INTRODUCTION

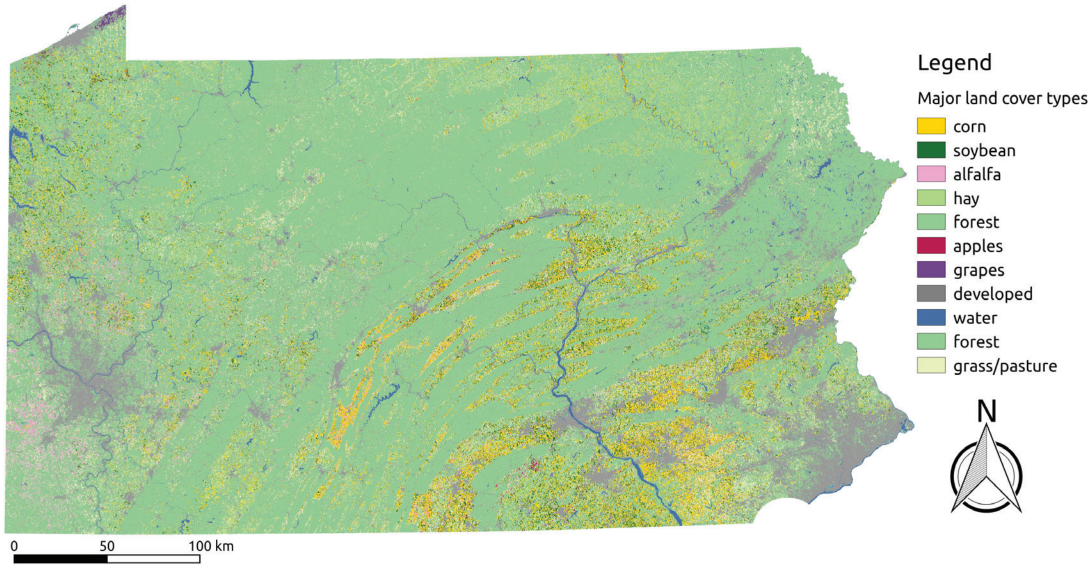
PENNSYLVANIA POLLINATOR PROTECTION PLAN

TABLE OF CONTENTS

THE IMPORTANCE OF POLLINATORS

Animal-mediated pollination is a fundamental process that forms the basis for much of our terrestrial biodiversity. Pollination – the transfer of pollen from one flower to another - is critical for flowering plants to cross-fertilize, produce seed, and produce fruit. While wind and water can disperse pollen of some plant species, animals pollinate 78% of all flowering plants in temperate regions such as Pennsylvania (Ollerton 2011). Moreover, nearly 75% of all food crops benefit from animal pollination, and 35% of them exclusively rely on pollinators for crop production (Klein et al 2007).

Pollinators thus play a vital role in our natural, agricultural and urban ecosystems. In addition to being essential for crop production, pollinators support diverse plant communities and the animals that depend on them. Healthy plant communities also support critical ecosystem functions, such as maintaining a balance of clean air and clean water by converting carbon dioxide into oxygen and preventing soil erosion (Marinelli 2005).



Land cover across Pennsylvania. Map of major land cover classes and their spatial distribution across the state. This land cover map of Pennsylvania was created using the 2016 USDA Cropland Data Layer. Mapping was performed with QGIS software. Figure generated by D. Sponsler, Penn State University.

While managed honey bees (*Apis mellifera*) are most commonly used for commercial pollination of agricultural crops, many insect and animal species provide valuable pollination services. These include other bee species (such as bumble bees, squash bees, and orchard bees), flies, butterflies and moths, beetles, hummingbirds and bats. Globally > 90% of the major global crops are visited by bees, ~ 30% are visited by flies, while other animal groups visit < 6% of crop types (Kleijn et al. 2015, Larson et al. 2001). In some cases, non-honey bee species are better pollinators for certain crops and plant species, while in others, the presence of wild bees improve crop pollination even if honey bees are present (Garibaldi et al 2013). **Given the diversity of types of landscapes, agricultural crops, and pollinators in Pennsylvania, the Pennsylvania Pollinator Protection Plan has been designed to provide information that will help support and expand populations of both wild and managed pollinators.**

THE IMPORTANCE OF POLLINATORS TO PENNSYLVANIA AGRICULTURE

Increasing abundance and diversity of bee populations leads to improved pollination of crops and higher yield (Southwick and Southwick 1992, Allen-Wardell et al. 1998, Garibaldi et al. 2013). Bee pollination can also increase quality, shelf life and commercial value of crops (Klatt et al. 2014). In total, animal-mediated pollination contributes approximately $25 billion annually to US agriculture (Calderone 2012), and generates an additional $20 billion in economic value in associated US industrial sectors (Chopra et al. 2015).

Pennsylvania has one the most diverse, and pollinator dependent, agricultural economies in the United States. Most counties in Pennsylvania grow at least 7 crop species, with the most diverse counties in the eastern part of the state growing between 9 and 12 species of crops (Aguilar et al. 2015). In the United States, only New York and California have comparable levels of crop diversity on a per county basis. Most US states have fewer than 4 crops per county and these tend to be crops such as corn and wheat that are not highly dependent on animal pollination.

Agricultural production can depend on pollinators in several ways (Klein et al. 2007). Pollination can:

- generate increased production of the parts of the plant that are consumed (for example, fruits, vegetables and nuts)
- increase production of seeds (for example, carrots require pollination to set seed but not to produce the carrot root)
- increase seed production for breeding alone (for example, varietals may be produced by cross-pollination)

Researchers at University of Pittsburgh and Pennsylvania State University recently examined the economic value of crops grown in Pennsylvania that benefit from pollination to produce fruits or vegetables, or to produce seed. Annually, Pennsylvania growers obtain approximately more than $250,000,000 in economic value from crops where pollination increase fruit and vegetable production, and an additional ~$9,300,000 in value from crops where pollination produces seeds (such as cabbage, carrots, broccoli). The top 20 economically valuable crops where pollination increases fruit and vegetable yield is shown in the table. Importantly, crops that use pollinators are a major source of nutrition for humans (Eilers et al 2011).

COMMODITY	ESTIMATED ANNUAL ECONOMIC VALUE (USD)	Calculation method
APPLES	124,462,768	1
TOMATOES (FIELD)	25,381,269	1
PEACHES	20,636,801	1
PUMPKINS	17,320,000	6
BLUEBERRIES	13,672,852	3
SNAP BEANS	9,051,000	6
STRAWBERRIES	7,711,608	1
BELL PEPPERS	7,359,413	2
SQUASH	5,300,170	5
CANTALOUPE	3,756,695	1
RASPBERRIES	3,716,696	5
CHERRIES (TART)	3,560,000	6
WATERMELON	3,134,102	5
CHERRIES (SWEET)	2,558,896	5
CHILE PEPPERS	2,325,343	5
CUCUMBER	1,785,647	5
PEARS	827,269	1
NECTARINES	606,298	5
EGGPLANT	598,994	4
PLUMS & PRUNES	462,767	5
TOTAL	**254,228,587**	

Calculation Methods:
1. Derived from NASS 2012 Census for PA (acreage) and 2012 Survey for PA (Yield and Price)
2. Derived from NASS 2012 Census for PA (acreage) and 2016 Survey for PA (Yield and Price)
1. Derived from NASS 2012 Census for PA (acreage), NASS 2012 Survey for PA (yield) and 2013 Survey (other states, price)
4. Derived from NASS 2012 Census for PA (acreage) and 2001 Survey (other states, yield and price)
5. Derived from NASS 2012 Census for PA (acreage) and 2012 Survey for US (Yield and Price)
6. Derived from NASS 2012 Survey for US (utilized production value)
Data from Jordan, A., Douglas, M., Patch, H., Grozinger, C., and V. Khanna, preliminary studies (University of Pittsburgh and Penn State).

Note that many crops can self-pollinate or be pollinated by wind, and thus production is not entirely dependent on animal pollinators (Klein et al. 2007). However, in the absence of pollinators, more land would need to be put into production in order to achieve similar yields (Aizen and Harder 2009).

THE POLLINATORS OF PENNSYLVANIA

The most recent bee species checklist for Pennsylvania reports 371 bee species in 51 genera (Fig. 1). However, this number is likely an underestimation given that adjacent states report over 400 species. We are currently revising this checklist and we have an updated total of 406 species for the state (Kilpatrick et al in prep.). About 70% of all wild bees in PA nest underground, and the remaining species use stems, wood and other structures for nesting. Only 5% show social behavior, and about 10% show narrow dietary breadth preferences.

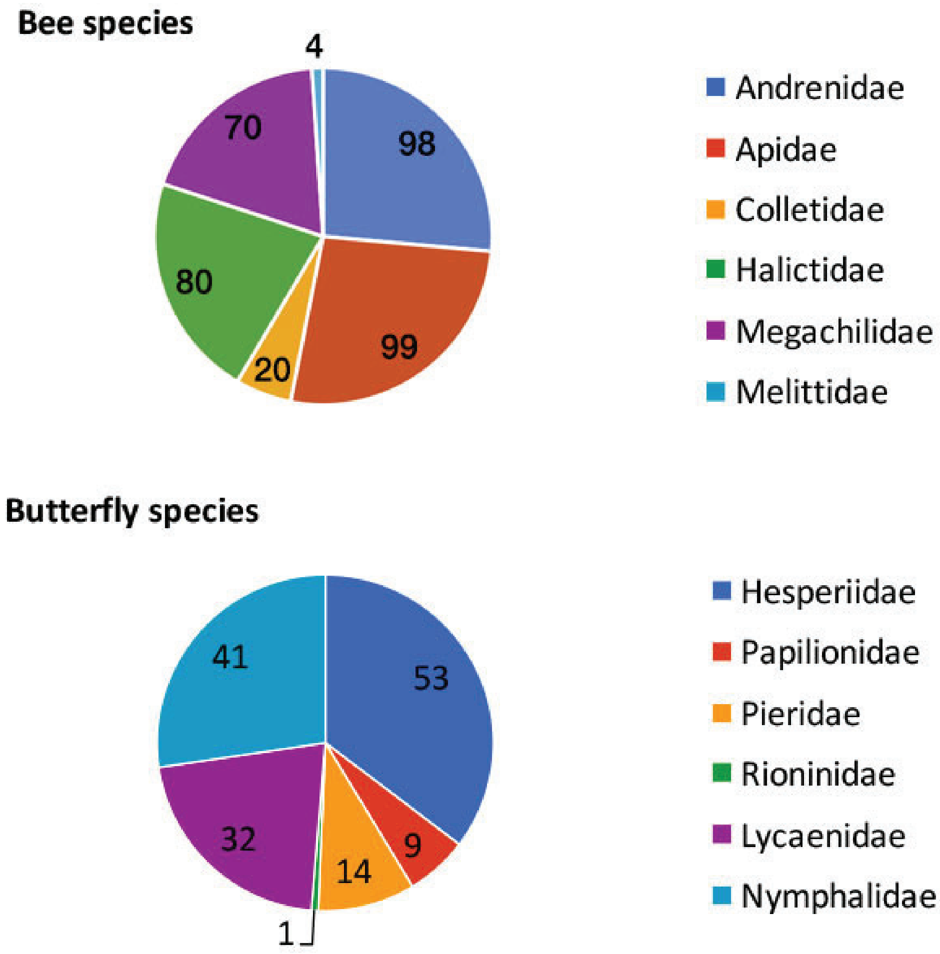


Figure 1. Number of bee and butterfly pollinator species per family reported for Pennsylvania. Data for bees from Donovel and van Engelsdrop 2010; data for butterflies from discoverlife.

Research at the Penn State Fruit Research and Extension Center in Adams County has found about 235 bee species in fruit orchards - for comparison there are 267 bees in the entire United Kingdom (Breeze et al. 2012, BWARS 2012). More than 50 of these species visit apple and cherry blossoms in the spring. The native ecosystem service of pollination for these bees is so great many growers (many of whom have orchards with less than 50 acres) do not have to rent increasingly expensive honey bees colonies for pollination services (Figure 2).

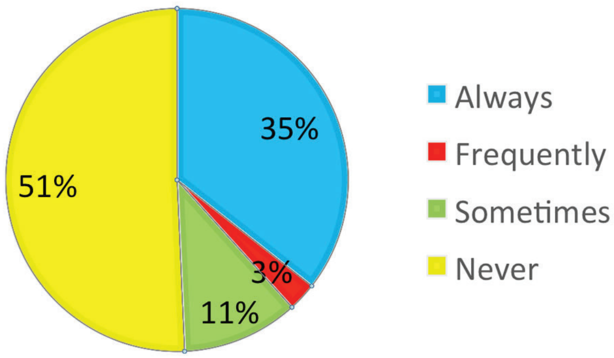


Figure 2. Proportion of surveyed Pennsylvania apple growers that rent honey bees for apple pollination. Data provided by D. Biddinger, Penn State University.

The roles of important non-bee pollinators in Pennsylvania have not been studied but likely include flies (mostly in families Syrphidae and Bombyliidae), some beetles, butterflies and moths (Inouye et al. 2015, Larson et al. 2001, Orford et al. 2015, Woodcock et al. 2014). Among these, flies are the most likely to pollinate plants in agricultural systems (Radar et al 2016). Flies in the family Syrphidae can provide key pollination services to crops such apples, pears, strawberries, cherries, plums, peaches and raspberries, among other crops.

A total of 14 introduced (non-native) bee species are currently present. These include the yellow-faced bee *Hylaeus leptocephalus* (Colletidae); the mining bee *Andrena wilkella* (Andrenidae); the sweat bees *Lasioglossum leucozonium* and *Halictus tectus* (Halictidae); the chimney bee *Anthophora plumipes* (Apidae); the mason bees *Anthidium manicatum, A. oblongatum, Osmia caerulescens*, and *O. taurus* (Megachilidae); the Mediterreanean wood boring bee *Lithurgus chrysurus* (Megachilidae); and the leafcutting bees *Megachile apicalis* , *M. concinna*, and *M. sculpturalis*. Another three non-native species are currently managed for crop pollination: *M. rotundata, O. cornifrons* (Megachilidae); and the honey bee *Apis mellifera* (Apidae).

POLLINATOR DECLINES

Globally, pollinator declines are a reflection of the overall declines in biodiversity that are associated with the sixth planetary extinction event (the last event, the so-called K-T extinction, occurred 64 mya and was the end of many species including the non-theropod dinosaurs (Dirzo et al. 2014 , Potts et al. 2010). Approximately one-third of all studied insect species are showing declines (based on data from the International Union for the Conservation of Nature). In the United Kingdom, for which we have some of the best data, some 30 to 60% of species in each insect order have declining population ranges. In Europe 37–65% of bee species are considered to be of conservation concern (Patiny et al. 2009). However for much of the world and for many insect taxa we have little or no data (IPBES 2016, National Research Council 2007).

In the United States, populations of honey bees have shown steep declines in recent years. The number of managed honey bee colonies have declined by 61% in the US during the past 70 years (van Engelsdorp and Meixner 2010), though recently the total numbers of honey bee colonies have been relatively stable (see data from the National Agricultural Statistics Service). However, while historically annual mortality rates were around 10%, currently beekeepers lose approximately 40% of their colonies each year (Steinhauer et al. 2015). Recent surveys of Pennsylvania beekeepers have recorded average overwintering losses of 20-90% in different counties, with a statewide loss of 52% of colonies in the winter of 2016-2017 (data provided by the PA State Beekeepers Association). In the face of these substantial winter losses, beekeepers must actively manage their colonies to make "splits" or obtain honey bees from southern providers each year.

In the United States, some of the most dramatic pollinator declines have been measured for bumble bee species (Cameron et al. 2011). Comparisons of current distributions to historic distributions for 8 bumble bee species showed the relative abundance of four species have declined by 96%. The other four species had either stable or expanding populations. Furthermore model-based approaches suggest overall bee abundance declines across 23% of US land area between 2008 and 2013 (Koh et al. 2016), but precise numbers are not available. Finally, monarch populations, which migrate across North America, have declined dramatically based on the sizes of overwintering populations in Mexico (Brower 2012).

Pennsylvania currently has 51 species of butterflies, 111 species of moths, and 3 species of bumble bees that are considered Species of Greatest Conservation Need according to the 2015 State Wildlife Action Plan. The bumble bee species include *Bombus affinis*, *Bombus terricola*, and *Bombus ashtoni*. The rusty-patched bumble bee, *B. affinis*, was the first bee species in continental US to be listed in the endangered species act. This bumble bee has not been detected in Pennsylvania since 2006, and it was presumably extinct from the northeastern US. More recently surveys from 2016 did not record the presence of the once ubiquitous *B. pensylvanicus* in Pennsylvania.

Very few data are available on the population stability of many of our insect pollinators, including the majority of our native bees, wasps, beetles and flies. However, a recent study of the bees of the northeast identified that wild non-*Bombus* species have declined by 15% in the past 140 years (Bartomeus et al. 2013). The 'Red List of Bees' from the Xerces Society includes *Epeoloides pilosula*, which has not been recorded in the northeast for over 50 years. In contrast, non-native species such as *A. manicatum* and *O. taurus* have a positive trend in abundance over time. Taken all together, this suggests that bee communities in Pennsylvania are currently changing as some species are in decline and abundance of non-native bee species is increasing, a general trend that can result in homogenization of communities and loss of biodiversity (Biesmeijer et al. 2006, Carvalheiro et al. 2013, Marini et al. 2014, Weiner et al. 2014).

