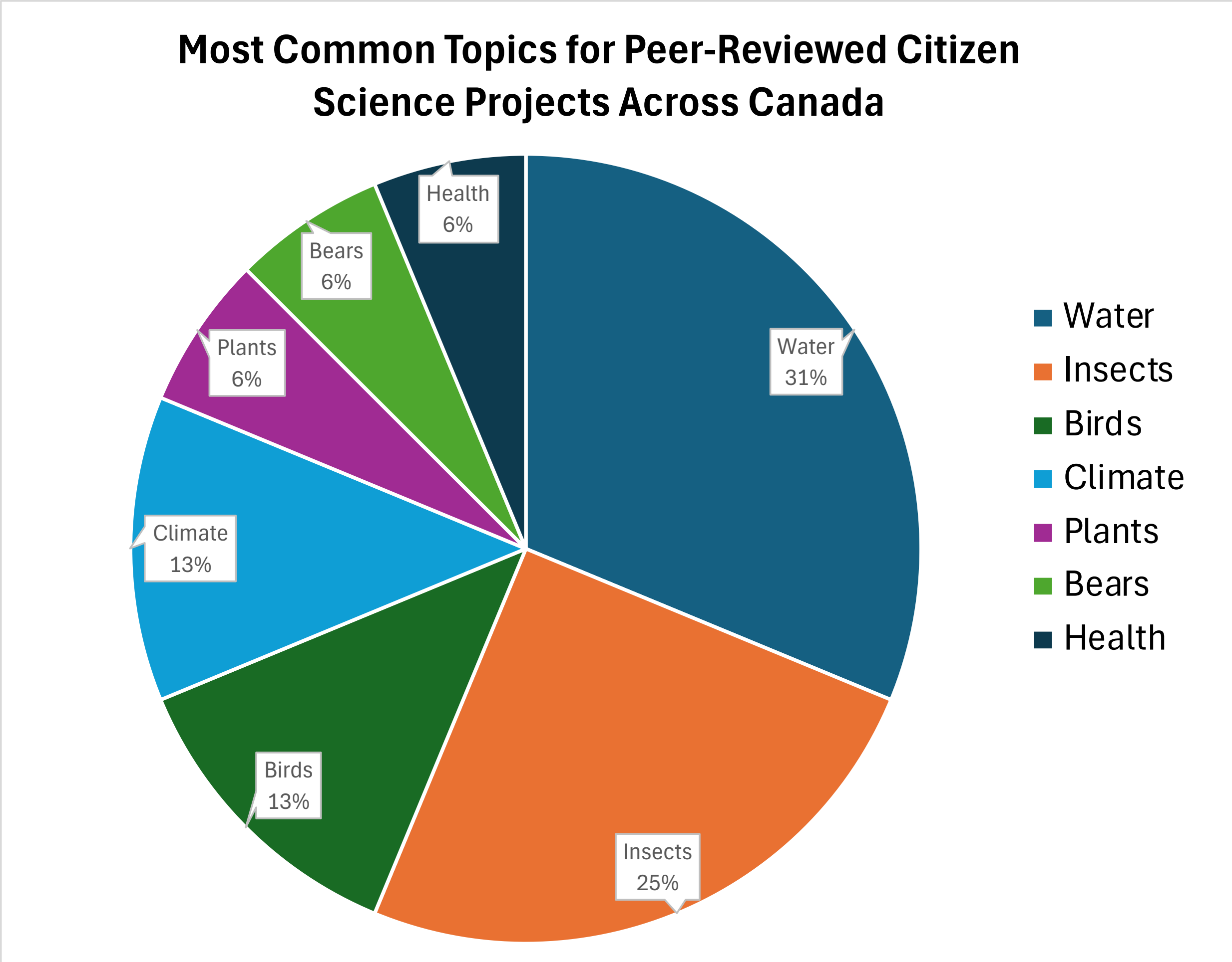

Figure 3. ***Distribution of the Most Common Topics for Peer-Reviewed Citizen Science Projects Across Canada.*** The pie chart above displays the distribution of topics for the 17 peer-reviewed citizen science projects extracted from Web of Science, SCOPUS, and PubMed scholarly databases, using the keywords "citizen science" and "Canada" in the title of the article. Full table and breakdown can be found in Appendix B in the supplemental material.

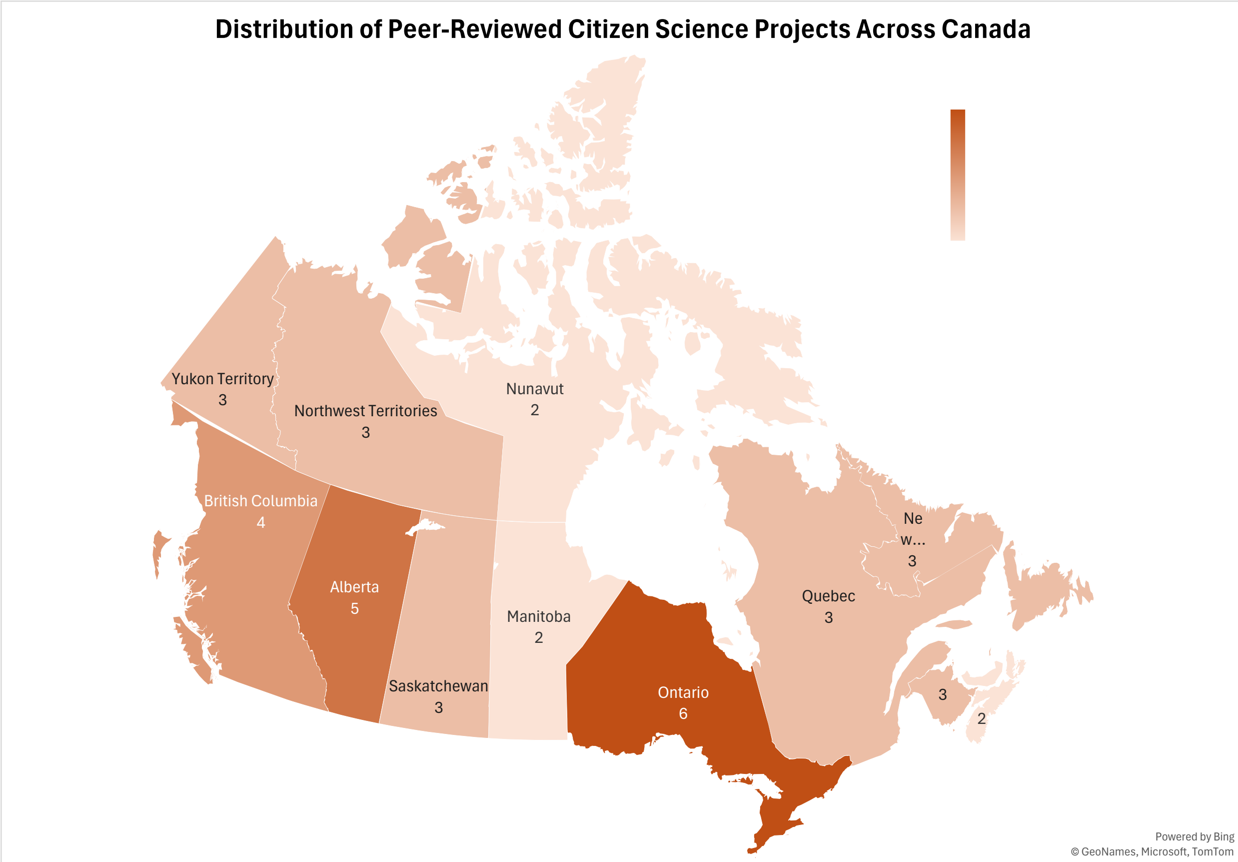

Figure 4. ***Geographic Distribution of Peer-Reviewed Citizen Science Projects Across Canada.*** The map above displays the geographic distribution for the 17 peer-reviewed citizen science projects extracted from Web of Science, SCOPUS, and PubMed scholarly databases, using the keywords "citizen science" and "Canada" in the title of the article. Full table and breakdown can be found in Appendix B in the supplemental material.

