Proceedings of the Pollination Science and Stewardship Symposium

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INTRODUCTION

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Pollination is a vital ecological process in terrestrial ecosystems. Pollinators are the organisms that provide this service, thus facilitating reproductive success in plant communities. Awareness of the importance of pollinators and pollination has increased in the last few decades, largely due to global declines in honey bee colonies and documented widespread declines of some bumble bee and other pollinator species. In Canada, the main pollinators are insects, with thousands of species from a wide range of taxa that regularly visit flowers. Among the most familiar and important insect pollinators are the butterflies and moths (Lepidoptera), many groups of flies (Diptera) and beetles (Coleoptera), and the Hymenoptera, which include the bees and many other types of wasps.

The symposium, Pollination Science and Stewardship, featured 12 presenters who spoke about current research and on topics relating to the diversity, conservation, ecosystem services, pesticide management, agriculture, citizen science, and stewardship for pollinators, with focus on Canada. The workshop also aimed to facilitate connections between pollination specialists and land managers, owners, stewards and biologists, thus enabling information and idea exchange such that these practitioners could then apply it to their own conservation work. More than 90 people attended the symposium. Participants included members of academia, industry professionals, agriculturalists, citizen scientists, artists, students, gardeners, and landowners interested in enhancing their properties for pollinators.

The symposium was supported by funding from Environment and Climate Change Canada Habitat Stewardship Program for Species at Risk, the British Columbia Ministry of Environment, the Royal Saskatchewan Museum, and the Entomological Society of British Columbia.

Butterflies, conservation, and citizen science in Canada

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Butterflies are colourful, relatively easy to identify, and popular with naturalists. Butterflies are also potential pollinators, even though they appear to be relatively delicate and clean when compared to furry, flower-wrestling, pollen-covered bees and syrphid flies. Recent work, however, shows the importance of non-syrphid flies to pollination (Orford et al. 2015, DOI: 10.1098/rspb.2014.2934), and by analogy we know little about the importance of butterflies. What we care about as biodiversity conservationists, however, is not just pollinators, or the "ecosystem service" of pollination, but the diversity and abundance of wild flowers and flower-visiting insects. In this regard, butterflies are ideal "flagship" organisms for the conservation cause.

Butterfly collecting laid the groundwork for the understanding of butterfly faunistics, and amateur collecting can be considered the original butterfly citizen science project. The non-consumptive approach to butterfly citizen science began in Canada as "Fourth of July Butterfly Counts" some 20 years ago, coordinated originally by the Xerces Society, and more recently by the North American Butterfly Association. There are still a few such counts, including the Dry Island Buffalo Jump Provincial Park Butterfly Count, in Alberta. This count involves park rangers with nets, and counters the common perception that nets are evil. However, the data from such counts is poor, because of the effect of weather on shifting phenologies and the difficulty of comparing a one-day sample from one year to similar samples from other years. A better approach is to conduct weekly Pollard Walks, along a standard transect or route. This method results in much more valuable data, but it requires considerable effort, and has not caught on in Canada, with a few exceptions, including my own Pollard route in Edmonton, which I have visited regularly during the butterfly seasons since 1999.

Another approach involves the creation of butterfly atlas projects, such as the British Columbia Butterfly Atlas, the Ontario Butterfly Atlas, and the Maritimes Butterfly Atlas. These projects update both distributional and phenological databases, and they can be popular. In Alberta, the Alberta Lepidopterists' Guild (ALG) considered an atlas project, but declined because of 1) a small number of potential participants for such a large geographic area, 2) the fact that atlas projects are not open-ended, and are intended to produce a book-like end product, and 3) the perceived redundancy of atlassing and the citizen science project eButterfly.org.

Instead of an atlas, the ALG initiated the Alberta Butterfly Roundup in the spring of 2015, an open-ended attempt to reconfirm the 173 species of butterflies known from the province. In the 2015 season, 53 naturalists participated, and of those, 33 contributed at least one species to the count. A total of 120 species were reported, and the top contributor found 24 of these. The Roundup helped document a new species for the province (regal fritillary, *Speyeria idalia*) and the westward spread of a "native" species, the dun skipper (*Euphyes vestris*). Although participants were encouraged to submit records through eButterfly, most records were submitted through the ALG Facebook Page and the ALG listserver (Albertaleps), both two to three times as popular as eButterfly. eButterfly received about the same number of submissions as the Albertabugs listserver, the Edmonton Natural History Club listserver, and emails directly to me. In the future, and to find the remaining 52 species, ALG is encouraging directed searches for species that are rare and localized in areas that are not often visited. The Roundup approach may not possess the same scientific rigour as an atlas project, but it does focus attention on butterflies, with potential benefits for conservation, and the monitoring of pollinators and floral resources in general.