Clearly, pollinator communities in Pennsylvania are changing dramatically. However, we only have limited data for a handful of key species. **It is therefore extremely important to conduct longitudinal studies that monitor insect biodiversity across the state.**

CAUSES OF POLLINATORS DECLINE

Changes in both managed and unmanaged pollinator populations are caused by a combination of interacting factors. The relative role of each of these factors differs across pollinator species, landscapes, and land management practices.

The main drivers of pollinator population declines across the world include **habitat loss, degradation, and fragmentation**, and the introduction of invasive species (Fischer and Lindenmayer 2007, Winfree et al. 2011). These negative habitat changes can reduce the population sizes, species composition, and richness (number of species) of pollinator communities by altering community interactions and reducing or removing nest habitats and the plant diversity pollinators rely on for pollen and nectar. As a result, pollination services to natural ecosystems and to agroecosystems can be reduced (Hadley and Betts, 2012, Kennedy et al. 2013, Steffan-Dewenter and Westphal 2008, Winfree et al. 2011). In the "Best Practices for Forage and Habitat" section, we discuss approaches for increasing the abundance and quality of urban, suburban, managed, agricultural, and natural landscapes to support diverse and plentiful pollinator populations.

Pesticide use - including insecticides, herbicides and fungicides - in urban and agricultural landscapes have been implicated as factors contributing to pollinator declines (Kevan et al. 1997, Potts et al. 2010, Rortais et al. 2005 Vanbergen et al. 2013). Pesticides represent a critical and often necessary tool for managing pests, diseases, invasive species and vectors of human disease. However, these pesticides can impact non-target populations as well. The impacts of pesticide use on pollinator populations are complex (see detailed discussion in "Best Practices for Pesticide Use" section and Johnson 2015). Pesticides can cause acute mortality or more subtle sublethal effects, they can vary greatly in their toxicity to different pollinator species, and the impacts of a pesticide on a pollinator can vary according to the pollinators' developmental state, nutritional status, and physiological condition. Additionally, pollinators are often exposed to multiple pesticides which can act synergistically or additively. Finally, some pesticides, such as herbicides, can indirectly impact pollinators by reducing the abundance or quality of flowering plant species in a treated area. In the "Best Practices for Pesticide Use" section, we discuss approaches for balancing disease, pest and invasive management while supporting pollinator populations.

A third challenge to pollinator populations is that posed by **pests and pathogens**. Research on non-managed pollinators is just beginning but the relationship been honey bees and pest and pathogens have revealed profound challenges and complex interactions (Cornman et al. 2012). The introduced mite, *Varroa destructor*, is a major problem for beekeepers in the US and Europe (Nazzi and Le Conte, 2016). Management of mite populations is often critical for ensuring productive colonies and without it losses are much higher than the economically accepted degree. These mites also vector deadly viruses, particularly deformed winged virus (DWV), which caused wing malformation during development (Dainat et al. 2012, de Miranda et al. 2011, Martin et al. 2012, Nazzi et al. 2012, Neuman and Carreck 2010, Ryabov et al. 2014). Importantly, it is clear that pathogens can spread between managed bees and wild bee populations in the surrounding landscape, though the full impacts of these pathogens in native bee species remains to be determined (Colla et al. 2006, Fürst et al 2014, Tehel et al. 2016). In the "Best Practices for Beekeepers" section, we discuss approaches for managing parasites, pathogens and diseases in honey bee colonies, to ensure both healthier honey bees and surrounding pollinator populations.

The challenges facing pollinators are world-wide and are predicted to be amplified in the future due to human population growth, conversion of land and intensification of land management for human use, climate change, and increased movement of potentially invasive species including pests and pathogens through trade and commerce (Bommarco et al. 2012; IPBES 2016).

Pennsylvania faces the entire suite of challenges to our ecosystems and our agricultural productivity, but it is a unique are because of its natural endowment of diverse pollinators that deliver ecosystem services. These services are vital in that Pennsylvania has a cropping system that is dependent on pollinators to a great degree and because managed pollinators like honey bees face considerable ongoing challenges. Conservation and sound management of Pennsylvania's land and biodiversity, and a minimalist approach to the use of chemicals in our agricultural, urban and wild landscapes forms the core of our plan to protect pollinators.

MANAGING CHALLENGES TO POLLINATORS IN PENNSYLVANIA

The sections that follow outline key best practices for supporting and expanding pollinator populations in Pennsylvania. These recommendations are derived from research, assessments, and practical experience that have been integrated from information provided by multiple organizations and stakeholder groups in Pennsylvania. The Pennsylvania Pollinator Protection Plan comprehensively discusses best practices to support pollinators in diverse landscapes, including urban, roadsides and rights of way, agricultural and natural areas. The Pennsylvania Pollinator Protection Plan thus meets the recommendations of the US National Strategy to Protect the Health of Honey Bees and Other Pollinators (Pollinator Health Task Force, 2015), and is broadly in accord with the pollinator protection plans produced by other states and other countries.

Overall, the goal of the Pennsylvania Pollinator Protection Plan is to summarize the challenges and opportunities related to supporting healthy pollinator populations, provide practical and state-specific approaches to conserving and expanding Pennsylvania Pollinator populations, while creating a "living document" that is linked to outside resources and that can be updated as new information, or new challenges, arise. Moreover, this document represents the development of a coordinated network of stakeholders and institutions that will work together in the future to safeguard the prosperity and well-being of the people of Pennsylvania by preserving healthy pollinator populations.

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CHAPTER 2

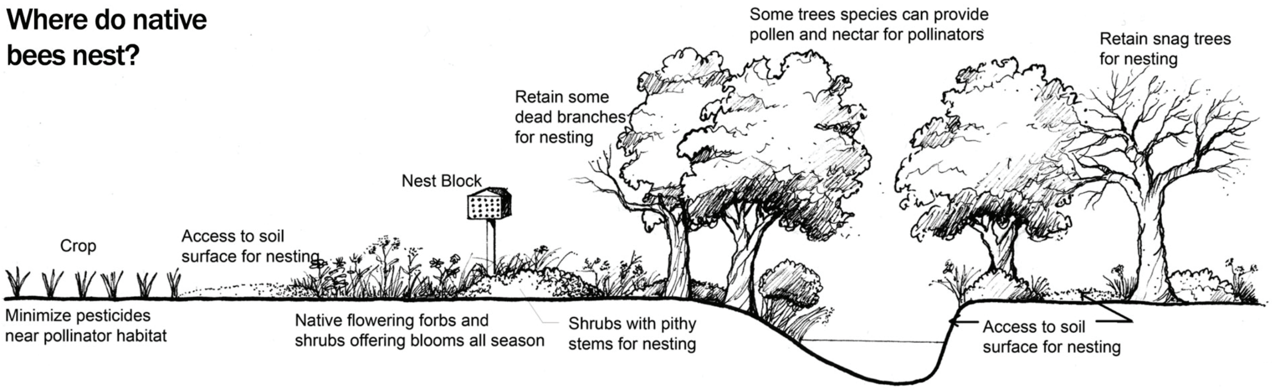
BEST PRACTICES FOR FORAGE AND HABITAT

TABLE OF CONTENTS

INTRODUCTION

To support healthy and diverse communities of pollinators, landscapes must provide appropriate nesting sites, abundant and high quality nutritional resources (flowering plants), a consistent supply of water, and minimal exposure to stressors such as pesticides. Because the nesting and nutritional needs of different pollinator species are quite diverse, it is critical to ensure landscapes contain an abundant and diverse array of nesting opportunities and flowering plant species. We will focus on best practices to generate high quality nesting and forage habitat in different types of landscapes in this section. Information on how to minimize pesticide exposure can be found in the "Best Management Practices for Pesticide Use" section.

Wild bees can nest in the ground (and thus require soil that can be easily dug out to form tunnels or chambers), in cavities found the ground (including empty rodent nests), trees or rocks, or they may excavate and nest in stems or twigs. Approximately 30% of native bee species in the US nest in wood, while 70% nest in the ground. Diverse nesting sites will be readily available in complex habitats (such as forest edge or hedgerows), but it is also possible to provide nesting boxes or other suitable sites in smaller areas, such as home gardens. For more information, see resources for creating nest sites developed by the Xerces Society, the USDA National Agroforestry Center, or Penn State.



Bees can nest in diverse sites in the landscape. Figure fromUSDA National Agroforestry Center, AF Note 34

Pollinators depend on flowering plant species for their food. All species of pollinators (bees, flies, butterflies, moths, hummingbirds, bats, etc) use nectar as their primary source of carbohydrates. Bees in particular also collect pollen from flowering plants as a source of protein, fats, and other micronutrients. High quality and abundant pollen is critical for female bees to produce eggs and rear their brood.

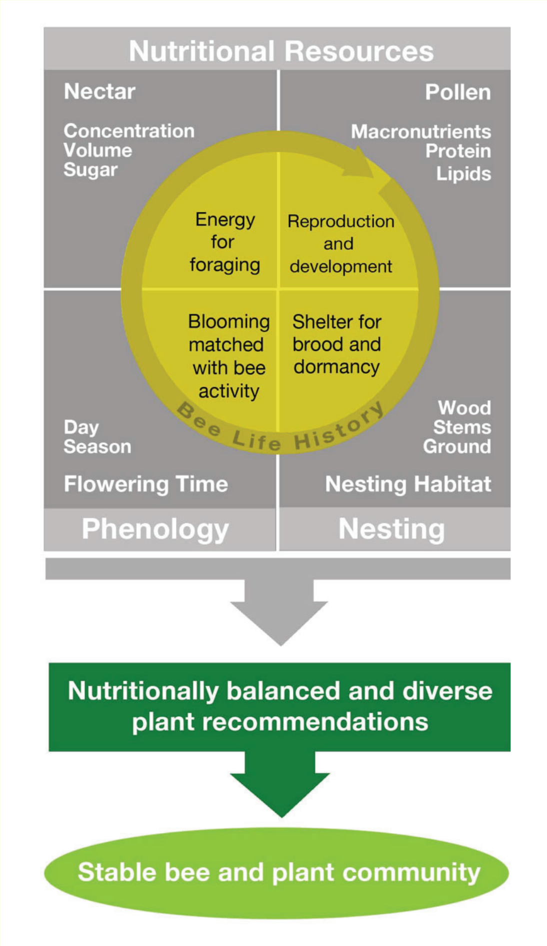
Pollinators vary greatly in

- the time of year that they are active (for example, orchard bees are active in the early spring while bumble bees are active from spring to fall)
- the time of day that they are active (moths are active at night, squash bees are active in the early morning and honey bees are active from mid-morning to evening)
- the type of flowers they can access (hummingbirds can access flowers with long corollas while bees cannot, bumble bees can perform "buzz pollination" and thus can access pollen from species such as tomatoes, while honey bees cannot)
- the color of flowers they are most attracted too (flies tend to be more attracted to white flowers while hummingbirds tend to be attracted to red flowers)
- the scent of the flowers they are most attracted to (bees prefer floral odors, flies prefer fetid odors, and some night flying moths are attracted to the carbon dioxide released by night flowering plants).
- their nutritional needs (bumble bees prefer pollen with higher protein content than honey bees, while hummingbirds prefer different kinds of sugars than bees).

Similarly, flowering plant species vary in their phenology (whether they bloom in the spring, summer and fall), the time of day that their flowers are open and accessible to pollinators, the flower color, the shape and physical structure of the flower, floral scents, and the quantity and nutritional quality of the nectar and pollen. **Thus, supporting diverse and healthy pollinator species requires abundant and diverse flowering plant species that bloom during the entire growing season.** There are multiple resources available to help identify appropriate flowering plant species to include in different landscapes, which will be discussed in more detail below. Additionally, regional guides to pollinator plants and habitat restoration guides can be found on Xerces' Pollinator Resource Conservation Center.

Finally, some pollinators require special food sources for their young. For example, butterfly and moth caterpillars often feed in specific plant species: for example, monarch caterpillars feed on milkweed, while swallowtail caterpillars feed on plants in the carrot family, such as wild parsnip, Queen Anne's Lace, parsley, and dill. **Thus, it is important to include a diversity of caterpillar host plants to support these pollinator species.**

Issues related to restoring and maintaining landscapes to support diverse pollinator communities were recently discussed in a publication from Penn State, and summarized in the figure below. Below, we discuss approaches to support pollinator communities in different contexts, including urban, roadsides and right of ways, agricultural and natural landscapes.



Conceptual schematic presenting a holistic framework for designing landscapes for bee conservation and habitat restoration. Developing a habitat that can support multiple pollinator species requires an understanding of the (1) seasonal and daily phenology of bee and plant species, (2) bee nutritional requirements and the nutritional quality of nectar and pollen from commercially available host-plant species, and (3) bee species nesting requirements. This information can be used to develop landscapes that supporting bees' annual life cycle by selecting plants whose (1) timing of bloom matches with bee active foraging periods, (2) nectar characteristics support bee energetic needs, especially during foraging, (3) pollen characteristics support bee reproduction and development, and finally, provide (4) nesting habitat for bees to rear brood and spend periods of time of inactivity and dormancy. The outcome of a comprehensive conservation effort is that we provide a diverse group of bee species appropriate nutrition and habitat that will stabilize their populations. Healthy and diverse bee populations will then be more effective pollinators of wild host-plant and crop species. Figure and legend from: Vaudo, Tooker, Grozinger and Patch. Current Opinion in Insect Science 2015, 10:133–141

BEST PRACTICES FOR URBAN AND SUBURBAN LANDSCAPES

Gardens and green spaces in urban areas can support diverse pollinator communities; in fact, some studies have found urban areas support more diverse communities than surrounding rural areas. These diverse pollinator communities can serve to better connect the public with the natural world, provide critical learning opportunities for K-12 students, ensure pollination of fruits and vegetables in urban gardens and farms, and provide additional habitat and forage for pollinator communities in surrounding areas. Furthermore, simple changes to land management and land use practices can dramatically increase the habitat and forage available in urban areas, and thus lead to more community involvement and engagement.

In Pennsylvania, individuals can certify their pollinator gardens through the Penn State Master Gardeners and find many valuable resources for designing pollinator gardens on the PA Pollinator Garden Certification website. Additional resources, including sample gardens designs, can be found in the Snetsinger Butterfly Garden website. Individuals are encouraged to visit local gardens and arboretums to learn more about pollinator gardens and native Pennsylvanian plants, such as the Pollinators' Garden at the Arboretum at Penn State, the Phipps Conservatory and Botanical Garden in Pittsburgh, and Longwood Gardens outside of Philadelphia.

Individuals are also encouraged to advocate for Township or Municipal native plant or pollinator habitat ordinances that provide for allowing areas around homes and businesses to incorporate a variety of plant types (not just short grasses and lawns) as long as they are managed and not neglected. Such recommendations for "neighborly natural landscaping" are provided from Penn State Extension, and York County, PA recently developed a sustainable landscape model ordinance. Incorporated towns, cities and communities can become certified with the Bee Friendly PA program and with Bee City USA. Below, we provide specific recommendations for producing and maintaining pollinator habitat and forage in different types of urban areas.

Lawn Care. Traditional lawns with low-cut grass and no flowering plants provides no nutritional resources for pollinators and limited nesting opportunities. Homeowners and landscapers may choose consider alternative strategies for managing these areas, such as incorporating "natural" landscapes. If lawns are preferred, to support pollinators it is recommended that homeowners:

- Allow plants such as dandelion, dead nettle and clover to bloom in lawns. They provide an important early source of pollen and nectar for pollinators.
- Mow as high as possible (greater than 3") to allow for blooming plants and nesting and overwintering habitat.
- Use an Integrated Pest Management (IPM) and Integrated Vegetation Management (IVM) approach to manage pests, diseases, and weeds (see Best Management Practices for Pesticide Use section). An IPM/IVM approach will reduce the use of pesticides, including herbicides,

and limit the exposure of pollinators to any pesticides that must be applied. For lawns in particular, mowing off flowers before applying pesticides can reduce exposure of foraging bees (though ground nesting bees will still be impacted).