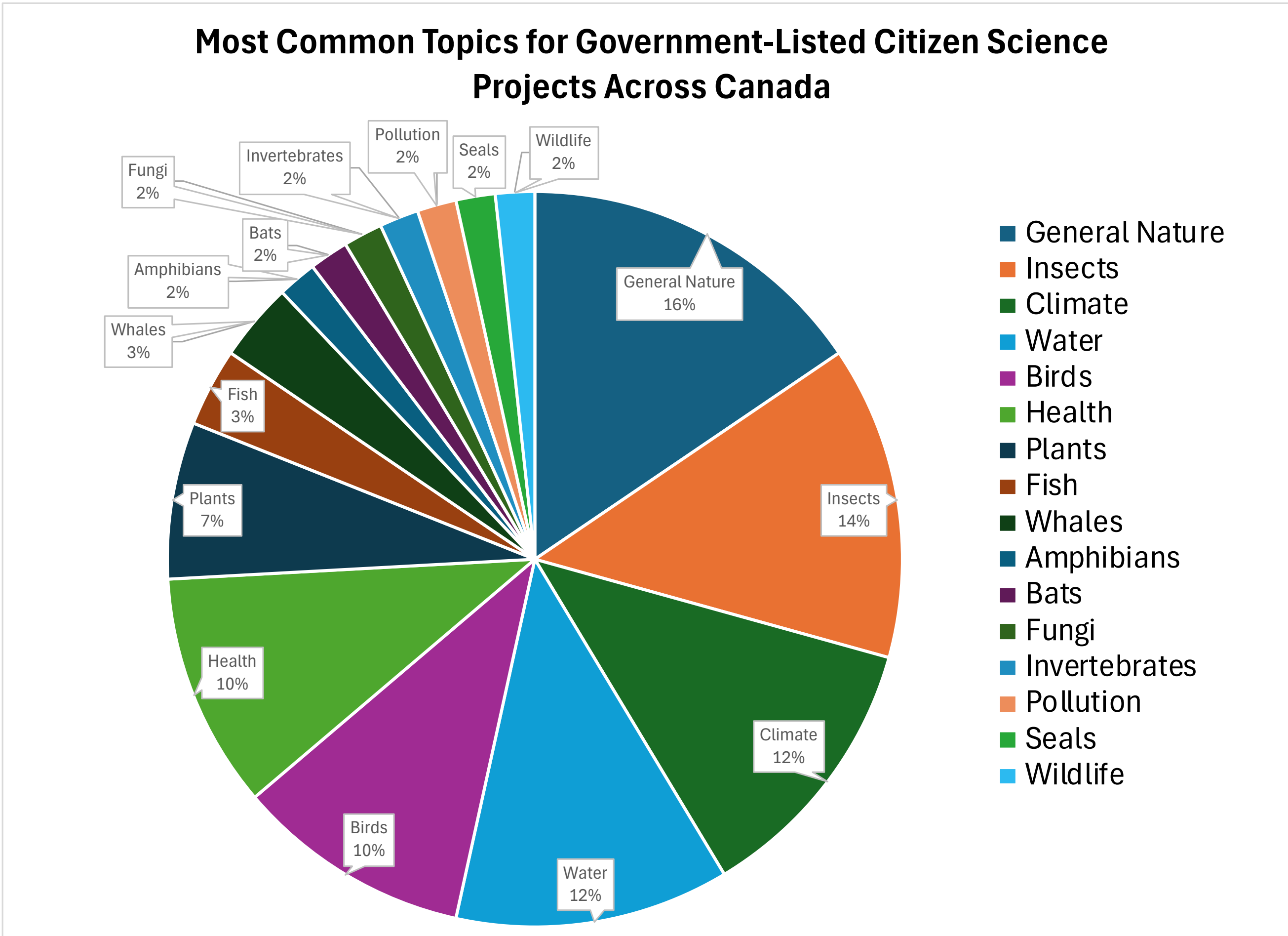

Figure 5. ***Distribution of the Most Common Topics for Government-Listed Citizen Science Projects Across Canada.*** The pie chart above displays the distribution of topics for the 57 citizen science projects listed on the official Government of Canada Citizen Science Portal. Full table and breakdown can be found in Appendix C in the supplemental material.

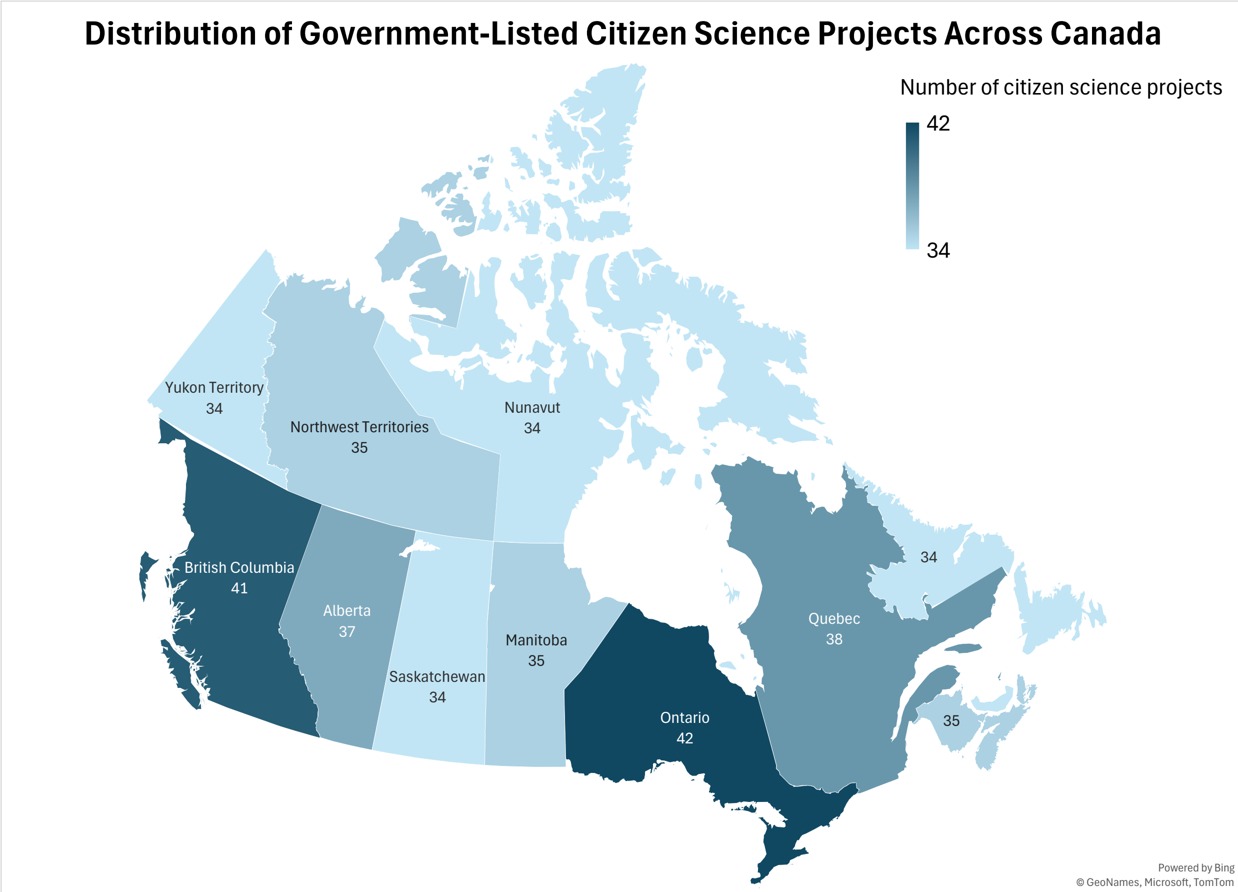

Figure 6. ***Geographic Distribution of Government-Listed Citizen Science Projects Across Canada.*** Chart displaying the geographic distribution of the 57 citizen science projects listed on the official Government of Canada Citizen Science Portal. Full table and breakdown can be found in Appendix C in the supplemental material.

Discussion

Strengths and Gaps in Current Citizen Science Tools

While there is relatively little information about citizen science activities across Canada, those that the review discovered, both in the peer-reviewed literature and on the Government of Canada portal were diverse in the topics and subjects examined. It is highly likely that, since the *In The Zone* Tracker was not included in the results of the systematic review, that there may be many other citizen science projects and activities that are occurring which are not being captured in databases and more permanent record. Thus, we can infer that there is likely to be a significant knowledge gap in Canada about the range and number of citizen science projects.

Involving volunteers in scientific data collection is not a novel concept but the range of activities aimed at this has increased significantly over the last two decades after the term "citizen science" gained prevalence in the 1990s (Riesch and Potter 2014; McKinley et al 2015). Specifically, the trend of digital citizen science has shown rapid growth. There have been an estimated 14 million virtual citizen science participants since the 2000s (Strasser at al 2023). Participation includes recorded observations or photo submissions, data transcription, and systematic monitoring by training volunteers to perform a technical field skill (Pocock et al 2017). As seen in the above systematic review, the diversity of citizen science project execution and subject matter has grown over time.

Earlier projects such as the Christmas Bird Count and the North American Breeding Bird Survey (BBS) are some of the longest citizen science initiatives running to-date, originating in the 1900s (Robbins et al 1986). They rely on basic data collection through counting the numbers of birds spotted across the Western Hemisphere during December 14^{th} and January 5^{th} of each year (Dunn et al 2005). The simplicity of recording these observations make these projects easy and accessible for the average human, hence the high participation and longevity of the program. These simple yet important observations from non-scientists and scientists together allow for widespread and low-cost data collection unlike any other data sets, which would have taken significantly more time if conducted independently (Dunn et al 2005; Nov et al 2014).

Although the rise of citizen science has allowed for a large volume of data submission, there is suspicion and uncertainty in terms of the credibility of the data being collected (Brown and Williams 2018, Dickinson et al 2010). While the Christmas Bird Count has been reported as the best available source of information on range-wide bird population trends (Faaborg 2005), this level of accuracy and integrity may not be true for other citizen science projects. As seen in the results of my systematic review, 15.7 – 29.4% of the observed citizen projects fail to report the number of participants in the study and total number of lifetime participants on their respective platforms, which highlights an issue of transparency and potential observer error (Dickinson et al 2010; Vohland 2021).

Another extensive issue in the realm of citizen science is the ephemerality or impermanence of non-academic websites and databases. With the constant stream of technological advancements that allow anyone to be a scientist with the press of a button, increasing numbers of citizen science projects are solely run online or are blended settings that heavily feature online components (Aristeidou and Herodotou 2020). Web-based programs have become common in the 2010s and 2020s, if not expected, but create a unique problem of their own. Link rot or link decay is a growing issue we face in the digital world, one that poses significant accessibility issues for citizen science. (Goh and Ng 2007). Link rot refers to the availability of a web page, whose URL could become nonviable or whose content could disappear after a certain duration of time (Markwell and Brooks 2003).

One of the reasons for the knowledge gap in Canada about citizen science projects likely is related to the ephemeral nature of internet records about them. Studies on the stability of web pages have found that without constant monitoring and updating, a page may have a half-life of 2-5 years (Markwell and Brooks 2003; Goh and Ng 2007). Without continuous maintenance of these web pages, valuable information will become nearly unretrievable without an archive. In the case of citizen science, link rot puts powerful data at risk of disappearing off the Internet. The effects of link rot were already evident throughout the above systematic review. When comparing the number of peer-reviewed projects to non-academic projects, it was found that 29 out of 57 (50.9%) fell under solely grey literature. A substantial amount of these pages had dead links or only provided updates through blogs or social media. It is understandable that many citizen science platforms choose to operate solely in the non-academic space due to cost, resources, and initial accessibility for users. However, further discussions need to be had about the preservation of citizen-submitted data, especially in the ecology space that relies so heavily on photos and counting records.

One solution to reducing the ephemeral nature of information about citizen science projects in Canada is the create mechanisms that ensure academic partners analyze the field work, data and outcomes, and write up the research in the peer-reviewed literature which is much more likely to create a more permanent record.

