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Responding to the US national pollinator plan: a case study in Michigan

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The long-term health of pollinators is a critical issue for the functioning of natural habitats and for agricultural production. In response to widespread public concern about the future of these ecologically and economically important animals, in 2015 the US Government released a national strategy to support pollinators, including research priorities, directives for funding, and timelines for achieving three overarching goals. Five years after this strategic plan was released, we evaluate progress toward the national targets for improved honey bee (*Apis mellifera*) overwintering survival, expanded pollinator habitat, and larger monarch butterfly (*Danaus plexippus*) populations, and find that the three goals of the plan have not yet been reached. Our research and extension programs to improve the health of honey bees, wild bees, and monarch butterflies in the US state of Michigan are described, providing opportunities to contribute to the national pollinator goals.

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Pollinating insects are essential to life on Earth, supporting the sustainability and resilience of natural habitats and agroecosystems (Williams *et al*. 2019; van Klink *et al*. 2020). Despite their importance, populations of insect pollinators face numerous challenges due to a combination of diseases, parasites, pesticides, climate change, and habitat loss (Goulson *et al*. 2015). As the international plight of pollinators has become more apparent, 16 nations have enacted pollinator supportive policies (FAO 2020). In the US, a 2014 Presidential Memorandum directed the US Department of Agriculture (USDA) and the Environmental Protection Agency (EPA) to co-lead a task force to create a strategy to promote the health of honey bees (*Apis mellifera*) and other pollinators (PHTF 2015). This task force released a national pollinator strategy in 2015 that included three key goals with timelines: (1) reduce honey bee overwintering losses in the US to no more than 15% by 2025, (2) increase the overwintering monarch butterfly (*Danaus plexippus*) population in Mexico to 6 ha by 2020 (as it is not feasible to count individuals, the area covered by overwintering monarchs is measured as a proxy for abundance), and (3) restore or enhance 7 million acres of habitat for pollinators in the US by 2020 (PHTF 2015). A Pollinator Research Action Plan (hereafter, "national plan") that highlighted the priorities for addressing the three goals was also developed (PHTF 2015).

In a nutshell:

- National goals for pollinator health in the US were established in 2015, but these goals have not yet been achieved
- We use research conducted in Michigan as a case study to highlight tactics to support monarch butterflies (*Danaus plexippus*), wild bees, and honey bees (*Apis mellifera*) at local and national scales
- There remains a continued need for focus on pollinator health and greater investment if the goals of the national plan for pollinators in the US are to be attained

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Michigan as a case study

Funding to address the national plan was made available through various routes, including the USDA. The USDA's National Institute of Food and Agriculture (NIFA) supported our research and extension team to address the goals in Michigan, a state reliant on wild bees and managed honey bees for crop pollination (Huang and Pett 2010) and containing summer breeding grounds of the eastern monarch butterfly (Flockhart *et al*. 2013). Because regional solutions to pollinator challenges are important, we highlight how our efforts in Michigan contribute to the national goals. We also draw on public databases to assess progress toward the national goals and show where further focus is needed. The year 2020 was a milestone year to achieve two of the three goals, providing an opportunity to revisit the strategy that inspired 5 years of work. Herein, we evaluate local and national progress and identify future needs for honey bees, monarch butterflies, and pollinator habitat to support wild bees.

Honey bee colony loss

Declines in honey bee health cannot be pinpointed to a single cause. Rather, an array of pressures, including parasites, pathogens, pesticides, and a lack of floral resources

