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The missing link: A case for increased consideration for plant-pollinator interactions for species at-risk recovery in Ontario

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ABSTRACT

The decline of native flowering plant populations due to anthropogenic impacts has been well documented in Ontario, Canada. Properly understanding a species' ecological requirements and natural history is a critical component to effective conservation management. Government agencies and environmental organizations rely on recovery strategies and other documents to mitigate threats and recover ailing populations. This study collected data from provincial and federal government reports for 53 at-risk insect-pollinated plant species as well as 11 at-risk pollinating insect species. These documents often lacked the basic information about plant species pollination requirements, pollinator needs, and recovery recommendations.

The validity of each different possible type of breeding system was known for 36% of the plant species, while some reproductive methods (e.g. cross-pollination but not self-pollination) were known for 34% of the species, and 30% did not have any information. Only 11% of all the plant species reviewed could self-pollinate without pollinators, while 40% can self-pollinate with them. Cross-pollination was beneficial in 43% of the plant species, although 57% did not have enough information to comment. Less information was known about potential pollinators: while 83% of the plant species had visitors identified to order or superfamily, only 28% had visitors identified to genus. For the plant species with at least one recovery strategy, 47% recommended further breeding system studies, 47% recommended pollinator studies, and 2% recommended managing pollinators and their habitat.

Only 36% of the at-risk pollinator species had one or more recovery strategies. Larval food plant species were known for 88% of the Lepidopterans. Adult food plant species were known for 45% of all at-risk pollinators, with an additional 27% considered to be "generalists". All four of the insect recovery strategies available called for more research into habitat needs and management. By identifying and addressing these knowledge gaps, more effective and efficient management plans may be implemented for future species recovery.

1. Introduction

Approximately 90% of all flowering plant species globally are animal-pollinated (Ollerton, Winfree, & Tarrant, 2011). While global and local declines in pollinators and the pollination services they provide has been documented, (Colla & Packer, 2008; Gallai, Salles, Settele, & Vaissière, 2009; Losey & Vaughan, 2006; Potts et al., 2010) research largely considers pollinator conservation in the context of agricultural systems (Klein et al., 2007). However, there are significant knowledge gaps surrounding impacts on natural ecosystems. Indeed, knowledge of plant-pollinator interactions and a community-centered approach have an exceedingly important role to play in the conservation of at-risk plant species (Tylianakis, Laliberté, Nielsen, & Bascompte, 2010).

Plant species may reproduce using one or more different types of breeding systems. The system depends on if they can set seed as a result of pollen transfer (pollination) from the male to female part of the same flower (self-pollination; autogamy), a different flower on the same plant (self-pollination; geitonogamy), a flower from a different plant (cross-pollination; xenogamy), or in rare cases, without any pollen transfer (asexual reproduction; agamospermy)(Dafni, Kevan, & Husband, 2005; Faegri & van der Pijl, 1979; Proctor, Yeo, & Lack, 1996) This pollen transfer can be carried out by physical contact between the plant parts, through wind, water, or gravity, or by external biotic vectors – animal pollinators (Dafni et al., 2005; Faegri & van der Pijl, 1979; Kevan & Baker, 1983; Proctor et al., 1996)

The importance of pollinators will vary depending on the breeding

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system(s) and other factors such as plant population size and genetics (Dafni et al., 2005; Ellstrand & Elam, 1993; Faegri & van der Pijl, 1979; Kevan & Baker, 1983; Proctor et al., 1996). Self-pollination can be automatic but often needs to be facilitated; i.e. have an external vector move the pollen within the flower (for autogamy) or between flowers on the same plant (for geitonogamy). For many plant species, increased seed set occurs through facilitated self-pollination rather than automatic self-pollination, due to greater pollen deposition on the stigma. Some species also require pollinators to facilitate pollination due to a need for a stigmatic cuticle to be broken for pollen adhesion and hydration (Aronne, Giovanetti, & De Micco, 2012; Galloni, Podda, Vivarelli, & Cristofolini, 2007; Sigrist & Sazima, 2004). In both cases, the benefit to the species is the ability to reproduce in the absence of other plants of the same species or in small separated populations, but it can also lead to inbreeding. Out-crossing, or cross-pollination, by necessity requires pollinators to move pollen between plants; this type of reproduction allows for the introduction or increase in genetic diversity in a population, through the recombination of genetics from two different parents, rather than the single parent in self-pollination. Plant populations that can reproduce through cross-pollination or outcrossing can be more resistant to external stressors, such as changes to habitat and weather or to disease and pests, as compared to those with smaller genetic variation; this is especially true for small populations (Dafni et al., 2005; Ellstrand & Elam, 1993; Faegri & van der Pijl, 1979; Kevan & Baker, 1983; Proctor et al., 1996).