Gardens, Landscapes, and Golf Courses. As noted above, there is a wealth of information on "neighborly natural landscaping" through Penn State Extension as well as how to create pollinator forage and habitat (including recommended plant lists) in gardens and larger landscapes on the Pennsylvania Pollinator Garden Certification website. Homeowners and landscapers can also obtain additional information through the Penn State Master Gardeners program, and through classes and workshops at the Phipps Conservatory and Botanical Garden. Briefly, recommendations for these gardens include

- Growing a diversity of flowering plant species that bloom throughout the season to provide nectar and pollen for foragers.
- Including host plant species for butterfly larva (i.e. monarch caterpillars and milkweed)
- Preferentially use native plant species for your particular region, since these are generally best suited to support pollinators and to grow under typical Pennsylvania conditions. However, other plants can also be beneficial and should be included as needed to increase forage diversity and quality.
- Avoid plant species that are considered invasive or noxious, and remove these if they are found in your property. A list of these plants is provided on the DCNR Invasive Plants List. Fact sheets with information on how to identify and control invasive plants are available at the DCNR Wild Plants Website.
- Double flowered plants and some hybridized plants generally do not provide much nectar and/or pollen. Include other plants in your garden in addition to these.
- Consider all types of plants - trees, shrubs, vines, perennials, annuals and herbs -that contribute to the habitat, taking advantage of all areas and layers. Plant in beds, containers and hanging baskets.
- Ornamental grasses, shrubs and non-flowering plants also contribute to the garden providing nesting sites for pollinators and protection from the weather.
- Include seasonal variety. Fall is particularly difficult for some pollinators as summer plants are declining and overwintering pollinators are preparing for the cold. Monarchs are also migrating south during this time.
- Use an Integrated Pest Management (IPM) and Integrated Vegetation Management (IVM) approach to manage pests, diseases, and weeds

(see Best Management Practices for Pesticide Use section). Mechanical and cultural methods are often very effective for addressing a variety of issues.

- Allow plants to stand over the winter. Delay garden clean-up until plants are starting to emerge (late spring) as many pollinators use standing gardens and debris as overwintering sites.
- Additional information on managing golf courses for pollinators can be found in "Optimizing Pest Management Practices to Conserve Pollinators in Turf Landscapes: current practices and future research needs" and in the Audubon Cooperative Sanctuary Program for Golf.

Urban Landscapes. Increasing green spaces in urban areas are associated not only with improved biodiversity but also with improved happiness and health of people living in these areas. Given the diversity of plant species that support pollinators, it is relatively straightforward to simultaneously increase green space and vegetation while improving pollinator habitat and forage. In particular, urban planners should:

- Choose native species that have pollinator benefit when choosing yard and street tree species. A listing of native tree and woody ornamental species that support pollinators can be found in publications from the extension programs at Michigan State University and University of Kentucky.
- Remove invasive species and replace with beneficial native plant species.
- Install green roofs where possible. Choose flowering and pollinator host plant species where possible.
- During public comment phase of public space design projects, work with municipal officials and design teams to specify plants that are beneficial to pollinators. York County, PA recently developed a sustainable landscape model ordinance.
- Work with, or join city park volunteer "friends" groups to promote pollinator habitat restoration and creation. An example of such an organization is the Friends of Wissahickon.

BEST PRACTICES FOR ROADSIDES AND UTILITY RIGHTS OF WAY

Roadsides cover more than 10 million acres of land in the US. Pennsylvania has more than 40,000 miles of roads, and is one of the top five states in the nation for road miles. More than 100,000 aces of roadside lands are managed in Pennsylvania. Additional land is provided by utility rights of way (ROW) and corridors, which create open space across diverse landscapes. These areas can be managed to provide habitat and forage for pollinators and other wildlife as well as increase aesthetic appeal. In 2015, the "Fixing America's Surface Transportation Act" (FAST Act-Public Law 114-94, Section 1415) directed the Secretary of Transportation to use existing authorities, programs and funding to encourage State Departments of Transportation to facilitate efforts to improve habitat and forage for pollinators.

Roadsides and ROWs can provide habitat and forage for pollinators in areas where there may be little appropriate habitat, and provide "corridors" connecting different regions, thereby supporting pollinator movement and allowing pollinators to access foraging resources and habitat in larger areas. Indeed, several studies have suggested that improving habitat on roadsides can increase the abundance and diversity of pollinators. While pollinators can be killed from collisions with cars when they cross roads, studies have indicated that the population losses from car collisions are small, and increasing pollinator habitat along roadsides can actually reduce the movement of pollinators across roads. Roadsides can also be managed to both support pollinators and limit larger wildlife, such as deer: for example, reduced mowing can increase the abundance of flowering native plants and reduce the amount of plants that are palatable for deer.

Managing roadsides and ROWs to support pollinator populations is a challenging task. Land managers need to balance the needs of drivers and utility companies (for example, areas around roads need to be maintained to ensure visibility, safety, access, and reduce erosion) and invasive species management, with support of the nutritional and habitat needs of diverse pollinator species. Moreover, roadsides and ROWs are located in diverse habitats, not all of which are appropriate for supporting pollinator habitat, and which likely contain residues of gasoline, motor oil, ethylene glycol as well as salt and sand from winter roadside management. Finally, roadsides and ROWs cover vast amounts of land, and thus it is most appropriate to consider management of selected locations and areas which are amenable to management and will provide the most benefit to pollinators.

Detailed information on managing roadsides and rights of way for pollinators can be found in resources from Pollinator Partnership, the Xerces Society, Monarch Joint Venture and the US Department of Transportation Federal Highway Administration. Listed below are general guidelines to consider while developing plan to restore, maintain and expand forage and habitat for pollinators along roadsides and ROWs.

- Build a coordinated network of individuals and groups interested in restoring and maintaining pollinator habitat. Volunteer groups can partner with Pennsylvania Department of Transportation (PennDot) through the "Adopt and Beautify" Program, while businesses and corporations can partner with PennDOT through the "Sponsor a Highway" Program.
- Evaluate potential sites and select an optimal site. Site selection criteria can include soil quality, proximity to other pollinator habitat, sunlight and water availability. It is also important to contact the US Fish and Wildlife Service to confirm that the site is not the habitat of a sensitive species. A site selection rubric can be found in these documents from Pollinator Partnership and Monarch Joint Venture.
- Develop a restoration and management plan, with clear expectations for timelines, budgets and goals. Expect that the project will require 3-5 years of sustained effort.
- Include a selection of plants that will provide nectar and pollen resources for pollinators throughout the growing season, as well as plants that serve as food sources for caterpillars of key pollinator species (such as milkweeds for monarch butterflies).
- Develop strategies for controlling invasive plant species at appropriate levels (for example, the evaluation plan may state that up to 20% of plant species in the site can be non-native species before management is needed).
- Provide nesting habitat for pollinators, such as areas with bare soil for ground-nesting species.
- Roadsides and ROWs will require periodic mowing. Develop a plan that ensures the needs of stakeholders are met while optimally supporting pollinators. For example, mowing once a year in the fall – after bloom - may reduce negative impact on pollinators, reduce the presence of invasive species, while ensuring visibility and safety. Alternatively, sections can be mowed at different times, to ensure that some flowering plants and habitat are always intact.
- Use an "Integrated Vegetation Management" and "Integrated Pest Management" approach to reduce the use of herbicides and pesticides in these areas, while still maintaining populations of invasive plant species and insect pests at below threshold levels. Use methods that reduce the impact of pesticides on pollinators, eg, minimizing

drift, including non-pesticide buffer zones, spraying only a portion of the area. See information in "Best Management Practices for Pesticide Use" for more information. Information on IVM approaches can be found in PennDOT's "Invasive Species Best Management Practices" publication.

- Develop an evaluation plan to document the success of the restoration and maintenance efforts.
- Celebrate the success of the management plan through social media and events, to encourage other organizations to participate in similar efforts.

BEST PRACTICES FOR AGRICULTURAL LANDSCAPES

Approximately 75% of major agricultural crops require or benefit from pollinators to set seed and produce fruit, and all crops can benefit from the arthropods that prey on or parasitize pest species, thereby reducing the negative impacts of these pest populations. Thus, there can be tremendous economic advantages to conserving and expanding populations of beneficial arthropods (managed and wild pollinators, predatory and parasitoid species) in agricultural landscapes.

There are many strategies growers can use to enhance and expand forage and habitat for pollinators in their farms. Growers can install hedgerows on the edges of agricultural fields, meadows in areas that are not in production, and add flowering cover crops within agricultural fields. All of these have multiple benefits in addition to supporting diverse communities of pollinators and beneficial insects, including serving as windbreaks and limiting water and soil runoff and erosion. Detailed information on how to select and prepare sites, choose appropriate plant species, install pollinator habitat and forage, and maintain these sites can be found in the following documents:

- Regional guides to pollinator plants and habitat restoration guides can be found on Xerces' Pollinator Resource Conservation Center.
- USDA-NRCS/Xerces Society: Hedgerow Planting for Pollinators: Pennsylvania Installation Guide & Job Sheet
- USDA-NRCS/Xerces Society: Conservation Cover for Pollinators: Pennsylvania Installation Guide & Job Sheet

- USDA-NRCS/Xerces Society/SARE: Cover Cropping for Pollinators and Beneficial Insects
- USDA National Agroforestry Center's factsheet on Windbreaks
- USDA National Agroforestry Center's factsheet on Enhancing Nest Sites for Native Bee Crop Pollinators
- USDA National Agroforestry Center's factsheet on Improving Forage for Native Bee Crop Pollinators
- USDA National Agroforestry Center's factsheet on Sustaining Native Bee Habitat for Crop Pollination
- Several programs are available to help growers install pollinator forage and habitat on their lands. These include:
- USDA-FSA Conservation Reserve Program (CRP)
- USDA-NRCS Conservation Stewardship Program (CSP)
- USDA-NRCS Environmental Quality Incentives Program (EQIP)
- USDA-NRCS Conservation Innovation Grants Program (CIG)
- USFWS Partners for Fish and Wildlife Program

BEST PRACTICES FOR NATURAL LANDSCAPES.

Pennsylvania has 121 state parks spanning 300,000 acres, 2.2 million acres of state forest, and 1.5 million acres of state game lands. However, approximately 70% of Pennsylvania's forested land is privately owned, and thus it is critical that a broad range of stakeholders are engaged in efforts to protect pollinators in pollinator conservation, especially considering that no state agency has legal authority over Pennsylvania's native terrestrial insects. This section provides recommendations for best practices to support and expand pollinator populations in larger tracts of relatively undeveloped forest and other natural habitats, including fields, wetlands, and riparian zones.

In addition to the information provided below, there are many comprehensive resources available that cover a broad range of management recommendations for pollinators on natural lands. The Pennsylvania Natural Heritage Program's (PNHP) Habitat Management for Pollinators[48] provides information on a variety of best management practices including ways to promote habitat variety to support all life stages of pollinators, maintain open habitats, control invasive plants, protect pollinator diversity and rare species, and select native and local plants for pollinators. Two comprehensive guides on habitat management for pollinators include the USDA Natural Resource Conservation Service's Pollinator Biology and Habitat, and the Xerces Societies' Pollinators in Natural Areas: A Primer on Habitat Management.

Incorporate Pennsylvania native plants, shrubs, and trees into wildlife habitat and reclamation efforts on public lands. Planting projects in forests and other natural habitats should include a variety of native trees, shrubs, grasses or forbs (wildflowers) to increase ecosystem functions and habitat diversity for pollinators and other wildlife. Native pollinators and other insects have evolved over time with native plants, and native plants are adapted to local climate and soil conditions. Furthermore, some native species can grow in very dry and nutrient-poor sites, do not need soil amendments, and rarely require fertilizer for establishment. Look for herbaceous and woody plants that will create continuous flowering throughout the growing season to ensure that nectar sources are present from spring through fall. Select a variety of plants with different flower colors and shapes that will bloom within each of the three growing seasons. When replanting disturbed sites, consider including an annual native like partridge-pea which can flower during the first growing season before other native perennials become established. As a general rule, maintenance activities such as mowing along roadsides and in rights of ways, and burning or mowing in early successional habitats that support native flowering plants, should be conducted in a patchy manner and outside of the growing season when possible.

The Pennsylvania Bureau of Forestry Planting and Seeding Guidelines document provides recommendations on how to restore a disturbed site with native grasses, sedges, rushes, flowering plants, shrubs, deciduous trees, and conifers. The PNHP Habitat Management for Pollinators[49] provides additional recommendations on how to select plants that will supply food to pollinators in their adult and immature life stages, and how to maintain pollinator habitats through management practices such as rotational mowing. The USDA Natural Resource Conservation Service's Pollinator Biology and Habitat document provides simple guidelines on how to assess plant community diversity, select plants for a site, and design the planting layout to maximize attractiveness to pollinators.

Prevent new invasive plant infestations and control existing ones. Some invasive plants can provide a temporary bloom of flowers for adult pollinators, but in the long term do much more harm than good by out-competing native caterpillar food plants and adult nectar plants and degrading other important habitat qualities. For a list of plants that are not native to the state, grow aggressively, and spread and displace native vegetation, see the DCNR Invasive Plants List. Fact sheets with information on how to identify and control invasive plants are available at the DCNR Wild Plants Website. Specific information on locations of invasive species and control efforts can be found at iMapInvasives.

Herbicides are necessary tools for land management and controlling invasive species, but these pesticides can have negative impacts on non-target species (including the plants that pollinators depend on for nutrition) and thus should be used as part of an **Integrated Vegetation Management** (IVM) approach. For more details, see the "Best Practices for Pesticide Use" section. Additionally, the following resources are comprehensive guides for controlling invasive plants and the use of herbicides in natural habitats:

- Safe Herbicide Handling in Natural Areas: A Guide for Land Stewards and Volunteer Stewards
- Upkeep and Maintenance of Herbicide Equipment: A guide for natural area stewards
- Weed Control Methods Handbook: Tools and Techniques for Use in Natural Areas

Deer Management. Deer browse on trees, herbaceous plants and shrubs can limit the food resources needed by local populations of adult and larval insects. Protecting pollinator nectar and host plants from excessive deer browse is a difficult challenge in many regions of Pennsylvania. Fencing and tree tubes are often necessary to protect investments in native plantings. Good overviews of how white-tailed deer shape their environment are available at DCNR's Role in Deer Management: Conserving Pennsylvania's Forests and Native Plants, in Penn State Extensions' White-Tailed Deer, and in the USDA Forest Service Northeastern Area's Impacts of White-Tailed Deer Overabundance in Forest Ecosystems: An Overview. Two publications that provide more detailed deer management recommendations include The Natural Lands Trust's Deer Management Options and the Cornell Cooperative Extension's White-tailed Deer Wildlife Damage Management Fact Sheet.

CHAPTER 3

BEST PRACTICES FOR PESTICIDE USE

TABLE OF CONTENTS

INTRODUCTION

Pesticides are used to control pest populations, and are generally named for the type of organism they control (see "Pesticide Terminology" box). Pesticides are important tools for homeowners, growers, land managers, public health officials and beekeepers to control insect pests, disease vectors (such as mosquitos), disease-causing organisms (bacteria, fungi), weeds, and invasive species that threaten the balance of our natural ecosystems.

However, pesticides can be toxic to non-target species. For example, insecticides used to control insect pests can be toxic to insect pollinators as well as non-insect species (including wildlife and humans). Pesticides can have indirect impacts on non-target species as well. For example, herbicides used to control weeds in fields may reduce the availability of flowering plants on field edges, robbing pollinators of valuable food sources.

Pesticide Terminology:

Pesticides: chemicals used to control pest populations. They are named by the type of pest they target: for example, insecticides are toxic to insects (and often mites), miticides are toxic to mites, herbicides are toxic to plants, and fungicides are toxic to fungi.

Active ingredient: the chemical in a pesticide formulation that is toxic to the targeted pest.

Adjuvant: Chemicals added to a pesticide to enhance the performance of the active ingredient. Adjuvants can allow the pesticide to adhere or spread over the plant and/or leaf more efficiently. Note that adjuvants alone can impact bees in laboratory studies.

Systemic pesticides: pesticides taken up and spread through an organism to kill pests that feed on that organism. For example, a systemic pesticide applied to a plant spreads through its vascular system and kills targeted pests (and sometimes non-pests) that feed on that plant. Pesticide exposure for pollinators occurs through the ingestion of systemic insecticides in plant parts such as nectar, pollen, leaves, and stems. Systemic pesticides can remain in the plant for several weeks to years after application.

Contact pesticides: pesticides which must make direct contact with the pest targeted for control.
Broad spectrum pesticide: a pesticide that can control a wide range of pests.

Residual pesticides: pesticides which can be used when a pest is a continual problem. A "residue" remains active long after it is applied, providing long-term control.

Moreover, long-term exposure to pesticides can facilitate the selection of pesticide-resistant pest populations, which limits the long-term utility of these pesticides.

Thus, it is critical that pesticides be used thoughtfully to reduce off-target impacts and ensure their long-term effectiveness.

Exposure of pollinators to chemicals. Since pollinators actively visit any flowering plants within their foraging range, their exposure rates to pesticides can be quite substantial. Studies from Penn State found that samples from honey bee colonies contained more than 120 pesticides and metabolites.

Pollinators (and other beneficial arthropods) can be exposed to pesticides when:

- Pesticides are sprayed where pollinators are foraging, either on managed flowering plants or flowering weeds.
- Pesticides drift to adjacent regions where pollinators are visiting blooming plants or nesting, during or immediately after pesticide application.
- Pesticide residues remain in the nectar or pollen of flowering plants and are collected by pollinators as food for themselves or their developing larvae. Pesticide residues in flowering plants can result from either a direct application or through pesticide-contaminated soil and water runoff from nearby locations. Indeed, recent studies have found that many pesticides in the pollen and nectar collected by foraging bees come from contaminated wildflowers.
- Pesticide residues are found in the water sources that pollinators drink or bring back to their nest.
- Pesticide residues are found in soil where pollinators are nesting, or contaminating nesting material.