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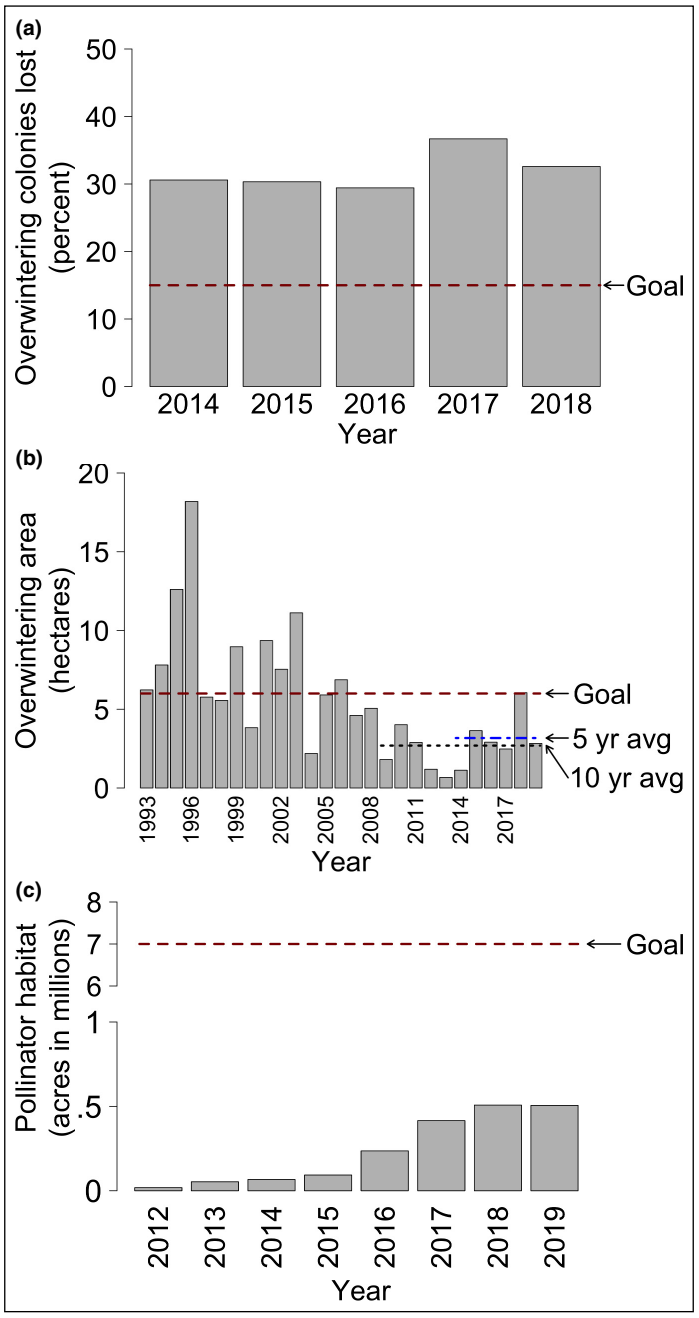


Figure 1. Progress toward the three primary goals (red dashed lines) of the US national plan. (a) Honey bee (*Apis mellifera*) overwintering losses remain 7–20% above the 15% 2025 goal (data from Bee Informed Partnership [BIP]). (b) Monarch butterfly (*Danaus plexippus*) populations are variable but declining, and currently below the 6-ha overwintering goal set for 2020 (data from Monarch Watch [x-axis labels given in 3-year increments for 1993–2019]). (c) US Department of Agriculture (USDA)-funded pollinator habitat (Conservation Practice [CP]-42, shown here) has increased by 0.5 million acres since 2012 but remains below the 7-million-acre 2020 goal (data from USDA).

in the landscapes around their apiaries (locations of beehives), put stress on honey bee populations (see Goulson *et al.* [2015] for insights). The varroa mite (*Varroa destructor*) feeds on the fat body tissue of honey bees, reducing their immune function and ability to detoxify pesticides while also transmitting diseases (Ramsey *et al.* 2019). At the same time, a lack of flowers in the landscape reduces forage for honey bees, starving colonies (Dolezal *et al.* 2020). These are a few of the many issues contributing to honey bee colony losses.

The general public in the US is aware that pollinators face threats, which in turn has put pressure on politicians and resulted in the implementation of pollinator-supportive policies at both national and state levels (Hall and Steiner 2019). This public pressure has raised awareness and promoted funding for programs addressing honey bee health, including long-term monitoring of colony survival. Data collected by the USDA and the Bee Informed Partnership (BIP; a national network of research labs and universities working to monitor and improve the management of honey bees) (USDA 2019; BIP 2020) suggest overwintering colony losses remain at 20–30% nationally, depending on the data source and method of calculating losses (Figure 1a). BIP data (Figure 1a) indicate colony loss rates still exceed the 15% target set for 2025 (PHTF 2015; BIP 2020), although there is considerable regional variation (Dolezal *et al.* 2020). Surveys of commercial beekeepers in Michigan (www.research.beeinformed.org/survey) indicate an average overwintering colony loss rate of 28.6% over the past 5 years, a rate 1.9% higher than the national average.

