CONSERVATION INNOVATION GRANTS

Final Report

Grantee Name: Regents of the University of California, Davis	
Project Title: Development and Validation of Protocols for Assessing Functioning of Pollinator Habitat Plantings for Agricultural Settings	
Agreement Number: 69-3A75-10-163	
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Deliverables from this project include

This collaborative national project included four main deliverable products designed to provide the first methodologies and guidelines for their implementation to help assess the functioning of pollinator habitats planted as part of NRCS stewardship programs.

(1) assessments of the effectiveness of pollinator restorations that are detailed enough to provide guidelines for improving and promoting this conservation practice on a region-wide basis, specifically
   a. estimates of changes in the abundance and diversity of pollinators, beneficial insects and pests resulting from restoration, and
   b. the relative values of specific plant species in each region for supporting pollinators,

(2) development of fact sheets outlining simplified protocols for collecting and interpreting data to assess the overall value of pollinator restoration sites,

(3) a series of region-specific demonstration workshops and field days for conservation practitioners and growers to disseminate recommendations and provide guidance on the use of technical notes, and

(4) web-based materials to make region-specific restoration recommendations and streamlined monitoring protocols widely available. This will be provided through Xerces extensive web portal on pollinators developed in part with collaboration from Dr. Williams. Each of these venues are well known to growers and practitioners and thus offer highly visible platforms for delivery of information to our target audience.

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Executive Summary

Recent honey bee declines and evidence that native bees can provide pollination services to economically valuable crops have motivated landowners and managers nationwide to enroll substantial acreage into NRCS conservation programs, such as EQUIP and CRP, that target planting of habitat to support pollinators. The success of these plantings depends on their ability to support native pollinators and other beneficial insects without attracting pests. This project quantified the ecological function of pollinator enhancement plantings and developed simple, standardized and streamlined monitoring protocols for assessing functioning of habitat installations.

Our goals were to (1) quantify the effects of pollinator habitat plantings on the abundance and diversity of pollinators, other beneficial insects and pests, (2) identify the value of individual plant species and the overall level of floral resources that help to support pollinators and other desirable insects, (3) develop streamlined monitoring protocols that enable practitioners to assess success of future pollinator habitat restorations, and (4) provide fact sheets, trainings and website materials that foster implementation of these streamlined protocols.

We quantified the ecological function of pollinator enhancement plantings at 51 sites in California, Michigan and New Jersey from 2011-2013, visiting 2-6 sites per year in each region and sampling the abundance of flowers, bees, other beneficial insects and pests 4-6 times at each site. Pollinator enhancements dramatically augmented the abundance and diversity of native bees and other beneficial insects compared to nearby controls that had not been planted. Pest abundances did not increase at pollinator enhancements relative to control sites.

Individual plant species differed in attractiveness to pollinators. We ranked all sown species that were evaluated at three or more spatially independent sites per region for three measures of attractiveness to bees: (1) a preference score that corrected for floral availability, (2) the abundance of bees and (3) the species richness of bees attracted. We developed fact sheets with plant choice recommendations for each region.

We developed an observation-based standardized bee monitoring protocol that allows agency staff, land managers, farmers and others to evaluate the performance of individual pollinator habitat plantings for attracting an abundance and diversity of native bees. We streamlined this protocol to balance the time and training required to conduct a survey with the need for accurate pollinator census data. We rigorously validated protocol methods by collecting observation data with varying levels of effort at all sites throughout the study and comparing results to the net-collected specimen data and species-level identifications used to assess the abundance and diversity of bees at pollinator plantings. Monitoting protocols were successfully tested during multiple regional trainings that will help foster implementation among NRCS staff and other stakeholders.

A one year no-cost extension allowed us to implement the final deliverable products. We used it to incorporate data from three seasons to design a streamlined pollinator (bee) monitoring tool, to develop outreach materials and to implement training sessions based on this tool. In part we required the extension because of the project start date which fell during the end of the final field season.

Introduction

The plight of pollinators is increasingly in the spotlight as evidence mounts that both managed and wild bee populations are declining enough to threaten losses in pollination service to economically important crops. Recent evidence that diverse floral resources foster bee health has made enhancement of pollinator habitat in agricultural landscapes a priority for NRCS, and substantial acreage is being enrolled in pollinator habitat restoration programs nationwide.

The success of NRCS investment in these expensive programs will depend on the ability of habitat plantings to support populations of native pollinators and other beneficial insects, without augmenting pest insects. However, the ability of agency staff to evaluate shifts in insect populations resulting from habitat installation is limited by the substantial time and training required for collection of insect monitoring data. To date there have been no rigorous, coordinated assessments to determine whether pollinator habitat enhancements are meeting program goals. Furthermore there are no standardized monitoring protocols that agency staff and other practitioners can easily employ. These gaps may impede the agency's ability to encourage enrollment in pollinator planting programs because of farmers' concerns about potential for attracting pests, and because benefits to pollinators have yet to be documented.

We conducted geographically broad, scientifically rigorous ecological assessments of pollinator habitat enrolled in federal incentive programs to quantify their benefits and inform future habitat establishment methods. Our goals were to (1) quantify the effects of pollinator habitat enhancements on populations of pollinators, other beneficial insects and pests, (2) identify the value of individual plant species in supporting pollinators, (3) develop streamlined monitoring protocols that enable practitioners to assess functioning of planted pollinator habitat, and (4) provide fact sheets, trainings and web-based information that foster implementation of these simplified technical guidelines.

We carried out all aspects of the project in parallel in three regions representing different US Ecoregions and where agricultural production practices differ, California, Michigan and New Jersey. We quantified the ecological function of pollinator enhancement plantings at 51 sites in California, Michigan and New Jersey from 2011-2013, visiting 2-6 sites per year in each region and sampling the abundance of flowers, bees, other beneficial insects and pests 4-6 times at each site. Compared to nearby controls that had not been planted, we found remarkable increases in the availability of floral resources and the abundance and diversity of native bees and other beneficial insects, with no corresponding increase in pests.

This project combined the expertise of leading scientists in bee conservation, habitat restoration, integrated pest management and ecosystem services from the University of California at Davis, Michigan State University and Rutgers University, along with the proven outreach success of the Xerces Society of Invertebrate Conservation. NRCS staff in each region shared locations and contact information of landowners engaged in pollinator habitat restoration, as well as feedback on the utility of the streamlined monitoring protocol. The Michigan team additionally collaborated with FSA and a native seed supplier (see Quality Assurance section for more details).

In addition to the federal assistance received ($343,884), this project was supported through a combination of in-kind and cash contributions, of which $343,929 was provided as cash match and $589 through in-kind contributions. All matching contributions were from non-federal sources.

Background

Pollination is a globally important ecosystem service. Over one-third of the global food supply benefits from animal pollination, and the proportion of pollinator dependent crops is increasing (Klein et al. 2007, Aizen et al. 2008). The economic value of insect-pollinated crops in the U.S. alone was estimated to be $18.9 billion in 2000. Recent research has shown that native bees can provide significant pollination services to crops as long as sufficient floral resources and nesting habitat exist in close proximity to agriculture (Kremen et al. 2004, Pywell et al. 2006).

Federal agencies are responding to the calls for conservation and restoration of wild and managed pollinator populations. The 2008 Farm Bill identified pollinators as a priority resource of concern. In 2009 the NRCS National Plant Materials Program proposed a National Action Plan for Pollinator Conservation, outlining an approach to support pollinator habitat restoration and collaborating with researchers to develop national and region-specific technology and best practices for implementing habitat restoration. NRCS and other groups have developed recommended plant lists and initiated restoration of pollinator habitat in agricultural landscapes across the country. In Michigan, a target of 2,500 acres in pollinator habitat is being met by NRCS/FSA, and pollinator plantings have been established at the Michigan PMC. The New Jersey NRCS mobilizes EQIP and WHIP funds to provide financial support for pollinator restorations. The California NRCS has installed demonstration pollinator enhancement plantings at the Plant Materials Center and at more than ten additional sites spanning the diversity of agricultural croplands throughout the state.

In spite of the great interest and continued investment in designing and implementing these pollinator habitat restorations, there has been no systematic assessment of the ecological impacts of these plantings. **This project directly addressed this knowledge gap and provided tools for streamlined assessment to NRCS and others.** The benefits of pollinator hedgerows emphasizing woody species are currently being validated for pollinators, pests and beneficial insects in California. No coordinated effort has been initiated to evaluate on-the-ground restorations using annual and perennial wildflowers, which are more acceptable to many growers. Evaluations of pollinator habitats have not been made for other regions of the country.

A major obstacle to adoption of habitat plants for pollinator conservation among farmers is a perception that habitat strips designed to augment pollinators and pollination will also increase pest populations. **This project documented pest levels to remove this obstacle to adoption.** Demonstrating the benefits of wildflower plantings on pollinator and other beneficial insect populations and identifying ways to avoid attracting pests will be essential for ensuring the long term success of this approach. Information provided by detailed ecological assessments will be critical for demonstrating to landowners that habitat enhancements have the desired outcome.

The choice of plant species used in habitat plantings can influence performance of the planting in terms of ability to establish and compete with weeds, ability to attract and support pollinators, and potential for augmenting pests. **This project quantified performance of individual plant species within pollinator plantings to inform selection of the most beneficial region-specific plant choices**

Funding and staffing limitations preclude NRCS and other agencies from conducting detailed ecological assessments into the future despite the recognized advantages that assessment would provide for ensuring restoration success through adaptive management approaches. **This project developed streamlined monitoring guidelines modeled after existing citizen science monitoring protocols, that can be implemented with minimal time or training.** We anticipate that landowners and NRCS staff will have diverse goals for these restorations and will likely be interested in the effectiveness of individual restorations throughout the lifetime of these plots. Streamlined methods are designed to be robust enough to meet the diverse applications.

The project will especially benefit specialty crop producers who rely on important pollination services for reliable high-level crop yield. In addition the work targets NRCS and other agency and practitioner staff who desire efficient monitoring tools to complete their own practice guidelines.

Review of methods

We used an innovative approach to pollinator habitat assessment in this project that (1) simultaneously addressed pollinators, other beneficial insects and pests, (2) provided critical information for improving current restoration guidelines by identifying important plant species, (3) developed previously unavailable streamlined bee monitoring protocols that are accurate and practical by engaging NRCS and other agencies in an iterative process, and (4) ensured the broad utility of streamlined protocols by testing them in several regions across the country. Prior to this project there was no methodology for assessing benefits of pollinator habitat to insect communities, and the lack of monitoring for the wildlife targets of government-incentivized habitat plots was an explicit concern of NRCS. In particular our Streamlined Bee Monitoring Protocol addressed concerns about the time and training required to conduct such monitoring.

Between 2011 and 2013 we quantified effects of pollinator habitat on insects and validated streamlined monitoring protocols in California, Michigan and New Jersey, three regions of major agricultural importance in North America. In each region, 3-6 new sites were identified for sampling in each year of the study, for a total of 15-18 similarly-aged sites per region.

Figure 1. Pollinator habitats were assessed in California, Michigan and New Jersey.

We developed technical sampling protocols prior to the first spring field season of 2011, and collected data from multiple sites in each region in the spring and summer of 2011, 2012 and 2013. We used standardized protocols to quantify floral resources, as well as the abundance and diversity of pollinators, other beneficial insects and pests. This approach allowed us to identify both plants and pollinators to the species level. At each sampling event throughout all regions and years we simultaneously collected observation-based data on native bee use of plantings to develop and validate a streamlined protocol that correlated strongly with our species-level data.

In 2013 and 2014 after the final year of data had been incorporated into the streamlined protocol, we engaged NRCS staff in an iterative process of training and field trials of the monitoring tool. The monitoring tool was finalized in spring of 2014 using all three years of data, and training sessions were conducted in all three regions in the summer of 2014.

Discussion of quality assurance

Key personnel

In California key personnel were Dr. Neal Williams, Kimiora Ward, MSc and Dr. Robbin Thorp of the Department of Entomology and Nematology at University of California – Davis. Professor Williams is an expert in native bees and pollination ecology for the University of California. He has continued investigating native plant use by bees and bee communities associated with restoration for the past six years. Ms. Ward (MSc, University of Washington), has over a decade of experience working for government agencies and nonprofit organizations in conservation project management, partnership building, landowner outreach, and habitat restoration with a focus on native plant materials development. Robbin Thorp, Professor Emeritus of Entomology has over 40 years of experience working with the native bees and other insects of California. Thorp provided expert verification of identifications for insect specimens collected during assessment of the pollinator restoration plots in each region in California. California personnel worked closely with Rachael Long, MSc, Cooperative Extension Specialist at University of California who has 25 years of experience in monitoring pest and natural enemy activity in a variety of agricultural landscapes. We also collaborated with NRCS State Biologist Thomas Moore, NRCS plant materials center director Margaret Smither-Kopperl, and Mark Van Horn, Director of UC Davis Student Research Farm.

Professor Rufus Isaacs, Berry Crops Entomologist, Michigan State University led the project in Michigan. Dr. Isaacs' program includes pest management and pollination research in fruit crops. He conducts a significant field research programs with fruit growers in Michigan and leads the USDA Specialty Crops Research CAPS project "Project ICP". He worked closely with Dr. Julianna Wilson and Emily May. Dr. Wilson has studied pollination in fruit crops, field crops, and biofuels, and has conducted evaluations of native plants for their suitability to support native bees. Emily May was a MSc student at Michigan State University studying wild bee communities in Michigan fruit crops and wildflower restorations. The Michigan team coordinated their efforts with Dale Allen, Michigan FSA who is the director of the CRP-SAFE program for pollinators, with State Biologists of the NRCS, with Steve Law, head of the NRCS EQIP program in Michigan, and with Michigan Wildflower Farm, one of the premier native seed suppliers in Michigan.

Dr. Rachael Winfree, Department of Ecology and Evolution, Rutgers The State University of New Jersey, studies is an expert in pollinators, community ecology, studying pollination services, how it is affected by global change and strategies for pollinator conservation/restoration. Dr. Dan Cariveau was a postdoc in Department of Ecology and Evolution at Rutgers. Dr. Cariveau is working on crop pollination by native, wild bees, as well as the importance of biodiversity for pollination services.

Outreach in all three regions was coordinated by The Xerces Society for Insect Conservation with existing pollinator restoration projects underway nationwide. Xerces provided critical feedback during development of the Streamlined Monitoring Protocol document, and helped coordinate and run training sessions for each region. With over ten years of experience in pollinator conservation and outreach, and extensive recent experience conducting workshops nationwide for staff of NRCS and other farm-related agencies, Xerces was uniquely positioned to provide relevant guidance for the technology transfer of our findings.

In each region, NRCS state biologists provided input on utility and usability of streamlined protocols and assisted in identifying sites where restoration plantings had been established with EQIP-eligible growers. NRCS staff will participated in trainings and provided feedback through participation in field trials of streamlined protocols. One of the demonstration plantings that was evaluated is at the California NRCS Lockeford Plant Materials Center. Dale Allen, FSA and SAFE Pollinator Program manager assisted the project with technical questions and will transmitted results of the project to his colleagues. The MI NRCS state biologist, Chris Reidy, is willing to work with the team on understanding how planting success contributes to the suitability of the plantings for pollinators and other insects. Tim Dunne, the State Resource Conservationist for New Jersey NRCS, has already facilitated the project by sharing information about existing pollinator restoration plantings which will be used in the study. He developed New Jersey's existing emphasis on pollinator habitat restoration and is supportive of further development of these programs. Two NJ regional NRCS Biologists and Cape May Plant Materials staff will participate in trainings, workshops, and continue collaboration with Rutgers University on pollinator issues with the intended result of better information for NRCS staff and agricultural producers on pollinator conservation. In addition, NRCS funded Winfree's current state CIG to evaluate targeted plant species for use in restoration plantings.

