PROTECTING POLLINATORS FROM HERBICIDES

Rethinking Weed Management at Home

Herbicide use can negatively affect pollinators and other beneficial insects and remove flowering plants in the landscape. Allowing some "wildness" in some or all of your yard and managing unwanted plants without chemicals can provide a variety of ecological benefits.

What does it mean to pollinators that herbicides are the most commonly applied pesticide in urban areas? Though insecticides pose the most obvious risk to bees and other pollinators, this factsheet focuses on herbicides because they too can be harmful. You may already be taking steps to conserve pollinators in your home yard, and we hope this information helps you take another step towards protecting these vitally important creatures.

Herbicide risks to pollinators and other invertebrates

A growing body of research provides evidence that herbicides can harm pollinators and other beneficial insects. Examples of risk to insects include negative health outcomes such as decreased reproduction or difficulty navigating. These effects are subtle, but can still weaken bees and reduce their populations over time. Herbicides can also negatively impact the plants and the broader environment that bees need to survive.

Perhaps the most drastic impact that herbicides have on bees and other pollinators is eliminating pollen and nectar by killing flowering plants across the landscape. Many plants seen as "weeds" can be important food sources for pollinators, and may also provide forage when no other plants are flowering in urban areas (Lowenstein et al. 2019; Hicks et al. 2016, Jachula et al. 2022). A nationwide monitoring project in France highlighted that herbicides could reduce availability of host plants for many butterflies, and diminish the number of butterflies in yards (Muratet & Fontaine 2015).

Herbicides sometimes end up on plants beyond the target weeds. While this contamination might not be at high enough levels to kill the non-target plants, it can make those plants poorer resources for pollinators. For example, dicamba and 2,4-D can reduce plant health, nectar and pollen production, and reproduction (Bohnenblust et al. 2015). Glyphosate residues in soil can affect the physiology of exposed plants, reducing the quality of leaves and potentially indirectly affecting herbivores that feed on plants grown in contaminated soils (Ramula et al. 2022).

Herbicides 101

Pesticide: a catch-all term for chemicals designed to kill unwanted organisms (including plants).

Herbicide: a type of pesticide designed to kill or halt the growth of plants. Herbicides kill or stunt plant growth in a variety of different ways. Some act quickly, while others may take weeks for symptoms to manifest. Some herbicides and their breakdown products persist in soil and water for months to years. Some broad definitions include:

- ***Contact*** herbicides kill the parts of the plant that the herbicide comes into contact with, typically just the vegetation above the soil surface, while systemic herbicides are absorbed throughout the plant, killing or disrupting both the leaves/stems as well as roots of the plant.
- ***Pre-emergent*** herbicides prevent seeds from germinating, while post-emergent herbicides are applied to control actively growing plants. Some herbicides act as both pre- and post-emergents.
- ***Selective*** herbicides control certain types of plants. These can be broad categories, such as all broadleaf plants or grasses, but some selective herbicides affect a smaller suite of species. Non-selective herbicides kill or disrupt all types of plants.

Health impacts of herbicides on pollinators

Relatively few studies have investigated the direct impacts of herbicides on pollinators, so unfortunately we don't know the impact most herbicides might have on pollinator species. However, research has found that some common herbicides can cause harm. In particular, the commonly used herbicide glyphosate and products that contain it have been found to:

- Interfere with honey bees' abilities to navigate (Balbuena et al. 2015) and learn the signals associated with food sources (Mengoni Goñalons and Farina, 2018). This could **impact bees' ability to efficiently forage for food.**
- Change the gut microbiome of honey bees (Motta et al. 2018, Dai et al. 2018, Blot et al. 2019), which may **increase susceptibility to harmful diseases.**
- Giant swallowtail, spicebush swallowtail, black swallowtail, and monarch butterfly eggs exposed to glyphosate were much less likely to hatch than unexposed eggs. Spicebush swallowtail had the greatest egg loss, with only 6% of exposed eggs hatching, compared to 100% of unexposed eggs (Albanese 2019). **Dramatic losses of swallowtail eggs could occur in and around treated areas.**

Other herbicide products have been found to cause harm, including:

- The common herbicide 2,4-D, often included in weed-and-feed products, can **kill or weaken** a variety of insects, notably honey bee larvae (Morton et al. 1972, Morton and Moffett 1972, Freydier and Lundgren 2016).
- Three unrelated formulated herbicide products were found to cause similar harm to metalmark butterfly caterpillars, leading the authors to believe that the observed impacts were due to other ingredients in the formulations or to impacts of the herbicides on food plant quality. Caterpillars exposed to formulated herbicides containing triclopyr, sethoxydim, or imazapyr were **significantly less likely to successfully pupate** than unexposed caterpillars, resulting in 24-36% fewer adults (Stark et al. 2012).

