

Habitat Restoration Strategies for Eastern Meadowlark (*Sturnella magna*, L.) in Ontario
by
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Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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

Abstract

Eastern Meadowlark (*Sturnella magna*, L.) is an at-risk grassland bird in Ontario. *S. magna* is declining in part from breeding habitat loss and quality decline. Habitat restoration has been proposed as a recovery measure. Information on *S. magna*'s habitat preferences and current *S. magna* restoration initiatives are lacking in Ontario. I studied microhabitat characteristics within restored tallgrass prairie sites in Norfolk County, Ontario. No *S. magna* were observed on the study sites. I compared microhabitat characteristics between potential nest attempt periods, between sites, and to time since disturbance. Visual obstruction was the only characteristic that differed between nest attempts ($p < 0.05$). All microhabitat characteristics differed between sites ($p < 0.05$). All characteristics except woody vegetation cover ($dCor = -0.00038$, $p = 0.52$) showed a correlation with time since disturbance. The levels of significance for all tests were determined to be artefacts of the small sample size and do not necessarily reflect true trends. Comparisons to the literature suggest that percent grass cover may have been too low and percent total cover too high to support *S. magna*, but results differed and were too sparse to make meaningful comparisons. Likely not enough time has passed since restoration for the sites to become suitable for *S. magna*. I distributed an online questionnaire to 334 people knowledgeable of *S. magna*, tallgrass prairies, and/or grassland birds about past, current, and future restoration strategies in Ontario. Thirty-five responses were received. Projects have occurred across southern Ontario with clusters near Windsor and in Northumberland County. Delayed hay harvesting was the most common management strategy in restored areas. About half of respondents indicated that post-restoration monitoring occurs at least some of the time. Sixty-three percent of respondents indicated that projects used interventions. Most respondents indicated that projects lacked in sufficiency and effectiveness. Limiting factors

included finances and maintenance, and strengths included having a broad focus, planning, and monitoring. Key targets for future projects were southern and eastern Ontario. Key targets for future research were a better understanding of *S. magna*'s habitat needs and lifecycle, responses to restoration, and use of anthropogenic grasslands. This thesis provides an overview of the state of *S. magna* restoration in Ontario. It provides a roadmap for restoration ecologists and conservation biologists to use when managing habitat for grassland birds in Ontario.

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Chapter 1: Introduction

1.1 Introduction

The Lake Erie Lowland ecoregion of southern Ontario is one of the most biodiverse regions in the southern Canada (Kraus & Hebb 2020). It is also one of the regions where biodiversity is most threatened, making it a ‘crisis ecoregion’ (Kraus & Hebb 2020). Southern Ontario is home to 14.7 million people – representing 36.6% of the country’s total population (Federal Economic Development Agency for Southern Ontario 2024). When humans and wildlife occur in the same places, it is usually wildlife that suffer the consequences. This is exemplified in the number of declining wildlife populations whose distributions overlap with areas of high human density. One of these declining species is the Eastern Meadowlark (*Sturnella magna*, L.) – a ground-nesting grassland specialist.

As of 2020, 31.8 % of the Huron-Erie Plains (a.k.a. Lake Erie Lowland) ecoregion was dominated by cropland or pasture (Statistics Canada 2025). This land type is relatively new in the evolutionary history of *S. magna*, but it has largely been able to adapt to this new habitat. Anthropogenic grasslands now make up a significant portion of *S. magna*’s breeding habitat (McCracken et al. 2013). Despite this shift, *S. magna* populations are still in decline nationwide (Environment and Climate Change Canada & Birds Canada 2024). This indicates that there may be more to the story when it comes to understanding *S. magna* breeding behaviour.

1.2 Sampling Methods

1.2.1 Nest Searching

Winter et al. (2003) provide an overview of four methods of nest searching in tallgrass prairie habitats: i) chain or rope dragging, ii) systematic walking, iii) haphazard walking, and iv) behavioural observation.

‘Chain or rope dragging’ involves pulling a chain or rope through vegetation, suspended by two people, in an attempt to flush birds sitting on a ground nest (Winter et al. 2003). This method works well in pastures or shortgrass and mixed-grass prairies, but is less effective in denser vegetation (Winter et al. 2003; Byers et al. 2017). This technique requires at least two people, and has decreased effectiveness in dense vegetation.

‘Systematic walking’ involves walking transects through a sampling area to flush birds sitting on ground nests (Winter et al. 2003). This technique can make use of a 1.5 m ‘sweeping stick’, which is used to disturb the surrounding vegetation while walking (Winter et al. 2003). Systematic walking offers an advantage to rope dragging since it can be conducted independently. A disadvantage to systematic walking, as well as chain or rope dragging, is that it requires the observer(s) to be highly focused on the ground in front of them. It is possible for the observer(s) to miss distant behavioural cues, such as carrying nest material or food (Winter et al. 2003).

‘Haphazard walking’ is similar to systematic walking without a sweeping stick, except without a predetermined route (Winter et al. 2003). Searchers travel through the sampling area in no particular pattern or route, and document any nests found or birds flushed. More intensive searches of a particular area are conducted when a bird is flushed from a probable nesting site. A

drawback to using this method is that searching effort may not be uniform throughout the field site, which can result in over- or under-sampling (Winter et al. 2003).

‘Behavioural observation’ involves watching adult birds within the field site for clues indicating breeding behaviour, such as alarm calls, flushing, holding nest material, food, or a fecal sac in the bill, distraction displays, *etc.* (Winter et al. 2003). The location of a nest is then determined from observing the movement patterns of adults displaying these behaviours. This method is labour-intensive, and may lead to problems with over- and under- sampling.

Some studies have restricted the sampling area within each site to a certain size to standardize search effort among sites (Byers et al. 2017; Dion, Hobson, and Larivière 1999). Byers et al. (2017) used a search area of 8 ha, while Dion, Hobson, and Larivière (1999)’s search area was only 4 ha.

1.2.2 Nest Monitoring

Winter et al. (2003) suggest recording a nest location using a Global Positioning System (GPS) unit, as well as placing a physical marker such as a flag, spray paint, orange-painted rebar, or flagging tape 5 m north of the nest. Studies have also used other techniques for delineating nests that avoid using brightly coloured markers, since this may alert predators to a nest location. For example, Dion, Hobson, and Larivière (1999) used a 1 m tall bamboo pole that was placed 5 m from the nest. Other studies have relied solely on GPS coordinates, and avoided using physical markers altogether (Dyson, Slattery, and Fedy 2019; Fogarty et al. 2017).

The most common method in the literature for determining nest success for grassland birds is by repeatedly visiting the nest until the expected fledging date. Expected fledging date can be determined by estimating nestling age or observing the date of egg laying or hatching (MacDonald

and Nol 2017). The frequency of visits varies between every 1 – 5 days (Byers et al. 2017; Dion, Hobson, and Larivière 1999; Ellison et al. 2013; Fogarty et al. 2017; Galligan, DeVault, and Lima 2006; Hovick and Miller 2016; Hubbard et al. 2006; Knapton 1988; Martin 1974). Some studies monitored nests remotely – either using an infrared camera (Byers et al. 2017) or a standard video camera (Ellison et al. 2013; Pietz, Granfors, and Grant 2012). While using remote cameras to monitor nests may limit researcher disturbance, the higher capital and maintenance cost is relatively expensive. Ribic (2012) stated that the cost of the video monitoring systems they built ranged from \$695 - \$1,113 USD, while noting that pre-assembled commercially-available systems can cost more.

Some studies have used egg candling or floating to estimate fledging date when a nest has been located prior to hatching (Dyson, Slattery, and Fedy 2019; Hovick and Miller 2016). Egg candling involves holding a light behind an egg to view a silhouette of the embryo and the air pocket (Weller 1956). The embryo's size and shape, extent of vascularization, yolk density, and air pocket size can be used to determine the number of days since laying (Weller 1956). Eggs can also be floated in water to determine their age (Westerkov 1950). The buoyancy and position of the floating egg can be used to determine the number of days since laying (Westerkov 1950). The fledging date can then be estimated from the laying date using the average incubation period for the species (Dyson, Slattery, and Fedy 2019; Hovick and Miller 2016). Both methods are commonly used in ornithological research, however their accuracy and consistency have been questioned (Maliguine et al. 2023).

Hovick and Miller (2016) state that “...eggs were candled to determine age...” (73), however provide no further detail nor external citation for their methods. Dyson, Slattery, and Fedy (2019) reference Weller (1956) for both their candling and floating methods. However,

Weller (1956) only describes candling methods, and not floating. Weller (1956) and Dyson, Slattery, and Fedy (2019) studied waterfowl rather than *S. magna*, so the details of their candling methodology were not applicable to my study. To the best of my knowledge, there are no published methods for egg candling or floating for *S. magna*.

1.2.3 Survey-based Data Collection

There are several different methods to gather broad knowledge from people in a research context, including questionnaires and interviews (Angelsen et al. 2011). Questionnaires consist of a set of standardized questions that are posed to respondents, and can be either posed by a researcher or self-administered (*i.e.*, an online questionnaire; Newing 2011). Questionnaires have the advantage of having standardized questions, allowing for direct comparisons among respondents. They also have a relatively short time-commitment. However, since the questions are pre-determined there is little room for elaboration or follow-up questions. This is especially true of self-administered questionnaires.

Interviews are another means of gathering knowledge. Interviews can either be unstructured (*i.e.*, questions are not determined in advance, and arise during the course of the interview) or semi-structured (*i.e.*, some questions are prepared in advance, but the researcher may also ask follow-up and clarification questions during the interview; Newing 2011). Interviews allow for gathering more in-depth information from respondents, and to follow different lines of inquiry depending on the responses given. However, the time commitment is usually greater with interviews than with questionnaires (Newing 2011).

The sampling approach used in surveys can drastically impact the conclusions that can be drawn from the results. As in most empirical studies, a random probability sampling approach is

generally regarded as the most informative method since it allows for drawing inferences to a larger population (Newing 2011). This method involves randomly drawing a sample from a pool of potential respondents, so that each potential respondent has an equal probability of being sampled (Newing 2011).

However, this method is not always achievable in all studies. In studies where the population is difficult to define, such as in my study, true random probability sampling is not possible (Newing 2011; Angelsen et al. 2011). If the population of potential respondents is unknown, then the probability of an individual being sampled is also unknown. Using a non-probability sampling approach limits the ability of being able to draw statistical inferences from the sample and applying them to a larger population. However, this is not always necessary depending on the research question (Angelsen et al. 2011). In my study, I aimed to gather information from respondents, not to describe the population of subject experts to which they belonged. Although non-probability sampling introduces bias, it can be an acceptable method given the right research question (Angelsen et al. 2011).

Snowball sampling is another non-probability sampling approach that has been used in survey studies. Snowball sampling involves asking a survey respondent to recommend another person to be surveyed (Angelsen et al. 2011; Newing 2011). This method is especially useful in studies where the population is unknown, or members of the population are difficult to identify (Angelsen et al. 2011). Snowball sampling can supplement non-probability sampling by filling in gaps in individuals that may have been missed when compiling the population of potential respondents. While this method introduces bias, it can be justified in similar ways to other methods of non-probability sampling discussed above.

1.3 Research Questions

There are gaps in our understanding of ideal habitat requirements for *S. magna*, especially in Ontario. Much of the existing literature on this species occurs outside of Ontario, and many include a caveat that the results presented may not be applicable outside of the region and/or ecosystem being studied. Furthermore, while habitat restoration has been identified as a recovery objective, there has not been a comprehensive assessment of what has been done to date. This provides an unclear path forward to achieving this goal. Through this research, I aimed to provide greater clarity on the habitat requirements of and restoration priorities for *S. magna* in tallgrass prairie ecosystems in southern Ontario. My research assessed the following questions:

- I. What are the characteristics of successful nesting habitat for *S. magna*?
- II. What restoration strategies are currently being employed in Ontario for tallgrass prairies and/or *S. magna*, and how can future efforts be improved?

1.4 Outline

The following chapters outline the results of investigations into the two research questions. Chapter 2 provides a literature review of *S. magna*'s Ontario breeding habitat and conservation status, and grassland restoration theory. Chapter 3 describes field investigations to address question I. Chapter 4 describes survey-based research to address question II. Chapter 5 provides a brief overview of the findings of the research and their applicability to the field of grassland bird restoration.

Chapter 2: Literature Review

2.1 Distribution

S. magna is a passerine bird species that breeds in Ontario and is a member of the New World blackbird family (Icteridae; Chesser et al. 2025). This species breeds in southeastern Canada, the eastern United States, Mexico, the Caribbean Islands, and the northernmost part of South America (Jaster et al. 2022). It is found year-round in most of its range, except for the most northern reaches (Canada, northern states; Jaster et al. 2022). Individuals in these areas, as well as some in the central United States, are migratory (Jaster et al. 2022).

2.2 Breeding Habitat

S. magna creates ground nests in open grassland habitats (Peck & James 1987; Leckie 2007). In eastern North America, *S. magna* nests in both grasslands and agricultural fields. In Ontario, nesting grassland habitat includes tallgrass prairies, savannas, and alvars (McCracken et al. 2013). This species has also been observed nesting elsewhere in North America in prairies (Fogarty et al. 2017; Herkert 1991, 1994; Samson 1980) and beaver meadows (Askins 1999; Askins et al. 2007). *S. magna* will also nest in restored areas such as reclaimed surface mines (DeVault et al. 2002; Ingold 2002; Galligan, DeVault, and Lima 2006; Lautenbach et al. 2020) and restored grasslands (Jaster, Jensen, and Forbes 2014; Herkert 1991, 1994). They have also been observed nesting in grasslands surrounding airports in Illinois (Kershner and Bollinger 1996) and on the Fort Riley military base in Kansas (Hubbard et al. 2006).

Due to the loss of native grassland habitats throughout North America, *S. magna* is most frequently found nesting in hayfields (Wiens 1969; Bollinger 1995; Jobin, DesGranges, and Boutin 1996; Norment, Runge, and Morgan 2010; Roseberry and Klimstra 1970; Askins et al. 2007; Horn and Koford 2004), pastures (Norment, Runge, and Morgan 2010; Roseberry and Klimstra 1970;

Hovick and Miller 2016), and fallow fields (Norment, Runge, and Morgan 2010; Herkert 1991). *S. magna* has also been observed nesting within tallgrass prairies on active cattle ranches in Oklahoma (Fogarty et al. 2017).

Peer-reviewed literature on *S. magna* breeding habits in Ontario is sparse. The few Ontario studies that exist have observed them nesting in old fields (Knapton 1988; McCracken et al. 2014), vineyards (Knapton 1988), pastures (Campomizzi & Lebrun-Southcott 2022; de Zwaan et al. 2022; McCracken et al. 2014), and hayfields (de Zwaan et al. 2022; McCracken et al. 2014).

Corace, Flaspohler, and Shartell (2009) studied the timing of hayfield mowing in parts of Michigan, Minnesota, and Wisconsin, and compared it to *S. magna* population trends. Breeding Bird Survey data from 1966 to 2003 were compared to hayfield mowing patterns throughout the region, based on a survey of resource professionals in 2001 and 2002 (Corace, Flaspohler, and Shartell 2009). They found that *S. magna* occurrence in hayfields within the Upper Great Lakes Region were common to very common. Hayfields also provided moderate or moderate-high habitat value for this species considering the availability of potential habitat in the surrounding area (Corace, Flaspohler, and Shartell 2009). Roseberry and Klimstra (1970) list apparent habitat preference of *S. magna* in order as: pasture, hayfield, winter wheat, and fallow fields.

Anecdotal observations indicate that *S. magna* tends not to nest in fields of row crops (Leckie 2007; McCracken et al. 2013). *S. magna* has been observed nesting in Conservation Reserve Program fields in the United States (Horn and Koford 2004), either dominated by warm-season (Byers et al. 2017) or cool-season species (Ellison et al. 2013). Additional agricultural habitat for this species includes current or recently managed commercial blueberry grassland-barrens in Maine (Vickery, Hunter, and Melvin 1994). *S. magna* was relatively infrequent in this

study, as they were only detected at 10% of census points. The authors note that this may indicate that blueberry grassland barrens may not be a major habitat type for *S. magna*.

2.3 Threats

The population decline for *S. magna* in Ontario has mainly been attributed to native grassland loss and nest destruction in agricultural habitats (McCracken et al. 2013). It was estimated that less than 1% of pre-settlement prairie and savanna habitat in Ontario remained as of 20 – 30 years ago (Bakowsky & Riley 1994; Catling 2008). More recent estimates of the amount of remaining native grasslands are lacking. The loss of native grasslands has resulted in a shift in nesting habitat to primarily agricultural fields (McCracken et al. 2013). Human and livestock activities within agricultural lands have had negative consequences on breeding productivity (McCracken et al. 2013).

In Ontario, most hay is harvested between early June and early July, depending on the desired protein level (Ontario Ministry of Agriculture, Food and Rural Affairs 2017). The breeding season for *S. magna* in southern Ontario lasts from approximately May 15 to July 31 (Ontario Breeding Bird Atlas 2021). As a result, hay harvesting and mowing can overlap with the egg or nestling stage, resulting in nest failure (Kershner & Bollinger 1996; Lusnier & Thompson 2009). Hayfield mowing has not demonstrated a uniform population decline in this species. The results of Corace, Flaspohler, and Shartell (2009)’s study indicated no strong correlation between mowing timing and population trends of *S. magna*. Rather, they suggest that *S. magna* population trends may be influenced by a landscape-level decline in hayfields over recent decades.

Another often-cited reason for grassland bird nest failure is due to trampling of nests by livestock. Nests in pastures or paddocks may be prone to trampling at high stocking rates, and

over-grazing can decrease habitat quality (McCracken et al. 2013). Similar to hayfield mowing, the impacts are not universal on *S. magna*. Some studies have found that *S. magna* breeding in pastures prefer moderate levels of grazing intensity (Baker & Guthery 1990). Others have found grazing intensity to have no or little effect on breeding *S. magna* (Bock et al. 1984; Hovick & Miller 2016; Campomizzi & Lebrun-Southcott 2022; Powell 2006).

2.4 Conservation Status

The Committee on the Status of Endangered Wildlife in Canada is an independent, national body that evaluates the conservation statuses of wildlife in Canada. The Committee conducts assessments of wildlife species who appear to be declining. Based on the results of the assessment, the Committee may recommend for a species to be listed under the Species at Risk Act, S.C. 2002, c. 29. The Committee conducted an assessment on *S. magna* in 2011, and recommended that it be added to Schedule 1 of SARA as Threatened (Committee on the Status of Endangered Wildlife in Canada 2011). That same year, *S. magna* was also assessed as Threatened by the Committee on the Status of Species at Risk in Ontario – Ontario’s equivalent for the Endangered Species Act, 2007, S.O. 2007, C. 6 (Committee on the Status of Species at Risk in Ontario 2011). *S. magna* was added to the Endangered Species Act the following year (Endangered Species Act, 2007, S.O. 2007, C. 6, O. Reg. 230/08), but wasn’t added to the Species at Risk Act until 2017 (Species at Risk Act, S.C. 2002, c. 29, Sched. 1, as amended).

2.5 Recovery Efforts and Knowledge Gaps

The Ontario government issued a combined Recovery Strategy for both Bobolink (*Dolichonyx oryzivorus*, Swainson 1827) and *S. magna* in 2013 under the ESA (McCracken et al. 2013). A proposed Federal Recovery Strategy for *S. magna* was released in 2022 (Environment

and Climate Change Canada 2022), but it has not yet been finalized at the time of writing. Protection and recovery objectives listed in the Recovery Strategies include identifying key areas for conservation, improving habitat quality, restoring the amount of native grassland, and maintaining suitable agricultural grasslands. The Ontario Recovery Strategy also suggests conducting research to identify options for modified hay harvesting and pasture management that minimize the impact on farmers (McCracken et al. 2013). Both strategies recommend developing incentive programs for landowners to restore grasslands on their property, developing guidelines for deciding on restoration strategies, and encouraging proper grassland management techniques.

The federal Status Report for *S. magna* acknowledges a lack of data on habitat preferences of this species in Canada specifically (Committee on the Status of Endangered Wildlife in Canada 2011). The proposed federal Strategy identifies population and metapopulation dynamics as a key knowledge gap, and suggests identifying regional populations which are the most at-risk (Environment and Climate Change Canada 2022). The Ontario Recovery Strategy identifies optimal vegetation characteristics, structure, and other microhabitat considerations as knowledge gaps. Further research into the unique habitat preferences of both *S. magna* and *D. oryzivorus* is recommended (McCracken et al. 2013).

Despite acknowledgements by both federal and provincial governments of the need for action, there have been delays in the listing of, reporting on, and recovery of *S. magna*. While the exact motives for delaying action on this species aren't explicit, there have been many cases from Canada and the United States where governments have delayed conservation actions due to economic or development reasons (Schlotterbeck 2003; Ferreira et al. 2019; Ando 1999).

2.6 Grassland Restoration

2.6.1 Strategies and Approaches

Restoring the above-ground vegetation is a major focus of grassland restoration efforts. Different methods of introducing desirable plant species to a restoration site exist, such as seeding, transplanting, planting plugs, *etc.*

Balsdon (2013) examined the effectiveness of restoring a grassland in Boyne Valley Provincial Park in Ontario with different plant application techniques. Plots within three different fields were established and re-seeded: 1) 30-year old field, 2) 7-year hayfield, and 3) annual crop rotation field. All three fields were tilled and vegetation growth was inhibited using tarpaulins for the duration of the 2010 growing season. The fields were planted with plugs and seeds of five grassland species native to southern Ontario in three transects: 1) plugs only, 2) seeds only, and 3) plugs and seeds. Additionally, the avian community in each field was surveyed three times during late May to early July in 2010 and 2011. Survivorship was compared between one and two years after planting using Fisher's exact test. Balsdon (2013) found similar levels of survivorship between plugs only and plugs + seeds transects. Both treatments had greater survivorship than seed only transects. There was no difference in *S. magna* abundance between 2010 and 2011 – only one individual was observed within the study area each year, both in the annual crop rotation field. While this study presents results for the first year post-planting, the effects of these treatments beyond 1 year are unknown.

Cray (2019) examined differences in soil bacteria species richness between remnant tallgrass prairie plots and restored plots across southwestern Ontario. The restored sites were either 1) seeded only, 2) seeded and transplanted with at-risk species from a nearby remnant site, and 3)

transplanted with sod mats from a nearby remnant site. The treatments had been applied five years prior to the study. Three soil subsamples were collected in each plot and pooled for analysis. Percent cover was estimated for each plant species using a 1 x 1 m quadrat in each plot. Sod mat treatment were found to have significantly higher soil bacteria species richness than the other treatment types. Soil bacteria species richness did not differ from the two “high-quality” reference sites (but was significantly higher than the “low-quality” reference site). There was no difference in plant species richness between any of the treatment groups or reference sites.

The different trends in above and below-ground species richness indicate that an important component of biodiversity may be missed in most restoration studies. Many restoration studies use plant diversity as an indicator of restoration success. When considered independently, the lack of trend in plant species richness after five years suggests that restoration has not yet had an effect. The significant difference in soil bacteria tells a different story. Restoration studies may be ignoring important indicators of ecosystem recovery by failing to study below-ground impacts of restoration.

2.6.2 Monitoring and Management

The importance of evaluating the results of restoration activities has been noted by the Society for Ecological Restoration and others (Society for Ecological Restoration International 2004; Gann et al. 2019; Holling et al. 1978). The term “adaptive assessment and management” was first used in 1978 by Holling et al. Their use of the term describes conducting an initial assessment of a site/project/problem by assembling existing data, building a model, collecting data, refining the model, evaluating results, and communicating conclusions. The ‘management’ half of the definition is more amorphous. Holling et al. (1978) note how different policy and institutional factors can greatly influence the management of a project. They emphasize how communicating

results is key to ensuring the results of the assessment end up in the hands of those responsible for implementing change, and not lost in the literature. Holling et al. (1978) also note that effective management takes time, and stress that rushing into a management plan may ultimately hinder results.

The adaptive management definition has evolved over the decades and there is a large volume of research on the topic. The adaptive management concept has been portrayed as a cyclical framework or loop (*e.g.*, West 2016), sometimes with multiple loops or a ‘figure 8’ shape (*e.g.*, Dai et al. 2025). Regardless of the framework used, adaptive management is seen as an essential component of any restoration project.

The ‘success’ of a restoration project may depend on the time scale of monitoring. O’Reilly-Nugent et al. (2024) compared differences in restored and reference grassland plots at the Cedar Creek Ecosystem Science Reserve in Minnesota. Thirty treatment and five control plots (6 x 6 m) were set up in 1993 within the same old field (F0), separated by a 1 m buffer. The field had previously been used for agriculture but had been abandoned in 1965. Six treatment plots were compared to one control plot. Treatments consisted of seed addition, burning, herbicide application, tilling, or seeding with a nurse crop. Two additional old fields of a similar successional age, F1 and F2, were used as non-intervention reference sites. A chronosequence was established from 21 old fields of various successional ages within a 3.5 km radius of F0. The chronosequence, including fields F1 and F2, represent a time period of 70 years (year of abandonment ranged from 1927 – 1997). The authors fitted a saturation growth curve to the standardized abundance of both native and non-native grasses and forbs. A Hamiltonian Monte Carlo Bayesian framework was used to estimate model parameters. Native grass and forb abundance in F0 was found to be significantly higher in treatment plots when compared to control plots, regardless of treatment

type. Abundance peaked 1- and 7-years post-interventions for native forbs and grasses, respectively. After 24 years, native forb and grass abundances did not significantly differ between treatment and control plots. Treatment plots in F0 were found to have a higher abundance of native forbs and grasses than F1 and F2 reference plots. Examination of the chronosequence plots showed that over a 70-year period, using no interventions ultimately leads to the same native grass and forb abundance as treatment plots in F0.

The results of O'Reilley-Nugent et al. (2024) demonstrate that the timescale of monitoring greatly affects how results are interpreted. While initial monitoring within the first decade since interventions showed significant results, the differences between the two methods disappeared 24 years later. The results of the chronosequence show that it can take several decades for grassland communities to reach a climax state.

O'Reilley-Nugent et al. (2024) is a rare example of long-term post-restoration monitoring. Most studies monitor restoration projects for a much shorter period, which may lead to drawing inaccurate conclusions about the project's success or failure. Alamenciak et al. (2023) conducted a review of 308 restoration studies throughout Canada. The majority (75%) of these studies only monitored for < 5 years post-restoration. Vörös et al. (2025) found a similar trend in 322 studies on grassland restoration from 1995 – 2021 from around the globe. They found that 81% of studies monitored for < 5 years post-restoration. They also found that 63% of studies actively managed sites post-restoration.

2.7 Habitat Preferences

2.7.1 Fire

Grasslands are early successional communities, which are maintained in this state by periodic disturbances. Historical records suggest that Indigenous people in southern Ontario have been conducting prescribed burns for centuries to maintain grassland communities for agriculture or hunting (Askins 1999; Askins et al. 2007). Prescribed burning may help to restore *S. magna* habitat by maintaining the community in an early-successional state.

Bock and Bock (1992) measured *S. magna* abundance in response to a wildfire in native and exotic mesa grasslands in Arizona. A fire began in July 1987 within an existing site being studied by the authors. Mean *S. magna* abundance was 0.00 and 0.09 the year of the burn in native and exotic plots, respectively. Mean abundance increased the following breeding season to 0.55 in both types of grasslands. *S. magna* continued to occupy both plots for the final two years of the study. Bock and Bock (1992) did not use inferential statistics to compare bird abundance between years, so it is unclear whether the differences observed indicate a real trend. The authors also acknowledge that their plots were small, were pseudoreplicates, and situated within the same 100 ha field. These limitations indicate that their results may not be widely applicable beyond this system.

Byers et al. (2017) measured *S. magna* nesting patterns in CRP fields in Wisconsin and Iowa from 2009 – 2011. Fields were prescribed burned during April – early May. The authors modeled apparent nest density with year and vegetation characteristics using generalized linear mixed models. *S. magna* mean nest density was 0.03 nests/ha the year of the burn. Nest density increased to 0.19, 0.25, and 0.22 nests/ha in years 1 – 3 following the burn, respectively. Year

since burn was the second-best performing model for nest density (Δ Akaike's Information Criterion for small sample sizes [AIC_c] = 1.69), preceded by litter cover. Several other studies have documented a similar response to burning by *S. magna* (Powell 2006, 2008; Robel et al. 1998).

There may be a compounding effect of fire and livestock grazing on *S. magna* nesting patterns. Hovick and Miller (2016) used two treatments to examine this effect: 'patch-burn grazed' and 'grazed-and-burned'. For patch-burn grazed, one third of each pasture was burned annually, and livestock were allowed to graze in both the burned and unburned portions of each pasture. In the grazed-and-burned treatment, the entire pasture was burned every three years, and grazing was permitted each year. Nest survival for the patch-burn grazed treatment ranged from 12 – 16%, whereas the survival for the grazed-and-burned treatment ranged from 2 – 31%. Patch-burn grazed pastures also had about twice as many nesting attempts as the grazed-and-burned pastures (64 and 31, respectively). Hovick and Miller (2016) conclude that employing a patch-burn grazed approach provides greater stability in habitat availability and nest survival among years than a grazed-and-burned approach, although they did not perform a statistical test to reach this conclusion. It is unclear whether differences in the number of *S. magna* nest attempts were in fact due to different fire/grazing regimes without the use of inferential statistics.

Other studies have not found a positive effect of burning on *S. magna*. Herkert (1991) examined *S. magna* responses to periodic disturbance in native and restored prairies and other grassland communities in Illinois from 1987 – 1990. Herkert (1991) recorded the presence and density of *S. magna* individuals rather than specific nest locations. Observations were collected from prairie sites that were classified into three treatments: 1 – 4 months post-burn (first growing season; year 0 *sensu* Byers et al. 2017), 13 – 16 months post-burn (second growing season; year 1 *sensu* Byers et al. 2017), and > 25 months post-burn (third or more growing season; year 2+ *sensu*

Byers et al. 2017). *S. magna* density among treatments was compared using paired t-tests. There was no significant difference among *S. magna* density among any of the burn treatments (p-value of pairwise comparisons ranged between 0.18 – 0.79).

Coppedge et al. (2008) examined the effect of patch-burn grazing vs. whole-field burn grazing on *S. magna* abundance using Analysis of Variance (ANOVA). Coppedge et al. (2008) found no significant difference in mean *S. magna* abundance between treatments ($p > 0.05$).

Burning in a heavily developed landscape like Southern Ontario is a challenge with the risk of property damage and human health concerns. This makes it difficult to maintain the proper disturbance regime of the ecosystem, and as a consequence alters the type of habitat available for species such as *S. magna*. The lack of a response to burning by *S. magna* may indicate that a decreased burning frequency in the system over time has altered the ecosystem and its structure.

2.7.2 Area-Sensitivity

S. magna exhibits some degree of area-sensitivity (McCracken et al. 2013; Environment and Climate Change Canada 2022). However, the minimum patch-size has been debated. Vickery, Hunter, and Melvin (1994) examined *S. magna* habitat associations in current or previous commercial blueberry grassland-barrens in Maine in 1989 and 1990. Vickery, Hunter, and Melvin (1994) recorded individual abundance rather than locating nests. The authors generated an incidence function using a logistic regression model to predict the probability of *S. magna* being present at different patch sizes. A Z-test was then used to determine the significance of the logistic regression coefficient. They controlled for sampling effort by only using one randomly-selected census plot per site to generate the incidence function. The incidence function showed a positive

correlation with patch size ($p < 0.01$, Z coefficient is not reported). However, they state that overall abundance was low, and caution that these results may not apply to other grassland systems.

Herkert (1994) examined the effect of patch size on *S. magna* densities in native and restored prairies, and cool-season grasslands in Illinois from 1987 – 1989. Similar to their earlier study (Herkert 1991), Herkert (1994) recorded the presence and density of individuals of these species rather than specific nest locations. They used a stepwise regression model to assess the relationship between area and habitat structure on *S. magna* breeding distribution patterns. They used the proportion of times *S. magna* was encountered on each transect as the dependent variable. Proportions were log-transformed prior to regression. Area was found to be a significant predictor of occupancy ($p < 0.01$), so they modeled the relationship between area and probability of occurrence with a logistic regression. Herkert (1994) defined the area requirement for a species as the area at which there was a 50% probability of observing said species. Based on this definition, the recommended area requirement was 5 ha for *S. magna*.

Samson (1980) identified a smaller area requirement than Herkert (1994). Samson (1980) examined *S. magna* habitat associations in prairies in Missouri in 1978 and 1979. Similarly to Herkert (1991, 1994), Samson (1980) measured the presence of individual *S. magna* rather than nests. They generated an incidence function, which plots the probability of occupation of a breeding population by area. Samson (1980) identified a minimum area of occupancy for *S. magna* as < 1 ha, but states that > 1 ha is needed to sustain a regular breeding population. Unfortunately, Samson (1980) does not provide their methodology for calculating incidence functions, making it difficult to reliably interpret their results.

2.7.3 Fragmentation

Habitat fragmentation and the presence of habitat edges may have an effect on *S. magna*, however the type of effect observed varies. Herkert (1991) measured the sensitivity (*i.e.*, level of tolerance) of *S. magna* to habitat fragmentation. They used a multiple regression analysis to generate an incidence function in fields of three size classes: small (< 20 ha), medium (20 – 100 ha), and large (> 100 ha). An index of tolerance to fragmentation was then calculated by determining the ratio of probability of occurrence on small and large fragments. The index ranged from 0 to 1, with 0 being most sensitive to fragmentation and 1 being the least sensitive (Herkert 1991). *S. magna* was assigned a sensitivity of 0.4, indicating mid-range tolerance of fragmented landscapes.

Hubbard et al. (2006) examined *S. magna* nesting patterns in tallgrass prairies on the Fort Riley military base in Kansas in 2005. They compared differences between the location of actual nests and random locations using the Wilcoxon Signed Rank Test, with a significance value of $p \leq 0.1$. Distance to the nearest edge was found to significantly differ between nest and random locations ($p = 0.049$). Nests were an average of 11% further from habitat edges than random locations, indicating avoidance.

Ellison et al. (2013) examined *S. magna* nesting patterns in CRP fields in Wisconsin. Ellison et al. (2013) conducted a removal experiment of woody tree rows adjacent CRP fields with nesting *S. magna*. They assessed for differences in nest density between treatments within field edge and field interior using paired Analyses of Covariance (ANCOVA)s (treatment and control plots were paired based on size). If one of the response variables in the paired model was insignificant, the model was replaced with a linear model. The authors also tested for differences in daily survival rate among treatments, distance to field edge, and interactions using a logistic

exposure method. AIC_c was used to rank the models. Nest density was found to increase near the field edge following tree removal ($F = 6.68$, $df = 1, 14$, $P = 0.022$). No significant change in nest density in the interior of the field was noted ($F = 1.41$, $df = 1, 17$, $P = 0.25$). A different trend was observed for daily survival rate. Distance from the edge and removal year 3 were terms in two of the significant models ($p = 0.018$ and $p < 0.001$, respectively).

Byers et al. (2017) also used a logistic exposure method using generalized linear models to analyze daily survival rate and used AIC_c to compare models. Distance to field edge were negative in both of the top models for daily survival rate.

2.7.4 Microhabitat Characteristics

Many studies have been conducted on the habitat preferences of *S. magna* in North America, at times with conflicting results. However, few studies addressing this question have been conducted in Ontario.

Byers et al.'s (2017) study in Wisconsin and Iowa measured vegetation characteristics surrounding *S. magna* nests as well as within the larger field. Litter cover was a positive term in the top performing model of nest density, while litter depth was a positive term in the top performing model for daily survival rate. Byers et al. (2017) suggest that fire may be influencing the amount of litter cover and depth, which in turn may be driving the observed patterns.

Kershner and Bollinger (1996) examined the breeding success of *S. magna* at airports in Illinois in 1994. They used paired t-tests to compare vegetation characteristics between nest sites and random sites. They measured the inverse of the amount of litter cover, which is the amount of bare ground. The authors documented an apparent avoidance by *S. magna* of bare ground – they found no bare ground within 0.25 m² of nests, compared with approximately 4.2% bare ground at

paired non-nesting sites within the same field ($p < 0.056$). In other words, *S. magna* were building nests in locations with greater litter cover.

Visual obstruction was developed by Robel et al. (1970) as a measure of visual nest obscurity in ground-nesting grassland birds. It takes into account the compounding effect of vegetation height and density to obscure an object from view. Visual obstruction can be interpreted as a measure of how well a nest is hidden from visual predators. As per Robel et al. (1970), a rod with brown and white stripes every 10 cm is held vertically with one end on the ground. A reading is taken (to the nearest 10 cm) where the lowest part of the pole can be seen. This reading is taken at a distance of 4 m and height of 1 m.

Byers et al. (2017) measured vegetation height-density at *S. magna* nests at a distance of 4 m and height of 1.5 m – a slight variation from Robel et al. (1970). Vegetation height-density was not a term in any of the top-performing nest density or daily survival rate models.

This method has been used in many studies to quantify a ground nest's obscurity. While it is a useful tool for standardizing methods among studies, it may not accurately model real-world predation scenarios. Nest predators such as snakes, weasels, birds of prey would likely approach a nest from a different angle than the one suggested in Robel et al. (1970). Ground predators would be viewing the nest from closer to the ground, while birds of prey would be viewing the nest from above. A nest's obscurity from the vantage point of potential predators would be more important to *S. magna* than from Robel et al. (1970)'s suggestion.

Others have used measures other than visual obstruction *sensu* Robel et al. (1970) to quantify nest obscurity. Bollinger (1995) used vertical patchiness, *i.e.*, the variation in vegetation height at which a Robel pole was visually obstructed. The authors examined *S. magna* breeding

habits in hayfields in New York from 1984-1986. They used stepwise multiple regressions to determine which vegetation characteristics were predictors of *S. magna* abundance within a field during the breeding season. Vertical patchiness was a negative term in the model for *S. magna* abundance (partial $r^2 = 0.08$, model $r^2 = 0.51$, $p < 0.05$). This indicates that *S. magna* may avoid areas that have greater vertical patchiness during the breeding season.

Coppedge et al. (2008) used angle of obstruction, which is “an index of visual obscurity that is a function of vegetation density and horizontal and vertical structure” (1198). They used general linear models to assess the effect of vegetation characteristics on *S. magna* abundance. Angle of obstruction was included as a negative term in the model for *S. magna* abundance.

The variety in methods used to quantify visual obstruction make comparing between studies difficult. The application of each method to real-world predation scenarios also varies, which has an effect on how results should be interpreted.

The percent cover of different vegetation types has been found to have an effect on *S. magna*. Kershner and Bollinger (1996)’s study of *S. magna* nest success in airport grasslands found that the vegetation surrounding nests tended to be dominated by 83.5% grass cover, 11.0% forb cover, and 5.4% clover cover. *S. magna* nest density in this habitat was 0.56 nests/ha, with only 14% of nests successfully fledging young. A success rate of 14 % is relatively low compared to studies of other grassland birds (19 – 46 %; Roseberry and Klimstra 1970; Granfors, Church, and Smith 1996; Robel et al. 1998; Winter and Faaborg 1999; Ingold 2002; Kershner, Walk, and Warner 2004; Hubbard et al. 2006). Kershner and Bollinger (1996) suggest that the low fledging rate may indicate that airports act as population sinks.

Vickery, Hunter, and Melvin (1994) used multiple linear regression to model the relationship between *S. magna* abundance and vegetation characteristics. Graminoid cover and low shrub cover (height: 0 – 60 cm) were significant positive terms in the model ($R^2 = 0.259$; $p < 0.001$ and $p < 0.05$, respectively), while high shrub cover (height: 60 cm – 2 m) was a significant negative term ($p < 0.05$). However, they state that overall *S. magna* abundance was low, and caution that these results may not apply to other grassland systems. A similar trend has been observed by Coppedge et al. (2008), who found both percent tallgrass cover and percent shortgrass cover to be positive terms in the model for *S. magna* abundance.

