Fall 2021

The Chrysalis

Emerging news from Monarchs Across Georgia

Our mission is to inspire caretakers of the natural environment through monarch and pollinator education

MONARCHS ACROSS GEORGIA

A committee of the Environmental Education Alliance of Georgia

Upcoming Events

Symbolic Migration Deadline
October 8, 2021
Purchase Passenger Tickets and submit butterflies.

MAG Fall Plant Sale
October 16, 2021
9 a.m. to 1 p.m.
Davidson-Arabia Mountain Nature Preserve Nature Center
3787 Klondike Rd.
Stonecrest, GA 30038

MAG Educator Workshop: Tifton
October 16, 2001
9 a.m. to 3:30 p.m.
NESPAL - UGA Campus
2356 Rainwater Rd.
Tifton, GA 31793
Register by Oct. 2, 2021

MAG Educator Workshop: Calhoun
October 23, 2001
9 a.m. to 3:30 p.m.
Gordon County Ag Services Center
1282 GA-53 Spur
Calhoun, GA 30701
Register by Oct. 9, 2021

For more information about these events, or to register, please visit http://www.eealliance.org/mag-events.

GLOBAL CHANGE ECOLOGY

Complex causes of insect declines

Reprinted with permission from Nature Ecology & Evolution

by Diana E. Bowler

Monarch butterflies perform one of the most spectacular events in the insect world — migrating thousands of kilometres across North America, over multiple generations, between their wintering and summer breeding grounds each year. This phenomenon was only fully described in the 1970s, but it is already in danger of being lost. Numbers of monarch butterflies have plummeted over the past decades[1–3]. Declines have been reported at both overwintering and breeding grounds, for both the west and east coast populations. The monarch is one of the most studied and recognizable insect species, but the causes of its decline are controversial. Writing in Nature Ecology & Evolution, Zylstra et al.[4] show how integrated modelling can help to quantify the relative importance of the main factors at play.

The monarch may be exceptional in terms of its migration, but it is less so in terms of its population trend. Many butterfly species are declining in North America and also in Europe[5–7]. These declining trends also mirror those of many other insect groups[8] but the trends are highly variable across time periods and taxa[9]. In the case of monarchs, multiple causes have been speculated to play a role in the decline. One is the loss of

Fig. 1. An adult monarch butterfly on a milkweed plant. Photo: Janet MacFarlane

milkweed host plants on which the larvae specialize (Fig. 1). Milkweed has declined due to changes in agricultural practices, especially the use of herbicides such as glyphosate that eradicate 'weeds' competing with crops[10]. Another potential cause is increased mortality during migration or overwintering due to, for instance, changes in nectar availability along the migration route or habitat at overwintering sites[11,12]. A third factor is the direct and indirect effects of climate change — including on monarch development and survival or the availability and quality of milkweed host plants[13]. Testing these hypotheses, however, has been persistently challenging owing to the complex life cycle of the species, which is spread out across multiple countries and seasons.

Zylstra et al. met this challenge by bringing together data from multiple butterfly

Continued on page 15

Monarch Watch begins 30th tagging season

Reprinted with permission from MonarchWatch.org

by Chip Taylor, Monarch Watch Director

Welcome to Monarch Watch's 30th tagging season! Over the years, thousands of taggers have contributed to our tagging database. It is an enormous record and a veritable gold mine of information about how the migration functions. The record represents over 2 million tagged butterflies and lists where, when and by whom each butterfly was tagged. The sex of each butterfly and whether the butterfly was wild-caught or reared, tagged and released is also recorded. The record also includes over 19,000 recoveries at the overwintering sites.

Please note that the tag codes that appear on tags issued since the fall of 2019 are four letters followed by three numbers — be sure to record the complete code on your datasheet for each monarch you tag and release.

Briefly, the tagging data have revealed new information on the origins of monarchs that reach Mexico, the timing and pace of the migration, differences among regions due to recolonization and weather, the impact of drought years and many other factors. None of these insights into the dynamics of the migration and the monarch annual cycle would have been possible without the assistance of all those who have so generously donated their time and data to the Monarch Watch Tagging Database (which will ultimately be transferred to a national archive).

Despite these successes, there is more to learn and a long-term record is crucial to understand the dynamics of such complex natural phenomena. The climate is changing and monarch habitats are continuing to decline and for these reasons it is likely that the migration will change as well. Continued tagging should enable us to track these changes, and for that, we hope you will continue to tag, to report your data and to generally support monarch conservation by creating habitats for monarchs or helping others do so.

Good luck with your tagging and thanks to all of you for participating in our program. Please visit our website for updates and to review the complete "Tagging wild and reared monarchs: Best practices" article via monarchwatch.org/tagging.

Status of the Population

As you may recall, I was concerned about the conditions monarchs would encounter as they returned from Mexico in March due to the devastating impact of the 11-day freeze in Texas in mid-February. That led to a project to determine 1) how the vegetation recovered from the freezing conditions, 2) the plants the monarchs used for nectar and 3) the phenology of the emergence of milkweeds. Those investigations were summarized in two entries posted to our blog in May and June of this year (see "Nectar plants used by monarchs during March in Texas" and "Monarchs and the freeze in Texas").