Putting the *In The Zone* Tracker in this larger national context

The limitations and successes of the *In The Zone* Tracker can be compared to other national citizen science activities. The average timespan of citizen science activities was nine years. The *In The Zone* Tracker was launched in 2017 and is now entering its ninth year, putting it **on par** with other citizen science projects of similar nature.

In my review of the non-academic Government of Canada citizen science portal, 50.9% of activities listed were not documented in scientific journals. Despite existing for nearly a decade, the *In The Zone* Tracker was not found scientific journals and was solely existing in web pages and grey literature. Its lack of documentation in academia places the *In The Zone* Tracker **on par** with the 50.9% of activities in grey literature. However, with this thesis I am to bring awareness to the *In The Zone* Tracker and provide scholarly context.

As of the Carolinian Canada Coalition's 2022-2023 Annual Report, the *In The Zone* Tracker Program has had 6,602 lifetime participants since its launch in 2017 (Carolinian Canada Coalition 2023). My systematic review found that activities in the non-academic Government of Canada citizen science portal had a median of 2753 participants, while the activities documented in academic databases had a median of 1087 participants. The *In The Zone* Tracker ranks **above average** in terms of lifetime participation.

Out of the 57 citizen science activities from the Government of Canada portal, only 7% of those activities focused on plants as a topic. Similarly, out of the 17 articles I reviewed from the three academic databases, only 6% of the described citizen science activities were plant focused. The most common subjects of study were birds, insects, and public health. There are relatively few citizen science activities about plants and botany which makes the *In The Zone* Tracker **rare** in comparison to its counterparts. Its focus on plants and multidimensional function as an activity, survey, and educational tool make it a **novel and relevant** activity with potential to be scaled up across Canada.

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CHAPTER 4: Conclusions and Future Directions

This chapter summarizes the main findings of my research, and places this work in the context of my student co-op with Carolinian Canada. I also briefly describe my initial thesis plans, and how and why they evolved, and I offer future suggestions for citizen science actions arising from my work in the NSERC CREATE program, TABES.

4.0 - Main Findings:

A. My evaluation of Carolinian Canada's *In The Zone* Tracker Program found that biodiversity loss **can** be reversed at a local level through non-governmental organizations implementing citizen science native planting projects to generate a net increase in species.

B. The majority of citizen science activities across Canada tend be ephemeral and need the support of researchers to publish and bring awareness to their work.

C. The main outcome of citizen science is not necessarily making people understand advanced concepts but finding common values and empowering them to make a difference in their community.

4.1 - It Starts At Home: Biodiversity Can Be Reversed Locally via Citizen Science

Non-governmental organizations and social enterprises such as Carolinian Canada Coalition can make changes and reverse biodiversity loss at a local level. Increases in biodiversity were estimated in two ways: (1) Specific numbers from *In The Zone* Tracker events such as the Pawpaw Parade and (2) Planting trends from self-reported citizen science data observed during my internship with the Carolinian Canada Coalition. As seen in the case studies in **Chapter 2**, community responses collected from the *In The Zone* (ITZ) Tracker program were able to inform optimal planting locations for pawpaw trees, cucumber magnolia plants, and seed orchards. The demand to participate in the Pawpaw Parade has increased each year since its inception. What started with 100 trees in 2019 has now grown to 500 trees planted in both 2023 and 2024 (Carolinian Canada Coalition F; Carolinian Canada Coalition I). This alone shows a confirmed and tangible net increase in native plant species within southwestern Ontario. The Pawpaw Parade has become an annual tradition that fosters a sense of community and reconciliation, which continues to gain traction each year.

In addition to specifically organized events such as the Pawpaw Parade, the *In The Zone* Tracker's general data does indicate an increase in species and overall biodiversity. ITZ survey questions discussed in **Chapter 2** and seen in **Appendix A** ask the participants a variety of healthy habitat questions. Some of these include estimating the number of different native plant species on the property and recalling how many new species were found on their property since their last report or within the last year. The ITZ Tracker does not explicitly ask for the names of species in their initial diagnostic questions – I did develop a storytelling module as part of my internship with Carolinian Canada Coalition as described in **Appendix E**. Once launched, this will give participants the option to share more detail about their garden, including any known species.

While the ITZ Tracker does not require its users to know exact types of species on the property, it does record the number of species and number of participants. With this knowledge we can infer that biodiversity has increased on some level despite plant species not being directly or accurately identified. Even if participants are not formally trained and unable to recall names of species, they do recognize distinct visual differences between a few plants in their surrounding environment. The *In The Zone* Tracker data is not specific enough to evaluate population trends or extinction risks, where accurate species identification is essential (Austen et al 2016). However, it does provide a baseline indication of number of species in a given area and allows users to report if they have planted any native plants on their property within the last year or since their last submission.

During my internship with the Carolinian Canada Coalition **(Appendix E)**, I analyzed the *In The Zone* Tracker data and observed an increase in number of species being planted on properties each year. Participants who chose to answer the questions pertaining to number of species on their property did report an increase in native plant species since their previous submission(s). However, the parameters and limitations of this thesis did not allow for me to get further ethics approval to examine and discuss these findings in detail. The goals of a citizen science program such as *In The Zone* can differ from the goals of academics. The *In The Zone* Tracker does not require a high level of quantitative and verifiable data and relies on the accuracy of self-reporting from non-experts. This comes with the risk of overstatement of achievements, which is why local citizen science efforts should be closely monitored by academics.

Community-run projects and events mediated by non-governmental organizations may seem negligible in comparison to larger scale conservation efforts, but Carolinian Canada Coalition's work has proven otherwise. Small but concrete changes are being made at a local level that are actively reversing biodiversity loss. These local acts have the potential to be adapted globally. Understanding local perceptions of change is key in implementing scalable global change (Pyhälä et al 2016). Society is becoming increasingly aware of the limitations and consequences of relying solely on corporations and governments for sustainability efforts. In a study conducted by the Pew Research centre, two thirds of Americans said that their government is doing too little to reduce effects of climate change (Tyson & Kennedy, 2020). In the same survey, 90% of participants favoured tree planting as the solution to absorbing carbon emissions (Tyson and Kennedy, 2020). Canadians share similar sentiments, with 60% wanting the federal government to do more to combat the effects of climate change (Winfield and Macdonald, 2012).

These attitudes explain the increased interest in grassroots movements by charities, non-governmental organizations, and social enterprises (Raj et al 2022). These groups partner with communities to understand their needs, advocate for causes they strongly believe in, and can mobilize quickly to communicate with government officials (Flores and Samuel, 2019). However, recent UN reports indicate that local response to sustainable development goals (SDGs) is relatively low and still in the early stages (Flores and Samuel, 2019).

Communities, especially those with Indigenous populations, could benefit from working with NGOs who function as a liaison in change-making. It is evident that groups such as Carolinian Canada Coalition have the power to organize citizen science projects that create meaningful and lasting progress towards increasing biodiversity. These projects have the potential to be scaled up globally and introduced to the ongoing conversations at conferences such as the UN Climate Change Conference (COP) and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES).

4.2 - Better Together: Citizen Science Projects Need Researchers to Bring Awareness

Following my experience in **Chapter 2** studying the *In The Zone* Tracker (**see Appendix A**), as well as conducting a systematic review of existing citizen science tools in **Chapter 3** (**see Appendix B and C**), the need to connect academics with citizen science projects is clear and indisputable. Grassroots movements, including citizen science, are beneficial in terms of their ability to mobilize quickly and find participants who are truly invested in social and environmental causes (Flores and Samuel, 2019). Citizen science can act to fills the gaps where governments and institutions fail by inviting the public to participate in data collection (Ellwood et al 2023; Pollock et al 2021).

For example, Canadian women in the 19th century were pioneers in inventing the modern field guide for flower identification in Canada (Bazely and McPherson 2022). These women were not yet welcome in the male-dominated scientific community and their contributions to the advancement of botanical knowledge went largely unrecognized (Bazely and McPherson 2022). The act of making field notes and recording garden observations was unpaid and a hobby they participated in out of curiosity and interest (Strasser et al 2019). These ‘amateur naturalists’ fell under the category of citizen science, a practice that continued into the 21st century.

Volunteer participation has been an integral component of research, especially in the field of ecology and conservation biology (Catlin-Groves 2012). With the rise of smartphones and laptops, citizen science in the last two decades has become more widely accessible, using members of the public to crowd-source data (Catlin-Groves 2012). As found in my systematic review from **Chapter 3** (**Appendix B and C**), 50.9% of the citizen science projects observed were documented in grey literature, mainly in the form of social media pages or specific websites. Grey lit allows for instant data collection in large volumes with a relatively simple submission process. For ecology-based projects, this data is usually comprised of photo observations or species counts (Paez 2017). There are both benefits and disadvantages of hosting and discussing citizen science projects within grey literature. In terms of benefits, there is increased public engagement and awareness (Walker et al 2021). Posting about citizen science projects in accessible and familiar spaces such as social platforms such as Facebook, TikTok, Instagram, and X (formerly Twitter) allows for the issue being studied to reach a larger audience. These technologies are user-friendly and low cost, making them less expensive than professional programs and organized field research though academic institutions (Sousa et al 2020).

While documenting citizen science in non-academic sources creates an initial sense of accessibility, it does pose a concern for long-term usage. Through the exploration of the *In The Zone* Tracker Program and its observed outcomes in **Chapter 2**, there was one main issue encountered – dead links and link decay. There were several blog posts about the Pawpaw Parade and cucumber magnolia module that I wished to access but were inaccessible due to error messages. This issue also arose during **Chapter 3**'s systematic review **(see Appendix B and C).** Many of the initial hyperlinks I visited for the posted citizen science activities lead to error pages, blank screens, and inactive social media accounts upon clicking. Additional web searches were often needed to find further information about these projects, requiring me to go beyond the Government of Canada's official citizen science portal.