Granfors, Church, and Smith (1996) studied *S. magna* nesting habits in rangelands and Conservation Reserve Program fields in Kansas. They used an ANOVA to compare vegetation characteristics between nest and non-nest sites, despite admitting that only some of the variables were normally distributed. The authors did not provide a list of which variables had normal distributions. They observed greater proportion of grass cover at *S. magna* nest sites than at non-nest sites ($p = 0.092$) – the exact proportions are not reported. Since it is unknown whether grass cover was normally distributed, and thus whether the ANOVA was valid, it is impossible to verify the accuracy of this assessment.

Hovick and Miller (2016) modeled *S. magna* nest survival with different vegetation characteristics using maximum likelihood models. The models were compared using AIC_C. Woody vegetation was included as the only significant term in the top-performing model. The authors also state that nests that were within a 0.5 m² quadrat of woody cover had a decreased probability of survival ($\beta_{\text{woody}} = -0.07$ on a logit scale, $SE = 0.04$, 95% CI = -0.15 and 0.001), although it is unclear what analysis was used to reach this conclusion.

Lautenbach et al. (2020) examined *S. magna* habitat associations in reclaimed surface mines in Ohio. Lautenbach et al. (2020) measured the occurrence of *S. magna* individuals within the study sites rather than locating nests. Three herbicides (metsulfuron methyl, triclopyr, and picloram) were applied to the study sites from 2014 – 2017 to target woody vegetation. An additional ‘herbicide and shredding’ treatment was conducted on some fields, where dead woody vegetation was cut, shredded, and left as litter following herbicide application. Surveys began 1 – 3 years post-treatment. The authors used an ANOVA and Tukey honest significant difference test to compare differences in woody cover between treatment types and before/after treatments. The authors used a hierarchical distance sampling framework to estimate *S. magna* density. Density was modeled using hazard rate, half-normal, exponential, and uniform functions. Models were compared using AIC. Mean percent woody canopy cover was the lowest after the ‘herbicide and shredding’ treatment (11.46%, SE = 2.32). *S. magna* density was greatest in sites treated with herbicide and shredding (0.30 birds/ha, SE = 0.17). Lautenbach et al. (2020)’s habitat models suggest that *S. magna* density decreases with increasing woody vegetation, and that an ideal level of woody cover would be 0 – 5%. The models indicated that *S. magna* may still be present at up to 10% woody vegetation cover. However, they caution that an increase in *S. magna* density does not necessarily mean an increase in habitat quality.

Chapter 3: Microhabitat Characteristics of Eastern Meadowlark (*S. magna*, L.) Nest Sites in Southwestern Ontario

3.1 Introduction

The Kunming-Montreal Global Biodiversity Framework was a response to alarm over biodiversity declines. One stark example of this decline is in grassland birds in Canada. Specifically, of all the groups of birds in Canada, the population of grassland birds has declined the most from 1970 – 2022 (Birds Canada & Environment and Climate Change Canada 2024). Grassland birds as a whole have declined by 67% Canada-wide within that period (Birds Canada & Environment and Climate Change Canada 2024). *S. magna* is one of those grassland species. The *S. magna* population in Canada has declined by an estimated 84% within the same time frame (1970 – 2022; Environment and Climate Change Canada & Birds Canada 2024). That constitutes an average annual decline of 3.46%. The majority of *S. magna*'s Canadian range falls within Ontario and Quebec (Committee on the Status of Endangered Wildlife in Canada 2011). Although this trend is nation-wide, *S. magna*'s restricted range allows for an indication of the general trend that can be expected of Ontario's population. The United States population appears to be declining as well, although at a slower rate. Grassland birds as a whole have declined in the United States by 43% from 1970 – 2022 (North American Bird Conservation Initiative 2025). Breeding Bird Survey data from 1966 – 2022 show a 2.7%/year decline in *S. magna* across the United States (Hostetler et al. 2023). The International Union for the Conservation of Nature lists *S. magna* on its Red List as Near Threatened, citing some uncertainty with population trend data from outside of the United States and Canada (International Union for the Conservation of Nature 2020).

The widespread loss and fragmentation of grasslands – both natural and anthropogenic – have caused *S. magna* population declines in southern Ontario and Quebec (Fyson et al. 2024).

Fire suppression by humans affects grassland habitat availability. Early successional systems like grasslands rely on widespread disturbances, like wildfires, to suppress the growth of woody species and to reset the successional cycle (Ratajczak et al. 2014). The suppression of such disturbances allows for grassland systems to succeed into shrubland and woodland ecosystems, which support a different avian community than grasslands. Widespread insecticide use is likely a factor in grassland bird population declines (Moreau et al. 2022). Many of these species are insectivores and breed or forage in agricultural areas, where insecticide use is the most widespread.

The factors behind *S. magna* declines in Canada largely mirror those of grassland birds at large. Habitat loss is thought to be a major underlying reason for the population decline. Historically, the Mixedwood Plains region of Ontario consisted of a mixture between Carolinian hardwood forests and grasslands (Crins et al. 2009). Early European accounts of the flora of southern Ontario describe vast prairies near present-day Sarnia, Windsor, Walpole Island, Brantford, and the base of Long Point (Bakowsky & Riley 1994). Accounts of early Indigenous farming practices in the area mention the maintenance of grasslands by burning to facilitate hunting grounds in this patchwork landscape (Askins 1999). These grasslands would have hosted a variety of grassland bird species, including *S. magna*. Colonization by Europeans resulted in a shift of farming practices in the area. Europeans brought with them their agricultural practices of widespread clearing for livestock rearing and crop production (Askins 1999; McCracken et al. 2013). The widespread deforestation that followed provided a plethora of grasslands for birds such as *S. magna* to occupy (Askins 1999). As a result, the population of *S. magna* during the centuries following colonization grew substantially (Askins 1999). In the early 1900s, agricultural practices began to shift even more towards cereal and row crop production – a trend that has continued until current day (Fyson et al. 2024). *S. magna* population trends responded accordingly, declining

substantially during the past century (McCracken et al. 2013; Environment and Climate Change Canada & Birds Canada 2024). This effect is still apparent in more recent decades. In the Upper Great Lakes area of the United States, county-level hayfield and pasture declines corresponded to a decline in the *S. magna* population (Corace et al. 2009). Compounding the loss of agricultural habitat is the widespread loss of native grasslands. The most recent estimates (*i.e.*, from the mid-1990s to early 2000s) are that less than 1% of these historic grasslands persist in Ontario (Bakowsky & Riley 1994; Catling 2008). Given that these estimates are currently about 20 – 30 years old, and that the Mixedwood Plains region is the most densely populated region in the province (Crins et al. 2009), it can be reasonably estimated that the remaining amount of historical grasslands has continued to decline.

The quality of remaining *S. magna* habitat is debated. Today, *S. magna* breeds almost exclusively in agricultural systems such as hayfields and pastures (McCracken et al. 2013). Agricultural habitats pose unique risks not encountered in natural grasslands. Hayfields and pastures are ‘ecological traps’ for *S. magna* – habitats which have high population levels but low reproductive outputs (Bock & Jones 2004). Hay harvesting normally occurs during peak protein content: late May – mid-June (Ochterski 2006; Ontario Ministry of Agriculture, Food and Rural Affairs 2017). At this time, *S. magna* is mid-way through the breeding season (Jaster et al. 2022; Ontario Breeding Bird Atlas 2021). Being ground-nesting species, their nests and eggs/nestlings are especially susceptible to damage or mortality due to compaction. Hay harvesting using heavy machinery during this period has been shown to result in high levels of nest failure and nestling mortality (Kershner & Bollinger 1996). Casualties of the fledglings of early-nesting pairs have also been observed, who are not yet capable of sustained flight and are unable to quickly flee oncoming threats (McCracken et al. 2013). Similar results occur in pastures with a high livestock

concentration (*i.e.*, stocking density). The occurrence of accidental trampling of nests and fledglings increases with stocking density for ground-nesting birds (Roseberry & Klimstra 1970; Hovick & Miller 2016).

The resulting effect of these threats is that of an ecological trap. The habitat is structurally suitable initially, however threats later emerge which reduce the reproductive output. In the case of hayfields, the effect is further augmented by subsequent loss of habitat when pairs attempt to re-nest. Since the hayfield has been harvested, it is one less available habitat patch on the landscape. In an area with many hayfields being harvested at the same time, this can cause an almost instant loss in habitat availability matched with an increase in demand.

S. magna was designated as Threatened under Ontario's Endangered Species Act in 2011. A couple of years later, Ontario's Ministry of Natural Resources published a joint Recovery Strategy for *S. magna* and *D. oryzivorus*; another grassland songbird facing similar threats and designated as Threatened a year prior to *S. magna*. The Recovery Strategy outlines a series of goals, objectives, and approaches to the recovery of these species (McCracken et al. 2013). It also lists recovery actions that had already been implemented or were currently being implemented when the Strategy was published. Two approaches that have been widely adopted in Ontario are 1) agricultural incentive programs, and 2) habitat restoration.

Agricultural incentive programs are an important management tool since active agricultural lands host the majority of Ontario's breeding *S. magna* population (McCracken et al. 2013). Both federal and provincial programs exist that provide farmers with a financial incentive to adapt their land management practices in order to safeguard grassland birds or to promote grassland habitat on their farms. The Habitat Stewardship Program for Species at Risk is one example – founded in 2000, this program offered by Environment and Climate Change Canada provides funding for

projects that work towards the recovery objectives of federally-listed Species at Risk (Environment and Climate Change Canada 2024). Another example is the Conservation Land Tax Incentive Program, which provides a tax rebate to landowners who have significant natural features on their property – including habitat for Species at Risk (Ontario Ministry of Natural Resources 2024). Another successful program outlined in the Recovery Strategy is the Alternative Land Use Services program. Alternative Land Use Services began in Norfolk County in 2005 as a direct land value compensation program for the conversion of marginal farmlands for wildlife habitat. Participating landowners are paid per acre, based on local market value, for non-productive farmland that they retire from production. The land can either be left to grow fallow, or additional compensation measures are available for restoration activities. The objective is for the retired land to become available to wildlife without a loss in revenue for farmers.

Incentive programs also exist that target the causes of direct mortality to grasslands birds – *i.e.*, hay harvesting and livestock trampling – rather than habitat management initiatives. Species at Risk Partnerships on Agricultural Lands is an umbrella initiative offered by Environment and Climate Change Canada and administered in Ontario by the Ontario Soil and Crop Improvement Association that offers a variety of specific programs that promote operational changes and Best Management Practices to conserve Species at Risk (Ontario Soil and Crop Improvement Association 2025c). The Forage Harvest Management program offers farmers \$40/acre for hayfields that are harvested July 15 or later (Ontario Soil and Crop Improvement Association 2025b). The Cross-Fencing for Rotational Grazing program reimburses farmers 50% of the cost of installing interior fences and water systems to create paddocks for rotational grazing (Ontario Soil and Crop Improvement Association 2025a). The intention is for some paddocks to be left ungrazed until July 15 or later to provide a refuge for ground-nesting grassland birds (Ontario Soil

and Crop Improvement Association 2025a). Similar to Alternative Land Use Services, the objective of these programs is to promote grassland bird habitat while mitigating financial losses to farmers.

A number of grassland restoration projects have been undertaken in southern Ontario in recent decades – albeit often with broad, ecosystem-wide objectives as opposed to species-specific habitat creation measures (McCracken et al. 2013). These projects are increasing the amount of non-agricultural grasslands on the landscape, which can provide more breeding sites for *S. magna* free from the hidden hazards of agricultural sites. The Recovery Strategy outlines Nature Conservancy of Canada as one of the key actors in this initiative, who had planned to restore 400 ha of grasslands in Ontario (McCracken et al. 2013).

Nature Conservancy of Canada has restored several former agricultural sites within the Norfolk sand plains region of Norfolk County since the early 1990s (L. Monck-Whipp, personal communication, November 10, 2021). Most of the Norfolk sites were restored using an assisted regeneration approach. With this approach, a site is restored to a reference ecosystem with minimal human actions or interventions (Gann et al. 2019; Atkinson & Bonser 2020). As described by Gann et al. (2019), the first step is to remove the disturbance or factor that is keeping the site in an unrestored state. Once this pressure is removed, minimal management actions will be done to help the site return to a state that resembles the target reference ecosystem (*e.g.*, seeding or planting, invasive species removal). The Norfolk Nature Conservancy of Canada sites have been restored to a tallgrass prairie ecosystem and are periodically managed with prescribed burning and invasive species removal to maintain the desired state (L. Monck-Whipp, personal communication, February 23, 2023).

Post-restoration monitoring must be conducted for the success of a restoration project to be properly evaluated. Gann et al. (2019) outline four stages of each restoration project:

- I. Planning and Design
- II. Implementation
- III. Monitoring, Documentation, Evaluation, and Reporting; and
- IV. Post-implementation Maintenance

After restoration activities are implemented, continued monitoring and evaluation of the desired outcomes can inform whether the system is on track to recovering towards the reference system, or if further actions need to be taken (Society for Ecological Restoration International 2004). It is these monitoring data that inform any maintenance activities that are needed to steer a system towards or to maintain the desired state. Rather than picturing a restoration project progressing through each stage in turn, a more effective framework could be a cyclical model. In a cyclical model, data from monitoring studies inform new actions that require planning, design, implementation, and evaluation (West 2016). Cyclical frameworks are referred to as ‘adaptive management’ systems (Holling et al. 1978).

The network of restored tallgrass prairie sites in southern Norfolk County provides a number of potential breeding sites for grassland birds like *S. magna*. These sites have not been formally evaluated for the presence of potential *S. magna* breeding habitat. These sites have also not been assessed as to whether they can be managed in a way to promote the establishment of an *S. magna* population if one is not already established.

Nature Conservancy of Canada’s restored sites provide a convenient study system for examining *S. magna* breeding habitat. This study addressed research question I) What are the

characteristics of successful nesting habitat for *S. magna*? I sought to answer this question by determining whether Nature Conservancy of Canada's restored tallgrass prairie sites in Norfolk County hosted breeding *S. magna* and, if applicable, determine the microhabitat characteristics of *S. magna* nesting sites. Examining the nesting sites and habitat use of breeding pairs on these sites can provide insight into the microhabitat features used by this species. This can provide valuable feedback for Nature Conservancy of Canada's restoration initiatives, as well as future *S. magna* habitat restoration projects.

For as long as standardized bird counts have existed in Ontario, Norfolk County has always had a relatively low *S. magna* population. Breeding Bird Survey data from a route near Port Dover (approximately 30 km from the restored Nature Conservancy of Canada sites) shows a declining *S. magna* population from 1968 – 2024 (Table 1). The Breeding Bird Survey data indicate that during the late 1960s and early 70s, about 24 – 30 individuals were detected during the survey each year. As the decades passed, those detections became fewer until only a handful of individuals were detected each year in the 2010s. The Atlas of the Breeding Birds of Ontario, 2001 – 2005 shows a similar trend. The Atlas estimates a relative abundance range of 0.01 – 1.69 within southern Norfolk County for *S. magna* (Leckie 2007; Figure 1). More recent data from eBird from 2012 – 2022 indicate that the *S. magna* population in Norfolk County during the breeding season can vary, ranging from 25 – 250 observations (Cornell Lab of Ornithology 2024). Data in all three datasets are primarily collected by citizen scientists, whose sampling effort can vary year-to-year due to external factors (*i.e.*, travel restrictions during the COVID-19 pandemic). Given these data, I hypothesized that *S. magna* may have been starting to breed on Nature Conservancy of Canada's restored tallgrass prairie sites, although in low numbers. I positioned my research as a first step at replication monitoring studies that will be needed to determine the paths to success of future *S.*

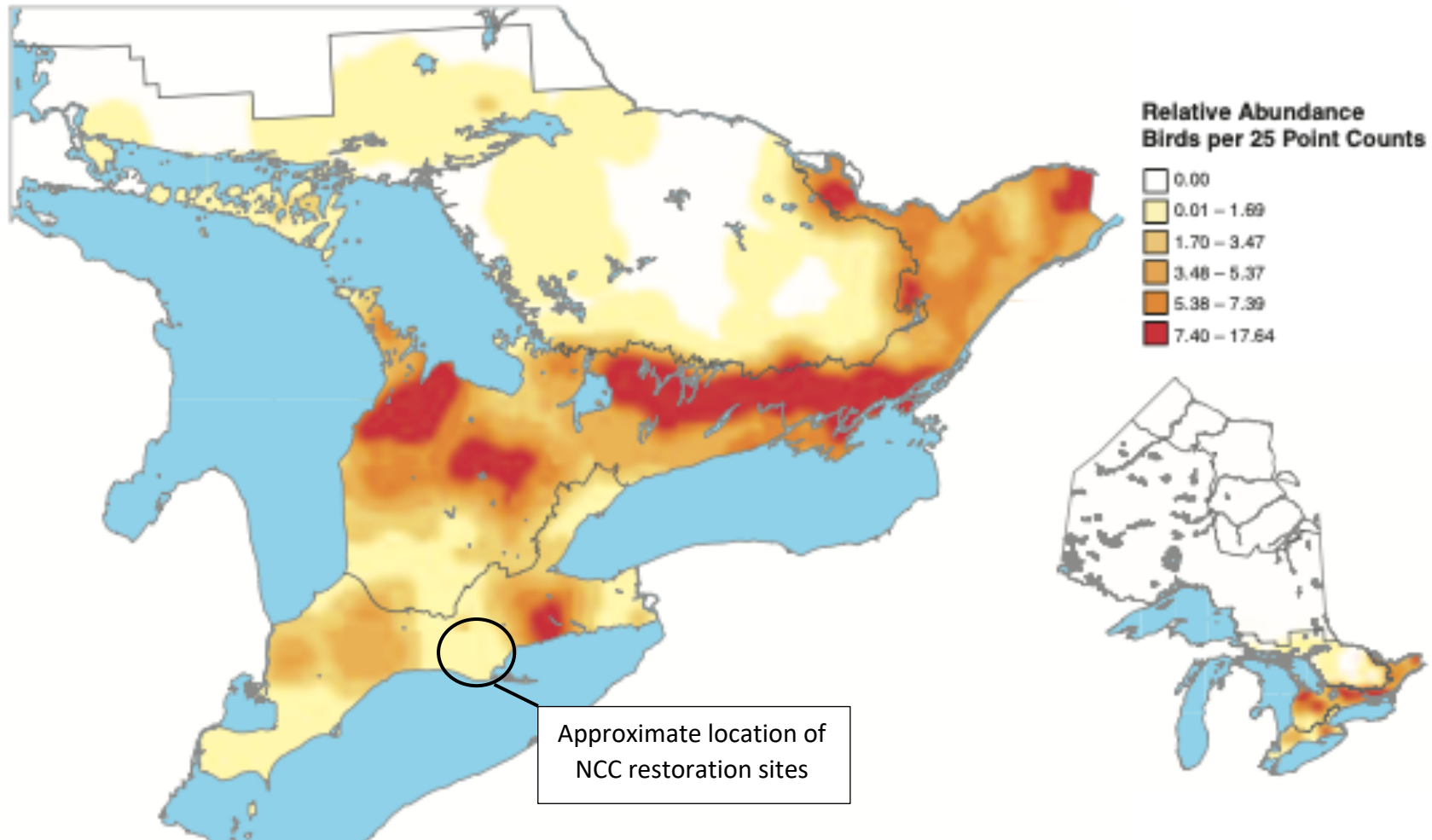
magna habitat restoration projects. Furthermore, this study acts as a framework and methodology for evaluating the establishment of an avian grassland specialist at a restored grassland.

Table 1. Number of Eastern Meadowlark (*Sturnella magna*, L.) individuals detected on the Breeding Bird Survey – Port Dover (68002) route from 1968 – 2024 (United States Geological Survey 2025). A dash indicates that no survey was conducted that year.

Year	Number of Individuals
1968	29
1969	28
1970	30
1971	24
1972	16
1973	23
1974	12
1975	13
1976	12
1977	6
1978	14
1979	16
1980	14
1981	3
1982	16
1983	10
1984	-
1985	1
1986	3
1987	6
1988	5
1989	6
1990	9
1991	-
1992	5
1993	-
1994	-

Year	Number of Individuals
1995	-
1996	6
1997	2
1998	-
1999	-
2000	-
2001	-
2002	-
2003	-
2004	-
2005	-
2006	2
2007	3
2008	4
2009	6
2010	2
2011	3
2012	3
2013	2
2014	1
2015	0
2016	0
2017	1
2018	2
2019	0
2020	-
2021	2
2022	2
2023	-
2024	-

Figure 1. Relative abundance per 25 point counts of Eastern Meadowlark (*Sturnella magna*, L.) in Ontario from 2001 – 2005, with the approximate location of Nature Conservancy of Canada's restored tallgrass prairie sites. Relative abundances were calculated from point count surveys conducted by volunteers. Point counts were 5 minutes in length, and birds were counted at an unlimited distance from the observer. Twenty-five point counts were conducted within each 10 x 10 km square in southern Ontario – this is the minimum effort per square to produce repeatable and precise relative abundance estimates. Relative abundance maps were created using an ordinary kriging method with unlimited distance nearest-neighbour approach. For further details, see Cadman et al. 2007. Figure adapted from Leckie 2007.



3.2 Methods

3.2.1 Study Sites

The study was conducted on Nature Conservancy of Canada sites in Norfolk County, Ontario. Each property contained at least one patch of restored tallgrass prairie community of a variety of sizes, ranging from 0.96 – 38.70 ha. Each unique patch ≥ 0.5 ha in size was considered a unique field site, as this is the recommended minimum size used in the Ecological Land Classification method for delineating vegetation communities in southern Ontario (Lee et al. 1998; Ontario Ministry of Natural Resources 2000).

Sites were removed from consideration if they were deemed to be likely unsuitable as *S. magna* habitat upon the first field visit, *i.e.*, dominated by shrubs or prescribed burned earlier that year. This resulted in 19 field sites to be considered. This decision was made based on generally accepted descriptions of *S. magna* breeding habitat (Committee on the Status of Endangered Wildlife in Canada 2011; McCracken et al. 2013), as well as documented trends of fewer *S. magna* observations at sites the year of a burn compared to pre- and post-burn years (Bock & Bock 1992; Robel et al. 1998; Powell 2006, 2008; Byers et al. 2017). No other restrictions on area were applied because of the uncertainty regarding minimum area requirements for *S. magna*. I recognized that this meant that I would likely overestimate the amount of suitable habitat for *S. magna*, but that casting a wide net would be able to capture as much data as possible to reveal any trends.

The time since restoration or burning varied among field sites (Table 2). The avian community at these sites consisted of other southwestern Ontario grassland specialists, such as Grasshopper Sparrow (*Ammodramus savannarum*, Gmelin), Barn Swallow (*Hirundo rustica*, L.), *D. oryzivorus*, Clay-colored Sparrow (*Spizella pallida*, Swainson), Eastern Kingbird (*Tyrannus*

tyrannus, L.), and Northern Bobwhite (*Colinus virginianus*, L.). *S. magna* and *D. oryzivorus* have very similar habitat requirements, enough for the two species to be issued a joint Recovery Strategy by the Ontario Ministry of Natural Resources (McCracken et al. 2013). The two species have been found breeding in the same fields in southern Ontario (McCracken et al. 2013; McCracken et al. 2014; Campomizzi & Lebrun-Southcott 2022). *A. savannarum*, *H. rustica*, *S. pallida*, and *T. tyrannus* are other grassland-nesting species found in southern Ontario. *C. virginianus* is a notable observation. It is an area-sensitive grassland specialist Species at Risk that has been the subject of recent re-introduction and conservation efforts in southern Ontario. The presence of these species on the study sites suggests that the restored sites are able to host the avifauna of a southern Ontario grassland community.

Table 2. Restoration and burning timeline for field sites. ‘Year Restored’ refers to the first growing season since initial restoration activities were completed. ‘Year Last Burned’ refers to the year which a prescribed burn last took place. ‘Time Since Disturbance’ is the difference between the study year (2022) and the year since the site was restored or last burned.

Site ID	Year Restored (L. Monck-Whipp, personal communication, November 10, 2021)	Year Last Burned (L. Monck-Whipp, personal communication, February 23, 2023)	Time Since Disturbance (years)
1	2010	-	12
2	2010	2020 – 2022	0 – 2
3	2009	2020 – 2022	0 – 2
4	2011	2020 – 2022	0 – 2
5	2011	-	11
6	2011	-	11
7	2011	-	11
8	2012	-	10
9	2012	-	10
10	2012	-	10
11	2012	-	10
12	2012	-	10
13	2012	-	10
14	2018	-	4
15	2013	-	9
16	2013	-	9
17	2019	-	3
18	2019	-	3
19	2019	-	3

3.2.2 Nest Searches

Nest searches were conducted with the approval of the University of Waterloo's Animal Care Committee (Application # 44018; Appendix C). Nest searches were conducted from May 17 – August 2, 2022, on days with no precipitation and a Beaufort wind scale level ≤ 3 , within daylight hours. These dates were modeled after the 'safe breeding dates' used by the Ontario Breeding Bird Atlas for this species in southern Ontario (*i.e.*, May 15 – July 31; Ontario Breeding Bird Atlas 2021).

Each field site was searched regularly throughout the field season for the presence of *S. magna* nests. Nest searches were conducted by walking transects along the perimeter of the field sites while watching for behavioural cues from adult *S. magna* that may indicate the presence of a nest (*i.e.*, carrying nesting material, food). These observations were intended to help estimate the approximate location of a breeding pair's territory and the likely nesting stage.

No *S. magna* individuals were observed during the study on any of the field sites. As a result, in-depth nest searches, monitoring, and nest site vegetation sampling were not needed.

Incidental searches were conducted simultaneously with vegetation sampling of field sites. The researcher made note of any *S. magna* observed and behavioural cues that may indicate the presence of a nest.

3.2.3 Vegetation Sampling

Five 1 m circular plots were placed within each field site, spaced to ensure even coverage throughout each site. Each plot was surveyed twice within the field season. *S. magna* typically rears two broods each breeding season (Jaster et al. 2022) and incubation typically lasts 13 – 14 days (Saunders 1932). The period where most nests contain hatchlings is between late May – early

August (Jaster et al. 2022). This hatchling period was divided into two plot survey periods (June 8 – 28 and July 4 – August 2) to approximate vegetation characteristics of potential first and second broods, respectively. These broods will hereafter be referred to as the first and second nest attempt, respectively.

The following microhabitat characteristics were measured at each plot:

- Percent litter cover
- Litter depth (cm)
- Visual obstruction (*sensu* Robel et al. 1970), measured from each cardinal direction
- Percent bare ground
- Percent grass cover
- Percent forb cover
- Percent woody vegetation cover

A list of the vegetation species and their relative abundances was collected at each plot following the Ecological Land Classification method (Lee et al. 1998), however these data were not used in any analyses.

3.2.4 Analysis

Seven field site plots were excluded from analysis due to incomplete data due to human error, or site inaccessibility due to recent herbicide application or the presence of ground-nesting wasps. Additionally, one vegetation species each from a plot in round 1 and a plot in round 2 were excluded from analysis due to incomplete data. All analyses were completed in R Statistical Software (v4.1.2, R Core Team 2021). See Table B2 (Appendix B) for a complete list of the packages used during analysis.

Percent bare ground and percent litter cover were found to be direct inverses of each other, so percent bare ground was removed from analysis to avoid unnecessary correlation among variables, and to avoid having too many variables for the sample size (Babyak 2004). Similarly, the visual obstruction measurements were averaged to reduce unnecessary correlation among variables. This averaged value will hereafter be referred to as ‘visual obstruction’.

The differences between vegetation characteristics at each plot between the first and second nest attempt were tested for normality using the Shapiro-Wilk test (Shapiro & Wilk 1965) and equal variances using Levene’s test (Levene 1960) in the *car* package (v3.0-12, Fox & Weisberg 2019).

The distribution of differences of percent grass cover was normally-distributed and with equal variance. Therefore, percent grass cover was tested for differences using the paired t-test (Student 1908; Lord 1956).

The distributions of differences of percent litter cover, percent forb cover, percent wood cover, litter depth, and visual obstruction were non-parametric. The distribution of these characteristics were tested with the Wilcoxon matched-pairs test (Wilcoxon 1945). Those with equal variances (*i.e.*, percent litter cover, percent wood cover, and percent forb cover) were tested for differences in medians, while those with unequal variances (*i.e.*, litter depth and visual obstruction) were tested for differences in overall distribution. The Hodges-Lehmann estimate (*i.e.*, pseudo-median returned by `wilcox.test` in R) was used to compare the magnitude of the differences between nest attempts (Hodges & Lehmann 1963). The Bonferroni correction was applied to the resulting p-values to correct for multiple comparisons (Bonferroni 1936).

Vegetation characteristics were tested for normality using the Shapiro-Wilk test (Shapiro & Wilk 1965) and for unequal variances using Levene's test (Levene 1960). All characteristics had a non-parametric distribution, so the Kruskal-Wallis test (Kruskal & Wallis 1952) was used to test for differences among sites. The values for characteristics that did not differ significantly between nest attempts (*i.e.*, all except visual obstruction) were aggregated. Visual obstruction was analyzed separately for each nest attempt. Those characteristics with equal variances (*i.e.*, percent grass cover and visual obstruction) were tested for differences in medians, while those with unequal variances (*i.e.*, percent litter cover, percent wood cover, percent forb cover, and litter depth) were tested for differences in overall distribution. The Hodges-Lehmann estimate was used to compare the magnitude of differences between nest attempts (Hodges & Lehmann 1963).

The time since disturbance (*i.e.*, restoration or prescribed burning) at each site was hypothesized to have an effect on vegetation characteristics. The values for characteristics that did not differ significantly between nest attempts (*i.e.*, all except visual obstruction) were aggregated. Visual obstruction was analyzed separately for each nest attempt. Sites which were burned between 2020 – 2022 were assigned a 'Time Since Disturbance' value of 1.5 years. This value is an estimation of the average time since disturbance, given the assumption that evidence of burning in the year of the study (2022, *i.e.*, 0 years since disturbance) would have been apparent to the researchers. One site showed signs of a burn in 2022 and was therefore excluded from the study prior to data collection.

Each vegetation characteristic was plotted against the time since disturbance of the site. A set of five polynomial regression models (degrees 1 – 5) were fit to the data. The R^2 values were compared to determine the model with the best fit (*i.e.*, R^2 value closest to 1). The model with the best fit was evaluated visually to determine whether it was monotonic or not.

Those variables with monotonic distributions (*i.e.*, percent litter cover and visual obstruction) were tested for the effect of time since disturbance at each site (Table 2) using the Spearman rank correlation (Spearman 1904).

Those variables with a non-monotonic distribution (*i.e.*, percent grass cover, percent wood cover, percent forb cover, and litter depth) were tested for the effect of time since disturbance (Table 2) using the distance correlation test (Székely et al. 2007) using the *energy* package (v1.7-11, Rizzo & Székely 2022).

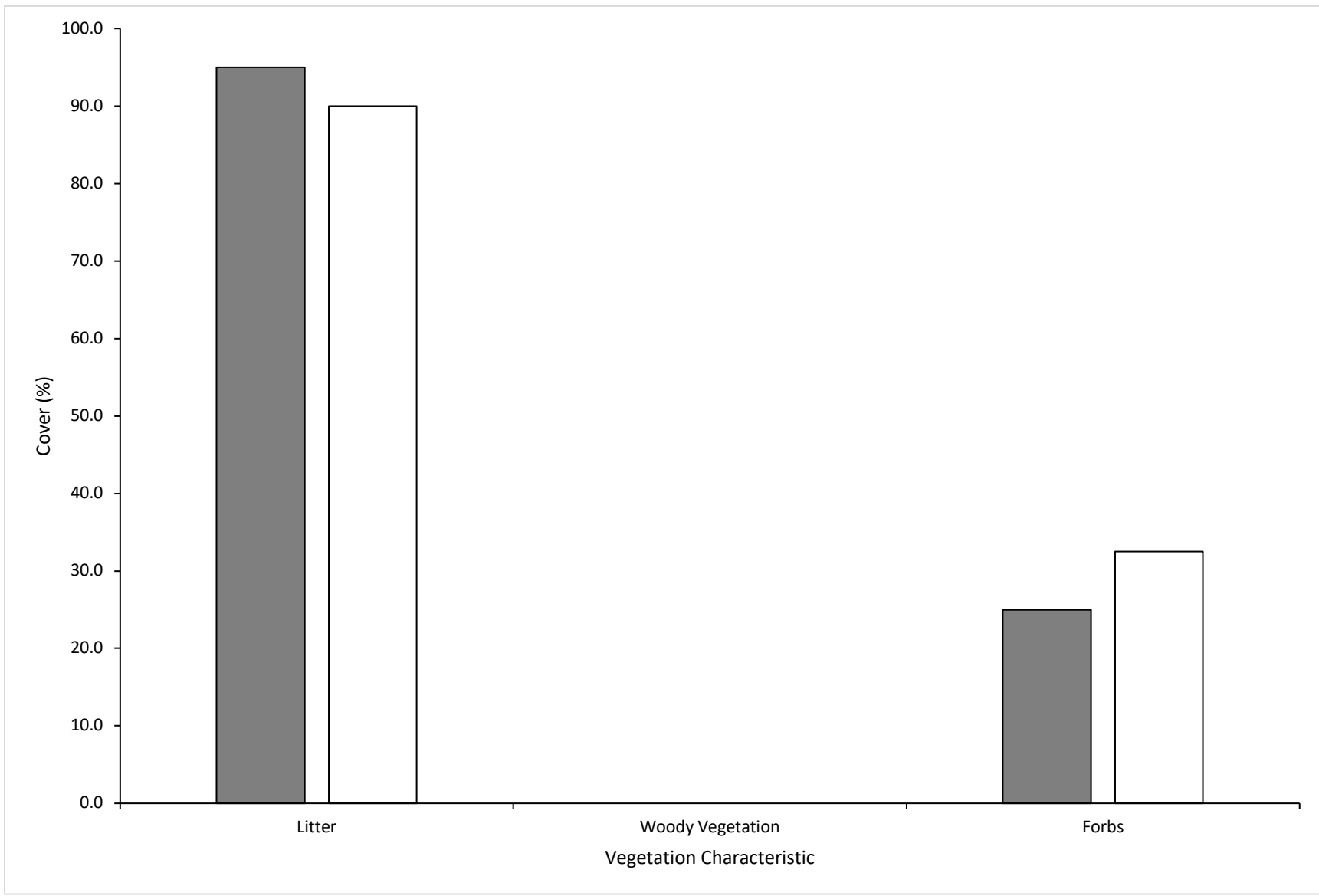
3.3 Results

3.3.1 Vegetation Characteristics Differences Between Nest Attempts

Visual obstruction was the only vegetation characteristic that differed significantly between nest attempts. There was no significant difference in median percent cover between nest attempts for litter ($p = 0.19$), woody vegetation ($p = 1.00$), or forbs ($p = 1.00$; Figure 2). Similarly, mean percent cover of grass ($p = 1.00$) did not differ between nest attempts (Figure 3). The distribution of litter depth also did not differ significantly between nest attempts ($p = 1.00$; Figure 4).

The distribution of visual obstruction is shown in Figure 5, which differed significantly between nest attempts ($p < 0.05$).

Figure 2. Median percent cover of litter ($p = 0.19$), woody vegetation ($p = 1.00$), and forbs ($p = 1.00$) by nest attempt (grey: first nest attempt, white: second nest attempt).



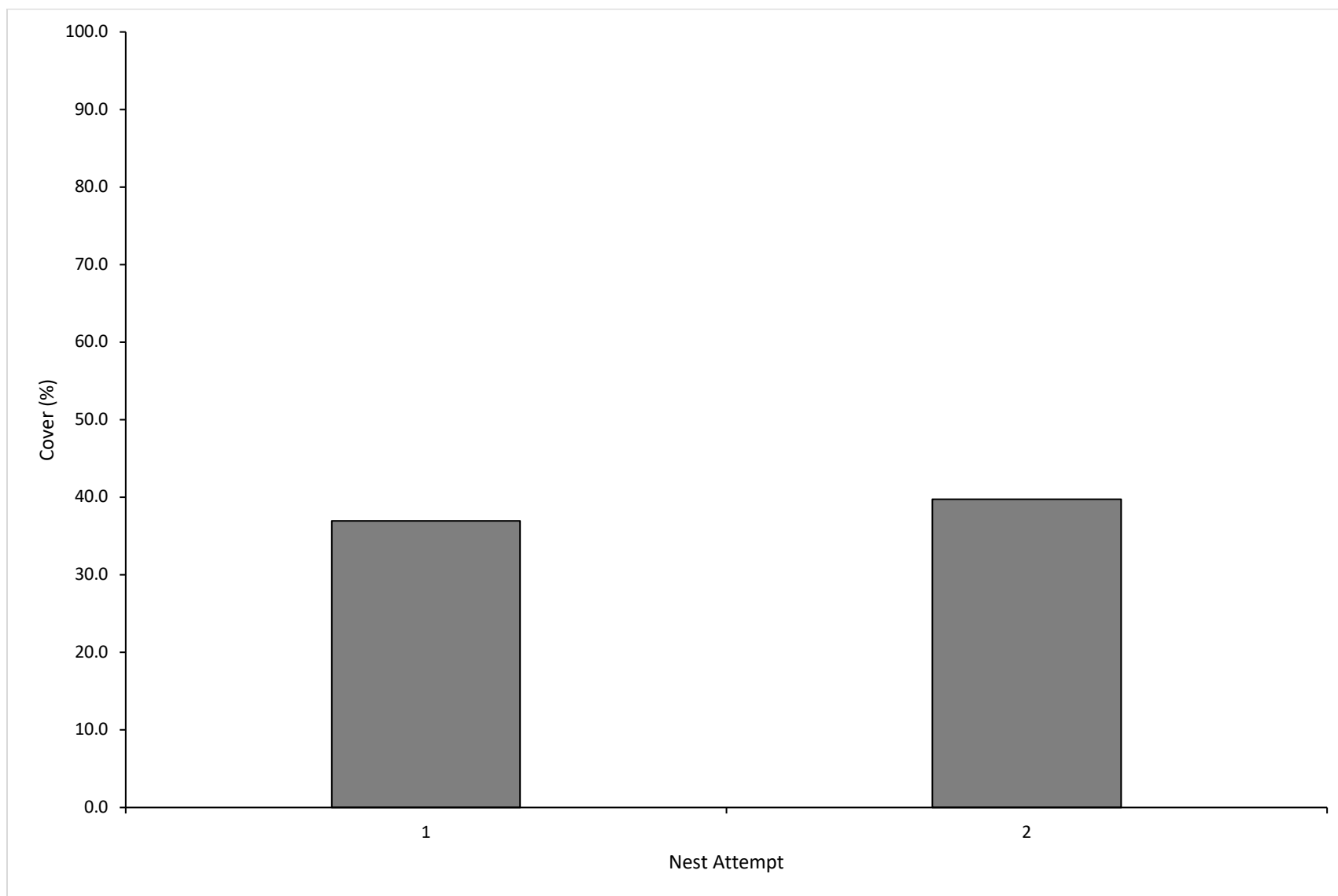


Figure 3. Mean percent grass cover by nest attempt ($p = 1.00$).

Figure 4. Distribution of litter depth during the first (A) and second (B) nest attempts ($p = 1.00$).