Overall, monarchs seemed to find enough nectar and milkweeds to get the breeding season underway. The next question was where were most of the eggs laid by returning females and would that egg laying lead to the production of a small, medium or large number of first-generation offspring. Although some of the returning monarch moved north before the appearance of milkweeds, my sense, based on numerous reports from mid to north Texas, was that the majority of eggs were laid in these regions. While the distribution of eggs looked favorable, the larvae still have to reach the adult stage and those first-generation offspring then have to recolonize the breeding areas to the north.

To assess the size of the first generation and success of the recolonization, I rely on the first sightings posted to Journey North. The number of first sightings grows from year to year as more people post their sightings. Nevertheless, I can still get a sense of the year-to-year differences based on the timing of the sightings and their number. To assess what has happened this year from late April to early June, I examined the Journey North first sightings maps from 2010-2021.

Tentatively, it looks like the recolonization of the summer breeding range this year is the best ever. I say "tentatively" because I have to look at the data more closely. But it does look like this will be a good year for monarchs. As of late June, it looked like the recolonization could produce an overwintering

Continued on page 4

Symbolic Migration: Send your butterflies by Oct. 8

The annual migration of millions of monarch butterflies across North America is among the world's most spectacular natural events. Facing declines in both the eastern and western populations of monarchs, countries across North America are cooperating to protect this fragile species.

Through the Symbolic Migration Project, youth can also become active participants in monarch conservation. By participating in this project, educators can access **lessons and activities** that engage youth in monarch biology and conservation. Participants create symbolic Ambassador Monarch Butterflies out of paper that are mailed and distributed to youth who attend schools near the Monarch Butterfly Biosphere Reserve in central Mexico. These symbolic butterflies build bridges of communication among participants in Mexico, the United States, and Canada. United by the monarch butterfly, youth celebrate and pledge to protect monarchs and their extraordinary migration.

Families, home schools, nature centers, youth groups, and classrooms are welcome. The complete details on how to participate are in the **LEADER PACKET** for the 2021-22 Symbolic Migration season.The postmark deadline is October 8, 2021.

To cover the costs of this important educational project, participants must **buy a $15 "Passenger Ticket"** for each Ambassador Butterfly folder submitted. These funds will support school visits in Mexico to deliver the butterflies and provide conservation education. Purchases are made through our secure website with credit/debit cards (Discover, MasterCard, or Visa) or mailed checks (U.S. banks only). Questions? Email symbolic-migration@eealliance.org.

The Symbolic Migration is a partnership project between Journey North, a program of the University of Wisconsin-Madison Arboretum, and Monarchs Across Georgia, a committee of The Environmental Education Alliance, a 501(c)(3) organization. Journey North manages the interactive Symbolic Migration participant maps and hosts all educational materials on the Journey North website. Monarchs Across Georgia administers the program and is responsible for all fundraising.

Be a MAG volunteer

Email us at mag@eealliance.org and let us know what volunteer opportunities interest you. There are many ways you can help, including:

- Writing newsletter articles
- Becoming a MAG workshop facilitator
- Reviewing grant applications
- Becoming part of our speakers bureau
- Posting information on our web pages
- Gathering news for our Facebook page
- Helping with an event

Other opportunities for active committee members include coordinating or helping out with grant administration or editing the newsletter. You could also work on the Symbolic Migration, Mexico Book Project, plant sales, pollinator habitat certification, volunteer coordination, or the e-blast and email list.

Apply for a MAG award

Do you know someone who goes above and beyond to create habitat for pollinators? Or how about someone or some place that is passionate about monarch conservation? If so, nominate them for the MAG Service Award or the Pollinator Habitat Award by Feb. 1, 2022.

The **MAG Service Award** recognizes significant contributions to monarch education, conservation, and/or habitat restoration in the state of Georgia. Two awards are available: one for an individual who is paid for the work (job) and one for a volunteer. Both awards measure the active impact the nominee has had on monarch education and general pollination.

The **Pollinator Habitat Award** recognizes a MAG-certified pollinator habitat that goes above and beyond the minimal certification criteria and has been established for at least three years.

Learn More: https://www.eealliance.org/mag-awards.

Monarch tagging

Continued from page 2

population ranging from 2-6 hectares with a real potential to be on the high end of that range. To be at the high end, temperature and rainfall have to be within +/-1.5 degrees and +/-2 inches of the long-term means from now through September. While this prediction holds for most of the range, it is particularly important for the conditions to be close to the longterm average for the Upper Midwest, since it is this region that contributes the greatest number of monarchs to the overwintering population.

For more on the influence of environmental conditions on the development of the populations each year, see the "Monarch population crash in 2013" posting to our blog in June.

Reared vs. Wild Monarchs

Our deep dive into the data has told us this record could be improved. For example, our analysis revealed substantial differences between wild and reared monarchs in the probability of reaching Mexico. The recovery rate is higher for wild-caught monarchs (0.9% vs 0.5%). This result means we are learning more about the migration as a natural process from wild-caught and tagged monarchs. That's not surprising. Still, the timing and origins of the thousands of reared, tagged and released monarchs that have been recovered in Mexico are of interest. We are analyzing data to determine why these recover rates are lower. Rearing conditions are surely a major factor but there are several others.