Web pages and their stable URLs tend to have a lifespan of 2-5 years (Markwell and Brooks 2006). Without maintenance or automatic forwarding measures, these pages eventually become unretrievable and unusable (Markwell and Brooks 2006). For citizen science projects that solely document their findings in grey websites, this is detrimental to the preservation of knowledge. Collecting data without proper data hygiene and upkeep is not just unproductive but wasting participants' time and efforts. This is especially true in communities that have already been over-burdened with citizen science monitoring tasks, receiving little to no financial compensation for their efforts (Walker et al 2021). For these reasons, non-governmental organizations and individuals organizing citizen science projects need to partner with academics. By taking these public findings and documenting them in an open access institutional repository, valuable data can be preserved for generations (Laakso et al 2011).

Academics and librarians play a critical role in knowledge dissemination (Boufarss and Harviainen 2021). The world of scholarly research and scientific journals is often perceived as inaccessible to the public. Information is largely kept behind paywalls and only accessible if one is a member of an academic institution, or through piracy. With open access, articles published in scholarly journals are unrestricted and accessible to the public (Laakso et al 2011). This is particularly useful for the field of citizen science. Participation in citizen science helps to increase public's trust in science, and transparent data sharing through open access further reinforces that trust. While some in the scientific community doubt the validity of citizen science data, there needs to be reciprocal trust between academics and the general public to advance knowledge (Catlin-Groves 2012). A partnership between citizen scientists and academics is mutually beneficial. Citizen scientists need to trust in researchers to bring awareness to their work and preserve it in scholarly journals, and academics need to be willing advocates for environmental and social causes.

4.3 - Feeling Good: The Main Goal of Citizen Science is Empowerment

It is understood that citizen science participation stems from genuine interest in a topic or concern for a pressing issue, but the greatest motivator is responsibility and gratification. With ecology-centered projects, the main goal of citizen science is not necessarily making people understand advanced concepts but helping them find common values and empowering them to make a difference in their community. In today's digital age, many citizen science projects involve solitary data collection from a participant with little to no socialization beyond submitting their results (Maund et al 2020). While this is simple and effective, it puts citizen science platforms at risk of failing to sustain engagement and successfully run their experiments (Maund et al 2020). Understanding the audience's motivations to participate is not only essential for maintaining engagement but for optimizing and designing an efficient project.

Some of the most effective citizen science projects are simple instructions with instant and visible results the basic user can understand. Common procedures include monitoring and counting species, photo submission, and transcribing old records (Follett and Strezov 2015). As observed in my systematic review of citizen science tools in **Chapter 3** (**see Appendix B and C**), projects with photo submissions (iNaturalist) and straightforward species counts (Christmas Bird Count, North American Breeding Bird Survey) gained the most participation and have persisted through time. Studies have shown that there is a relationship between reliability of crowd-sourced data and confidence of the participants (See et al 2013). Participants feel confident in performing these tasks and therefore their data collected is of higher quality.

However, there is a challenge in assigning participants with simpler tasks, boredom. Overly detailed instructions can be intimidating to the public, but oversimplification can leave them feeling underwhelmed (Walker et al 2021). If there's no long-term goal or evidence of impact, participants may be disappointed and discouraged from participating further. Communities want to witness tangible change and know their efforts were not futile. Seen in **Chapter 2** and **Appendix A**, the *In The Zone* Tracker asks for user motivations in addition to collecting gardening data. The 'My Green Life' portion is dedicated to understanding each user, asking if they feel good in nature, feel connected to nature, can identify species in their garden, if they want to grow more native plants in the future, and if they learned something useful **(Appendix A).** Qualitative questions like these can make the project feel more personal and create an emotional connection. There is an aspect of community building in asking these questions, which encourages and empowers users. Regardless of expertise level, this creates a sense of intrinsic motivation to participate. These motivations can be of self-interest, focused on feeding their own curiosity or they can be altruistic in nature, focused on contributing to the greater good of the environment (Hobbs and White 2012). Through factors like social responsibility and gratification, we can empower people to participate in citizen science and share knowledge.

It is important to note that in contrast to the *In The Zone* Tracker, most citizen science activities do not survey what people learned or how they feel and instead focus on straightforward quantitative data collection (Pocock et al 2017). Evaluating the outcomes of citizen science activities from the point of view of non-experts is an avenue for further research and can help scientists better understand motivations behind public participation. Ultimately, although it may be achieved, the *In The Zone* Tracker does not train its users to become experts or increase science literacy – its main outcome is to make people feel a positive connection to nature.

4.4 - Contextualizing My Work: Initial Thesis and Internship Plans

When I began my Master's in September 2022, I had several different plans in mind as to what I would investigate in my thesis. My original plan was to study biodiversity in southwestern Ontario as a nature-based solution; specifically, native plants to restore rural areas and combat the effects of waste. This was inspired by my studentship with NSERC CREATE TABES, a training program with a focus on waste valorization and the circular economy, designed to prepare researchers for a career in the bioindustry sector.

One of my TABES program requirements was a four month long industrial for-profit internship (see **Appendices D and E**), which I had anticipated would be conducted with Carolinian Canada Coalition since the beginning of my Master's. Carolinian Canada Coalition's work is funded in part by the Deshkan Ziibi Conservation Impact Bond (CIB). From this, I was introduced to Professor Diane-Laure Arjaliès who leads the CIB research team at Ivey Business School at the University of Western Ontario. With these components in mind, my initial research plans were projected to consist of:

1. Interning with the Carolinian Canada Coalition to execute an ecological restoration plan, using biodiversity-based methods to generate a healthy landscape.
2. Connecting with rural communities and performing field surveys in southwestern Ontario to identify habitat and waste management needs.
3. Developing habitat restoration techniques that are aligned with traditional Indigenous ways of living.
4. Working with the Conservation Impact Bond (CIB) team to understand its function as a novel financial tool to enable conservation efforts.

Through the first half of 2023, I was simultaneously working towards my TABES program requirements while completing my Master's coursework requirements. During this time, we were seeking the approval of NSERC for my TABES program internship. Their terms of the mandatory internship stated that it must be conducted in an industrial for-profit environment. Carolinian Canada Coalition is a non-governmental nonprofit organization, functioning as an ecosystem recovery network. At face value, an NGO would not meet the requirements of an industrial for-profit internship. We had to prove that although the Carolinian Canada Coalition is a non-profit, they can also act as a social enterprise with for-profit components such as native planting seed kits and native plant identification tags at local nurseries. Therefore, this explanation met the criteria of the internship and was approved in March 2023. The timeline of my NSERC CREATE TABES program and internship with the Carolinian Canada Coalition can be found in **Appendices D and E.**

My TABES experience involved a technology commercialization course, teaching students how to frame their research for industry and the workplace. I also completed several summer courses, attended guest talks, was a guest speaker for the CREATE program's podcast, and presented at annual conferences. Being a TABES trainee gave me a unique, applied, enriching graduate school experience compared with that of my peers in the Department of Biology. There were opportunities for both professional and personal growth, which have made me a more confident and critical scientist. I learned to apply my research to both industrial and academic settings, which was an invaluable experience that informed the interdisciplinary nature of my research.

My internship with the Carolinian Canada Coalition started in August 2023 after receiving approval from NSERC, and we soon began the process of obtaining a data-sharing agreement with the Carolinian Canada Coalition to analyze the *In The Zone* (ITZ) Tracker data. This experience took longer than anticipated but taught me first-hand about the critical steps required in creating a formal agreement to conduct collaborative research. I learned to negotiate with multiple parties to achieve conditions for a data exchange that satisfied all our expectations. Through our continuous exchange to obtain the data agreement, I completed other tasks under the supervision of Michelle Kanter, Jennifer Nantais, and Tristan Bentley. This included: Developing an original storytelling module, writing text and designing the CCC's Landowner Leader fact sheet, and designing a biodiversity marketing survey in partnership with the IVEY Business School.

I conceptualized two surveys in my initial brainstorm of internship responsibilities and planned to collaborate with Professor Diane-Laure Arjaliès. One was a conservation biologist survey for my thesis. This survey would have consisted of interviewing conservation biologists in Ontario with the goal of understanding their perception of the CIB, Truth and Reconciliation, and *One Planet, One Health.* The results from this survey would help to determine current levels of awareness amongst ecologists and reinforce the importance of Indigenous voices and traditional knowledge in conservation spaces.

The second survey was a biodiversity marketing survey, as mentioned above. This survey would have been conducted in partnership with the Carolinian Canada Coalition and issued to both practitioners (sellers) and businesses/corporations (buyers), to better understand the emerging biodiversity market and their current sustainability practices. I developed a draft of the following questions for the survey:

- What motivates you/your company to be sustainable?
- What is the biggest barrier you face in your sustainability efforts?
- What is your current commitment level in achieving sustainable practices?
- What steps have you taken to reduce your environmental impact?
- What practices and policies do you have in place to ensure sustainability?
- How do you measure the success of your sustainability initiatives/goals?
- How have you incorporated traditional knowledge into your sustainability practices?
- What are the factors you look for when buying/selling nature-based solutions?
- What policies have you implemented to ensure that your business operations are equitable and benefit all stakeholders and Indigenous rights holders?

- Has your approach to buying/selling changed in the context of sustainability and Truth and Reconciliation?
- Are your practices: Accessible? Good quality? Sustainable? Economically feasible? Legal? Transparent?

The data agreement between York University and Carolinian Canada Coalition was signed in January 2024. Obtaining this agreement changed the goals of my thesis, and there was a plan to study the tracker responses in depth. I performed an initial data sweep and analyzed the ITZ Tracker responses to the survey questions **(Appendix A)**. The ITZ dataset was raw and untouched prior to my internship, meaning I would be the first to segment and observe any insights from this data. My first course of action was creating an Excel sheet that recorded each survey question, their responses, and the number of people who chose each response. This alone was a prolonged and meticulous task. The data spanned over seven full years, from 2017 to 2023. I highlighted user trends and preferences, as well as offered suggestions for tracker improvement – such as phrasing of questions and ordering of the questions to generate the most engagement. I shared my initial findings from my first sweep in a presentation to the entire Carolinian Canada Coalition team in April 2024.