The national plan called for improved understanding of the links between pesticides and pollinator health in agricultural landscapes (PHTF 2015). Southern Michigan is dominated by agriculture (Meehan and Gratton 2016) and many of these farms – particularly fruit and vegetable producers – depend on honey bees for pollination (Huang and Pett 2010). While visiting these farms, honey bees are exposed to pesticides from within and outside of the crop (Long and Krupke 2016; Graham *et al.* 2021). We explored pesticide exposure in Michigan agricultural landscapes to address this aspect of the national plan, and because routes of pollinator pesticide exposure under field conditions within natural and agronomic ecosystems remain unclear (Berenbaum 2016). The main exposure route for honey bees and other pollinators is typically perceived to be pesticide-treated crops (Goulson *et al.* 2015), but native plants and agricultural weeds growing in and around agroecosystems can become contaminated, serving as a source of exposure (Long and Krupke 2016; McArt *et al.* 2017). In Michigan cucurbit farms, we found that the majority of pesticides in pollen came from agricultural weeds rather than the crops themselves (Wood *et al.* 2019a). These results highlight the importance of reducing off-target drift, and suggest caution when locating native plant buffers to promote bees and their pollination services. Habitat management should be integrated with pollinator safety concerns, particularly when used alongside crops where water-soluble pesticides are taken up by plants or foliar sprays drift into habitat managed for pollinators (Wood and Goulson 2017). Pollinator habitat could be located strategically in landscapes based on wind

and water movement to minimize these risks. In addition, our findings hint at the large spatial scale of pesticide management needed to promote pollinators (Wood *et al*. 2019a), given that several types of pesticides can be transported (eg via dust) well outside the cropping area (Krupke *et al*. 2012). Because honey bees are highly mobile, often flying several kilometers to forage, protective actions are needed at landscape scales to reduce pesticide exposure. Over the longer term, reducing the quantity and toxicity of pesticides applied through regulation and greater investment in integrated pest and pollinator management (IPPM) programs should be considered to support this change (Egan *et al*. 2020).

In the US, although large-scale commercial beekeepers maintain most honey bee colonies, small-scale beekeepers have experienced colony loss rates of 30–50%, a rate higher than that of commercial counterparts (Lee *et al*. 2015). Most small-scale beekeepers find it difficult to manage varroa mites and implement practices that promote honey bee health (Whitehead 2017). In addressing the national plan, we therefore focused our extension efforts in Michigan on educating small-scale beekeepers about improved management of honey bee pests and diseases. To facilitate these educational opportunities, we joined the BIP's sentinel apiary program in 2016, which developed a national effort to monitor honey bee colonies and act as an early warning system for colony health issues. Apiaries in this program have fewer varroa mites than the national average, indicating the value of an early warning system for honey bee pest and disease management (Kulhanek and Reynolds 2018). Our Michigan State University (MSU) Apiculture Extension program shared colony health data with small-scale beekeepers to enhance education and decision making (Figure 2; Table 1) and used sentinel apiaries for beekeeping education through newsletters, blog posts, and workshops, engaging with beekeepers, military veterans, and veterinarians. Based on our experiences, there is a need for converting data-driven knowledge into timely guidelines that are made available to the public and implemented by stakeholders through local beekeeping programs.

Monarch butterfly habitat management

Eastern monarch butterfly populations have fallen by ~80% since the 1990s (we focus here on the monarch population east of the Rocky Mountains, but it should be noted that the western population has undergone an even more precipitous decline; Schultz *et al*. 2017). Although not important agricultural pollinators, concern over monarch status has galvanized public support for insect conservation (Gustafsson *et al*. 2015), and they are considered a bellwether species for the status of pollinators in general. Monarchs breed in the eastern US and Canada each summer, laying eggs on milkweeds (*Asclepias* spp), on which larvae then feed. During fall and spring, monarch butterflies migrate between northern breeding grounds and overwintering sites thousands of miles away on oyamel fir trees (*Abies religiosa*) in central Mexico. Public concern was sparked in 2014 when the overwintering monarch population fell to historically low numbers and covered only 0.6 ha (Gustaffson *et al*. 2015). The national plan set a goal of increasing this to 6 ha by 2020; although population size has fluctuated (Monarch Watch 2020), it remains well below this level (Figure 1b). At last count (winter 2019–2020), the overwintering colony size was 2.47 ha, and a recent analysis found no evidence of population growth (Thogmartin *et al*. 2020).