Each of the lead collaborators involved in this proposal was already developing wildflower species recommendations to sustain native bee populations through provision of floral resources. With funding from the New Jersey State CIG program, Dr. Winfree collaborated with the NJ Plant Materials Center and the Xerces Society to evaluate 20 different native plants for their attractiveness to pollinators in single-species arrays. This project was on a smaller spatial scale, but provided detailed experimentally-based information complementary to our proposed field assessments. Drs. Williams and Isaacs had conducted preliminary trials in California and Michigan, respectively, and testing the value of native plant mixes of varying diversity for enhancing pollinators. The Xerces Society and collaborators was previously funded through a CIG grant to tailor plant lists to particular cropping systems and identify region-specific native plant establishment practices.

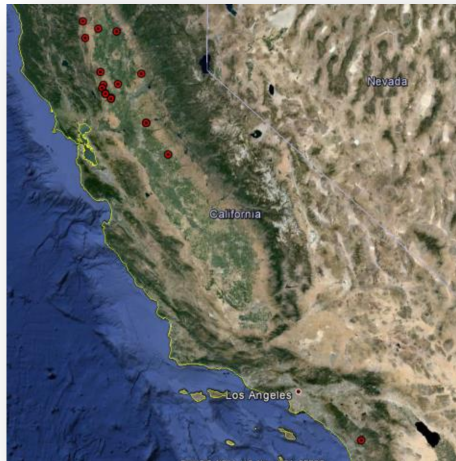
Quantification of habitat functioning

Each year of the study between 2011 and 2013, we selected between three and six pollinator habitat plantings in each region for sampling (Table 1, Figure 2). We chose habitat sites that had been planted within the last 3-10 years and had established successfully enough that at least three target wildflower species were expected to bloom during the monitoring period. Xerces staff contributed to this effort each year by assisting with sample site identification and facilitating collaborations with landowners.

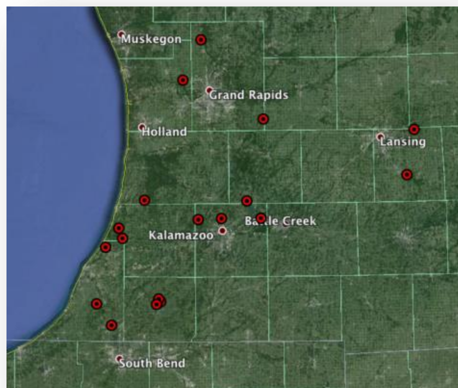
Table 1. Sites sampled in each region and year.

Region	Year sampled	County	Site	Date planted	Planted Area (ac)	Site type
California	2011	Butte	STO	2009	0.97	NRCS restoration, walnuts
			SCH	2010	0.24	NRCS restoration, almonds
		Glenn	BUR	2010	0.1	NRCS restoration, rangeland
		San Joaquin	PMC	2008	0.2	NRCS Plant Materials Center demonstration
		San Diego	LER	2010	0.24	NRCS restoration, avocado and citrus
		Yolo	RUS	2010	1	Row crop agriculture
	2012	Colusa	GAL	2011	2.9	RCD-led restoration, almond and rangeland
		Glenn	MAS	2010	0.57	NRCS restoration, rangeland
		Yolo	HRFE	2011	0.48	Native seed production farm demonstration
			HER	2011	0.44	Row crop agriculture
			MEE	2011	0.46	Row crop agriculture
			DUR	2011	0.2	Organic row crop
	2013	Kern	LHI	2012	0.9	Almond, pistachio, pomegranate orchards
		Glenn	MAR	2010	0.15	NRCS restoration, organic row crop
		Placer	PLA	2012	0.1	Land trust restoration, pasture
		Stanislaus	DRC	2012	2.21	NRCS restoration, almond orchard
		San Joaquin	PMC2	2011	1.35	NRCS Plant Materials Center pollinator meadow trials
		Yolo	HRFW	2012	0.41	Native seed production farm demonstration
Michigan	2011	Berrien	CAL	2009	1.12	Blueberry farm
			LAV	2008	2.2	NRCS restoration on lavender farm parcel
			SCH	2010	2.5	NRCS restoration
		Ingham	KOR	2010	1	Tree fruit farm
			MAS	≤ 2007	22	Michigan DEQ restoration
		Van Buren	GAL	2009	1.26	Blueberry farm
	2012	Allegan	HAR	2009	2.65	Blueberry farm
		Barry	PARF	2010	58	KNC-led restoration
		Kent	ROG	2009	7	NRCS restoration
			THO	2009	9	NRCS restoration adjacent to corn/soybean
		Ottawa	HIG	2009	4	NRCS restoration adjacent to corn/soybean
		Van Buren	ROO	2010	41.3	NRCS restoration on tree fruit farm
	2013	Cass	ANT	2006	12.3	Prairie restoration on foundation property
			BOH	2002	6.4	Prairie restoration on foundation property
			PARS	2011	6	Prairie restoration on foundation property
		Kalamazoo	HIL	2007	6	KNC-led restoration on private property
			KNC	2005	144	Prairie restoration on nature center property
			SAN	2004	55	Prairie restoration on land conservancy property
New Jersey	2011	Burlington	SCO	2010	2	near alpaca pastuure
		Hunterdon	BOW	2010	0.3	old field
		Middlesex	CRA	≤ 2009	2	old field
			HRP	≤ 2008	0.3	old field (near corn field)
		Somerset	URW	2010	1.5	old field
		Sussex	MOT	2010	0.3	old field
	2012	Atlantic	BEL	2011	1.5	farm strip
		Burlington	ABR	2011	1.5	near farm field
			DEF	2011	0.5	farm strip
		Cape May	MAR	2011	0.5	near christmas tree farm
		Warren	ALL	2011	2	old field (near corn field)
			ROT	2011	1	old field
	2013	Adams (PA)	PUL	≤ 2009	1.5	old field
			RLO	≤ 2009	3.5	near orchard
		Cumberland	SHE	2012	1.5	near farm field
		Hunterdon	FOX	2012	2	old field
			MUL	≤ 2009	0.75	old field
		Mercer	DRG	2012	3	near farm field

a) California



b) Michigan



c) New Jersey

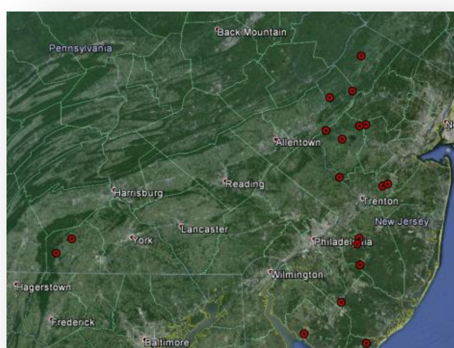


Figure 2. Pollinator habitat restoration sites sampled between 2011 and 2013 in California, Michigan and New Jersey.

We ensured consistency of the sampling protocol, including the spatial sampling design, floral assessment and technical pollinator monitoring protocol through extensive meetings and discussions among the regional teams. This occurred prior to the beginning of activities and was repeated annually to update and adapt the protocol and in a consistent way.

Sampling protocol

Each sample site consisted of the landowner's pollinator habitat planting plus a control plot of similar configuration, area and surrounding land use (Figure 3). Control plots were located between 100 and 800 m distant from restored plots so that at each site pollinators from a single insect community were choosing between the two habitat types.

Figure 3. Pollinator habitat (blue) and paired control (yellow) sampled at a site in New Jersey.

Each site was sampled 4-6 times during the active growing season to span the range of bloom times of planted wildflowers. Pollinator visitation rates, their floral resource preferences and pest/beneficial insect levels were quantified in enhanced vs. unenhanced control plots.

The technical pollinator monitoring protocol quantified insect visitation rates to flowers and compared the abundance and diversity of net-collected native bees at enhanced sites to paired control sites. Key floral resources were identified by separating netted insects according to the wildflower species they were visiting, and by relating insect visitation to the flower abundance of each plant species. The technical protocol also quantified the abundance and community composition of pests and their natural enemies in restored vs. unenhanced control plots using timed vacuum samples.

All field assistants worked closely with key project personnel and received extensive training on both insect and plant identification in each region. We validated proficiency of field assistants' plant and insect identification using sight-identification tests of specimens in the lab and live insects and plants in the field before data were collected.

We sampled pollinators visiting flowers from four 40m x 2m transects in the pollinator habitat and another 4 transects in the control. Transects were distributed through the planted and control plots using a stratified random design at each sampling event. Half of each transect (1m x 40 m) was sampled for ten minutes in the morning and the other half was sampled for ten minutes in the afternoon to capture the full range of pollinator species with varying diurnal activity periods. Field samplers collected all bees, flies, butterflies and wasps visiting flowers (in contact with the reproductive structures) with hand nets, keeping collected insects separated by the flower species they were sampled from.

To evaluate pollinator preference for particular plant species, we adjusted pollinator counts from each plant species by the relative abundance of its flowers. We quantified floral abundance and floral display size of each blooming species at each sampling event. Within one day of pollinator collections, we counted the number of fresh open flowers for each species in each of ten $1m^2$ quadrats per transect for a total of 40 quadrats per treatment (planted vs. control) and 80 quadrats per site. At least one time during the sampling season we measured the diameter of five typical flowers for each species so we could multiply flower counts by the average flower size to calculate total floral area.

For two of the three sample years of the study in each region, we quantified the abundance of pests and natural enemies in planted habitat plots and paired controls at each sampling event. At the end of pollinator sampling we conducted four 30-second vacuum samples per transect. At each of the four sample points on each transect, we vacuum sampled all vegetation within a $1m^2$ area using a Stihl® leaf blower modified into a vacuum with a fine mesh bag placed over the intake to capture the sample. Insect samples were either frozen in the lab until insects could be separated from plant material and identified (MI and NJ) or processed through a modified Berlese trap where insects sorted themselves from plant material and were stored in alcohol (CA). All sampled insects were identified to family or lower taxonomic level to determine whether they were pests, natural enemies, or neutral insects.

Net-sampled pollinators were curated and bees identified to the species level by Professor Robbin Thorp in California, the project team and Dr. Jason Gibbs in Michigan and Dr. Jason Gibbs and Dr. John Ascher in New Jersey. Other pollinating insects were categorized into broader taxonomic groups of interest: butterflies and moths (Lepidotera), hover flies (Diptera: Syrphidae) and wasps (Hymenoptera; non-bee or ant). California specimens are currently housed in the Entomology Department and will be accessioned in the Bohart Museum of Entomology at University of California, Davis. Michigan specimens have been accessioned in the Albert J. Cook Arthropod Research Collection at Michigan State University. New Jersey specimens are accessioned at the Rutgers University Entomological Museum.

Streamlined protocol development

Our streamlined assessment protocols were built upon previously published citizen science monitoring methods, and designed to allow us to identify the minimum effort required to obtain ecologically relevant information on bee abundance and richness. Determining how best to design and implement the streamlined protocols was an integral part of data collection during each sampling event. We quantified floral resources and insect visitation rates using technical protocols while simultaneously collecting simplified data at varying levels of intensity at each site. We collected observational data on pollinators in incremental units so we could compare results based on varying amounts of effort to the results from our detailed technical protocols. We compared the information gained by streamlined assessments to the full data set to determine the minimum effort required to reflect the abundance and diversity of bees at a restoration site. This allowed us to specify a minimum sampling effort required for NRCS staff and other practitioners to evaluate restorations accurately with most efficient use of time. We continued to refine this analysis and solicit input from NRCS staff through the spring of 2014 in order to develop our final recommendations for sampling intensity.

Within one day of pollinator sampling at each sampling event, field assistants collected observational data on pollinators visiting flowers from the planted habitat and paired control plots. These streamlined data were collected in incremental units. Each of the pollinator sampling transects was divided into four 10 m sections. Each section was observed for 2.5 minutes (for a total of 10 minutes of observation per transect). Field assistants counted the number of pollinators visiting flowers, recording visitors to each flower species separately. Visitors were categorized into broad morphological groups, following the groupings developed for native bee monitoring in citizen science programs developed by Xerces (Table 3; Ullmann et al 2009).

Table 3. Morpho-groups floral visitors were assigned to during development of streamlined protocol

Morpho-group		**Corresponding taxa**
Bees	Honey bee	*Apis mellifera*
	Bumble bee	*Bombus* sp.
	Large carpenter bee	*Xylocopa* sp.
	Hairy leg bee	*Anthophora* sp. (Anthophorini), *Diadasia* sp. (Emphorini) , *Eucera* sp. (Eucerini), *Exomalopsis* sp. (Exomalopsini), *Melissodes* sp. (Eucerini)
	Green sweat bee	*Agapostemon* sp. (Halictidae)
	Striped sweat bee	*Halictus* sp. (Halictidae)
	Small dark bee	*Andrena* sp. (Andrenidae), *Ceratina* sp. (Ceratinini), *Lasioglossum Evylaeus* sp. (Halictidae)
	Tiny dark bee	*Dialictus* sp., *Hylaeus* sp. (Halictidae)
	Metallic hairy belly bee	*Osmia* sp. (Megachilidae)
	Striped hairy belly bee	*Megachile* sp., *Anthidium* sp., *Anthidiellum* sp. (Megachilidae)
	Cuckoo bee	*Epeolus* sp. (Nomadinae), *Triepeolus* sp. ((Nomadinae), *Nomada* sp. (Nomadinae), *Sphecodes* sp. (Halictidae)
Flies	Hover fly	Syrphidae
	Tachinid fly	Tachinidae
	Bee fly	Bombyliidae
	Other fly	All other flies
Leps	Butterfly	All butterflies
	Moth	All moths

Throughout all three years of the project, we worked with NRCS staff to refine the monitoring tool and guidance materials to meet agency needs. We received feedback from the Assistant State Conservationist, Rose Lake Plant Materials Center and FSA Conservation Chief in Michigan, as well as from NRCS collaborators in California and New Jersey, and NRCS regional biologists before finalizing the tool.

In collaboration with Xerces staff in all three regions, we invited NRCS staff to participate in field trials of the monitoring tool in spring 2014 after incorporating results from the final year of data collection into the streamlined monitoring protocol. End-user feedback from these field trials ensured that the final bee monitoring tool was aligned with the time commitments and expertise available to NRCS staff evaluating restorations.

Xerces Society staff then worked with the research partners to refine the content and format of the streamlined monitoring tool based on the feedback from NRCS and on Xerces Society experience developing other outreach materials. This included developing a training guide (Appendix A) that included (a) a clear overview of the sampling procedure, (b) help in bee identification, and (c) multiple strategies and data sheets for using the monitoring protocol on different habitat types (e.g. meadows, hedgerows, and cover crops).

Xerces Society staff also used the simplified native bee sampling protocol developed for this project as the foundation for a honey bee monitoring protocol for the FY2014 Honey Bee Habitat Effort in the northern plains and Great Lakes states. Funding from a national contribution agreement between the NRCS and the Xerces Society was used to rework the bee monitoring protocol into a format that could work for landowners. However, because of strong interest in honey bee monitoring outside of the 5-state honey bee habitat area, CIG funds were used to format the completed protocol into a user-friendly document for a broader, national audience.

Implementation of streamlined protocol

Project partners engaged in regular meetings with Xerces Society staff to discuss the format of the streamlined protocols and develop plans for field trials of protocols, dissemination of tools to NRCS nationwide, and trainings.

Xerces Society field staff then developed the training materials and programs in collaboration with research partners in all three project regions: CA, MI, and NJ. The workshops were held in each of the three project regions in the summer of 2014 (Table 4). Each training workshop involved an introduction to native bees and habitat monitoring, an overview of bee identification, including practice identifying and grouping pinned specimens, a review of the monitoring protocol, and a field component where attendees practiced the protocol and bee identification on pollinator wildflower and/or hedgerow habitats. Project partners worked to ensure a student to teacher ratio of at least 4:1 so that each attendee could get excellent and immediate feedback on their identification of bees in the field, as well as on their use of the monitoring protocol.