By this time, my internship had well-exceeded the expected four months I was required to complete as part of my NSERC CREATE TABES trainee conditions. The Carolinian Canada Coalition team valued my contributions, and we agreed to extend my internship through Fall 2024. I then performed an engagement tracking analysis, recording how many submissions the tracker received on each day, of each month, of each year, from the tracker's inception in 2017 to 2023. This engagement tracking was cross-referenced with a list of Carolinian Canada Coalition's events, e-blasts, and website visits to determine the main sources of traffic. As these data were previously untouched, it took a substantial amount of time to go through and extract basic metrics.

The *In The Zone* dataset is powerful and robust with the potential to expand into multiple projects. A powerful dataset is defined as one that is relevant, represents real-world circumstances, accurate, complete, and original (Gong et al 2023). The *In The Zone* data certainly fits these criteria. It offers a unique collection of citizen gardening data, providing a real profile of the current state of the environment in southwestern Ontario. It already has several years' worth of data points, and its accuracy will only continue to increase as more participants submit their responses over time. This data is unique because of the uniqueness of the ITZ tracker itself. The ITZ Tracker is multi-dimensional citizen science program, acting as a landscape survey of both qualitative and quantitative data, an educational resource, and a community outreach tool. This provides an interesting set of trends to analyze. It goes beyond simple species names or counts. The ITZ Tracker seeks to understand its users and their motivations and educate them about nature-based solutions as a form of traditional knowledge.

Had time permitted, there were plans to perform a deep dive on the *In The Zone* Tracker data, which would have required further ethics applications. I considered an in-depth review of biodiversity in southwestern Ontario, using the ITZ personal gardening data as a case study to determine ecological blind spots in the region. This would have included statistical analysis of trends using a chi-square test and ANOVA, as well as specific data segmentation for four main points:

1) <u>Segment data by land use</u> based on the 8 options listed in the property identification profile section.
2) <u>Segment data by commitment level</u> based on garden project engagement levels.

3) <u>Segment data by property type</u> based on 10 options listed in the survey's property submission fields.

4) <u>Segment data by action level</u> based on Healthy Goals interest on a scale of 0 -10.

After assessing the vastness of the ITZ Tracker data, I decided not to proceed with this plan. Even after my year-long internship with the Carolinian Canada Coalition, there is still much to be discovered within the ITZ dataset. For the purposes of this thesis, I solely examined the story and function of the ITZ Tracker in **Chapter 2** (**Appendix A**). I did not require further ethics approval, as the ITZ survey questions are publicly available to anyone who chooses to submit a property.

Had I analyzed the in-depth biodiversity trends in southwestern Ontario, I would have required further ethics approval as I would be working with personal participant data collected by the tracker. It took a significant amount of time to get NSERC's approval of my studentship with the Carolinian Canada Coalition and to obtain the data-sharing agreements between York University and Carolinian Canada Coalition. Due to the vastness of the data and the existing delays, we decided against submitting an ethics approval for additional tracker exploration. These reasons precluded the possibility of going through with further ethics approval for personal ITZ Tracker data analysis. Approval would have allowed for a deeper analysis of the *In The Zone* Tracker data, but the timeline of this process would have also extended the duration of my Master's by another three to six months. Further ethics approval was also not required for **Chapter 3** (**Appendix B and C**), as I was synthesizing and evaluating publicly available citizen science tools in grey literature.

4.5 - Spreading Roots: Conclusions and What's Next?

Citizen science has progressed with the aid of modern technology and accessible data sharing, allowing for greater interest and collaboration between the scientific community and the general population (Catlin-Groves 2012). This has created awareness and increased advocacy for nature but to generate a wider impact, additional and continued actions must be encouraged and supported. Plants and invertebrates remain an area of underrepresented focus in the field of ecological citizen science projects (Barua et al 2012) and their importance is largely overlooked, hence tools such as the *In The Zone* Tracker are essential in spreading botanical knowledge and appreciation of surrounding ecosystems.

Future analysis of the *In The Zone* Tracker dataset should focus on specific data segmentation and statistical tests. The analysis conducted in this thesis and at my internship with the Carolinian Canada Coalition extracted main engagement trends and common gardening habits in southwestern Ontario. To capitalize on the robustness of the ITZ Tracker data, I recommend the following initiatives:

1) Add the option to list species names as an open-ended tracker survey response, as well as contact survey participants to determine a list of species being planted in southwestern Ontario. This will allow for a more accurate estimate of overall biodiversity.
2) Use the qualitative tracker data to classify garden properties into types, such as ornamental, edible, native, non-native, and determine most common land use practices in southwestern Ontario.
3) Use the qualitative tracker data to assess the commitment levels and action levels. This can aid in gauging participants' feelings towards native planting and understanding the successes and barriers of maintaining a garden.

4) Calculate the geographic distribution of the properties being logged in the tracker and determine if there are location clusters with higher levels of planting activity.
5) Expand on the engagement tracking that I performed, which consisted of extracting the number of tracker submissions on each day of each year, from 2017 – 2023. Superimpose the tracker submission data with Carolinian Canada Coalition's events schedule to visualize popular times of traffic for the tracker.

Analyzing citizen science gardening datasets offers the opportunity to gain powerful insights into the current state of a community, revealing trends and factors that influence existing biodiversity. This knowledge helps inform the best methods for sustaining citizen science engagement that increases indigenous plant biodiversity in southwestern Ontario. There has been a lack of plant awareness in environmental education and conservation messaging, which is why it is crucial to understand the motivations of the general population (Balding and Williams, 2016). Participants seek gratification, whether this be through gaining new knowledge or receiving recognition for making a positive contribution to the environment. A successful and engaging citizen science project will comprise of specific tangible goals, easily accessible tools, visible results, all while creating a community that connects users to uplift each other. This can be achieved in a variety of ways; through websites and apps, educational tools and outreach, community events and social media campaigns. A combination of these components optimizes performance from citizen scientists.

Raising plant awareness and emphasizing the importance of indigenous plants is key in the complex task of building resilient ecosystems that maintain balance and fight the effects of climate change. Citizen science initiatives can be supported by the monetary aid of environmental finance tools along with the advocacy and expertise of academics. From this, large volumes of data can be collected which increase our understanding of the world around us and inform policy changes and conservation actions. By empowering citizen scientists, we can bridge the gap between ecology research and the public. Addressing these issues locally offers the potential to be scaled up globally and make real progress towards a sustainable future; one that leaves land in a better condition than how it was found.

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Appendices

Appendix A: *In The Zone* Tracker Survey Version 2 - Current Version

Property Identification

I am (check one)	Property owner	Property manager	Property employee	Renter	Landscaper	Community gardener	Volunteer	Student	Other
My garden project is to… (choose one)	Explore – Participate in the *In the Zone* community but no planting	Simple Start – Add a few plants (e.g. in a pot, garden, lawn)	Dig In - Grow a wildlife garden (e.g. wildflower garden, water garden, woodland garden)	Connect - Plan a makeover that supports and connects to local ecosystems	Other				
Select a Property	Dropdown of all properties user has submitted								

Property

Properties are now separate from the tracker – each property is its own submission and can be linked back directly to the trackers related to it through a database key.

Property Submission Fields										
Garden Name										
Property Type	□ Place of Worship	□ House	□ Condo or town-house	□ Apartment	□ Rural	□ Commercial (office, business, industrial etc.	□ Farm	□ Park	□ Community garden	□ School / Campus

Institution Name (if applicable)										
Address										
City										
Postal Code										
Province										
Property Size	**#**	**Used to calculate property size, algorithm converts to hectares**								
Unit of Measurement										
Is it publicly accessible?	**Yes/no**									

1. Healthy Goals

I want to grow native plants	**Yes - Yes reveals all other questions on page** **No** **Unsure**	
How interested are you in growing native plants for healthy gardens? Rate on a scale from zero (not at all) to 10 (very interested).	**0-10**	
Rate your garden type on a scale from 1 (formal) to 10 (wild)	**1-10**	

2. Healthy Habitat

Native plants grow on my property (they may be wild or planted)	**Yes**		No	Unsure			
Estimate portion of total plants from 0 (none) to 10 (all)	**0-10**						
Estimate number of different native plant species on this property	#		**# species, not individual plants**				
Did you plant native seeds or plants on your property since last report or last year?	**Yes**		**No**	**Unsure**			
How many did you plant?	**Markup – no data tied to this**						
Plants	#		**Used to calculate # plants planted**				
Seeds	#		**Used to calculate # plants planted**				
Species	#						
Check all types (choose any)	☐ **Trees**	☐ **Shrubs**	☐ **Vines**	☐ **Flowers**	☐ **Grasses**	☐ **Aquatic**	☐ **Other**
Estimate size of total area planted or enhanced since last report or last year	#		**Used to calculate project size, algorithm converts to hectares**				
Units of Measurement							

How many new species were added to the property?	**#**					
Where did you plant? (check all that apply)	**□ Garden**	**□ Replace lawn**	**□ Replace pavement**	**□ Other...**		
Year of last planting or seeding of native plants	**Date**					
I get native plants from local and ethical seed sources. Rate from 0 (never) to 10 (always)	**0-10**					

Why I like growing native plants. (Choose Any)	**□ Better for wildlife**	**□ Less expensive**	**□ Lower maintenance**	**□ Climate-friendly /drought-tolerance**	**□ Better survival**	**□ Natural Beauty**	**□ Other**

3. Habitat Area

I have habitat	**Yes**	No	Unsure						
Estimate portion of entire property with habitat from 0 (none) to 10 (all).	**0-10**								
What types of habitat do you have on your property (check all that apply)?	**Markup – no data tied to this**								
Aquatic (choose any)	**□ Pond**	**□ River**	**□ Lake**	**□ Creek**	**□ Drain**	**□ Shore**			
Natural	**□ Woodland**	**□ Wetland**	**□ Prairie**						
Cultural	**□ Wildflower**	**□ Water Garden**	**□ Trees**	**□ Shrubs**	**□ Hedge**	**□ Green roof**	**□Balcony/container garden**	**□ Alien (non-native) plants**	**□ Other**