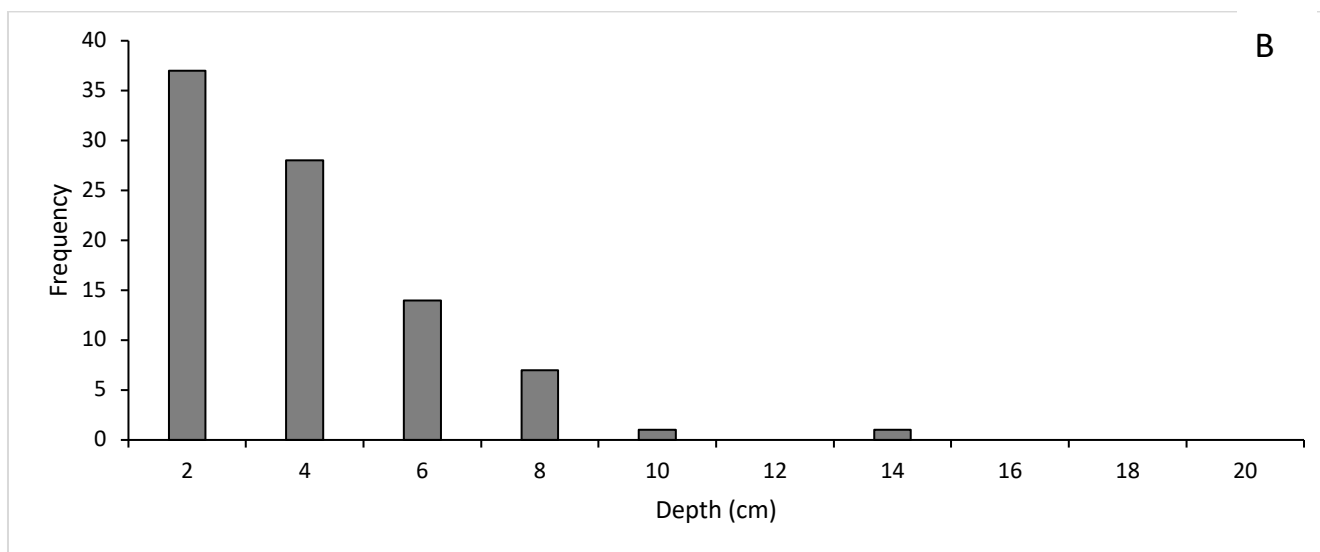
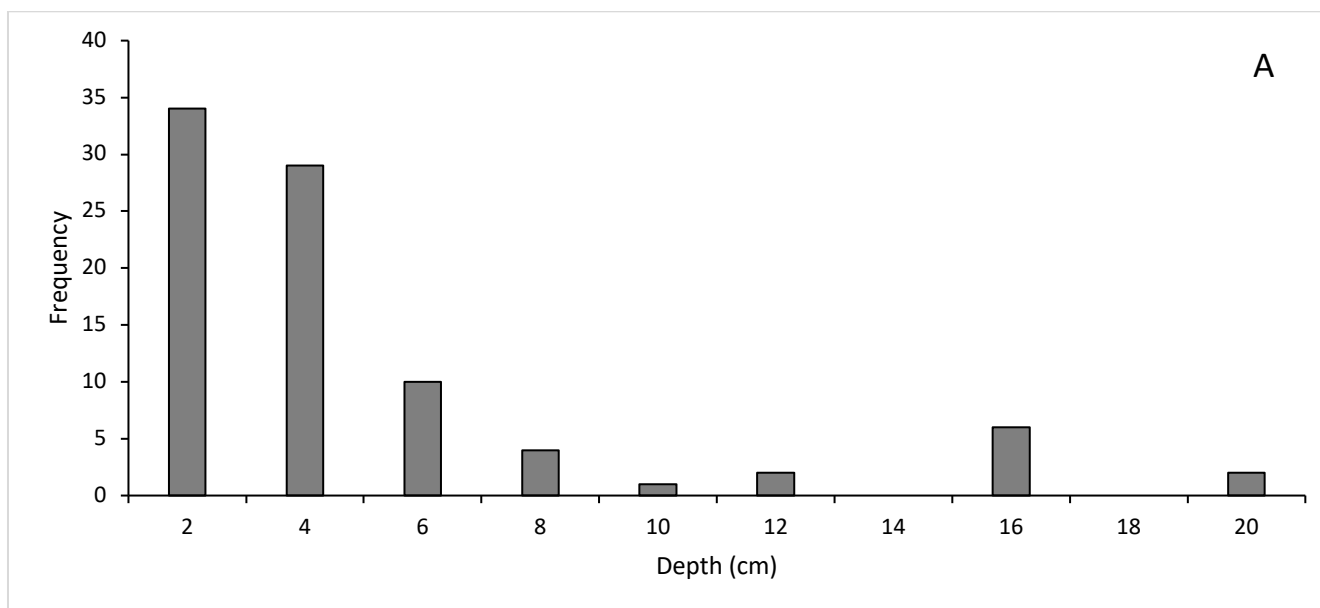
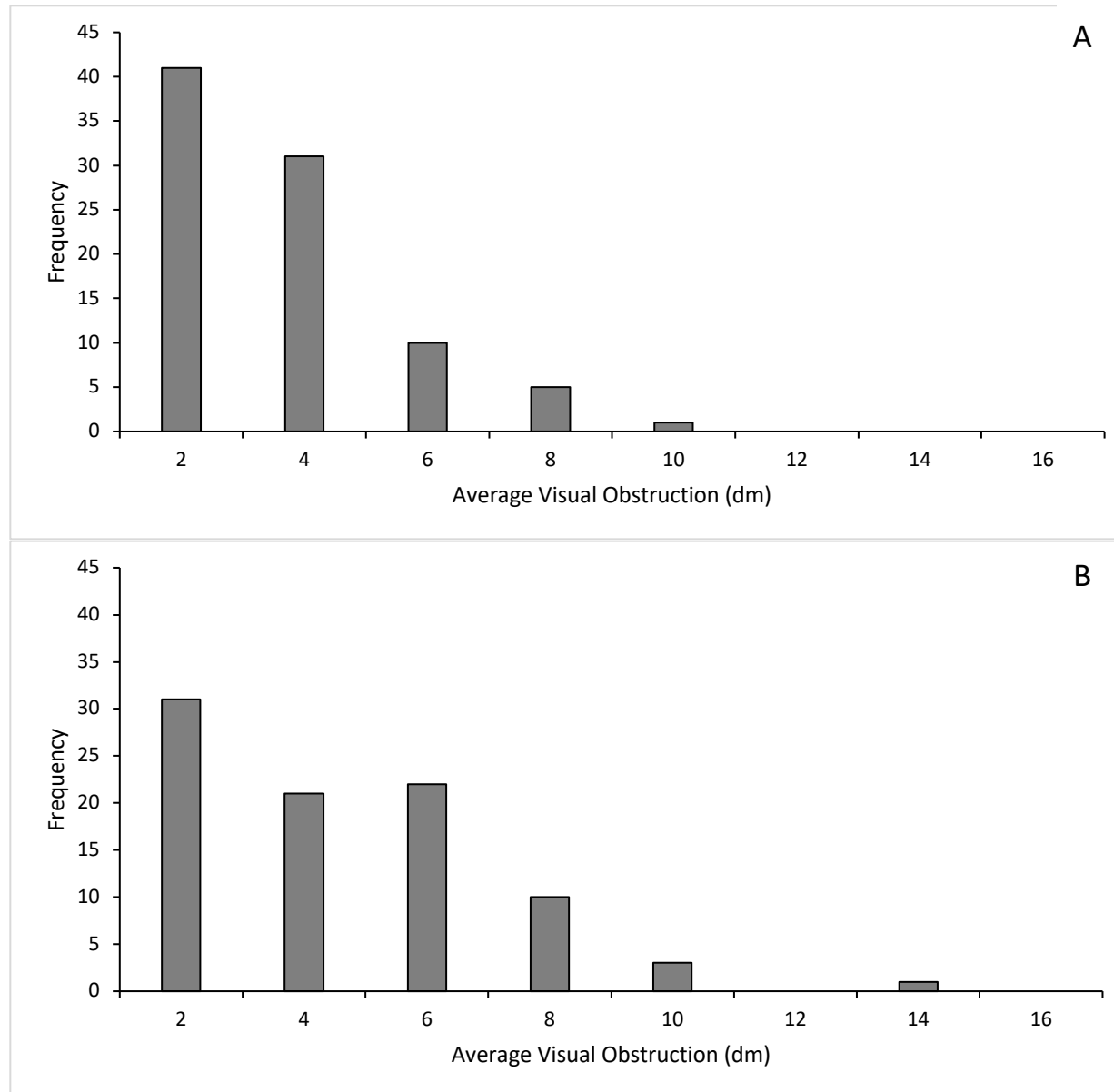


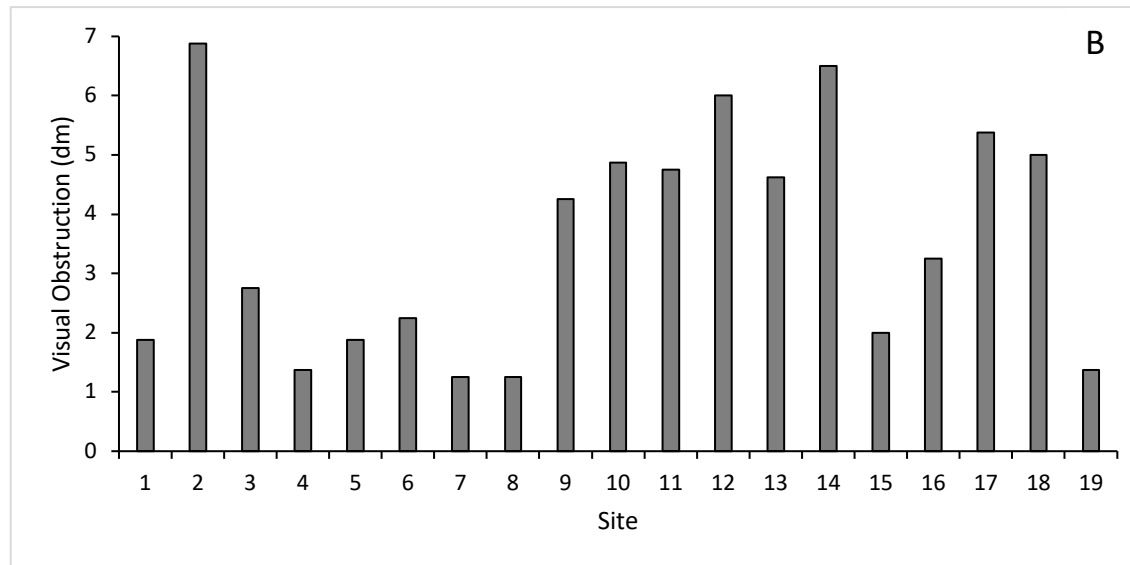
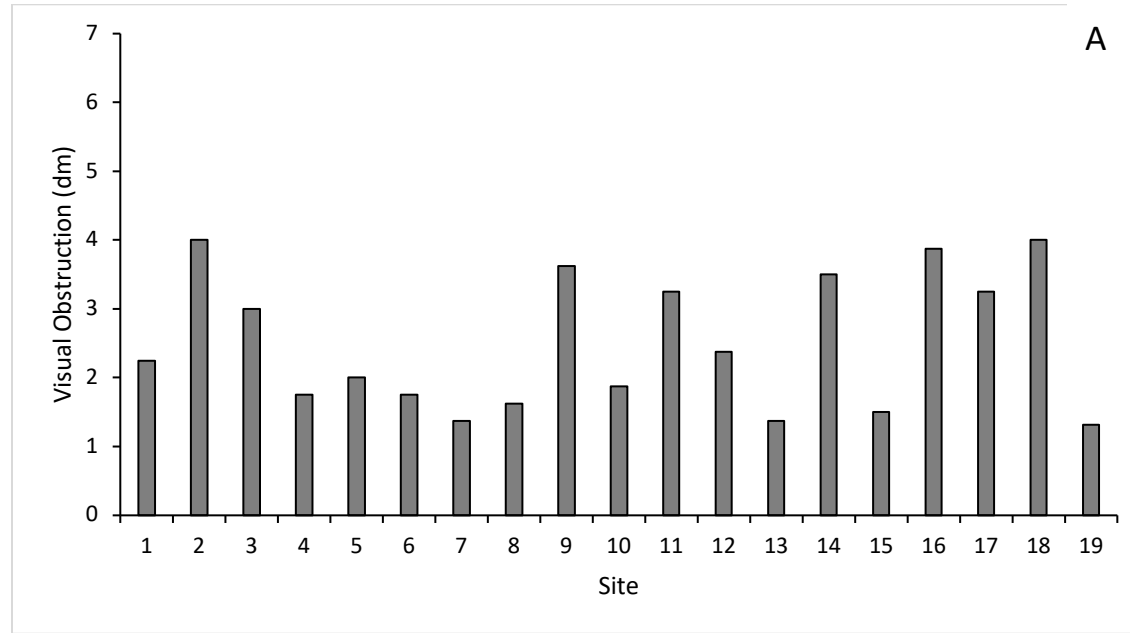
Figure 5. Distribution of visual obstruction during the first (A) and second (B) nest attempts ($p < 0.05$).



3.3.2 Vegetation Characteristics Differences Between Sites

All vegetation characteristics differed between sites (Figures A2 – A6, Appendix A). Visual obstruction differed significantly between sites for both nest attempts ($p < 0.05$). Median visual obstruction ranged between 1.3 dm and 4.0 dm during the first nest attempt, and 1.3 dm and 6.9 dm during the second (Figure 6).

Figure 6. Median visual obstruction at each site during the first (A) and second (B) nest attempts ($p < 0.05$).



3.3.3. Disturbance Effect of Vegetation Characteristics

Most of the vegetation characteristics show a correlation with cycle year, with the exception of percent woody vegetation cover ($dCor = -0.00038$, $p = 0.52$). Grass cover, forb cover, and litter depth have non-linear correlations with cycle year (grass cover: $dCor = 0.032$, $p < 0.05$, Figure 7; forb cover: $dCor = 0.022$, $p < 0.05$, Figure 8; litter depth: $dCor = 0.074$, $p < 0.05$; Figure 9).

Visual obstruction has a negative linear correlation with cycle year for the first nest attempt ($\rho = -0.29$, $p < 0.05$; Figure 10) but no correlation for the second nest attempt ($\rho = -0.20$, $p = 0.06$; Figure 11).

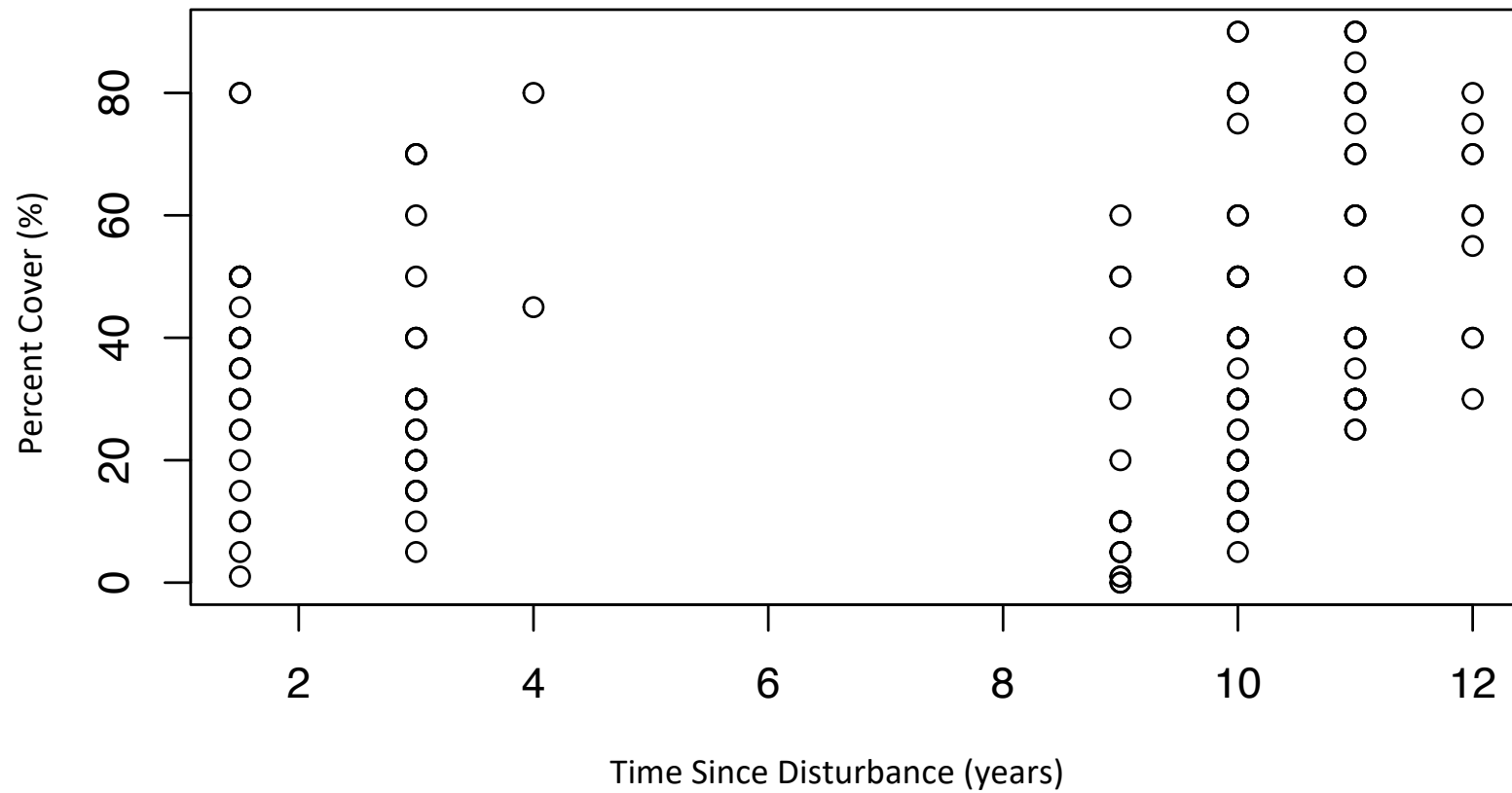


Figure 7. Percent grass cover and time since disturbance (years) of the study site. $dCor = 0.032$ $p < 0.05$. Adjusted $R^2 = 0.20$.

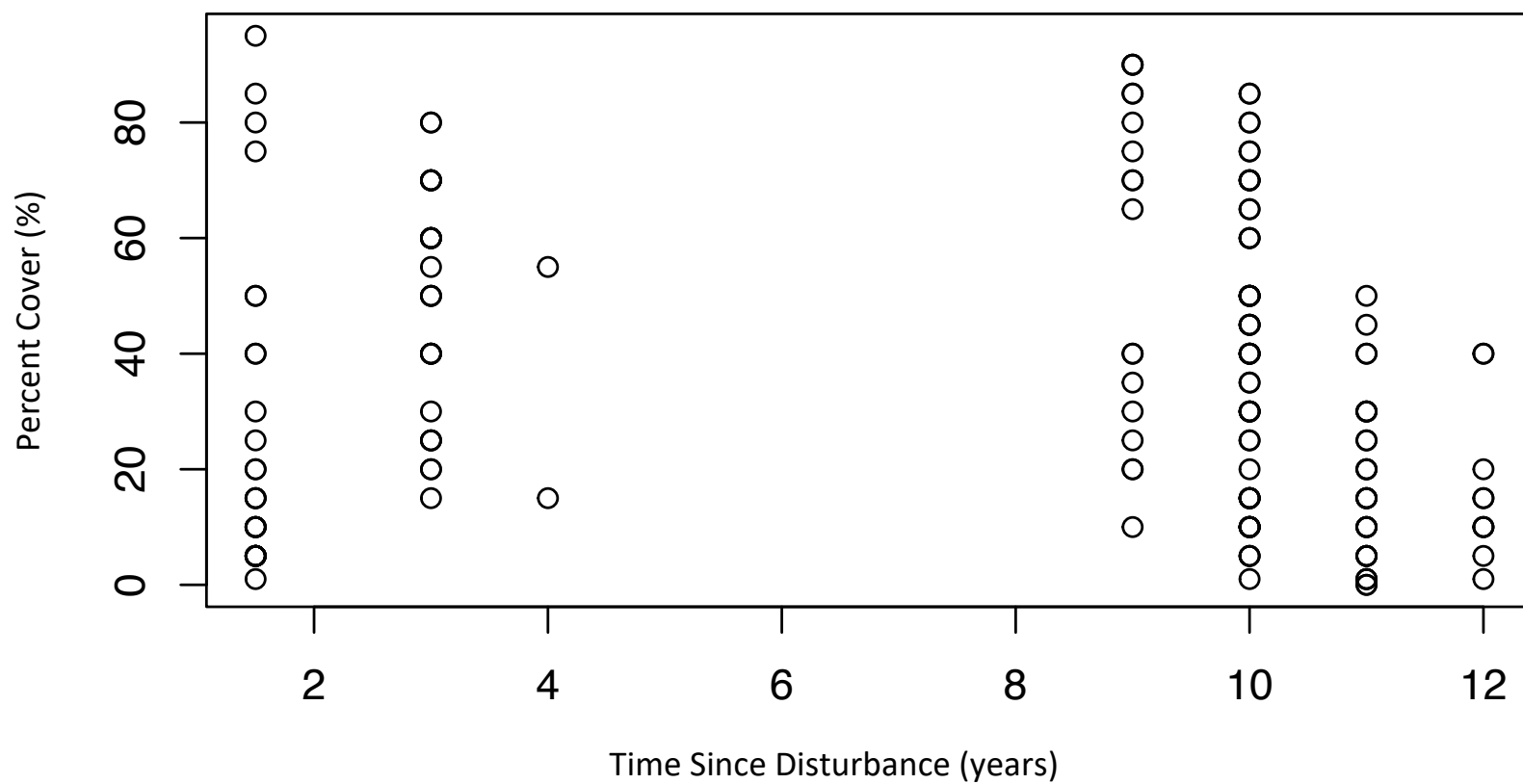


Figure 8. Percent forb cover and time since disturbance (years) of the study site. $dCor = 0.022$, $p < 0.05$. Adjusted $R^2 = 0.24$.

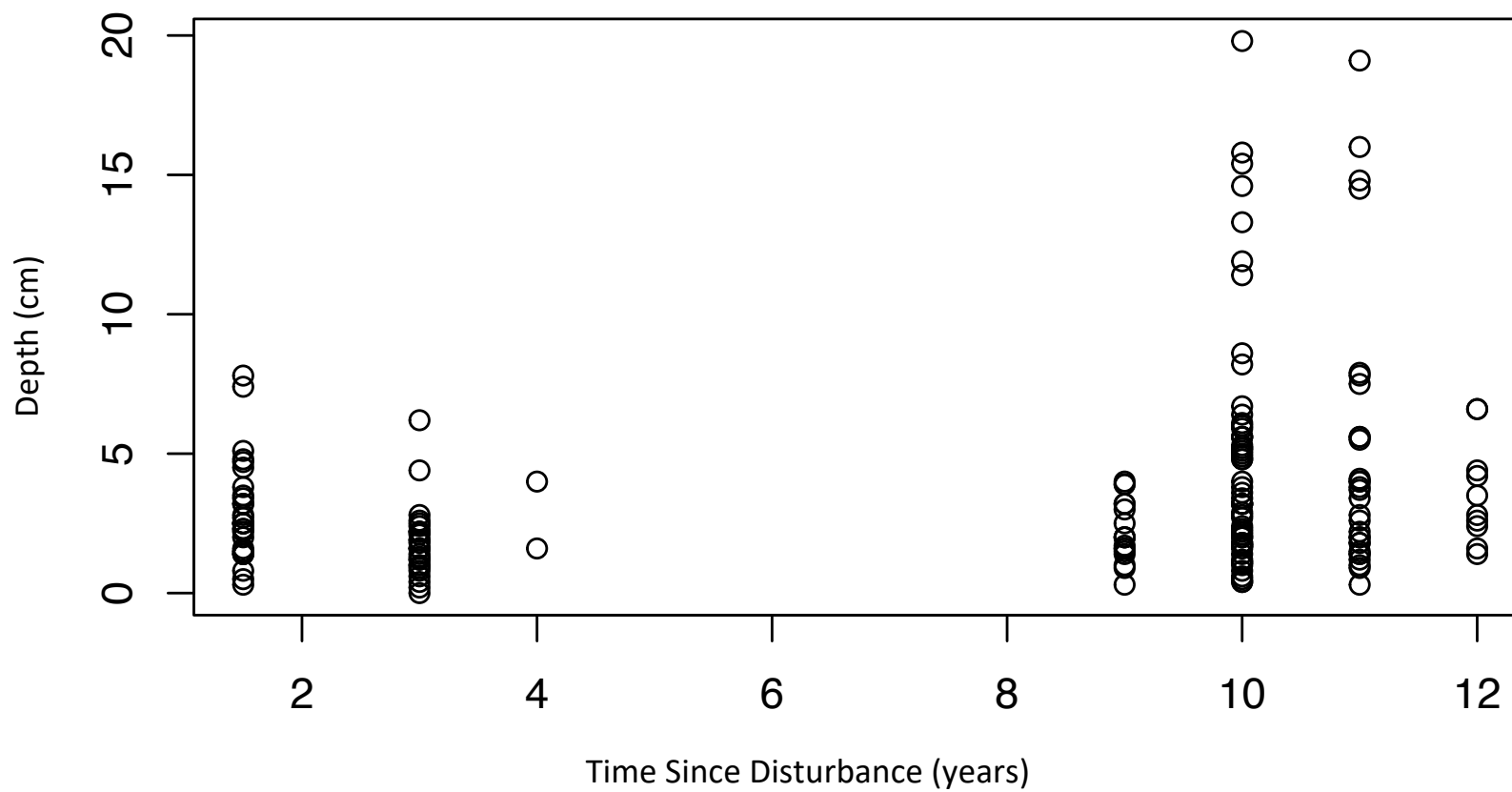
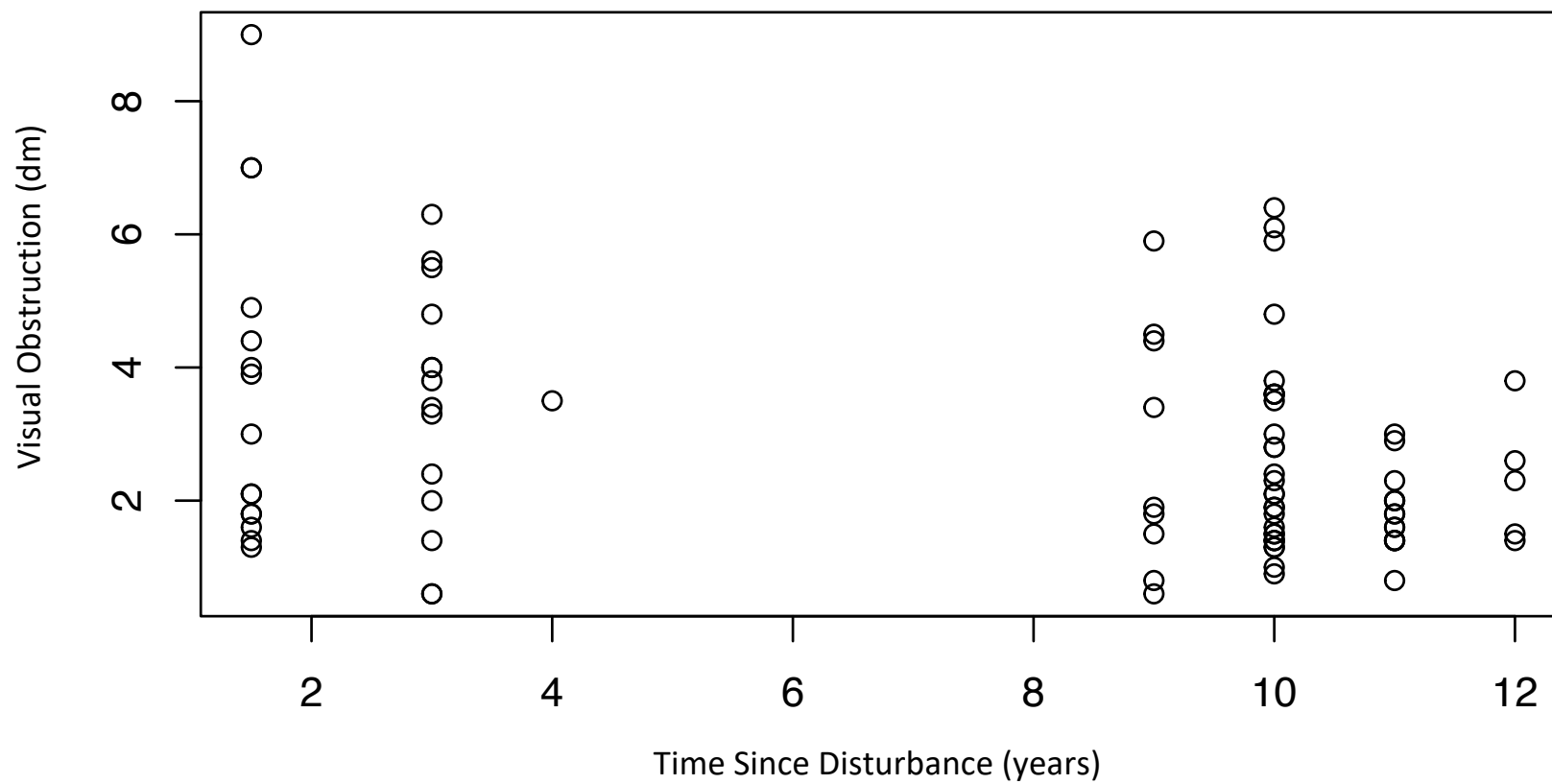


Figure 9. Litter depth (cm) and time since disturbance (years) of the study site. $dCor = 0.074$, $p < 0.05$. Adjusted $R^2 = 0.096$.

Figure 10. Visual obstruction and time since disturbance (years) at the study site during the first nest attempt. $\rho = -0.29$, $p < 0.05$.

Adjusted $R^2 = 0.097$.



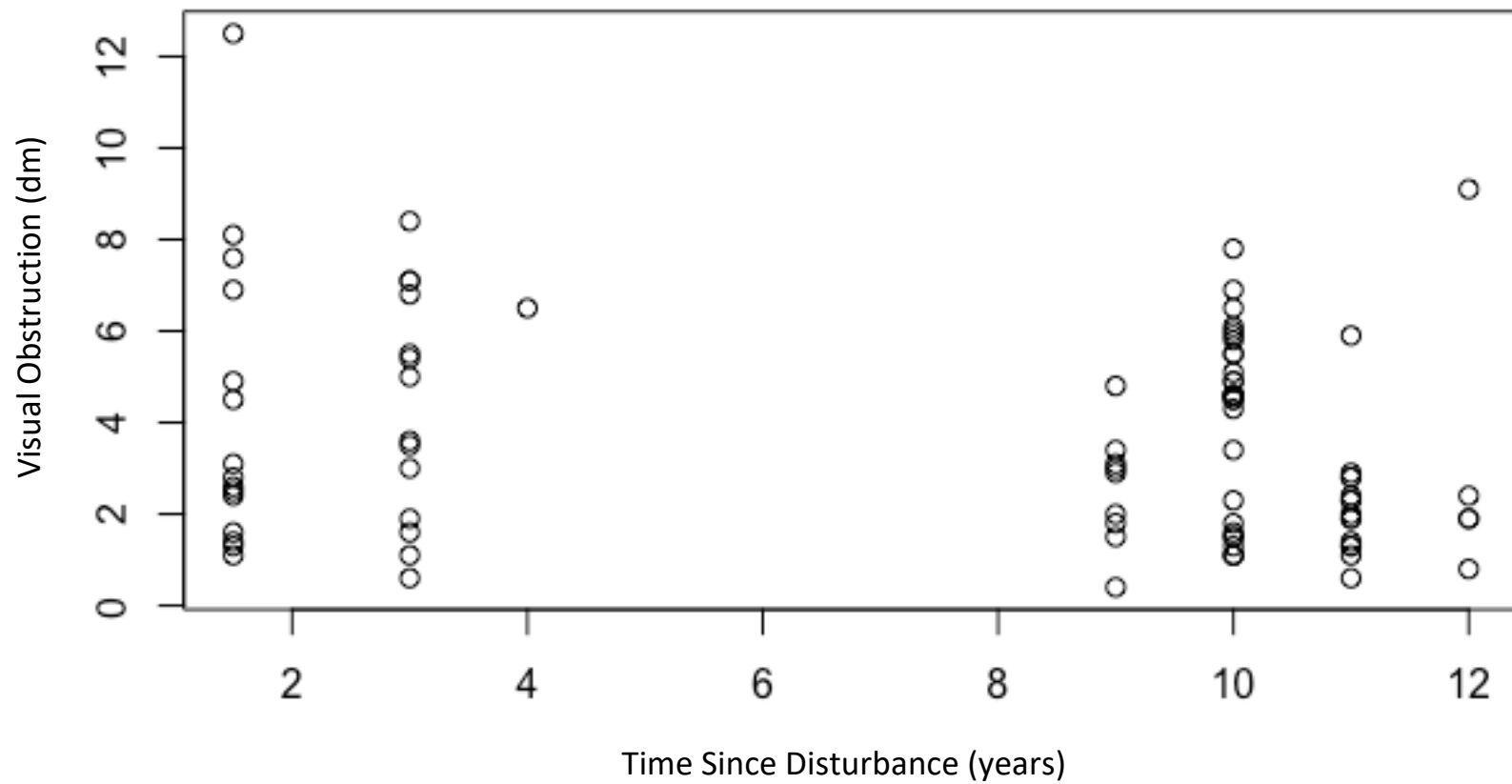


Figure 11. Visual obstruction and time since disturbance (years) at the study site during the second nest attempt. $\rho = -0.20$, $p = 0.06$.

3.4 Discussion

This study addressed research question I) What are the characteristics of successful nesting habitat for *S. magna*? I sought to answer this question by determining whether Nature Conservancy of Canada's restored tallgrass prairie sites in Norfolk County hosted breeding *S. magna* and, if applicable, determine the microhabitat characteristics of *S. magna* nesting sites. I hypothesized that *S. magna* may have been starting to breed on Nature Conservancy of Canada's restored tallgrass prairie sites, although in low numbers.

Nineteen restored tallgrass prairie sites in Norfolk County, Ontario were searched extensively for the presence of *S. magna* during the breeding season. No *S. magna* individuals were observed at any of the sites during the study period, leading to the conclusion that these sites did not host breeding *S. magna* populations in 2022. As a result, data on nest fate and microhabitat characteristics were not collected. Vegetation data were collected at randomized plots within each site.

Despite the unsurprising lack of *S. magna* on the study sites, the second objective can still be addressed by comparing the site features to the literature. I tested for differences in vegetation characteristics between sites to assess whether certain sites would have been more suitable habitat than others. Sites were found to differ significantly from each other for each vegetation characteristic. However, the level of significance is believed to be an artefact of the dataset since the sites do not appear to differ substantially once the data is plotted. The sites therefore have relatively homogenous microhabitat features and are therefore suitable to be compared as a group to habitat descriptions in the literature.

The median litter cover at my study sites was relatively high at 95% (Figure A2, Appendix A). Litter cover has been found to positively influence *S. magna* nest density (Byers et al. 2017) and adult abundance (Coppedge et al. 2008). Byers et al. (2017) examined *S. magna* nest density in response to prescribed burning in restored agricultural grasslands in Iowa and Wisconsin. Nest density and litter cover were the lowest the year of the burn, and increased in the following three years (Byers et al. 2017). Litter cover and year since burning were the two variables in the highest performing model predicting *S. magna* nest density, both with positive coefficients (Byers et al. 2017). Coppedge et al. (2008) examined the effect of patch-burn grazing on grassland bird abundance on a tallgrass prairie reserve in Oklahoma. Percent litter cover was positively represented in the top model predicting *S. magna* abundance at the sites (Coppedge et al. 2008). Similarly, Kershner and Bollinger (1996) found that *S. magna* nest sites at Illinois airports had no bare ground, compared to an average of 4.2% bare ground at control sites. This implies that in some cases, litter coverage as high as 100% may be suitable for *S. magna*. Conversely, Rotenberry and Weins (1980) found a negative relationship between *S. magna* abundance and the amount of bare cover in grasslands across central and western North America.

The median litter depth in my study was 2.8 cm (Figure A6, Appendix A). Warren and Anderson (2005) found that mean litter depth was greater at *S. magna* nest sites (4.45 cm) than control sites (1.00 cm; $F = 6.37$, $P = 0.021$). Byers et al. (2017) examined daily survival rate of *S. magna* nests in Wisconsin and found that the top performing model for predicting *S. magna* daily survival rate included positive litter depth with negative distance to field edge. This suggests that daily survival rate may be higher in areas with greater litter depth, depending on the distance from the field edge (Byers et al. 2017). Distance from the field edge was not something measured in my study, which may have an influence on *S. magna* habitat suitability. Similarly, Rotenberry and

Weins (1980) found a positive relationship between *S. magna* abundance and litter depth. Conversely, Delisle and Savidge (1997) observed the abundance of meadowlarks (*Sturnella* spp.) in Nebraska to be negatively correlated with litter depth. However, abundance data was pooled for observations of both *S. magna* and Western Meadowlark (*Sturnella neglecta*, Audubon).

The mean percent grass cover in my study was 38% (Figure A3, Appendix A). McCracken et al. 2014 found that *S. magna* in Norfolk County were observed at sites with an average of about 45 – 80% grass cover. Similarly, Wiens (1969)'s study in Wisconsin found that mean percent grass cover was 96% in *S. magna* territories and 98% at nest sites. These data imply that the average grass cover at my sites may have been too low to provide optimal habitat for *S. magna*. This trend is reflected in Coppedge et al. (2008), whose model for *S. magna* abundance in Oklahoma also included positive terms for percent tallgrass and percent shortgrass cover. Similarly, Vickery, Hunter, and Melvin (1994) found that *S. magna* abundance in Maine was positively correlated with graminoid cover.

The median forb cover in my study was 30% (Figure A5, Appendix A). Wiens (1969) found mean percent forb cover to be 30% in *S. magna* territories and 11% at nests. This implies that *S. magna* may be assessing forb cover at two different spatial scales: the territorial level and the nest site level. Optimal *S. magna* habitat may be fields that have a certain overall percent cover with a patchy distribution, resulting in areas with lower percent forb cover for nest sites.

Other studies have found total cover, rather than just one structural type, to have an effect on *S. magna*. In Missouri, a combined percent grass and forb cover of 20 – 40% was found to be optimal for *S. magna* (Skinner et al. 1984 in Askins et al. 2007). A similar effect was observed by Bollinger (1995), whose models indicated a negative relationship between *S. magna* density in hayfields in New York with percent total cover. While individual mean and median percent cover

of grass and forbs at my sites appear to fit within the optimal range, when combined the total percent cover may have been too high to provide suitable *S. magna* habitat.

Shrub distribution at my sites was patchy and non-uniform within a site. The median percent wood cover in my sites is 0% (Figure A4, Appendix A). The relatively small size of my vegetation plots (1 m diameter) may have been at too fine of a scale to accurately represent shrub abundance at a site. Adult abundance during the summer has been shown to be positively correlated with shrub cover in Arizona (Bock & Bock 1992). Further investigations at a coarser scale would have to be done to confirm the percent shrub cover at my sites in order to be able to compare to the literature. Structural differences such as shrub height may have an impact on species distributions. Vickery, Hunter, and Melvin (1994) found that *S. magna* abundance was positively correlated with the amount of low shrubs, but negatively correlated with the amount of high shrubs. Grouping all shrubs together may obscure structural differences that may influence *S. magna* distribution.