Table 4. Streamlined Bee Monitoring Protocol trainings

Region	Workshop location	Date	Attendees
California	Lockeford NRCS Plant Materials Center (Lockeford, CA)	20-Aug-14	16: including 14 NRCS staff and partner biologists, and 2 Conservation District partners
Michigan	Michigan State University Clarksville Reseach Center (Clarksville, MI)	22-Jul-14	16: including 15 NRCS staff
New Jersey	Duke Farms (Hillsborough, NJ)	31-Jul-14	7: including 4 Conservation District staff, and several recipients of NRCS CIG grants targeting pollinator conservation

As noted above, the simplified monitoring protocol was also used as the foundation for a honey bee monitoring protocol used in the northern plains and Great Lakes region as a component of a 5-state honey bee habitat effort in FY2014. Over 220 NRCS staff, partners and clients have been trained via webinar on the use of this tool. That training includes recognition of the contribution of this CIG grant and academic partners, and highlighted the value of CIG grants for supporting adoption of innovative conservation practices. To view the webinar, you can visit www.conservationwebinars.net/webinars/usda-nrcs-honey-bee-monitoring-training/ .

All technical guidance developed for this grant was posted to the Xerces Society website (http://www.xerces.org/streamlined-bee-monitoring-protocol/), as well as to departmental websites (http://winfreelab.com/outreach/, http://www.isaacslab.ent.msu.edu/Extension.html and https://polleneaters.wordpress.com/outreach/).

Findings

Goal 1: Effects of pollinator habitat plantings on pollinators, other beneficial insects and pests

Across all regions and years we sampled 273 species of wildflowers blooming in pollinator habitat plantings and nearby controls. Pollinator plantings increased the abundance of floral resources in CA and MI (Figure 5), and increased diversity of flowering species in all three regions.

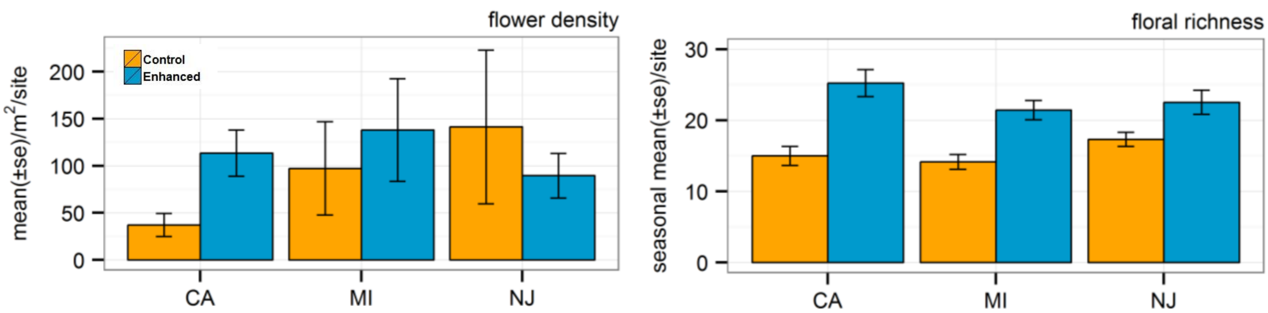


Figure 5. Mean ± std error flower density (left panel) and flowering plant richness (right panel) at control and enhanced plots in each region. Data are for all plots across three sampled years.

We collected 1683 individual bees of 89 species in California, 1916 individuals of 89 species in Michigan, and 5186 individuals of 138 species in New Jersey.
Pollinator plantings also significantly increased the abundance and diversity of native bees in all regions (Figure 6). In CA in particular abundance increased over five-fold and richness more than doubled. Plantings also supported abundant honey bees relative to the controls in both CA and MI. IN NJ controls were equal to the enhancements which reflects the pattern in floral abundance (Figure 5). Syrphids and butterflies were also greater at enhanced plots than at controls in all regions.

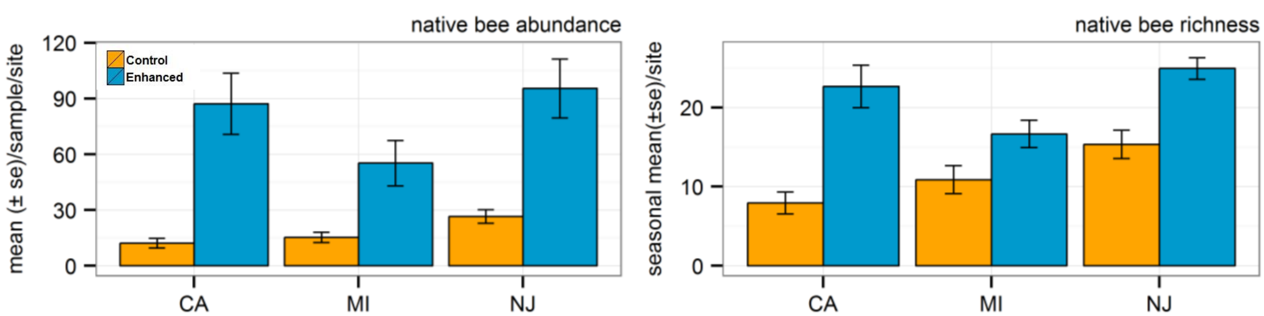
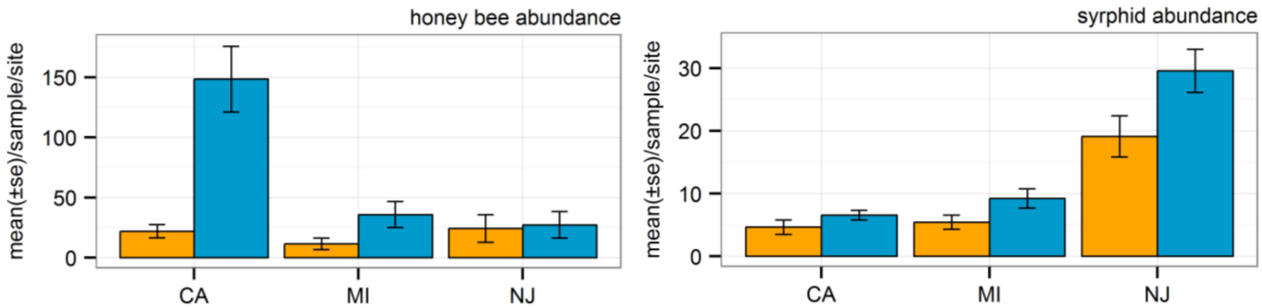


Figure 6. Mean ± std error native bee abundance (left panel) and species richness (right panel) at control and enhanced plots in each region. Data are for all plots across three sampled years.



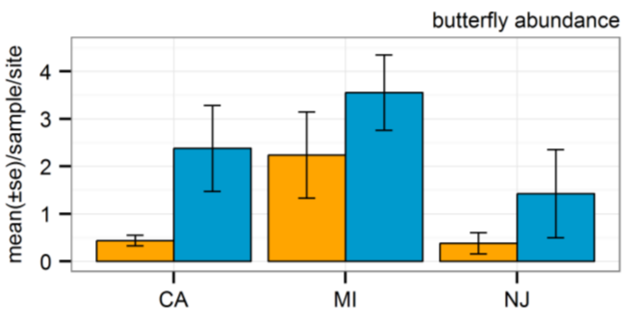


Figure 7. Abundance (mean ± std error) of other beneficial insect taxa and butterflies at control and enhanced plots in each region. Despite the potential of some butterflies has pests, they are included as beneficials because of their pollinating potential.

Pests tended to be no different or less abundant in planted habitat than in controls, while natural enemies were no different or more abundant in pollinator habitat.

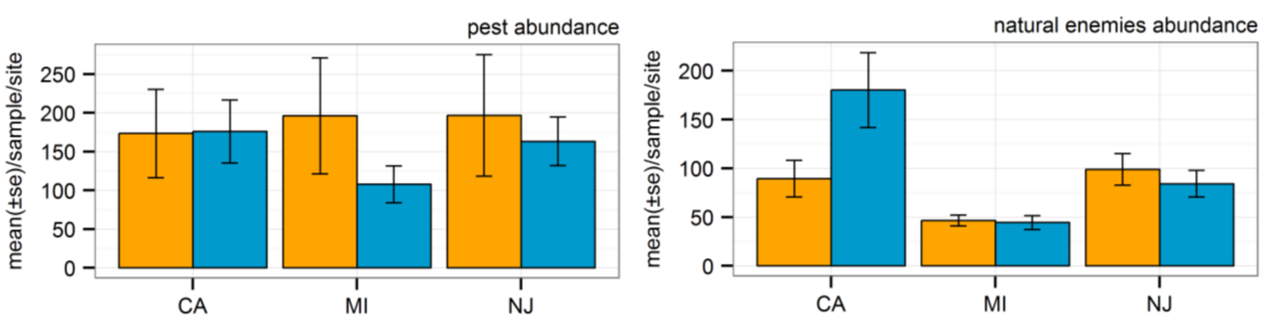


Figure 8. Mean ± std error of abundance of pest insects and natural enemies at control and enhanced plots in each region. Pests included all taxa that are known agricultural or general pests. Natural enemies included predators and parasitoids of pest insects.

Goal 2: The value of individual plant species in supporting pollinators.

Native bees were sampled from 159 plant species in California, 45 of which were intentionally sown in pollinator restorations. Bees in Michigan were sampled from 150 plant species, 49 of which were intentionally sown, and in New Jersey from 212 plant species, 63 of which were sown.

To evaluate the contribution of individual plant species to supporting pollinators we assessed each species in terms of three measures of pollinator use, and we ranked plant performance during the early season, mid-season, late season and across the whole year, so that early-performing plants are not outranked by plants that bloom in the late season when bee populations are larger. The first metric is a standardized preference score (P) that corrects for floral density:

$$P = (b - f)/(b + f)$$

where b = the proportion of native bee specimens (abundance) sampled from a given plant species at a particular site and date, and f = the proportion of the total floral density contributed by that plant species during that sample. This score ranges from -1 to 1, with positive scores indicating bee preference, or greater bee visitation than expected for a given floral density, 0 meaning bee visitation in proportion to floral density, and negative scores meaning avoidance, or visitation less than expected for a given floral density. Preference (P) was calculated for each plant in each, using plants from both the pollinator planting and control at each site to calculate proportions since the sampling design was set up as a choice experiment between treatments. Samples from each region were categorized as falling in early, mid-season or late season categories for that region, and preference scores for each plant species were averaged within these categories, as well as averaged over all samples throughout the year. The second metric is the proportion of native bee specimens sampled from each plant species at the site (with restored plot and control pooled) on each sample date, again averaged over early samples, mid-season samples, late samples and the whole year. The third metric is the proportion of total native bee species richness sampled from each plant species and averaged over early, mid, and late season samples as well as over the whole year.

On average, plants intentionally sown were more preferred and attracted a higher abundance and diversity of native bees than volunteer plants (Figure 9). The relative increase in bee use of intentionally sown plants compared to volunteer plants varied between regions, with California seeing the greatest increase. Further analysis is required to determine whether that reflects relatively poor volunteer flora or better selection of pollinator plants in that region.

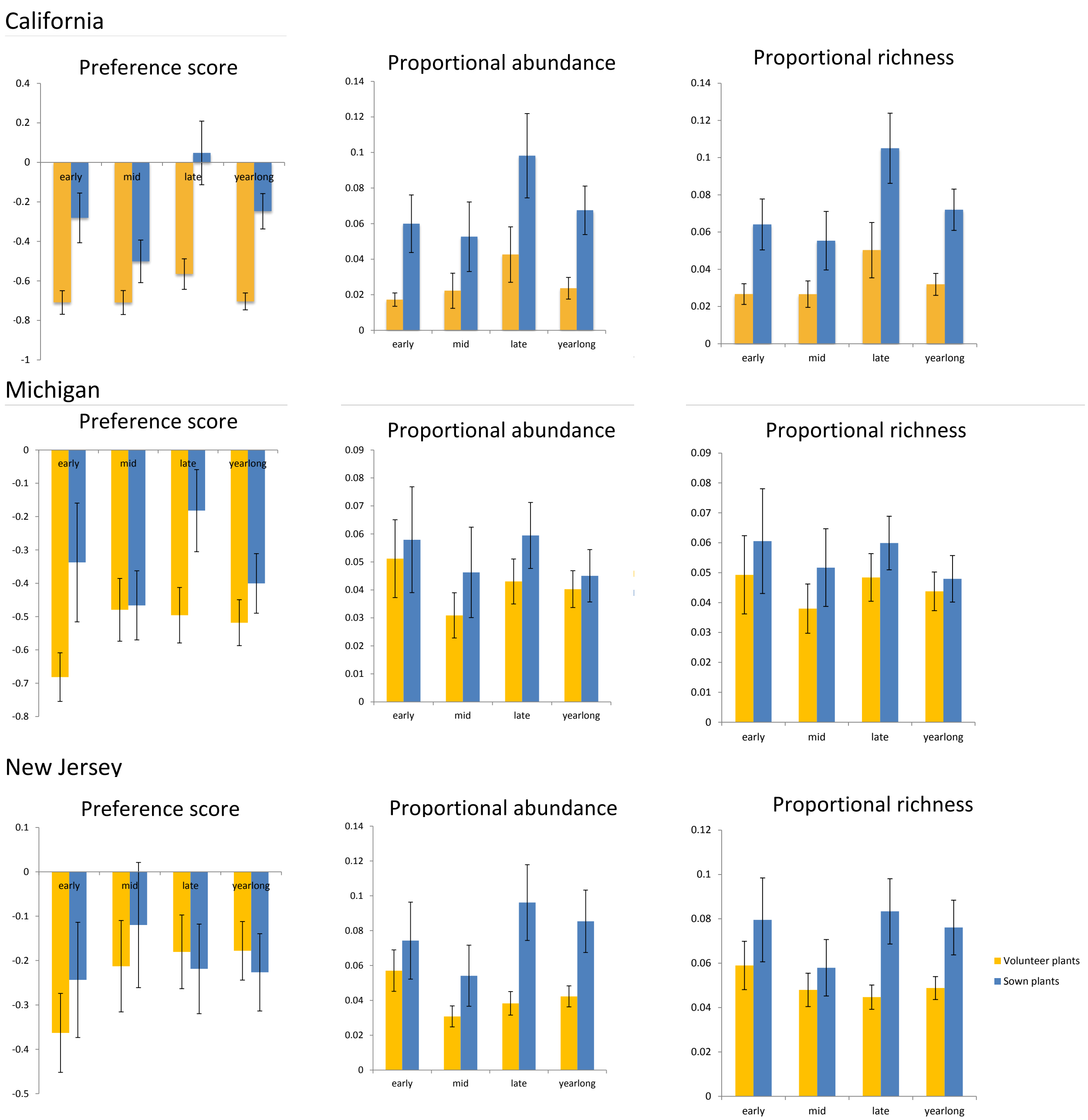


Figure 9. Wild bee use of plants intentionally sown in pollinator habitat plantings compared to volunteer plants in the plantings and nearby controls, as measured by average preference score, average proportional abundance and average proportional species richness of floral visitors. Preference score is a measure standardized between -1 and 1, with positive values indicating preference, 0 indicating no preference and negative values indicating avoidance.

Within each seasonal category and over the entire year, each sown plant species that was sufficiently sampled (i.e., sampled from 3 or more spatially independent sites) was ranked according to its average preference score, average proportional native bee abundance and average bee richness, then these ranks were summed to give each plant an overall rank that combines all three metrics (Table 5).

Plants varied in their utility to bees, with some planted species providing no benefit. The relative increase in benefits to bees achieved with pollinator habitat plantings compared to controls could be improved with selection of only high-performing species.

Table 5. Performance of plants sown in pollinator habitat restorations in terms of three measures of wild bee use. Preference = mean standardized preference score of bee visitation corrected for floral density, range = -1 to 1, where + = preferred, 0 = neutral, - = avoided. Abundance = mean proportional abundance of wild bee floral visitors. Richness = mean proportional richness of wild bee visitors. Values are calculated for each sample date at each site and averaged over all samples falling in the early, mid-season and late categories, and over all samples for the year. Rank = rank of the summed ranks of each measure within each seasonal category and over the whole year. Plants sampled from fewer than three sites over the three year study were excluded.