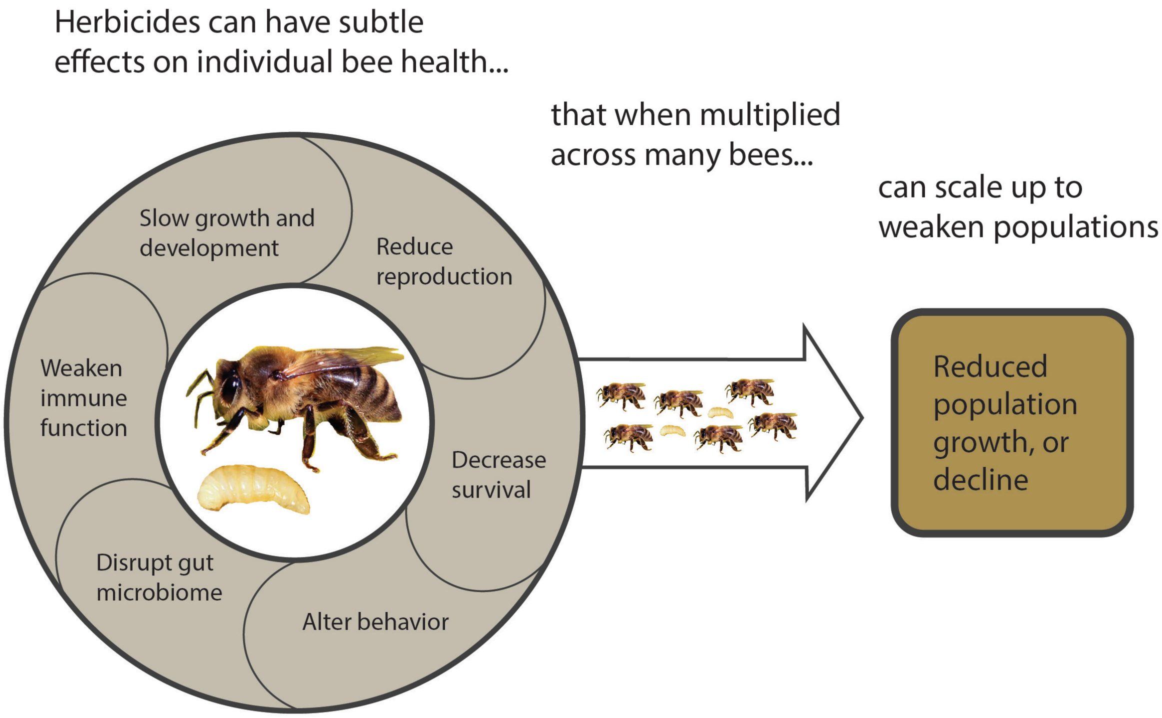
These less obvious impacts can add up in ways that harm pollinator populations. Federal regulations rarely account for these important concerns, which is why just "following the label" when using herbicides is insufficient to protect pollinators and other invertebrates.

How are pollinators exposed?

There are many ways bees and other pollinators can be exposed to herbicides, and avoiding herbicide use when flowers are in bloom only removes one of the most obvious ways bees can be exposed. They may encounter residues remaining on plant surfaces while walking across them. Seventy percent of our native bee species nest in the ground, and can easily come into contact with contaminated soil, particularly when the herbicide is applied directly to the soil as a granular (spread as dry pellets) or a drench (applied as liquid near the roots). Pollinators may also ingest herbicides in plant nectar, pollen, or leaves. Larvae may be exposed via contaminated pollen stored in the nest. Systemic herbicides applied to flowering plants can end up in nectar and pollen, exposing pollinators before the plant shows symptoms of exposure to the herbicide (Thompson et al. 2022).