Habitat loss and other anthropogenic activities has resulted in the decline of many plant species around the world and in Ontario (Eckert et al., 2010; Federal Provincial & Territorial Governments of Canada, 2010; Ontario Biodiversity Council, 2011; Prugh, Sinclair, Hodges, Jacob, & Wilcove, 2010; Venter et al., 2006). Small populations of rare or endangered plant species are susceptible to effects of genetic drift, inbreeding depression, uneven sex ratio, and gene flow on their genetic diversity and fitness, which can have implications for conservation of these species (Barrett & Kohn, 1991; Eckert et al., 2010; Ellstrand & Elam, 1993; Schemske et al., 1994; Tsaliki & Diekmann, 2011). Similar effects can be found for pollinators, particularly bees (Jha, 2015; Saccheri et al., 1998; Zayed & Packer, 2005; Zayed et al., 2005). The interaction between pollinators and plants, in terms of cross-pollination, is especially important in small populations. While habitat restoration and creation projects are becoming increasingly common, ecosystem-level considerations such as the role of insect pollinators are not often considered (Bortolotti, Bogo, de Manincor, Fisogni, & Galloni, 2016; Kearns, Inouye, & Waser, 1998; Patrício-Roberto & Campos, 2014; Schuepp, Herzog, & Entling, 2014; Winfree, Bartomeus, & Cariveau, 2011).

While studies and reports use the terms pollinators, potential pollinators, probable pollinators, floral visitors, and insect visitors interchangeably as insects that transfer pollen within or between flowers, there is a distinct difference between a true pollinator and an insect that visits a flower. As well, not all flower visits result in the successful transfer of pollen, and not all pollinators have the same efficiency in pollen transfer (Faegri & van der Pijl, 1979, Dafni et al., 2005; Fisogni et al., 2016; Johnson & Steiner, 2000; Kevan & Baker, 1983; Ne'eman, Jürgens, Newstrom-Lloyd, Potts, & Dafni, 2010; Ollerton, Killick, Lamborn, Watts, & Whiston, 2007; Popic, Wardle, & Davila, 2013; Vázquez, Morris, & Jordano, 2005; Watts, Sapir, Segal, & Dafni, 2013). This variation can occur for various reasons, such as the insect not coming into contact with the anthers and/or the stigma due to size or behavior, not visiting or having previously visited a flower of the right species or at the right stage of development, having previously groomed or removed pollen from its body so that it is not available for transfer, or being unable to carry or transfer viable pollen externally due to body shape, structure, or chemical secretions.

In order to determine a true pollination visit, the stigma would have to be evaluated for the presence of viable pollen grains and/or future visits prevented and fruit set evaluated; however, these are techniques that are used less frequently than simple visual observations of foraging insects (Dafni et al., 2005; Faegri & van der Pijl, 1979). The importance of using the right term depends on the context of the study; for example, distinguishing a pollinator vs a floral visitor is important in studies of a plant species' reproductive system but less so when evaluating the plant species an insect forages on. Due to the varying usages of terms in the studies we reviewed, and the difficulty in determining the validity of each term, we use the term pollinators in the broader sense, presenting information on floral visitors or potential pollinators regardless as to their efficacy in this paper.

In Ontario, Canada, at-risk species are listed under the provisions of the 2007 *Endangered Species Act* (Queen's Printer for Ontario, 2008). The Committee on the Status of Species At Risk in Ontario (COSSARO) assesses species that may be experiencing declines using the best available scientific information and issues reports on their findings. Within three months of receiving a report, the Ontario Ministry of Natural Resources and Forestry then lists the species under the Endangered Species Act. Within one or two years of a species being listed as Endangered or Threatened, respectively, the Ministry produces a recovery strategy and response statement. If a species is listed as Special Concern, the Ministry produces a management plan within five years. No recovery strategies or plans are produced for species that are considered to be extirpated (Ontario Ministry of Natural Resources & Forestry, 2015; Queen's Printer for Ontario, 2008, 2016).

A similar process exists on the national level under the 2002 *Species At Risk Act* (SARA), with the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assessing species (COSEWIC, 2015; Environment & Climate Change Canada, 2016; Government of Canada, 2002). The timelines for the production of the federal recovery strategies are similar to the provincial: one to two years for species newly listed as Endangered or Threatened, respectively, under SARA and three to four years for Endangered or Threatened species, respectively, that had previously been listed when SARA came into effect in 2003. The relevant government Ministry must provide a response within five years of the SARA listing taking place. Note that there is no timeline for the listing of a species under SARA after COSEWIC has assessed the species (Government of Canada, 2002).

Government agencies and environmental organizations rely on these recovery strategies and other documents to mitigate threats and recover ailing populations. However, many of these documents lack the basic information about plant species pollination requirements and pollinators, the host and food plants of pollinators, or the species' habitat needs.

Here, we analyze government documents related to at-risk species in Ontario for mentions of protecting pollinators of at-risk insect-pollinated plant species, as well as recommendations to fill knowledge gaps with respect to their larval and adult food plant species (for insect pollinator species) and pollinators and breeding systems (for plant species). This knowledge will help us to highlight particular areas that need to be considered going forward to effectively conserve these species.

2. Materials and methods

We first performed a broad review of all plant and insect species at risk in Ontario (Queen's Printer for Ontario, 2016) to determine the species that would be included in our assessment. As of September 2016, 58% of all at-risk insect species (11 out of 19 total) were determined to be probable pollinators based on their taxa type and life history. Seventy percent of all at-risk plant species (vascular plants only, or 53 out of 76 species) were visited by insects and/or required a pollinator to reproduce. Note that we treated the Boreal and Great Lakes populations of Showy Goldenrod (*Solidago speciosa*) as one single species in our review, even though they are assessed by COSEWIC and COSSARO as different designatable units (populations) within the same species and have different risk of extinction findings (statuses)