Causes of monarch butterfly decline vary and their relative importance remains a topic of active research, with different threats more prominent in different areas (Inamine *et al*. 2016; Zaya *et al*. 2017); for example, overwintering sites in Mexico are especially vulnerable to logging and to range shifts caused by climate change (Sáenz-Romero *et al*. 2012; Vidal *et al*. 2014). Hazards along migratory pathways also contribute to population decline, as in some years floral resources are insufficient to fuel migration (Saunders *et al*. 2019). Finally, in breeding grounds in the US Midwest, the primary suspected driver of monarch decline is the loss of milkweed host plants due to agricultural intensification. Since the 1990s, >90% of corn (*Zea mays*) and soybean (*Glycine max*) growers have transitioned to herbicide-resistant crops (USDA 2018) and now control weeds with broad-spectrum herbicides. Given that milkweed was once common in crop fields, this shift in weed control may have removed 850 million (~40%) of milkweed stems from Midwest landscapes (Pleasants 2017), causing a decline in monarch host plant availability.

The national plan called for an assessment of monarch population patterns and their relationship to habitat variables (PHTF 2015). Michigan is an important part of the monarch's breeding range (Flockhart *et al*. 2013), and



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Figure 2. Beekeepers collect a sample of honey bees to be analyzed as part of the BIP sentinel apiary monitoring program.

Table 1. Bee Informed Partnership (BIP) report of varroa mite *(Varroa destructor)* levels from one sentinel apiary managed by Michigan State University (MSU)

Varroa mites (per 100 bees)						
Hive	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**
S19-SAOI-1	0.0	1.4	0.3	**6.6**	1.1	0.0
S19-SAOI-2	0.0	0.4	0.0	0.4	–	–
S19-SAOI-3	0.5	0.0	0.5	1.6	0.7	0.0
S19-SAOI-4	1.0	**3.1**	1.3	**3.8**	0.6	0.0
S19-SAOI-5	0.0	0.0	0.0	1.7	0.9	0.0
S19-SAOI-6	0.0	0.6	0.9	**8.1**	0.8	0.8
S19-SAOI-7	**3.1**	2.0	**5.8**	**18.6**	0.3	0.5
S19-SAOI-8	2.0	0.0	0.0	0.9	0.0	0.0
Monthly average (± SE)	0.8 ± 0.4	0.9 ± 0.4	1.1 ± 0.7	5 ± 2.0	0.6 ± 0.1	0.2 ± 0.1

Notes: beekeeper: MSU; report date: 1 Nov 2019. BIP considers ≥3.0 mites per 100 bees (numbers in bold) as approaching a high threshold at or beyond where the beekeeper may want to consider a varroa mite control strategy. A dash (–) indicates that the colony lost its queen and was combined with another colony. SE: standard error.

therefore our research focused on methods to enhance habitat within this region. We found that managing milkweed with strategically timed disturbance during the growing season could be used to enhance monarch habitat quality. Common milkweed (*Asclepias syriaca*) is a robust perennial plant, and when stems are set back (eg by mowing or fire), new shoots emerge soon afterward. Monarchs prefer to lay eggs on young, newly grown milkweed stems than on those that have flowered or are senescing (Bergstrom *et al*. 1994), and when milkweed stems regrow after being cut back, they receive more eggs than undisturbed stems (Figure 3a; eg Haan and Landis 2019a; Knight *et al*. 2019). Milkweed stems that regrow post-disturbance are also safer for eggs and larvae. Predators of monarch eggs and early stage caterpillars are diverse and abundant (Hermann *et al*. 2019; Myers *et al*. 2020), but fewer predators occur on stems that regrow following disturbance (Figure 3b; Haan and Landis 2019a) and for newly hatched monarchs survival on these stems is double that of survival on undisturbed stems (Figure 3c; Haan and Landis 2020). Consequently, monarchs may have historically benefitted from mechanical cultivation of crops, which disturbed milkweeds and caused stems to periodically regenerate in the summer (Haan and Landis 2019b).