California		Early season performance				Mid-season performance				Late season performance				Year-long performance			
Species	Sites	Preference	Abundance	Richness	Rank	Preference	Abundance	Richness	Rank	Preference	Abundance	Richness	Rank	Preference	Abundance	Richness	Rank
Grindelia camporum	15	NA	NA	NA	NA	0.64	0.50	0.38	1	0.65	0.41	0.27	1	0.65	0.46	0.32	1
Phacelia californica	11	0.18	0.29	0.27	2	0.31	0.27	0.22	2	0.03	0.13	0.19	3.5	0.22	0.25	0.23	2
Eschscholzia californica	18	0.64	0.34	0.25	1	0.29	0.24	0.21	3	0.13	0.05	0.08	7	0.36	0.22	0.19	3
Trichostema lanceolatum	6	NA	NA	NA	NA	-1.00	0.00	0.00	15.5	0.31	0.16	0.18	2	0.19	0.15	0.17	4
Helianthus bolanderi	6	NA	NA	NA	NA	0.06	0.04	0.08	5	-0.11	0.23	0.17	3.5	-0.04	0.16	0.14	5
Phacelia tanacetifolia	13	0.05	0.17	0.19	3	-0.44	0.09	0.12	4	-1.00	0.00	0.00	10	-0.20	0.13	0.15	6
Phacelia ciliata	6	0.24	0.08	0.13	4	0.00	0.03	0.08	6	NA	NA	NA	NA	0.18	0.06	0.12	7
Eriogonum fasciculatum	4	NA	NA	NA	NA	-0.64	0.03	0.07	8	0.48	0.12	0.13	5	-0.22	0.06	0.09	8
Lupinus succulentus	12	-0.48	0.07	0.08	7	0.20	0.02	0.06	7	0.57	0.01	0.04	8	-0.30	0.06	0.07	9
Madia elegans	6	-0.16	0.03	0.06	8	-0.85	0.01	0.04	11	-0.22	0.11	0.12	6	-0.47	0.06	0.08	10
Nemophila maculata	3	-0.18	0.06	0.07	5.5	-1.00	0.00	0.00	15.5	NA	NA	NA	NA	-0.34	0.05	0.06	11
Collinsia heterophylla	3	-0.70	0.11	0.07	5.5	-1.00	0.00	0.00	15.5	NA	NA	NA	NA	-0.78	0.08	0.05	12
Lupinus formosus	6	-0.87	0.01	0.03	13	-0.67	0.03	0.06	9	-0.52	0.01	0.02	9	-0.63	0.02	0.04	13
Lasthenia glabrata	3	-0.39	0.02	0.03	11	NA	NA	NA	NA	NA	NA	NA	NA	-0.39	0.02	0.03	14
Lupinus densiflorus	14	-0.76	0.05	0.06	9	-0.74	0.01	0.01	12.5	NA	NA	NA	NA	-0.75	0.03	0.03	15
Trifolium obtusiflorum	4	-1.00	0.00	0.00	15	-0.47	0.02	0.04	10	NA	NA	NA	NA	-0.60	0.02	0.03	16
Nemophila menziesii	5	-0.40	0.02	0.05	10	-1.00	0.00	0.00	15.5	NA	NA	NA	NA	-0.67	0.01	0.03	17
Trifolium fucatum	4	-0.51	0.01	0.01	12	NA	NA	NA	NA	NA	NA	NA	NA	-0.51	0.01	0.01	18
Clarkia unguiculata	3	-1.00	0.00	0.00	15	-0.66	0.00	0.00	12.5	NA	NA	NA	NA	-0.72	0.00	0.00	19
Layia chrysanthemoides	3	-1.00	0.00	0.00	15	NA	NA	NA	NA	NA	NA	NA	NA	-1.00	0.00	0.00	20

Table 5 (continued).

Michigan		Early season performance				Mid-season performance				Late season performance				Year-long performance			
Species	Sites	Preference	Abundance	Richness	Rank	Preference	Abundance	Richness	Rank	Preference	Abundance	Richness	Rank	Preference	Abundance	Richness	Rank
Monarda fistulosa	17	0.21	0.22	0.14	2	0.37	0.42	0.28	1	0.14	0.23	0.11	1.5	0.28	0.34	0.21	1
Verbena stricta	3	NA	NA	NA	NA	0.98	0.07	0.15	2	0.99	0.06	0.11	3	0.98	0.07	0.13	2
Euthamia graminifolia	3	NA	NA	NA	NA	NA	NA	NA	NA	-0.15	0.12	0.10	5	-0.15	0.12	0.10	3
Ratibida pinnata	16	0.92	0.20	0.20	1	-0.17	0.18	0.18	3	-0.70	0.07	0.07	10	-0.31	0.14	0.14	4
Coreopsis tripteris	4	NA	NA	NA	NA	NA	NA	NA	NA	0.67	0.05	0.07	7	0.67	0.05	0.07	5
Echinacea purpurea	12	-0.62	0.01	0.02	8	-0.25	0.04	0.06	8	0.07	0.13	0.14	1.5	-0.16	0.07	0.09	6.5
Rudbeckia hirta	15	-0.10	0.11	0.15	3.5	-0.23	0.13	0.14	4	-0.66	0.09	0.09	8	-0.34	0.11	0.13	6.5
Verbena hastata	3	0.42	0.06	0.07	5	-0.05	0.04	0.06	6	NA	NA	NA	NA	0.07	0.05	0.06	8
Coreopsis lanceolata	15	-0.28	0.06	0.07	7	-0.32	0.02	0.04	11	-0.18	0.11	0.09	6	-0.27	0.06	0.06	9
Heliopsis helianthoides	5	0.85	0.10	0.13	3.5	-0.31	0.02	0.06	10	-0.09	0.04	0.07	12	-0.14	0.03	0.07	10.5
Desmodium canadense	5	NA	NA	NA	NA	-0.65	0.09	0.08	7	-0.39	0.02	0.03	16	-0.58	0.07	0.07	10.5
Silphium integrifolium	7	NA	NA	NA	NA	-0.11	0.00	0.02	12	0.18	0.03	0.05	9	0.12	0.02	0.05	12
Symphyotrichum novae-angliae	3	NA	NA	NA	NA	NA	NA	NA	NA	-0.67	0.07	0.07	12	-0.67	0.07	0.07	13
Asclepias syriaca	9	-0.34	0.08	0.10	6	-0.20	0.03	0.04	9	-0.01	0.01	0.02	15	-0.19	0.03	0.05	14
Tradescantia ohiensis	3	-1.00	0.00	0.00	9.5	-1.00	0.00	0.00	16	0.87	0.14	0.08	2	-0.53	0.04	0.02	15
Rudbeckia triloba	5	NA	NA	NA	NA	-0.72	0.01	0.01	14	0.30	0.02	0.05	12	-0.29	0.01	0.03	16
Asclepias tuberosa	7	-1.00	0.00	0.00	9.5	-0.52	0.02	0.02	13	0.75	0.07	0.14	4	-0.51	0.02	0.03	17
Oligoneuron rigidum	4	NA	NA	NA	NA	-1.00	0.00	0.00	16	-0.54	0.01	0.06	14	-0.63	0.01	0.04	18
Eupatorium perfoliatum	3	NA	NA	NA	NA	-0.15	0.06	0.07	5	-1.00	0.00	0.00	18	-0.66	0.02	0.03	19
Dalea purpurea	3	NA	NA	NA	NA	-1.00	0.00	0.00	16	-1.00	0.00	0.00	18	-1.00	0.00	0.00	20.5
Arnoglossum atriplicifolium	3	NA	NA	NA	NA	NA	NA	NA	NA	-1.00	0.00	0.00	18	-1.00	0.00	0.00	20.5

New Jersey		Early season performance				Mid-season performance				Late season performance				Year-long performance			
Species	Sites	Preference	Abundance	Richness	Rank	Preference	Abundance	Richness	Rank	Preference	Abundance	Richness	Rank	Preference	Abundance	Richness	Rank
Monarda fistulosa	11	0.80	0.02	0.13	5	0.76	0.44	0.22	1	0.51	0.35	0.16	2	0.65	0.38	0.19	1.5
Symphyotrichum racemosum	4	NA	NA	NA	NA	NA	NA	NA	NA	0.51	0.53	0.53	1	0.51	0.53	0.53	1.5
Solidago canadensis	7	NA	NA	NA	NA	0.93	0.01	0.03	9	0.54	0.12	0.13	3	0.58	0.11	0.12	3
Solidago gigantea	4	NA	NA	NA	NA	NA	NA	NA	NA	-0.20	0.33	0.32	4	-0.20	0.33	0.32	4
Gaillardia pulchella	6	0.71	0.27	0.20	1.5	0.85	0.08	0.08	5.5	0.26	0.14	0.13	6	0.52	0.13	0.12	5
Rudbeckia hirta	12	0.10	0.24	0.24	3	0.10	0.22	0.22	2	-0.23	0.12	0.11	9.5	-0.09	0.16	0.16	6
Pycnanthemum tenuifolium	3	NA	NA	NA	NA	-0.11	0.16	0.21	5.5	-0.64	0.30	0.18	5	-0.37	0.23	0.19	7
Asclepias tuberosa	3	0.15	0.16	0.13	6	0.24	0.11	0.12	3	0.81	0.04	0.10	7	0.34	0.10	0.12	8
Coreopsis lanceolata	9	0.62	0.24	0.23	2	0.54	0.08	0.09	4	0.45	0.03	0.07	11	0.52	0.10	0.11	9
Leucanthemum vulgare	5	0.16	0.30	0.27	1.5	-0.63	0.01	0.01	11	-1.00	0.00	0.00	17	-0.34	0.14	0.13	10
Penstemon digitalis	4	0.58	0.19	0.16	4	-0.39	0.00	0.01	12	NA	NA	NA	NA	0.10	0.10	0.09	11
Echinacea purpurea	4	NA	NA	NA	NA	0.22	0.05	0.05	7	0.53	0.08	0.07	8	0.44	0.07	0.06	12
Verbena urticifolia	4	NA	NA	NA	NA	-0.74	0.06	0.10	8	-0.22	0.08	0.14	9.5	-0.48	0.07	0.12	13
Coreopsis tinctoria	6	-0.37	0.06	0.06	8	0.04	0.08	0.09	6	-0.18	0.01	0.02	14.5	-0.11	0.04	0.05	14
Euthamia graminifolia	5	NA	NA	NA	NA	NA	NA	NA	NA	-0.74	0.05	0.06	12	-0.74	0.05	0.06	15
Eupatorium hyssopifolium	3	NA	NA	NA	NA	NA	NA	NA	NA	-0.84	0.04	0.06	13	-0.84	0.04	0.06	16
Dianthus barbatus	3	-0.34	0.03	0.08	7	-1.00	0.00	0.00	14	NA	NA	NA	NA	-0.51	0.03	0.06	17
Achillea millefolium	8	-0.32	0.01	0.03	9	-0.67	0.01	0.04	10	-0.28	0.01	0.05	14.5	-0.45	0.01	0.04	18
Sisyrinchium angustifolium	5	-0.67	0.00	0.01	11	-1.00	0.00	0.00	14	NA	NA	NA	NA	-0.72	0.00	0.01	19
Dianthus armeria	4	-0.51	0.01	0.01	10	-1.00	0.00	0.00	14	-1.00	0.00	0.00	17	-0.82	0.00	0.00	20
Lobelia inflata	3	NA	NA	NA	NA	NA	NA	NA	NA	-1.00	0.00	0.00	17	-1.00	0.00	0.00	21

Goal 3: Streamlined monitoring protocols.

Analysis of the observation-based bee monitoring data collected side by side with net collected specimens from all three regions revealed a strong and significant correlation between observed abundance of wild bees and both abundance and species richness of wild bees sampled from monitoring sites (Table 6). Observed morpho-species richness was also significantly correlated with season-long specimen richness, but not was not overall as strongly correlated as abundance.

Table 6. Pearson correlation coefficients for season-long observation data and season-long specimen data. Bolded values are significant at *P* <0.05.

Observation data	Bee Specimen data	CA 2011	CA 2012	CA 2013	MI 2011	MI 2012	MI 2013	NJ 2011	NJ 2012	NJ 2013
Bee Abundance	Abundance	**0.99**	**0.96**	**0.97**	**0.88**	**0.84**	**0.97**	**0.99**	**0.96**	**0.97**
Bee Abundance	Richness	**0.84**	**0.91**	**0.75**	**0.79**	**0.79**	**0.80**	**0.91**	**0.80**	**0.58**
Bee Richness	Abundance	**0.76**	**0.79**	**0.77**	**0.64**	**0.66**	0.41	0.54	0.39	0.56
Bee Richness	Richness	**0.92**	**0.78**	**0.87**	**0.80**	**0.74**	0.25	**0.76**	**0.63**	0.32

We used subsampling of the streamlined observation-based data to determine the effect of the intensity of the sampling effort on the correlation between observation –based and specimen-based data sets. We found that short sampling intervals of observed abundance were sufficient to predict season-long specimen richness at a high level of accuracy. Time of year had an important effect on the sampling accuracy and in all three regions the most effective timing was variable across years (Figures 10-12). In California, the most effective sampling usually took place in May and June. In most years in both Michigan and New Jersey, sampling in July or August produced effective results. When we tested a two-sample approach in May and June in California and in June and July in Michigan and New Jersey the asymptote was rapidly reached. This suggests that sampling once in each of those months will produce the most effective results in all three regions (Figure 13).

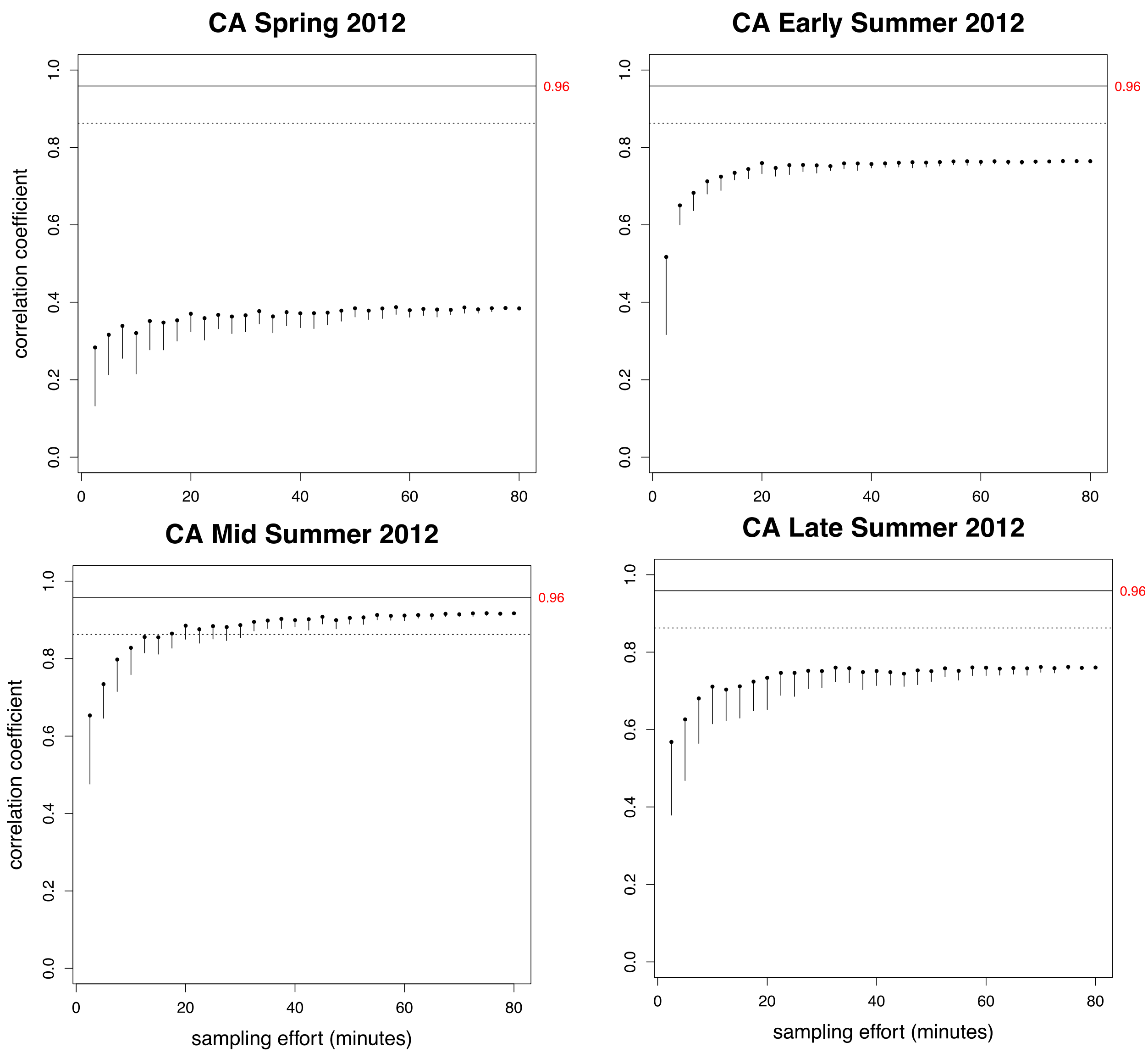


Figure 10. Relationship in California 2012 data between sampling effort (minutes) and the correlation (Pearson's r) between the observed bee abundance in samples conducted in various seasons and the year-long bee species richness at the site. Each point represents the average (mean and 25% quantiles) of randomly drawn samples of a given number of minutes of effort, subsampled from one sample round. The relationship asymptotes at the r-value of the correlation between the complete observation data set and year-long specimen richness. The dotted line represents 90% of the correlation coefficient.