Impacts of exposure to chemicals on pollinators. The impact of chemicals on pollinators depends on the toxicity of the chemical to the pollinator species, the amount of exposure (quantity and duration), and the individual's physiological state (toxicity may vary between adults and larvae, for example, and individuals stressed by other factors may be more sensitive). Furthermore, exposure to other chemicals (other pesticides as well as adjuvants used with pesticide) can increase the sensitivity of an individual to a pesticide (see recent review from Penn State).

Herbicide use may have sublethal impacts on pollinators and can reduce the nutritional resources available to pollinators, by

- Reducing the amount of flowering weedy plants available to pollinators. Several studies have found that these weedy flowering plants are key resources for pollinators.
- Drifting into field margins and delaying the onset of flowering and numbers of flowers of non-target plants visited by pollinators in these areas (see a recent Penn State study).

Insecticide and fungicide exposure can have a variety of impacts on pollinators, including:

- Immediate death, if exposure levels are sufficiently high.

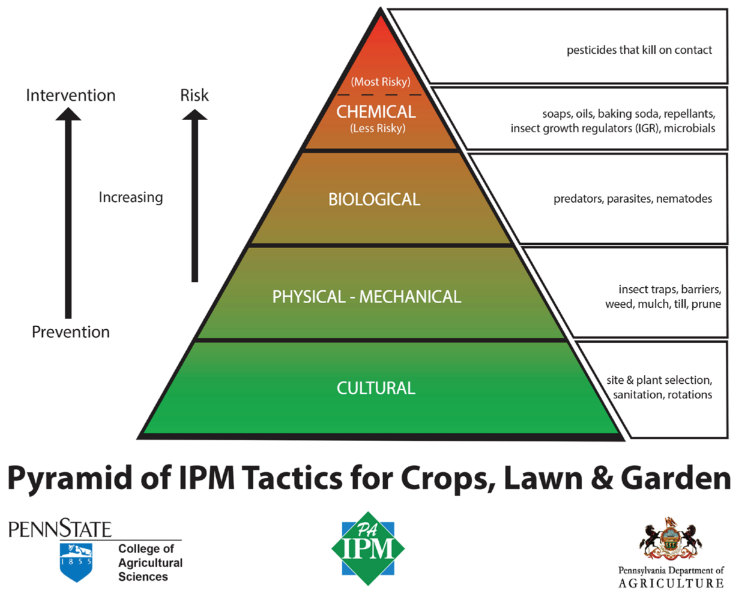
- Decreased life span, if exposure levels are below lethal doses but impair the pollinators' ability to forage, locate their nest site, or combat parasites and pathogens.
- Reduced brood production, if exposure reduces egg production or viability, or if the brood is fed nectar or pollen containing pesticides that cause lethal or sublethal effects.
- Reduced overwintering survival.

Death and decline of bees or other pollinators may be caused by several factors. It is important to investigate any bee kill as soon as possible after it is discovered, so that appropriate samples can be collected and tested. More information can be found in the Pennsylvania Pollinator Protection Plan section on Best Practices for Beekeepers. If pesticide exposure is suspected, the incident should be reported immediately to PDA's Health and Safety Division, 717-772-5231. The U.S. Environmental Protection Agency also encourages reports of all pesticide-related bee kills to beekill@epa.gov.

GENERAL RECOMMENDATIONS FOR PESTICIDE USE

It is strongly recommended that pesticides be used only as part of an **"Integrated Pest Management"** or **IPM** approach. More details can be found on the Pennsylvania IPM website. In general, to use an IPM approach, you should

- Take steps to **prevent the introduction** of pests and diseases (for example, use disease resistant stocks of plants or honey bees).
- **Monitor levels of pests and diseases** to know when it is necessary to use methods to control these populations.
- **Determine a "tolerance" threshold**, above which the damage caused by pests and diseases is not acceptable (for example, treatment is not always



Overview of IPM strategies for controlling pests and diseases in plants.

necessary at the first sign of a pest, but rather should be initiated only when pest or disease levels are unacceptable).

- Use **multiple non-chemical methods** to control pest and disease populations (such as physical removal of pests, weeds, or diseased tissue, as well as encouraging or introducing populations of pathogens or predators that help control pest populations).
- If non-chemical control strategies have not been effective at keeping pests and diseases under a "tolerance" threshold, **use chemicals and chemical application methods which are (a) approved for use in controlling the identified pest/disease and (b) have reduced effects on non-target species.**

When choosing and using a chemical pesticide:

- **Make sure you understand and follow all requirements for pesticide applicator certification in Pennsylvania.** You are required to become certified if you apply any restricted use pesticides (RUPs) or if you perform commercial or public applications. The PA Department of Agriculture (PDA) and Penn State Extension work together in this process. For more information see the Pesticide Education website or the Pennsylvania Pesticide Control Act of 1973.
- **Select a pesticide that is registered for use in Pennsylvania to control the identified pest/disease but has the least toxicity to pollinators, humans, and other wildlife.** To assess the relative toxicity of a pesticide to pollinators, use the "Bee Precaution Pesticide Rating" online tool from the University of California Statewide Agricultural & Natural Resources Integrated Pest Management Program.

  The Pacific Northwest Extension Publication How to Reduce Bee Poisonings from Pesticides (available as a pdf or as an app for your phone) also provides an overview of how both managed and wild bees can be affected by pesticides.

  The Forest Stewardship Council provides guidance on selecting pesticides with decreased risk to wildlife.

Developing an Integrated Pest Management (IPM) strategy to control an invasive pest. In 2014, the Pennsylvania Department of Agriculture and Pennsylvania Game Commission confirmed the presence of the Spotted Lanternfly (Lycorma delicatula) in Pennsylvania. This pest can utilize more than 70 plant species, 25 of which occur in PA. It can cause significant damage to key crops, including cultivated grapes, tree fruits, and hardwoods. It is found in all landscapes, from urban to natural.

The PA Department of Agriculture has initiated a comprehensive program to educate members of the public on the Spotlted Lanternfly, promote detection of infestations, and implement an Integrated Pest Management strategy which spans mechanical control, host tree reduction, and trap trees. This IPM strategy successfully contrzols populations of this devastating pest while minimizing off-target impacts on other insect species.

Relative toxicity of different pesticides is also provided in "Wild Pollinators of Eastern Apple Orchards And How to Conserve Them" (pg 17). and in Purdue Extension's guide to Protecting Honey Bees from Pesticides.

The Xerces Society has created a database of research articles related to the impacts of pesticides on pollinators and other invertebrates.

- **The label is the law!** Read the label and follow instructions before handling and applying a pesticide.
- **Check the label (under "Environmental Hazards") for any pollinator or bee language (i.e. "highly toxic to bees").** Some pesticides now include an "EPA Pollinator Protection Box" which includes a bee and pollinator hazard icon and explains restrictions that should be addressed when applying the pesticide. It also gives instructions on minimizing drift and limiting pesticide exposure to bees and other pollinators.
- **Use application methods and approaches that minimize the exposure of pollinators to the pesticide.**

  - Target spray or use approaches that reduce drift of pesticides to surrounding areas.

  - Pesticides should ideally be applied when pollinators are not foraging, either at dusk or when a plant is not flowering.

  - Consider how long a pesticide remains active before it degrades or how it may spread through the plant: systemic pesticides may provide long-lasting protection against pests but also may contaminate the nectar and pollen of flowers.

- **Know where managed bee colonies are and notify beekeepers when you are applying pesticides nearby.**

  - It is strongly recommended that applicators notify beekeepers with registered apiaries in the area prior to pesticide applications. Bees will forage across several miles. Therefore, pesticide applicators should identify and notify beekeepers within five (5) miles of a treatment site at least 48 hours prior to application or as soon as possible. Timely notification will help ensure ample time for the beekeeper and applicator to develop a mutually acceptable strategy to manage pests while mitigating risk to honey bees. This may include covering hives, moving hives, or choosing the time of day to apply. Notifying beekeepers does not exempt applicators from complying with pesticide label restrictions. Many insecticide labels prohibit use if pollinators (bees) are present in the treatment area or the crop is in bloom.

- The PDA has created an interactive searchable map on the PAPlants website where pesticide applicators can identify and obtain contact information for registered apiaries (locations where honey bee colonies are kept). Businesses or individuals registered in PAPlants can search this site by county, township or spray location to identify nearby hive locations and work with their owners to protect the bees.

In addition to the general guidelines outlined above, below we provide specific considerations for pesticide use in different environments. We also provide guidelines for pesticide applicators to minimize potential negative impacts on honey bee colonies.

BEST PRACTICES FOR PESTICIDE USE IN URBAN AND SUBURBAN AREAS

In urban and suburban areas, homeowners, businesses, landscapers, park managers and public health officials may need to control the spread of pests and diseases, to ensure healthy, and attractive landscapes, to optimize yield from fruit and vegetable gardens, and to help control human pests and disease vectors, such as ticks and mosquitos. **In all cases, an IPM approach is critical for ensuring goals are met while minimizing non-target damage.**

For more detailed information on pollinator-friendly control of pests and diseases in lawns, ornamental plants, vegetable gardens, and parks see "agricultural areas" and "natural areas" sections in the Pollinator Protection Plan. Additional information on managing golf courses (there are over 660 in Pennsylvania alone) for pollinators can be found in "Optimizing Pest Management Practices to Conserve Pollinators in Turf Landscapes: current practices and future research needs" and in the Audubon Cooperative Sanctuary Program for Golf.

Human Pests and Disease Vectors. Individuals can protect themselves from human pests and disease vectors by using an IPM approach, which can reduce populations of these pests around homes, schools and businesses and/or greatly reduces the chances of individuals being exposed to these pests. This, in turn, decreases broad spectrum pesticide usage that can negatively impact pollinators. Information on key public health pests can be found on the Penn State Extension website.

Ticks can vector a number of human diseases, including Lyme disease. However, tick bites can be avoided using a number of basic precautions, thereby reducing or eliminating the need for large-scale pesticide treatments of properties. Individuals should:

- Avoid wooded or brushy areas (where ticks or more common)
- Wear long sleeves and pants, hats, use appropriate pest repellants (such as those containing DEET, see the EPA repellant website for more information) if spending time in areas where there may be ticks
- Inspect themselves for ticks and remove any ticks promptly.
- If bitten, individuals should be carefully monitored for signs of disease and contact a physician if symptoms develop.
- More information can be found on the PA Department of Health website.

One of the most concerning and widespread vectors of human disease are mosquitos. In the US, some mosquito species can carry West Nile Virus, which can infect humans, birds, and horses, and was identified in Pennsylvania in 2000. In 2015, it was reported that mosquitos transmitted Zika Virus, causing an outbreak in Brazil which led to increased reports of birth defects. The main mosquito vector for the Zika Virus is *Aedes aegypti*, which is not established in Pennsylvania. A related mosquito species, *Aedes albopictus*, is found in southeast and southcentral Pennsylvania, but it is not as efficient a vector of the virus. Thus far (May 2017), there have been no reported cases of local Zika transmission in Pennsylvania from mosquito bites.

Pennsylvania has developed comprehensive response plans for both West Nile Virus and Zika Virus. These plans rely heavily on an IPM approach to reduce pesticide use and off-target impacts of pesticide exposure.

Individuals can control mosquito populations around their homes, businesses, and schools and reduce their exposure to mosquitos through the following practices:

- Mosquitos breed in standing water, and thus the most effective way to reduce mosquito populations is to remove standing water, add predatory fish to standing water, and/or use *Bacillus thuringiensis* subspecies *israelensis* (BTI), a naturally occurring bacteria found in soils that is wildly available for purchase, and is toxic to mosquito larvae in water, but has a relatively low toxicity to other insects and humans.
- Homeowners are encouraged to prevent mosquitos from entering their homes by using screens and keeping doors and windows sealed.

- Individuals can prevent bites by staying inside during periods of peak mosquito activity (dawn and dusk, though note that *Aedes albopictus* is active during the day), wearing long-sleeved shirts and clothing, or using an insect repellant.
- Before spraying their property with insecticide, homeowners should consult with their local West Nile County Coordinator.
- If public health officials determine that spraying is necessary, precautions should be taken to notify beekeepers (using the PA Plants site to identify nearby beekeepers) and members of the public, and use pesticides with reduced toxicity to bees and other wildlife.

Additional information for managing mosquito populations can be found at:

- Ecologically Sound Mosquito Management in Wetlands
- Help Your Community Create an Effective Mosquito Management Plan

BEST PRACTICES FOR PESTICIDE USE IN ROADSIDES AND RIGHTS OF WAY

Roadsides cover more than 10 million acres of land in the US. Pennsylvania has more than 40,000 miles of roads, and is one of the top five states in the nation for road miles. More than 100,000 acres of roadside lands are managed in Pennsylvania. The landscapes must be managed to support the needs of drivers, utility companies, and other stakeholders (eg, ensuring visibility and access) but can also provide excellent habitats to support pollinator populations.

Managing weedy and invasive plant species in roadsides and rights of way can be challenging. The Pennsylvania Department of Transportation utilizes biological/cultural, chemical and mechanical/manual methods which collectively form an **Integrated Vegetation Management (IVM) program:**

- Mowing operations are the cornerstone to controlling invasive species and to maintaining a safety-first roadside.
- Tree removal operations account for over sixty percent of the IVM budget to control the forest invasion of the roadside.
- While accounting for only twenty percent of the IVM expenses, the herbicide application program handles the bulk of the vegetation management controls.

Information on the Pennsylvania Department of Transportation's IVM approaches can be found in PennDOTs "Invasive Species Best Management Practices" publication.

More details on programs supporting land management in roadsides and rights of way can be found in the "Best Practices for Forage and Habitat in Roadsides and Rights of Way" section of the Pennsylvania Pollinator Protection Plan. Additional information on managing invasive and weedy species can be found below, in the "Best Practices for Pesticide Use in Natural Areas" section.

BEST PRACTICES FOR PESTICIDE USE IN AGRICULTURAL AREAS

Approximately 75% of major agricultural crops require or benefit from pollinators to set seed and produce fruit, and all crops can benefit from the arthropods that prey on or parasitize pest species, thereby reducing the negative impacts of these pest populations. Thus, there can be tremendous economic advantages to conserving and expanding populations of beneficial arthropods (managed and wild pollinators, predatory and parasitoid species) in agricultural landscapes. Unfortunately, many beneficial arthropods are also sensitive to the chemicals that are used in these agricultural landscapes. However, use of insecticides, fungicides, and herbicides is critical in many agricultural systems to control pests.

Here, we provide an overview of best practices for pesticide use in agricultural systems, to help growers maximize the yield and economic benefits they receive from beneficial arthropods, and minimize the cost of pesticide applications. However, agricultural crop production is obviously a highly specialized process, requiring integration of information on crop-specific requirements, soil, weather and climatic conditions, and current and future pest and disease pressures. Thus, these recommendations are quite general, and growers are encouraged to contact Penn State extension specialists for more detailed information.

Additional information can be found from the Pennsylvania Vegetable Growers Association, the State Horticultural Association of Pennsylvania the Pennsylvania Association for Sustainable Agriculture, and Food Alliance.

Integrated Pest and Pollinator Management (IPPM). Using an "Integrated Pest and Pollinator Management" approach helps growers both manage pests and promote populations of pollinators and other beneficial arthropods, to maximize their yields and economic benefits (see review from Penn State researchers). Integrated Pest Management is a well-established approach which uses multiple methods (biological, cultural, physical and chemical) to control pest populations below economic thresholds. IPPM integrates pollinators into this established framework. IPPM recommendations will be specific for certain crops, regions, and agricultural practices. However, there are several basic principles that can be consistently applied to balance the use of pesticides and pollination services (see online resources from Xerces Society)

- **Pesticides should only be used when pest and disease levels exceed a pre-determined economic threshold, and after other options (biological, physical, and cultural control) have been deployed.** While no one uses pesticides unless there is a perceived need, there are certainly differences in perception of need. For example, some believe that pesticides should be used prophylactically as an 'insurance' against pest build-up. Because this practice can increase overall pesticide use and the likelihood of off-target effects, growers are encouraged to refrain from pesticide use unless a pest or disease threat is clearly imminent.
- **Adjust the timing of pesticide treatment** to minimize exposure risk to pollinators. This may include using pesticides before bloom or spraying at night, taking into consideration the half-life of pesticides.
- **Adjust pesticide application methods** to reduce drift, and avoid aerial spraying. Pesticides should not be sprayed under conditions with high wind (> 9 mph), to minimize drift. Proper droplet size, ensuring spray equipment is properly calibrated, and lowering the boom to be right above the canopy are also key in minimizing drift.
- I**nclude buffer zones** between treated areas and habitat. Recommendations range from 40 feet (for ground-based applications), to 60 feet (for air-blast sprayers) to 125 feet (for crops treated with pesticides known to be highly toxic to pollinators). Windbreaks can be used to minimize aerial drift, and filter strips can minimize runoff.