While research is ongoing, manipulating the frequency, timing, and extent of disturbance to milkweed during the summer may increase the abundance of monarchs migrating south from the US Midwest each fall. Common milkweed is abundant along roadsides that are mowed for safety and aesthetic reasons, although not necessarily with appropriate frequency or timing. Some state government agencies (Departments of Transportation) already play important roles in roadside habitat management, particularly along the I-35 corridor, a highway that runs from Texas to Minnesota (https://bit.ly/3gOF9ht). A key challenge, however, is incorporating milkweed disturbance in ways that complement conservation objectives for other organisms. For example, cutting back vegetation reduces pollinator floral resources for several weeks, but some species regrow and flower later, which could extend bloom and fill resource gaps for bees in late summer (Haan and Landis 2020). To begin testing the role of disturbance more broadly, in 2020 we launched a community science study, ReGrow Milkweed for Monarchs (www.canr.msu.edu/msumilkweedregrow), in which participants across the eastern US and Canada cut back milkweed and monitor monarch eggs and larvae on regenerating stems.

Promoting pollinator habitat

The national plan set the goal of restoring or enhancing 7 million acres for pollinators by 2020. However, unlike the targets for the other goals, there is no database tracking creation of pollinator habitat nationally. This lack of measurement is partially because different groups are engaged in efforts to promote pollinator habitat. Federal and state investments in on-farm conservation are complemented by state and local efforts to develop pollinator habitat in nature preserves, parks, roadsides, and gardens. Improved documentation of habitat creation across these settings will identify where habitat has been created, whether goals have been met, and if certain regions need targeted efforts. We found evidence for approximately a half million acres of pollinator habitat established under funding from the Conservation Title of the law passed every five years that sets US agricultural policy (The Farm Bill). These programs are funded through the Farm Service Agency (FSA), contributing 7% of the 7-million-acre national target established since 2012 (Figure 1c; PHTF 2015; FSA 2019). However, caps on this funding have slowed the initial expansion. Creation of new pollinator habitat takes time; first, the funding allocation in the Farm Bill must reach the USDA and be assigned to state FSA and Natural

Resource Conservation Service (NRCS) offices, then agreements have to be established with landowners, seed mixes must be acquired, land prepared for seeding, and plants allowed to mature to bloom before pollinators receive benefits. Greater investment in land conservation programs could improve floral resources for pollinators in the US and support a range of conservation, agroecology, and climate-change mitigation goals (Sidhu and Joshi 2016).

A major contributor toward the 7-million-acre goal was the establishment of a Conservation Practice (CP) within the Conservation Reserve Program (CRP), CP-42, which prescribes more flowering forb species than typical CRP grasslands. Research in Michigan addressing the national plan via testing the benefits of CRP for bees on farms found that CRP grasslands provide greater floral resources and support more bee foragers than analogous non-CRP lands (Quinlan 2020). Creating perennial wildflower patches on farms also contributes to the national pollinator habitat goal and increases wild bee biodiversity (Williams *et al.* 2015). The FSA further incentivized pollinator habitat creation through the State Acres For wildlife Enhancement (SAFE) program, which pays 90% of the cost share plus an annual land rental fee for 10–15 years. The SAFE and CP-42 programs resulted in the establishment of over 25,000 acres of pollinator habitat on farms in Michigan, with 5487 acres within CP-42 (FSA 2020). These habitat investments benefited pollination on blueberry (*Vaccinium corymbosum*) farms in Michigan, with greater yields adjacent to habitat plantings after 4 years (Figure 4; Blaauw and Isaacs 2014). A more recent study, however, found no benefit in nearby crops during early establishment (Nicholson *et al.* 2020), highlighting the need for plants to establish and bees to respond before pollination increases. Caps on CP-42 and SAFE also limit the contribution Michigan (or any state) makes toward achieving this national goal with federal funding; for example, Michigan contributes ~1% of the national acreage in CP-42 despite additional land available for this practice.