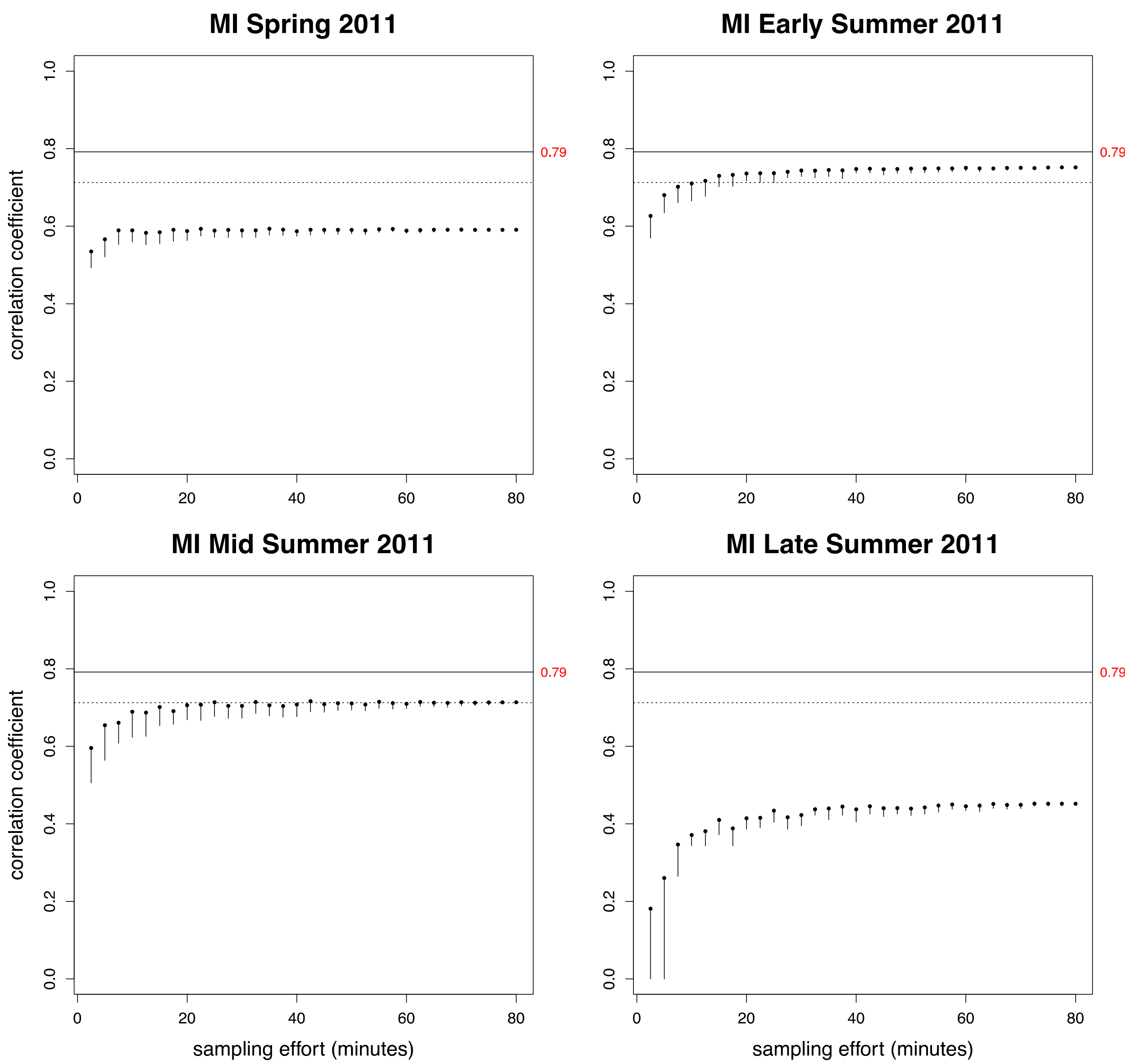


Figure 11. Relationship in Michigan 2011 data between sampling effort (minutes) and the correlation (Pearson's r) between the observed bee abundance in samples conducted in various seasons and the year-long bee species richness at the site. Each point represents the average (mean and 25% quantiles) of randomly drawn samples of a given number of minutes of effort, subsampled from one sample round. The relationship asymptotes at the r-value of the correlation between the complete observation data set and year-long specimen richness. The dotted line represents 90% of the correlation coefficient.

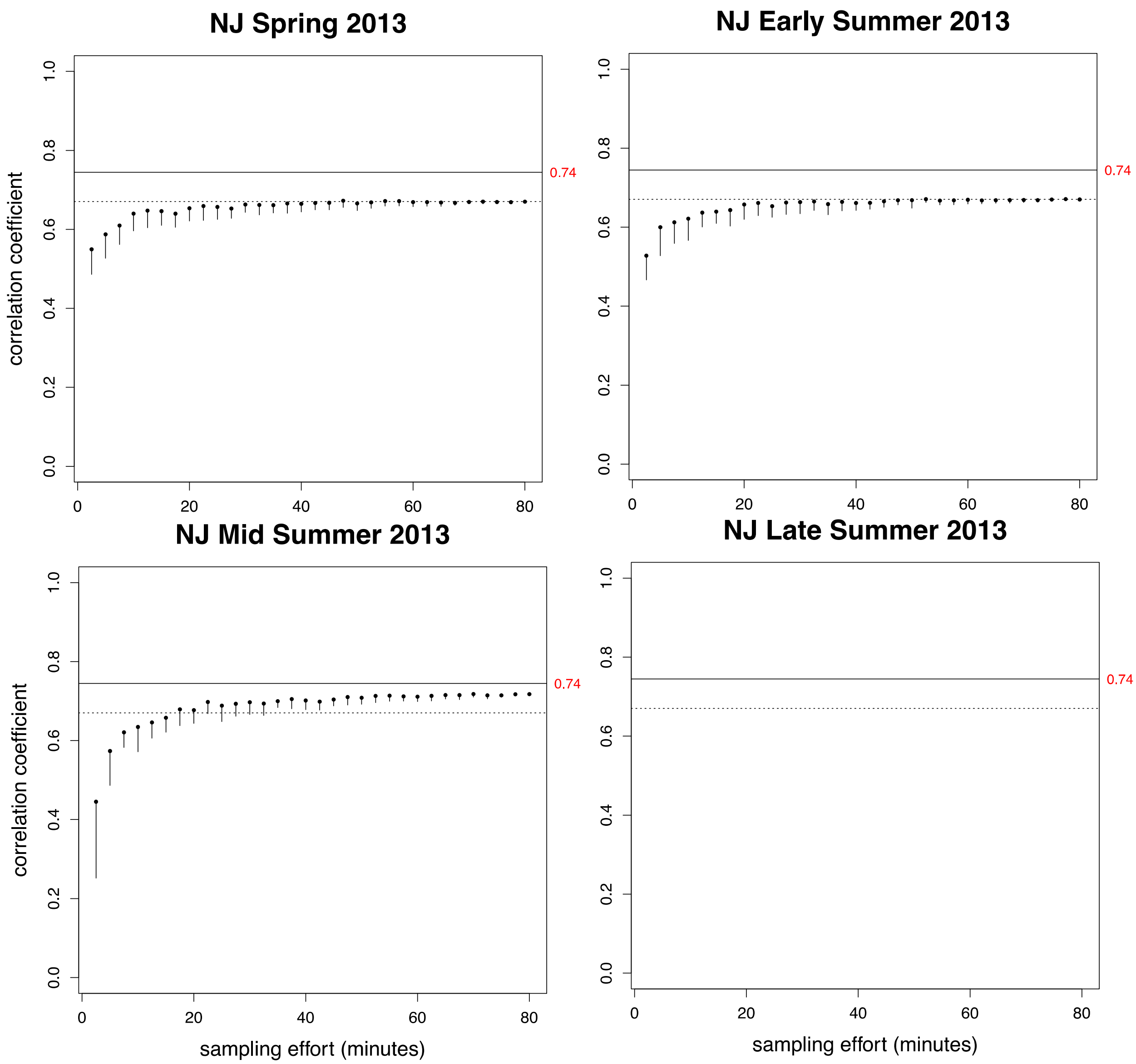


Figure 12. Relationship in New Jersey 2013 data between sampling effort (minutes) and the correlation (Pearson's r) between the observed bee abundance in samples conducted in various seasons and the year-long bee species richness at the site. Each point represents the average (mean and 25% quantiles) of randomly drawn samples of a given number of minutes of effort, subsampled from one sample round. The relationship asymptotes at the r-value of the correlation between the complete observation data set and year-long specimen richness. The dotted line represents 90% of the correlation coefficient.

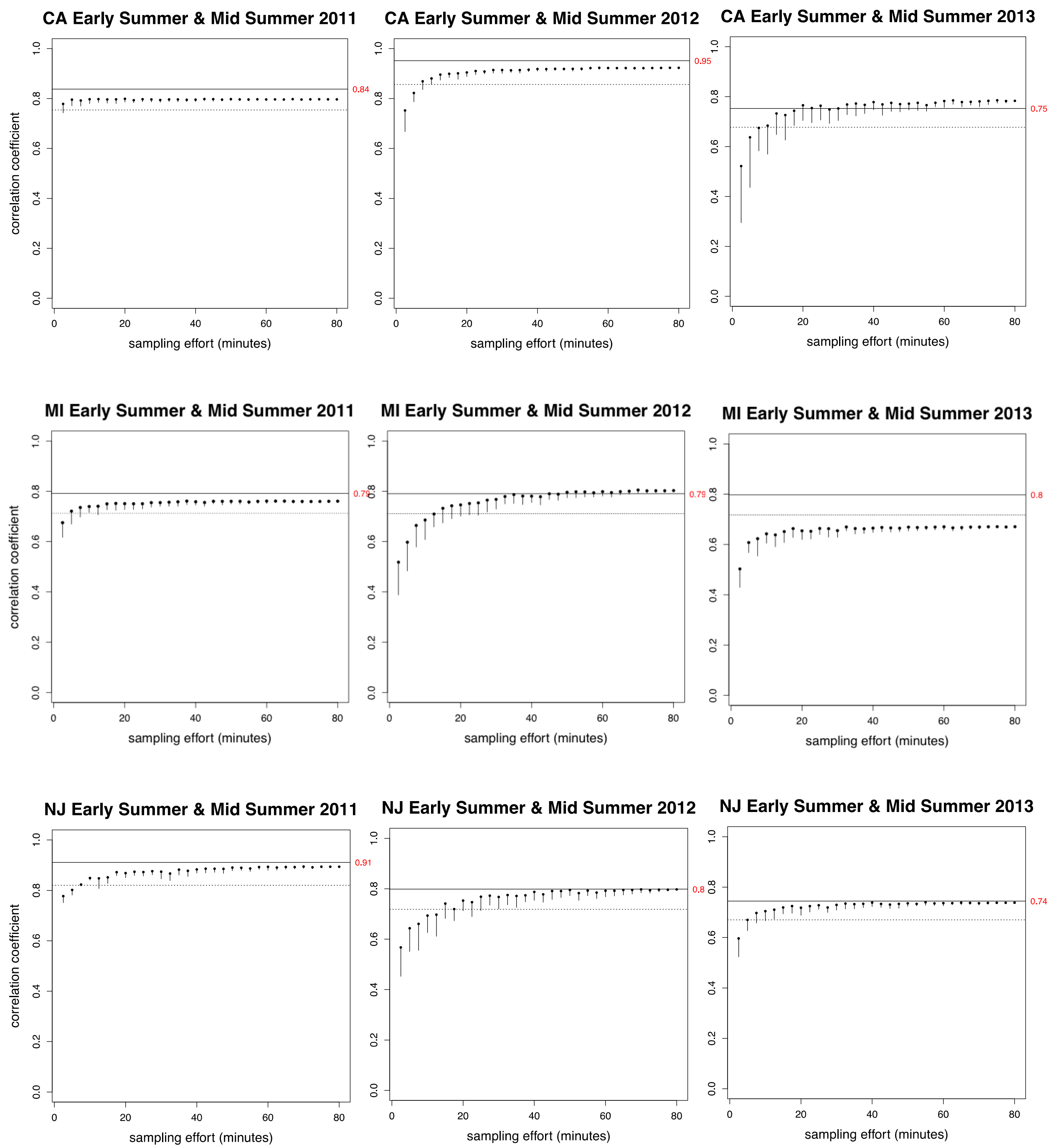


Figure 13. Relationship in each region and year between sampling effort (minutes) split between two samples in early summer and midsummer and the correlation (Pearson's r) between the observed bee abundance in samples and the year-long bee species richness at the site. Each point represents the average (mean and 25% quantiles) of randomly drawn samples of a given number of minutes of effort, subsampled from one sample round in early summer and one in midsummer. The relationship asymptotes at the r-value of the correlation between the complete observation data set and year-long specimen richness. The dotted line represents 90% of the correlation coefficient.

Based on these results we developed a streamlined monitoring protocol with recommendations for sampling effort and seasonal timing in California, Michigan and New Jersey (Appendix A). Simply observing and recording the number of native bees on flowers during two site visits of 15 minutes each provide good estimates of both abundance and diversity of wild bees visiting the site. The best data came from counting native bees in the middle of the growing season (for example May-July in California and July-August in New Jersey and Michigan), and separating the site visits by two to three weeks. We included information on insect identification so that trainees could learn to distinguish among wild bees, honey bees, flies and wasps, as well as information on how to consistently implement a standardized monitoring protocol. Honey bees are not informative of wildlife response to habitat provision because their numbers depend more on the ever-changing proximity of hives than on the quality of habitat.

This protocol can be used in three ways: (1) to rank pollinator plantings from least to most diverse in terms of bee communities supported, (2) to indicate whether plantings have increased pollinator populations and species diversity, when sampled in conjunction with samples from reference sites and (3) to document changes in pollinator diversity and abundance over time.

Figure 14. Participants in the July 24, 2014 NRCS field training of the streamlined monitoring protocol in Michigan.

Trainings offered in each region on the use of the streamlined protocol were well-attended and participants reported they had increased awareness of the importance of monitoring for pollinator use of habitat plantings, increased interest in implementing a monitoring program, increased confidence in insect identification and in collection and interpretation of monitoring data (Table 7).