Not all weeds are the same

Many unwanted plants are harmless. In fact, in some cases valuable pollinator plants are seen as "weeds" since they are not as attractive to humans as they are pollinators (for example: milkweeds, native thistles, and yarrow). However, other weeds can aggressively take over areas and cause harm. These invasive and noxious weeds warrant control. In residential sites this doesn't necessarily require an herbicide; see "Solutions" below for other management ideas.



Health effects of herbicides on individual bees as larvae or adults, especially those that affect reproduction and survival, can scale up to larger impacts on bee populations. Figure: Emily May.

Butterflies are particularly vulnerable, as they can be present on plants throughout their life cycle. Eggs, caterpillars, and chrysalises on host plants can be exposed if the host plant is sprayed, or if pesticides drift onto the host plant from a spray nearby. Caterpillars can ingest pesticides by eating contaminated host plants.

Herbicide use in residential landscapes

While many herbicide uses can be concerning, there are several factors in towns and cities to be aware of in order to better protect pollinators from herbicides.

- ***Cosmetic use:*** In towns and cities herbicides are often applied for cosmetic reasons.
- ***High use rates:*** Herbicides are generally applied to small areas, but are often applied frequently and abundantly. In fact, more pesticides are used per acre in urban areas than in many agricultural areas (Atwood and Paisley-Jones. 2017), though total herbicide use is higher in agriculture. Additionally, pre-mixed products for home use often contain many times higher herbicide concentrations than are used in agricultural settings.
- ***Untrained applicators:*** Home gardeners are often unfamiliar with herbicide best practices (Varlamoff et al. 2001). This may lead to poor application practices, like spraying at incorrect rates, wrong times of year, or allowing herbicide drift.
- ***Hidden sources:*** Herbicides can often be hidden, found in other residential lawn care products like “weed and feed” fertilizer granules.

Herbicides can move off site

Many herbicides used in our communities do not stay put. In towns and cities, herbicides are routinely applied to weeds in pavement cracks and along paved surfaces like sidewalks, driveways, and roads. Even compacted lawns often act as hard surfaces. When it rains, chemicals applied to these areas can contaminate nearby soil and waterways. In fact, in a nationwide study the United States Geological Survey (USGS) found pesticides in 96% of urban streams, and mixtures of pesticides in 90% (Nowell et al. 2021).

Herbicides applied to lawns and paved surfaces move easily into nearby soil and waterways, contaminating urban streams. Photo: Mississippi Watershed Management Organization, Flickr [CC BY-NC 2.0].

Factors that make an herbicide risky

People often are interested in knowing the most risky herbicides to avoid using at home. Unfortunately, it is difficult to create a list of the most risky herbicides because little testing has been done on their impacts on most invertebrates. Beyond that, many herbicides with different names have similar modes of action, meaning simply avoiding certain chemicals is no guarantee that the alternatives are any safer. Similarly, just because a product is approved for organic use does not mean it is non-toxic to pollinators and other invertebrates.

As you work to understand the risks of herbicides it helps to be aware of the chemical characteristics that can increase the potential that an herbicide will harm invertebrates. These include:

- ***Toxicity:*** the chemical's ability to cause injury. Some herbicides can cause harm at low levels that could result from everyday, legal use.
- ***Persistence:*** how long the chemical lasts in the environment. Some herbicides, like those designed to kill weed seedlings, bind tightly to the soil and remain active for months. These herbicides can also kill desired plants, including those providing food and habitat to pollinators and other invertebrates.
- ***Drift:*** the movement of a chemical through the air. Some herbicides are known to travel long distances, harming plants far from where they were applied. While some spray drift can be reduced by the way an herbicide is applied, some herbicides tend to also evaporate off of plants and soil after application, resulting in tiny particles in the air ("vapor drift") that applicators have little control over.
- ***Leaching:*** the movement of a chemical through the soil. Some herbicides that dissolve readily in water are likely to move through the soil and into groundwater, surface water or even nearby pollinator habitat.
- ***Application method:*** herbicides applied throughout a site carry a higher risk than targeted applications, as the amount used and area sprayed is larger, increasing the risk of off-site movement. Spot treating only individual plants, applying closer to the ground, and using larger droplet sizes and lower nozzle pressure can reduce drift.