For those of you who prefer to rear, tag and release, we have a few suggestions as to how you might improve the odds that your reared monarchs will reach the overwintering sites in Mexico. One way is to rear monarchs in a way that maximizes their exposure to environmental changes (day/night temperatures, changing photoperiod, etc.) that occur in the fall. In other words, rearing outdoors in a protected area (porch, pole barn, open garage) would likely produce better results than rearing indoors.

For wild-caught monarchs, we have several goals. First, we need to increase the number of taggers from western Minnesota and Iowa westward into Nebraska and the Dakotas. This region is known to produce large numbers of monarchs and those tagged have high recovery rates. Increased tagging in this area will give us a more complete understanding of dynamics of the migration. Second, we need to increase the number of wild monarchs that are tagged since these provide the most valuable data. Third, we need to increase the number of taggers who tag from the beginning of the tagging season in early August until the migration ends. Tagging records for the entire season will help us establish the proportion of the late season monarchs that reach the overwintering sites. Many taggers run out of tags well before the season ends and it would help us to know when this happens; the date may be reported via the tagging data submission form.

Tagging Monarchs

Tagging should begin in early/mid August north of 45N latitude, in late August at other locations north of 35N and in September and early October in areas south of 35N. For peak migration dates in your area please visit monarchwatch.org/tagging.

Quality butterfly nets are available from the Monarch Watch Shop (item# 120003; shop.monarchwatch.org or 1-800-780-9986).

Monarchs are difficult to catch in flight so it is best to locate monarchs feeding on flowers or in roosts late in the day or early in the morning. With a net in hand, approach slowly from behind. Sweep the net forward quickly and flip the end of the net bag over the handle to capture the butterfly deep in the net bag. Collapse the end of the net bag so the wings of the butterfly are closed over its back. Place thumb and forefinger over the leading edge of the wings (from outside of the net) and then reach into the net to firmly grasp the thorax and remove the butterfly for tagging.

Recording Tagging Data

- It is very important that participants record their complete name and contact information on every sheet.
- When you record the data, be sure to use the complete tag code for every tagging record. Without the complete code, identification can be virtually impossible.
- Do not use the page number or "do not use" tags on your tag sheets; these do not provide meaningful data to the tagging program.
- Use the datasheet example as a guide for the information to include for each tagging record. Be sure to record the complete tag code, date, and complete location for each and every monarch you tag and release.

Continued on page 5

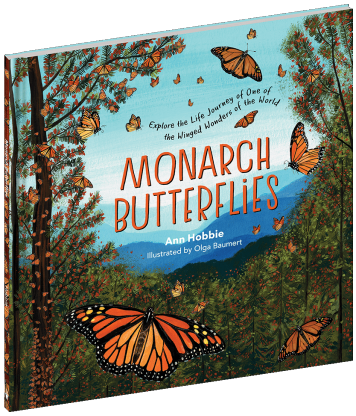
RESOURCES

Monarch Butterflies: Explore the life journey of one of the winged wonders of the world

The accessible text of this book by Ann Hobbie and rich illustrations by Olga Baumert have won the appreciation of families and teachers across the U.S. – not just for being a great children's book, but as a source of inspiration for anyone who picks it up. Written by the chair of the board of directors at Monarch Joint Venture (MJV), the book educates children and families on what they can do to help protect monarch butterflies from the impacts of climate change and habitat loss.

MJV is a national partnership of federal and state agencies, non-governmental organizations, businesses, and academic programs working together to conserve the monarch butterfly migration. Hobbie has more than 20 years of experience teaching children, training teachers, and writing curriculum related to monarchs, schoolyard ecology, and schoolyard gardening.

Her expertise and passion certainly come through in this book – she manages to inform and inspire readers with words that do not distort any of the scientific facts about the monarchs. Hobbie presents detailed information about the monarch life cycle, anatomy, and the wonders of the annual migration. She also writes about the cultural significance of monarchs in Day of the Dead celebrations.



The book broaches how human behavior has harmed monarchs and offers significant ways for kids to make a positive difference. Solution-oriented ideas include converting lawns into native plant gardens, community science efforts such as tagging migrating monarchs and participating in population counts, and supporting organizations that work to conserve butterflies.

Monarch Butterflies was published by Storey Publishing in April 2021.

Monarch tagging

Continued from page 4

Submitting Your Data
Please submit your data once you are finished tagging for the season! Recovery data are useless if we are unable to verify when and where the butterflies were tagged and released. Please consider submitting your data online via our simple form. You may also download a Monarch Watch Tagging Datasheet in spreadsheet format which allows us to compile the data in a more efficient manner. The spreadsheet may be filled out using Excel, Numbers, Google Sheets or another spreadsheet application then saved and submitted online. Datasheets and complete instructions are available online at monarchwatch.org/tagging.

Monarch Tag Recoveries
Tagged monarchs in the U.S., Canada, and Northern Mexico ("domestic" recoveries) are often found by people who are not familiar with Monarch Watch's tagging program. Using the contact info on the tag, recovery information is submitted and added to our database.

The majority of tags are recovered in Mexico. Early each year, we visit the overwintering sites, particularly El Rosario and Sierra Chincua, where we purchase tags from the guides and ejido members. The ratio of untagged to tagged monarchs is quite high and it takes several hours on average to find each tag among the dead butterflies on the trails and under the monarch-covered trees. We pay approximately $5 for each tag, reasonable compensation for the time and energy spent locating them.