Visual obstruction has been measured different ways in the literature. Some studies have used measures similar to those described in Robel et al. (1970), like vertical patchiness (Bollinger 1995) or angle of obstruction (Coppedge et al. 2008). Even studies that measure visual obstruction *sensu* Robel et al. (1970) vary in the observation height and distance from the pole. For that reason, it is difficult to form any direct comparisons between the results of other studies and my own (*sensu* Robel et al. 1970, measured at the height and distance recommended therein). Bollinger (1995) found that *S. magna* abundance was negatively correlated with vertical patchiness, which is the coefficient of variation of vegetation height when a Robel pole was visually obstructed. In other words, *S. magna* abundance was lower in areas with greater variation in visual obstruction (Bollinger 1995). Similarly, Coppedge et al. (2008) found that *S. magna* abundance was negatively correlated with the angle of obstruction, which is “an index of visual obscurity that is a function

of vegetation density and horizontal and vertical structure” (1198). Further investigations would have to be done using multiple different visual obstruction techniques in order to compare to the literature.

A review of *S. magna* habitat from the literature suggests that while some microhabitat features may have been within the suitable range, there is some ambiguity as to the suitability of others. Furthermore, the majority of research on *S. magna* breeding habitat has been done in the United States. As a result, comparisons between the literature and the study sites may not be overly informative.

A more likely reason for the lack of *S. magna* may be the effect of time. Restoration efforts can be slow – it can take years to observe the desired effect. These study sites were restored at various times between 2009 – 2019. The process of transitioning from a pre-restoration community to a tallgrass prairie community is still in its early stages, especially for the more recently restored sites. *S. magna* may come to occupy these sites as time progresses if they succeed to a more suitable state.

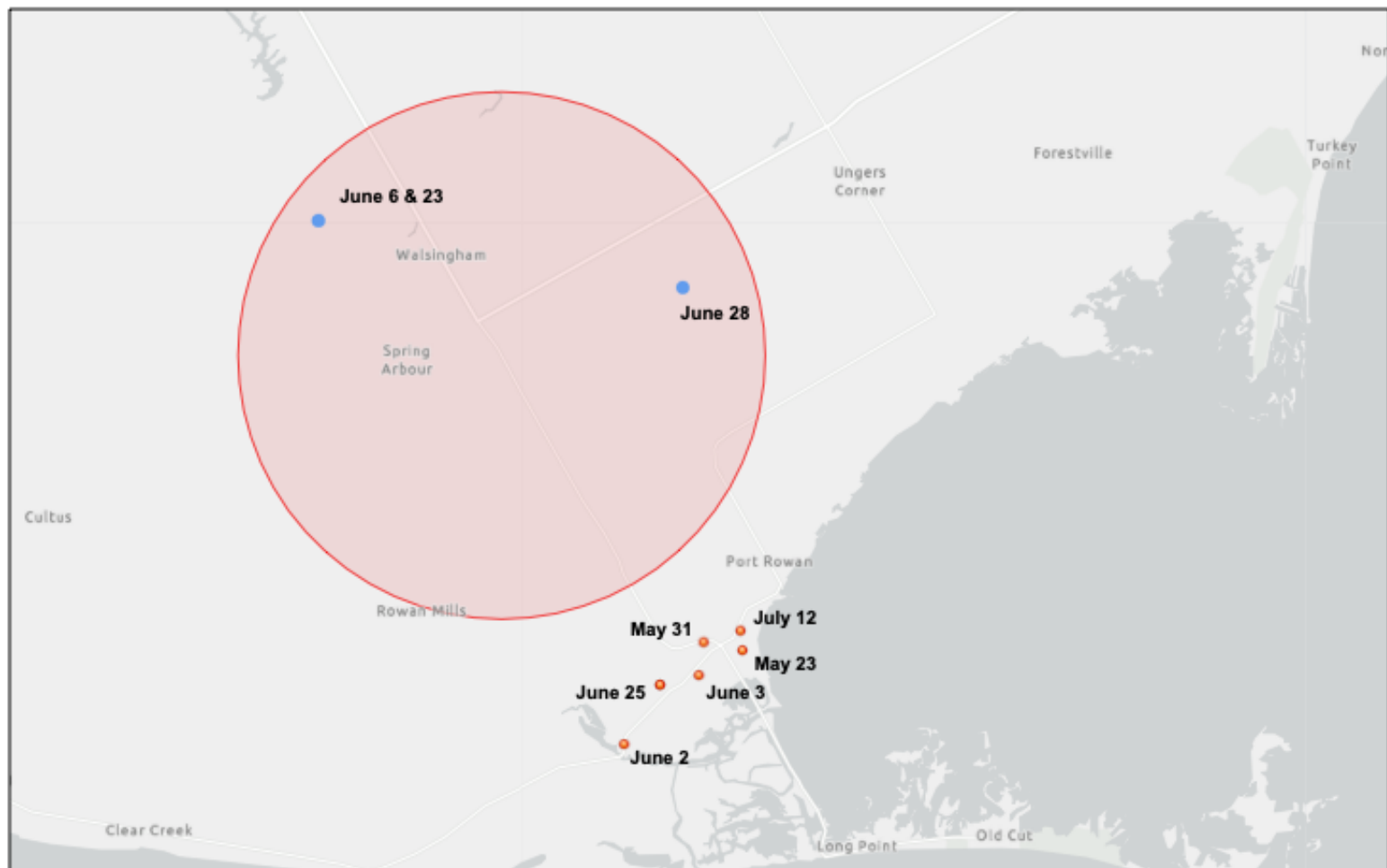
The initial purpose of testing for a correlation between each vegetation characteristic and time since disturbance was to see whether succession following a disturbance had influenced the vegetation characteristics of a site, and therefore potential *S. magna* habitat. Although many of the vegetation characteristics were found to have a significant correlation with time since disturbance, this has been determined to be an artefact of the constraints of the data once the correlation was plotted.

The effect of disturbance and succession on measures of *S. magna* site preference has been observed in multiple studies. *S. magna* have been shown to be absent or in very low densities in

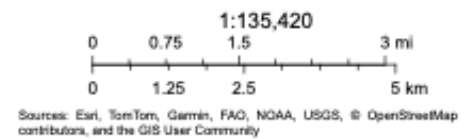
the year of a burn, but returned the following years (Bock & Bock 1992; Powell 2006, 2008; Byers et al. 2017). Managing rangelands for successional heterogeneity, such as using patch-burn grazing strategies, have been shown to provide stable *S. magna* nest survival rates over time (Hovick & Miller 2016). Similarly, *S. magna* abundance has been found to increase with field age (Bollinger 1995).

As hypothesized, the *S. magna* population in the area surrounding the study sites was low. I observed two *S. magna* in the area during the study period, although located outside of the boundaries of my study sites (Figure 12). One individual was observed singing within a hayfield adjacent to site 15 on June 6. An individual was again heard singing from the same location on June 23. No other sightings occurred at this location for the rest of the study period. Another *S. magna* was observed flying across the road near site 3 on June 28. Other *S. magna* sightings that occurred within the vicinity of my study sites during the study period are shown in Figure 12.

Figure 12. Eastern Meadowlark (*Sturnella magna*, L.) observations in the vicinity of the study sites during the study period (May 17 – August 2, 2022). The general area of the study sites is shown as the red circle. The red dots indicate *S. magna* sightings as reported on eBird (Cornell Lab of Ornithology 2024). The blue dots indicate sightings observed by the researcher during the study.



3/2/2025



Data from eBird for the decade leading up to data collection (*i.e.*, 2012-2022) indicate that the breeding *S. magna* population in Norfolk County shows large annual fluctuations (Figure 13). Notably, the number of *S. magna* observed in Norfolk County reached a 10-year peak in 2022 at 250 individuals (Figure 13).

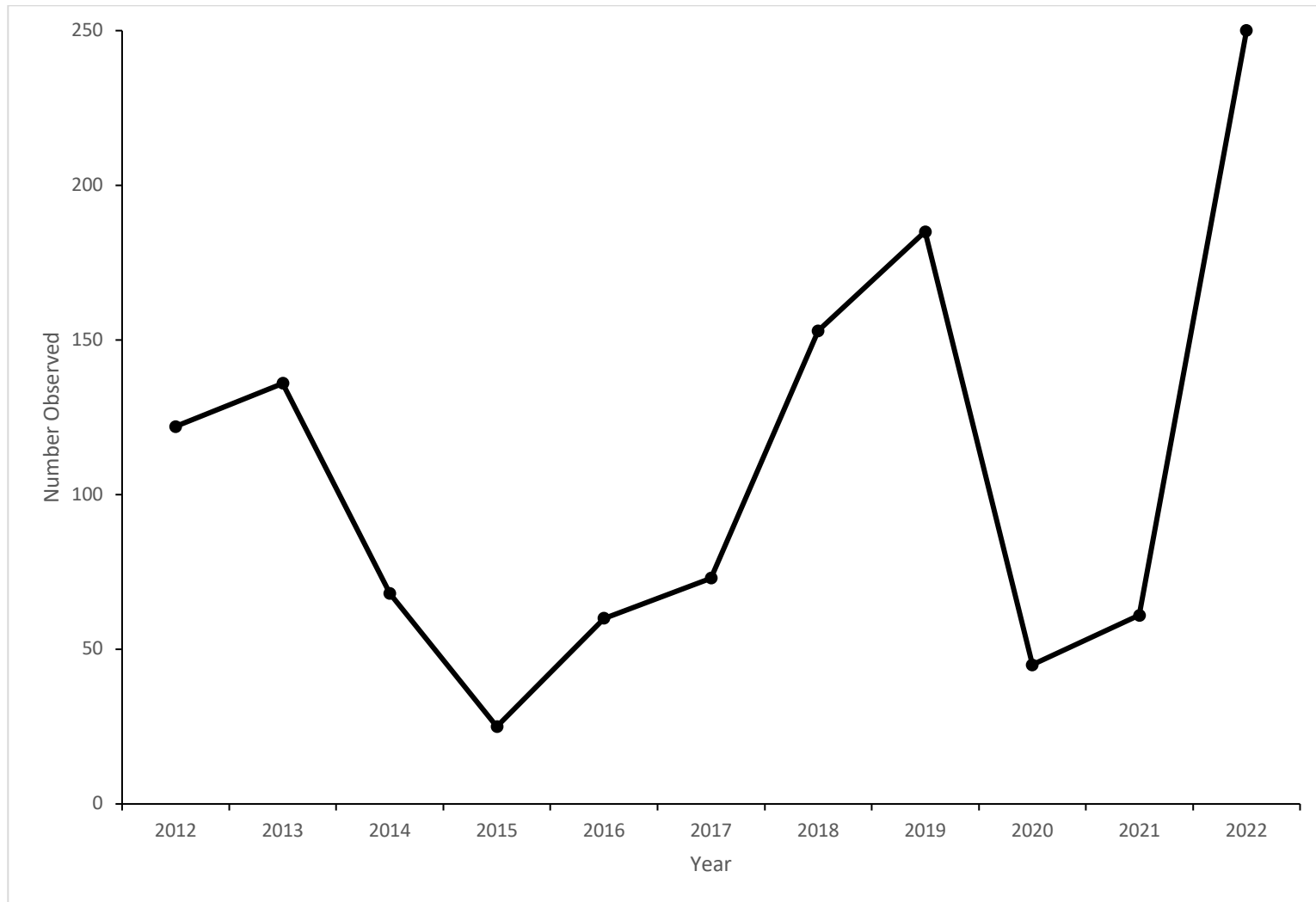


Figure 13. Number of Eastern Meadowlarks (*Sturnella magna*, L.) observed in Norfolk County, Ontario from April 15 – August 7 2012 – 2022 submitted to eBird (Cornell Lab of Ornithology 2024).

These data show that *S. magna* were present in variable numbers in Norfolk County and in the general area during the study period, but not located on any of the study sites. McCracken et al. (2014) also noted a relatively low population of *S. magna* in the region. This trend has been persistent in Norfolk County for decades. This may indicate a wider-scale, landscape-level cause.

The area-dependency of *S. magna* has been debated, with some studies finding little influence of field size on abundance, while others have found the opposite (McCracken et al. 2013). Furthermore, the validity of area-sensitivity studies on grassland birds have been questioned due to the confounding effect of field size on probability of occurrence (Horn et al. 2000). It is possible that *S. magna* exhibit area sensitivity in Ontario, or that other landscape-level factors influence the use of smaller habitat patches. For example, the distribution of *S. magna* on the landscape has been found to be influenced by habitat features at multiple scales ranging from 200 – 3200 m (Ribic & Sample 2001; Renfrew & Ribic 2008; de Zwaan et al. 2022; Sanchez Castillo 2022). Horn & Koford (2004) suggest that the amount of habitat at a landscape level may influence the use of smaller habitat patches by some grassland birds. In other words, if less habitat is available at a landscape level, then grassland birds may use smaller patches than they otherwise would in a landscape with lots of available habitat. Furthermore, McCracken et al. (2014) suggest that horizon distance of a habitat patch (*i.e.*, the perceived distance of the horizon in an open field) may have a greater influence on grassland bird abundance than the size of the patch itself. In other words, two equally-sized habitat patches may differ in habitat suitability due to their shape or the presence of non-woody edges (McCracken et al. 2014).

I conducted a preliminary post-restoration monitoring study for the presence of *S. magna*. The lack of *S. magna* observed on the restored sites indicates that these sites were not hosting breeding *S. magna* populations in 2022. This indicates that these sites either 1) were not providing

the habitat needed to support this species, or 2) the site-level habitat was suitable for *S. magna*, but other landscape-level features were not. This study provides valuable data that Nature Conservancy of Canada can use to guide further maintenance efforts at these sites. Continued monitoring is recommended to assess how these communities change over time and whether they will provide habitat for sensitive prairie species like *S. magna* in the future.

Chapter 4: Habitat Restoration for Eastern Meadowlark (*S. magna*, L.), Grassland Birds, and Tallgrass Prairies in Ontario

4.1 Introduction

S. magna has shown considerable declines in recent decades, as evidenced by the State of Canada's Birds published in late 2024 (Environment and Climate Change Canada & Birds Canada 2024). The report has documented a nation-wide population decline of *S. magna* of 84% from 1970 – 2022 (Environment and Climate Change Canada & Birds Canada 2024). *S. magna* is found in Canada primarily in Ontario and Quebec. Although the State of Canada's Birds describes a nation-wide trend, *S. magna*'s limited distribution can give an idea of the general population trend being experienced in Ontario. The United States population of *S. magna* is experiencing a similar downward trend, although at a slower rate of 2.7%/year according to Breeding Bird Survey data (Hostetler et al. 2023). At an international level, the International Union for the Conservation of Nature lists *S. magna* as Near Threatened, citing population trend uncertainty from areas outside of the United States and Canada (International Union for the Conservation of Nature 2020).

The cause of this decline is likely because of the related loss, conversion, and/or decline of their habitats (McCracken et al. 2013; Environment and Climate Change Canada 2022). *S. magna* breed in natural grasslands or in agricultural areas such as hayfields or pastures (McCracken et al. 2013). The federal proposed Recovery Strategy for Eastern Meadowlark (*Sturnella magna*) in Canada identifies pockets in southern and eastern Ontario as areas of critical habitat for this species (Environment and Climate Change Canada 2022). This area is known as the Mixedwood Plains ecoregion, which is also the most densely populated region in the province (Crins et al. 2009). The growing human population in this area results in the conversion of many natural areas to agricultural or developed lands (Crins et al. 2009). The remaining hayfields and

pastures that are used by *S. magna* can constitute an ‘ecological trap’ – areas with high population levels but low reproductive outputs – due to higher-than-expected levels of nest failure from hay harvesting and livestock trampling (Bock & Jones 2004). *S. magna* is a ground-nesting species, so their nests and nestlings are vulnerable to ground disturbances. Since they often nest in working agricultural fields, common disturbances are livestock and hay harvesting (McCracken et al. 2013).

Both the Ontario provincial Recovery Strategy and the federal proposed Recovery Strategy for *S. magna* list restoration initiatives and increasing habitat quality and quantity as approaches to recovery (McCracken et al. 2013; Environment and Climate Change Canada 2022; Table 3). The approaches in the federal proposed Recovery Strategy, under strategy 1.2 Ecosystem and Natural Process (Re) Creation, distinguish between habitat restoration and creation (Table 3). In both approaches, the Strategy calls for the restoration of previous habitat or the creation of new habitat “...for the species in appropriate landscapes (*e.g.*, areas with high density of birds, areas with high quality habitat or potential for high quality habitat).” (Environment and Climate Change Canada 2022, 32; Table 3). This demonstrates that increasing the total area of available habitat, regardless of whether an area previously hosted *S. magna*, is a priority for the recovery of this species.

Table 3. Restoration-related objectives presented in the provincial and proposed federal Recovery Strategies for Eastern Meadowlark (*Sturnella magna*, L.).

Source	Strategy / Objective	Approach
Environment and Climate Change Canada 2022	1.2 Ecosystem and Natural Process (Re) Creation	Restore habitat and natural processes (<i>e.g.</i>, prescribed burns) that provide suitable breeding habitat for the species in appropriate landscapes (<i>e.g.</i>, areas with high density of birds, areas with high quality habitat or potential for high quality habitat). Create suitable habitat for the species in appropriate landscapes (<i>e.g.</i>, areas with high density of birds, areas with high quality habitat or potential for high quality habitat).
McCracken et al. 2013	4. Increase habitat supply of native grassland	4.1 Identify and implement incentive programs and/or agro- economic policies that will provide an effective stimulus to landowners to increase the extent of native grasslands that contribute to recovery.

The provincial Recovery Strategy recommends a different approach to increasing habitat availability. The provincial Strategy calls for the implementation of monetary programs to incentivize agricultural landowners to increase the amount of native grassland on their property (Table 3). Several strategies of this nature are already in place, either nationally or solely in Ontario. The Habitat Stewardship Program for Species at Risk is one example – founded in 2000, this program offered by Environment and Climate Change Canada provides funding for projects that work towards the recovery objectives of federally-listed Species at Risk (Environment and Climate Change Canada 2024). Another successful program outlined in the Recovery Strategy is the Alternative Land Use Services program. Alternative Land Use Services began in Norfolk County in 2005 as a direct land value compensation program for the conversion of marginal farmlands for wildlife habitat. Participating landowners are paid per acre, based on local market value, for non-productive farmland that they retire from production. The land can either be left to grow fallow, or additional compensation measures are available for restoration activities. The objective is for the retired land to become available to wildlife without a loss in revenue for farmers. A newer example that was started after the publication of the provincial Recovery Strategy is the Conservation Land Tax Incentive Program. This program provides a tax rebate to landowners who have significant natural features on their property – including habitat for Species at Risk (Ontario Ministry of Natural Resources 2024).

Incentive programs also exist that target the causes of direct mortality to grasslands birds – *i.e.*, hay harvesting and livestock trampling – rather than habitat management initiatives. Species at Risk Partnerships on Agricultural Lands is an umbrella initiative offered by Environment and Climate Change Canada and administered in Ontario by the Ontario Soil and Crop Improvement Association that offers a variety of specific programs that promote operational changes and Best

Management Practices to conserve Species at Risk (Ontario Soil and Crop Improvement Association 2025c). Species at Risk Partnerships on Agricultural Lands' Forage Harvest Management program offers farmers \$40/acre for hayfields that are harvested July 15 or later (Ontario Soil and Crop Improvement Association 2025b). The Cross-Fencing for Rotational Grazing program reimburses farmers 50% of the cost of installing interior fences and water systems to create paddocks for rotational grazing (Ontario Soil and Crop Improvement Association 2025a). The intention is for some paddocks to be left ungrazed until July 15 or later to provide a refuge for ground-nesting grassland birds (Ontario Soil and Crop Improvement Association 2025a). Similar to Alternative Land Use Services, the objective of these programs is to promote grassland bird habitat while mitigating financial losses to farmers.

Several restoration initiatives have already been undertaken in Ontario targeting *S. magna*, grassland birds, or tallgrass prairies (McCracken et al. 2013; Environment and Climate Change Canada 2022). Many projects have been undertaken by non-profit organizations, such as Tallgrass Ontario and Nature Conservancy of Canada, as well as by private landowners (McCracken et al. 2013).

Follow-up monitoring and adaptive management are necessary to evaluate the success of any restoration project. Restoration projects typically go through four stages (Gann et al. 2019):

- I. Planning and Design
- II. Implementation
- III. Monitoring, Documentation, Evaluation, and Reporting; and
- IV. Post-implementation Maintenance

After initial restoration activities have been undertaken, the Monitoring, Documentation, Evaluation, and Reporting (MDER) stage is when monitoring is conducted to evaluate the outcomes of the restoration against the project's goals. Data from these monitoring studies can then be used to inform what maintenance activities are needed to keep the restored ecosystem on course to reach the desired outcome (Post-implementation Maintenance stage). An adaptive management approach would be for the restoration cycle to begin anew using information gained from the MDER stage. This allows for a project to be always adapting to the changing conditions of a complex restored ecosystem.

While it is important to continually assess ongoing projects, it is also important to assess the effectiveness of past projects. This assessment will determine ways that these past projects can be improved upon in order to make more effective progress towards meeting the restoration recovery goals for *S. magna*. This study addressed research question II) What restoration strategies are currently being employed in Ontario for tallgrass prairies and/or *S. magna*, and how can future efforts be improved? I sought to answer this question by determining what restoration strategies have been or are currently being employed in Ontario for *S. magna*, grassland birds, or tallgrass prairies, and determining how future restoration projects in Ontario can be improved to better target *S. magna*. The findings from this study will provide an assessment of the progress to date on achieving the restoration-oriented recovery goals outlined in the two Recovery Strategies. From these findings, restoration practitioners and land managers will be able to make informed decisions about the design of future projects and more effectively work towards restoring habitat for *S. magna*, grassland birds, or tallgrass prairies in Ontario.

4.2 Methods

4.2.1 Study Design

An online questionnaire was distributed via email to ‘subject experts’ – individuals who are knowledgeable and/or experienced with restoration ecology, avian biology, and/or grassland ecology in Ontario, especially concerning *S. magna*. The questionnaire was self-administered by the respondents using Qualtrics (Qualtrics, Provo, UT).

Keeping consistent with traditional questionnaire design, the majority of the questions were closed (*i.e.*, the respondent chooses an answer from a given set of options rather than answering in their own words; Newing 2011). The questionnaire also included multiple open-ended questions to allow the respondents to provide context and details not originally anticipated when designing the questionnaire. The questions were organized into the following sections:

- I. Respondent Information
- II. Knowledge
- III. Past and Current Restoration Strategies
- IV. Future Restoration Strategies
- V. Conclusion

Responses were anonymous (*i.e.*, no identifying information was collected during the survey).

4.2.2 Sampling

A non-probability sampling approach was used to identify potential participants. It was conducted in two stages.

A search of the Web of Science database (Clarivate 2022) was conducted using the following Boolean search phrase:

((“Eastern Meadowlark” OR “sturnella magna”) OR (grassland OR (“tallgrass prairie” OR “tall grass prairie” OR “tall-grass prairie”)) OR “grassland bird”) AND Ontario

The search was limited to publications within the past five years (i.e., since 2018) to minimize the possibility of authors’ contact information being out of date. This search yielded 111 peer-reviewed publications. The publications were reviewed for relevance to the search terms, resulting in 27 relevant publications. The contact information for all authors were gathered from the publications or from a cursory online search. The contact information for 70 potential respondents was compiled.

The public online directories of relevant organizations and institutions were reviewed for individuals that were deemed to be potentially knowledgeable in the subject matter. This was assessed via job title, role in the organization, and/or material published by the organization. The contact information for 263 potential respondents was compiled from online directories.

The following list of organizations and institutions, including their relevant publications, were reviewed for potential respondents:

- Environment and Climate Change Canada
- Natural Resources Canada
- Parks Canada
- Ontario Ministry of Agriculture, Food and Rural Affairs
- Ontario Ministry of Environment, Conservation and Parks
- Ontario Ministry of Natural Resources

- Tallgrass Ontario
- Conservation Authorities
- Carolinian Canada
- Nature Conservancy of Canada
- Wildlife Preservation Canada
- Birds Canada
- *rare* Charitable Research Reserve
- Ojibway Prairie
- Ontario Nature
- Recovery Strategy for the Bobolink (*Dolichonyx oryzivorus*) and Eastern Meadowlark (*Sturnella magna*) in Ontario (McCracken et al. 2013)

4.2.3 Data Analysis

The closed questions from the questionnaire were summarized into nominal or ordinal categories, depending on the question, and summarized using descriptive statistics with Microsoft Excel (Microsoft Corporation 2022). In some cases, numerical coding was used to assign values to the responses to enable the calculation of descriptive statistics.

Thematic coding was used to analyze the open-ended questions using NVivo (QSR International Pty Ltd 2022). The content of the answers to the open-ended questions were organized based on themes present in the responses. The set of codes was developed concurrently with data analysis since the themes emerged as data analysis progressed.

Likert plots were created in R Statistical Software (v4.1.2, R Core Team 2021) using the *likert* package (v1.3.5, Bryer & Speerschneider 2016). See Table B2, Appendix B for a complete list of the packages used during analysis.

4.3 Results

The survey was distributed via email to 334 potential respondents (Table 4). The survey received 35 responses for an overall response rate of 10.5%. Response rates of online questionnaires vary widely depending on questionnaire length, the use of incentives, visual presentation of the questionnaire, and whether researchers follow-up with potential respondents (Deutskens et al. 2004). Given the length of the questionnaire (22 questions with an estimated completion time of 1 hour), lack of incentives, and lack of follow-up, a response rate of 10.5% is believed to be appropriate. The relatively long estimated completion time likely dissuaded some potential respondents from completing the survey. The questionnaire was designed to gather detailed, in-depth responses in lieu of conducting an interview. For this reason, a longer survey with more detailed questions was prioritized at the expense of a likely lower response rate. The purpose of the study was for respondents to share information “interview-style” rather than to assess them as a sample of a larger population. As a result, the relatively low response rate does not affect any analyses that would have been dependent on a minimum sample size.

For data on respondent background and self-assessed respondent knowledge, see Figure A1, Appendix A and Table B1, Appendix B.

Table 4. Source of name and contact information of potential respondents.

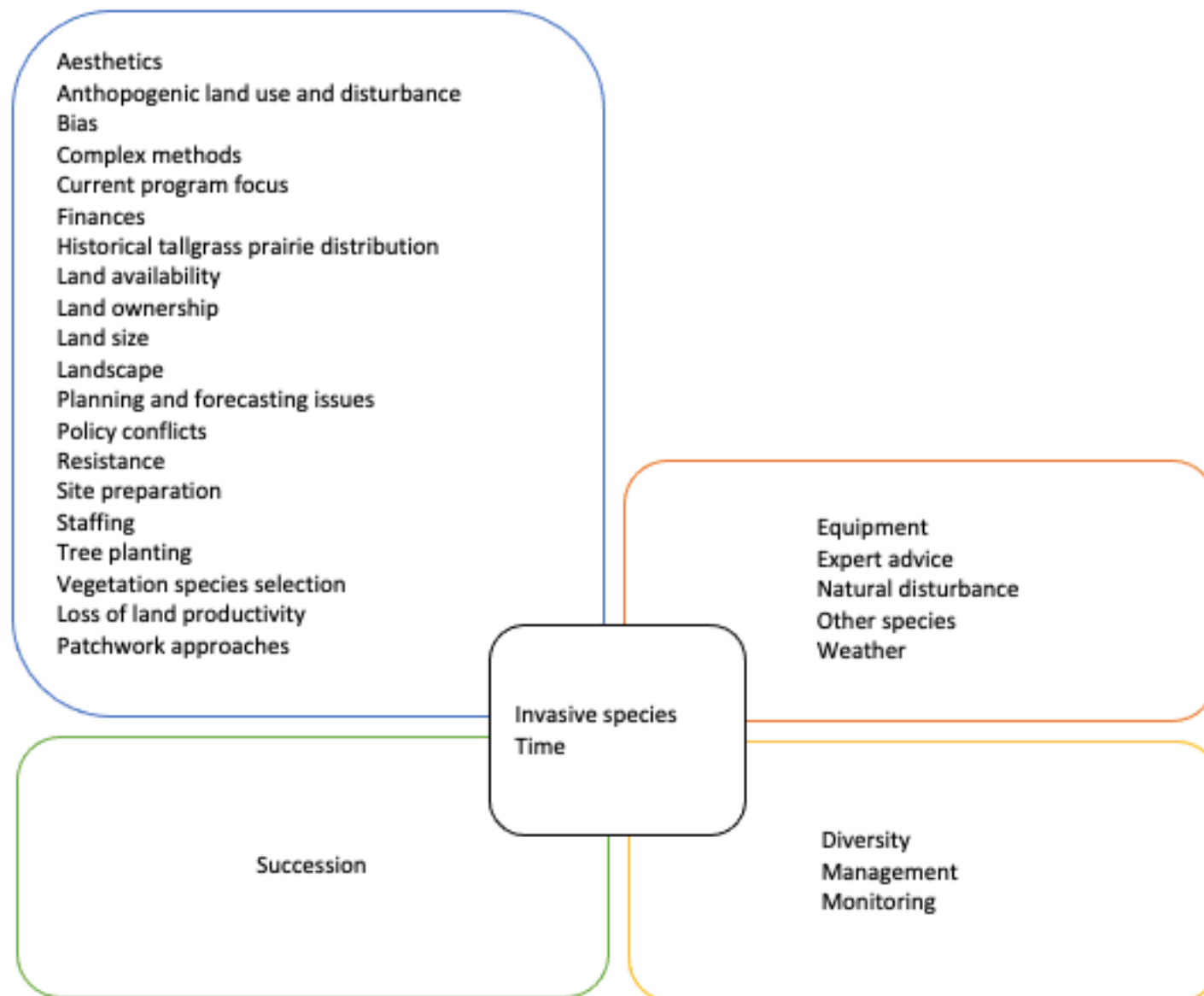
Source	Number of Potential Respondents
Published peer-reviewed sources	70
Online directories	263
Personal recommendation	1
Total	334

4.3.1 Past and Current Restoration Strategies

Respondents indicated problems, issues, or barriers that have come up during past restoration projects with themes associated with the four restoration stages (Gann et al. 2019; Figure 14):

- I. Planning and Design
- II. Implementation
- III. MDER
- IV. Post-implementation Maintenance

Figure 14. Problems, issues, and/or barriers of past and/or current Eastern Meadowlark (*Sturnella magna*, L.), grassland bird, or tallgrass prairie restoration projects in Ontario, organized by restoration stage: Planning and Design (blue); Implementation (orange); Monitoring, Documentation, Evaluation, and Reporting (MDER; yellow); and Post-implementation Maintenance (green).



The most common themes, regardless of restoration stage, were ‘finances’ (n = 15), ‘management’ (n = 9), and ‘invasive species’ (n = 7; Figure 15). Three respondents indicated that they had encountered no problems, issues, or barriers during restoration projects of this type (Figure 15).

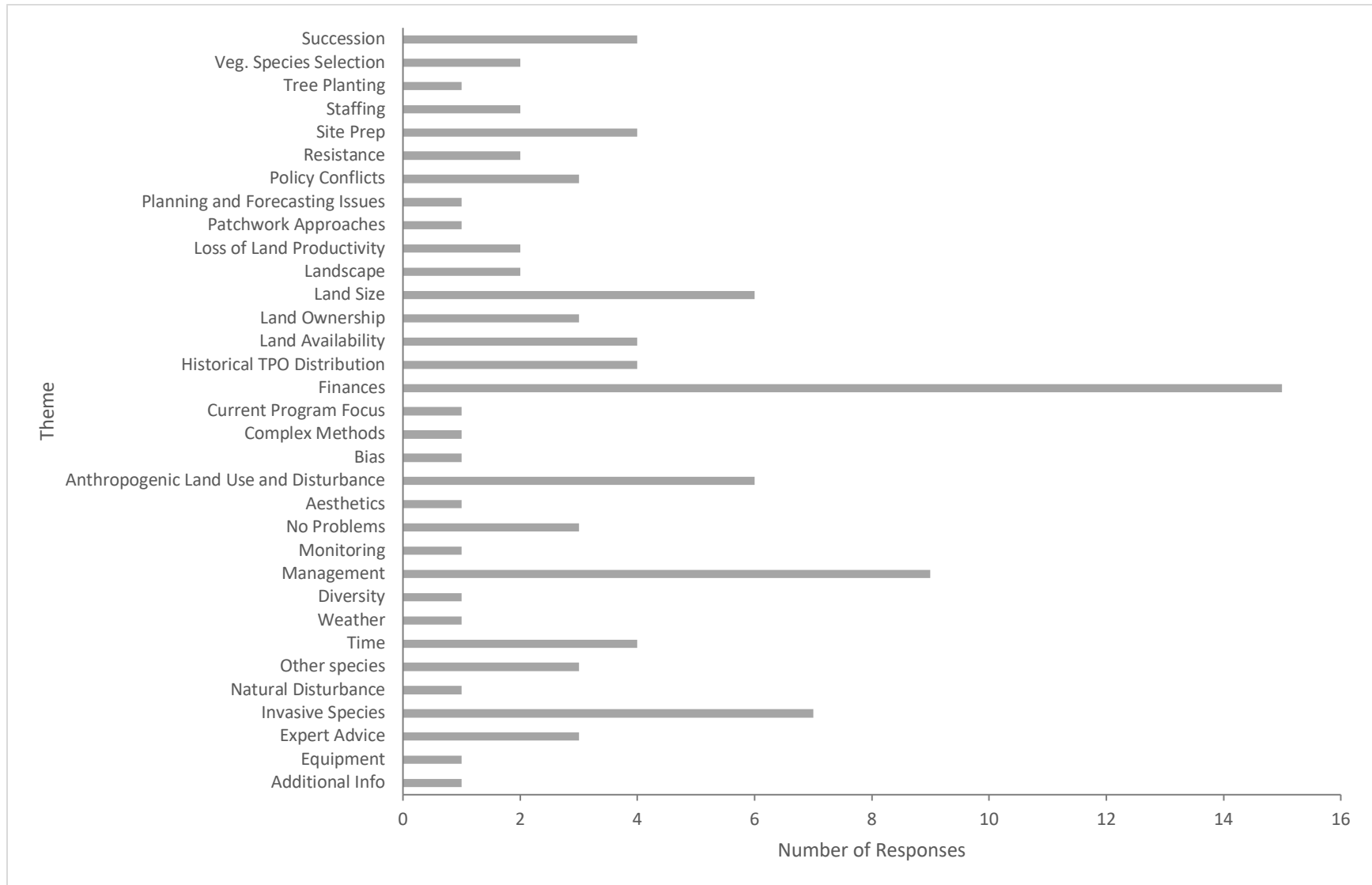


Figure 15. Problems, issues, and/or barriers of past and/or current Eastern Meadowlark (*Sturnella magna*, L.), grassland bird, or tallgrass prairie restoration projects in Ontario.

Non-profit organizations were the actors most frequently noted as carrying out current restoration activities ($n = 11$; Figure 16). Private landowners were also frequently noted ($n = 5$), often in partnership with other organizations like non-profit organizations or Conservation Authorities (Figure 16).

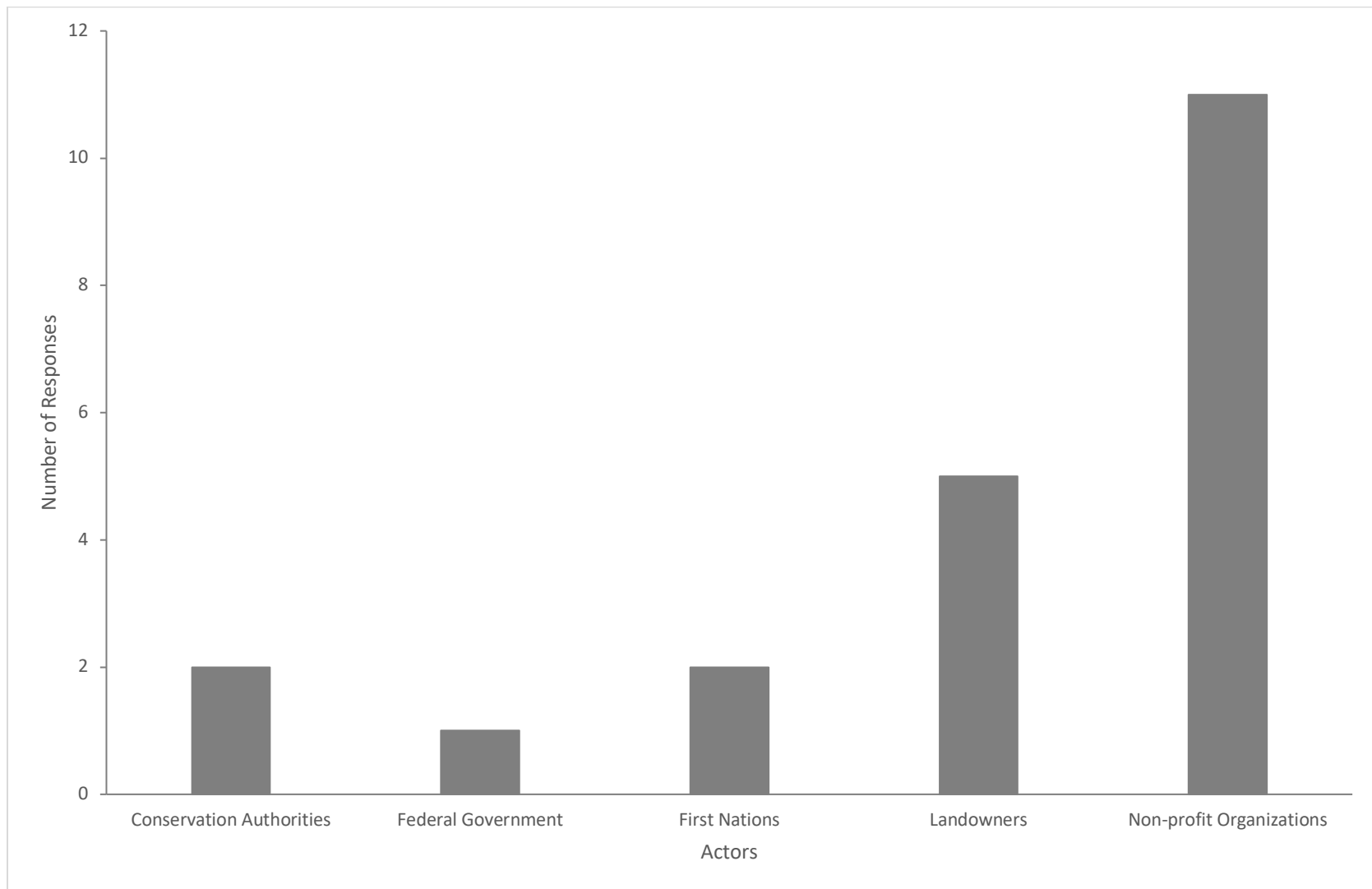


Figure 16. Actors participating in current and/or ongoing Eastern Meadowlark (*Sturnella magna*, L.), grassland bird, and/or tallgrass prairie restoration projects in Ontario.

Current restoration activities were described as being located across southern and eastern Ontario (Figure 17 - Figure 19). In addition to the locations shown in Figure 17, two respondents indicated that restoration projects occurred across the province, and another indicated that they occurred on Conservation Authority land. One respondent indicated that current projects were occurring in “the wrong places”.

Figure 17. Location of current restoration projects for Eastern Meadowlark (*Sturnella magna*, L.), grassland birds, or tallgrass prairies in Ontario.