Solutions

1. **View yards as habitat and embrace ecological beauty.**
   - Accept some weeds in your yard. Instead of pursuing manicured aesthetics with no weeds, allow some level of "wildness" in some or all of your yard. You'll likely notice the ecological benefits this provides. (Note this does not apply to noxious or invasive weeds).
   - Remember, plants that are considered by some to be weeds can in fact be native wildflowers.
2. **Use alternative weed management instead of herbicides.** In residential areas non-chemical solutions are often more feasible than in larger landscapes because site sizes tend to be smaller.
   - Prevent unwanted weeds in sidewalk cracks and driveways by scraping dirt and sediment from cracks with hand tools. Consider removing existing weeds with a flame weeder or steamer.
   - Hand weed or use mechanical removal methods. A variety of tools are available that make weeding easier than simply using a trowel, like hoes, cape cod weeders, and claw weeders.

If you don't manage the grounds where you live, talk to those who do and use the ideas presented here as a guide. If you employ land care professionals, ask them about their weed management methods and let them know you don't want herbicides applied in your yard. If you are a renter, often landlords, workplace grounds managers, HOA officials, and others are open to small and meaningful changes. Photo: iStock.com/Susana Florez

In one study, only 6% of spicebush swallowtail eggs exposed to the herbicide glyphosate ended up hatching. Dramatic losses of swallowtail eggs could occur in treated areas. Photo: John Flannery, Flickr [CC BY-NC 2.0].

- Weed early, when the plants are small. Remove weeds before they go to seed which will reduce the weed population in subsequent years.
- Use dense plantings to outcompete new weeds after mechanical removal.
- Consider mulch to suppress weeds in garden beds. For larger site preparation, sheet mulching, covering with black tarps, or solarization (covering with a clear plastic tarp) are methods that can be used instead of herbicides. Though effective, there are trade offs to be aware of. For more information, see the Xerces Organic Site Preparation guide.
  i. Mulch: While effective at weed suppression, if you use it in an area where bees might nest, thick mulch can eliminate nesting sites for ground nesting bees.
  ii. Solarization: Plastic sheeting has an environmental cost, and heating the soil can harm soil life.

3. **Prevent pests by creating resilient yards.** Design in ways that minimize the chance for weeds to take hold.
   - Select plants that are well suited to the soil type, moisture, and sun availability of your site.
   - Include multiple plant species throughout your yard. Not only will this potentially increase insect diversity, it also makes your yard more resilient in the face of disturbance and weed pressure.
   - Water wisely. Frequent, shallow watering (like from overhead sprinklers or shower heads) can encourage weed growth. Instead, water deeply to promote deep root growth, making garden plants more able to outcompete weeds. If you use drip irrigation, only water around garden plants and leave the in-between space dry.
   - Improve soil health and ensure soil pH is in the desired range to help desired plants outcompete weeds.
   - Mow lawns higher and less frequently to encourage deeper root growth and to shade out weeds.
   - Consult local resources, including gardening clubs or native plant societies, for advice specific to your location.
4. **If you do decide to use an herbicide, consult with state or county Extension or other trusted resources to learn how to both effectively manage the weed issue and do so in the least harmful manner.** Knowing the lowest effective amount of the least toxic option can limit harm. The University of California has a helpful tool to evaluate toxicity to bees: https://ipm.ucanr.edu/bee-precaution-pesticide-ratings/.
   - We encourage you to think through how to make the herbicide application a one-time event, not something you rely on. Follow an application with prevention techniques so you don't need to return to herbicides in the future.
   - Target your application to the specific plant you want to remove, and understand the best timing for that species. If it is a species you need to tackle around flowering or before seedset, remove flowers before applying an herbicide so you don't spray a flowering plant.
   - If your reason to use herbicides is maintaining a manicured landscape, consider designating areas of your yard that can be managed less intensively to provide habitat. People have different preferences for their yard, but we encourage you to find ways to make your yard as pollinator friendly as possible within your desired landscape. Some ideas include:
     i. Leave less visible areas more wild for pollinators.
     ii. Allow some non-problematic weeds to grow.
     iii. Consider using low growing ground cover plants to replace or diversify your lawn.
     iv. Plant native pollinator plants that fit your aesthetic.
   - Time saved by designating less intensively managed sections can be spent managing more visible areas in a sustainable manner.