A portion of the cost of the tagging kits attempts to cover the recovery effort. However, when there is high mortality at the overwintering sites the number of recoveries is also high and the cost of purchasing tags exceeds these funds. Tax-deductible contributions to Monarch Watch to help offset the costs associated with running the tagging progrm are always welcome and very much appreciated: monarchwatch.org/donate. Thank you for your support!

Pipevine swallowtail & Dutchman's pipe

Pipevine Swallowtail (*Battusphilenor*)
Also known as the blue swallowtail, the pipevine swallowtail butterfly is found in southern North America and Central America. Adults have very rapid flight and continuously flutter their wings when feeding. Their wingspan can stretch from 2¾ to 5 inches. The forewing of the adult is black on top and gray below. Males have smaller cream or pale spots compared to females, and their spots run along the fringe of the wings. Males are also a brighter metallic blue in the rear hindwing region. The bottom half of the hindwing of both sexes is metallic blue. A single row of seven orange spots and small, pale cream dots are found at the edge of the wing embedded in the blue section. This is the pipevine swallowtail's most identifiable characteristic.

Pipevine swallowtail eggs.

Females lay batches of eggs on the underside of host plant leaves (pipevines, the *Aristolochia* species). The eggs are orange-brown, spherical, laid singly or in small clusters. Mature larvae are black-brown caterpillars with fleshy black or orange tubercles, with the longest pair occurring near the head. Caterpillars feed in small groups when young, but become solitary when older. The chrysalis is brown to yellow green. Leaves of pipevines are toxic to many vertebrate animals, and *Battusphilenor* adopts this chemical characteristic from feeding off its host plant in the larval stage.

While most plants of the genus *Aristolochia* are commonly called pipevines (since flowers of some species resemble tobacco pipes), it has been observed that only the native species can act as hosts for the pipevine swallowtails. In Georgia, the native species include Virginia snakeroot (*Endodecaserpentaria* formerly *A. serpentaria*), Woolly Dutchman's pipe (*A. tomentosa*) and Dutchman's pipe (*A. macrophylla*).

However, the non-native Elegant Dutchman's pipe (*A. elegans*), also known as calico flower, is a threat to the pipevine swallowtails. While *A. elegans* is attractive, its leaves are distasteful to the pipevine swallowtail larvae that will die of starvation rather than eat it. Similarly, plants in the native Florida genus *Smilax* can also be a threat to these butterflies. The leaves have a similar shape to pipevines, and female butterflies can confuse the two when laying their eggs. Pipevine swallowtail caterpillars on *Smilax* plants will not survive.

Pipevine or Dutchman's Pipe (*Aristolochia macrophylla*)
The deciduous vine, called pipevine or Dutchman's pipe was once extensively grown in home gardens to adorn arbors and pergolas. It was chosen for its thick canopy of leaves that provided cool shade when grown over porches.

Aristolochia macrophylla. Source: Missouri Botanical Garden.

It is a characteristic plant of the southern Appalachian hardwood forests, typically growing 20 to 35 feet by means of twining stems. The fast-growing, green stems bear large, heart-shaped leaves, about 12 inches wide, dark green above and pale gray underneath.

This vine can be a valuable addition to butterfly gardens since it is the larval host of the pipevine swallowtail. Flowers of this plant occur singly or 2-3 per cluster, and they have been known to attract hummingbirds. The pipe-shaped flowers are mottled green and burgundy in color, with yellow tubes.The fruits occur as cylindrical, cucumber-like capsules, 3-4 inches long, which stay green most of the summer eventually ripening to gray or black.

A characteristic plant of the southern Appalachian hardwood forests, Dutchman's pipe is often cultivated outside its native range. Flowers of this genus were once used as an aid in childbirth, since they were thought to resemble a human fetus. It thrives in moist, organic well-drained soil and part shade. It is important to note that the plants of the genus *Aristolochia* contain a toxin known as aristolochic acid. Ingesting any part of the pipevine may cause irreversible kidney failure.

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Eight simple actions that individuals can take to save insects from global declines

Akito Y. Kawahara[a,b,c,1], Lawrence E. Reeves[c,d], Jesse R. Barber[e], and Scott H. Black[f]

Insects constitute the vast majority of known animal species and are ubiquitous across terrestrial ecosystems, playing key ecological roles. As prey, they are critical to the survival of countless other species, including the majority of bats, birds, and freshwater fishes (1). As herbivores, predators, and parasites, they are major determinants of the distribution and abundance of innumerable plants and animals. The majority of flowering plants, the dominant component of most terrestrial ecosystems, depend on insects for pollination and hence reproduction. As consumers of waste products, insects are essential to the recycling of nutrients. Humans and their agriculture rely heavily on such "ecosystem services" provided by insects (Fig. 1 *A*–*J*), which together have at least an annual value of ∼$70 billion (2020 valuation) in the United States (2). Insects also provide humans with honey, silk, wax, dyes, and, in many cultures, food. Insects have become essential subjects in medical and basic biological research. Furthermore, insects are one of the most easily accessible forms of wildlife, with a diversity of morphology, life history, and behavior that seems ready-made for inspiring appreciation of nature and its conservation (Fig. 1 *K*–*T*).