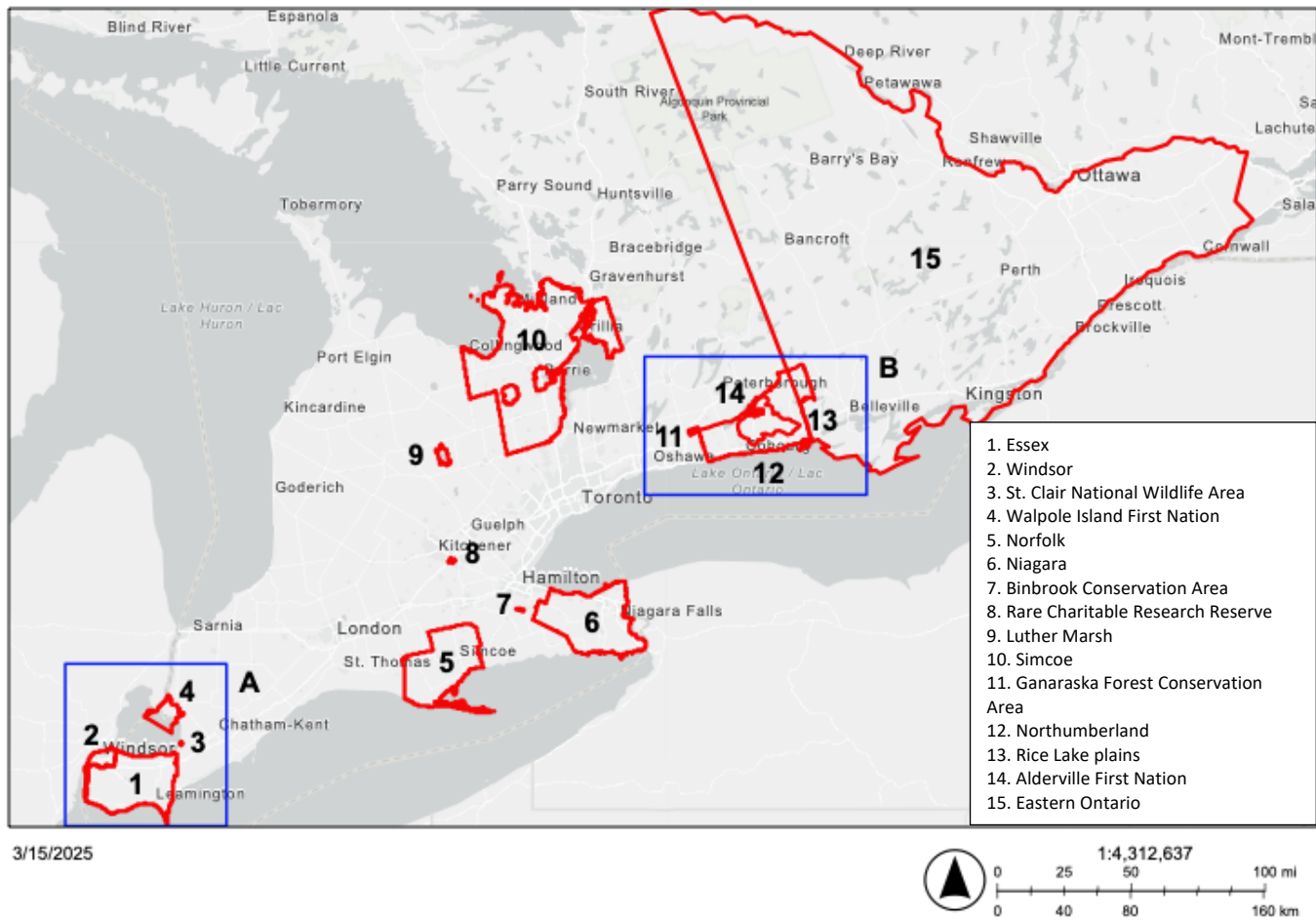


Figure 18. Location of current restoration projects for Eastern Meadowlark (*Sturnella magna*, L.), grassland birds, or tallgrass prairies in southwestern Ontario.

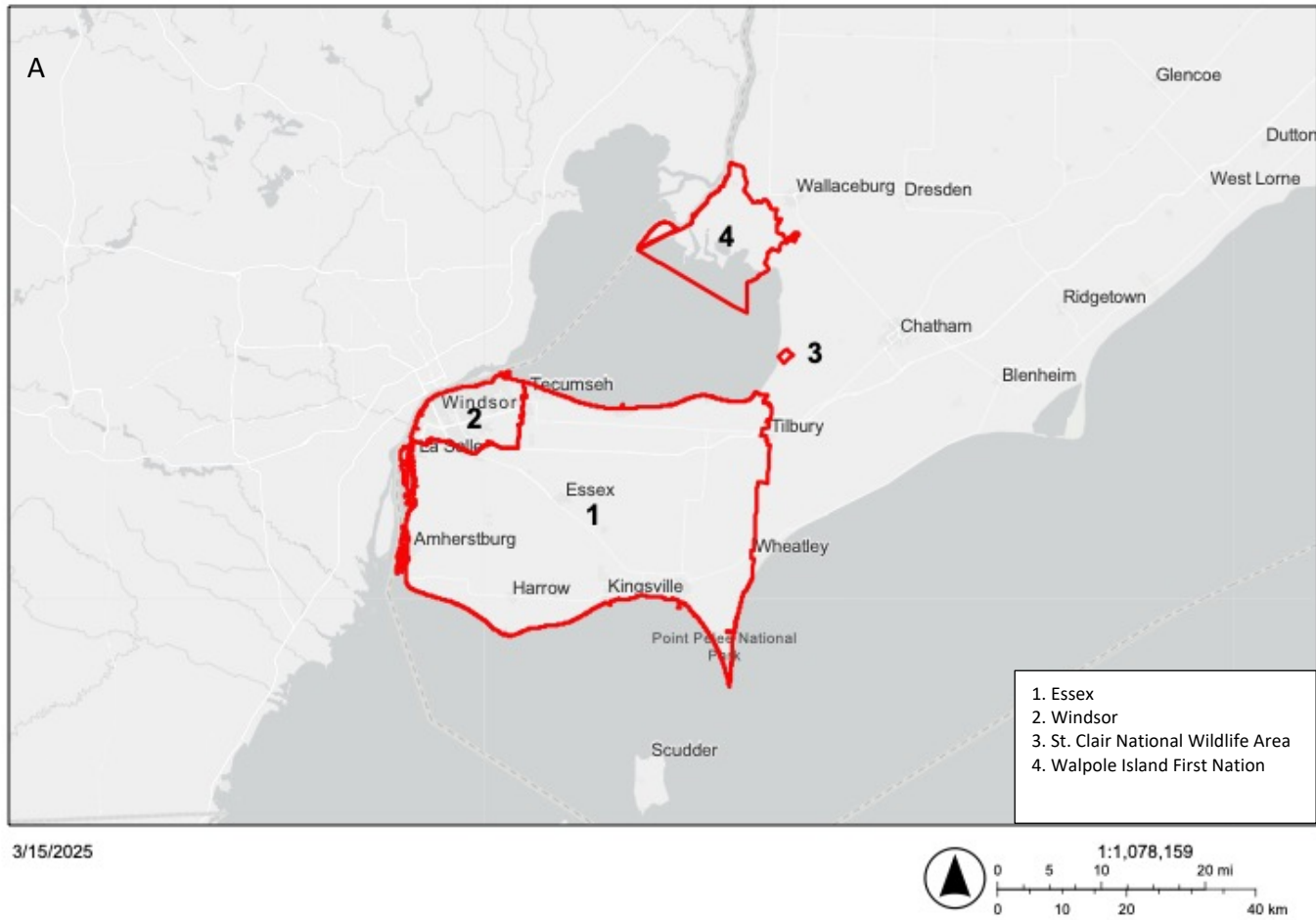
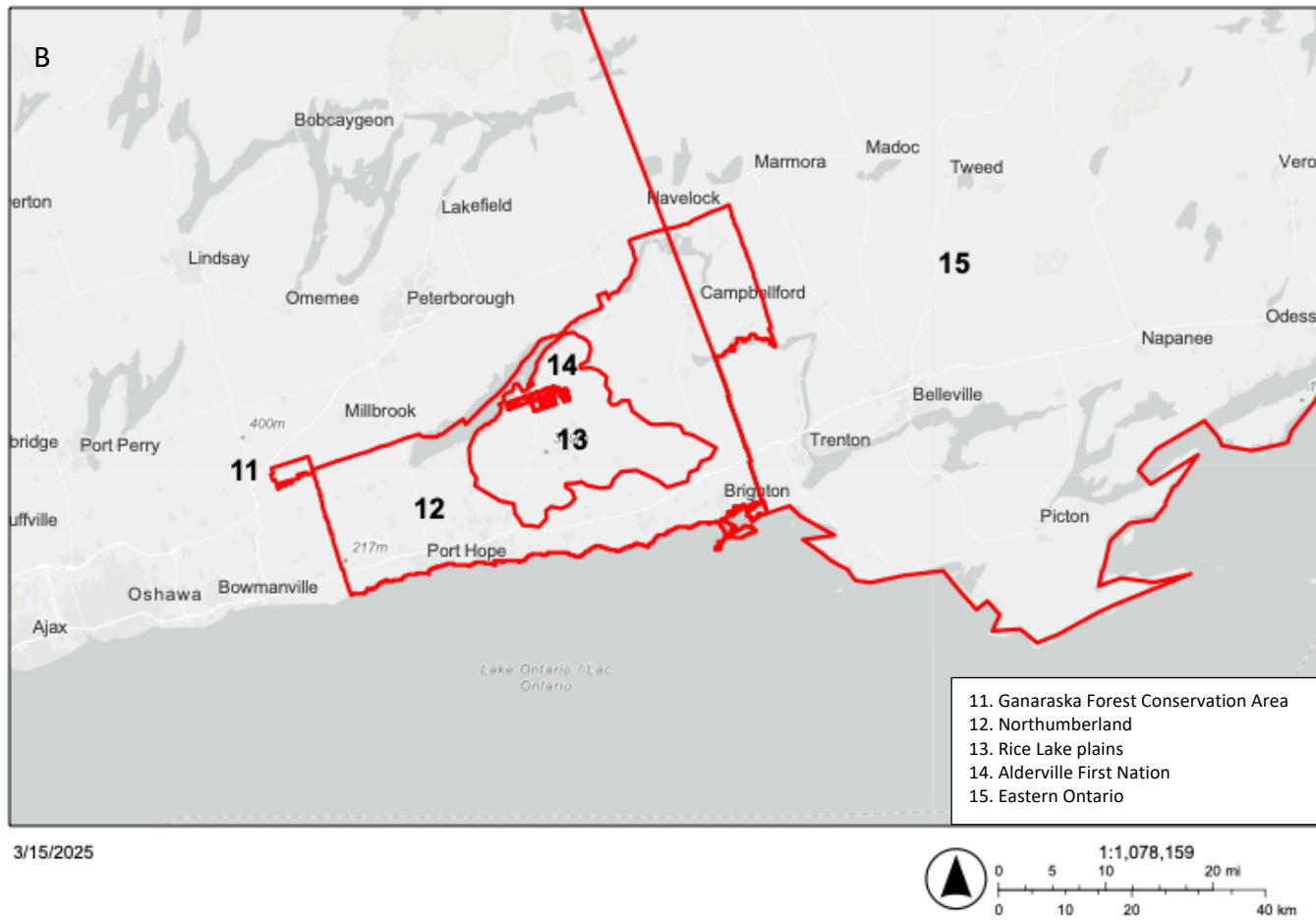


Figure 19. Location of current restoration projects for Eastern Meadowlark (*Sturnella magna*, L.), grassland birds, or tallgrass prairies in southeastern Ontario.



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Delayed hay harvesting was the most frequently noted management practice for current restoration activities (n = 4; Figure 20). Management was also commonly described as being subpar (n = 2; Figure 20).

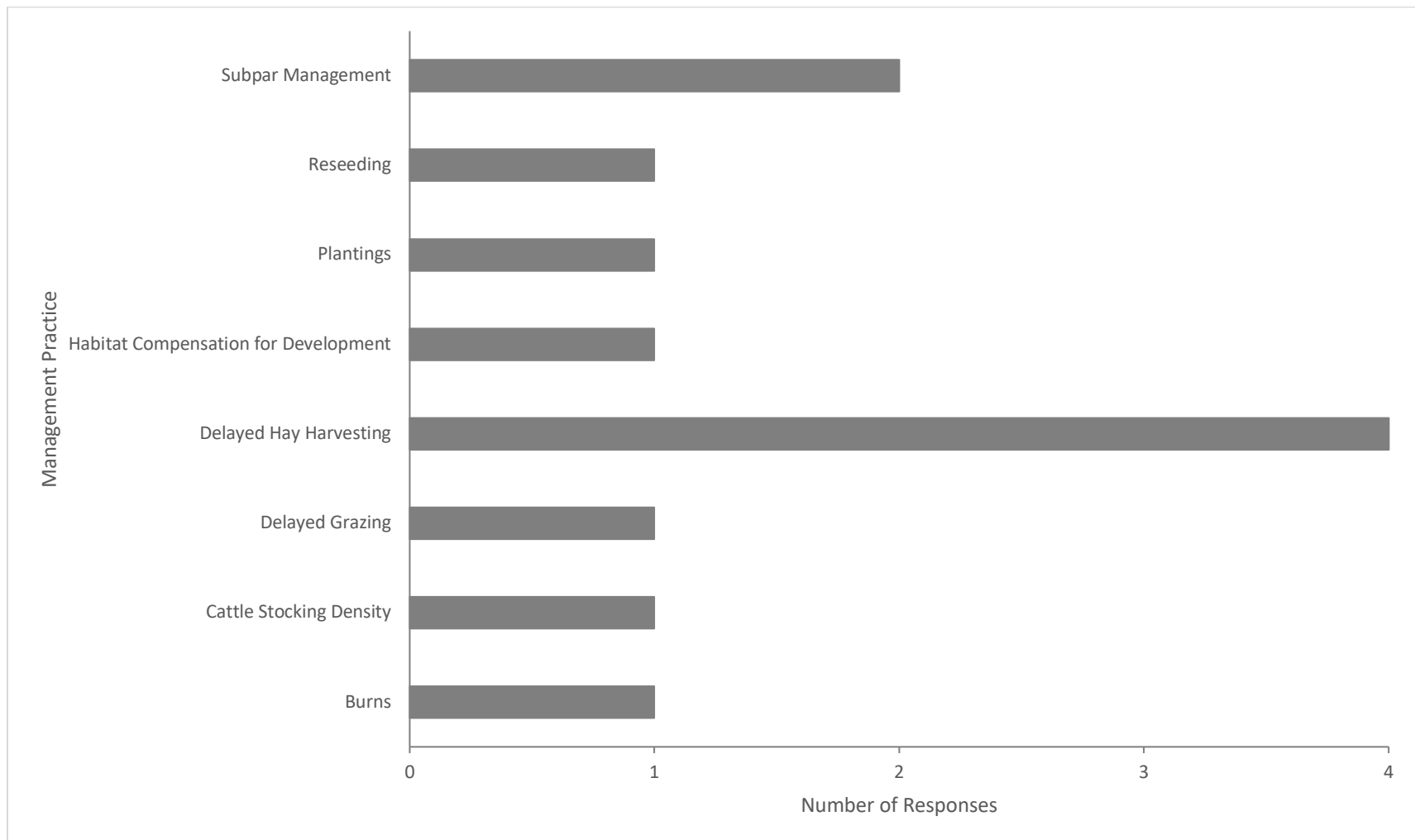


Figure 20. Management practices for current and/or ongoing Eastern Meadowlark (*Sturnella magna*, L.), grassland bird, and/or tallgrass prairie restoration projects in Ontario.

When asked to rate the sufficiency of current restoration efforts in Ontario for *S. magna*, most respondents indicated that they were unsure (n = 11, 37%; Figure 21). Otherwise, the distribution skewed towards being insufficient, with respondents answering ‘not at all sufficient’ the second most frequently (n = 8; Figure 21).

The reasoning behind the above rating was varied. Respondents often noted habitat loss (n = 4) and quantity (n = 4; Figure 22). Four respondents indicated that restoration efforts were in fact sufficient (Figure 22).

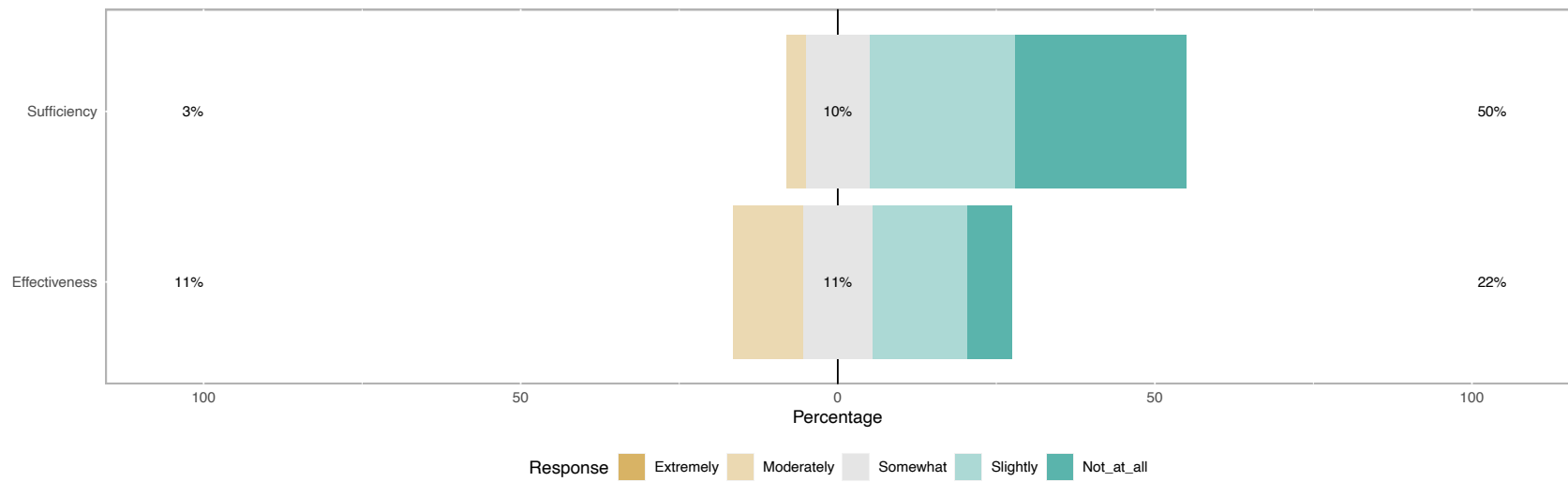
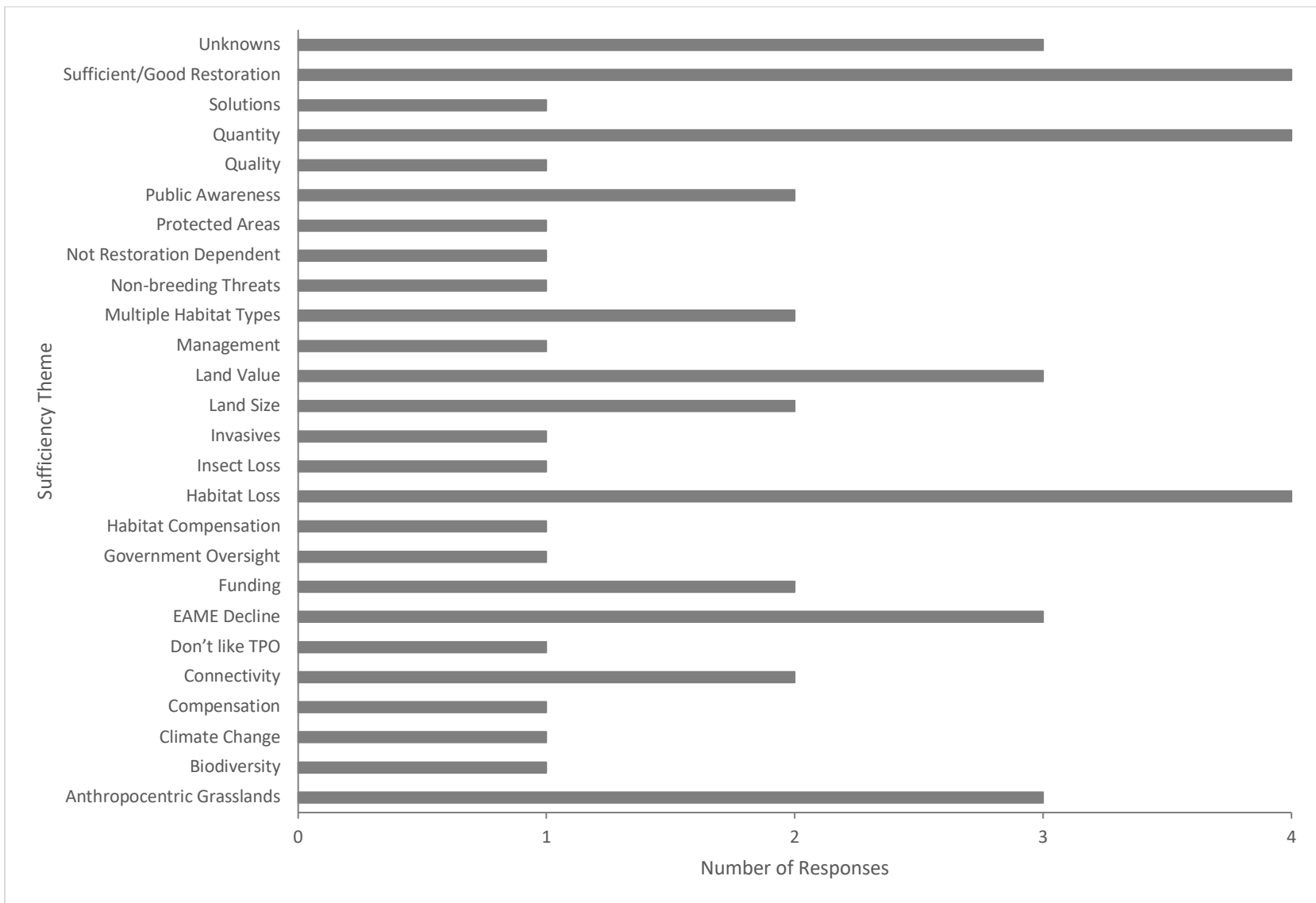


Figure 21. Sufficiency and effectiveness of current restoration efforts for Eastern Meadowlark (*Sturnella magna*, L.) in Ontario.

Figure 22. Respondents' reasons for sufficiency rating (Figure 21) of current Eastern Meadowlark (*Sturnella magna*, L.) restoration projects in Ontario.



When asked to rate the effectiveness of current restoration projects in Ontario for *S. magna*, most respondents indicated that they were unsure (n = 15, 56%; Figure 21). Otherwise, the distribution skewed towards ineffectiveness, with respondents answering ‘slightly effective’ the second most frequently (n = 4; Figure 21).

The reasoning behind the above rating was varied. Respondents often noted a lack of follow-up (n = 3) and implementation (n = 2; Figure 23). Three respondents indicated that restoration efforts were in fact effective (Figure 23).

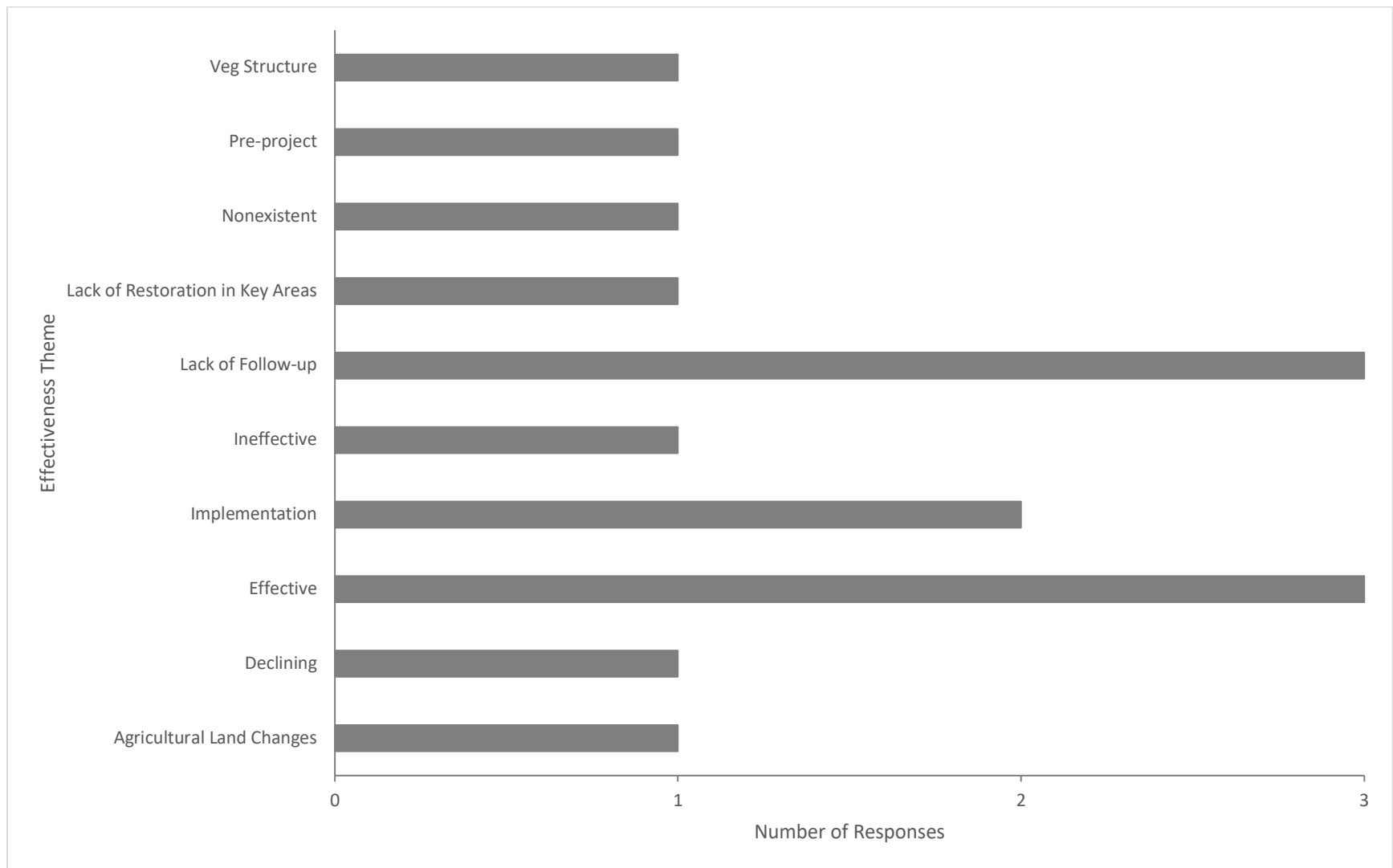


Figure 23. Respondents' reasons for effectiveness rating (Figure 21) of current Eastern Meadowlark (*Sturnella magna*, L.) restoration projects in Ontario.

When asked how often *S. magna*, grassland bird, and/or tallgrass prairie restoration projects in Ontario were monitored after completion of restoration activities, most respondents indicated that projects were ‘sometimes’ monitored (n = 11), ‘rarely’ (n = 7), or ‘very often’ (n = 4; Figure 24). Two respondents indicated that they were ‘unsure’.

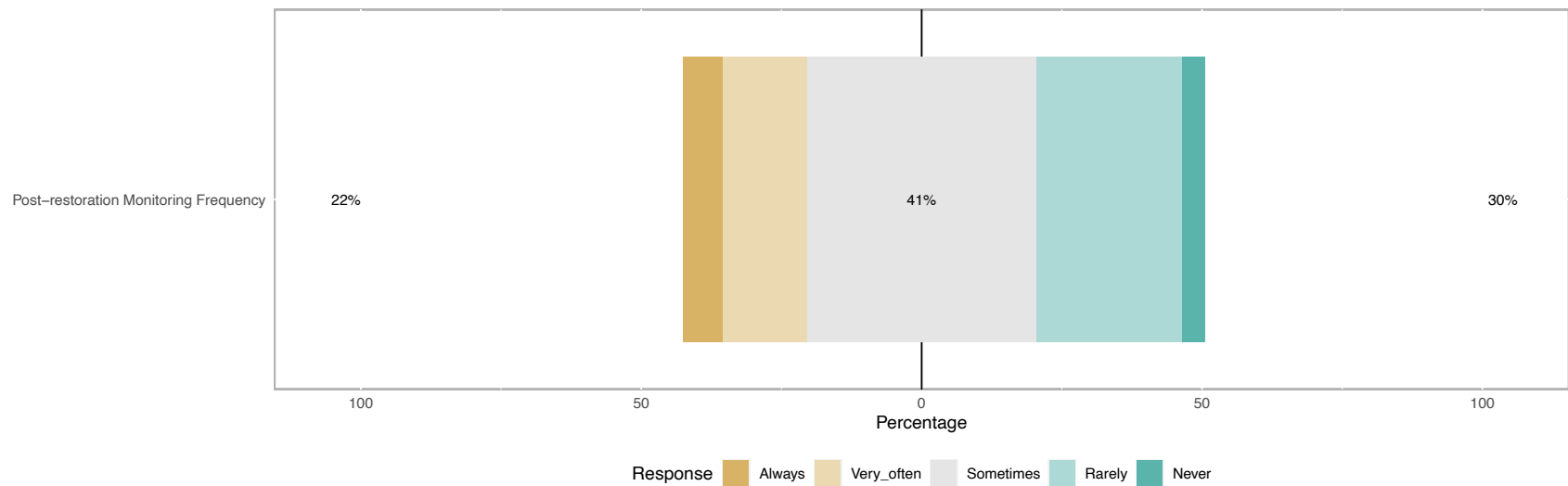


Figure 24. Frequency of post-restoration monitoring of Eastern Meadowlark (*Sturnella magna*, L.), grassland bird, and/or tallgrass prairie restoration projects in Ontario.

When asked whether *S. magna*, grassland bird, and/or tallgrass prairie restoration projects in Ontario include restoration interventions or not (a.k.a., active vs. passive restoration), most respondents indicated that projects ‘mostly include interventions’ (n = 12; Figure 25). Six respondents indicated that they were ‘unsure’ about the use of interventions.

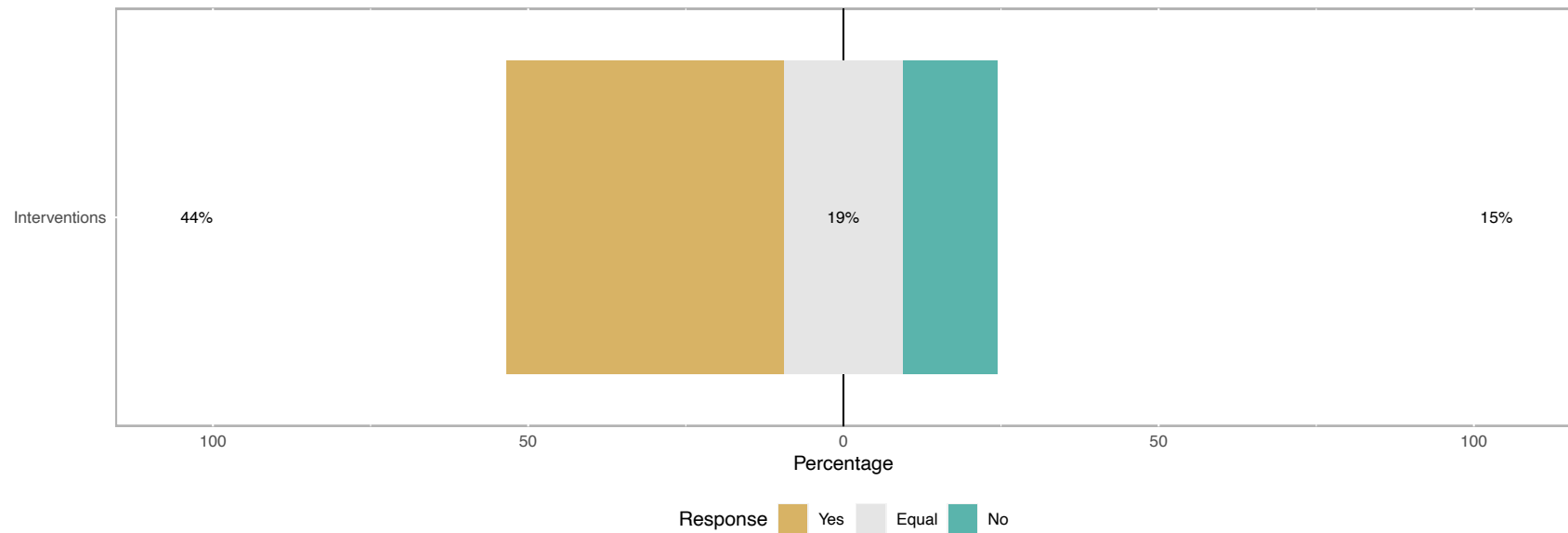


Figure 25. Use of restoration interventions during Eastern Meadowlark (*Sturnella magna*, L.), grassland bird, and/or tallgrass prairie restoration projects in Ontario.

Respondents described strengths of past or current *S. magna*, grassland bird, and/or tallgrass prairie restoration projects with themes associated with the four restoration stages (Gann et al. 2019; Figure 26). The most common themes, regardless of restoration stage, were ‘broad focus’ (n = 7) and ‘management’ (n = 4; Figure 27). One respondent indicated that there were many strengths, and another that there were no strengths (Figure 27).

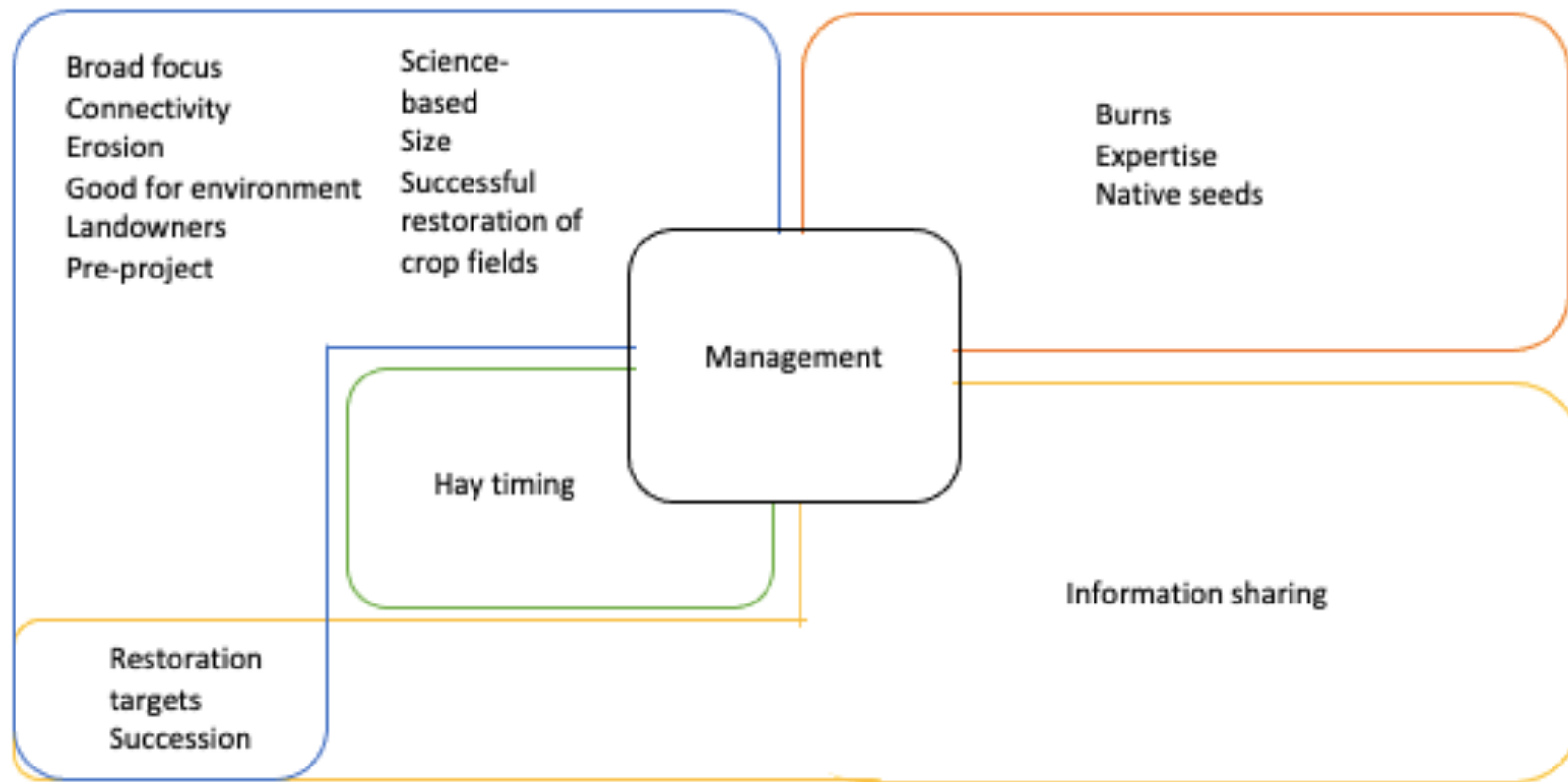
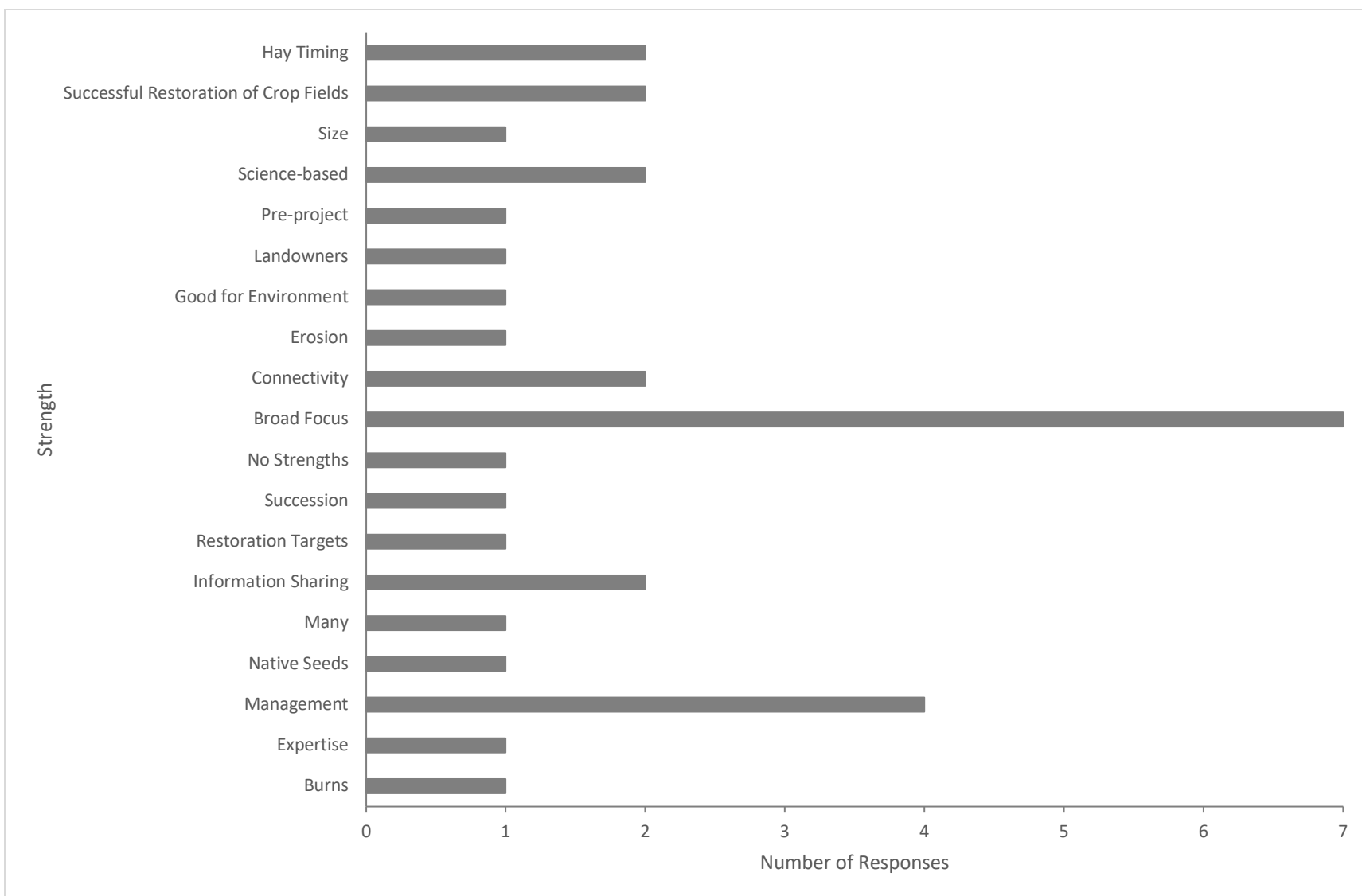


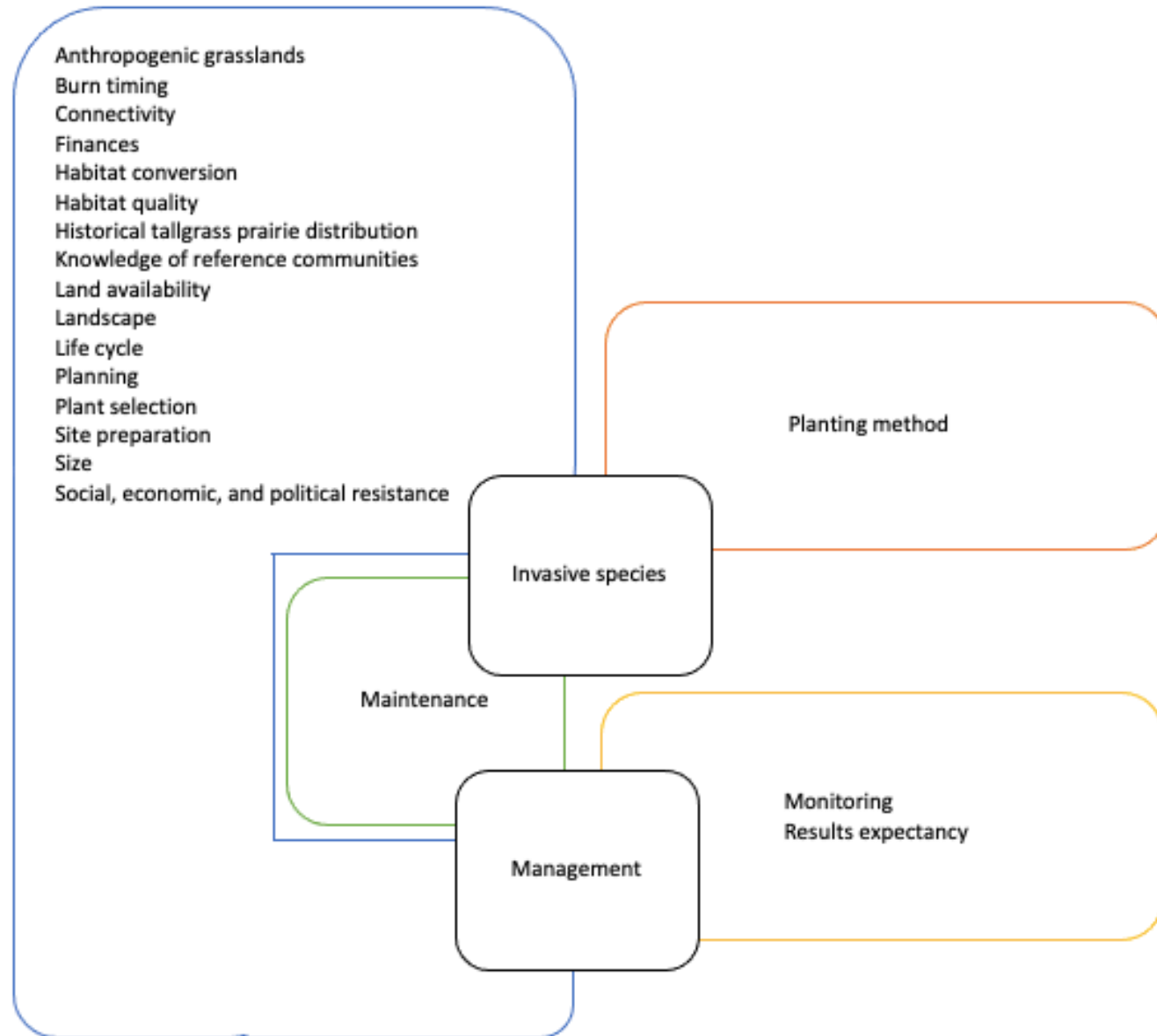
Figure 26. Strengths of past and/or current Eastern Meadowlark (*Sturnella magna*, L.), grassland bird, and/or tallgrass prairie restoration projects in Ontario, organized by restoration stage: Planning and Design (blue); Implementation (orange); Monitoring, Documentation, Evaluation, and Reporting (MDER; yellow); and Post-implementation Maintenance (green).