4. Neighbourly Connections

My garden is connected (within 25 metres of neighbouring habitat e.g. gardens, trees, flower pots)	**Yes**	**No**	Unsure
What portion of surrounding lands have habitat (e.g. gardens, trees, flower pots), from 0 (none) to 10 (all).	**0-10**		
How socially connected do you feel to your neighbours? from 0 (not at all) to 10 (regular interactions)	**0-10**		

5. Save energy

I have trees	**Yes**	No	Unsure
Estimate the amount of tree canopy (shade) on your property from 0 (none) to 10 (all).	**0-10**		

6. Save Water

I use organic (pesticide and herbicide-free) practices	Yes	No	Unsure						
Estimate portion of property managed organically from 0 (none) to 10 (all).	**0-10**								
I grow plants to buffer shores, drains, downspouts, wetlands, sloped or wet spots	**Yes**	**No**	**Unsure**						
Estimate portion of rain absorbed on property (vs. running off property) from 0 (none) to 10 (all).	**0-10**								
I grow drought tolerant plants	**Yes**	**No**	**Unsure**						
Estimate drought tolerant portion of total plants from 0 (none) to 10 (all).	**0-10**								
I use other water saving strategies in my garden (choose any)	**□ Rain garden**	**□ Water efficient landscaping**	**□ Xeriscaping**	**□ Low impact design (LID)**	**□ Mulching**	**□ Rain barrels**	**□ Drip lines**	**□ Time of day watering**	**□ Other**

7. Wildlife

I have watched wildlife on or near my site.	**Yes**	No	Unsure									
Frequency of wildlife sightings. Rate from 0 (none) to 10 (daily).	**0-10**											
What did you see? (choose any)	□ **Butter-flies**	□ **Bees**	□ **Fish**	□ **Frogs**	□ **Snakes**	□ **Turtle**	□ **Birds**	□ **Squirrel**	□ **Deer**	□ **Bats**	□ **Rare species**	□ **Other**
Estimate number of NEW wildlife species seen since your last report or last year	**#**											
Check all ways you helped wildlife in your garden since the last report or last year (choose any)	□ **Leaf litter**	□ **Stones**	□ **Logs**	□ **Brush piles**	□ **Standing dead trees (snags)**	□ **Bat houses**	□ **Bird boxes**	□ **Bee hotels**	□ **Pits and mounds**	□ **Water feature**	□ **Citizen Science**	□ **Other**

8. Community Connections

I share my garden, garden stories or photos with others (e.g. family, friends, classmates, colleagues and groups)	Yes	No	Unsure
Rate the frequency you share native plants, stories, tips or photos from 0 (never) to 10 (weekly)	0-10		
Estimate number of people reached including on social media and at events since last report or last year.	#		
Number of people directly connected to my garden (myself, family, helpers)	#		

9. Green Economy

I invested time or money into my garden	Yes	No	Unsure									
Estimate portion of your garden budget spent on native plant gardening since your last report or last year from 0 (none) to 10 (all)	0-10											
Estimate total number of days invested in your garden (by everyone) since your	#											

last report or last year.												
Estimate the total number of days you helped others with native plant gardening since your last report or last year.	#											
What resources would help you grow more native plants? (pick any)	☐ Advice	☐ Annual catalogue	☐ Lower prices	☐ Better labels	☐ Availability at my local nursery	☐ Special events e.g. plant sales or seed shares	☐ On-line orders	☐ Seed collecting guidelines	☐ Demonstration gardens	☐ Work shops	☐ Garden assistance	☐ Other

10. My Green Life

I feel good in nature	Yes	No	Unsure
I feel connected to nature. Rate from 0 (no) to 10 (very connected).	0-10		
I can identify native plants and animals in my garden. Estimate portion from 0 (none) to 10 (all).	0-10		
I want to grow more native plants. Rate from 0 (no) to 10 (definitely).	0-10		
I learned something useful or interesting from *In the Zone*. Rate from 0 (nothing) to 10 (a significant amount).	0-10		
Share your wildlife story, garden notes or other comments	Text box		
I agree to share my story publicly for educational purposes	Yes	No	
Garden Points	Calculated in Spreadsheet with Formula		

Appendix B: Systematic Review of Citizen Science Activities in Scholarly Databases with search terms "citizen science" AND "Canada" in publication titles

(17 entries)

Database	Publication	Citizen science platform	Project Start Date	Project End Date	Project Duration (years)	Number of participants in the study	Total number of Canadian users	Location	Topic	How was it reported
Web of Science, SCOPUS	Citizen science reveals the establishment of *Chamaesphecia empiformis* (Esper) (Lepidoptera: Sesiidae), a long-lost biological control agent for *Euphorbia cyparissias* (Euphorbiaceae), in Ontario, Canada	iNaturalist	2015	2023	8	13	87,548	Ontario	Insects	Peer-reviewed
Web of Science, SCOPUS	Capelin beach spawning diaries: an analysis of 30 years of citizen science data from the island of Newfoundland, Canada	Spawning diaries survey via Science Branch, Fisheries and Oceans Canada (DFO)	1992	2021	29	29	44,000	Newfoundland	Fish	Peer-reviewed

Web of Science, SCOPUS, PubMed	How Can We Do Citizen Science Better? A Case Study Evaluating Grizzly Bear Citizen Science Using *Principles of Good Practice* in Alberta, Canada	GrizzTracker	2017	2024	7	N/A	300	Alberta	Bears	Peer-reviewed
Web of Science, SCOPUS, PubMed	Citizen science in monitoring food environments: a qualitative collective case study of stakeholders' experiences during the Local Environment Action on Food project in Alberta, Canada	The Local Environment Action on Food (LEAF)	2018	2020	2	26	1000	Alberta	Health	Peer-reviewed
Web of Science, SCOPUS	Integrated modeling of waterfowl distribution in western Canada using aerial survey and citizen science (eBird) data	eBird	1990	2019	29	5901	75,000	Manitoba, Saskatchewan, Alberta, British Columbia, Nunavut, Northwestern Territories, and Yukon	Birds	Peer-reviewed

Web of Science, SCOPUS	Harmful Algae and Oceanographic Conditions in the Strait of Georgia, Canada Based on Citizen Science Monitoring	Pacific Salmon Foundation (PSF) , Fisheries and Oceans Canada (DFO), Ocean Networks Canada (ONC)	2015	2018	3	92	N/A	British Columbia	Algae, Water	Peer-reviewed
Web of Science, SCOPUS	Landsat 8 Lake Water Clarity Empirical Algorithms: Large-Scale Calibration and Validation Using Government and Citizen Science Data from across Canada	NSERC Canadian Lake Pulse Network	2017	2019	2	N/A	17	Alberta, British Columbia, Ontario, Quebec, New Brunswick, Newfoundland and Labrador, Northwest Territories, and Yukon	Water	Peer-reviewed
Web of Science, SCOPUS	Structured and unstructured citizen science: Seven decades of expanding bird populations in central Ontario, Canada	Christmas Bird Count: 1900 Breeding Bird Survey: 1966	1948	2016	68	N/A	10,000	Ontario	Birds	Peer-reviewed

Web of Science (x2), SCOPUS (X2) - for corrections	Incorporating citizen science, museum specimens, and field work into the assessment of extinction risk of the American Bumble bee (Bombus pensylvanicus De Geer 1773) in Canada (vol 23, pg 597, 2019)	Bumble Bee Watch	2014	2017	3	2,170	N/A	Ontario and Quebec	Insects	Peer-reviewed
Web of Science, SCOPUS	Estimating the annual distribution of monarch butterflies in Canada over 16 years using citizen science data	eButterfly and Journey north	2000	2015	15	22, 974	3,000	Canada	Insects	Peer-reviewed
Web of Science, SCOPUS	Identification of native and non-native grass shrimps Palaemon spp. (Decapoda: Palaemonidae) by citizen science monitoring programs in Atlantic Canada	Community Aquatic Monitoring Program (CAMP)	2016	2016	0	1,483	N/A	New Brunswick, Nova Scotia, PEI	Water	Peer-reviewed

Web of Science	Employing the Our Voice citizen science model to support age- and activity-friendly communities in Chile, Brazil, Canada, England, and USA	Our Voice	2018	2018	0	N/A	N/A	Canada	Health	Peer-reviewed
Web of Science, SCOPUS	Entomological citizen science in Canada	eButterfly and BugGuide	2012	2024	12	N/A	3,000	Canada	Insects	Peer-reviewed
Web of Science, SCOPUS	Winters too warm to skate? Citizen-science reported variability in availability of outdoor skating in Canada	RinkWatch	2013	2015	2	N/A	1500	Canada	Climate	Peer-reviewed

Web of Science, SCOPUS, PubMed	Citizen Science: linking the recent rapid advances of plant flowering in Canada with climate variability	PlantWatch	2001	2012	11	N/A	N/A	Canada	Plants, Climate	Peer-reviewed
SCOPUS	Navigating The Waters of Citizen Science: Lessons Learnt From a Pilot Lake Monitoring Project in Saskatchewan, Canada	Survey	2013	2013	0	65	200	Saskatchewan	Water	Peer-reviewed
SCOPUS	URBAN: Development of a Citizen Science Biomonitoring Program Based in Hamilton, Ontario, Canada	Urban-Rural Biomonitoring and Assessment Network (URBAN)	2010	2012	2	11	300	Ontario	Water, Wetlands	Peer-reviewed

Appendix C: Systematic Review of Activities Listed in the Government of Canada's Official Citizen Science Portal

Database	Project name	Citizen science platform	Data Start date	Data End date	Project duration (years)	Number of participants in the study	Total number of Canadian users	Location	Topic	How was it reported
Government of Canada	Abeilles citoyennes via Université Laval	Abeilles citoyennes via Université Laval	2019	2024	5	131	131	Quebec	Insects	Grey and peer-reviewed
Government of Canada	Agroclimate Impact Reporter	Agroclimate Impact Reporter via Agriculture Canada	2013	2024	11	N/A	325	Canada	Climate	Grey and peer-reviewed
Government of Canada	BC Parks iNaturalist Assessment	iNaturalist	2019	2024	5	13,000	160,000	British Columbia	General nature	Grey
Government of Canada	BC's Big Nature eBird challenge	eBird	2020	2024	4	N/A	29, 610	British Columbia	Birds	Grey
Government of Canada	Beetle Watch with Douglas College	Beetle Watch	2020	2021	1	N/A	165	British Columbia	Insects	Grey
Government of Canada	Beluga Bits with the Assinboine Park Zoo	Zooniverse	2016	2024	8	30,000	100,000	Canada	Whales	Grey
Government of Canada	Birds Canada	eBird, Breeding Bird Survey,	1998	2024	26	N/A	70,000	Canada	Birds	Grey