This benign characterization of insects seems self-evident now, but its emergence is historically recent, especially in the United States. In the mostly agricultural 19th century United States, political pressure generated by increasing crop losses to insects led to the creation of a government-supported corps of professional entomologists. Great advances in fundamental knowledge resulted, but entomology became closely tied to the chemical/pesticide industry, which increasingly adopted a strident insects-as-enemy dialogue, broadened to include disease vectors (3). The 1962 publication of *Silent Spring* (4) marked a dramatic turn toward a more balanced view, but the transition has been slow, not least because the challenges of crop pest and disease vector management remain enormous.

Ironically, even as insects gain recognition as essential members of ecosystems, a concern has arisen that their diversity and abundance may be in global decline, owing to habitat degradation and loss, climate change, pollution, and other causes (e.g., 5–8). Although the evidence is as yet fragmentary and controversial (9, 10; see also articles in this issue), there is every reason to suspect that such forces, combined with human population growth and urbanization, are leading to declines among insects and many other organisms (e.g., 11). There is thus abundant justification for trying to slow or mitigate potential ecological catastrophes triggered by biodiversity losses. Multiple proposals exist. For example, Forister *et al.* (12) called for immediate conservation actions at four levels: nations, states, provinces, and cities; working lands; natural areas; and gardens, homes, and other personal property. Others have proposed intermediate and long-term action plans for insect conservation and recovery (e.g., 13, 14). Implementing these plans and actions, especially those that require approval of governments or nations, can take time. Fortunately, at an individual level, people can play a key role with immediate local impacts. In light of the importance of insects to human existence and the negative trends in insect abundance and diversity that have been shown in numerous recent studies, it is vital that people learn how they can take action.

To help individuals broaden participation in the conservation of insects and to promote the adoption of behaviors and habits expected to mitigate insect declines, we propose eight simple actions, most with immediate impact, that many people can undertake on their own, regardless of background, occupation,

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The authors declare no competing interest.

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Fig. 1. Examples of insects that are beneficial to humans (*A*–*J*), and examples of amazing things that insects do (*K*–*T*). *A*, Pollinator: Honey bee (*Apis mellifera*). *B*, Bumble bee (*Bombus* sp.). *C*, Decomposer: Dung beetle (Scarabaeidae: Scarabaeinae). *D*, Biocontrol: Ladybird beetle (*Harmonia* sp.). *E*, Ecosystem service: Ants (Formicidae). *F*, Silk production: Silk moth (*Bombyx mori*). *G*, Research: Fruit fly (*Drosophila melanogaster*). *H*, Vaccine development, including coronavirus: Alfalfa looper moth (*Autographa californica*). *I*, Dye production: Cochineal scale insect (*Dactylopius coccus*). *J*, Environmental assessment: Stonefly (Plecoptera). *K*, Visual systems: Dragonflies (e.g., *Neurothemis* sp.) have near 360° vision. *L*, Visual defense: Hawkmoth caterpillars (*Hemeroplanes triptolemus*) scare predators by flipping over and resembling a snake. *M*, Immunity and symbiosis: Parasitic wasps (e.g., *Aleiodes indiscretus*) subdue their host with a virus. *N*, Acoustic defense: Tiger moths (*Bertholdia trigona*) use ultrasound to jam bat sonar. *O*, Biomechanics: Water striders (e.g., Gerridae) walk on water. *P*, Agriculture: Leaf cutter ants (*Atta* sp.) farm fungi. *Q*, Chemical defense: Bombardier beetles (*Brachinus* sp.) blast boiling benzoquinones at predators. *R*, Migration: Monarch butterflies (*Danaus plexippus*) migrate thousands of kilometers. *S*, Longevity: Periodical cicadas (e.g., *Magicicada septemdecim*) live for nearly two decades. *T*, Visual mimicry and luring: Firefly (*Photinus pyralis*) females mimic other firefly light flash signals to lure mate-seeking males and consume them alive. See *SI Appendix* for further information about each insect. Image credits: Fig. 1*A*: Michael J. Raupp (photographer); Fig. 1*B*: Flickr/James Johnstone, licensed under CC BY 2.0; Fig. 1*C*: L.E.R.; Fig. 1*D*: Flickr/John Spooner, licensed under CC BY-NC 2.0; Fig. 1*E*: iNaturalist/Jakob Fahr, licensed under CC BY-NC 4.0; Fig. 1*F*: L.E.R.; Fig. 1*G*: iNaturalist/alexis_orion, licensed under CC BY 4.0; Fig. 1*H*: iNaturalist/Anita Sprungk, licensed under CC BY-NC 4.0; Fig. 1*I*: Wikimedia Commons/Peggy Greb, licensed under CC BY 3.0; Fig. 1*J*: Flickr/USFWS Mountain-Prairie, licensed under CC BY 2.0; Fig. 1*K*: L.E.R.; Fig. 1*L*: André Victor Lucci Frietas (photographer); Fig. 1*M*: Wikimedia Commons/USDA; Fig. 1*N*: Aaron J. Corcoran (photographer); Fig. 1*O*: Flickr/Brad Smith, licensed under CC BY-NC 2.0; Fig. 1*P*: L.E.R.; Fig. 1*Q*: Flickr/Katja Schulz, licensed under CC BY 2.0; Fig. 1*R*: Jeffrey Gage (photographer); Fig. 1*S*: Michael J. Raupp (photographer); and Fig. 1*T*: Flickr/James Jordan, licensed under CC BY-ND 2.0.

or geographic location. The first five of these are aimed at creating more and better insect-friendly habitats, the loss of which is likely a leading cause of insect declines. The remaining three are aimed at adjusting public attitudes toward insects to increase support for conservation actions. Further information on each action item can be found in *SI Appendix*.