Figure 27. Strengths of past and/or current Eastern Meadowlark (*Sturnella magna*, L.), grassland bird, and/or tallgrass prairie restoration projects in Ontario.



Respondents described weaknesses of past or current *S. magna*, grassland bird, and/or tallgrass prairie restoration projects in Ontario with themes associated with the four restoration stages (Gann et al. 2019; Figure 28). The most common themes, regardless of restoration stage, were ‘maintenance’ and ‘finances’ (both n = 5), followed by ‘size’ and ‘management’ (both n = 4; Figure 29).

Figure 28. Weaknesses of past and/or current Eastern Meadowlark (*Sturnella magna*, L.), grassland bird, and/or tallgrass prairie restoration projects in Ontario, organized by restoration stage: Planning and Design (blue); Implementation (orange); Monitoring, Documentation, Evaluation, and Reporting (MDER; yellow); and Post-implementation Maintenance (green).



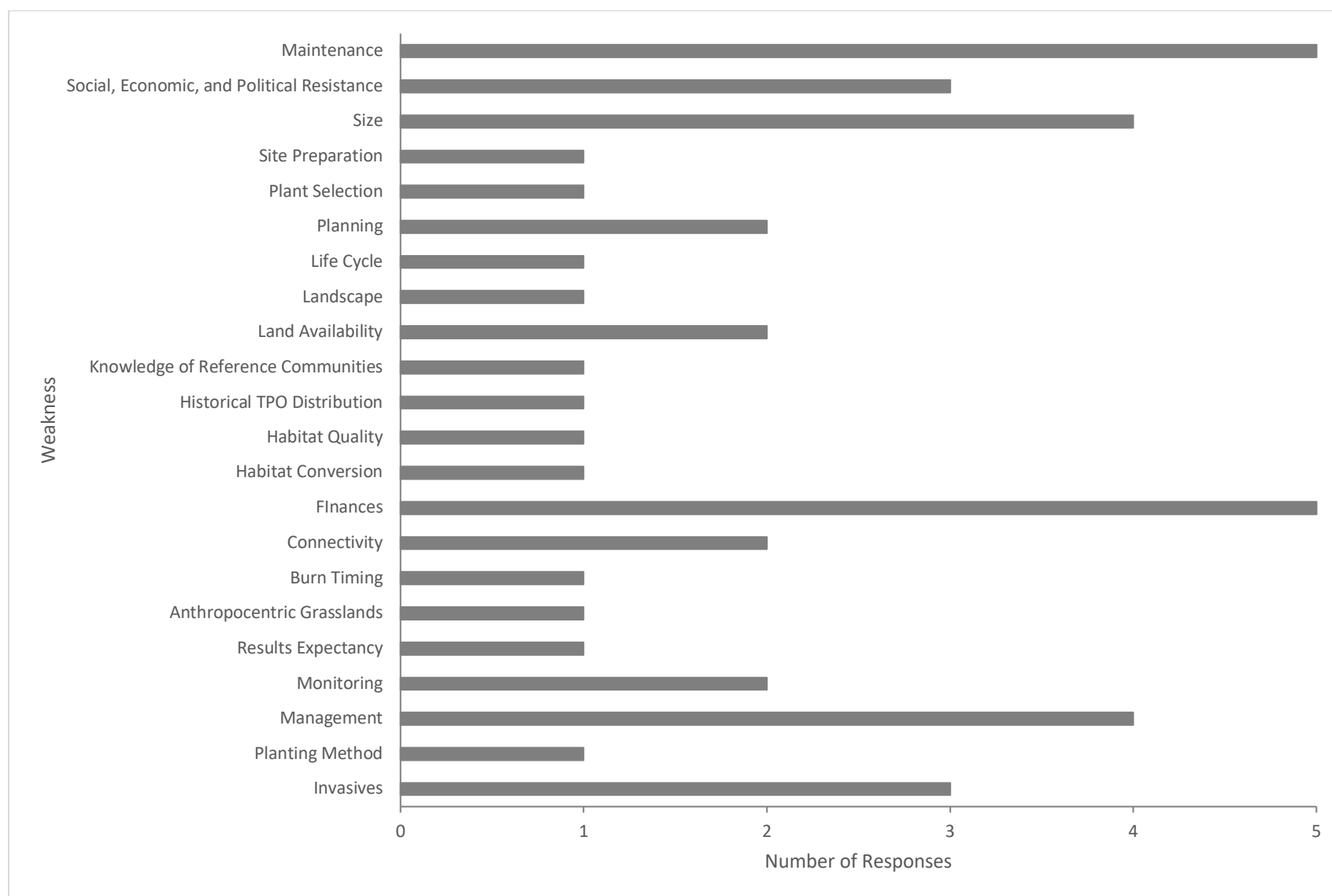


Figure 29. Weaknesses of past and/or current *S. magna*, grassland bird, and/or tallgrass prairie restoration projects in Ontario.

4.3.2 Future Restoration Strategies

Respondents were asked for technical ways (*e.g.*, restoration methods, monitoring programs, *etc.*) that future *S. magna*, grassland bird, and/or tallgrass prairie restoration efforts could be improved. Responses contained themes associated with the four restoration stages (Gann et al. 2019; Figure 30). The most common themes, regardless of restoration stage, were ‘management and monitoring’ (n = 10) and ‘pre-project’ (n = 3; Figure 31). Two respondents indicated that there were many improvements (Figure 31).

Figure 30. Technical improvements to future Eastern Meadowlark (*Sturnella magna*, L.), grassland bird, and/or tallgrass prairie restoration projects, organized by restoration stage: Planning and Design (blue); Implementation (orange); Monitoring, Documentation, Evaluation, and Reporting (MDER; yellow); and Post-implementation Maintenance (green).

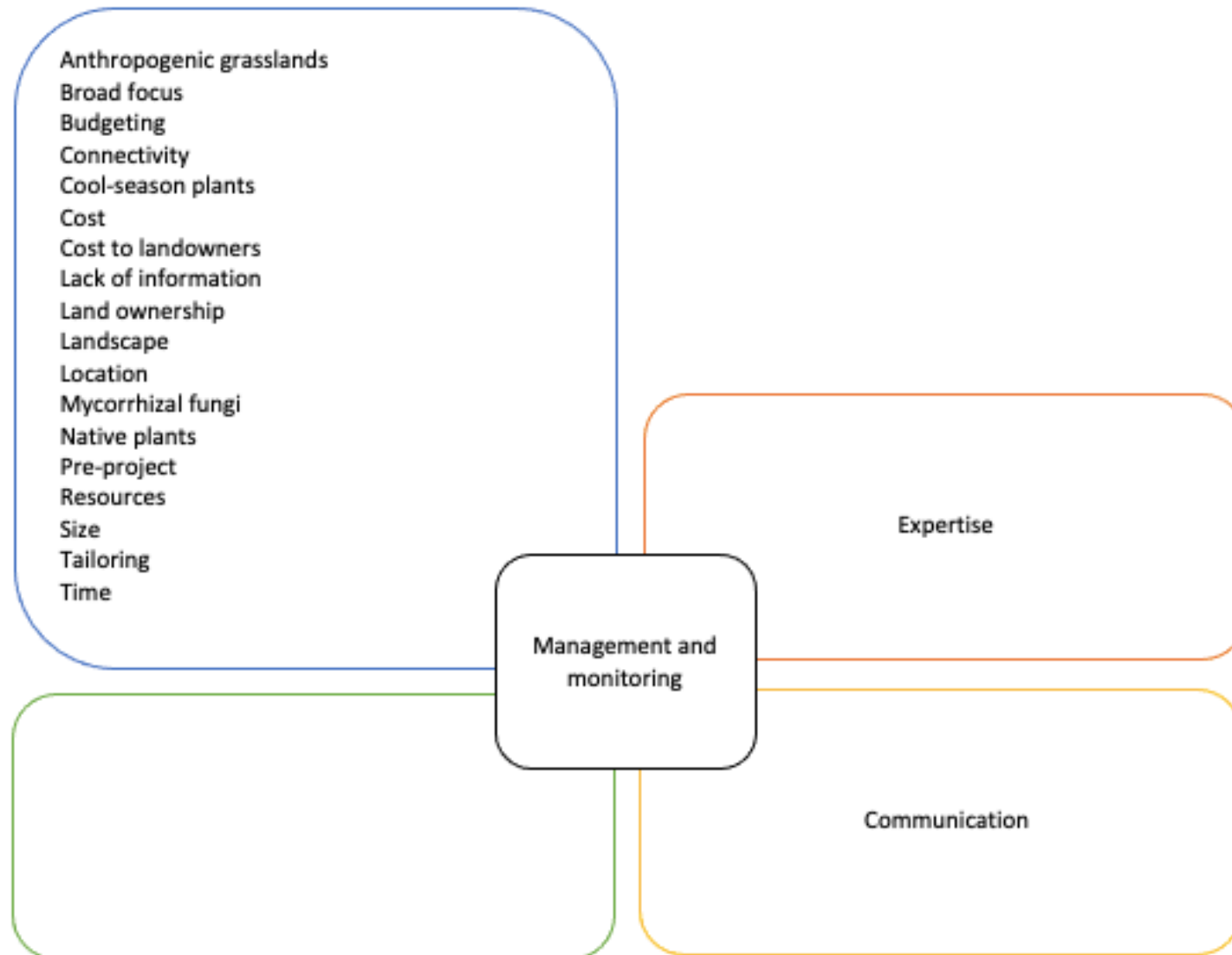
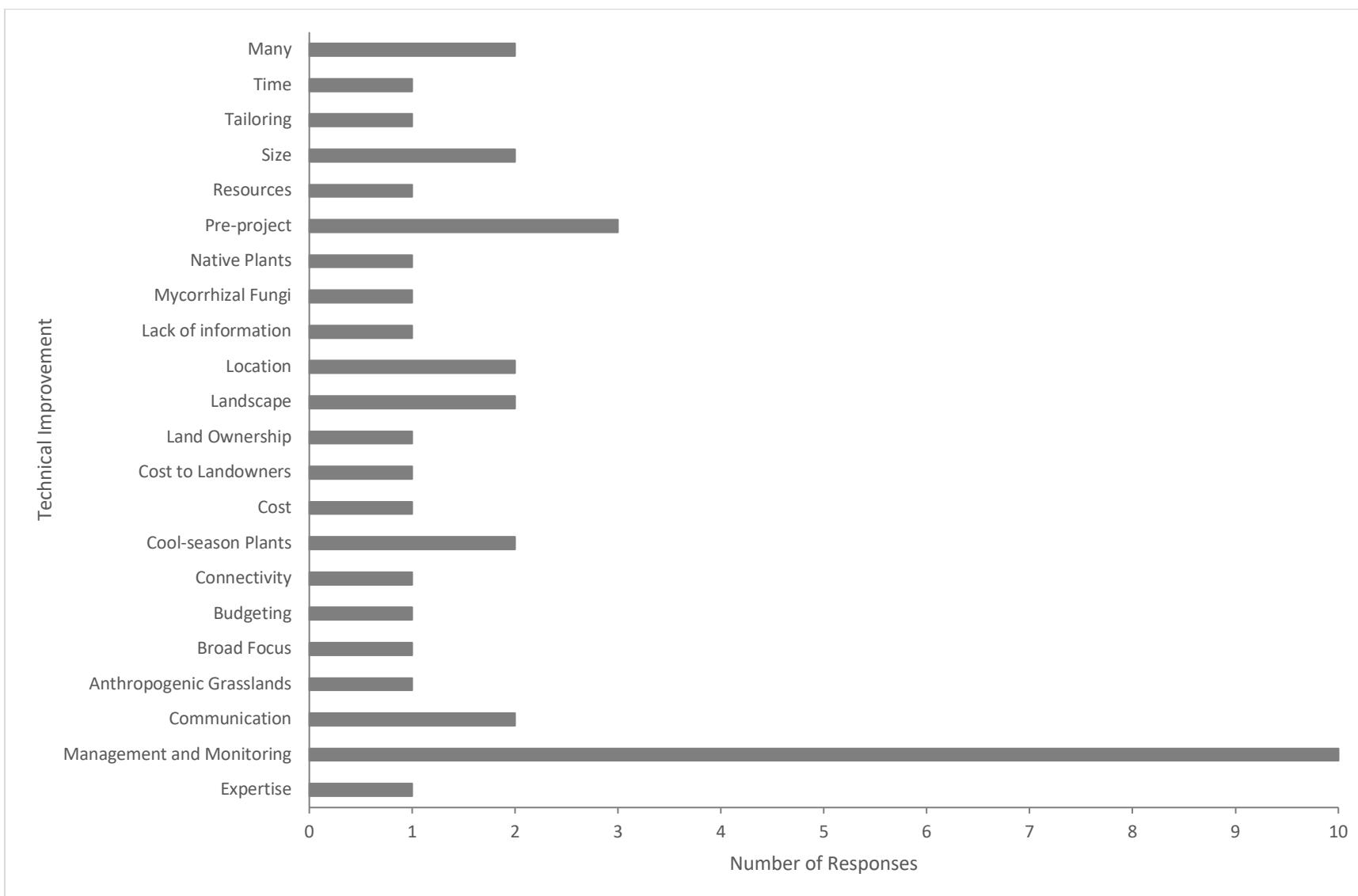


Figure 31. Technical improvements to future Eastern Meadowlark (*Sturnella magna*, L.), grassland bird, and/or tallgrass prairie restoration projects.

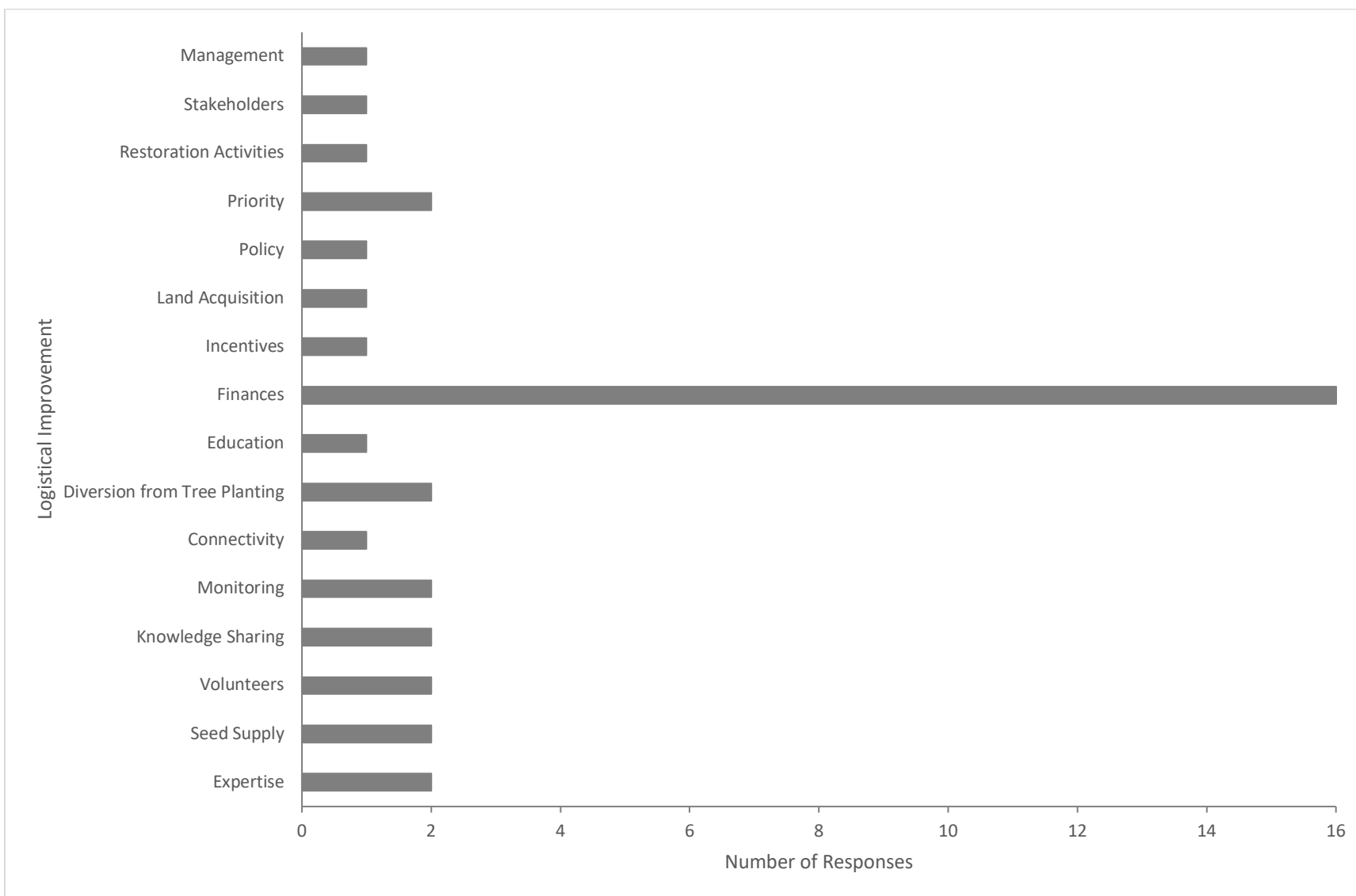


Respondents were asked for logistical ways (*e.g.*, monetary, labour, *etc.*) that future *S. magna*, grassland bird, and/or tallgrass prairie restoration efforts could be improved. Responses contained themes associated with the four restoration stages (Gann et al. 2019; Figure 32). The most common theme, regardless of restoration stage, was ‘finances’ (n = 16; Figure 33).



Figure 32. Logistical improvements to future Eastern Meadowlark (*Sturnella magna*, L.), grassland bird, and/or tallgrass prairie restoration projects, organized by restoration stage: Planning and Design (blue); Implementation (orange); Monitoring, Documentation, Evaluation, and Reporting (MDER; yellow); and Post-implementation Maintenance (green).

Figure 33. Logistical improvements to future Eastern Meadowlark (*Sturnella magna*, L.), grassland bird, and/or tallgrass prairie restoration projects.



Respondents were asked to list the top three most important geographical areas in Ontario for future *S. magna* restoration projects. Responses were assigned points according to the rank given by the respondent: 1st worth 3 points, 2nd worth 2 points, and 3rd worth 1 point. The points were added for each geographical area to determine the ranking among all responses. The three highest ranked areas were ‘southern Ontario’, ‘southwestern Ontario’, and ‘eastern Ontario’ (Table 5).

Table 5. Ranked geographical areas for future Eastern Meadowlark (*Sturnella magna*, L.) restoration.

Weighted Rank	Geographical Area	Number of Points
1	Southern Ontario	39
2	Southwestern Ontario	19
3	Eastern Ontario	15
4	Central Ontario	11
5	Farmland	3
5	Protected land	3
5	Northern Ontario	3
6	Existing areas with <i>S. magna</i>	2
7	Energy corridors	1
7	Historical tallgrass prairie range	1
7	Non-intensive agricultural areas	1

Respondents were asked to list the top three most important research areas for future *S. magna* restoration. The two highest ranked themes were ‘restoration’ (n = 8) and ‘anthropogenic vs. native or restored grasslands’ (n = 6; Table 6).

Table 6. Ranked research targets for future Eastern Meadowlark (*Sturnella magna*, L.) restoration.

Weighted Rank	Theme	Number of Responses
8	Restoration	4
6	Anthropogenic vs. Native or Restored Grasslands	2
3	Agricultural Trends	1
3	Habitat Flexibility	1
3	Habitat Size	1
3	Locations	1
3	Nest Predation	1
3	Threats	1
3	Timing of Habitat Use	1
3	Vegetation	1
3	Succession	2
2	Climate Change	1
2	Connectivity	1
2	Habitat Features	1
2	Landowner Incentive Programs	1
2	Landscape Composition	1
2	Migration and Wintering Areas	1
2	Nesting Dates	1

Weighted Rank	Theme	Number of Responses
2	SAR Status	1
2	Use of Restored Habitat	2
1	Brood Success	1
1	Hay Species	1
1	Historical Use of Eastern Grasslands	1
1	Population Dynamics	1
1	Prairie and Savannah Ecology	1

Respondents were asked for any knowledge gaps that, if better understood, would improve *S. magna* habitat restoration in Ontario. Themes were either associated with better understanding *S. magna*, better understanding of restoration, or both. The most common themes overall were ‘agricultural effects’ (n = 3), ‘habitat unsuitability’ (n = 2), and ‘management strategies’ (n = 2; Figure 34). ‘Agricultural effects’ was the most common theme associated with *S. magna*, and ‘management strategies’ was the most common theme associated with restoration (Figure 34). ‘Habitat structures’ (n = 1) and ‘optimization’ (n = 1) were themes associated with both categories (Figure 34). One respondent indicated that there were no knowledge gaps.

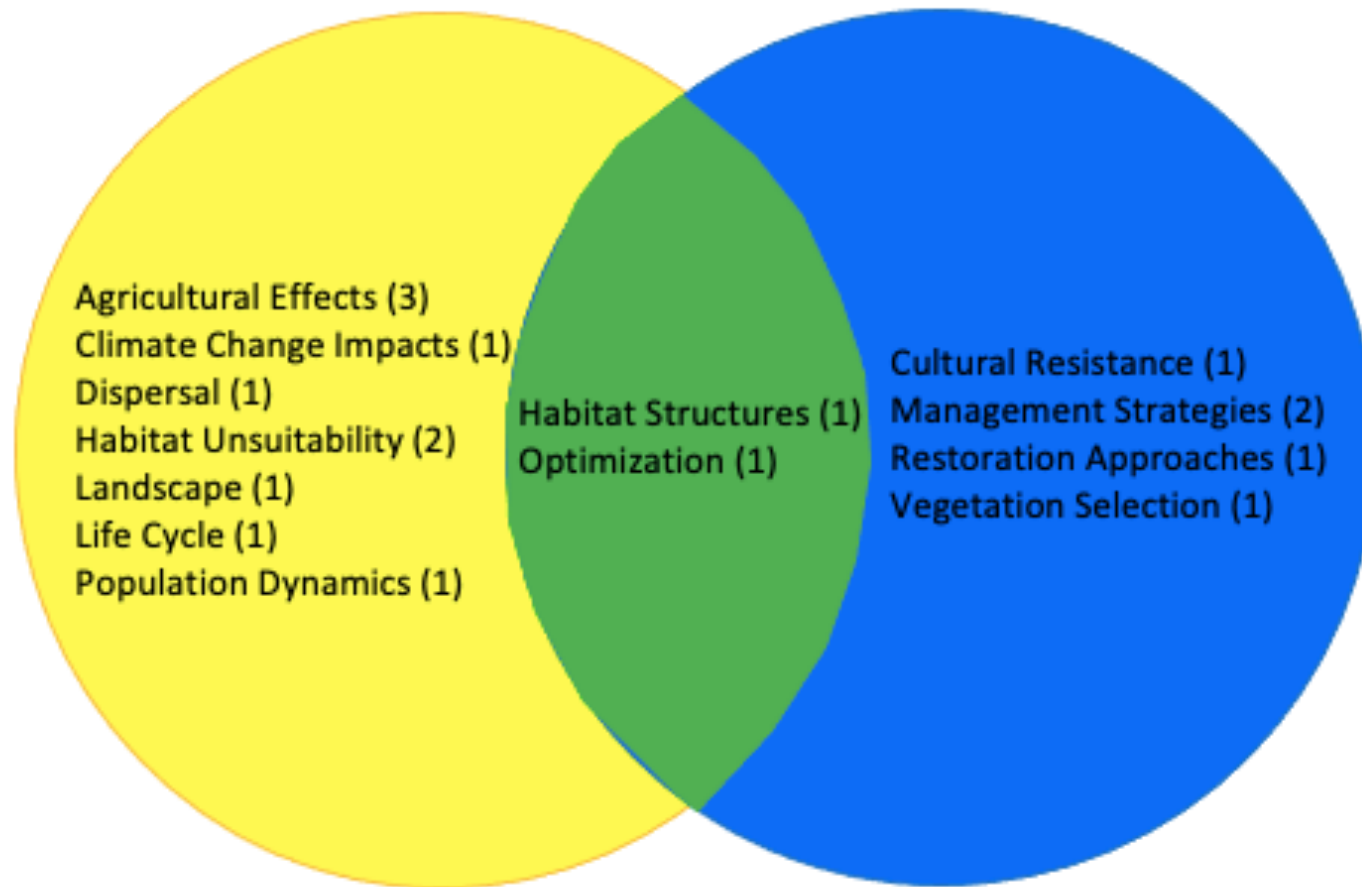


Figure 34. Knowledge gaps regarding Eastern Meadowlark (*Sturnella magna*, L.) habitat restoration in Ontario, organized by theme: *S. magna* (yellow), restoration (blue), and both (green). Number of responses for each knowledge gap is given in brackets.

4.4 Discussion

This study addressed research question II) What restoration strategies are currently being employed in Ontario for tallgrass prairies and/or *S. magna*, and how can future efforts be improved? I sought to answer this question by determining what restoration strategies have been or are currently being employed in Ontario for *S. magna*, grassland birds, or tallgrass prairies, and determining how future restoration projects in Ontario can be improved to better target *S. magna*.

An online survey about restoration strategies for *S. magna*, tallgrass prairie, and grassland bird habitat restoration in Ontario was sent to 334 knowledgeable individuals. Thirty-five responses were received. The survey asked the respondents to assess their knowledge of the subject matter in order to inform the reliability of the information received from the survey. The respondents' self-assessed high familiarity with the subject matter and experience with relevant restoration projects provides confidence in the reliability of the information disseminated by the respondents (see Figure A1, Appendix A).

The results of the survey provided insights to the following questions:

- I. What restoration activities have already been conducted, and where?
- II. What strategies were used during restoration?
- III. Have past projects been effective at restoring *S. magna*, grassland birds, or tallgrass prairies?
- IV. What are the limitations or strengths of current or past restoration strategies?
- V. How can future restoration projects for *S. magna*, grassland birds, or tallgrass prairies be improved?

These questions provide a framework for examining the results of the survey and how they relate to the overall research question.

4.4.1 What restoration activities have already been conducted, and where?

The responses given by the survey show that restoration activities for *S. magna* have taken place across southern Ontario. Certain areas have had clusters of restoration projects, such as in Windsor and Northumberland County.

The most recent data from the latest Ontario Breeding Bird Atlas data (from 2021 – 2025) show that *S. magna* is uniformly distributed across southern Ontario during the breeding season (Figure 35; NatureCounts 2025). *S. magna* is also found in pockets further north on Manitoulin Island, in Sault Ste. Marie, along the Highway 11 corridor, and in the upper Ottawa Valley. There are gaps in the distribution in areas of far southwestern Ontario, in Norfolk County, and in the Stratford area. Interestingly, the gaps in *S. magna*'s distribution in southwestern Ontario and in Norfolk County roughly align with the location of some restoration projects noted by the survey respondents. Ontario Breeding Bird Atlas data from Atlas-1 (1981 – 1985) and Atlas-2 (2001 – 2005) show that *S. magna* were more consistently found in these parts of the province historically (Figure 36 and Figure 37; NatureCounts 2025). This suggests that *S. magna* have been declining in these regions for the past few decades. It is unclear whether the restoration projects in these areas are in response to the local decline in *S. magna* specifically, a decline in grassland habitat more generally, or whether this relationship is coincidental. Nonetheless, this relationship should be investigated further as it may indicate the need for further restoration in these areas, as *S. magna* are no longer finding the habitat there that they need.

Multiple respondents provided *rare* Charitable Research Reserve as an example of a previous grassland restoration project. *rare* is a land-trust located near Cambridge that consists of a complex of natural areas totalling approximately 1500 acres (rare Charitable Research Reserve 2023). *rare* has an established research program on tallgrass prairie ecology featuring work from several Ontario universities and research institutions (Schneider et al. 2017; Cray et al. 2021; Sharkey 2022).

Other respondents noted restoration and conservation work done by Alderville First Nation and Walpole Island First Nation. Alderville First Nation, located just south of Rice Lake, is located within the Rice Lake Plains area. Walpole Island First Nation is located on Walpole Island, which lies along the northeastern shore of Lake St. Clair. Historical accounts for both of these regions describe extensive grasslands (Bakowsky & Riley 1994).

Ojibway Prairie is another area that was noted by respondents. Located in Windsor, Ojibway Prairie is a complex of both native and restored prairie and savannahs. Six of the adjacent properties are managed by the City of Windsor, while a nearby nature reserve is managed by Ontario Parks (City of Windsor 2024). Ojibway Prairie Provincial Park is the largest protected native prairie remnant in Ontario (Ministry of the Environment, Conservation and Parks 2025). Estimates from historical accounts suggest that the original grassland occupying this area totalled 45 km² (Bakowsky & Riley 1994).

Luther Marsh Wildlife Management Area is another area that was noted by respondents for grassland restoration efforts. Located near Grand Valley, Luther Marsh is managed by Grand River Conservation Authority. Several grassland restoration projects have been completed at Luther Marsh. The 2019 management plan for the area designated 204 ha for grassland restoration (Tupman n.d.). Since the designated lands were adjacent to the existing wetland, one of the main

goals was to provide nesting habitat for waterfowl. The project also aimed to attract grassland specialists like *S. magna*. An additional 40 ha of nearby farmland were converted to tallgrass prairie in 2019 by the Canadian National Railway Company, Ducks Unlimited Canada, and the Ontario Ministry of Natural Resources (Ducks Unlimited Canada 2025). The project was intended as a pre-emptive habitat offset measure by Canadian National for proposed works to expand railway infrastructure in the area. The intention was to offset negative impacts to grassland bird habitat.

Figure 35. Distribution of Eastern Meadowlark (*Sturnella magna*, L.) in southern and central Ontario using Ontario Breeding Bird Atlas (Atlas-3) data (2021 – 2025). Occurrence data are shown in 10 x 10 km squares. Red: confirmed breeding evidence, orange: probable breeding evidence, yellow: possible breeding evidence, grey: historical presence (*i.e.*, pre-2021). The Atlas-3 results are preliminary, and full data collection and analysis methods have not yet been published. For an explanation of the methods from Atlas-2 (2001 – 2005), please see Cadman et al. (2007). Figure is adapted from NatureCounts (2025).

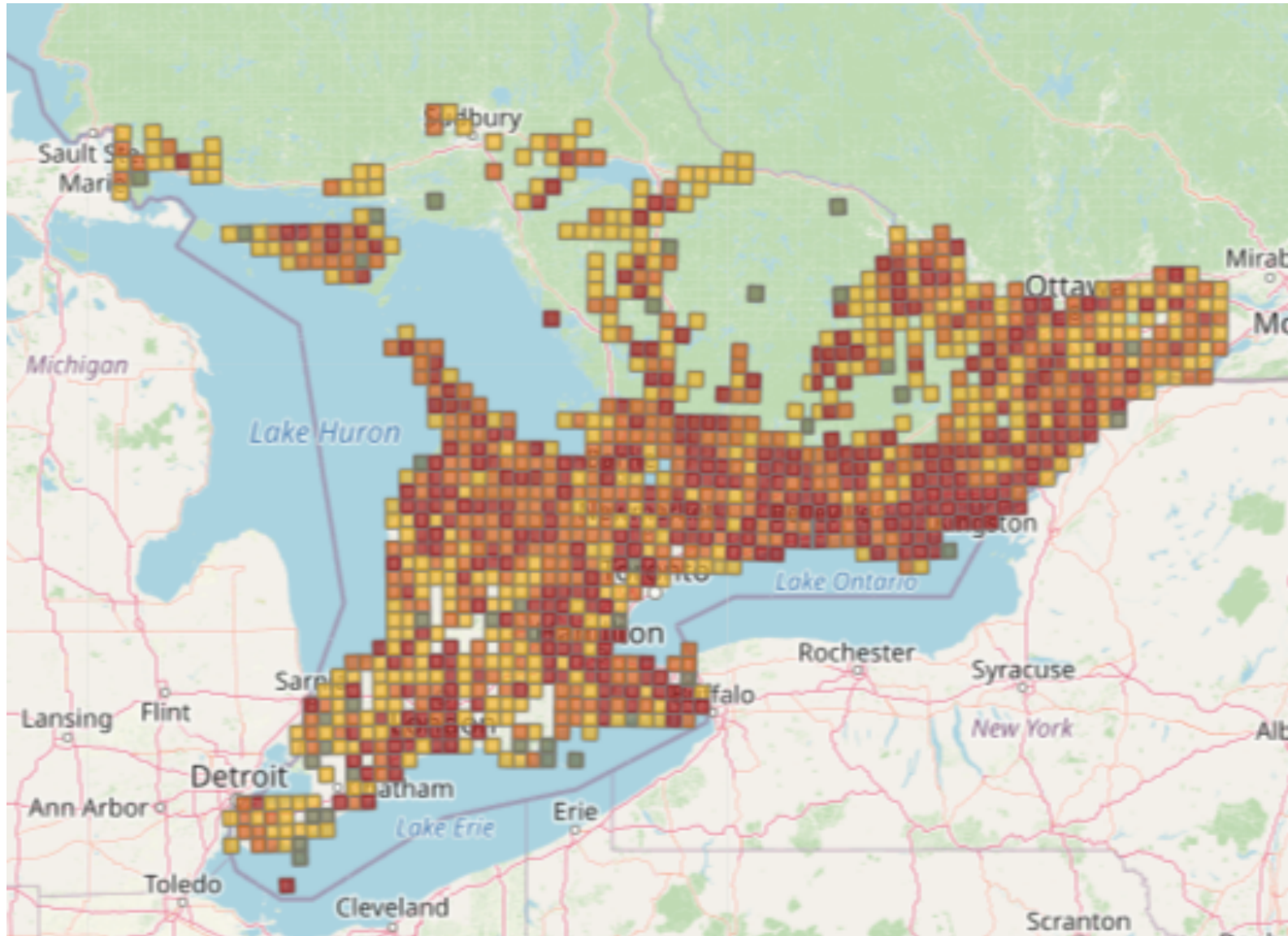


Figure 36. Distribution of Eastern Meadowlark (*Sturnella magna*, L.) in southern and central Ontario using Ontario Breeding Bird Atlas (Atlas-2) data (2001 - 2005). Occurrence data are shown in 10 x 10 km squares. Red: confirmed breeding evidence, orange: probable breeding evidence, yellow: possible breeding evidence. For an explanation of the methods, please see Cadman et al. (2007). Figure is adapted from NatureCounts (2025).