		Christmas Bird Count								
Government of Canada	Breathe Easy with Sierra Club Canada Foundation	Breathe Easy	2020	2024	4	N/A	9,000	Ontario	Pollution	Grey
Government of Canada	Budworm Tracker with Natural Resources Canada	Budworm Tracker with Natural Resources Canada	2015	2022	7	356	N/A	New Brunswick, Quebec	Insects	Grey and peer-reviewed
Government of Canada	The Canadian Aquatic Biomonitoring Network (CABIN) with Environment and Climate Change Canada	The Canadian Aquatic Biomonitoring Network (CABIN) with Environment and Climate Change Canada	2006	2024	18	N/A	522	Canada	Water	Grey and peer-reviewed
Government of Canada	CANADIAN SCLEROTINIA INITIATIVE with the McGill Pulse Breeding and Genetics Lab	CANADIAN SCLEROTINIA INITIATIVE with the McGill Pulse Breeding and Genetics Lab	N/A	N/A	N/A	N/A	N/A	Ontario, Quebec	Fungi	N/A
Government of Canada	Canadian Wildlife Health Cooperative (CWHC)	Canadian Wildlife Health Cooperative (CWHC)	1992	2024	32	N/A	5,000	Canada	General nature	Grey and peer-reviewed
Government of Canada	Citizen Science in	iNaturalist	2016	2024	8	55	160,000	British Columbia	General nature	Grey

	Surrey iNaturalist									
Government of Canada	Citizen Science Pain Research	Citizen Science Pain Research	N/A	N/A	N/A	N/A	N/A	British Columbia	Health	N/A
Government of Canada	City Nature Challenge Bioblitz	iNaturalist	2016	2024	8	83, 528	160,000	Canada	General nature	Grey
Government of Canada	Coastie	Coastie, Parks Canada	2021	2024	3	2,300	2,300	Canada	Water	Grey and peer-reviewed
Government of Canada	Colony B	Colony B	2016	2024	8	92	92	Canada	Health	Grey
Government of Canada	Community Collaborative Rain Hail and Snow Network	Community Collaborativ e Rain Hail and Snow Network via Agriculture Canada / Environment and Climate Change Canada	2011	2024	13	N/A	20,000	Canada	Climate	Grey
Government of Canada	Community Science Program at the Invasive Species Centre	EDDMapS	2015	2024	9	N/A	18,000	Ontario	General nature	Grey
Government of Canada	Counting seals at Sable Island with Parks Canada via Zooniverse	Zooniverse ,Parks Canada	2013	N/A	N/A	220	100,000	Nova Scotia	Seals	Grey

Government of Canada	Cuscuta DNA barcoding	iNaturalist, Canadian Food Inspection Agency	2023	N/A	N/A	30	160,000	Canada	Plants	Grey
Government of Canada	DRAW - Data Rescue: Archives & Weather	DRAW - Data Rescue: Archives & Weather	2016	2024	8	15	N/A	Canada	Climate	Grey
Government of Canada	Eagle Watch	Eagle Watch	1992	2024	32	N/A	121	Alberta	Birds	Grey and peer-reviewed
Government of Canada	eButterfly	eButterfly	2012	2024	12	N/A	3,000	Canada	Insects	Grey and peer-reviewed
Government of Canada	EcoSpark	EcoSpark	1996	2024	28	N/A	1,100	Ontario	General nature	Grey and peer-reviewed
Government of Canada	FluWatch	FluWatch	1999	2024	25	N/A	1,188,962	Canada	Health	Grey
Government of Canada	Friends of the Muskoka Watershed Citizen Science Program	Friends of the Muskoka Watershed Citizen Science Program , Facebook	2022	2024	2	N/A	797	Ontario	Water	Grey
Government of Canada	Frog Watch	NatureWatc h	2000	2024	24	N/A	976	Canada	Amphibians	Grey and peer-reviewed
Government of Canada	IceWatch	NatureWatc h	2000	2024	24	N/A	976	Canada	Climate	Grey and peer-reviewed
Government of Canada	iNaturalist Canada	iNaturalist	2014	2024	10	N/A	160,000	Canada	General nature	Grey and peer-reviewed

Government of Canada	Infant and child studies in language, music, and cognition with the University of Toronto	Infant and child studies in language, music, and cognition	N/A	2024	N/A	N/A	N/A	Ontario	Health	Grey and peer-reviewed
Government of Canada	Leveraging Op en Data Analytics and Machine Learning to Improve Menta l Health Research and I nnovation	Leveraging O pen Data Analytic s and Machine Learning to Improve Men tal Health	2024	2024	0	N/A	N/A	Ontario	Health	Grey and peer-reviewed
Government of Canada	Mackenzie-Beaufort Ice Breakup Facebook Group	Facebook, Natural Resources Canada	2016	2024	8	N/A	2,000	Northwest Territories	Climate	Grey
Government of Canada	Milkweed Watch	NatureWatc h	2017	N/A	N/A	N/A	976	Canada	Plants	Grey and peer-reviewed
Government of Canada	Mission Monarch	Mission Monarch	2016	2024	8	N/A	2,658	Canada	Insects	Grey and peer-reviewed
Government of Canada	National Harvest Survey	National Harvest Survey, Environment and Climate Change Canada	1967	2024	57	N/A	45,000	Canada	Birds	Grey and peer-reviewed
Government of Canada	Neighbourhoo d Bat Watch	Bat Watch	2015	2024	9	N/A	500	Canada	Bats	Grey and peer-reviewed

Government of Canada	North American Breeding Bird Survey	North American Breeding Bird Survey , Environment and Climate Change Canada	1966	2024	58	N/A	3,000	Canada	Birds	Grey and peer-reviewed
Government of Canada	Notes from Nature - Digitizing Biological Collections in Canada	Notes from Nature - Digitizing Biological Collections in Canada , Agriculture Canada	2022	2024	2	2,753	2753	Canada	Plants	N/A
Government of Canada	Ocean Networks Canada	Ocean Networks Canada	2007	2024	17	N/A	32,000	Canada	Water	N/A
Government of Canada	Pacific Salmon Foundation (PSF) Citizen Science Program	Pacific Salmon Foundation (PSF) Citizen Science Program	2015	2024	9	N/A	1,000	British Columbia	Fish	N/A
Government of Canada	PlantWatch	NatureWatc h	2000	2024	24	N/A	976	Canada	Plants	Grey and peer-reviewed
Government of Canada	Prairie Pest Monitoring Network (PPMN)	Prairie Pest Monitoring Network (PPMN)	1997	2024	27	N/A	2,000	Alberta, Manitoba, Saskatchewa n	Insects	Grey and peer-reviewed

Government of Canada	Protect fish species in Canada - wildlife health tracker	Wildlife Health Tracker, Canadian Food Inspection Agency, Canadian Wildlife Health Cooperative (CWHC).	2016	2024	8	N/A	5,000	Canada	Fish	Grey
Government of Canada	Report an Earthquake with Natural Resources Canada	Natural Resources Canada	2009	2024	15	N/A	1,035	Canada	Climate	Grey
Government of Canada	Shark sightings	Fisheries and Oceans Canada	2007	2024	17	N/A	N/A	Canada	Water	Grey
Government of Canada	Smart Platform: Social Innovation for Public Health	Smart Platform: Social Innovation for Public Health	2020	N/A	N/A	N/A	N/A	Canada	Health	Grey
Government of Canada	Snow Knowledge Collective	Snow Knowledge Collective	2020	2024	4	N/A	176	Canada	Climate	Grey
Government of Canada	Stop-Carcasses	iNaturalist	2018	2024	6	85	160,000	Quebec	General nature	Grey
Government of Canada	Tree Check Month	Canadian Food Inspection Agency	2022	2024	2	N/A	N/A	Canada	Insects	Grey

Government of Canada	Visual Assessment Survey Tool	Visual Assessment Survey Tool with Niagara Coastal Community Collaborative	2021	N/A	N/A	N/A	678	Ontario	Water	Grey
Government of Canada	Volunteer bird surveys	eBird, Breeding Bird Survey, Christmas Bird Count	2017	2024	7	N/A	70,000	Canada	Birds	Grey
Government of Canada	Watch out for invasive insects	Canadian Food Inspection Agency, PPMN	1997	2024	27	N/A	2,000	Canada	Insects	Grey
Government of Canada	Water Rangers	Water Rangers	2015	2024	9	N/A	25,000	Canada	Water	Grey
Government of Canada	Waterton Lakes National Park	Parks Canada	N/A	2024	N/A	N/A	52,000	Alberta	General nature	Grey
Government of Canada	Wild Whales with Ocean Wise Sightings Network	Ocean Wise Sightings Network, Fisheries and Oceans Canada	2002	2024	22	N/A	48,000	British Columbia	Whales	Grey and peer-reviewed
Government of Canada	WormWatch	NatureWatch	1996	2024	28	N/A	976	Canada	Invertebrates	Grey and peer-reviewed