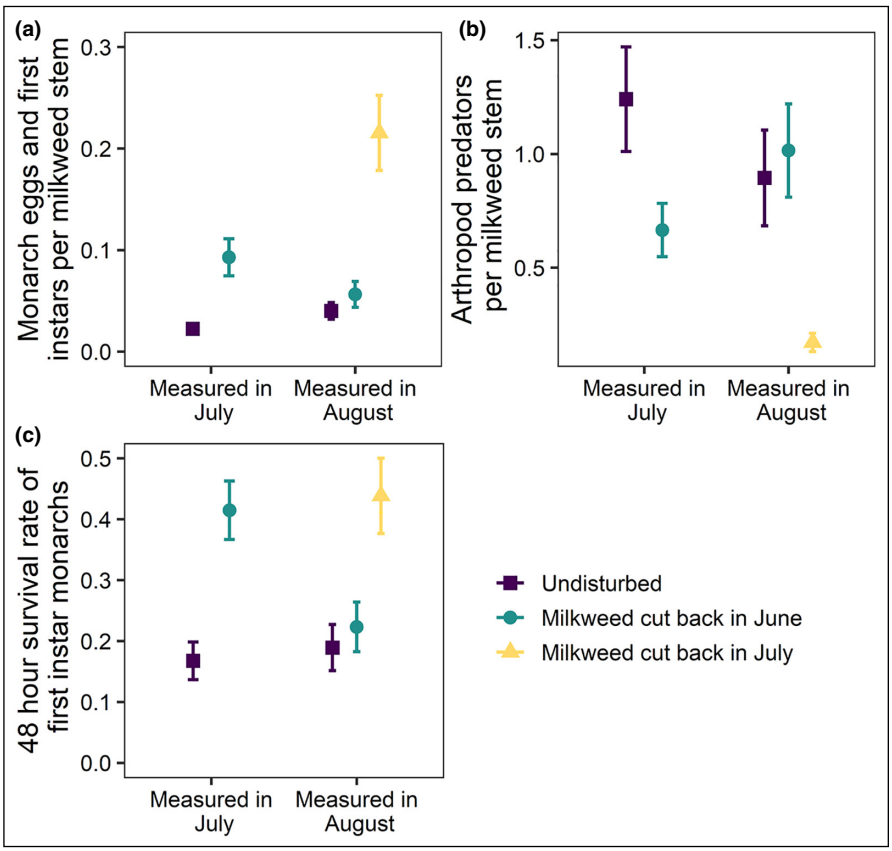


Figure 3. Disturbance events that cut back milkweed (*Asclepias* spp) cause regrowth that (a) attracts ovipositing monarchs, (b) contains fewer arthropod predators, and (c) results in higher survival of newly hatched monarch larvae. Points represent means and error bars denote one standard error. Data from (a) and (b) are from 23 milkweed patches; eight were surveyed in 2017 and 15 were surveyed in 2018. Each patch was divided into thirds, with one-third left undisturbed, one-third cut back in mid-June, and one-third cut back in mid-July. In the left portion of each plot are data collected in July, when undisturbed stems were compared to those that regrew after disturbance in June. On the right of each plot are data collected in August, when stems that had been cut back in July were also regrowing. (c) Results from an experiment in which 13 milkweed patches were cut back using the same methods and first-instar monarch caterpillars were placed on milkweed stems to measure survival over 48 hours. Reprinted with permission from Elsevier (Haan and Landis 2019a, 2020).

Many regions of the country have been identified as having a deficit of wild pollinators due to intensive land management, with a subset of those regions having a pollination mismatch where there is a high proportion of pollinator-dependent crops (Koh *et al.* 2016). In Michigan, we focused on identifying these regions of mismatch. Pollinator-dependent crops in southern Michigan are known to have pollination deficits (Isaacs and Kirk 2010; Reilly *et al.* 2020), indicating that increased habitat investment could help promote pollination. For instance, pollination of blueberry fields in Michigan could be improved if nearby corn or soybean fields grown on marginal land (poor soil) were converted into pollinator-supportive habitat. These nearby marginal lands were identified through landscape modeling and are within the flight range of bumble bees (Y Zhang pers comm). Marginal land could be prioritized for conservation payments, supporting pollinators and reducing pollination deficits in adjacent crops.

The benefits of habitat investments for climate resiliency are also considered within the national plan (PHTF 2015). Our research tested native plants for their attractiveness to insects, ability to establish, and drought tolerance (Rowe *et al.* 2018). This research created a searchable database (www.nativeplants.msu.edu) that provides users with suggestions based on their needs and local conditions. The use of tailored seed mixes



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Figure 4. Pollinator habitat can promote pollination in crop fields. Shown here is a blueberry (*Vaccinium corymbosum*) farm in western Michigan with an adjacent wildflower planting, with bee balm (*Monarda fistulosa*) in full bloom.

would provide several benefits: plants could establish readily, be more resilient to the local climate, and better match the needs of private and public users, whether for improved pollination or conservation aims.