- **Select pesticides with reduced toxicity to pollinators.** Several online tools and websites provide information about the relative toxicity of pesticides to pollinators and other wildlife; these are listed on page 5.
- Using **tank mixes** of different pesticides can reduce the cost of applying pesticides (in terms of labor and fuel) and reduce exposure of pollinators to the applied pesticides (as they would be exposed during a single application period versus multiple applications). However, there is increasing concern that combinations of pesticides have synergistic impacts on pollinators. Additionally, combining pesticides in a single application may encourage the prophylactic use of pesticides as "insurance", to avoid an additional application at a later time. Thus, it is important to again balance the costs and benefits of tank mix applications. More information can be found in a seminar from Professor Reed Johnson, Ohio State University. Additionally, the "Bee Precaution Pesticide Rating" online tool provides information about the toxicity of pesticide mixtures.

Crop-specific IPPM recommendations have been developed for tree fruit, squashes, pumpkins and gourds, and other crops.

Case Study: Negative Impacts of Prophylactic Pesticide Use

Neonicotinoids have been incorporated into seed coatings for field crops, under the premise that these systemic pesticides will be incorporated into the growing plant and protect the plant from herbivore damage over a long period of time. There has been a tremendous increase in the use of neonicotinoids in recent years, largely driven by their use in seed treatments for field crops such as corn and soybeans (see recent study from Penn State).

However, several studies, including those at Penn State, have demonstrated that in northern temperate climates, neonicotinoid seed treatments in soybeans are either not effective, because they do not provide protection against major crop pests that attack older plants, or can actually reduce yields by reducing populations of predatory species, resulting in increased populations of slugs, which feed on soybean seedlings and are not impacted by neonicotinoid exposure. Additional studies found no yield benefit of neonicotinoid seed treatments in corn. Furthermore, neonicotinoids are highly water soluble and can persist for months or years in the soil. Thus, while there are situations in which pest pressure warrants the use of neonicotinoid seed coatings, these coatings should be used cautiously and only when needed. Highly charged public debate on neonicotinoids has led to calls to limit their use, which is unfortunate because in many contexts, and when used responsibly, neonicotinoids can be more effective and safer to wildlife than other pesticide classes. For more details, see Best Management Practices for Handling Seeds Treated with Neonic Pesticdes and Xerces Neonic and information from the Xerces Society.

BEST PRACTICES FOR PESTICIDE USE IN NATURAL AREAS

The use of pesticides in natural areas such as forests is sometimes needed to protect ecosystem biodiversity, forest resources, watersheds, stream buffers, and threatened habitats from significant damage by various forest pests and competing native vegetation. The principal targeted pests for treatment in Pennsylvania are non-native invasive species such as the gypsy moth, hemlock woolly adelgid, elongate hemlock scale, emerald ash borer, and invasive plants. In addition, competing vegetation in some locations requires control so that forest regeneration can proceed according to established silvicultural practices. In all cases, an **Integrated Pest Management (IPM)** and **Integrated Vegetation Management (IVM)** approach must be used along with site-specific environmental reviews, to protect pollinators and other beneficial organisms from unnecessary harm.

Furthermore, Pennsylvania State Forests are independently certified according to the Forest Stewardship Council (FSC) standards, and the Pennsylvania Department of Conservation and Natural Resources(DCNR) Bureau of Forestry follows the best management practices guidelines provided by the FSC. The FSC provides extensive guidelines on pesticide use and alternative pest control strategies that are required for certification.

To illustrate Best Management Practices (BMP) for pesticide use in natural habitats, programs utilized by the PA DCNR are briefly described below, with an emphasis on pollinator protection and mitigation practices for non-target species. The approaches discussed here can be used by private landowners for their forested areas. Use of biological control and other management strategies are highlighted to describe the IPM and IVM approaches to pest management.

Gypsy Moth. Gypsy moth, an exotic species introduced to the United States in 1868, causes tremendous damage to forest trees. A gypsy moth suppression program in Pennsylvania began in 1972 to minimize gypsy moth defoliation and prevent tree decline and mortality in targeted areas. The program is request-based, whereby the landowner or managing agency requests areas to be treated. The DCNR Bureau of Forestry has very specific criteria, operations manuals, participation guidelines, environmental review process, and pre- and post-treatment evaluations.

The program currently uses three insecticides to treat forest areas: *Bacillus thuringiensis* subspecies *kurstaki* (BTK) (Foray 76B - based on a naturally occurring bacteria that can only affect certain species of lepidopteran larvae), tebufenozide (Mimic 2LV - an insect growth regulator which also only affects lepidopteran larvae), and Gypchek (the gypsy moth virus). Gypcheck is specific for gypsy moth, but since it is in limited supply it is only used when there are other lepidopteran species of concern present. Biocontrol programs are also in place, which take advantage of disease organisms, parasitoids and predators.

Hemlock Woolly Adelgid and Elongate Hemlock Scale. The Pennsylvania Hemlock Conservation plan was developed to provide a sustainable conservation strategy for eastern hemlock. While the primary focus is currently on DCNR-managed hemlocks in State Forests and State Parks (Cook Forest State Park is an example of a high value hemlock site), the IPM approach is applicable to private forest lands. See DCNR Bureau of Forestry Hemlock Conservation Plan for full details.

Neonicotinoids are used to protect eastern hemlocks from hemlock woolly adelgid (HWA) and the elongate hemlock scale (EHS) in high value focus areas. The use of systemic insecticides is needed to keep hemlocks alive long enough so that predatory beetle populations can become well enough established to control these pests. Hemlock trees only have to be treated once every 5 to 7 years to prevent HWA infestations from building up.
If neonicotinoid treatment is required, precautions are taken to minimize potential non-target impacts. These include:

- Avoiding flowering plants (e.g., mountain laurel) and flowering trees (e.g., basswood) if they are next to a treatment tree.
- Preferentially injecting the soil surrounding the tree, but only if sufficient organic matter is present around the base of the tree. Neonicotinoid insecticides, if bound to organic matter, only move about 18 inches in the soil. Thus it is critical that sufficient organic matter be present around a hemlock tree before the soil injection method is used.
- If a hemlock is next to a stream, or does not have sufficient organic matter, or if the water table is too high, direct stem injection can be used to limit the exposure.

Emerald Ash Borer. The Pennsylvania DCNR Bureau of Forestry has developed a comprehensive strategy to control Emerald Ash Borer populations and conserve ash trees in Pennsylvania forests as part of a national strategy to control EAB.

The strategy includes the use of the systemic insecticide ememectin benzoate (Tree-age), identifying "lingering ash" or surviving trees for breeding resistant populations, and releasing EAB parasitoids. Ememectin benzoate has the advantage of preventing attack by EAB, protecting the tree for 3 to 5 years, and becoming concentrated in the sapwood of the tree. Ash is wind pollinated, so the impact of the insecticide to pollinators is minimal. Ememectin benzoate is a restricted use pesticide, so only certified licensed applicators can use this insecticide to inject ash trees. More information on the use of insecticides to protect ash trees from EAB.

Invasive Plants.

The PA DCNR Bureau of Forestry is committed to managing invasive plant species across all state forest lands and has developed a comprehensive program. The goals of the Bureau of Forestry's invasive plant management program are to 1) control and eradicate novel and high threat invasive plant species populations, and 2) limit the spread of additional invasive species that threaten forest and wetland ecosystems or forest management activities.

However, managing invasive plant species in natural landscapes can be challenging, time-consuming, and expensive, and typically requires an individualized approach for each plant species. It is often not possible to simply remove all individuals of an invasive plant population, and there are often multiple invasive species. Thus, to prioritize invasive species management, it is necessary to determine a "treatment threshold" (as in all IPM and IVM approaches), which requires a full evaluation of the potential threat to the ecosystem, the density and scale of the infestation, how recently the species was introduced, whether the location has been targeted for management, and the available resources that can be used for managing a particular species.

For a list of plants that are not native to the state, grow aggressively, and spread and displace native vegetation, see the DCNR Invasive Plants List. Fact sheets with information on how to identify and control invasive plants are available at the DCNR Invasive Plants Website. Specific information on locations of invasive species and control efforts can be found at iMapInvasives.

When a population of invasive plant species has been identified for management, they can be physically removed or treated with herbicides. The Forest Stewardship Council provides guidance on selecting pesticides with decreased risk to wildlife.

Competing Vegetation Treatment Program on State Forest Lands. The DCNR Bureau of Forestry Silviculture Section coordinates vegetation treatments each year on State Forest Lands where the end goal is to regenerate a forested area by replacing undesirable native and exotic invasive vegetation with a desirable mix of trees, shrubs, and small herbaceous plants. Regenerated forests provide sustained ecological, economic, and social values. For more details, see the Pennsylvania Bureau of Forestry Planting and Seedling Guidelines.

The following plant species are often targeted for control:

- Common invasive woody species such as striped maple, American beech root sprouts, sweet birch, pin cherry, red maple, witch hazel, mountain laurel, and a host of exotic invasive species such as tree-of-heaven, paulownia, Japanese angelica, Japanese honeysuckle, multiflora rose, Japanese barberry, etc.
- Common herbaceous species such as Hayscented and New York fern, Japanese stiltgrass, mile-a-minute vine, Japanese knotweed, etc.

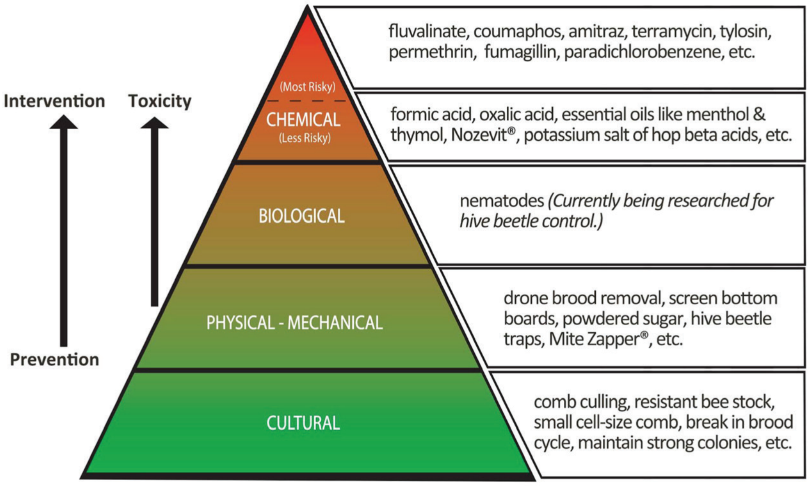
Forest regeneration is accomplished by:

- **Mechanical control**, which is used preferentially to minimize competing vegetation.
- **Biological control**, which is used for mile-a-minute vine, spotted knapweed, tree-of-heaven, and purple loosestrife (biological control for garlic mustard is pending).
- When needed, **herbicides labeled for forestry use by the rules of a Forest Stewardship Council (FSC) Certified Forest may be used.** It should be noted that the herbicide treatments used rarely eradicate the presence of invasive vegetation from the site. Herbicide operations are meant to open a window of opportunity to establish a diversity of desirable regeneration on the forest floor. These operations usually buy foresters three to five years of time to establish desirable vegetation.
- **Hand-planting of desired seedlings**
- **Deer-exclosure fencing**

Upon sufficient control of these undesirable forest plants, DCNR Foresters are able to establish a new cohort of desirable trees, shrubs, and herbaceous plants that will in turn create the forest of the future.

BEST PRACTICES FOR PESTICIDE USE ASSOCIATED WITH HONEY BEE COLONIES

Using pesticides to control pests in honey bee colonies. Honey bee colonies in Pennsylvania are hosts to many parasites and pathogens that can weaken colonies and lead to colony losses. The most important parasite is the Varroa mite (*Varroa destructor*), and uncontrolled Varroa mite populations are strongly associated with overwintering colony losses in the United States and Europe. It is strongly recommended that beekeepers monitor and manage Varroa populations using an Integrated Pest Management (IPM) approach.



Pyramid of IPM Tactics

IPM tactics to control Varroa populations in honey bee colonies.

Honey bees are also parasitized by Nosema microsporidia (*Nosema apis* and *Nosema ceranae*) which are intestinal parasites that weaken colonies and have been linked to large-scale colony losses in Europe. Wax moths (*Galleria mellonella*) are commonly found in very weak or abandoned colonies and can damage brood, honey stores, and wax comb. In some parts of Pennsylvania, small hive beetles (SHB) (*Aethina tuminda*) are found in honey bee colonies; SHB can contaminate honey stores and, at high population levels, lead to colony losses. Honey bees in the United States also host more than 20 different types of viruses, many of which can infect other pollinator species as well.

Several of these (Deformed Wing Virus and Israeli Acute Paralysis Virus) have been correlated with honey bee colony losses. Finally, brood diseases such as American Foulbrood (*Paenibacillus larvae*), European Foulbrood (*Melissococcus plutonius*), and Chalkbrood (*Ascosphaera apis*), can kill brood. While Chalkbrood and European Foulbrood are typically "stress" diseases and strong colonies can recover from these, American Foulbrood is the most virulent and contagious and requires immediate notification of the Pennsylvania Apiary Inspection Program, and Pennsylvania State Beekeepers Association and treatment.

Details about these and other parasites and pathogens can be found in the "Field Guide to Honey Bees and their Maladies", produced by Penn State Extension. This guide provides details about how to recognize and monitor levels of these pests and diseases and approaches to prevent infestation. Finally, the USDA offers a free diagnostic screening service to help beekeepers monitor for mites, Nosema and brood diseases.

To manage pests and diseases in a honey bee colony, an IPM approach is critical. Many of the chemicals used to control these parasites in honey bee colonies can be toxic to honey bees and humans, and can lead to increased levels of parasites in some cases. Moreover, extensive use can facilitate the selection and spread of resistant pest populations. For example, many populations of Varroa are now resistant to fluvalinate (a pyrethroid), coumaphos (an organophosphate), and amitraz (an amidine) which are commonly used for Varroa control.

If a chemical treatment is warranted, it is important for bee keepers to read and follow all pesticide label directions. It is also important to understand the risks involved in using products not registered by EPA or FDA for use on or around managed bees.

Information on how to employ an IPM approach for managing Varroa levels can be found in the IPM Pyramid above. Detailed information (including videos) for how to monitor and treat for Varroa can be found at the Honey Bee Health Coalition. Additional information about using IPM approaches to manage Nosema infections can be found here. Beekeepers should contact experienced beekeepers in their local bee clubs, the PA Department of Agriculture Apiary Program or Penn State Extension for more detailed information about current best practices to manage pests and diseases.

More useful information can be found on best management practices to reduce pesticide exposure to managed bee colonies in the Best Practices for Beekeepers section of the Pennsylvania Pollinator Protection Plan.

CHAPTER 4
BEST PRACTICES FOR BEEKEEPERS

TABLE OF CONTENTS

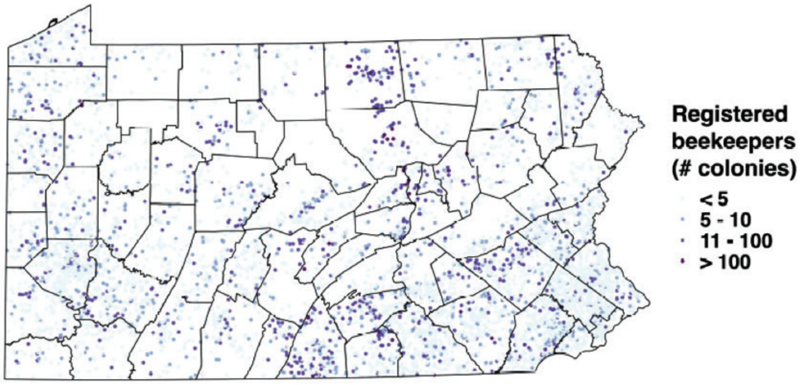
INTRODUCTION

Beekeeping is an art and a science which has been practiced for thousands of years. While beekeeping practices have changed through the years, beneficial management decisions, including attention to necessary nutrition and health needs, continue to be important requirements faced by every beekeeper.

Honey bees (*Apis mellifera*) are the most commonly managed bee in Pennsylvania, and indeed around the world. In this section, we will focus on best practices for managing honey bees in Pennsylvania. However, several other bee species are managed for pollination services, including bumble bees and orchard bees. These species are native in Pennsylvania and in landscapes with sufficient nesting habitat and forage, can be quite abundant (see also the "Best Practices for Forage and Habitat" section). Thus, growers can often use the pollination services of wild bee populations. Information on managing

- honey bees and wild bees for tree fruit production can be found in the Penn State Tree Fruit Production Guide as well as the Pennsylvania Apple Pollination Guide
- honey bees and bumble bees for vegetable production can be found in the Mid-Atlantic Commercial Vegetable Production Guide
- wild squash pollinators is provided by this guide to Integrated Crop Pollination for Squashes, Pumpkins and Gourds
- bumble bees can be found in Xerces' Conserving Bumble Bees
- orchard bees can be found SARE's How to Manage the Blue Orchard Bee

In Pennsylvania, beekeepers who manage 10 or fewer honey bee colonies make up about 82% of the 4,500 registered beekeepers in PA. Many of these hives are permanently located and managed on the beekeeper's property. Some of these hobbyist or backyard beekeepers are very experienced, while others are beginners.



Map of apiaries in Pennsylvania. Each dot represents a registered apiary/bee yard in PA as of November 2016. Developed by Margaret Douglas, Penn State University.