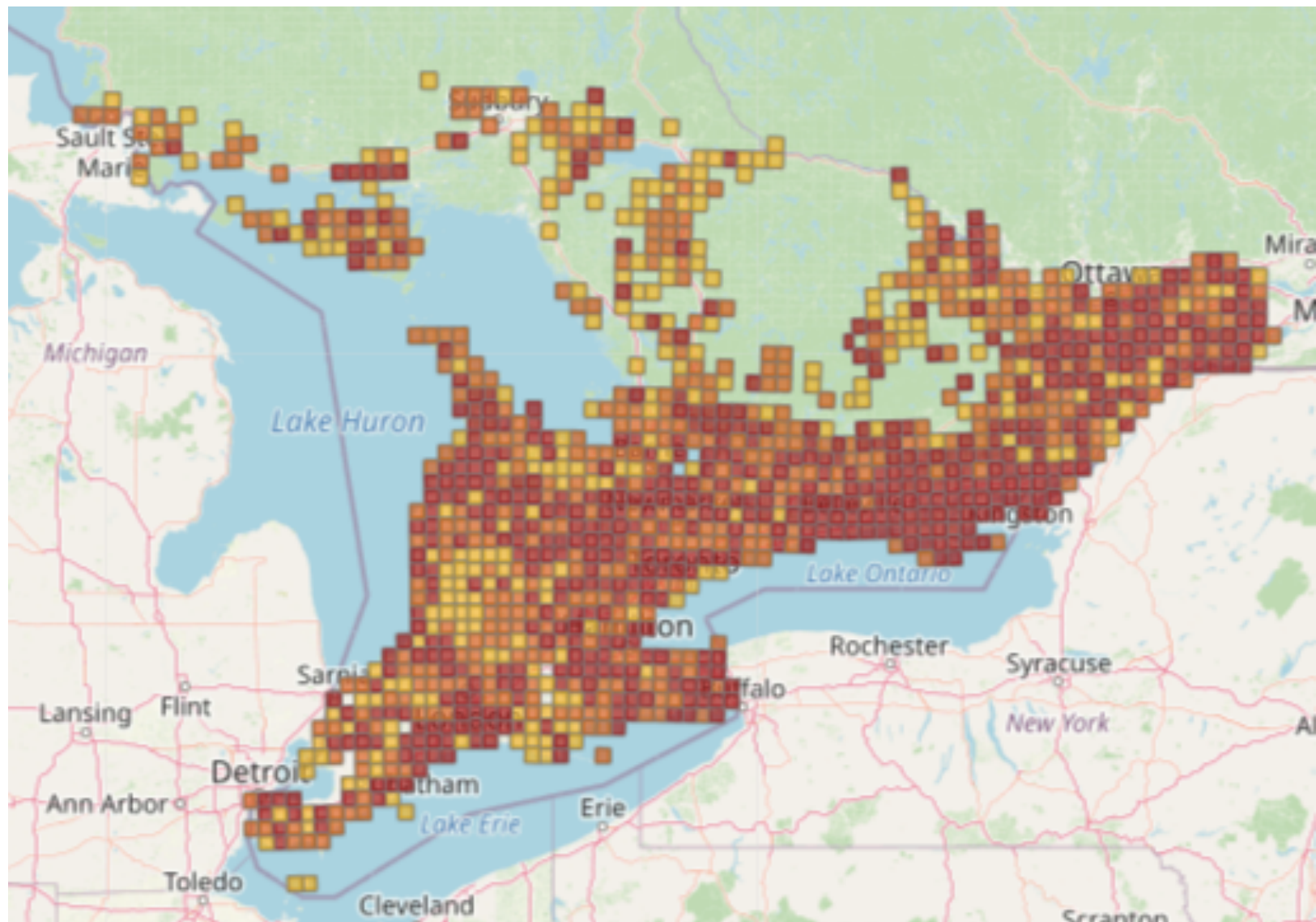
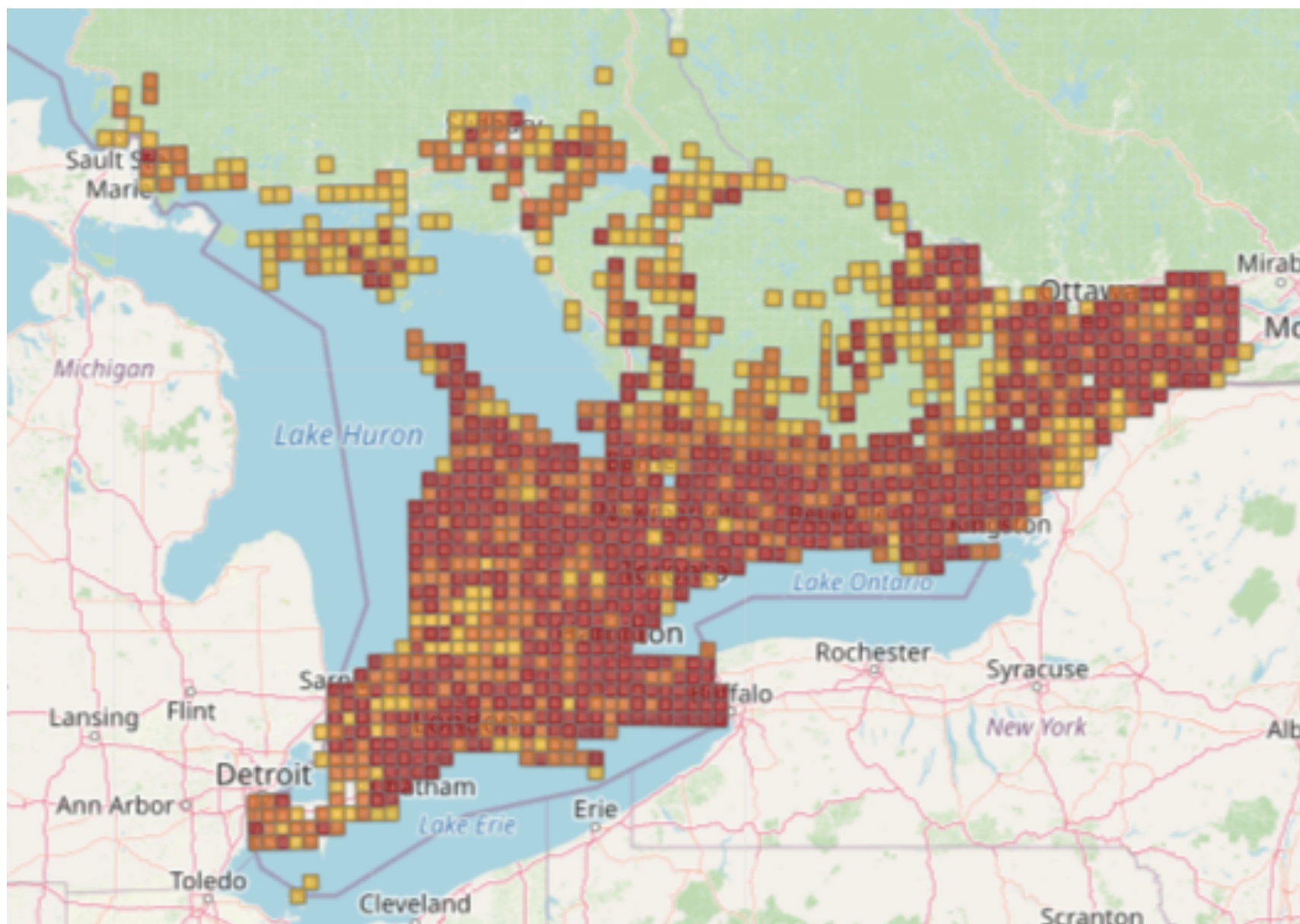


Figure 37. Distribution of Eastern Meadowlark (*Sturnella magna*, L.) in southern and central Ontario using Ontario Breeding Bird Atlas (Atlas-1) data (1981 - 1985). Occurrence data are shown in 10 x 10 km squares. Red: confirmed breeding evidence, orange: probable breeding evidence, yellow: possible breeding evidence. For an explanation of the methods, please see Cadman et al. (1987). Figure is adapted from NatureCounts (2025).



Interestingly, one respondent indicated that they were currently working on a Kirtland's Warbler (*Setophaga kirtlandii*, Baird) habitat restoration project in Simcoe County. They indicated that the early-successional habitat used by *S. kirtlandii* – young, spaced-out Jack pine (*Pinus banksiana*, Lamb.) stands – also attracted breeding *S. magna*. Van Dyke et al. (2024) examined the avian community of *P. banksiana* plantations in Michigan that were part of *S. kirtlandii* habitat restoration efforts. Although no *S. magna* individuals were found within the plantation, numerous other grassland specialists were observed such as *S. pallida*, Eastern Bluebird (*Sialia sialis*, L.), Field Sparrow (*Spizella pusilla*, Wilson), and Upland Sandpiper (*Bartramia longicauda*, Bechstein). The potential use of *P. banksiana* plantations by grassland birds in Ontario should be investigated further, as these projects may have the ability to restore habitat for multiple different species.

4.4.2 What strategies were used during restoration?

Delayed hay-harvesting was cited by respondents most often as a management practice for *S. magna* habitat. The effect of hay harvesting and mowing differs among studies. Corace et al. (2009) found that mowing hayfields in the Upper Great Lakes region of the United States had no effect on breeding bird populations in said fields, including *S. magna*. Similarly, Herkert (1991) found that *S. magna* preferred to nest in areas that had been previously mowed. Conversely, Ingold (2002) found the opposite trend – that the nest density of grassland birds was higher on unmowed plots than mowed plots. Kershner and Bollinger (1996) found that *S. magna* nest density declined as mowing frequency increased. The difference seems to lie in the timing of when mowing occurred. Lusier and Thompson (2009) examined grassland bird nest survival in relation to the timing of mowing in hayfields in Arkansas. They found that when a field was mowed early (*i.e.*,

between May 26 – 31), 100% of the nests were destroyed. However, when a field was mowed later (*i.e.*, between June 17 – 26), only 4% of the nests were destroyed.

Respondents were divided on the frequency of post-restoration monitoring (Figure 24). This is similar to results found by Mendez-Toribio et al. (2021), who conducted a survey of restoration practitioners who had worked on projects in Mexico. In their study, 57% of respondents indicated that a monitoring plan was in place before works began. Similar trends have been found for restoration projects in Canada. Alamenciak et al. (2023) conducted a review of peer-reviewed literature on restoration across Canada. They found that 75% of the studies they reviewed were monitoring for less than five years post-restoration. Post-restoration monitoring is held as a core stage of restoration projects by the Society for Ecological Restoration (Gann et al. 2019). However, post-restoration monitoring may be seen as an ‘extra’ step, especially when working with a limited budget (Mendez-Toribio et al. 2021). Mendez-Toribio et al. (2021) found that of the projects that had established a monitoring plan at the beginning, only 47% had funding allocated specifically for that purpose. Although finances can be a barrier, there are ways that restoration practitioners can optimize monitoring efforts to make the most out of a limited budget. Baird et al. (2021) compared the accuracy and cost of using an expert, citizen scientists, stakeholders, or remote sensing to conduct post-restoration monitoring. They found that while the expert had the most accurate data, citizen-scientists and stakeholders had similar levels of accuracy at a coarse scale. The cost of using citizen-scientists and stakeholders was higher due to associated research costs such as transportation and food, but this cost is expected to be lower in a non-research context. Remote sensing was the fastest and most accessible option, however was the least accurate and most expensive.

In my study, 63% of respondents indicated that projects either mostly used interventions or used a mix of interventions and “passive” techniques. This percentage is comparable to the results of other surveys on restoration strategies (*i.e.*, 75% in Mendez-Toribio et al. 2021). While the results are comparable to other studies, the variability highlights how the context of a specific project can impact the techniques used (Rohr et al. 2018). Budgetary constraints can also influence the decision whether to use interventions or not, as using interventions is usually more expensive (Rohr et al. 2018). Some jurisdictions require compensatory restoration when there has been environmental destruction in order to monetarily compensate the public for a loss in ecosystem services during the period before the system has been restored. Since strategies that use interventions are generally faster at achieving the target system, they can actually be more cost-effective than “passive” strategies (Rohr et al. 2018). The mixed results may also be due to different interpretations of the terminology. In older literature, the terms “active” and “passive” are used to distinguish between projects done using interventions and those without. The language in the field of restoration has shifted away from these terms, as they present a dichotomy that is not always representative of all methodologies (Rohr et al. 2018). Expanded categories have been proposed, such as “natural restoration” (formerly “passive”), “assisted restoration” (formerly “active”), and “reconstructive restoration” (a new term describing a combination of the previous two categories; Gann et al. 2019, Atkinson & Bonser 2020).

4.4.3 Have past projects been effective at restoring *S. magna*, grassland birds, or tallgrass prairies?

Responses on the effectiveness and sufficiency of grassland restoration projects tended towards the negative end but were largely mixed overall. This may be due to ambiguity in the language used. What exactly defines an ‘effective’ project and the level of restoration needed to

be deemed ‘sufficient’ is inherently subjective. It is therefore not surprising that the results to these questions were variable. However, they may still provide some insights into the state of *S. magna* and grassland restoration in Ontario.

Respondents indicated that current efforts in Ontario were largely insufficient and ineffective at restoring *S. magna* habitat. This indicates that more restoration projects need to be undertaken for *S. magna* in Ontario to address this insufficiency. It also indicates that those plans need to be adjusted in order to be more effective at restoring habitat. Many reasons were cited for the lack of sufficiency, including low quantity and habitat loss. A common reason cited for a lack of effectiveness was a lack of follow-up. This reflects the need for restoration plans to include a post-restoration monitoring stage which incorporates adaptive management practices (Gann et al. 2019).

Notably, a number of respondents indicated that current levels were in fact sufficient and/or effective. One respondent indicated that effectiveness varies from project to project. This may be due to the inherent variability and complexity that is at play in all restoration projects (Rohr et al. 2018). However, this may also indicate a lack of standardization in approach when it comes to restoring this grassland habitats. Several respondents indicated uncertainties with funding sources as a barrier to restoration. Variation in monetary resources from project to project may impact what resources are available to restoration practitioners, thereby potentially affecting the success of the project. This may also be due to uncertainties around habitat needs and best practices, highlighting the need for increased communication among restoration practitioners to share knowledge and results.

4.4.4 What are the limitations or strengths of current or past restoration strategies?

Project financing and maintenance were found to be prominent issues in relevant restoration projects in Ontario. This reflects a wider trend, since many restoration projects experience issues with securing funding (Rohr et al. 2018). The issues around financing seem appropriate due to the fact that most respondents indicated that restoration projects were carried out by non-profit organizations. Due to their structure, non-profit organizations usually operate under conservative budgets. There are actions non-profits can take to better secure funding, such as involving stakeholders in the project from the beginning (Gann et al. 2019). Rohr et al. (2018) also suggest involving experts, such as ecological economists, in pre-planning discussion to help with cost-effective decision making.

Respondents also indicated issues with location as a limitation to a project's success. Many respondents indicated that areas devoted for restoration were too small to target area-sensitive species such as *S. magna*. Additionally, respondents indicated that there is a lack of understanding of how patch size and the surrounding landscape influences habitat selection by grassland bird species. Many studies have documented area-sensitivity in *S. magna* (e.g., Askins 1993; Vickery, Hunter, and Melvin 1994), with minimum patch size requirements of anywhere from 1 – 20 ha (Samson 1980; Herkert 1994; Forman et al. 2002). However, the area-sensitivity of *S. magna* is debated, with several studies failing to find a correlation between *S. magna* abundance and patch size (e.g., Winter 1998; Winter & Faaborg 1999; Horn et al. 2000). As noted by the respondent, many studies have been done on how factors like edge effects, fragmentation, and habitat occurrence at a landscape scale affect grassland bird habitat occupancy, sometimes with conflicting results or with confounding factors (Wiens 1969; Herkert 1991; Forman et al. 2002; Ellison et al. 2013; McCracken et al. 2014; de Zwaan et al. 2022).

One respondent indicated that grassland restoration was being done in areas of the province where grasslands were not historically found, which may be limiting their success. However, this claim contradicts with published surveys of existing prairie remnants. Survey respondents noted that restoration projects were occurring across southern Ontario (Figure 17). Remnants of these habitats are also found throughout southern Ontario (Bakowsky & Riley 1994; Adelman & Schwartz 2013). While it can be difficult to know exactly where prairies existed in Ontario pre-colonization, it appears that most restoration projects are occurring in areas that were occupied by native grasslands at some point. It is possible that without protection or management, some of these remnants have been converted to other land uses or have transitioned to late-successional systems. Over time, this can result in a loss of knowledge of the location of historical prairies and it can make it appear that restoration is occurring in areas that had not previously hosted these ecosystems.

Respondents also indicated that communication with the public and stakeholders can present a challenge. Respondents indicated that grasslands are not seen as valuable ecologically to the public. They indicated that many members of the public view grasslands as “weedy” and that restored areas are often converted back to agriculture or other land uses if ownership changes. Cairns & Heckman (1996) note the relationship between a restoration project and the local community. They note that due to humanity’s expansion across the globe, any landscape-level restoration project will inevitably influence and be influenced by local communities. The responses to my survey highlight the importance of this relationship, while also noting how a damaged relationship can present challenges to a restoration project. As noted in this survey, improving communication between stakeholders and restoration practitioners is crucial to maintaining this relationship. This may involve using non-traditional scientific means of communication. Green et

al. (2018) note that communicating results to the public via storytelling rather than traditional channels (i.e., peer-reviewed literature) can improve understanding and emotional investment.

Respondents also indicated challenges with communicating appropriate timelines to stakeholders. Restoration is a slow process, and it can sometimes take years to see measurable signs of success. Respondents indicated that the expectation by funders is for a project to be able to be deemed successful or not earlier than these results can be apparent. Respondents indicated that this can make it difficult to secure long-term funding. Cooke et al. (2020) discuss the issue of defining success in applied environmental science. They acknowledge that ‘success’ can vary on a case-by-case basis, and defining what exactly a ‘successful’ project looks like is not as straightforward as it seems. Although providing an all-encompassing definition of ‘success’ is difficult, the authors provide a list of best practices to achieving a result that can be deemed ‘successful’, such as defining research questions and approaches with project partners, balancing short- and long-term goals, and making partners aware from the beginning of the limitations of the research.

Many respondents indicated that a broad-focus approach to restoration was seen as a strength of current projects. They indicated that projects that focused on restoring a target community, rather than habitat for a specific species, had greater levels of success since multiple aspects of the ecosystem were considered. Ecologists have been championing the concept of ecosystem-level conservation for decades (Lea 2004). The long-time focus on species at risk is borne out of simplicity, rather than accurately representing reality. Species declines affect the entire ecosystem. Expanding the ‘at-risk’ definition to include whole ecosystems rather than single species conserves the entire system that is being affected. Grassland systems in particular can benefit from this approach. In 2000, Defenders of Wildlife published a list of the 21 most

endangered ecosystems in the United States. This list included both “Eastern Grasslands, Savannas, and Barrens” and “Tallgrass Prairie” (as cited in Lea 2004).

Respondents also indicated that projects which carried out aspects of all restoration stages, such as pre-project planning, active management, and post-restoration monitoring had greater success than those which were primarily focused on the actual restoration. This general idea has also been discussed in restoration literature. Angelopoulos et al. (2017) conducted a literature review of river restoration projects across Europe. They found that the majority of projects had not completed pre-project planning and/or post-restoration monitoring. As a result, most projects had no reported evaluation of success. In response, the authors developed a framework to be used in future river restoration projects which emphasizes developing monitoring goals and defining success during the project planning stage. While this framework was designed with river restoration in mind, the concepts within are broad enough to be applicable to a range of environments, including terrestrial systems.

Collaboration and local community involvement was also seen as a strength. Respondents discussed the benefits of working with local landowners to restore habitat through incentive programs. Incentive programs have been in place in Ontario with respect to grassland birds for years. Programs such as Alternative Land Use Services and Species at Risk Partnerships on Agricultural Lands provide monetary benefits to landowners (primarily farmers) who implement conservation measures on their lands for grassland birds (ALUS Canada 2022; Ontario Soil and Crop Improvement Association 2025c). These programs can serve to connect local people to the environment and highlight the importance of their land for local wildlife. These programs also show landowners how hosting wildlife on working lands does not necessarily have to be a barrier to agricultural production.

Respondents also indicated that knowledge-sharing between organizations is vital to the long-term success of restoration projects. Alamenciak et al. (2023) found that most authors of peer-reviewed restoration literature in Canada were associated with academic institutions. They suggest that this indicates a barrier to sharing knowledge with practitioners outside of academia (*i.e.*, government, non-profit, *etc.*), as academic literature tends to be read most often by other academics. The Ontario Ministry of Natural Resources and Ministry of Environment, Conservation and Parks are in the process of creating a database of restoration projects in Ontario (S.D. Murphy, personal communication, November 13, 2025). This database would be a valuable resource to share restoration strategies, successes, and setbacks across disciplines. It would also serve as a way to connect restoration practitioners to foster greater collaboration.

4.4.5 How can future restoration projects for *S. magna*, grassland birds, or tallgrass prairies be improved?

Southern and eastern Ontario were among the most highest ranked geographical targets for future *S. magna* habitat restoration in Ontario, which matches with their proposed critical habitat (Environment and Climate Change Canada 2022). Interestingly, although southwestern Ontario was also ranked highly as a geographical target, there has not been any critical habitat identified in that part of the province (Environment and Climate Change Canada 2022). The Recovery Strategy presenting the critical habitat has not been finalized and was open for a period of public comment, so it's possible for previously overlooked habitat in southwestern Ontario to be included in a final version. It is also possible that there is a disconnect among restoration practitioners about the actual and perceived distribution of *S. magna* habitat and occurrence in Ontario.

Respondents indicated that priority areas for future *S. magna* restoration projects should take place in southern, southwestern, and eastern Ontario. All of these areas are currently occupied

by breeding *S. magna* to some degree – however as discussed above, there are noticeable gaps in parts of southwestern Ontario (Figure 35; NatureCounts 2025). Restoration efforts in this part of the province may restore habitat to the landscape that may otherwise be lacking. *S. magna* seems to be distributed relatively uniformly throughout southern and eastern Ontario. Restoration in these areas may increase the amount of habitat available so that it could support a growing *S. magna* population if required. Doing so would help stabilize the *S. magna* populations in these regions so that they become a stronghold for this species. Respondents also indicated that future restoration efforts should be focused on areas with less-intensive human activity, such as protected public lands (*i.e.*, provincial parks and conservation areas) and light-use farmland (*i.e.*, hobby farms).

Respondents indicated a desire for more research into topics related to restoration of *S. magna*. This indicates that restoration practitioners are interested in learning more about restoring these systems. Respondents also indicated a desire for more research into the use of anthropogenic and native grasslands by *S. magna*. *S. magna* has been known to occupy both types of grasslands in Ontario, however anthropogenic grasslands often pose unique threats not experienced in native grasslands (*e.g.*, mowing; McCracken et al. 2013). Alternatively, other studies have not shown hayfield mowing to have an effect on *S. magna* abundance (Corace et al. 2009). This discrepancy warrants further investigation into the potential for anthropogenic grasslands to be managed for *S. magna*. The proposed Recovery Strategy for *S. magna* also prioritizes exploring more incentive programs for agricultural grasslands to be managed for this species (Environment and Climate Change Canada 2022). Further research should also be done on the potential for anthropogenic grasslands to be ecological traps (Bock & Jones 2004). Similarly, a number of respondents indicated a lack of knowledge in the effects of agricultural operations on *S. magna*.

4.5 Conclusion

I conducted a survey of knowledgeable individuals on habitat restoration practices for *S. magna*, grassland birds, and tallgrass prairies in Ontario. Respondents provided valuable insights into the current state of this type of restoration in the province, strengths and weaknesses, and opportunities for improvements to future projects. The findings from this study were largely expected based on other academic literature within the restoration ecology field. The information provided by the survey not only offers a valuable synthesis on the current state of this field of study, but also confirms that grassland restoration in Ontario is under the same constraints as other fields of restoration. The first step in solving a problem is to acknowledge that it exists, which is what this study accomplished. The respondents of the survey have provided a summary of the challenges of Ontario grassland restoration, which can be used to create a roadmap for practical ways to move forward.

Chapter 5: Conclusion

Through this research, I aimed to provide greater clarity on the habitat requirements of and restoration priorities for *S. magna* in tallgrass prairie ecosystems in southern Ontario. My research assessed the following questions:

- I. What are the characteristics of successful nesting habitat for *S. magna*?
- II. What restoration strategies are currently being employed in Ontario for tallgrass prairies and/or *S. magna*, and how can future efforts be improved?

I used restored tallgrass prairies in Norfolk County to assess *S. magna* nesting habitat. While no *S. magna* individuals were observed nesting on these sites, this research was nonetheless able to provide valuable insights into possible habitat preferences of this species in Ontario. This research also illuminated how poorly understood *S. magna* breeding dynamics and habitat needs are in Ontario. This realization has implications for ongoing and future grassland restoration projects in Ontario that aim to provide habitat for this species.

I gathered information from knowledgeable individuals to explore current restoration activities for *S. magna* and/or tallgrass prairies in Ontario and areas for improvement. The individuals gave many insights into the strengths and challenges of restoration in these fields. They also provided valuable context on current restoration approaches and practices for these ecosystems. This research highlighted some common and widespread issues with the field of restoration in Ontario, as well as identifying what needs to change in order to remove these barriers. Another lesson learned is that ecological restoration is never a ‘one size fits all’ approach – each project presents its own challenges and warrants a different approach depending on the site history and desired outcome. One commonality is that many respondents agreed that those projects which aim to restore an entire ecosystem (*i.e.*, tallgrass prairie community) rather than targeting a specific

species (*i.e.*, *S. magna* habitat) tend to have the most success in reaching the desired outcome. Most importantly, this research identified knowledge gaps and topics for future study to better understand the role of restoration in *S. magna* conservation.

The landscape of southern Ontario is rapidly shifting. Climate warming and a growing human population are just some of the threats facing species in this region in the coming decades. As a future-focused field, restoration practitioners must grapple with increasing threats like climate change, invasive species, and urbanization. Research such as that presented here – holistic examinations of the current state of an issue that identify topics for future study – are essential for the ever-changing field of restoration. I hope that the findings from this research present a road map for Ontario’s restoration ecologists and conservation biologists to use when tackling the problem of declining grassland birds, such as *S. magna*.

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Appendices

A. Supplementary Figures

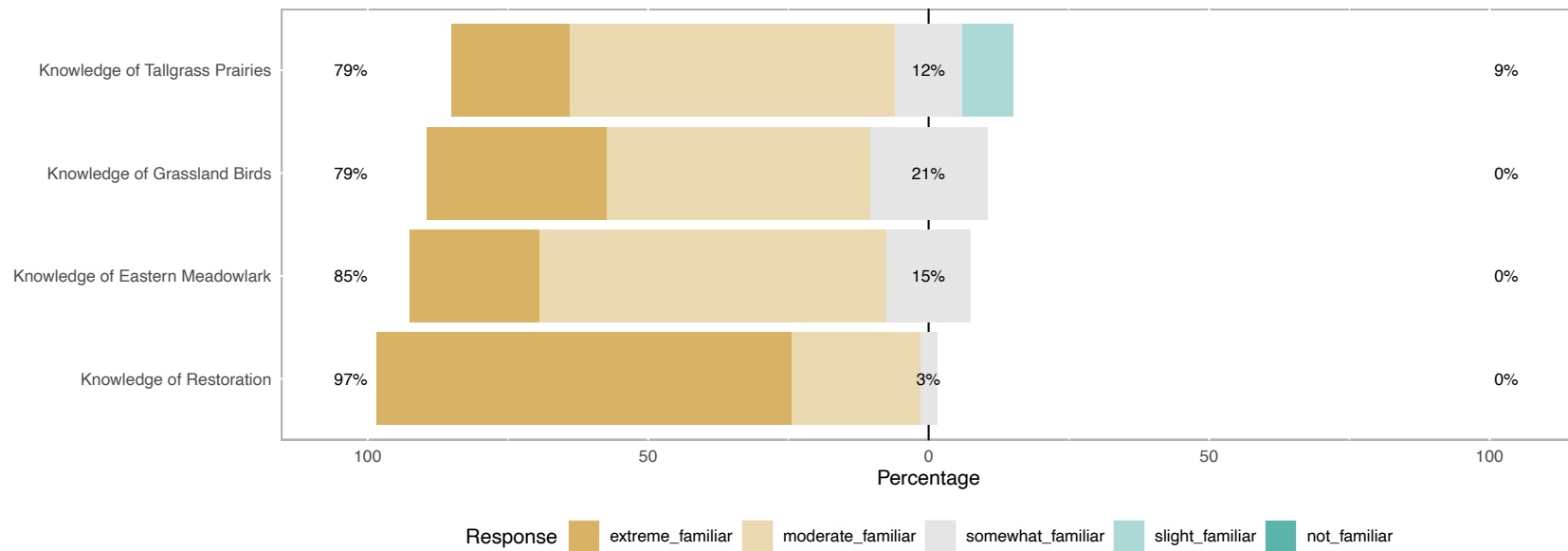
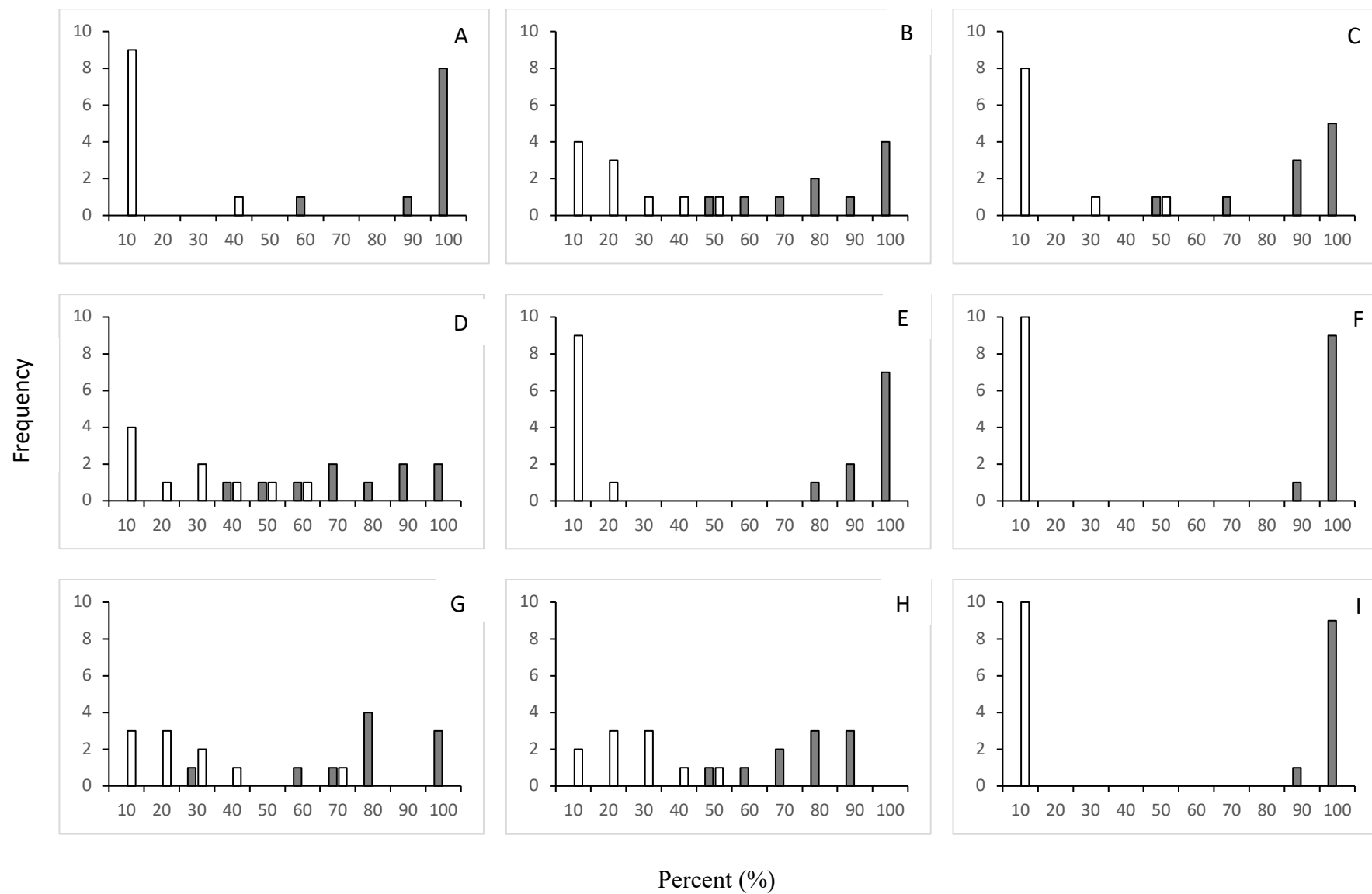
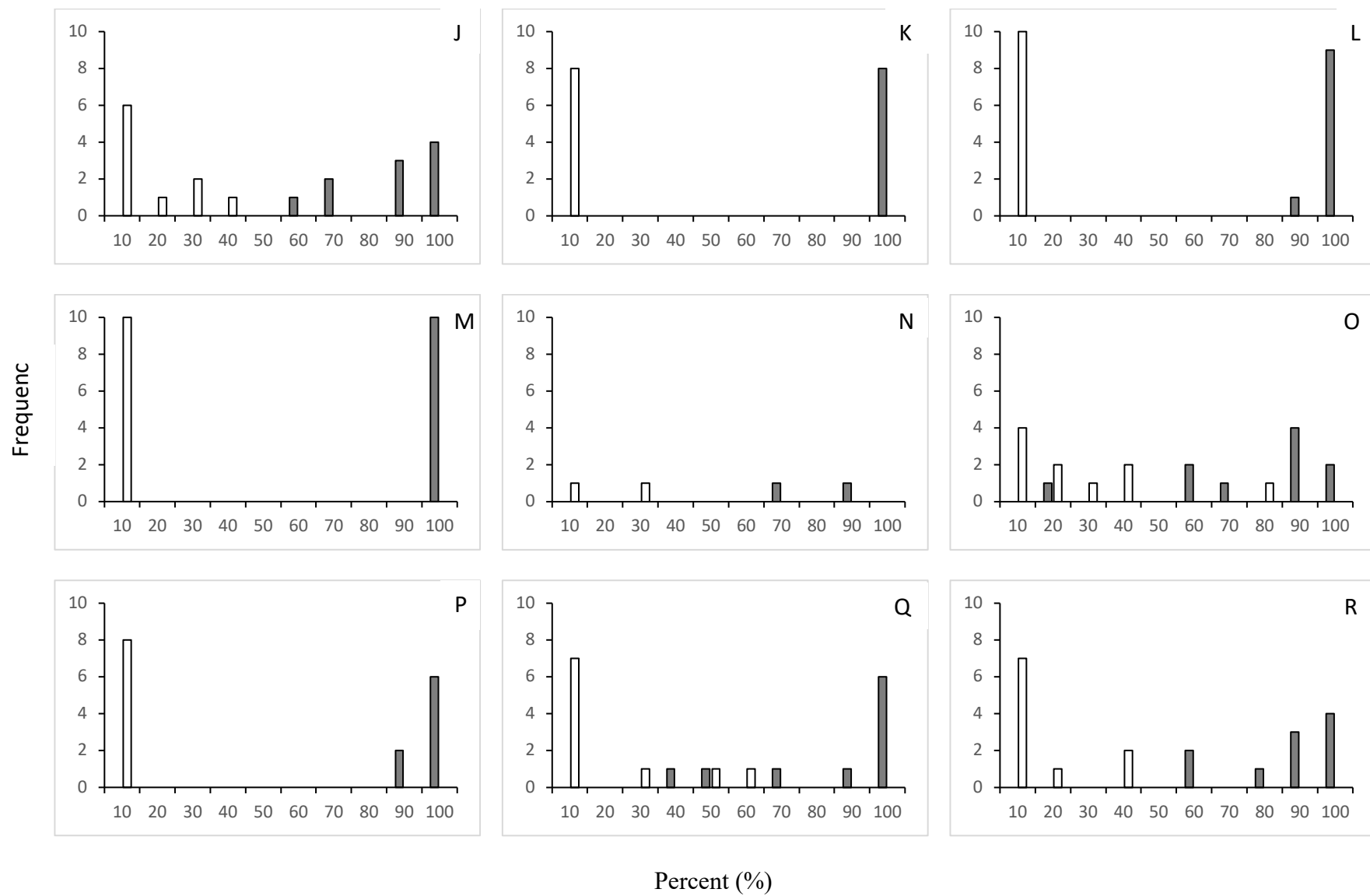


Figure A1. Respondents' self-assessed familiarity with tallgrass prairies, grassland birds, Eastern Meadowlark (*Sturnella magna*, L.), and restoration in Ontario.





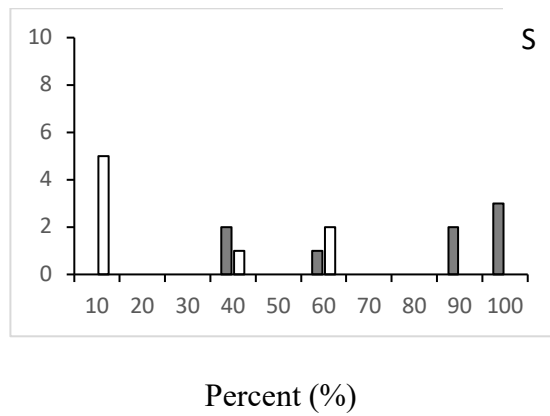


Figure A2. Distribution of percent litter cover (grey) and percent bare ground (white) at each site. A: BB1, B: BB2, C: BB4, D: BB5, E: CBC1, F: CBC2, G: CBC3, H: CBC4, I: CBC5, J: LBC1, K: LBC2, L: LBC3, M: LBC4, N: LBC6, O: UBC1, P: UBC2, Q: UBC3, R: UBC4, S: UBC5. $p < 0.05$.