Biology and diversity of moths in Canada: a conservation perspective

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Butterflies and moths comprise the order Lepidoptera, one of the four most diverse orders of insects. Moths make up about 90% of Lepidoptera; the butterflies are just one small branch of the group. Approximately 5,100 species of moths live in Canada, with about 2,650 species known in B.C. Most moth larvae feed on living plant tissue, as exposed or concealed feeders on leaves, or as borers in stems, roots, flowers, and fruit.

Not all moths feed as adults, but those that do are looking for food energy such as nectar from flowers, which makes them potential pollinators. Many diurnal species are generalist flower visitors, but some species are very specialized. Males of many diurnal micromoth species, such as choreutids (Choreutidae) and fairy moths (Adelidae), patrol around nectar sources to find females, and exploit whatever flower species are present. Other moths, such as *Greya* and *Lampronia* (Prodoxidae), are more specialized. Females lay eggs in the flowers of their host plants, and they have been observed pollinating while ovipositing. In yucca moths (the Genus *Tegeticula* in the Prodoxidae), this specialization has developed into the famous mutualism between moths and plants. Yucca plants are completely dependent on yucca moths for pollination. Female yucca moths deposit pollen on the flower stigma after injecting eggs into the yucca flower ovary. The larvae then hatch and feed in the developing seed pods of the yucca plant. Thus, they require pollination of the flower for their food to develop. The larvae eat only some of the developing seeds, leaving some to produce the next generation of plants. This text-book case of mutualism gets more complicated; two species of "cheating" yucca moths have evolved. These cheaters lay eggs on developing seeds that have been fertilized by the pollinator moth species, so they are completely dependent on the yuccas and the pollinating yucca moth species.

Many orchids rely on specialized moth pollinators that have co-evolved with the plants. Some orchids have pollinia—sticky anther tips that break off and attach to the visiting insect—to aid pollen transfer. Although moth–orchid pollination information is often scanty, several moth species have been observed with pollinia attached, so they clearly play a role in orchid pollination. Some orchids have evolved a system of placing the nectar at the base of a long spur, so the pollinating insect must reach deep into the plant and increase its chances of bumping the pollinia. This has triggered an evolutionary arms race where the insects evolve longer mouthparts to access nectar, and the plants evolve longer spurs to promote pollination. An extreme case is Darwin's Orchid (*Angraecum sesquipedale*), with a 40+ cm spur. At the time, no insect was known with long enough mouthparts to reach the nectar, and Charles Darwin predicted in 1862 that a moth must exist with the necessary mouthparts. It was discovered in 1902: *Xanthopan morganii praedicta* has a 40-cm-long proboscis.

Biology, conservation & stewardship for flies in Canada

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Many species of true flies (Diptera), especially flower flies (Syrphidae), are significant wild pollinators. Diptera contribute approximately half of the pollination services in most environments and become increasingly important with increasing latitude. For example, flies are the primary (and often only) pollinators north of the Arctic Circle, but despite this their ecological impact has been historically underappreciated, and relatively little is known about the specifics of many plant–pollinator interactions. Potential conservation efforts are currently hampered by inadequate taxonomic knowledge, coupled with poor knowledge of distribution for most species. Even within the taxonomically well-known family Syrphidae, there is a need for increased collecting effort and development of widely accessible, user-friendly identification tools. Several case studies of potentially endangered species and conservation efforts are discussed.

Biology, conservation and stewardship for bees in Canada

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Bees are the most important pollinators of both crop and native plant species. Although a few managed species are thought to provide most of the pollination services to crops, a growing body of evidence suggests that wild bee species play an important role. This is especially true for native plant species, some of which have intimate relationships with their bee pollinators. Over 800 species of bee are recorded from Canada, most of these occurring in ecozones in the southern half of the country. Our recent efforts have focused on documenting the patterns of diversity and distribution of Canada's bees, this being facilitated with DNA barcoding. These initiatives have also allowed for the first comprehensive assessment of the conservation status of the bee fauna of Canada. However, there is still much to learn. This session covers our current knowledge of bees in Canada, including their diversity, distribution, gaps in taxonomic knowledge, and conservation status.

Global bee diversity and conservation

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More than 20,000 species of wild bee exist in the world, and almost none of them fit the standard archetype people have as to what bees are. Those archetypes relate to the domesticated honey bee, which is not native to North America; further, honey bees have been shown to often not be as important for pollination of crops as wild bees are. This presentation focuses on the taxonomic, ecological and behavioural diversity of the bees of the world, and compare bee diversity globally with that from Canada.