Bee monitoring and taxonomy

Long-term pollinator monitoring is necessary for understanding population status and trends, and for assessing conservation actions, including habitat restoration (Bartomeus *et al.* 2013). A National Academy of Sciences report (NRC 2007), the national plan, and a group focused on monitoring US wild bees (Woodard *et al.* 2020) identified the need for consistent national sampling. Currently, a patchwork of projects collects bees and records their abundance unevenly, using non-standardized methods. Collection records for some of these efforts are publicly available (eg Global Biodiversity Information Facility), but individual project leaders decide whether these records are to be shared. To facilitate better understanding of wild bee trends, records should be amalgamated into a single database (eg the Bees, Wasps and Ants Recording Society in the UK; Woodard *et al.* 2020). In an effort to create such a resource, the US National Native Bee Monitoring Network (www.usnativebees.com) is developing a framework to coordinate methods and datasets, providing a baseline for examining trends over space and time.

Another challenge to long-term monitoring and comparisons to historical records is that identifying wild bee species can be challenging even for collectors who have access to high-quality reference specimens, a situation exacerbated by a shortage of professional bee taxonomists (especially for difficult groups, such as *Dialictus* spp; Michener 1974). Even large bumble bees (*Bombus* spp) can be difficult to identify (Williams *et al.* 2014). This taxonomic impediment has led to a bottleneck in monitoring efforts; given the limited monitoring currently taking place, there is not enough capacity to identify the bees being collected. This bottleneck must be addressed before monitoring programs can be scaled up. Although greater use of advanced technologies, such as machine learning (Nizam *et al.* 2019; see also https://beemachine.ai) and DNA barcoding (Schmidt *et al.* 2015), are potential solutions, investment in training and employing expert taxonomists at the federal and state levels, as well as at research universities, is needed. Indeed, a combination of these approaches will be essential for meeting the demand for high-quality identifications to understand the national status and trends of wild bees and other pollinators.

The national plan also identified a lack of bee specimen digitization as a barrier to detecting long-term population trends. In Michigan, we are working toward overcoming this barrier by digitizing the two historical bee collections in the state housed at Michigan State University (Albert J Cook Arthropod Research Collection) and the University of Michigan (Museum of Zoology), which will facilitate assessment of changes in wild bee populations over time. Examination of these specimens revealed inconsistent historical collecting, creating gaps when interest, collection bias (that is, a focus on rare rather than common specimens), and/or lack of funding limited the number and diversity of bees in these collections (Figure 5). The gaps in historical collection underscore the need for coordinated efforts linking local digitizing to a national database for verified records. Inconsistent collecting is particularly problematic for rare species, which can be over- or underrepresented in historical collections with respect to their relative abundance, as their status can often only be determined through regular, targeted searches. This is highlighted by our recent rediscovery of the kleptoparasitic bee *Epeoloides pilosulus* in Michigan, a species last recorded in the state in 1944 (Wood *et al.* 2019b).

Promoting the goals of the national pollinator plan

By evaluating data collected by the USDA and national/international nonprofit organizations (BIP and Monarch Watch), we find that progress toward the goals of the national pollinator plan is falling short in all categories. Honey bee overwintering losses remain at levels above the goal (Figure 1a; BIP 2020), monarch populations continue to be lower than needed for population stability (Figure 1b; Monarch Watch 2020), and pollinator habitat remains millions of acres short of the goal to support wild and managed pollinators (Figure 1c; FSA 2019). Further investment is needed to promote pollinators in the US to achieve the national goals. The lessons learned from Michigan (summarized below) can be used to promote future progress toward the national plan.

Rapid communication

The adoption of better management practices by small-scale beekeepers can reduce mite populations and improve honey bee overwintering success (Kulhanek and Reynolds 2018). Encouraging participation in monitoring projects (see the BIP sentinel apiary program) and supporting quick delivery of results back to the beekeepers is essential for improved

colony health. Additional improvements could be made by evaluating the delivery of this information to identify educational tactics (pedagogies) that best suit small-scale and commercial beekeepers.

Addressing challenges regionally

States with landscapes dominated by row crops may have pesticide exposure profiles similar to those of Michigan (Douglas *et al.* 2020). These states could improve honey bee health through increased environmental pesticide monitoring and developing crop-specific IPPM programs limiting pesticide exposure (Biddinger and Rajotte 2015). Tools that allow beekeepers to locate apiaries in nutrient rich, low pesticide landscapes are also emerging (eg https://beescape.org). Managed Pollinator Protection Plans developed at state and tribal levels to provide non-regulatory guidance on reducing pesticide exposure of managed bees could also promote communication between pesticide applicators and beekeepers.