Table 7. Participant survey results from the Streamlined Bee Monitoring Training on August 20, 2014 at the California Lockeford Plant Materials Center.

Lockeford PMC, August 20, 2014 Streamlined Bee Monitoring Training, Participant Survey Results
17 participants (9 NRCS staff, 5 conservation practitioners, 2 educators, 1 no answer)

	Mean scores		
Question	Before	After	Change
1. Monitoring pollinator use of habitat installations is important for me professionally (1=not important, 5=very important)	4.06	4.24	+ 0.18
2. I am likely to implement a pollinator monitoring program (1=not likely, 5=very likely)	3.94	4.38	+ 0.44
3. I am confident in my ability to distinguish native bees and honey bees from flies, wasps and other insects (1=not confident; 5=very confident)	2.41	4.31	+ 1.90
4. I know how to set up transects to conduct standardized observations of flower-visiting insects for a variety of habitat types and planting designs (1=not confident; 5 = very confident)	1.87	4.56	+ 2.70
5. I know how to collect and record standardized data on the abundance of native bees and honey bees using habitat (1= not confident; 5=very confident)	1.87	4.44	+ 2.57
6. I know how to interpret data on the abundance of native bees and honey bees at different sites and over time at the same site (1=not confident; 5=very confident)	1.71	3.63	+ 1.91

Goal 4: Fact sheets and web based materials.

The Streamlined Bee Monitoring Protocol training guide is available on the Xerces web portal http://www.xerces.org/streamlined-bee-monitoring-protocol/, as well as on the Williams, Isaacs and Winfree Lab pages at UC Davis, Michigan State University and Rutgers (https://polleneaters.wordpress.com/outreach/, http://www.isaacslab.ent.msu.edu/Extension.html and http://winfreelab.com/outreach/).

A fact sheet (Appendix B) summarizing the benefits to pollinators, lack of increase in pests and providing plant choice recommendations for each region is available at https://polleneaters.wordpress.com/outreach/.

Conclusions and recommendations

- Planting wildflowers to provide forage for managed and wild bee populations is becoming an increasingly popular and widespread tool to bolster pollinators across North America. To date little quantitative formation has existed to quantify their ability to support pollinators and thus rigorously justify the cost and effort of installation. The results from our project provide the first robust information to support these actions as a valuable means to improve wild bee abundance and biodiversity in agricultural lands. Pollinator habitat plantings provide measurable benefits for bees across regions and represent a valuable return for investment. **We recommend such plantings as a valuable tool to promote wild pollinator communities. We further recommend efforts be made to motivate landowners to increase enrollment for pollinators**.
- Plant species included in these plantings vary widely in their utility to bees, with some currently used planted species providing little or no benefit and others providing attractive forage for extended parts of the growing season (Table 5). **The relative increase in benefits to bees achieved with pollinator habitat plantings compared to controls could be improved with selection of only high-performing species, such as those included in the recommended best plants** (see regional Factsheets).
- Documentation of functional success is part of cost share contract for pollinator habitat and other conservation actions supported through CRP and EQIP. NRCS has not had a practically realistic protocol that can be implemented broadly given time constraints and that has been validated to document effectiveness. Our streamlined monitoring provides such a practical protocol for use by agency staff and others to determine the success (functioning) of the habitat. It has been rigorously validated in three distinct regions and is robust in each. Observation data based on our standard streamlined protocol can be used for accurate monitoring of bee abundance and diversity in response to plantings. **This streamlined monitoring tool can be implemented among regions and used by landowners and practitioners to self-assess the success of pollinator habitat plantings**.

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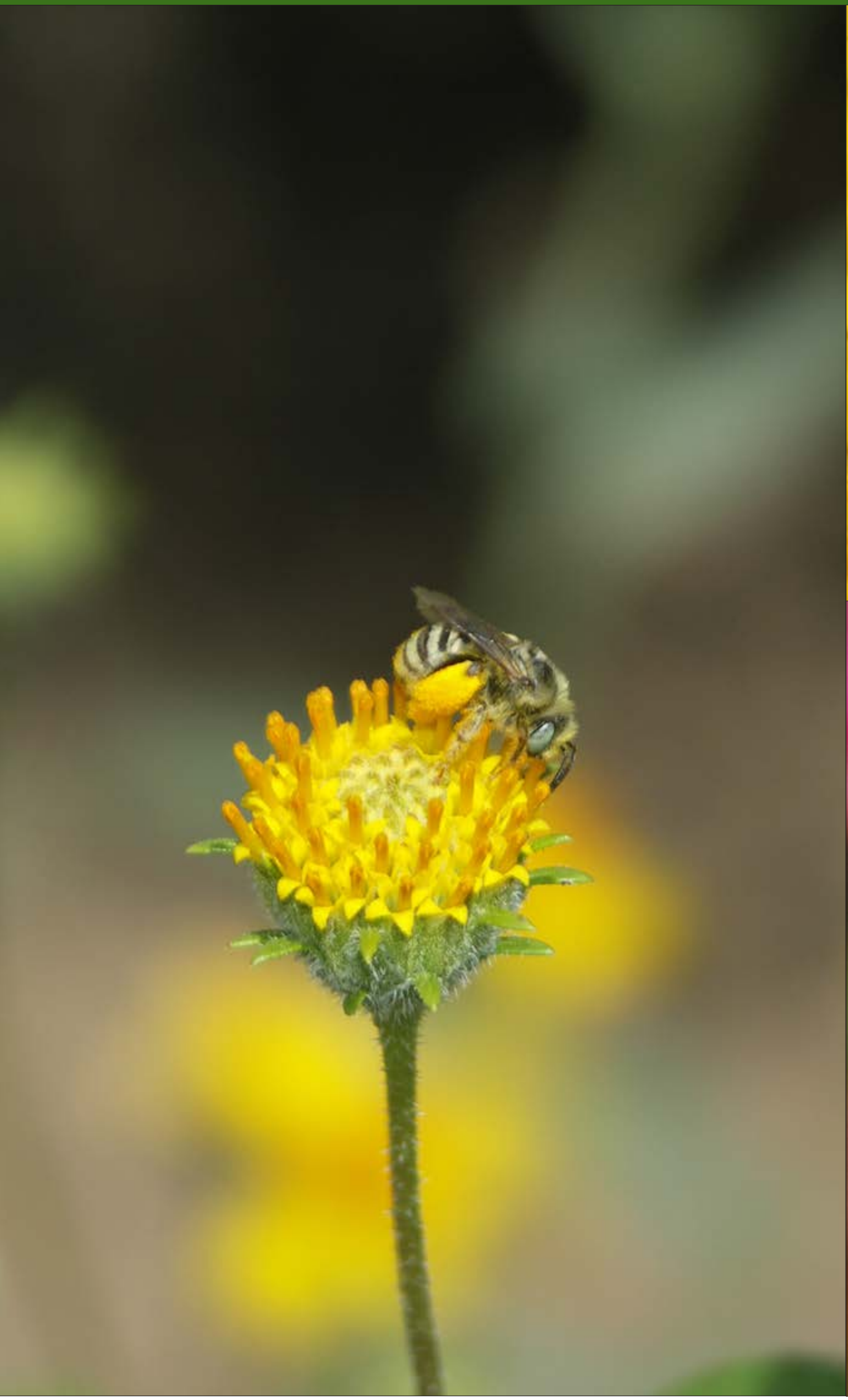
Appendix A

Streamlined Bee Monitoring Protocol

STREAMLINED BEE MONITORING PROTOCOL FOR ASSESSING POLLINATOR HABITAT



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THE XERCES SOCIETY
FOR INVERTEBRATE CONSERVATION

Protecting the life that sustains us

The Williams Lab at University of California, Davis, Isaacs Lab at Michigan State University, and Winfree Lab at Rutgers University conduct research into how habitat and habitat restoration projects support and increase the value of wild bees in crop pollination. Working to better understand the ecology of wild pollinators and the pollination services they provide, their research examines pollinator diversity, community ecology of plant-pollinator networks, the ecology and behavior of pollinators, pests and natural enemies within agricultural systems and surrounding landscapes, and the persistence of pollinator populations and communities in the face of global change. They collected and analyzed three field seasons of data on plants and bees at pollinator plantings to develop this streamlined protocol.

The Xerces Society for Invertebrate Conservation is a nonprofit organization that protects wildlife through the conservation of invertebrates and their habitat. Established in 1971, the Society is at the forefront of invertebrate protection, harnessing the knowledge of scientists and the enthusiasm of citizens to implement conservation programs worldwide. The Society uses advocacy, education, habitat restoration, consulting, and applied research to promote invertebrate conservation.

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We are grateful to the many photographers who allowed us to use their wonderful photographs in this monitoring guide. The copyright for all the photographs is retained by the photographers. The photographs may not be reproduced without permission from the photographer.

Citation

Ward, K., D. Cariveau, E. May, M. Roswell, M. Vaughan, N. Williams, R. Winfree, R. Isaacs, and K. Gill. 2014. *Streamlined Bee Monitoring Protocol for Assessing Pollinator Habitat*. 16 pp. Portland, OR: The Xerces Society for Invertebrate Conservation.

Cover Photos

Front: Clockwise from left to right: Eucerine ground-nesting bee, Mace Vaughan, The Xerces Society; Green sweat bee, Rollin Coville; and Bumble bee on red currant, Mace Vaughan, The Xerces Society.

Back: Small carpenter bee, Rollin Coville.

Contents

Section 1

INTRODUCTION

Declines in native bee populations and increased challenges in maintaining sufficient honey bees for pollination in the United States have underscored the need for greater flowering resources in agricultural landscapes. The USDA Natural Resources Conservation Service (NRCS) and the Farm Service Agency (FSA) recognize the value in supporting pollinators and have devoted millions of dollars annually to help farmers and other landowners plant and maintain pollinator habitat on private lands.

Assessing the effectiveness of different habitat restoration practices is a key component of augmenting floral resources for bees, so that conservation strategies can be adapted and improved. A standardized monitoring protocol is presented in this document to allow agency staff, land managers, farmers, and others to evaluate the performance of individual pollinator habitat plantings. This protocol can be used to assess pollinator plantings in three ways. First, it allows users to rank multiple pollinator plantings from least to most diverse in terms of bee communities supported. This may be particularly useful when comparing different management or implementation techniques, or even different seed mixes. Second, by including samples at reference sites, such as old fields or weedy field borders that have not been planted for pollinators, it can indicate whether plantings have increased pollinator populations and species diversity. Third, it can be used to determine whether pollinator diversity and abundance change over time.

This streamlined protocol balances the time and training required to conduct a survey with the need for accurate estimates of the abundance and diversity of pollinators attracted to the pollinator habitat plantings. To develop this streamlined protocol, bee abundance and diversity were observed and recorded at flowers in pollinator habitat plantings and unrestored reference sites over a three-year period in California, Michigan, and New Jersey. These locations represent three important agricultural regions of the United States. Simultaneously, species richness of native bee communities was assessed at the same sites through more thorough sampling with nets followed by species-level identifications. Observation data and net-collection data at each site were compared to determine the sampling effort required to accurately measure the abundance and diversity of bees at pollinator plantings.

Bees are the most important group of pollinators in North America, responsible for pollinating crops and wildflowers.

This research found that simply observing and recording the **abundance** of native bees on flowers during two site visits of 15 minutes each provide good estimates of both abundance and diversity of bees visiting that site. The best data came from counting native bees in the middle of the growing season (for example May–July in California, and July–August in New Jersey and Michigan), and separating the site visits by two to three weeks. The research also shows that a single 30-minute survey (400 ft of transect) during these same time periods is adequate for assessing bee diversity. However, two 15-minute surveys provide a much more reliable assessment.

Finally, it is important to understand that counting honey bees does not provide a good measure of the value of habitat for bees and other pollinators. The number of honey bees visiting a planting is most heavily influenced by the number of managed bee hives nearby. Seeing abundant honey bees is certainly a sign that a habitat supports bees, but it doesn't indicate how well that planting increases the abundance and diversity of bees.

Therefore, in order to assess changes in the abundance of bees that are using habitat created or enhanced for pollinators, you will need to know how to distinguish native bees from honey bees and other flower-visiting insects. You will also need to understand how to consistently implement a standardized monitoring protocol. In the following pages, we guide you through basic bee identification (Section 2), followed by instructions on the monitoring protocol (Section 3).

Section 2

BEE IDENTIFICATION

There are approximately 4,000 species of bees native to North America, and along with that diversity comes great variation in appearance (see Box 1, p.7). One feature all bees share is their dependence on pollen for rearing young. Their adaptations for carrying pollen often make them easy to distinguish from other insects. Usually, bees are quite hairy, allowing pollen grains to stick to them, and females have special pollen carrying structures on their legs or bellies. The location of these pollen-carrying structures and the appearance of obvious pollen loads (dry powder vs. moist balls) can be helpful in identifying bees from wasps or flies, and can even help distinguish between groups of bees.

The size and location of bees' eyes and antennae also help distinguish them from other similar-looking insects, such as flower flies. Specifically, bees' eyes are positioned at the sides of their heads, giving their heads a somewhat heart-shaped appearance, and their antennae are long and straight. In contrast, bee-mimicking flies tend to have large eyes that take up most of their heads, and short, stubby antennae that are often hard to see. Bees also have four wings, whereas flies have two, but this can be hard to see unless they are at rest on a flower or leaf.

To help separate bees from wasps, it is useful to know that bee bodies tend to be rounder than many wasps. Wasps often have a more pointed abdomen and a thinner waist.

Is It a Bee?

HONEY BEES

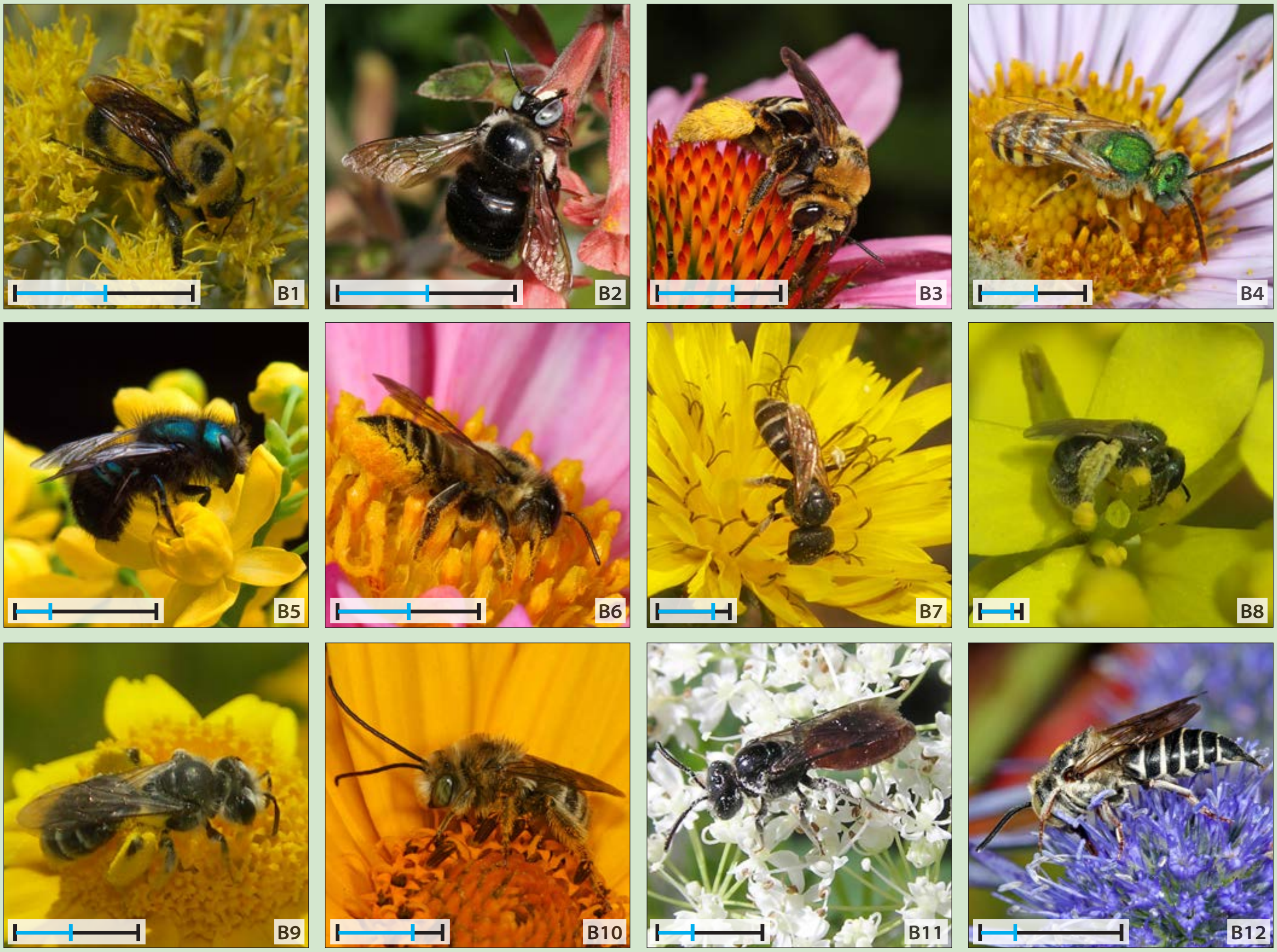
For this protocol, it is important to distinguish native bees from European honey bees. While support of honey bees is one goal of providing pollinator habitat, honey bees can be an unreliable indicator of the planting's ability to attract pollinators because their numbers depend on the location of honey bee hives or apiaries.