The Federal General Status Program of Canada, Wild Species 2015

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The General Status Program arose from the Accord for the Protection of Species at Risk (1996) and one of the resulting sections of the *Species at Risk Act* (SARA), which include the requirement to assess and report regularly on the status of all wild species in Canada. The resulting amassing of data provides the baseline for assessing the status of all species in Canada—including invertebrates. A report is completed every five years and the results are published. The first step in the assessment process is the refinement of lists for Canada and each province and territory for the species group that is being reported on. The lists are based on published literature, museum collections and personal knowledge of experts. The next step involves pulling together whatever basic information is available on the distribution, trends, habitat, threats and range extent using the same sources as for the lists. These are some of the criteria that are used to determine a conservation status rank or general status rank.

The conservation status assessments for the 2015 Wild Species report were done following NatureServe methodology. This is the same process that is used for the status ranks that are provided by the Conservation Data Centres and Heritage programs within each of the jurisdictions. The factors, methods and the calculator are all found at www.natureserve.org. In British Columbia the results, including the resulting lists are held and maintained with in the B.C. Conservation Data Centre. The first report in 2000 assessed 1,670 species (mainly vertebrates) and the 2015 report will assess approximately 30, 000 (final number to be determined), including capsular and non-vascular plants and many groups of invertebrates. One of the focusses for the 2015 report was assessment of as many of the pollinator groups as possible, including the bumble bees, which. The bumble bees had been done initially in 2010, as well as the rest of the bees were assessed as well as moths, bee flies, beetles and wasps, to name a few. This presentation describes the assessment process and methodology, as well as discusses a number of ways the General Status Program has been used to improve knowledge and benefit species conservation in Canada.

The General Status program originated in order to fulfill the requirements of SARA of enabling a metric to use to determine overall trends in the biodiversity of species in Canada. Other beneficial offshoots include (but are not limited to), helping to inform assessment priorities for the Committee on the Status of Wildlife in Canada (COSEWIC), to establish a baseline of data for all species, identify knowledge gaps by highlighting species where little is known and further inventory is required and provide taxonomic lists for all of the jurisdictions and Canada. One can also get a snapshot of the diversity of different groups in the different regions of Canada as well as see where across the jurisdiction something may be declining or in good shape.

Pollination, pollinator diversity, and the determinants of plant reproduction

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Understanding the role of pollinators in determining plant reproduction is critical for conserving and restoring ecosystems, as well as for maintaining food security. While some crop plants are self-compatible and require little input from pollinators to produce fruit and seeds, many plant species in natural systems require pollinators to effect pollen transfer. Recent research reveals that when many plant species are in an area, they receive inadequate pollination and produce suboptimal levels of fruit and seeds, yet the mechanisms behind these observed patterns are unclear (Vamosi *et al.* 2006). Species in species-rich areas may be more specialized, having traits that attract certain pollinators and restrict access of others (Vamosi *et al.* 2014). While these traits may confer advantages when a favoured pollinator is present, they also put the plant species at risk of lower reproduction if their specialist group of pollinators is absent. Here, I summarize a number of approaches how specialization may affect pollen delivery and conserve the ecosystem function of pollination.

The initial approach to evaluating whether a plant species is receiving adequate pollination service from pollinators is to estimate "pollen limitation", typically through a manipulative experimental design where the proportion of fruits or seeds set under natural pollination conditions is compared to that under supplemental pollination conditions (Knight *et al.* 2005). Thousands of pollen limitation experiments have now been conducted throughout the world, with estimates that ~60% of species are pollen-limited. In other words, these pollen-limited species would produce more fruits or seeds if pollinators were optimally abundant. Reasons for this widespread pollen limitation are currently unclear but some have posited that the pattern is a reflection of an impending "pollination crisis" (Ingram *et al.* 2002), evidenced by the observations that pollinators are declining in abundance and diversity at an alarming rate (Potts *et al.* 2010). While pollen limitation can be observed to increase with disturbance and loss of pollinators (Da Silva *et al.* 2013), it is important to recognize that natural processes may also cause plant species to exhibit pollen limitation as well. For example, observational studies comparing the pollen limitation of species that were visited by diverse arrays of pollinators were often no less pollen limited than those populations that received visits from few species of pollinators (Davila *et al.* 2012), indicating that we do not fully understand the functional role of pollinator diversity in communities. In examining the contribution that differences in floral visitor composition make to increased selfing and seed production of plant populations, we find that increased visitation by particular functional groups ensures reproductive success of focal plant species more so than pollinator diversity (Adderley and Vamosi 2015). Thus, while entire flowering communities may benefit from functionally diverse pollinator communities, the reproductive success of a single pollinator species is more contingent on a specialized subset of pollinators.