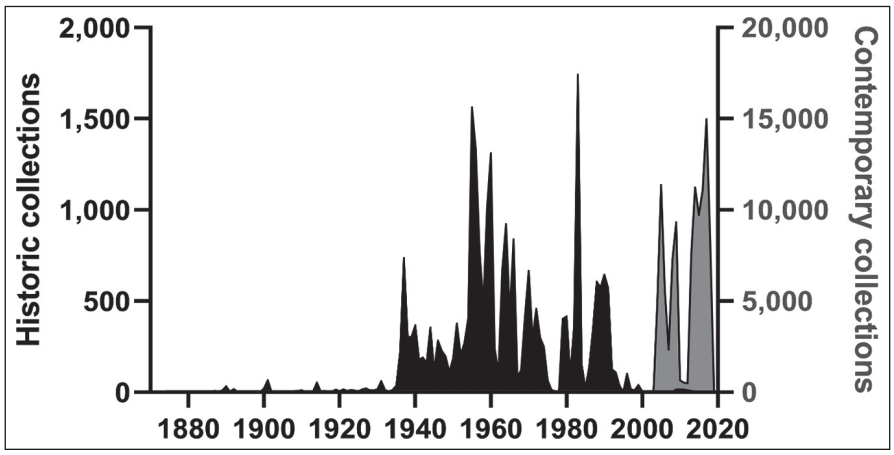


Figure 5. Number of bee specimens in the Michigan State University Albert J Cook Arthropod Research Collection, sorted by collection year. Collection efforts changed over time based on funding, interest, and expertise. Note that historical (pre-2000) collections have a different y-axis scale than contemporary (post-2000) collections. Although this difference in magnitude highlights an increase in contemporary sampling efforts, historical collection efforts may not be wholly represented in museum collections because museum space is limited, and it is likely that not all specimens were deposited or that collection efforts focused on rare specimens rather than proportional sampling of entire bee communities. Conversely, contemporary data represent all specimens from recent sampling efforts.

Expanding pollinator habitat

There is evidence of the benefit of flowering habitats for pollinators, and matching funds are available to support habitat creation (Gaines-Day and Gratton 2017). For example, the NRCS Environmental Quality Incentives Program provides 50% of the cost share for farmers to establish flowering annual cover crops and forages in association with commercial beehives in six Midwest states where over 60% of honey bee colonies are found in summer. Taking greater advantage of these programs could help achieve the national goals. Moreover, a national pollinator habitat database to compile the location, extent, and attributes of pollinator habitat would be valuable for coordinating the diverse types of habitats established for pollinators and for tracking progress toward the national goals.

Synergies between goals

The goals of the national plan were designed to overlap, creating synergies to support multiple pollinator taxa (PHTF 2015). For example, creation of pollinator habitat benefits wild bees, monarch butterflies, and honey bees. General pollinator habitat conservation could also be adapted to support populations of at-risk bee species. Designing habitat for wild bees is difficult, however, because they require a wide variety of habitat types. Another approach to promoting progress is to invest in educational programs delivered to a diverse range of stakeholders. The Pollinator Champions program (www.pollinators.msu.edu/programs/pollinator-champions) is a free, self-paced online course to help translate our pollinator information to the public. To date, this program has trained 2173 individuals, with 323 going on to become Certified Pollinator Champions. We expect this program will have multiple benefits, including increases in habitat creation and reductions in pollinator pesticide exposure.

Conclusions

Our review suggests that despite advances in research documented in Michigan and elsewhere across the US, we are not yet meeting the goals of the national plan. Some lessons learned from our experiences are applicable across the US and further afield. The shortfall toward reaching the 2020 national goals for habitat enhancement and monarch butterflies highlights a need for further investment in pollinator supportive policies and funding. Updates to the Farm Bill set for 2023 could raise the caps on national funding for pollinator-supportive habitat installed on farmland while also supplying funds for regional and local programs, such as those we highlight for bees and monarch butterflies. Efforts to engage with policy makers over the next 2 years could therefore help reach the goals of the national pollinator plan and at the same time support agriculture and natural resources across the US.

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