You Can Make a Difference

Pesticide reduction is a key step towards protecting pollinators, and is a step easily accomplished throughout our communities. Towns and cities can be important havens for pollinators and other beneficial insects – in fact research shows that insects are able to thrive in small habitat patches, like gardens or city parks. Avoiding herbicide use increases the quality of these patches by reducing the risks of pollinator exposure, and ensures the floral resources pollinators rely on remain in the landscape. Thank you for taking this further step towards protecting pollinators!

References

Albanese, D. 2019. Negative Effects of Common Herbicides on Non-target Invertebrates. Georgia Southern University, College of Graduate Studies, Department of Biology. Electronic Theses and Dissertations, 1966. https://digitalcommons.georgiasouthern.edu/etd/1966

Atwood, D., and C. Paisley-Jones. 2017. Pesticides industry sales and usage: 2008-2012 Market Estimates. Washington, DC: US Environmental Protection Agency.

Balbuena, M. S., L. Tison, M.L. Hahn, U. Greggers, R. Menzel, and W. M. Farina. 2015. Effects of sublethal doses of glyphosate on honeybee navigation. *The Journal of Experimental Biology* **218**:2799–2805. DOI:10.1242/jeb.117291

Bohnenblust, E. W., A. D. Vaudo, J. F. Egan, D. A. Mortensen, and J. F. Tooker. 2015. Effects of the herbicide dicamba on nontarget plants and pollinator visitation. *Environmental Toxicology and Chemistry* **35**(1):144-51. DOI:10.1002/etc.3169

Belsky, J. and N.K. Joshi, 2020. Effects of fungicide and herbicide chemical exposure on Apis and non-Apis bees in agricultural landscape. *Frontiers in Environmental Science* **8**:81. DOI:10.3389/fenvs.2020.00081

Blot, N., L. Veillat, R. Rouzé, and H. Delatte. 2019. Glyphosate, but not its metabolite AMPA, alters the honeybee gut microbiota. *PloS one* **14**:e0215466. DOI:10.1371/journal.pone.0215466

Dai, P., Z. Yan, S. Ma, Y. Yang, Q. Wang, C. Hou, Y. Wu, Y. Liu, and Q. Diao. 2018. The herbicide glyphosate negatively affects midgut bacterial communities and survival of honey bee during larvae reared *in vitro*. *Journal of Agricultural and Food Chemistry* **66**:7786–7793. DOI:10.1021/acs.jafc.8b02212

Freydier, L. and J.G. Lundgren, 2016. Unintended effects of the herbicides 2, 4-D and dicamba on lady beetles. *Ecotoxicology* **25**:1270-1277.

Herbert, L. T., D. E. Vázquez, A. Arenas, and W. M. Farina. 2014. Effects of field-realistic doses of glyphosate on honeybee appetitive behaviour. *The Journal of Experimental Biology* **217**:3457–3464. DOI:10.1242/jeb.109520

Hicks, D.M., P. Ouvrard, K.C. Baldock, M. Baude, M.A. Goddard, W.E. Kunin, N. Mitschunas, J. Memmott, H. Morse, M. Nikolitsi, and L.M. Osgathorpe. 2016. Food for pollinators: quantifying the nectar and pollen resources of urban flower meadows. *PloS one* **11**(6), p.e0158117. DOI:doi.org/10.1371/journal.pone.0158117

Jablonowski, N. D., A. Schäffer, and P. Burauel. 2011. Still present after all these years: persistence plus potential toxicity raise questions about the use of atrazine. *Environmental Science and Pollution Research International* **18**:328–331. DOI:10.1007/s11356-010-0431-y

Jachuła, J., Denisow, B., M. Wrzesień, and E. Ziółkowska. 2022. The need for weeds: Man-made, non-cropped habitats complement crops and natural habitats in providing honey bees and bumble bees with pollen resources. *Science of the Total Environment* **840**:156551. DOI:10.1016/j.scitotenv.2022.156551

Lowenstein, D.M., K.C. Matteson, K.C. and E.S. Minor. 2019. Evaluating the dependence of urban pollinators on ornamental, non-native, and 'weedy' floral resources. *Urban Ecosystems* **22**:293-302. DOI:10.1007/s11252-018-0817-z

Meftaul, I.M., K. Venkateswarlu, R. Dharmarajan, P. Annamalai, and M. Megharaj. 2020. Pesticides in the urban environment: A potential threat that knocks at the door. *Science of the Total Environment* **711**:134612. DOI:10.1016/j.scitotenv.2019.134612