Honey bees vary in coloration from orange-brown to a very dark brown. They always have stripes on their distinctive "torpedo" shaped abdomen. They will always have a thorax covered in light brown hair. Honey bees, like bumble bees, carry pollen in baskets on their hind legs. These pollen baskets are slight indentations surrounded by long, hooked hairs. If the pollen baskets are empty you can see the flattened wide shape of the middle of the hind legs, and if they are full, you see the pollen is carried in moistened clumps, unlike the powdery dry pollen loads of many native bees.

Honey Bees

BOX 1: THE VARIETY OF NATIVE BEES

Pictured here are examples of the wide diversity of native bees you might observe on flowers. Look for some of the features described below.



Size: Native bees can range in size from tiny, dark-colored sweat and mining bees that are 1/8th to 1/4 inch long (e.g., B4, B7, B8), to bumble bees (B1) and large carpenter bees (B2) that are more than 1 inch long.

Shape: Native bees can be relatively slender, as in some of the small carpenter bees. They can be moderately wide, similar to European honey bees. Or they can be quite stocky and robust, as in the bumble bees or large carpenter bees.

Color: Bees vary greatly in color on their body surface (exoskeleton) and in the color of their hairs. Their exoskeleton can range from black, yellow, or red to metallic green and blue. Hair colors found on bees include black, grey, brown, yellow, orange, and white, and frequently create striped patterns.

Distribution of Hair: The patterns and locations of hair can make some bees look very "fuzzy" (e.g., bumble bees) while other species are hairy only in certain areas (e.g., legs) and, overall, may look quite shiny or bald.

Pollen Transport: Honey bees and bumble bees carry a mixture of pollen and nectar located on a flattened area on the hind leg called the pollen basket. Other bees carry pollen in a dense mass of stiff, branched hairs called the scopae. The scopae are often located on the hind legs, but in some species they are located on the underside of the abdomen. Note: only female bees have pollen-carrying structures.

Pollen: Bees can carry moistened pollen loads (mixture of pollen and nectar) or dry pollen. The wet pollen balls in the pollen baskets of European honey bees helps set them apart from all of the native bees in North America except bumble bees.

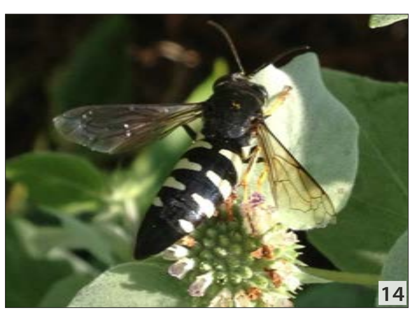
Approximate size: smallest (**blue**) / largest (**black**)

WASPS

Wasps are close relatives of bees and share many features, including 4 wings, stripes, and heart-shaped heads with the eyes on the sides. However, wasps are carnivores and do not have adaptations to collect and carry pollen. They are not very hairy and have little or no pollen on their bodies when visiting flowers. Wasp coloration results from patterns in their exoskeleton, giving them a shiny appearance compared to bees, which usually–but not always–get their stripes from colored hairs. Wasps have been described as having a "tough" or "mean" look with their more slender pointed bodies compared to the more rounded shape of bees. One very common family of wasps folds their forewings lengthwise when at rest, making them look more narrow.

DO NOT COUNT WASPS WHEN USING THIS BEE PROTOCOL.

Wasps

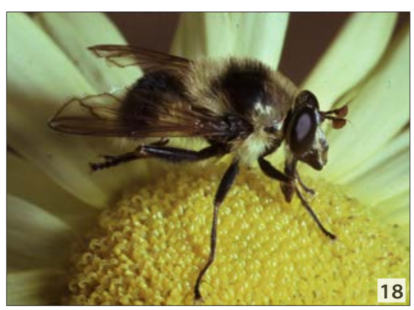


FLIES

Although many flies look very similar to bees, several features make them easy to distinguish. First, the flies that look like bees have eyes that are large and round, often making up the bulk of their head and sometimes giving the head a helmet-like appearance. Their antennae are short and thick, coming out like a 'V' from the middle of their face. Although they may be visiting flowers for nectar, they are not carrying pollen back to their young, so in general they are not as hairy as bees (although some species mimic bumble bees), and they never have hairy pollen-carrying structures on their legs. Flies also have two wings, rather than four wings like bees and wasps. However, it is often difficult to see this feature unless the insects are at rest.

DO NOT COUNT FLIES WHEN USING THIS BEE PROTOCOL.

Flies



Section 3

MONITORING PROTOCOL

SUPPLIES NEEDED FOR MONITORING

During your site visit you will need:

- A stopwatch, wristwatch, or timer on your phone
- Thermometer
- Data sheets
- Monitoring protocol
- Clipboard
- Pencils/ pens
- Long measuring tape (eg. 100–150 ft)
- Flags or stakes to mark transect start and end
- Permits (if necessary)
- Optional: camera or phone with high quality camera
- Suggested: sunscreen, hat, water, first aid kit, and plant list/ identification guide

The goal of this streamlined bee monitoring protocol is to efficiently document bee diversity and abundance on pollinator habitat plantings in order to measure their success in supporting pollinators, or to document changes in the bee community over the years after seeding. Plantings can include meadows, hedgerows, cover crops, or field trials of pollinator plant seed mixes.

During two separate site visits per year, you will conduct timed assessments, observing and counting bees visiting flowers along transects. Your two site visits should be separated by two to three weeks. In California, you can survey bees anytime between May and July. In the Great Lakes or Mid-Atlantic regions you should survey between early July and late August.

Bees are most active when weather conditions are good, so you must survey your site when it is warm, sunny, and calm. Ambient temperatures should be greater than 60°F, wind speeds ideally should be less than 8 mph, and skies should be mostly clear (partly cloudy or overcast skies are OK if you can still see your shadow). You will get the best data during an afternoon visit, so conduct surveys between noon and 4 pm. For each site or planting that you survey, allow enough time to mark or find the transects, collect two 7.5-minute samples, and walk between transects. We estimate about 30 minutes per site will be needed for each visit.

Each time you visit a site, you will survey two 100 ft transects (or the equivalent length split into smaller sections). Keep the transects in full sun because bee activity declines in the shade. Each 100 ft transect should be sampled for 7.5 minutes, and only count bees on flowers in a 3 ft wide strip. If you are sampling a relatively large meadow or cover crop that will easily fit a 100 ft transect, one of the transects should be 10–20 ft from the planting edge (running parallel with the edge) and the other should be either 250 ft from the edge, or in the center of the habitat, whichever is shorter (Figure 1). If sampling a small planting, do your best to set up 200 ft of transects through each plot. For example, this may be four 50 ft transects (Figure 2). If you are sampling a hedgerow, then run one transect along each side of the hedgerow, only counting bees in a 3 ft wide strip (Figure 3).

Select and photocopy the appropriate data sheet for your site (p.12–14). Record the site name, the date and your name at the top of the data sheet, as well as whether this is your first or second visit to the site. Note the weather conditions to show that the sample was conducted during optimal conditions for bees. Also note the type of planting (e.g., hedgerow, meadow, cover crop, etc.).

When sampling each transect, record the time of day you start, then start the timer and begin walking down the transect. Plan your transect walk so that your shadow does not move in front of you or across where you are counting bees. As you slowly walk, survey three feet to one side of the line you are walking, trying to watch all the open flowers. Record each bee you see visiting a flower (visiting = landing on the reproductive structures of a flower for more than 0.5 seconds). Pause the timer if you need time to record an insect or to shift over to another subsection of the transect you are surveying. Then start the timer again when you are ready to resume observations. Tally native bees and honey bees separately on your data sheet.

- Try to pace yourself so you reach the end of the 100 ft transect when the 7.5 minutes are up.
- If the timer goes off before you have reached the end of the transect, quickly walk to the end of the transect and take a rough count of the native bees and honey bees visiting flowers.
- Don’t count the same bee twice even if it visits several flowers–the goal is to count the number of bees using the site, not the rate of flower visitation.

In the notes section of the data sheet, record important site information, such as the dominant flowers in bloom and which species seem to be attracting the most native bees or honey bees.

Interpretation of results: The number of native bees counted by this streamlined survey protocol is positively correlated with the diversity of bees at a site. If multiple sites are surveyed, the differences in diversity of the bee community likely will reflect differences in habitat quality among sites. Thus, native bee counts can be used to rank the quality of sites or the quality of a pollinator seed mix. If data are collected over several years, these bee counts can also assess the change in the bee community at a site over time.

LAYOUT OF SAMPLING TRANSECTS

Figure 1. *For larger habitat plantings, survey bees on two 100 ft transects parallel to the edge of the habitat. One transect should be 10–20 ft from the edge, and the other should be 250 ft from the edge or at the center of the habitat, whichever is shorter.*

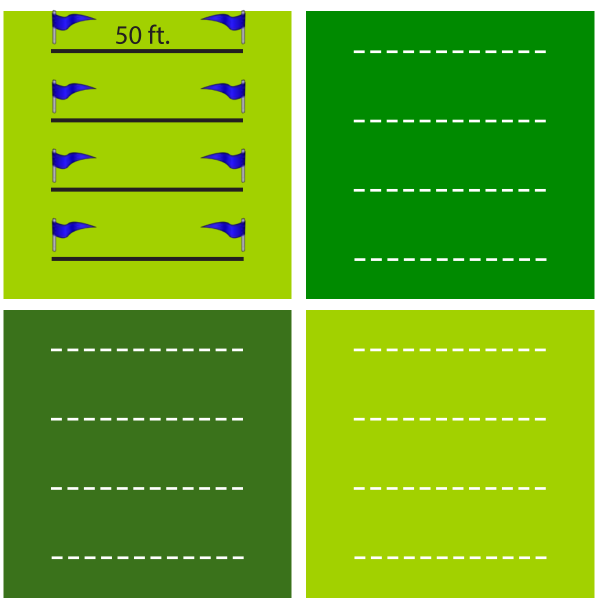


Figure 2. *For smaller habitat plantings, such as field trials of pollinator seed mixes, you can work to fit 200 ft of transect into each block. For example, the upper left block demonstrates establishing four parallel 50-foot-long transects. When walking each transect, you are only observing bees in a 3 ft wide strip along the transect path. The dotted lines in the other blocks in this figure indicate similar sampling efforts.*

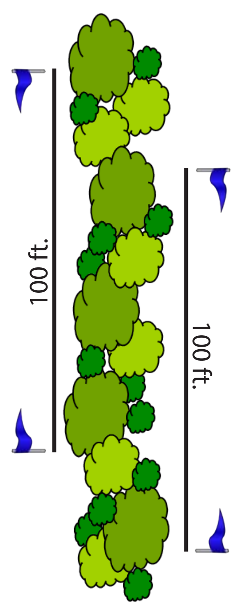


Figure 3. *For hedgerows, survey bees on two 100 ft transects on opposite sides of the hedgerow. If the two sides are difficult to access, sample a single transect that is 200 ft long. You will observe bees in a 3 ft wide strip along each transect.*

please remember to photocopy

Bee Monitoring Data Sheet: Large Habitat (See Figure 1)

Site Name: ______________________ **Date:** ____/____/____ **Observer:** ______________________

Visit #: ____ **of 2** **Skies (circle):** Clear / Partly Cloudy / Bright Overcast **Temp:** ______ °F

Type of planting (circle): Meadow / Range / Cover Crop / Other (describe): ______________________

Conduct observations in the afternoon (noon–4 pm), when temperatures are over 60°F, skies are clear (partly cloudy or bright overcast is OK as long as you can see your shadow) and wind speed is low (a gentle breeze or less). **Conduct observations on two 100 ft transects in open areas of the planting.** One transect should be 10–20 ft from the edge, and the other should be 250 ft from the edge or at the center of the habitat, whichever is shorter. Observe plants in each transect for 7.5 minutes. For each transect, record the number of native bees and honey bees visiting flowers (touching reproductive structures of flowers) within 3 ft of one side of your transect line. You can note flies, wasps, or other floral visitors in the notes.

Transect	Start Time	End Time	# Native Bees	# Honey Bees	Notes
Transect 1 (10–20 feet from edge of planting)					
Transect 2 (center of planting)					

Site notes (e.g. details of the planting, dominant plants in bloom, proximity of honey bee hives, etc.): ______________________

Bee Monitoring Data Sheet: Small Planting Blocks (See Figure 2)

please remember to photocopy

Site Name: ____________________ **Date:** ____ / ____ / ____ **Observer:** ____________________

Visit #: _____ **of 2** **Skies (circle):** Clear / Partly Cloudy / Bright Overcast **Temp:** ________ °F

Type of planting (circle): Field Trials / Meadow / Cover Crop / Other (describe): ____________________

Conduct observations in the afternoon (noon–4 pm), when temperatures are over 60°F, skies are clear (partly cloudy or bright overcast is OK as long as you can see your shadow) and wind speed is low (a gentle breeze or less). **Conduct observations on 200 ft of transects, evenly spaced through the planting.** Observe plants in all combined transects for a total of 15 minutes. For each transect, record the number of native bees and honey bees visiting flowers (touching reproductive structures of flowers) within 3 ft of one side of your transect line. You can note flies, wasps, or other floral visitors in the notes.

Transect	Start Time	End Time	# Native Bees	# Honey Bees	Notes
Transect 1 length:_______					
Transect 2 length:_______					
Transect 3 length:_______					
Transect 4 length:_______					

Site notes (e.g. details of the planting, dominant plants in bloom, proximity of honey bee hives, etc.): ____________________

Bee Monitoring Data Sheet: Linear Planting (See Figure 3)

please remember to photocopy

Site Name: ______________________ **Date:** ____/____/____ **Observer:** ______________________

Visit #:_____ **of 2** **Skies (circle):** Clear / Partly Cloudy / Bright Overcast **Temp:**________ **°F**

Type of planting (circle): Hedgerow / Windbreak / Insectary Strip / Other (describe): ______________________

Conduct observations in the afternoon (noon–4 pm), when temperatures are over 60°F, skies are clear (partly cloudy or bright overcast is OK as long as you can see your shadow) and wind speed is low (a gentle breeze or less). **Conduct observations on two 100 ft transects along either side of the planting.** Observe plants in each 100 ft transect for 7.5 minutes. For each transect, record the number of native bees and honey bees visiting flowers (touching reproductive structures of flowers) within 3 ft of one side of your transect line. You can note flies, wasps, or other floral visitors in the notes. If it is less than 6 ft wide, consider using a single 200 ft transect.