In addition to beekeeping management decisions, all beekeepers should be aware of laws and regulations concerning beekeeping. Whether a beekeeper is engaging in a hobby or a gainful enterprise, there are laws and regulations which have been enacted to protect against negligence which would adversely affect other people or property. It is a beekeeper's responsibility to provide the best environment for their honey bees while being a good neighbor.

This section provides general recommendations and expectations for beekeeping management.

BEEKEEPER EDUCATION

Beekeepers are urged to attend beginning beekeeper classes, conferences, and workshops. In addition, beekeepers may wish to consider joining the Pennsylvania State Beekeepers Association, as well as one or more of the over 30 local beekeeping organizations in Pennsylvania. These organizations provide helpful information- including critical information on local conditions - through their meetings and newsletters.

New beekeepers should seek reliable instruction before keeping honey bees. It is important to understand basic bee biology and behavior. All beekeepers need to be aware of what a healthy hive looks like at different times of the year. A beginner class will also help the new beekeeper understand bees and plan their beekeeping management. Instruction includes methods of acquiring bees, treating diseases, mites and risk management.

A beekeeping guide and an award winning Beekeeping 101 course are available online from Penn State. More advanced online courses will be available soon.

Caution is advised when using social media for information and discussion. While there is a great deal of accurate and helpful information online, sometimes the posted information is incorrect. This document will show a list of some of the trusted websites about beekeeping.

The PA Apiary Advisory Board has created the Voluntary General Best Management Practices for Maintaining European Honey Bee Colonies in the Commonwealth of PA. These Best Management Practices (BMPs) provide information for maintaining honey bee colonies in Pennsylvania and contain proven guidelines for keeping bees in any landscape, from urban to rural.

Following these BMPs can help to minimize nuisance situations and provide useful and practical guidelines for beekeepers, as well as municipalities considering zoning or ordinances changes.

If you are interested in selling your honey, please follow the guidelines of the Pennsylvania Department of Agriculture's Bureau of Food Safety, outlined in the following documents on selling honey, processing honey, and information on the Food Safety Modernization Act's guidelines for preventative controls for human foods.

HONEY BEE COLONY REGISTRATION

The Pennsylvania Bee Law, passed in 1994, was a collaborative effort between the Pennsylvania State Beekeepers Association and the Pennsylvania Department of Agriculture's Bureau of Plant Industry .

According to the Bee Law, anyone who manages honey bees in PA is required to register their bees with the Pennsylvania Department of Agriculture.

Instructions detailing how to register or review your personal beekeeper account on PA Plants are available. Alternatively, you may still use the Mail-In Apiary Registration form. The Apiary License is valid for up to two years and costs $10. Registered beekeepers may access their apiary accounts, and the information associated with them, by logging on to PA Plants.

The PA Department of Agriculture (PDA) enforces the Bee Law through the State Apiarist and Apiary Inspectors. There are usually six Apiary Inspectors working in various PA counties from mid-April through most of October and the State Apiarist works year-round out of the Harrisburg office.

Apiary registration has a number of benefits:

- Increasing the efficiency of the apiary inspection service. Apiary inspection is an early detection safeguard for the beekeeping industry.

If necessary, methods such as quarantines and best management practices may be used to slow the spread of pests, diseases, and pathogens.

- Many public health pesticide applicators will attempt to contact beekeepers if they plan to spray within in a certain distance of registered bee yards. By maintaining accurate bee yard locations and contact information on PA Plants, it is easier for pesticide applicators to notify the beekeeper. The beekeeper can then decide whether to move or cover hives. Please note that the pesticide applicators are not required to do this. Sometimes due to an immediate public health risk or weather concerns, the pesticide application must be done immediately and the beekeeper is not notified. Additional information on beekeeper notification of pesticide applications can be found in the "Best Practices for Pesticide Use" section of this pollinator protection plan.

If a beekeeper wishes to sell queen bees or nucleus colonies to other PA beekeepers, they will be inspected twice a year. If no disease is found, a Queen Rearer and/or Nucleus Producer Permit will be issued. This permit is valid for one year.

The Bee Law also monitors the movement of honey bees, queens, and used equipment entering or exiting Pennsylvania in order to mitigate bee disease outbreaks. Bees and used equipment are inspected within 30 days of the proposed shipment date. A permit is issued if no disease is found.

SELECTING AN APIARY LOCATION

The plants or floral resources available to honey bees and other pollinators are crucial to their success. Flowering plants within a one-half to one mile radius of an apiary are the most critical to the health of the bees, although bees will forage up to 3 miles from their apiary if forage is scarce. Access to a diversity of flowering plant species is extremely important to the health of the bees and bees forage throughout the year - from early spring through late fall. Bees also need access to consistently available water.

Beekeepers can use Google Maps/Earth and explore within a one to two-mile radius of the intended apiary. Beekeepers should select locations that have an abundance of diverse vegetation, since these are more likely to provide year-round forage. Key landscape plants include trees and clover. In addition, remember that many plants bloom only for a few weeks, and thus having a diversity of plants will help ensure longer access to forage.

If the hives are located on the beekeeper's property, he or she may wish to plant pollinator friendly plants to add to the bees' diet diversity. More information and methods to improve the forage quality of a landscape can be found in the "Best Practices for Forage and Habitat" section of this pollinator guide. Beekeepers should also add a source of water close to the hives if there is not a natural source close by.

The beekeeper should consider supplemental feeding if nectar and pollen resources are not available. If bees do not do well in a location after two years, consider relocating to a more appropriate location with more plant diversity.

BEEKEEPING THROUGHOUT THE YEAR

Pennsylvania's geography is highly diverse. Differences in geography and plant communities are evident with changing latitude, longitude, and altitude. Because of this, the same flowers may bloom at different times across the Commonwealth, creating local honey flows. A honey flow occurs when at least one of the bees' major nectar sources is in bloom and the weather is favorable for nectar collection. Established colonies throughout Pennsylvania can produce surplus honey in May and June. However, the central, south, and eastern counties often experience fewer summer rains, resulting in fewer inches of

Collaborating With Researchers

Researchers are eager to study the impact of floral resources, genetic stocks, and the environment on honey bees and other pollinators. However, such studies often require large numbers of colonies or observations. Beekeepers, individually or through beekeeping organizations, are encouraged to participate and help with this valuable research. Below are examples of large-scale projects where beekeepers and researchers are collaborating to answer key questions.

During the month of April, beekeepers are encouraged to participate in the annual PA State Beekeepers' Association winter survival survey.

Dr. Christina Grozinger, Director of Penn State's Center for Pollinator Research and her lab, are working in collaboration with Penn State's Center for Environmental Informatics, University of Minnesota, and the PA State Beekeepers' Association on an exciting project called Landscapes for Bees. This research is working to identify landscape features promoting honey bee health.

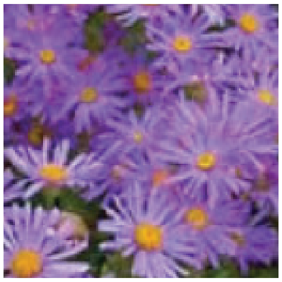
The Bee Informed Partnership is working with beekeepers in a number of states to monitor honey bee health using hive scales to track colony weight gain or loss and monthly disease assessments of Varroa and Nosema loads. (Note: as bees return to the hive with nectar and pollen, the hive weight will increase. During a nectar flow, the increases can be dramatic.)

Dr. Margarita Lopez-Uribe and her lab at Penn State are currently studying the health of feral bee populations in Pennsylvania, to determine if these bees represent stocks that are more resilient to pests and diseases, particularly Varroa mites. The Tracking Feral Bee Health study welcomes beekeeper participation.

water, which can reduce or eliminate a fall honey flow. Micro-climates around mountainous areas, forests and lakes, as well as housing developments and large agricultural tracts, can have a varying impact on honey flows. Local beekeeping organizations have detailed information concerning conditions nearby and are excellent resources for new beekeepers.

In the **spring**, from April to June, there are usually abundant forage sources to support colony growth and expansion; therefore, surplus honey can be expected from an established colony. While weather variations can cause stress due to excess rain or temperature swings that keep bees from flying, beekeepers should monitor and inspect their hives often, adding boxes, or supers, as needed during a honey flow, due to the increased nectar collection.

Dandelion



Aster

Joe Pye Weed

Goldenrod

The **summer** months are often difficult for honey bees. During the summer, there is often a lack of variety in blooming plants available for pollinators. Such a lack of resources may create a critical time in the life of a hive due to the low-quality pollen and poor nectar flow. Beekeepers should inspect their hives and consider supplemental feeding during this period as needed. Urban areas may contain managed private, public, or community gardens where the floral resources may be adequate for pollinators. In most of Pennsylvania, jewelweed, golden rod, boneset, Joe Pye weed, Japanese knotweed, and asters provide late summer forage sources. During this time of year, monitoring for Varroa mite levels is essential. Supplemental feeding will reduce stress and provide nutrition for healthy brood rearing. Vigorous, healthy, young bees are needed in the fall to keep the hive healthy and produce surplus honey.

In the **fall**, it is important for a hive to have many young healthy vigorous bees going into the winter. By October, a typical 10 frame colony with two deep boxes, should have a total hive weight, including equipment, bees, honey, nectar, and pollen, of about 125 pounds. (Note: A frame from a deep box can weigh 7-8 pounds when full of capped honey. A frame from a medium box can weigh 3-4 pounds when full of capped honey.)

Water should always be accessible to colonies. Account for pesticide, fertilizer, utility, industrial or landfill runoff when selecting sites near water. Utilize artificial water sources such as bird-baths, trickle hoses or in-hive feeders if natural water is not available. Remember to keep these sources full of water from early spring until late fall.

Supplemental feeding is a must in times of limited forage and drought. Sugar syrup, candy blocks and pollen substitutes may be used and are essential management requirements.

Swarm season is primarily from April to late June in most parts of the state. Honey bees will build populations during this time that exceed their hive capacity. A portion of the bees in the colony will leave with the queen in search of a new home. Such behavior is how honey bees naturally reproduce their colonies. Swarms often occur following a brief weather event which prevented the bees from flying. Swarm Essentials, a book by Pittsburgh beekeeper Stephen J. Repasky, offers helpful advice and information about swarms.

Keeping records of inspections, treatments, supplemental feedings, queen problems, and other management tasks is helpful to all beekeepers. Some beekeepers use a notebook while others prefer to do this electronically through a program like Hive Tracks.

Burgh Bees Community Bee Yard, Pittsburgh, PA

Near Harrisburg, PA

Shadetree Apiaries, Dysart, PA

SPECIAL CONSIDERATIONS FOR URBAN AND SUBURBAN BEEKEEPERS

Being a good neighbor is an important concern. Beekeepers have successfully kept bees across Pennsylvania from homes and business, rooftops, public and private gardens in urban areas to suburban neighborhoods to farm and rural areas for years.

Here are several management practices **which will help keep the neighbors and the bees happy:**

- Talk to your neighbors about bees.
- Make sure the bees are gentle.
- Place hives in a manner which directs bees to fly at least six feet air, over the heads of people and animals. Hives can be placed beside hedges, shrubs, fences, buildings, etc.
- Hive entrance should not directly open to neighbor's yard.
- Provide a consistent source of fresh water near hives from early spring through late fall.
- Check to be sure there are no confined animals nearby (dog kept on a chain, etc.).
- Work bees on sunny, warm days when most of the foragers will be away from the hive.
- Use your smoker properly.
- If working bees is likely to disturb a neighbors' outdoor activities, wait for a more convenient time to work the bees.
- Read, sign and follow the Voluntary General Best Management Practices For Maintaining European Honey Bee Colonies in the Commonwealth of Pennsylvania.
- Give your neighbors a jar of honey!

OUTREACH TO THE PUBLIC

Educating the public is an important, but sometimes overlooked responsibility of all beekeepers. Most people are interested and want to hear about bees. It is important to remember that many adults think there are three types of flying insects: butterflies, flies, and (if they sting) bees and thus are eager to learn about the different kinds of insects and pollinators in their area. Honey bees and other pollinators are very important to everyone and beekeepers are often their spokesperson.

Outreach opportunities and events can include:

- Giving a talk or demonstration at a school, children's day camp, or Scout meeting.
- Giving a talk or demonstration at a Rotary or church meeting can have a big impact on how the public views bees and other pollinators.
- Sometimes beekeepers will need to provide facts and education to local government officials at their township or borough meetings. Think ahead and have accurate answers ready for the questions they are likely to ask.

There are many resources available for individuals interested in engaging the public. Some beekeeping organizations and associations have materials, information, and/or powerpoints available for use when beekeepers give presentations. Many of the larger conferences have at least one workshop or session which provides ideas for presentations to the public. Additionally, experienced beekeepers are often pleased to share ideas and provide pointers regarding outreach when asked.

The PA State Beekeepers offer a great program to recognize bee-friendly communities across the state. Town managers in all communities can review the criteria for the Bee Friendly PA program and apply. Beekeepers can encourage their local governments to become more bee friendly and apply for this award.

Penn State's Center for Pollinator Research offers Pollinator Garden Certification to qualifying pollinator friendly gardens and an attractive sign is available for purchase.

DISEASE AND PEST CONTROL

Introduction. A number of parasites, pests, predators and diseases, and other maladies can be harmful to honey bees. It is the beekeeper's responsibility to monitor, identify and remedy these situations. Beekeepers should routinely open and inspect hives to monitor for the presence of pests and diseases. It is critical for beekeepers to learn to identify normal honey bee development and to be able to identify the queen, workers, drones, and stages of larval growth. This will ensure beekeepers can detect problems early and take necessary steps to deal with any issues.

Many common pests and diseases, of honey bee colonies, such as wax moths, small hive beetles, ants, chalkbrood, and European foulbrood will not thrive in a strong colony and are usually symptoms of a weak, small or otherwise stressed colony. Colonies may be stressed by poor weather conditions, poor forage, or heavy varroa mite infestations. Even infections with Nosema, a gut microsporia, can often be cleared by a healthy colony (additional information about Nosema infections).

It is strongly recommended that beekeepers use an Integrated Pest Management (IPM) approach to manage pests and diseases when necessary. Further information about IPM approaches can be found in the "Best Practices for Pesticide Use" section of this pollinator plan.
Beekeepers should also visit the Pennsylvania Department of Agriculture Apiary and Pollinator Services website for additional information, identification, and controls for diseases and pests.

In this section, we will discuss Varroa Mites and American Foulbrood in more detail, as these are the most serious disease and parasite of honey bees in Pennsylvania.

Varroa mites. Varroa mites (*Varroa destructor*) are currently the most devastating parasite for honey bees in the United States. This parasite was introduced to the country in the 1980's. Infestations with Varroa mites have reportedly killed most of the wild or feral bee colonies. Managed bee colonies have struggled as well, and uncontrolled mite infestations are consistently found to be the primary factor underlying winter colony losses in scientific studies and surveys. Varroa mites can spread quickly as bees drift or rob other colonies.

The female Varroa mite enters a brood cell just before capping, lays a male egg and several female eggs inside the cell, and the offspring hatch and feed from the developing pupa. The male mite mates with his sisters, and the mated adult female Varroa emerge with the adult bees. The adult Varroa mites will be carried by (and feed on) the adult bees until they enter another brood cell to reproduce. (The Life Cycle of Varroa)

When the Varroa mite feeds on the bee, it can also transmit viruses and suppress the bee's normal immune response. While several viruses are transmitted by the Varroa mite to the honey bee, one of the most common and noticeable viruses is Deformed Wing Virus (DWV). When bees are infected by DWV alone, they usually do not exhibit any symptoms. However, when pupae are infected with DWV and Varroa mites, DWV titers (virus load) can reach very high levels and damage the developing bee. When the adult bees emerge, some have no wings and others have unusable, misshaped wings. They are unable to fly, perform fewer tasks in the colony, and have a reduced lifespan. Some bees may be discolored and/or have shortened, rounded abdomens. The presence of bees with deformed wings is usually a sign of a high Varroa mite infestation.

Photo credit: University of FL, Young bee with DWV

Photo credit: Jason Graham, University of FL, Two female Varroa mites on honey bee pupa

Photo credit: txbeeinspection.tamu.edu, Two Varroa mites riding on bee

Treatments to control Varroa mites have changed over the years. It is strongly recommended that beekeepers follow an Integrated Pest Management (IPM) approach to managing Varroa populations. An IPM approach may involve a variety of cultural, physical-mechanical, and, when necessary, chemical management techniques. Further information on IPM approaches to managing diseases and pests can be found in the "Best Practices for Pesticide Use."

A key component of an IPM approach is monitoring pest and disease levels to determine when treatment is necessary. Beekeepers should monitor the Varroa mite levels in colonies at least four times a year (ideally monthly during the growing season), and monitor colonies to check if mite treatment was successful. The level of mites can change very rapidly in a short period, especially in the late summer and early fall. That is when the population of bees is decreasing, but the overwintering bees are being reared. Mite levels can be easily monitored using a sugar shake or roll (see this publication for detailed directions and videos, and a spreadsheet).

Approaches a beekeeper may use to control Varroa mite populations as part of an IPM strategy include:

- Use or breed for mite tolerant or hygienic bees including, but not limited to, Varroa Sensitive Hygiene or VSH stock, some Russian strains of bees, and "ankle biters"
- Some PA beekeepers are participating in a northern queen rearing project. For more information, contact the PA State Beekeepers Association.