The Eight Action Items

Create insect-friendly habitats:

1. Convert lawns into diverse natural habitats. Traditional European or Western lawns are biodiversity deserts (15). There are more than 40 million acres of lawns or turf grass in the United States alone (16), and these groomed/mowed monocultures support few insects and other wildlife. With increasing global fragmentation of natural environments, insects will need quality habitat to be preserved and restored, including travel corridors and stepping stones to allow movement across the landscape (5, 7, 17). Because many insects need little space to survive, even partial conversion of lawns to minimally disturbed natural vegetation—say 10%—could significantly aid insect conservation, while simultaneously lowering the cost of lawn maintenance through reduced watering, and requisite herbicide, fertilizer, and pesticide applications.

If every home, school, and local park in the United States converted 10% of their lawn space into natural habitat, this would increase usable habitat for insects by more than 4 million acres. Converting lawns into natural habitat is relatively easy, and if preexisting turf grass is needed to be removed beforehand, this can be done with a sod cutter or through solarization before seeding. Fallen leaves, twigs, and fruit in this space should be left in place, and vegetation should be minimally trimmed or not trimmed at all, as many insects depend on new growth and complex plant structure. A model effort is the "Thousands of Gardens – Thousands of Species" project in Germany, funded by 2.5 million euros from the German Federal Ministry for the Environment (18).

2. Grow native plants. Although there are exceptions, increasing evidence shows that growing native plants provides more benefits to native insects, on average, than growing nonnative ornamental species. Native insects have tight ecological relationships with native plants that have been shared for millions of years. Many different kinds of insects rely on these plants as a food source or nesting sites. These insects are in turn prey for birds and other wildlife, thus native plants indirectly attract many vertebrates. For example, almost all songbirds (~96%) feed insects to their young (19), and declines in suburban backyard birds have been linked to an increased number of nonnative plants (20). Native plants, being adapted to local climates and rainfall regimes, can also be easier to maintain. If native plants are unavailable, growing a diversity of nonnatives, especially species that produce nectar, can still benefit insects. For homes that lack yards, native plants can be added to balconies, roofs, or between the curb and sidewalk in cities. There are many books on the native flora of particular regions, and additional information on native plants can be obtained from local and mail-order plant nurseries, native plant societies, conservation organizations, and university extension programs (see *SI Appendix*). We argue that the beauty of one's yard should not be determined by how well a lawn is maintained or how uniformly its hedges are trimmed, but instead by the diversity of its native plants.

3. Reduce pesticide and herbicide use. Pesticides often harm nontarget, natural insect populations (reviewed in 5, 7), whereas reduction of their use fosters beneficial arthropods (e.g., 21). Pesticides have been found far from their application source (22) and, in some regions, are more prevalent in urban streams than in those near agricultural lands (23). Many pesticides are applied for cosmetic purposes, that is, aimed only at improving the appearance of nonagricultural green spaces such as lawns, gardens, or parks. Reduction or elimination of cosmetic pesticide use, already legislatively mandated in Nova Scotia and Ontario (24), could greatly benefit both terrestrial and aquatic insect communities.

Mosquito suppression is another frequent motivation for home pesticide use. Pesticide barrier treatments (PBTs), in which pest control companies regularly apply chemicals to vegetation surrounding a home, harm beneficial insects (25) and are thought to promote the development of pesticide resistance in mosquitoes (26). Simple alternative control measures can greatly reduce the need for these chemicals, although judicious use of insecticides is sometimes needed to combat mosquitoes that vector diseases. Nonchemical measures include wearing long sleeves when mosquitoes are active, keeping window screens in good repair, and most importantly, identifying and removing standing water in containers (e.g., buckets, pots, birdbaths, gutters, and old tires), which serve as larval habitat for some mosquito species. Two of the most important pathogen vectors and pest species globally, *Aedes aegypti* and *A. albopictus* mosquitoes, utilize these larval habitats in residential areas. Although not all mosquito species use containers as larval habitats, eliminating standing water in the yard is a free, easy, and ecologically sound method to reduce mosquito abundance.

4. Limit use of exterior lighting. Since the 1990s, nighttime light pollution has increased sharply, even doubling in some of the world's most biodiverse areas (27, 28). The majority of nocturnal insects are attracted to artificial lights, and these lights are powerful sensory traps that can indirectly kill insects via exhaustion or result in predation before sunrise (29). In Europe, nocturnal moths are declining more quickly than moths and butterflies that fly during the day, and this trend is likely attributable to light pollution (30). Artificial light has also been shown to reduce reproductive success in fireflies because these insects use light to attract mates (31). To reduce harm to insects, people should turn off unneeded lights, dim necessary light sources, use motion-activated lighting, shield bulbs, and switch to bulbs that produce amber- or red-colored light, which produce wavelengths that are less attractive to insects (32). UV-blacklight "bug zappers," with a purported function to attract pests such as biting flies, mainly kill harmless, nontarget insects (33). Insect populations will benefit from conservation efforts to protect dark night skies.