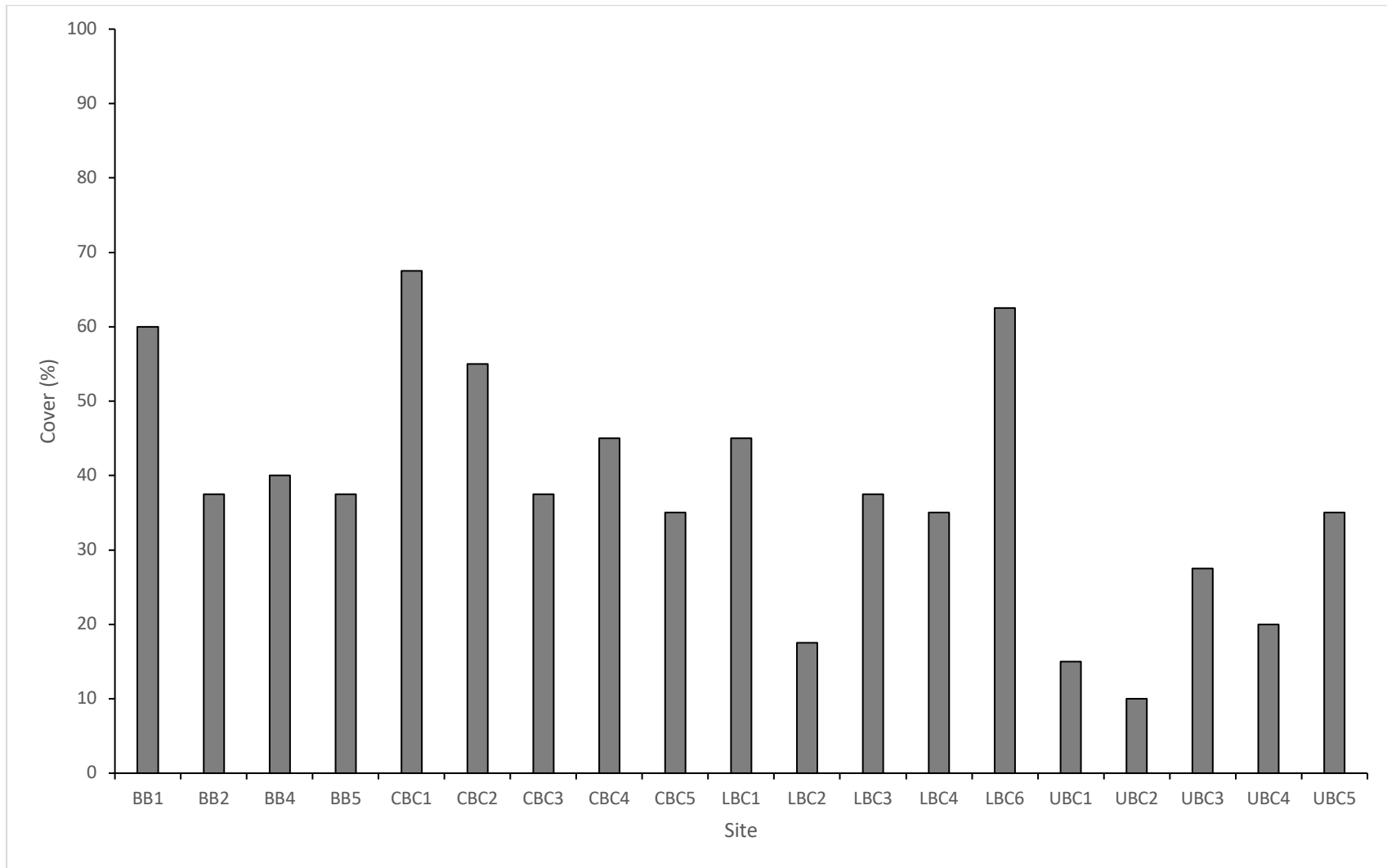
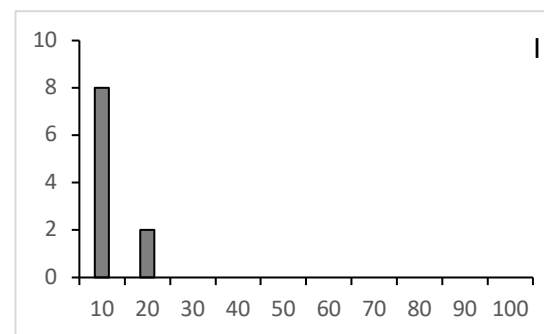
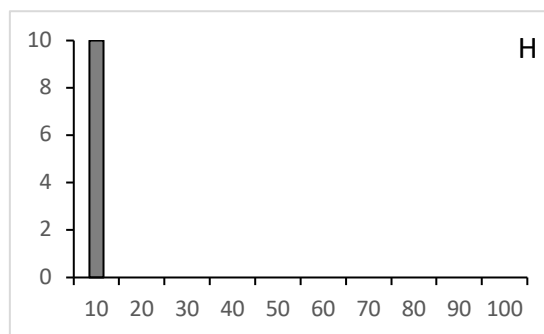
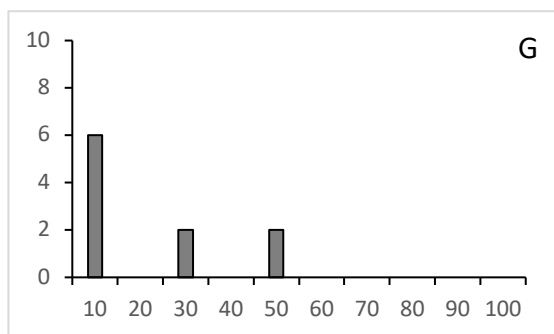
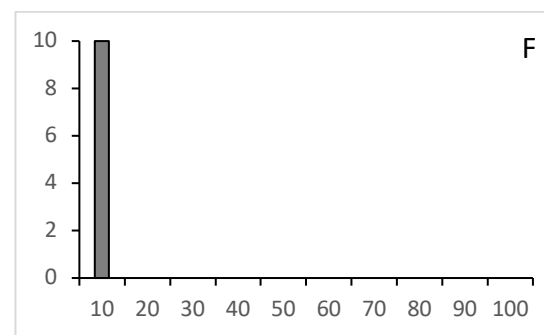
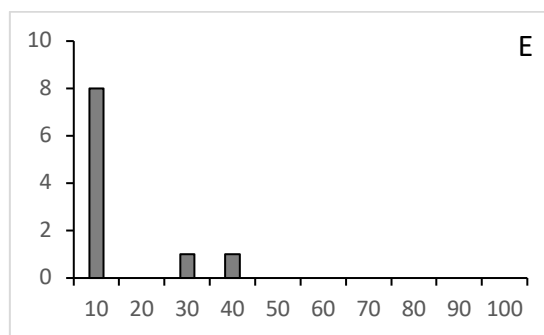
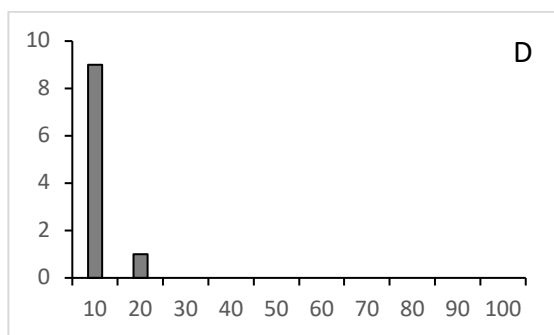
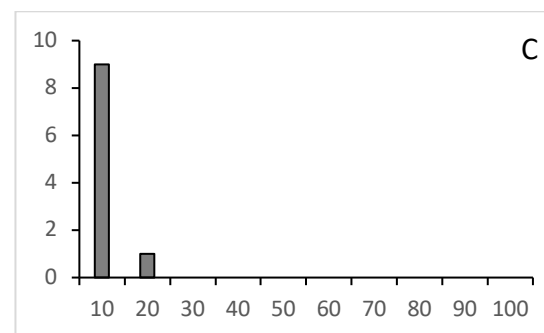
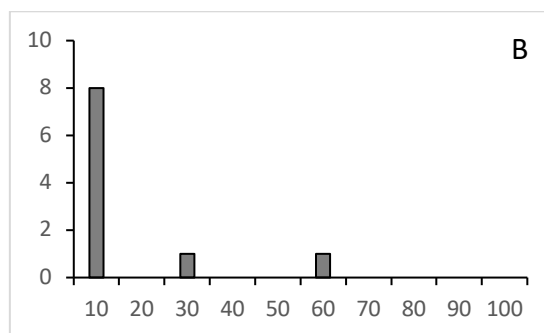
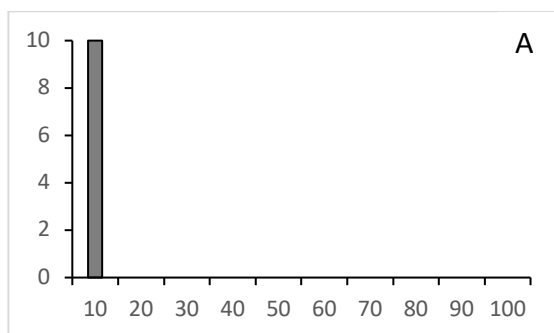
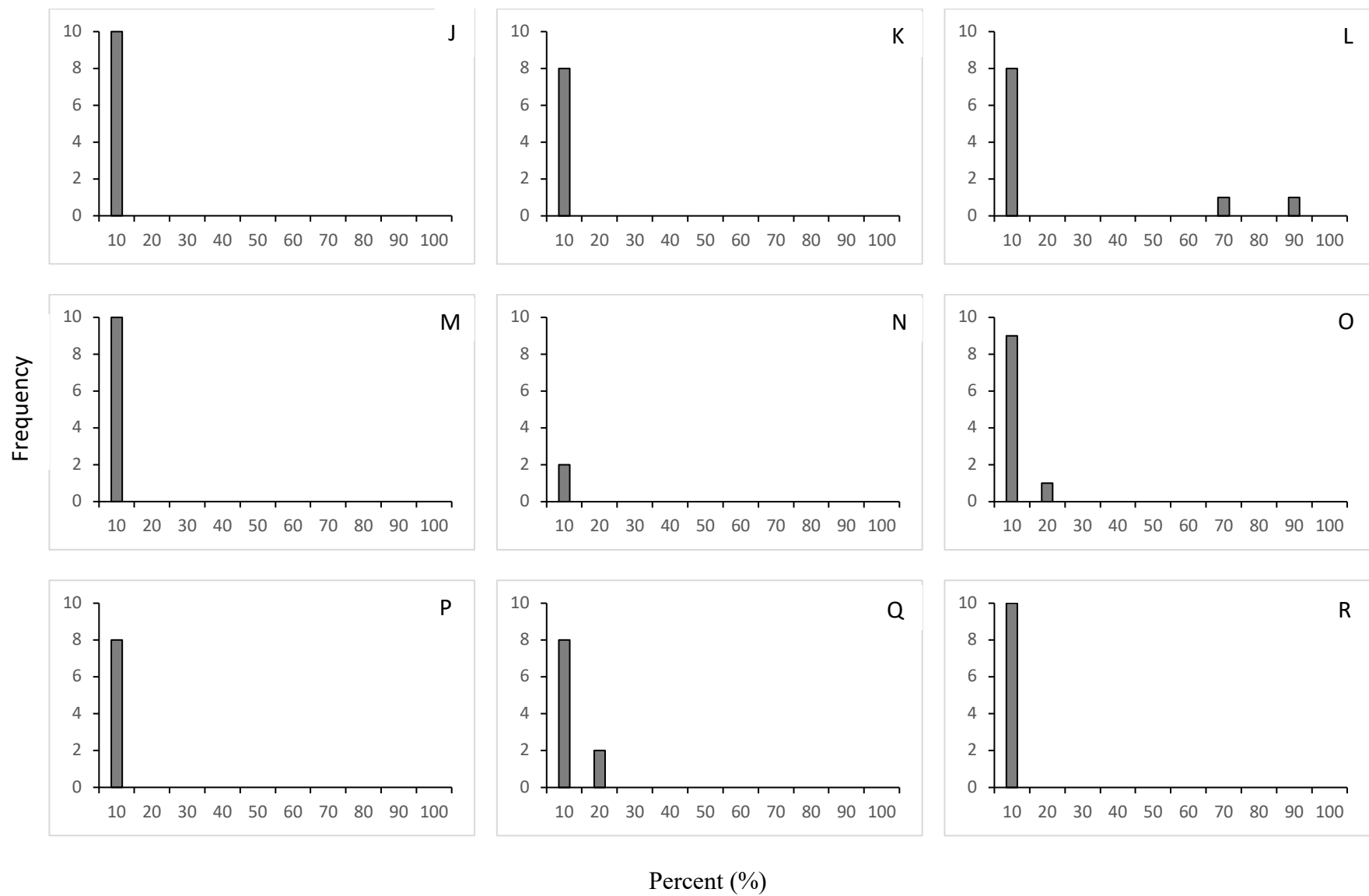


Figure A3. Median percent cover of grass at each site ($p < 0.05$).



Percent (%)



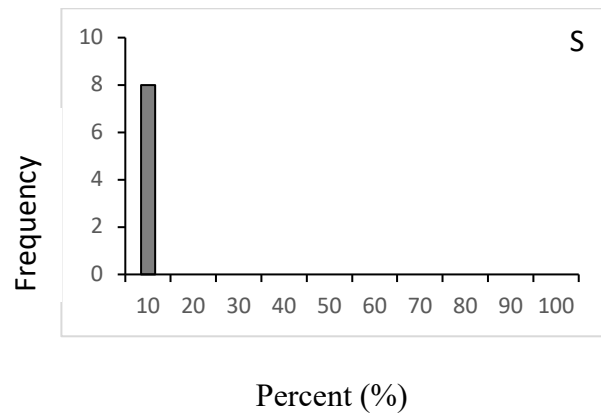
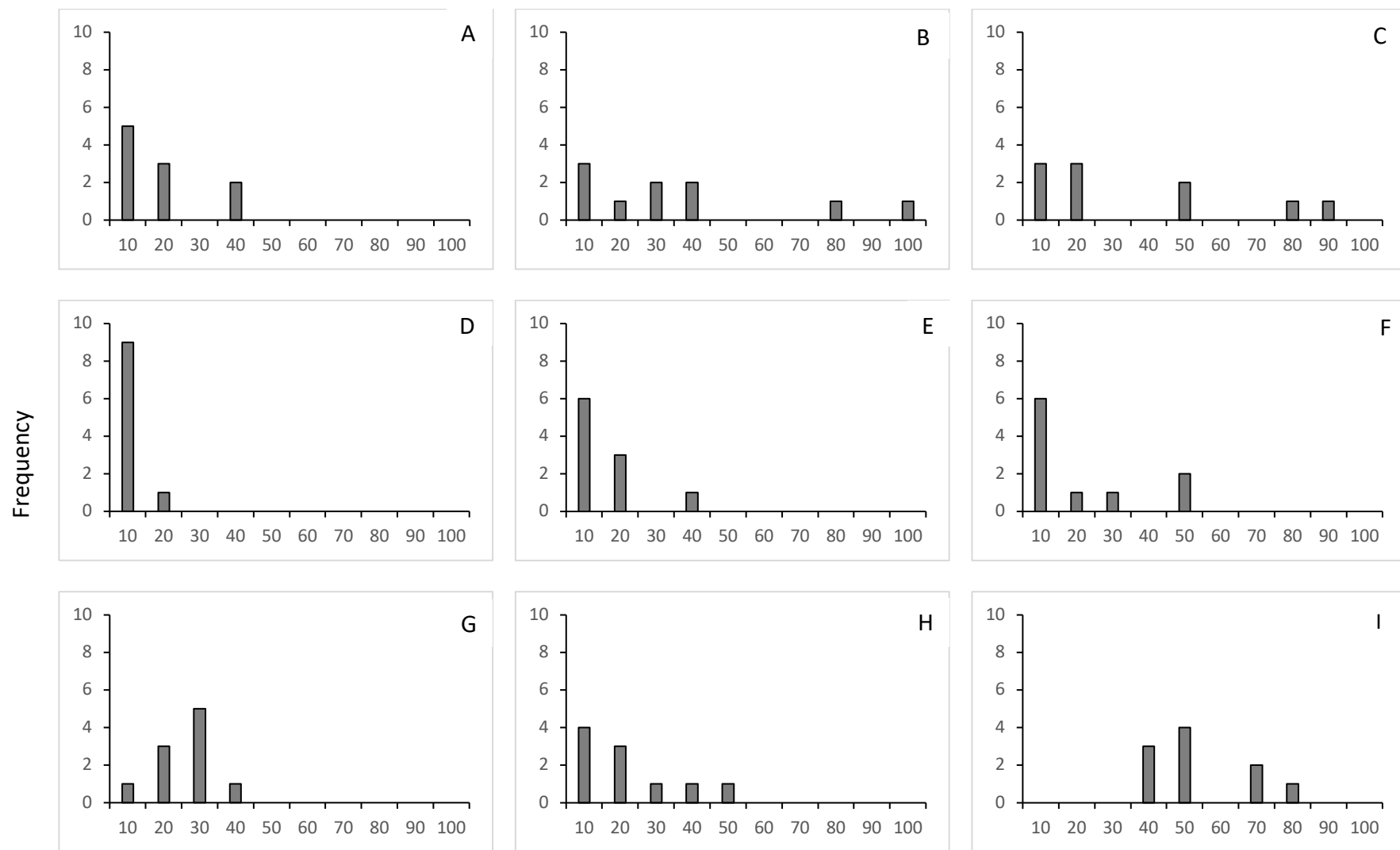
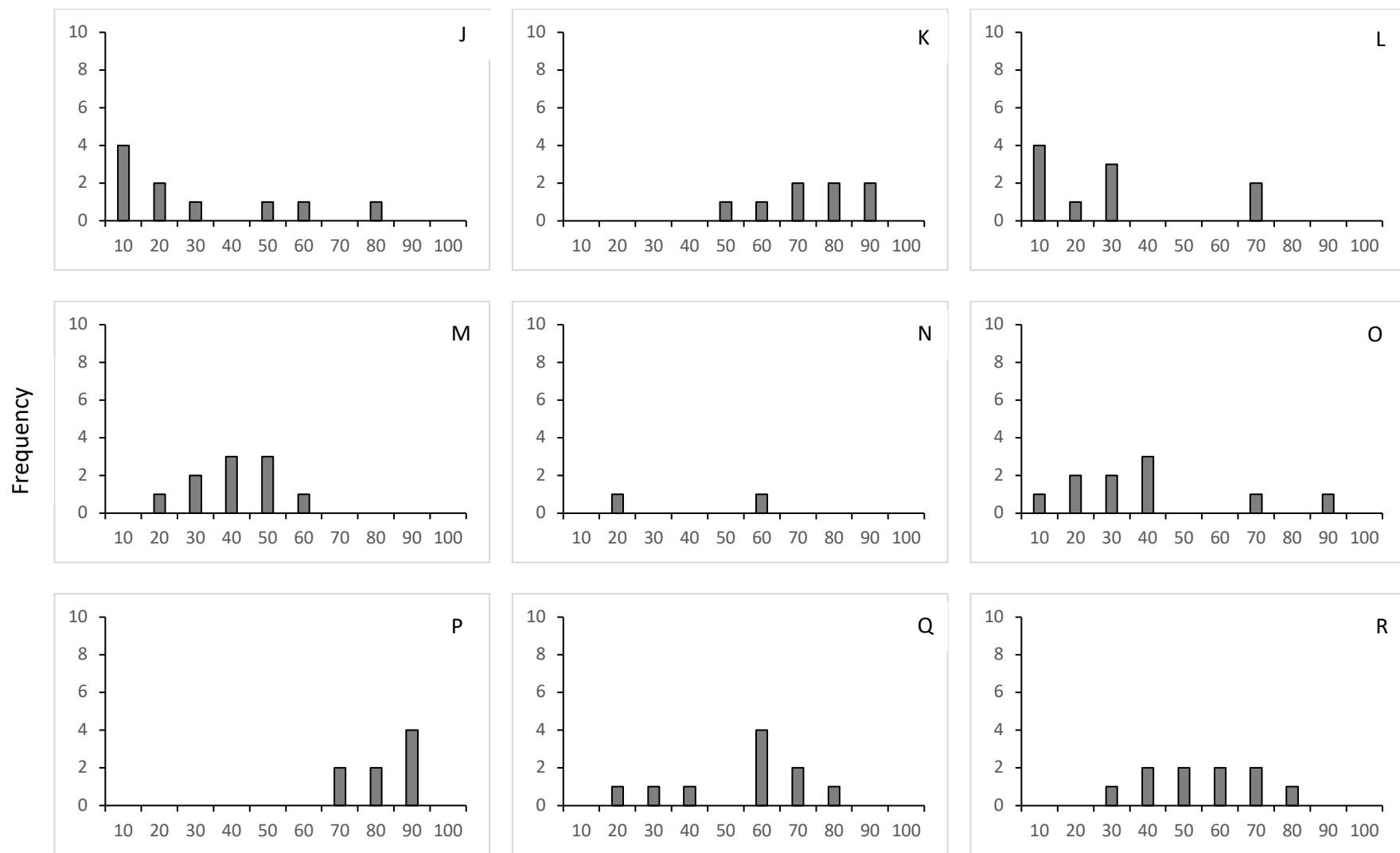
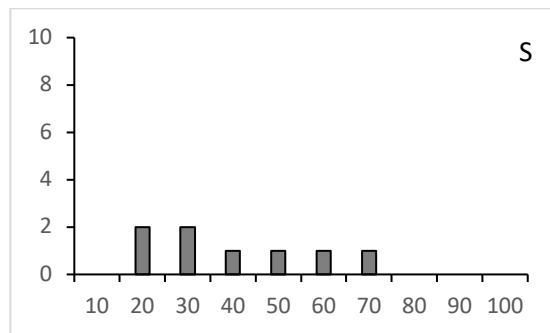


Figure A4. Distribution of percent wood cover at each site. A: BB1, B: BB2, C: BB4, D: BB5, E: CBC1, F: CBC2, G: CBC3, H: CBC4, I: CBC5, J: LBC1, K: LBC2, L: LBC3, M: LBC4, N: LBC6, O: UBC1, P: UBC2, Q: UBC3, R: UBC4, S: UBC5. $p < 0.05$.

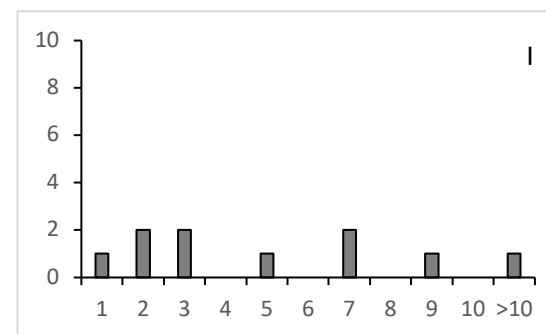
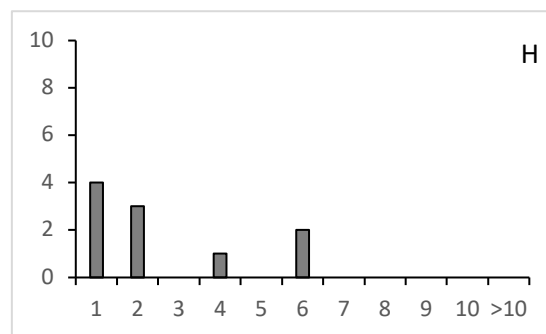
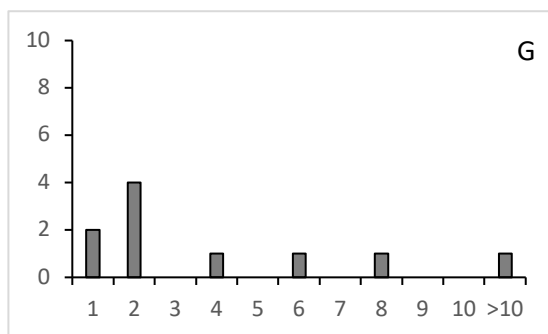
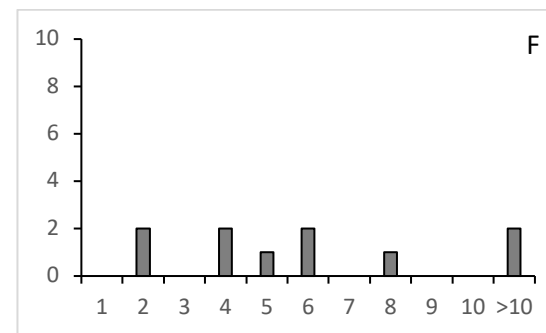
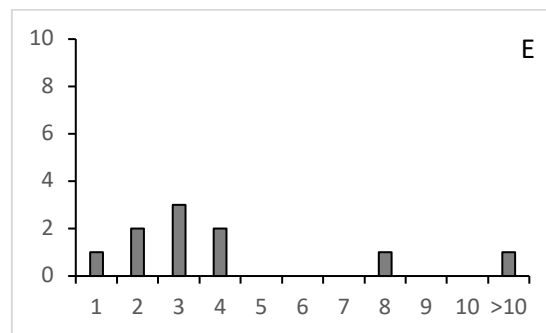
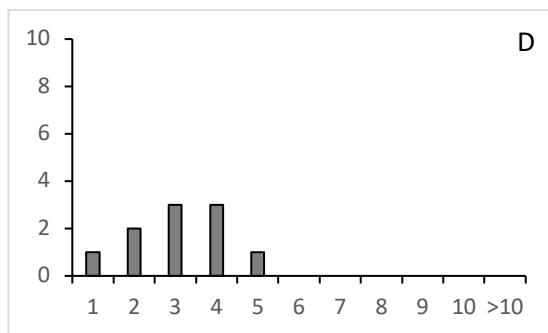
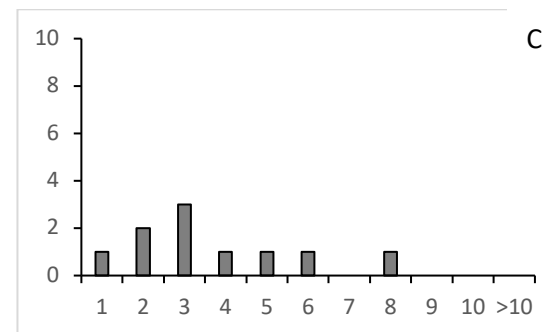
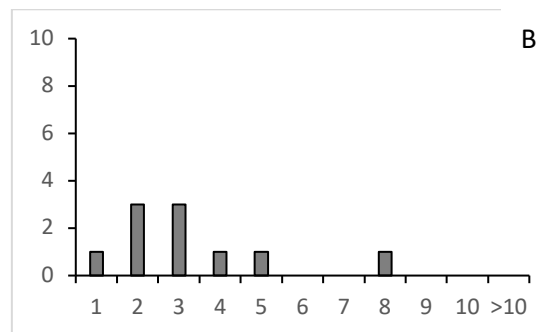
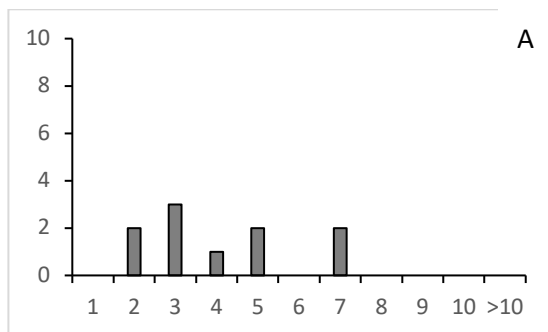






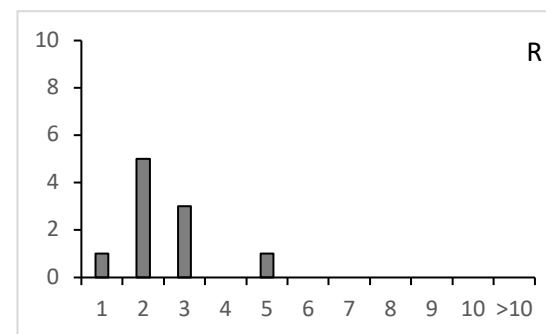
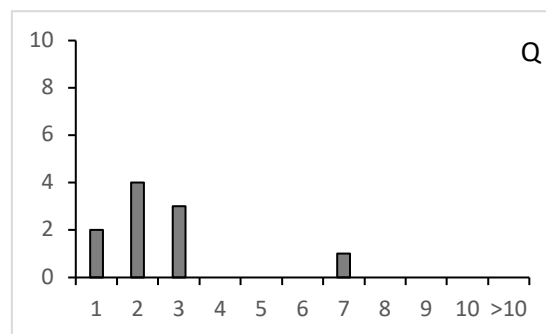
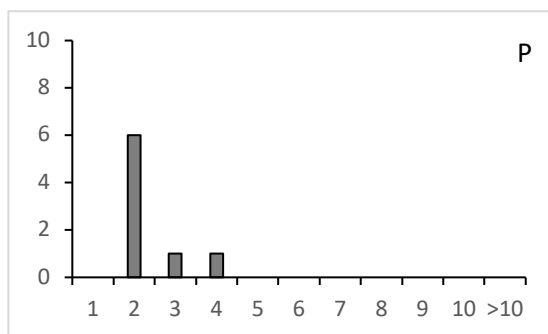
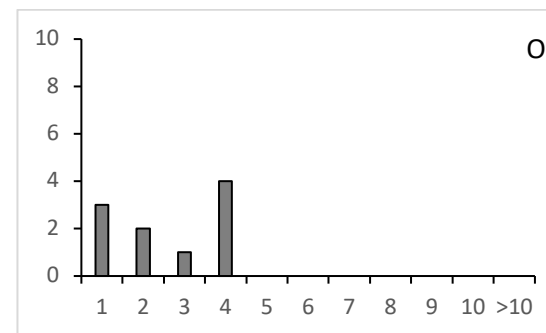
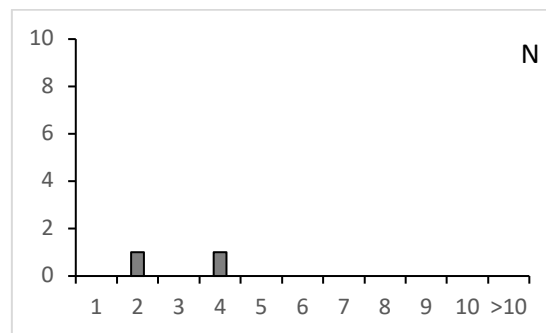
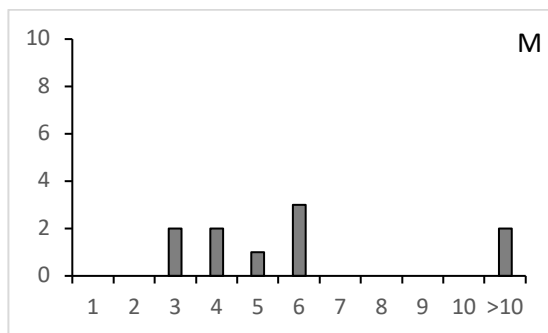
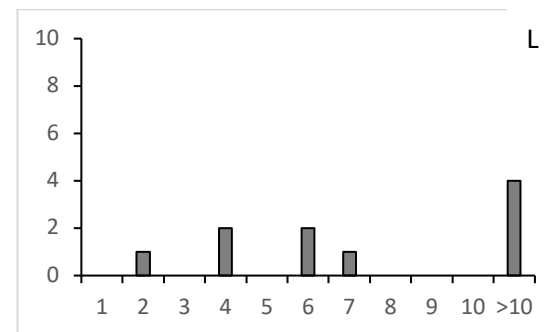
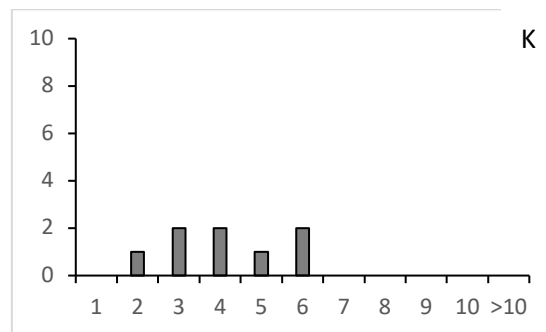
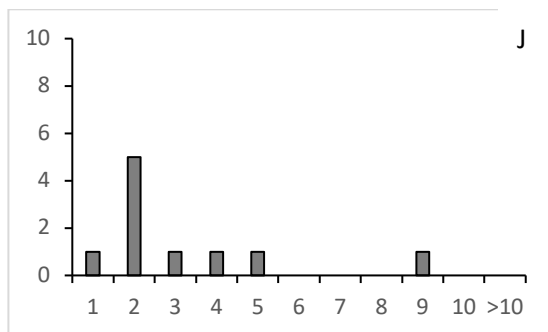
Percent (%)

Figure A5. Distribution of percent forb cover at each site. A: BB1, B: BB2, C: BB4, D: BB5, E: CBC1, F: CBC2, G: CBC3, H: CBC4, I: CBC5, J: LBC1, K: LBC2, L: LBC3, M: LBC4, N: LBC6, O: UBC1, P: UBC2, Q: UBC3, R: UBC4, S: UBC5. $p < 0.05$.



Depth (cm)

Frequency



Depth (cm)

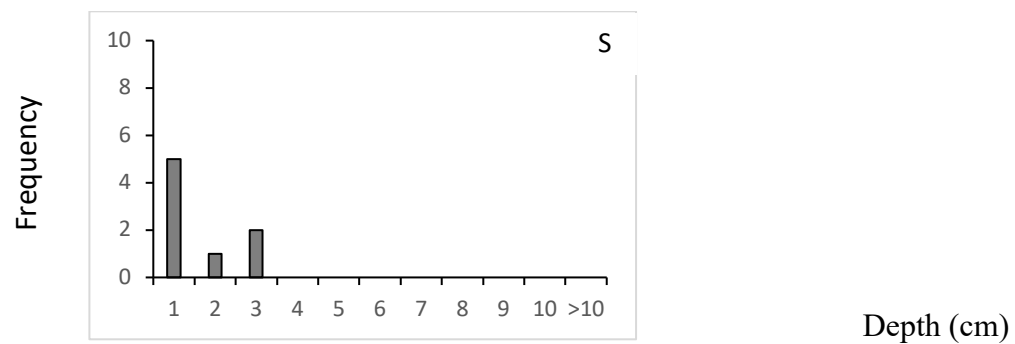


Figure A6. Distribution of litter depth (cm) at each site. A: BB1, B: BB2, C: BB4, D: BB5, E: CBC1, F: CBC2, G: CBC3, H: CBC4, I: CBC5, J: LBC1, K: LBC2, L: LBC3, M: LBC4, N: LBC6, O: UBC1, P: UBC2, Q: UBC3, R: UBC4, S: UBC5. $p < 0.05$.

B. Supplementary Tables

Table B1. Respondents' self-reported past participation in restoration activities in Ontario for Eastern Meadowlark (*Sturnella magna*, L.), grassland birds, or tallgrass prairies.

Response	Number of Respondents
Yes	24
No	8
Unsure	1

Table B2. R packages used during the data analysis, figure creation, and preparation of this thesis.

Package	Reference
car	Fox J, Weisberg S (2019). <i>An R Companion to Applied Regression</i> , Third edition. Sage, Thousand Oaks CA. https://socialsciences.mcmaster.ca/jfox/Books/Companion/ .
carData	Fox J, Weisberg S, Price B (2022). <i>carData: Companion to Applied Regression Data Sets</i> . R package version 3.0-5, https://CRAN.R-project.org/package=carData .
energy	Rizzo M, Szekely G (2022). <i>energy: E-Statistics: Multivariate Inference via the Energy of Data</i> . R package version 1.7-11, https://CRAN.R-project.org/package=energy .
ggplot2	Wickham H (2016). <i>ggplot2: Elegant Graphics for Data Analysis</i> . Springer-Verlag New York. ISBN 978-3-319-24277-4, https://ggplot2.tidyverse.org .
likert	Bryer J, Speerschnieder K (2016). <i>likert: Analysis and Visualization Likert Items</i> . R package version 1.3.5, https://CRAN.R-project.org/package=likert .
report	Makowski D, Lüdtke D, Patil I, Thériault R, Ben-Shachar M, Wiernik B (2023). “Automated Results Reporting as a Practical Tool to Improve Reproducibility and Methodological Best Practices Adoption.” CRAN. doi: 10.32614/CRAN.package.report (URL: https://doi.org/10.32614/CRAN.package.report), https://easystats.github.io/report/ .
rstatix	Kassambara A (2023). <i>rstatix: Pipe-Friendly Framework for Basic Statistical Tests</i> . R package version 0.7.2, https://CRAN.R-project.org/package=rstatix .
xtable	Dahl D, Scott D, Roosen C, Magnusson A, Swinton J (2019). <i>xtable: Export Tables to LaTeX or HTML</i> . R package version 1.8-4, https://CRAN.R-project.org/package=xtable .

C. Ethics Approval Letters

UNIVERSITY OF WATERLOO
ANIMAL CARE COMMITTEE
NOTIFICATION OF APPROVAL:

All research and teaching activities at the University of Waterloo which use live, non-human vertebrate animals must be conducted in compliance with the Animals for Research Act of Ontario (Revised Statutes of Ontario), the Guide to the Care and Use of Experimental Animals from the Canadian Council on Animal Care and the University of Waterloo's Guidelines for the Care and Use of Animals in Research and Teaching.

Principal Investigator: Stephen Murphy (School of Environment, Resources and Sustainability)

Student investigator: Claire Atherton (School of Environment, Resources and Sustainability)

Title: Eastern Meadowlark Habitat Restoration in Tallgrass Prairie Ecosystems in Southern Ontario

Approval Date: 03/28/22

Application #: 44018

Invasiveness Category: C

Species Approved:

Number of Animals Approved:

The Animal Care Committee has reviewed the proposed project and the Committee has determined the project complies with the requirements of the Animals for Research Act, the Canadian Council on Animal Care's Guide to the Care and Use of Experimental Animals, and the University's Guidelines for the Care and Use of Animals in Research and Teaching.

Approval to conduct the proposed project is in effect for a period of 12 months from the date shown unless a more frequent review has been specified by the Animal Care Committee. Multi-year projects must be renewed annually and may be renewed up to three times for a total maximum cumulative active period of 4 years. A renewal request must be submitted for review well in advance of the expiration date to prevent any suspensions of the project.

The proposed project must be conducted according to procedures described in the application. Requests for amendments must be submitted using the amendment request through the research ethics system.

If you have any questions concerning this notification, please contact Research Ethics at extension 35278 or by email at oreaupp@uwaterloo.ca.

A Post Approval Monitoring (PAM) visit may be requested at a future date. The PI will be notified by email when a PAM is required.

Signed on behalf of the Animal Care Committee:



Paul Craig, Chair, Animal Care Committee



Cindy Futher, Research Ethics Advisor

UNIVERSITY OF WATERLOO

Notification of Ethics Clearance to Conduct Research with Human Participants

Principal Investigator: Stephen Murphy (School of Environment, Resources and Sustainability)

Student Investigator: Claire Atherton (School of Environment, Resources and Sustainability)

File #: 44919

Title: Ecological Restoration for Eastern Meadowlark (*Sturnella magna*) in Ontario

The Human Research Ethics Board is pleased to inform you this study has been reviewed and given ethics clearance.

Initial Approval Date: 12/15/22 (m/d/y)

University of Waterloo Research Ethics Boards are composed in accordance with, and carry out their functions and operate in a manner consistent with, the institution's guidelines for research with human participants, the Tri-Council Policy Statement for the Ethical Conduct for Research Involving Humans (TCPS, 2nd edition), International Conference on Harmonization: Good Clinical Practice (ICH-GCP), the Ontario Personal Health Information Protection Act (PHIPA), the applicable laws and regulations of the province of Ontario. Both Boards are registered with the U.S. Department of Health and Human Services under the Federal Wide Assurance, FWA00021410, and IRB registration number IRB00002419 (HREB) and IRB00007409 (CREB).

This study is to be conducted in accordance with the submitted application and the most recently approved versions of all supporting materials.

Expiry Date: 12/16/23 (m/d/y)

Multi-year research must be renewed at least once every 12 months unless a more frequent review has otherwise been specified. Studies will only be renewed if the renewal report is received and approved before the expiry date. Failure to submit renewal reports will result in the investigators being notified ethics clearance has been suspended and Research Finance being notified the ethics clearance is no longer valid.

Level of review: Delegated Review

Signed on behalf of the Human Research Ethics Board



Karen Pieters, Manager, Research Ethics, karen.pieters@uwaterloo.ca, 519-888-4567, ext. 41495

This above named study is to be conducted in accordance with the submitted application and the most recently approved versions of all supporting materials.

Documents reviewed and received ethics clearance for use in the study and/or received for information:

file: e-mail_recruitment_script_peer-review_and_org_directory-version2.pdf

file: Questionnaire_Draft_3.pdf

file: Information and Consent Letter_version3.pdf

file: Feedback Statement (at end of survey)_version2.pdf

file: Study Results Email_version2.pdf

file: Notification of Publication_version2.pdf

Approved Protocol Version 3 in Research Ethics System

This is an official document. Retain for your files.

You are responsible for obtaining any additional institutional approvals that might be required to complete this study.