HONEY BEE HEALTH COALITION™

- Use screened bottom boards. Varroa will fall through the boards can cannot re-enter the brood nest.
- Use drone foundation/frames. Varroa are more attracted to drone versus worker brood, and thus can be "trapped" in drone brood.
- Create a break in the brood cycle. Since Varroa reproduce in the brood, this can greatly reduce Varroa populations.
- Experiment with new "grooming" tools for honey bees.
- Apply naturally occurring chemicals like formic acid (Mite-Away Quick Strips), oxalic acid (trickle or vapor), and natural hops compounds (Hopguard). Follow directions carefully.
- Apply "harder" chemical miticides as needed. Beekeepers should follow directions carefully and rotate their chemical treatments to help prevent mites from becoming resistant to the miticide. Resistance has developed for Coumaphos or Check-mite strips, preventing them from being as effective as they were in the past. As a result, these chemicals are not used very often to treat Varroa mites.
- The following techniques may or may not be successful at treating Varroa mites:
  - Sprinkle powdered sugar on bees to dislodge the mites.
  - Apply essential oils (especially lemon, mint and thyme oils).
  - Spray sugar esters (Sucrocide).
  - Apply mineral oil (food grade) as vapor and in direct application on paper or cords.
  - Apply thymol crystals (synthetic chemical).

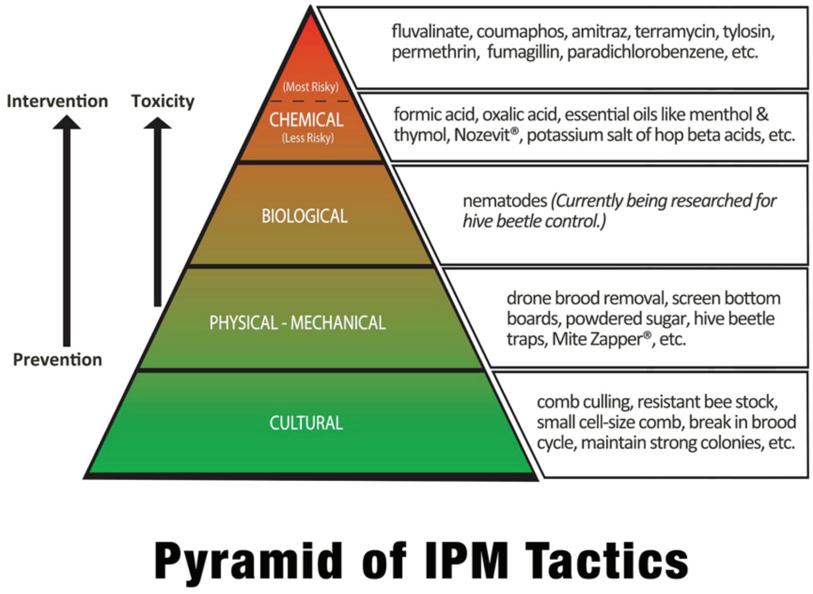
Beekeepers should always read and follow the label directions when applying miticides. Rotate chemical treatments to help slow down resistance development.

Miticides legal to use in Pennsylvania to treat honey bees for Varroa mites:

- Apivar. The active ingredient is amitraz (formamidine).
- Mite Away Quick Strips. The active ingredient is formic acid, an organic acid.
- Api Life Var. This consists of wafers soaked in 74% thymol oil as an active ingredient and also contains eucalyptol, menthol, and camphor, essential oils.
- Apiguard. The active ingredient is thymol, an essential oil.
- Oxalic acid. The active ingredient is oxalic acid, an organic acid and it may be applies as a trickle or vapor.
- Hopguard II. The active ingredient is potassium salt (16%) of hops beta acids, an organic acid, and a natural compound in hops.

Miticides legal to use in Pennsylvania on Varroa mites, but with **widespread mite resistance:**

- Apistan. The active ingredient is Tau-fluvalinate, a synthetic pyrethroid.
- CheckMite. The active ingredient is Coumaphos, an organophosphate, which is also labeled for use as small hive beetle control.

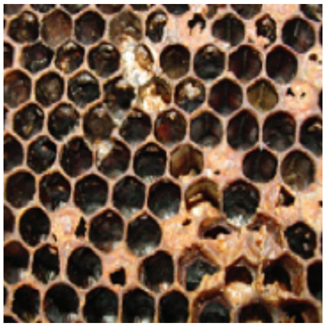


IPM tactics to control Varroa populations in honey bee colonies

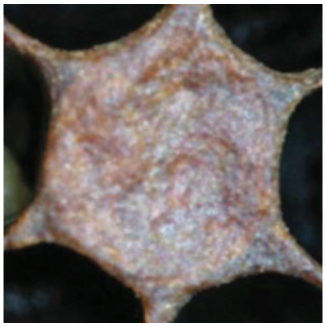
American Foulbrood. Beekeepers should follow protocols to prevent the spread of AFB.

AFB is caused by the spore forming bacterium *Paenibacillus larvae*. Adult bees do not show symptoms, but can spread disease by feeding food contaminated with the spores to the young larvae. AFB may also be spread by drifting or robbing bees and by the beekeeper through various management practices (not cleaning the hive tool, switching frames from infected hive into uninfected hive, by using extracted honey supers or purchased used equipment with AFB scale present).

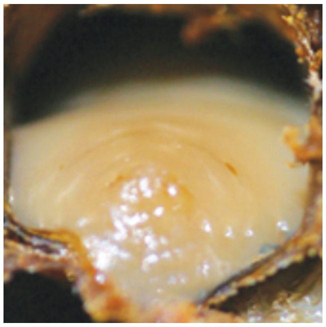
Photo credit: www.agric.wa.gov.au



Spotty brood with perforations in cappings. Photo credit: NC State Extension**.**



Sunken cell cappings. Photo credit: http://www.afb.org.nz/visual-symptoms-of-afb



Early stage of AFB infected larvae. http://www.afb.org.nz/visual-symptoms-of-afb

Symptoms of AFB often include:

- spotty, uneven brood patterns
- perforations in cappings
- capped cells which look sunken
- capped cells which may look wet or greasy
- a distinctive smell may be noted
- brown gooey dead larvae, which will rope out about one inch when pulled with a stick or toothpick, after the capping is removed
- scale, which forms as the dead larvae dries out, and "cements" to the cell floor, becoming very difficult to remove
- scale which may be difficult to see (colors range from light brown to black)
- the colony weakening or dying

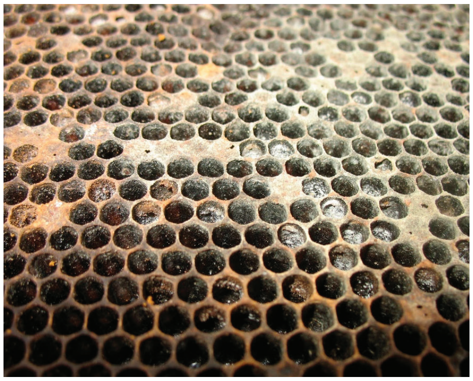


Photo credit: Queen's Printer for Ontario, Crown Copyright, Ontario Ministry of Agriculture, Food, and Rural Affairs

Photo credit: John Skinner: beeinformed.org

If a beekeeper has concerns that his or her honey bees may have AFB, they should contact the State Apiarist at the PA Department of Agriculture. The State Apiarist will then arrange for a State Apiary Inspector to come an inspect the bee yard. If the inspector suspects that the hive has AFB, a sample will be taken and tested. The samples are currently being tested at the PA Department of Agriculture. The colonies in that bee yard will be quarantined until the lab results are available.

Samples are tested to determine if they are positive for AFB and, if positive, whether they would be susceptible or resistant to treatment with the antibiotic Oxytetracycline (Terramycin). If the strain of AFB is resistant to Oxytetracycline, then the antibiotic Tylan (Tylosin) could be used. Early vegetative stages of AFB can be controlled with use of antibiotics. However, antibiotics will **not** kill the hard scale found in the cell. **Each scale can contain up to one billion viable spores which can spread AFB to other bees.** AFB spores remain viable for decades and are hard to kill. Therefore, many beekeepers chose to burn hives infected with AFB. Burning is the safest way to avoid contamination of neighboring hives which may rob honey from the failing hive. If the sample is positive for AFB, the beekeeper will receive a copy of the lab results, treatment information, and a sheet to sign and return indicating which treatment was used.

Additional treatment options which may be available include shaking the bees onto new foundation (if it is early enough in the season), killing the bees and destroying the equipment, or killing the bees, wrapping the equipment, and having the equipment gamma irradiated.

If one of the treatment options is to treat with a listed antibiotic and the beekeeper wishes to do so, he or she will need to schedule an appointment with a veterinarian to visit the bee yard. The veterinarian will examine the hive and review the paperwork. He or she will determine whether to write a prescription or veterinary feed directive for the appropriate antibiotic.

The Apiary Inspector will re-inspect the bee yard after the treatment to check for additional AFB development. If none is found, the bee yard quarantine is removed. The inspector will also inspect colonies in nearby apiaries and educate beekeepers about AFB and the symptoms. Please contact the State Apiarist or State Apiary Inspector for additional information.

The United States Department of Agriculture's Bee Research Laboratory (USDA-ARS) and Animal and Plant Health Inspection Serve (USDA-APHIS), Beltsville, Maryland are working with Bee Informed Partnership to provide for the diagnosis of American Foulbrood and Nosema, as well as counts of Varroa mite and tracheal mites. This is a temporary service until full staffing is available through the USDA-ARS Disease Diagnostic Service. (Information on how to take and ship samples.)

REDUCING EXPOSURE TO PESTICIDES

Pesticides can have a number of negative effects on honey bees, which are discussed in detail in the "Best Practices for Pesticide Use" section of this plan. Thus, beekeepers, pesticide applicators, and land managers need to take precautions to reduce pesticide exposure. In this section, the focus is on steps which beekeepers can take.

Bees can fly up to about five miles from their colony, but most of their flying is done up to two miles from the hive. A two-mile radius involves a large area, covering approximately 8,658 acres. This land may be used for a wide variety of uses including agriculture, industrial, residential, recreation, and transportation. A variety of pesticides may be used on this land depending on its use. The term 'pesticide' includes insecticides, fungicides and herbicides.
It is important for beekeepers to understand which pesticides may be applied that can impact flying bees or the nectar, pollen, water, and propolis the bees may be collecting, and take steps to reduce exposure to these pesticides.

Beekeepers should be aware that in addition to agricultural crops, various chemicals and pesticides are used in a wide variety of places for a wide variety of reasons. Often the beekeeper will not know when these pesticides are applied.

Here are a few examples of non-agricultural locations where pesticides are often used:

- lawns for residential and business properties
- flower and vegetable gardens and other food plants
- fruit and ornamental trees
- golf courses
- parks and recreation areas
- schools and daycares
- restaurants and markets
- industries
- water and waste treatment sites
- landfills
- farm or zoo animals
- public health spraying for insects carrying diseases
- public spraying for invasive insects
- land along highways
- land along other transportation hubs
- utility right of ways along power lines or gas pipeline

Below are suggestion actions a beekeeper can take to reduce their bee's exposure to pesticides:

- Register your apiary so that it is included on the PaPlants website. Pesticide applicators are encouraged to contact beekeepers near their applications to give them notice of an upcoming pesticide application.
- The PA Department of Environmental Protection has a West Nile Virus Control Program notification website. Anyone is welcome to register to receive email notification of scheduled spraying dates and general locations and the results of the mosquito testing.
- Prior to the start of the growing season, talk with nearby landowners, land managers, farmers, or pesticide applicators to better understand their pesticide application program. Realize that the landowner or pesticide applicator may need to apply certain pesticides at specific times to control pests and/or diseases. However, many suggestions for reducing the negative impacts of pesticides on honey bees and other pollinators can be found in the "Best Practices for Pesticide Use" section of this pollinator protection plan. Provide individuals with this document, and highlight the following key points:

1. There are many pesticide options available and multiple online resources to help identify pesticides that have reduced toxicity for bees.

2. Work with the landowner or pesticide applicator to have the pesticides applied at dusk or very early in the morning. Fewer bees and pollinators are foraging and the pesticide has a chance to dry or dissipate before bees come in contact with it.

3. Ask the land owner or pesticide applicator not to apply the pesticide on a windy day. This reduces pesticide drift.

4. Other approaches (using targeted spraying or larger droplet size) can reduce drift.

- Work with neighboring landowners and ask to be notified two days before a pesticide is applied on their property.
- Ask for the product trade name and learn the mode of action, toxicity, target and half-life of that chemical. Some products are very targeted and pose little acute risk to non-target species. Products break down at different rates, but when combined with rapid growth of early crops, most risks should be minimized in 2-10 days.
- Avoid applying synthetic miticides or apiary chemicals in hives at the same time that there is a likely exposure to neighboring pesticides. Combinations of hive controls and pesticide controls may synergize and increase toxicity to honey bees.
- Replace some old comb annually with new foundation. Toxins can accumulate in beeswax.

Beekeepers may wish to have a plan in place if pesticides are applied nearby whether the hives are moved or not. Here are some suggestions:

- Every beekeeper should have a plan for temporarily relocating hives in the event of unavoidable pesticide exposure. Hives should be moved at least one mile, preferably four miles from the treated area.
- If moving hives is not possible, use netting or large, light colored, wet fabric to cover hives until risk passes. DO NOT CLOSE ENTRANCES. Without ventilation to regulate inside temperatures, bees can easily suffocate. Do not cover colonies more than two days.
- Move bees hives either early morning, after dark or during rainy days. If you must move during peak flight times, leave a 'catch' hive where bees can gather, that can be picked up later.

- Feed bees immediately after relocating, unless they are moved into an area with good blooming floral resources. If there are not many floral resources, it may take a number of days for bees to find new floral sources.

Suggestions for beekeepers providing pollination services for crops:

- Pollination contracts are recommended. An example of such a contract can be found the Mid-Atlantic Apicultural Research & Extension Consortium.
- Develop a mutual strategy to ensure expectations and responsibilities between beekeepers and growers/owners, and pesticide applicators are fully understood.
- Exchange contact information with beekeeper, farmer, grower, property owner, and pesticide applicator.
- Determine crop treatments which are acceptable to all involved. Penn State Extension's Pesticide Education division may be able to help with effective pesticide recommendations which are beneficial to crops and not toxic to honey bees and pollinators. Combining fungicides and insecticides in tank mixes can also be discussed. More details can be found in the "Best Practices for Pesticide Use" section of the Pennsylvania Pollinator Protection Plan.
- Define when hives will be moved in and out, how many hives will be used, and where they will be placed. Agree on the strength of the hive.
- Discuss the use and availability of access roads. Place hives to minimize problems with farm worker travel and spray routes.
- It is recommended that beekeepers consider Ag Insurance for personal liability or property damage.
- Always get the landowner's permission to keep the bees on the property.
- The use of a 'bee flag', developed by Mississippi Farm Bureau, or other marker will help the grower be mindful of hive locations.
- The beekeeper's contact information should be posted with large lettering at the apiary.
- Place hives on raised parcels of land. Avoid drop-offs, valleys or swales where chemical drift can collect.
- Beekeeper should file and maintain apiary registrations and inspection reports at their home or business.
- If necessary, construct bear fencing. Bears are in nearly every county of Pennsylvania. A map of black bear harvest can be found with the PA Game Commission's website. (Information and recommendations for the construction of bear fences. These are just a few of the companies available to help with the construction of bear fences. *Listings of these commercial goods and services does not constitute an endorsement by the Pennsylvania Pollinator Protection Plan.*)

Beekeepers placing colonies on natural or idle land may wish to consider the following recommendations:

- Always get landowner permission and contact information. Determine if a written contract is needed.
- The beekeeper may wish to give his or her contact information directly to the landowner.
- Develop a mutual strategy to ensure expectations and responsibilities between beekeepers and landowners are fully understood.
- Define when hives will be moved in (and out), how many hives will be used, and where they will be placed.
- It is recommended that beekeepers consider Ag Insurance for personal liability or property damage.
- Be sure access roads for field and utility workers are not blocked by hives.
- Do not locate unmarked colonies near fields or orchards belonging to another landowner or farmer.
- The use of a 'bee flag' marker will help the grower be mindful of hive locations.
- The beekeeper's contact information should be posted in large lettering at the apiary.
- Maintain apiary registrations
- Construct bear fencing. See references in previous section.
- Place hives on raised parcels of land. Avoid drop-offs, valleys or swales where chemical drift can collect.

REPORTING BEE KILLS

- **It is important to remember that a variety of factors can cause the decline or death of a bee hive. Pesticides are one of these factors, but many other issues may be involved. It is important to examine the bees and the hive to accurately determine the cause(s) of the problem. Beekeepers may contact the State Apiarist at (717) 346-9567 or your local State Apiary Inspector for assistance and help.**
- Different symptoms will be seen depending on the type of pesticide the bees and other pollinators are exposed to. The online booklet, "How to Reduce Bee Poisoning from Pesticides" by H. Riedl, E. Johansen, L. Brewer, and J. Barbour contains helpful information about symptoms, and various toxicities of pesticides for honey bees and other pollinators.