5. Lessen soap runoff from washing vehicles and building exteriors, and reduce use of driveway sealants and de-icing salts. Soaps used to wash cars, motorbikes, or the exteriors of buildings often produce significant quantities of pollutants including ammonia, heavy metals, nitrogen, petroleum hydrocarbons, phosphorus, and surfactants that can drain directly into local water systems (34). Natural waterways contain a diversity of aquatic insects, including some of the most threatened animals on Earth (5). As water levels in aquifers precipitously decline globally, we recommend reducing cosmetic and recreational water use and using reclaimed water when possible. Domestic soap usage can be made more environmentally friendly by using biodegradable soaps.

Coal-tar–based sealants, such as polycyclic aromatic hydrocarbons (PAHs), often applied to driveway asphalt, are released as runoff into the soil and the atmosphere, harming both terrestrial and aquatic ecosystems (35). Some states and municipalities have banned their use (36). Alternative soy-based sealants are less toxic. In cold climates, rock salt (halite) is often

applied to pavement, including driveways and sidewalks, to prevent icing. However, rock salt is only effective at temperatures above 15°F, and the melted salt can reduce plant growth, cause gastrointestinal disorders in pets, and interfere with insect development, reproduction, and behavior, while damaging concrete (37). Snow blowers, electric snow/ice melt mats, and sand are less harmful, as are salt-free, ice melting chemical formulations such as SafePaw® (safepaw.com).

Increase awareness and appreciation of insects: **6. Counter negative perceptions of insects.** People rarely protect what they do not know and appreciate (38). In many countries, the public is largely unaware of the benefits and services that insects provide, and negative perceptions of insects are widespread (14). Such perceptions can reflect cultural beliefs not grounded in scientific evidence (38) and can be amplified by media sensationalism such as films depicting large, scary insects, or the use of dramatized and misleading headlines.

A concerted effort is needed to counter negative perceptions towards insects. One way to do so is for individuals to know the benefits that insects bring to humankind. These benefits can be easily remembered as the "5Ps": Insects are 1) *pollinators*, 2) *prey*, 3) *physical* decomposers; they 4) help *progress* in science and technology; and they 5) provide *pleasure*. Writing blogs, such as on the "bug of the week" (bugoftheweek.com), and taking photos of insects and writing about them on social media are ways to increase appreciation. Smartphone images can magnify insects and make them more meaningful (14), especially if the images are of high resolution and draw attention. If one's insect pictures are not high quality, spectacular insect macro photos can be found online (e.g., flickr.com, bugshot.net; images taken by others must be credited appropriately). Insect photos can be deposited in web-based biodiversity portals, such as iNaturalist (inaturalist.org), an app that allows participants to document and share their natural history observations in a common social network. The app is an effective outreach tool that can get people quickly interested in nature and counter their negative perception of insects. Although it helps to know the insect species' name when uploading images to iNaturalist, it is not required; unidentified species will be subsequently identified by experts. iNaturalist and other community science (also called citizen science) networks have the potential to generate a wealth of baseline information to understand global insect diversity patterns; iNaturalist has effectively informed many scientific studies on species monitoring, biodiversity patterns, and assessing conservation planning (e.g., 39). Community science efforts that contribute to the monitoring of insects include "Bumble Bee Watch" in North America (bumblebeewatch.org), the "Big Butterfly Count" in Europe (bigbutterflycount.org), and "National Moth Week" worldwide (nationalmothweek.org). These are just a few examples of ways professionals and amateurs can observe, learn, and contribute to insect conservation (see *SI Appendix* for additional examples).

Another means to encourage positive messages about insects is to support and participate in insect-focused public activities. Educational events such as insect fairs, butterfly houses, and live insect zoos exist in Asia, Europe, and North America, and they provide opportunities for participants to handle, learn about, and observe insects (40). Spectacular biological phenomena, such as glowworms in the caves of Australia and New Zealand, migrating monarch butterflies in Mexico, and synchronous fireflies in Malaysia and the United States, all attract thousands of annual visitors (41).

Insect appreciation can also be increased through developing mechanisms that promote insects in culture. An example of a country with prevalent appreciation for insects is Japan. There, insects appear frequently in popular media, animated films, and celebrity quiz shows and are often portrayed as interesting and beneficial (42). Many Japanese insects have approachable common names, and insects appear in anime films and cartoons, often with anthropomorphic traits. Insect enthusiasts in other countries should make efforts to advocate for common names with positive connotations, such as the damselfly "violet dancer" (*Argia fumipennis*) or the orthopteran "rainbow grasshopper" (*Dactylotum bicolor*). There should also be concerted efforts to standardize common names of species that appear often in the media (e.g., Asian giant hornet, *Vespa mandarinia*) and move away from common names with a negative undertone such as "murder hornet." Japan could serve as a model for elevating insect appreciation through celebrity nature advocacy, animation films, and the use of creative common names, as means of improving attitudes toward insects.