Conversely, the prevalence of certain plant traits within a community can influence pollinator composition (Bruckman and Campbell 2014). In an investigation of the effects of changes in plant composition that altered the prevalence of zygomorphy (i.e., floral symmetry and the restrictiveness of flowers to certain pollinators), the conversion to grazing pasturelands negatively impacted species richness and phylogenetic diversity. Changes in community composition and structure had strong effects on the prevalence of zygomorphic species, likely driven by nitrogen-fixing abilities of certain clades with zygomorphic flowers (e.g., Fabaceae). Land conversion can thus have unexpected impacts on trait distributions relevant for the functioning of the community in other capacities (e.g., cascading effects to other trophic levels (i.e., pollinators) (Villalobos and Vamosi 2016). These patterns indicate that we may be able to predict which pollinators will be available to various crop plants by understanding their relationships with the floral community and climate (Kerr *et al.* 2015).

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Pollination in Agriculture: Insects and Ecological Intensification

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Agricultural expansion and intensification are central to the current demise of biodiversity, affecting plants, animals (including insects) and fungi. The new buzz-phrase "ecological intensification" goes beyond the restoration of biodiversity to the reestablishment of ecosystem functionality. According to Food and Agriculture Organization of the United Nations (FAO 2013) it is "a knowledge-intensive process that requires optimal management of nature's ecological functions and biodiversity to improve agricultural system performance, efficiency, and farmers' livelihoods". Animal pollination accounts for approximately one-third of our food supply, and new data from around the world indicate that wild pollinators are far more important than managed ones in many cropping systems. Yield drags of 20–30% have been documented for numerous crops often stated to not require insect pollination, new cultivars are not tested for their pollination requirements and their floral ecology is generally ignored, and scant attention and little regard has been paid beyond bees to other insect groups essential to pollination ecosystem services. Landscape management in agricultural and urban environments that is focused on pollinator habitats has, at the same time, encouraged populations of biocontrol agents, notably parasitoids and some predators that depend on floral resources for part of their life cycles. The FAO's call to "optimize management [as] a knowledge-intensive process that requires optimal management of nature's ecological functions and biodiversity to improve agricultural system performance, efficiency and farmers' livelihoods" strongly suggests intensive and well-informed human intervention. An example may be the use of managed pollinators to disseminate microbial biological control agents against crop pathogens and insects pests on crops. The multiple benefits of better yields through pollination plus crop protection that are coupled to reduced uses of chemical pesticides, conservation of water and less consumption of fossil fuels. The knowledge deficits, changing perspectives, and current emerging practices around ecological intensification through biological control of pest diseases, IPM and pollination are discussed.

Agriculture in the Okanagan: past, present and future

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The Okanagan is the second most important agricultural region in British Columbia. In the late-1800s and early 1900s, agriculture began in the Okanagan with mixed farming, in particular beef cattle and tree fruits. Over the years, various crops and animals have been produced, such as vegetables, fruit, forage, beef and dairy, with tree fruits becoming predominant. Changing climate, with higher winter temperatures and longer growing seasons, has allowed a switch in crops. Today, tree fruits, particularly sweet cherry and apples, and wine grapes, are the main agricultural crops in valley. These trends are expected to continue in the near future.

Honeybee genetics and breeding a better honeybee

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The genome contains the evolutionary history of a given species. The modestly sized honey bee genome was sequenced in 2006, and since then many discoveries have been made about the honey bee's ancient history, its population expansions and adaptations, and its genetic health. Here, we present the findings of several major studies from our group that demonstrate a means through which both beekeepers and researchers can gain valuable information about the genetic health and history of the honey bees with which they work. First, we examine the evolution and genetic underpinnings of the honey bee immune system and uncover valuable insights into how novel forms of social immunity have evolved. Second, we demonstrate how, by applying genomic data such as this within the beekeeping industry, we can make better, informed decisions about the genetic health of our colonies.

Inventory and stewardship for pollinators in the Okanagan and Similkameen valleys

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British Columbia has the highest bee diversity in Canada (at least 450 species) with approximately one-third of the species within the Western Interior Basin in the south–central area of the province not occurring anywhere else in Canada. Additional pollinator groups, including butterflies and flies, are also diverse and endemic to this region. However, this ecozone also coincides with some of the most desirable real estate in the country, resulting in immense urban, rural and agricultural land-development pressure, combined with threats from livestock overgrazing, wildfire suppression, natural succession, and recreational use. Engaging land managers in stewardship actions for pollinators is challenging, and first involves understanding the species richness and distribution within the area of interest. To meet these objectives, a long-term project to better understand the pollinator (primarily bee and butterfly) fauna in the Western Interior Basin was started in 2010, initially to engage landowners, but also to contribute to national knowledge of the bee diversity in Canada, and to try and prioritize species that are priorities for assessment by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). Ultimately, these data will be used to map bee species with plant communities as a means to prioritize sites for pollinator protection. This talk highlights some of the results from those and other invertebrate conservation work.