- Communication is key to understanding and solving bee kills. If pesticide poisoning is suspected, bee kills should be reported to the Pennsylvania Department of Agriculture (PDA). Contact the State Apiarist, **(717) 346-9567** or the Pesticide Division through the Chief of the Division of Health and Safety as soon as possible **(717) 772-5212**. After talking with the beekeeper and determining if this could be a bee kill caused by a pesticide misuse, an Apiary Inspector and Pesticide Inspector will be sent to the site to collect samples and additional information as quickly as possible. Sampling of dead bees must be timely as dead bees degrade rapidly. The pesticide inspector will also be looking for signs of misuse of pesticides. Bees, and possibly some wax from the colony, will be collected, following a protocol, and taken for laboratory testing of pesticide residue. When testing is complete, PDA will file a report with the EPA. PDA Pesticide Division's goal is to determine whether pesticide misuse has occurred, not to determine the cause of the bee kill. If proven, the person responsible for the pesticide misuse may be fined.
- The beekeeper should write down as much detailed information as possible, including when the bees began dying, weather (day and night temperatures, wind, sunny, rainy, etc.), dates and types of nearby pesticide applications if known, and symptoms of dying bees. Pictures or video of the bees are helpful.
- Bee Informed Partnership offers emergency response kits to help determine the cause of a colony death or decline.

CHAPTER 5

RECOMMENDATIONS FOR RESEARCH, POLICY AND COMMUNICATION

TABLE OF CONTENTS

These recommendations have been developed with input from the Pennsylvania Pollinator Protection Plan (P4) Task Force and Advisory Board, and from Pennsylvania stakeholders and members of the public who submitted suggestions on the P4 during an open comment period in Fall 2017. These recommendations are based on the diverse experiences, expertise, and perspectives of these groups, and from reviewing strategies developed by other states with similar opportunities and challenges as Pennsylvania. These recommendations are intended to provide a broad framework in which to consider and improve pollinator health in Pennsylvania, and can be used by a variety of communities and stakeholder groups at multiple levels, from local to state-wide.

RECOMMENDATIONS FOR RESEARCH

1. Improve baseline information on wild pollinator populations in agricultural and non-agricultural systems. Aside from managed honey bee colonies, we have little information about the status and trends of other pollinators (wild bees, butterflies, moths, flies, etc) in Pennsylvania. Developing this baseline information can include aggregating information from historical records, developing a streamlined and continuous monitoring system, and providing an accessible online portal to obtain records and disseminate information.

In Pennsylvania, pollinators in agricultural systems are well monitored, but other areas of the state, but other areas of the state are woefully under-surveyed. Furthermore, the monitoring methods do not consider abundances of colonies (the reproductive unit) for social species, although methods to accomplish this are well developed for some species, and could be developed for additional social species. Comprehensive and accessible information on the population trends of pollinator species and communities is critical to better understanding the status of pollinator populations in Pennsylvania, identifying factors that undermine the health of these populations, and determining where and how resources should be allocated to best support pollinator populations. This goal could potentially be coupled with "communications" recommendations below, to create a trained citizen-scientist network to aid in performing and supporting these surveys (see "recommendations for communication" point 6 below).

2. Develop science-based, metrics and methods for assessing and improving pollinator habitat. Many of the guidelines for improving forage and habitat are fairly generalized, and do not necessarily provide clear criteria for where best to focus efforts on improving habitat (for example, which locations would benefit most from habitat restoration practices in terms of overall increases in pollinator abundance and diversity, and which locations should be targeted to support specific pollinator species), which restoration practices will best support pollinator populations (which will vary depending on the goals of the restoration, for example, to support the most diverse pollinator communities or support the most important agricultural pollinators) and how to best determine if habitat restoration efforts have been successful (for example, identify easy-to-measure, short-term metrics that effectively predict longer-term, community-scale changes). For agricultural systems, these guidelines should include considerations of using cover crops, altering crop harvest patterns (such as letting some of a crop typically harvested in a vegetative stage progress to a flowering stage), or other farm-level management practices as a means of improving pollinator habitat.

Moreover, while these guidelines are usually designed for a fairly small scale (individual gardens or farms), they should be expanded to better understand how to most effectively create and manage pollinator habitat in natural areas, roadsides and rights of way, and urban areas.

3. Improve understanding of the nutritional ecology of pollinators. Multiple studies have shown that pollen from different plants can have vastly different nutritional profiles. Pollen from different plants may have different amino acids, different ratios of protein, carbohydrate and fats, and different ease of digestion (see Chapter 2, Best Practices for Forage and Habitat). A better understanding of both the nutritional needs of different pollinator species and the nutrition provided by Pennsylvanian plant species would allow the development of improved practices for restoring or creating pollinator habitat.

4. Understand the role of climate change on pollinators and pollinator food sources. With its diverse landscape, Pennsylvania hosts a range of microclimates and types of ecosystems. More research is needed on how climate change will impact pollinators (both stationary and migratory populations) and their food sources. Natural habitats, public lands, riparian zones, and rights of way can play an important role as habitat and corridors for pollinators as they respond to climate change. Best management practices can help attract and sustain pollinators as they move through these habitats.

5. Identify the pollinator species or pollinator communities that most efficiently pollinate agricultural crops and support natural ecosystems. Multiple studies have demonstrated that wild bees serve as better pollinators for some crops than managed honey bees, while other studies have demonstrated that wild bees and honey bees together provide the best pollination services. However, we know little about which bees – or combination of bees – serve as the best pollinators for many Pennsylvania crops.

6. Determine the optimal distribution and densities of managed bees to support stakeholders' requirements. Currently, recommendations for the numbers of managed bees (including honey bee colonies, bumble bee colonies, Osmia bees) needed to optimize pollination services for different crops are not well-defined and are likely over-estimated. Moreover, the extent to which Pennsylvania growers can meet their pollination needs from the ecosystems services of wild bee communities is not well understood. Similarly, there are no clear guidelines that beekeepers can use to assess the number of bee colonies that can be successfully supported – and produce large honey crops – by a given landscape.

7. Evaluate the impact of pesticide use (particularly herbicides) on pollinator habitat and forage quality. Studies have demonstrated that herbicides can reduce growth, flowering, and resource quality of important pollinator plants, if they come in contact with these plants through leaching or drift or when they are deliberately oversprayed (see Chapter 3, Best Practices for Pesticide Use). With the expanded use of auxinic herbicides, the risk of non-target plant injury, particularly broadleaf plants, is greatly increased. The indirect effects of herbicide damage on pollinator-supporting plant species poses a serious threat to the provisioning capacity of intentional pollinator plantings as well as the floral abundance and food quality of naturally occurring plants. These issues may arise in agricultural, urban, suburban and natural landscapes, as well as on roadsides and rights of way.

8. Evaluate the impact of pesticide type, application procedure and surrounding landscape conditions (such as soil type) on pesticide residue levels and persistence in the pollen and nectar of adjacent flowering plants, soil, and water. Increasingly, data suggests that pollinators are exposed to pesticides (insecticide, fungicides, herbicides, and additional ingredients in pesticide formulations) while foraging on flowering plants that are not directly targeted by a pesticide application, but are simply adjacent to a treated crop or area. Better understanding how pesticides move through the landscape and are incorporated into growing plants will allow for the development of more targeted and precise pesticide application protocols in agricultural, natural, and urban areas, and roadsides and rights of way.

RECOMMENDATIONS FOR POLICY

1. Obtain information on management practices from registered beekeepers. During the registration process, surveying beekeepers on their management practices and overwintering survival outcomes would generate an outstanding data set which could be used to determine which practices and landscape conditions are most successful in supporting healthy honey bee colonies.

2. Consider requiring pesticide applicators to contact registered apiaries within vicinity of pesticide application. It is currently only recommended, but not required, that applicators contact registered apiaries. However, given the size and diversity of agricultural systems in Pennsylvania, any such requirement would need to be developed in a manner that is manageable for pesticide applicators and useful for beekeepers. For more information, see Chapter 3, Best Practices for Pesticide Use.

3. Develop methods to better document pesticide use in Pennsylvania. Mitigating pollinator exposure to pesticides requires a solid understanding of where and when pesticides are applied. While national pesticide surveys provide rough estimates of pesticide use in agricultural systems in Pennsylvania, these surveys leave out many crops and do not provide any information on pesticide use in other landscapes. These surveys also do not describe when pesticides are applied during the growing season, a key factor influencing pollinator exposure. Pennsylvania could launch its own pesticide reporting program, similar to the one currently used in California. Note, however, that the Pennsylvania landscape is much more diverse than California, and pesticides are applied in smaller-scale operations. Thus, careful planning would be needed to develop a reporting system that does not overburden pesticide applicators, growers, land managers, etc.

4. Create incentives for seed producers to provide a diverse array of options for growers, including seeds that are not coated with neonicotinoids. Data from Pennsylvania (see Chapter 3, Best Practices for Pesticide Use) have demonstrated that neonicotinoid seed treatments on soybeans can actually lead to reduced yield, but growers have few options when they are purchasing their seeds.

5. Establish an affordable lab service at PA Department of Agriculture or Penn State University that beekeepers and growers (in Pennsylvania and nationally) could utilize to evaluate bee health. Bee health evaluations can include measuring virus and pesticide loads in managed bees, the diversity and abundance of the wild bee community in a particular location, and/or the number of wild colonies providing pollination services. Pathogens and pesticides are considered major factors underpinning bee declines, but measuring levels of these stressors requires sophisticated molecular and chemical approaches which are out of reach of beekeepers. Research has documented that wild bee populations are providing much of the pollination services in PA apples and pumpkins, and may also be doing the same in blueberries, strawberries, and other crops. Currently, growers have access to services for analyzing the status of multiple soil health metrics, and plant nutrients such as petiole tests, and water quality. A comparable service could be designed for growers wishing to evaluate populations of wild bee species in their farmscape. For bumble bees, this might take the form of an annual collection and PCR analyses to estimate colony abundance. For other species, this may include a structured measure of visitation rates.

6. Expand incentive programs for conserving pollinators to lands beyond the farm, at spatial scales relevant to those pollinator species that visit the crop. Currently, USDA-NRCS programs (such as EQIP, CSP & WHIP) can cost share the development of pollinator habitat on farms and forests. But adjacent land, owned by a different farmer, could also help provide pollinator habitat. Incentivizing these cost-share programs so they are designed at the landscape scale (across farms) could benefit multiple growers, and would better support pollination services at smaller-scale operations.

RECOMMENDATIONS FOR COMMUNICATION AND COLLABORATION

1. Develop an annual meeting of Pennsylvania Pollinator Protection Plan Task Force and Advisory Board members. This meeting will facilitate communication, resource sharing, the development of new collaborations, and ensure that the P4 is regularly updated to reflect current information, opportunities and challenges.

2. Develop a series of short videos highlighting aspects of the Pennsylvania Pollinator Protection Plan and disseminate these through social media. These videos could be linked to short surveys and questionnaires to evaluate impact of these videos, and help identify sections of the P4 that could be adjusted to more effectively communicate information.

3. Develop training modules for specific aspects of the P4 that can be used by and address the needs of different stakeholder communities. These modules can address individual chapters or chapter sections, such as creating pollinator habitat, managing pesticide use, or keeping bees in different types of landscape. These modules can be very targeted (eg, improving the public's ability to read and understand pesticide use and toxicity labels) or broad. These training modules could be required for certain groups (such as pesticide applicators, or individuals who are receiving support from programs to develop pollinator habitat on their lands).

4. In the same way the P4 itself was created, utilize the P4 partnership to help coordinate and facilitate participation of scientists, policymakers, concerned citizens, and others in the development and implementation of future research, conservation, and planning efforts.

For example, the Northeast Fish and Wildlife Diversity Technical Committee is developing a monarch conservation strategy on behalf of the Northeast Association of Fish and Wildlife Agencies (to be completed by February 23, 2018). They are seeking assistance from stakeholders in each state in the Northeast to share existing information on monarch conservation efforts, and to help develop strategies to address gaps in those efforts as needed. The P4 partnership includes individuals with the information, expertise, and connections needed to inform future local and regional efforts to support pollinators.

Additionally, this group should collaborate with the Pennsylvania Biological Survey to develop a white paper that discusses the status of 'orphan taxa' in Pennsylvania. Orphan taxa are species that have fallen through gaps in the state code and lack state agency oversight regarding their status and management. Orphan taxa include many pollinating insects such as native butterflies, moths, bees, wasps, beetles, flies, etc. This paper can investigate the many implications of having orphan taxa (e.g., fiscal, environmental and human health, etc.) and suggest strategies to advance research, conservation, and management of this large and diverse group of overlooked species.

5. Develop resources that individuals can use to better identify pollinator species and pollinator plants in Pennsylvania. These can include a checklist of Pennsylvania bees and key pollinator plants, and accessible online resources (including modifications to existing resources such as Discover Life).

6. Organize citizen-scientists to help monitor pollinator populations in Pennsylvania. With sufficient training, informational resources and organizational support, Pennsylvania citizens can become important contributors to a long-term plan to monitor pollinator populations in the state (see research recommendation #1).

7. Develop a group that supports individuals who manage non-Apis bee species, such as bumble bees or *Osmia* bees. The Pennsylvania State Beekeepers Association (PSBA) provides valuable information and support for individuals who manage honey bee colonies, and can advocate effectively for honey bee health in Pennsylvania. With a growing interest in managing non-Apis bee species, a similar group could be developed, or the PBSA could be expanded to include these other managed bees.

8. Promote the Pennsylvania State Wildlife Action Plan. The conservation status of pollinators and other invertebrates were evaluated for this plan, which was updated in 2015. The invertebrate assessment report can be found in Appendices 1.1 and 1.2 (Pages 76-149), which is available online. There are urgent conservation and management issues that need to be addressed to 'keep common species common', conserve species of global and regional importance, maintain PA-rare species, and reduce knowledge gaps to better assess the conservation status of species.

9. Highlight and celebrate the diversity of pollinators in Pennsylvania, and our efforts to support them. These efforts can include photo contests of pollinators, monthly news articles featuring local citizens (including growers) whose efforts support pollinators, pollinator-themed scavenger hunts for K-12 students, and so forth. The development of pollinator gardens in regions with high visibility (such as state and municipal buildings) can also help promote understanding of pollinators and pollinator conservation.

10. Develop a rating system to help growers effectively communicate their efforts to support pollinators to consumers. This rating system or alternative communication strategy can be developed for different crops, types of growers, markets, and consumers. This rating system should be developed by a consortium of researchers, extension specialists, growers, and retailers.

RECOMMENDATIONS FOR ASSESSMENT

Below are suggestions for assessing the effectiveness of the P4 in terms of reaching a broad audience in Pennsylvania and encouraging more individuals and organizations to actively participate in supporting pollinator populations. Participation may take many forms, including obtaining improved information, working with existing groups that support and advocate for pollinators, and implementing changes in backyards, farms, businesses, communities, or regions. The P4 could be considered effective if we could demonstrate:

1. Increased number of participants in the PA State Beekeepers Association, and/or an equivalent managed non-Apis bee organization. The PSBA provides valuable information, resources and guidance for individuals managing honey bee colonies, which can support both beekeepers and their bees. Establishing an equivalent group for managed non-Apis bees would similarly support this growing beekeeper group in Pennsylvania.

2. Increased average honey bee colony overwintering survival. This information is generated annually from the PA State Beekeepers Association Annual Survey and the Bee Informed Partnership's annual Management and Loss Surveys. The 2016-2017 winter loss rate in Pennsylvania was ~50%. The target for the US National Strategy to Promote the Health of Honey Bees and Other Pollinators is to reduce losses to 15% by 2025.

3. Increased numbers of certified PA Pollinator Gardens through the PSU Master Gardeners Program. The certified PA Pollinator Garden program provides critical information for individuals wishing to create pollinator habitat in their backyards or businesses, and sets criteria to evaluate the effectiveness of these practices.

4. Increased acres of pollinator habitat in public and wild lands.

5. Increased numbers of people taking training modules developed to disseminate information from PA Pollinator Protection Plan.

6. Increased "pollinator literacy" of individuals viewing informational videos developed about the P4. See "recommendations for communication" point 2. Pollinator literacy can be evaluated via short questionnaires or surveys of individuals watching these videos on social media.

7. Increased numbers of people viewing and downloading the PA Pollinator Protection Plan.

CONCLUSIONS AND FUTURE DIRECTIONS

The development of the Pennsylvania Pollinator Protection Plan (P4) brought together individuals representing 28 state and national organizations and stakeholder groups, establishing a strong network that can be leveraged to address ongoing and arising issues in pollinator health in Pennsylvania. The P4 is a comprehensive, information-rich, and living document that provides recommendations for best practices to support pollinator populations – and the diverse communities and stakeholders that value and depend on them – throughout the state. The best practices outlined in the P4 were developed to ensure that the incredible diversity of Pennsylvania's pollinator species and their ecosystem services are appreciated, promoted, and protected across the different landscapes of Pennsylvania. This recommendations section represents the input of a diverse community of individuals, and is intended to serve as a framework for using the P4 as a platform for supporting the pollinators and people of Pennsylvania.