Mengoni Goñalons, C. and W.M Farina. 2018. Impaired associative learning after chronic exposure to pesticides in young adult honey bees. *The Journal of Experimental Biology* **221**(7), p.jeb176644. DOI:10.1242/jeb.176644

Morton, H. L., and J. O. Moffett. 1972. Ovicidal and larvicidal effects of certain herbicides on honey bees. *Environmental Entomology* **1**:611–614. DOI:10.1093/ee/1.5.611

Morton, H. L., J. O. Moffett, and R. H. Macdonald. 1972. Toxicity of herbicides to newly emerged honey bees. *Environmental Entomology* **1**:102–104. DOI:10.1093/ee/1.1.102

Morton, H. L., J. O. Moffett, and R. D. Martin. 1974. Influence of Water Treated Artificially With Herbicides on Honey Bee Colonies. *Environmental Entomology* **3**:808–812. DOI:10.1093/ee/3.5.808

Motta, E. V. S., K. Raymann, and N. A. Moran. 2018. Glyphosate perturbs the gut microbiota of honey bees. *Proceedings of the National Academy of Sciences of the United States of America* **115**(41):10305–10310.

Muratet, A., and R. Benoît. 2015. Contrasting Impacts of Pesticides on Butterflies and Bumblebees in Private Gardens in France. *Biological Conservation* **182**:148–154. DOI:10.1016/j.biocon.2014.11.045

Myers, J.H., G. Rose, E. Odell, P. Zhang, A. Bui, and V. Pettigrove. 2022. Household herbicide use as a source of simazine contamination in urban surface waters. *Environmental Pollution* **299**:118868. DOI:10.1016/j.envpol.2022.118868

Nowell, L.H., P.W. Moran, L.M. Bexfield, B.J. Mahler, P.C. Van Metre, P.M. Bradley, T.S. Schmidt, D.T. Button, and S.L. Qi. 2021. Is there an urban pesticide signature? Urban streams in five US regions share common dissolved-phase pesticides but differ in predicted aquatic toxicity. *Science of the Total Environment* **793**:148453. DOI:10.1016/j.scitotenv.2021.148453

Ramula, S., A. Kalske, K. Saikkonen, and M. Helander. 2022. Glyphosate residues in soil can modify plant resistance to herbivores through changes in leaf quality. *Plant Biology* **24**:979–986. DOI:10.1111/plb.13453

Rowe, A., and M. Bakacs. 2017. Organic Land Care Best Management Practices. Rutgers NJAES Cooperative Extension, E357.

Stark, J.D., X.D. Chen, and C.S. Johnson. 2012. Effects of Herbicides on Behr's Metalmark Butterfly, a Surrogate Species for the Endangered Butterfly, Lange's Metalmark. *Environmental Pollution* **164**:24–27. DOI:10.1016/j.envpol.2012.01.011

Thompson, L. J., S. Smith, J. C. Stout, B. White, E. Zioga, and D. A. Stanley. 2022. Bumblebees can be exposed to the herbicide glyphosate when foraging. *Environmental Toxicology and Chemistry* **41**(10):2603-2612. DOI:10.1002/etc.5442

Varlamoff, S., W.J. Florkowski, J.L. Jordan, J. Latimer, and K. Braman. 2001. Georgia homeowner survey of landscape management practices. *HortTechnology* **11**(2):326-331. DOI:10.21273/HORTTECH.11.2.326

Acknowledgments

AUTHORS: Written by Aaron Anderson, Emily May, Emily Ruth Spindler, and Aimee Code. Reviewed by Heidi James, Gail Langellotto. Laura Rost, Sharon Selvaggio, and Stefanie Steele. Editing and design by Emily May. **PHOTO CREDITS:** Herbicide sprayer by Shutterstock.com/Virrage Images; Violets in lawn by Karin Jokela/Xerces Society, Regal fritillary butterfly on thistle by USFWS Mountain-Prairie (Flickr CC BY 2.0). **DISCLAIMER:** This document is provided only as a guide. Xerces does not endorse any of the ingredients or products listed in this document. Ingredients and/or products are listed for identification and reference only. The appearance of a named ingredient or product is not, and should not be construed, as an endorsement by Xerces or a rejection of similar materials.

This publication was made possible by Carroll Petrie Foundation and the generosity of Xerces Society members and individual donors.