Appendix D: MSc and NSERC CREATE TABES Trainee Timeline

Date	Event
September 2022	MSc Biology program begins
November 3rd - 22nd 2022	BIOL 5086: Critical Skills in Ecology and Evolution with Prof. Bridget Stutchbury Grade: A+
December 12th 2022	Indigenous Canada course through University of Alberta via Coursera. Completed and certificate obtained
January 1st 2023	Officially joined the NSERC CREATE TABES program
January 2023 - December 2024	Monthly presentations for NSERC CREATE Trainees
January 2023 - April 2023	MECH 6502: Technology Commercialization with Prof. Andrew Maxwell Grade: A+
March 1st - April 5th 2023	BIOL 5088: Advanced Topics in Ecology and Evolution with Prof. Laurence Packer Grade: A
March 10th - 12th 2023	Participated in full-weekend BEST Startup Experience Entrepreneurship Event hosted by Lassonde School of Engineering
March 12th 2023	Placed in the Top 9 finalists of the BEST Startup Experience. 'Prepped 4 U' - a healthy, sustainable, affordable meal program for students on campus.
March 23rd 2023	NSERC CREATE Julia's first monthly trainee spotlight presentation
May 1st - 2nd 2023	NSERC CREATE 2023 Annual Summit - Julia's first conference poster *"The Emerging Biodiversity Market: The Conservation Impact Bond in Southwestern Ontario"*
June 2nd 2023	TABES Webinar Series guest talk *"Valorisation of organic residues with fungi: food, feed and more"* presented by Prof. Patrik Lennartsson
June 15th -19th 2023	TABES Summer Course: *Advanced Experiential Learning of Applied Biotechnology (Theory)*

June 20th - 22nd 2023	TABES Summer Course: *Advanced Experiential Learning of Applied Biotechnology (Practical)*
June 23rd - 26th 2023	TABES Summer Course: *Data Science/Machine Learning in Bioprocesses*
June 27th 2023	TABES Summer Course: *Concept development from ideas to innovation and applications*
June 28th 2023	TABES Summer Course: *Intellectual property*
June 29th 2023	TABES Summer Course: *EDI Initiative*
June 30th - July 3rd 2023	TABES Summer Course: *Environmental and Societal Stewardship*
July 13th 2023	YULearn REDDI Series course: Advancing Organizational Change to Foster a Culture of Belonging
July 18th 2023	YULearn REDDI Series course: Challenging Notions of Ableism: Breaking Barriers to Social Inclusion
July 21st - August 12th 2023	Drafted a poster submission for the IPBES (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services) 10th Plenary Stakeholder Day titled, *"The Emerging Biodiversity Market"*
July 26th 2023	YULearn REDDI Series course: Acknowledging and Addressing Racism
August 2023	TABES mandatory internship with Carolinian Canada Coalition begins
August 14th 2023	TABES Webinar Series guest talk - *"Online monitoring tools for upstream processing in bioindustries"* presented by Prof. Carlos Osorio
August 16th 2023	*"The Emerging Biodiversity Market"* poster accepted by the IPBES Secretariat
August 27th 2023	*"The Emerging Biodiversity Market"* poster presented in person at IPBES 10 Stakeholder Day in Bonn, Germany.
August 27th - September 1st 2023	Virtually attended IPBES 10 Stakeholder Day and the IPBES 10TH Plenary Sessions

September 2023	MITACS EDGE professional development course *"Spur up your project management and time management skills"* completed and certificate obtained
October 24th 2023	TABES Webinar Series guest talk - "*Industrial Ecology"*
October 30th 2023	YULearn REDDI Series course: Employment Equity Principles Towards Inclusion
November 13th 2023	Invitation to be a guest speaker on the *Inclusive Conversations: Empowering Voices* podcast
November 17th 2023	*Inclusive Conversations: Empowering Voices* podcast preliminary planning with Tim Hampton and Angela Huang
December 15th 2023	*Inclusive Conversations: Empowering Voices* podcast recording session with Tim Hampton and Angela Huang
December 18th 2023	Oral presentation at the 1st Annual Inaugural Biology Graduate Program Research Colloquium
January 15th - March 14th 2024	*MobilizeU at YorkU* Knowledge Mobilization course
January 17th 2024	*Inclusive Conversations: Empowering Voices* podcast episode 4 is published
February 21st 2024	YULearn REDDI Series course: *Impacts and Effects of Microaggressions in the PSE Environment*
February 22nd 2024	*Rights, Equity, Diversity, Decolonization and Inclusion (REDDI) Series* Completion Certificate obtained
February 27th 2024	YorkU CREATE program feedback luncheon
April 15th 2024	*MobilizeU at YorkU* Knowledge Mobilization Course Completion Certificate obtained
April 29th - 30th 2024	NSERC CREATE 2024 Annual Summit - oral presentation and poster presentation, titled *"How Citizen Science, Open Access Shared Data, and Truth and Reconciliation are Linked to the Emerging Biodiversity Market"*
April 30th 2024	Awarded 2nd place in the NSERC CREATE 2024 Annual Summit poster competition

September 16th 2024	TABES Webinar Series guest talk *"Strategies for Polyhydroxyalkanoates Production in a Biorefinery Concept"*, presented by Prof. Luciana Porto de Souza Vandenbrghe
December 11th 2024	Oral presentation at the 2nd Annual Inaugural Biology Graduate Program Research Colloquium

Appendix E: Carolinian Canada Coalition Internship Timeline

Date	Duty Performed
March 29th 2023	NSERC approval of Julia's Carolinian Canada Coalition (CCC) internship. Proved that environmental charities can have a 'for-profit' aspect through selling native planting seed kits at local nurseries.
July 24th 2023	Virtually introduced via email to the Carolinian Canada Coalition team.
July 25th 2023	First video call with the CCC team and Executive Director, Michelle Kanter. Organized a regular weekly meeting time with Jennifer Nantais, CCC's Program Specialist who would oversee my work.
August 2023	Internship with Carolinian Canada Coalition begins. Expected: 4 months as per TABES Master's student guidelines.
	Summarized current *In The Zone* Tracker resources for a methodology write-up.
	Preview of the *In The Zone* Tracker database with Tristan Bentley, CCC's IT Manager.
September 2023	Wrote an introductory blog post for the CCC website, expressing my goals for this internship.
	Brainstormed initial internship tasks with Jennifer that I could complete as we waited for a data sharing agreement for me to analyze the *In The Zone* (ITZ) Tracker data. We decided on: Developing an original storytelling module, writing text and designing the CCC's Landowner Leader fact sheet, and a biodiversity marketing survey in partnership with the IVEY Business school.
	Discussed data sharing agreement with Jennifer, Michelle, and Dawn, and determined areas of segmentation for me to investigate once granted access to the ITZ Tracker data.

October 2023	Finalized my internship responsibilities with Jennifer and got approval from Michelle and Dawn.
	Wrote a first draft of text for the Landowner Leader fact sheet and began designing an infographic poster template on Canva.
	Continued negotiating text for the data sharing agreement between York University and Carolinian Canada Coalition
November 2023	Wrote a second draft of text for the Landowner Leader fact sheet and reviewed with Jennifer for approval.
	Created a storytelling module, where *In The Zone* Tracker participants can choose to share their gardening story in further detail than the initial ITZ Tracker allows. This involved: Developing original questions and deciding on the best format for optimal user feedback (i.e. multiple choice, drop-down checklist, open-ended answer, photo submission options).
December 2023	Updated text for *In The Zone* Tracker survey questions including rearranging question order to generate higher engagement and clarifying/adding definitions for ecological concepts.
	Created a second draft of the Landowner Leader infographic.
	Continued negotiating text for the data sharing agreement between York University and Carolinian Canada Coalition.
January 2024	Discussed a proposal for *Plants, People, Planet*'s special issue on methodologies for investigating plant awareness. Suggested the idea of documenting the *In The Zone Tracker*'s development as a citizen science tool in a peer-reviewed journal.
	Data sharing agreement is finalized and signed on January 23rd, 2024.
	Given a full walk-through of the *In The Zone* Tracker database with Tristan Bentley, CCC's IT Manager.

February 2024	Initial dive into the ITZ Tracker data where I would extract and record answers to each tracker question, from years 2017-2023.
	Developed original idea for an awards module to give ITZ Tracker participants recognition for their contributions and increase potential engagement and motivation.
	Reported initial data analysis and trends to Jennifer and Tristan, asked for feedback, and discussed potential data points for further analysis.
March 2024	Performed tracker data analysis to determine trends and gaps in the data: Which ITZ Tracker questions had high engagement, and which had low engagement?
	Brainstormed how to increase ITZ Tracker engagement based on which questions were being left unanswered. Found there is a need for clarification of ecological concepts in several of the questions. Suggested informative pop-up bubbles that can simplify and provide further context for questions.
April 2024	Continued working on draft text detailing the history and inner-workings of the *In The Zone* Tracker, to be submitted to a peer-reviewed journal.
April 9th 2024	Gave a 1-hour presentation to the entire Carolinian Canada Coalition team, summarizing my findings from the analysis I performed on the ITZ Tracker data. I shared the most popular answers to survey questions, detailing: • Purpose of gardening projects • Property ownership rates • Percentage of native plants in gardens • Use of local and ethical seed sources • Percentage of habitat surrounding the property • Presence of trees • Methods to save water • Number of wildlife species appearing on the property • How users communicate about their gardens • How much money users invest in their garden • How many users feel connected to nature.

	I offered future suggestions and improvements for the tracker - defining ecological concepts in simpler terms and implementing the ITZ Tracker throughout more schools.
April 29th - 30th 2024	Presented some of my internship findings at the NSERC CREATE 2024 Annual Summit. Gave an oral presentation and poster presentation, titled *"How Citizen Science, Open Access Shared Data, and Truth and Reconciliation are Linked to the Emerging Biodiversity Market."*
May 2024	Continued working on draft text detailing the history and inner-workings of the *In The Zone* Tracker, to be submitted to a peer-reviewed journal.
June 2024	Wrote a blog post for the CCC website detailing my experience at the NSERC CREATE 2024 Annual Summit, where I presented my poster about the *In The Zone* Tracker as a multi-dimensional citizen science tool.
August - September 2024	Conducted *In The Zone* Tracker engagement analysis; yearly and monthly tracker submissions, as well as number of tracker entries each day, of each month, of each year, from 2017-2023.
September 20th 2024	Attended Carolinian Canada Coalition's full day in-person design thinking workshop at ReForest London. Contributed to the development of the Healthy Landscape Tracker through group brainstorming and exercises.
October 2024	Analyzed highest *In The Zone* Tracker engagement times and cross-referenced with list of Carolinian Canada Coalition's events, email-blasts, and website visits to determine where survey traffic might have originated from.
November 2024	Wrapped up outstanding internship responsibilities.