Transect	Start Time	End Time	# Native Bees	# Honey Bees	Notes (Describe where transect is located)
Transect 1 (side A) length:_______					
Transect 2 (side B) length:_______					

Site notes (e.g. details of the planting, dominant plants in bloom, proximity of honey bee hives, etc.): ______________________

Appendix A

ADDITIONAL RESOURCES

Bee Conservation Publications

Buchmann, S. L. and G. P. Nabhan. 1996. *The Forgotten Pollinators*. 292 pp. Washington, D.C.: Island Press.

National Research Council. 2006. *Status of Pollinators in North America*. 307 pp. Washington, D.C.: National Academies Press. (Available at: http://www.nap.edu/catalog/11761.html.)

Mader, E., M. Shepherd, M. Vaughan, S. H. Black, and G. LeBuhn. 2011. *Attracting Native Pollinators. Protecting North America's Bees and Butterflies*. 384 pp. North Adams, MA: Storey Publishing.

Bee Biology and Identification Publications

Michener, C. D., R. J. McGinley, and B. N. Danforth. 1994. *The Bee Genera of North and Central America*. 209 pp. Washington, D.C.: Smithsonian Institution Press.

Michener, C. D. 2000. *The Bees of the World*. 913 pp. Baltimore, MD: The Johns Hopkins University Press.

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Williams, P. H., R. W. Thorp, L. L. Richardson, and S. R. Colla. 2014. *Bumble Bees of North America: An Identification Guide*. 208 pp. Princeton, NJ: Princeton University Press.

Plant Lists & Conservation Resources

Fiedler, A., J. T. Tuell, R. Isaacs, and D. Landis, 2007. *Attracting Beneficial Insects with Native Plants*. 6 pp. Michigan State University Extension Bulletin E-2973.

Rutgers University Outreach:

http://winfreelab.rutgers.edu/outreach

http://winfreelab.rutgers.edu/documents/NativeBeeBenefits2009.pdf

Michigan State University, Native Plants and Ecosystem Services: www.nativeplants.msu.edu

The Xerces Society Pollinator Plant Lists: http://www.xerces.org/pollinator-conservation/plant-lists/

The Xerces Society Pollinator Conservation Resource Center: http://www.xerces.org/pollinator-resource-center/

Citizen Science Opportunities

Bumble Bee Watch (www.bumblebeewatch.org): Citizen science database for collecting bumble bee observations in North America.

The Great Sunflower Project (www.greatsunflower.org): A citizen science project that identifies bees visiting flowers.

Bug Guide (www.bugguide.net): An online resource devoted to North American insects, spiders, and their kin, offering identification, images, and information.

Partner Websites

University of California, Davis: http://polleneaters.wordpress.com/

Rutgers University Outreach: http://winfreelab.rutgers.edu/

Michigan State University: www.isaacslab.ent.msu.edu

The Xerces Society: www.xerces.org/pollinator

Some native bees, such as this small carpenter bee, can be tiny and wasp-like.

The Xerces Society's Bring Back the Pollinators campaign is based on four principles: grow pollinator-friendly flowers, protect bee nests and butterfly host plants, avoid pesticides, and spread the word. You can participate by taking the Pollinator Protection Pledge and registering your habitat on our nationwide map of pollinator corridors.

www.bringbackthepollinators.org

Appendix B

Fact sheet

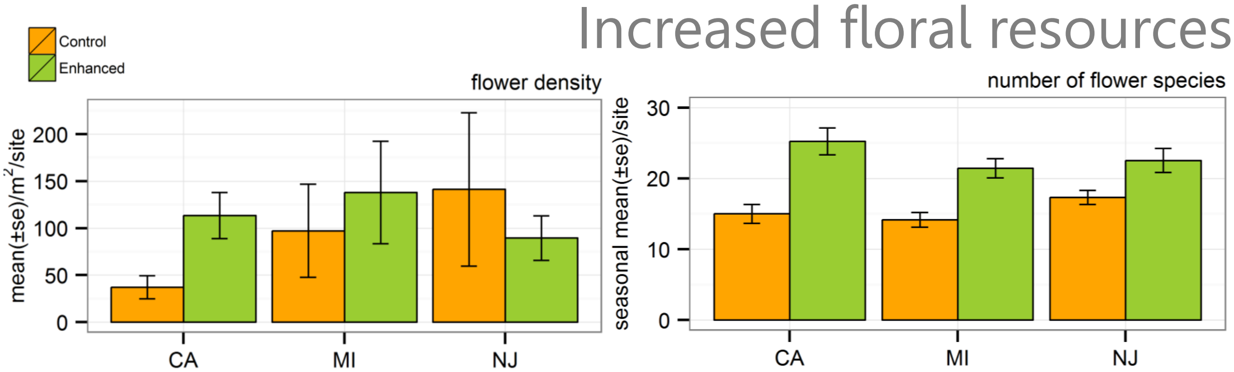
Habitat for bees and beneficials:

documenting successful function

Native bees and honey bees are important pollinators for many crops. To sustain large populations, native bees need floral resources before and after crop bloom. This has motivated landowners nationwide to enroll hundreds of thousands of acres into pollinator plantings. Continued enrollment requires a robust assessment of their success in supporting pollinators and other beneficial insects, while not augmenting pests. Three years of intensive monitoring (2011-2013) from 51 sites in California, Michigan and New Jersey provide robust assessment of the success of pollinator habitat to enhance floral resources for bees and other beneficial insects throughout the growing season.

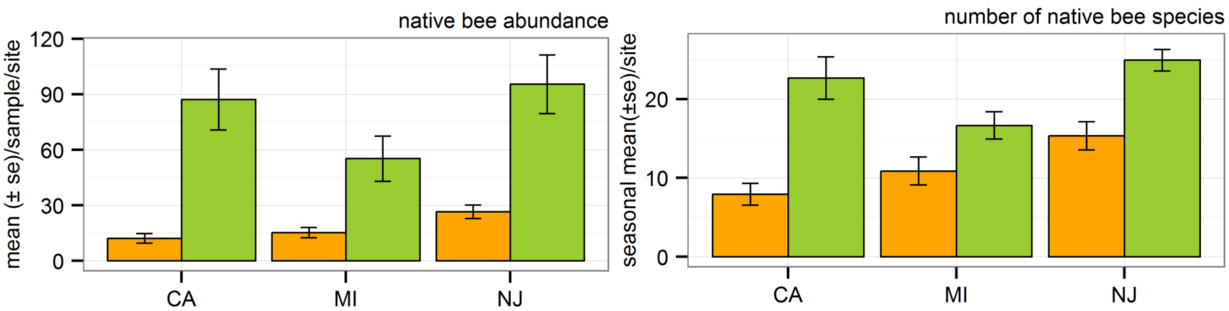
Pollinator habitats dramatically increased the abundance and diversity of native bees and the abundance of other beneficial insects when compared to nearby controls that had not been planted. They did not increase important crop pests.

Increased floral resources



Across all regions and years we sampled 273 species of wildflowers blooming in pollinator habitat plantings and nearby controls. Pollinator plantings increased the abundance of floral resources in CA, and increased the diversity of flowering species in all three regions.

Benefits to bees

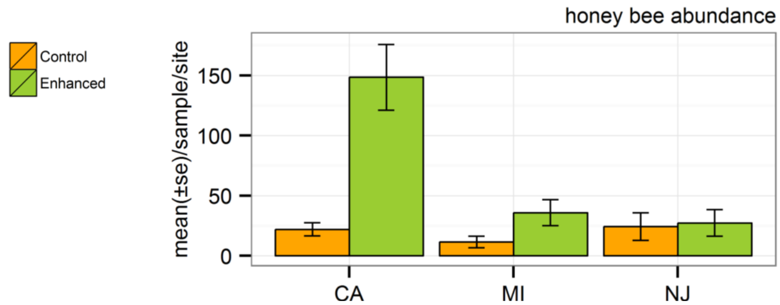


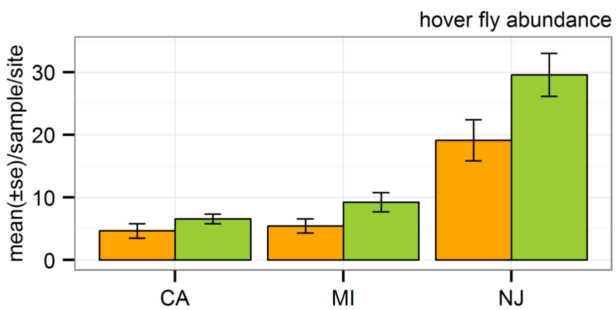
Native bee abundance and diversity increased even more dramatically in pollinator plantings compared to controls. The number of native bees visiting flowers was on average 3.5-7 times higher in planted habitat, and the average number of native bee species was 1.5 to nearly 3 times higher.

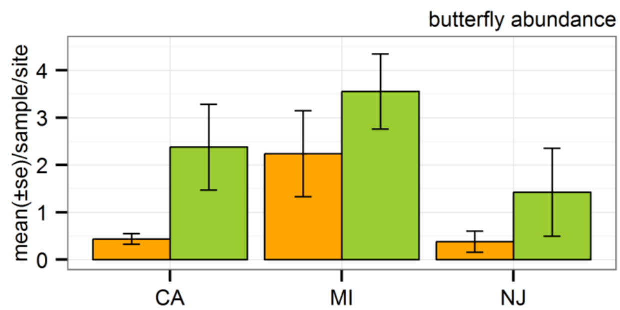
Funded by NRCS Conservation Innovation Grant Agreement number 69-3A75-10-163

Benefits to other beneficial insects

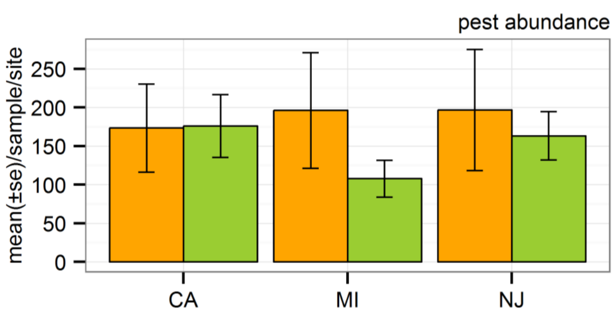
Honey bees were substantially more abundant in pollinator habitat than in controls in California, and they were more abundant or no different in other regions. Hover flies and butterflies also tended to be more abundant in habitat plantings in all regions.

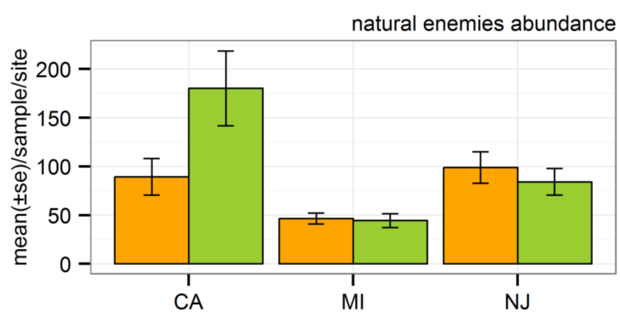






No increase in pests or natural enemies





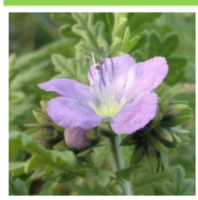
Pests tended to be no different or less abundant in planted habitat than in controls, while natural enemies were no different or more abundant in pollinator habitat.

Meet the wildflowers

California

Our findings provide very useful information to improve ongoing pollinator habitat restoration efforts. In addition to quantifying the performance of current pollinator habitat species mixes, we identified top wildflower species that support the most abundant and diverse bee communities. Top performing plants were selected based on wild bee preference[1], average bee abundance visiting per sample and average bee diversity per sample. Plants with insufficient information were excluded (those sampled from fewer than three spatially independent sites over the study).

Top wildflowers

	Species	Life span	Bloom season: Early	Mid	Late
	Great Valley phacelia *Phacelia ciliata*	Annual	■		
	California poppy *Eschscholzia californica*	Annual/Perennial	■	■	
	California phacelia *Phacelia californica*	Perennial	■	■	■
	Valley gum plant *Grindelia camporum*	Perennial		■	■
	Bolander's sunflower *Helianthus bolanderi*	Perennial		■	■
	vinegarweed *Trichostema lanceolatum*	Annual			■

1. preference calculated as standardized proportion total bee visitation to the plant species divided by its proportion of total flower density at the site and date.

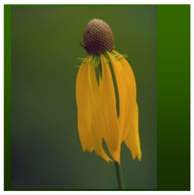
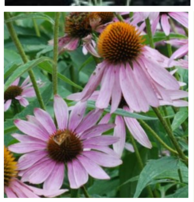
Photos: Kimiora Ward

Meet the wildflowers

Michigan

Our findings provide very useful information to improve ongoing pollinator habitat restoration efforts. In addition to quantifying the performance of current pollinator habitat species mixes, we identified top wild-flower species that support the most abundant and diverse bee communities. Top performing plants were selected based on wild bee preference[1], average bee abundance visiting per sample and average bee diversity per sample. Plants with insufficient information were excluded (those sampled from fewer than three spatially independent sites over the study).

Top wildflowers

	Species	Life span	Bloom season: Early	Bloom season: Mid	Bloom season: Late
	pinnate prairie coneflower *Ratibida pinnata*	Perennial	■	■	
	wild bergamot *Monarda fistulosa*	Perennial	■	■	■
	hoary verbena *Verbena stricta*	Annual/Perennial		■	■
	flat-top goldenrod *Euthamia graminifolia*	Perennial			■
	tall tickseed *Coreopsis tripteris*	Perennial;			■
	eastern purple coneflower *Echinacea purpurea*	Perennial			■

1. preference calculated as standardized proportion total bee visitation to the plant species divided by its proportion of total flower density at the site and date.

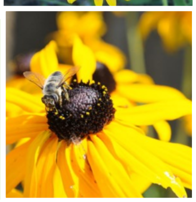
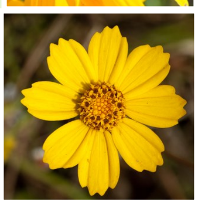
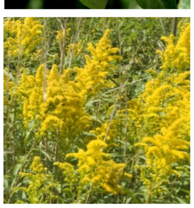
Photos: RATPIN: TG Barnes, MONFIS: Hardyplants, VERSTR: J. Pisarowicz, EUTGRA: J. Kline, U.Wisc., CORTRI: E. van der Pijil, ECHPUR: Jmeeter

Meet the wildflowers

New Jersey

Our findings provide very useful information to improve ongoing pollinator habitat restoration efforts. In addition to quantifying the performance of current pollinator habitat species mixes, we identified top wildflower species that support the most abundant and diverse bee communities. Top performing plants were selected based on wild bee preference[1], average bee abundance visiting per sample and average bee diversity per sample. Plants with insufficient information were excluded (those sampled from fewer than three spatially independent sites over the study).

Top wildflowers

	Species	Life span	Bloom season		
			Early	Mid	Late
	Indian blanket *Gaillardia pulchella*	Annual/Perennial	■	■	
	blackeyed Susan *Rudbeckia hirta*	Annual/Perennial	■	■	
	lanceleaf tickseed *Coreopsis lanceolata*	Perennial	■	■	
	wild bergamot *Monarda fistulosa*	Perennial		■	■
	Canada goldenrod *Solidago canadensis*	Perennial			■
	smooth white oldfield aster *Symphyotrichum racemosum*	Perennial			■

1. preference calculated as standardized proportion total bee visitation to the plant species divided by its proportion of total flower density at the site and date.

Photos: GAIPUL: Wikimedia, RUDHIR: Dcoetzee, CORLAN: R. Spellenberg, MONFIS: Hardyplants, SOLCAL: AnRo0002, SYMRAC: E. Honeycutt