7. Become an educator, ambassador, and advocate for insect conservation. An individual's outreach to others, through formal or informal teaching, discussion, etc., is a powerful means for increasing awareness and appreciation of insects, especially when the audience is children (43). The first wild animal a child encounters is likely to be an insect in their immediate surroundings. Positive early experiences can be crucial for the development of an appreciation for nature, given the limited time that children now typically spend outdoors (44, 45). Between the ages of 6 to 12 is when an emotional connection to animals typically peaks (44), and this time is therefore important for natural history education and retention. Professional researchers can contribute to this age group by volunteering to provide interactive insect-themed walks or outdoor activities in schools or through churches, scouts, and other programs serving children. Researchers can also teach from afar through "Skype a Scientist" (skypeascientist.com). There are multiple funding sources for K–12 insect education initiatives, such as the Chrysalis Fund from the Entomological Society of America (entsoc.org/chrysalis-fund). Entomological societies across the world should create similar opportunities. Fostering an appreciation of insects, nature, and the outdoors to children is

especially impactful, as they will become the stewards of the natural world.

It is also important to talk to adults about insect conservation, and an excellent place to do so is during outdoor group walks and hikes that allow for hands-on, positive interactions with insects. Engage participants by introducing insects through storytelling and personal experiences that can improve retention and interest, for example by including explanations of how they are beneficial. Facts related to the 5Ps (see above), such as that >90% of temperate bird species feed on insects (46), or that the majority of freshwater fish, including popular gamefish species, rely on insects (47), are examples of messages that will inform the public about the positive benefits that insects provide.

8. Get involved in local politics, support science, and vote. Insect-friendly environmental policies at any level of government will only be adopted if insects are recognized as important. Political advocacy, especially at the local level, can significantly advance insect conservation. For example, landscaping requirements of many homeowners' associations in the United States have led to overuse of pesticides that harm native insects, birds, and other animals. Members of such associations should advocate to make those rules more environmentally friendly and promote neighborhood interest in conservation (action items 1–5) through discussion with their board and the use of yard signage. Citizens can also interact with local parks departments, planning commissions, city councils, and other governing bodies to advocate for evidence-based policies and practices that help insects. Participating in the design and conservation planning of urban landscapes can have an immediate "bottom-up" effect on local politics and species conservation. For example, residents in the United States successfully advocated for the Miami blue butterfly to be listed under the U.S. Endangered Species Act (naba.org/miamiblue.html). Public advocacy focusing on issues that directly and indirectly impact insects and the environment more broadly can contribute to positive changes at the local and national levels. People should attend events that support increased reliance on science in policy-making, such as the "March for Science" (marchforscience.org), and advocate for larger-scale insect- and conservation-friendly changes, such as banning pesticides in towns, and large environmental initiatives, such as the Paris Climate Agreement (unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement) and the Convention on Biological Diversity (cbd.int/). Becoming locally active and voting for evidence-based science can have long-term global impacts to protect insects. Public opinion is a powerful tool for conservation and can compel decision makers to act (14).

Concluding Remarks

We propose eight simple action items by individuals that can create insect-friendly environments and raise public awareness. Preservation and restoration of habitats that support insect diversity, as well as wildlife more broadly, is a critical element in ensuring their conservation. Any or all of our proposed actions can be adopted to slow insect declines. We encourage people to start by picking one of the eight action items discussed above, before adding others. Simple measures, such as being able to recite the 5Ps will help to educate the public about the benefits that insects provide.

It is also important to be mindful of the impacts of our daily actions and decisions. Avoiding some behaviors or adopting others will contribute both directly and indirectly to insect conservation. Further, taking actions that address issues such as climate change can synergistically promote insect diversity. Climate change is increasingly recognized as a primary factor driving local and regional plant and animal extinctions (48), and therefore actions that contribute to reducing one's carbon footprint are critical. The combined impact of millions of people providing direct and indirect contributions is necessary to confront the global issues related to insect declines. See *SI Appendix* for full accreditation for photographs and additional reading materials.

Data Availability. There are no data underlying this work.

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Jet propulsion: The secret of fluttering butterflies

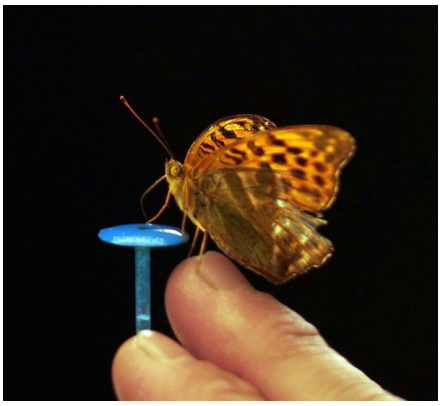
Fluttering butterflies are an eye-catching sight loved by all, and it is due to their large wings that they flutter about rather than fly in direct paths. Moreover, their fluttery flight gives them the advantage of evading predators. Admirers all over the world can also vouch for the difficulty they face when trying to catch a resting butterfly. A study by evolutionary ecologists at Lund University in Sweden has found out the reason for these evasive tactics – jet propulsion.

When taking-off, butterflies clap their wings above their bodies, and this creates jet propulsion. Earlier research had suggested that a pocket of air was likely formed that shot out like a jet when butterflies clapped their wings together. Lund University researchers Christoffer Johansson and Per Hinningson have now tested this theory – with six silver-washed fritillaries they caught. They also tested the benefits of having flexible wings, with regard to the air flow created around the butterfly. The study was published in January 2021 in the Journal of the Royal Society Interface.

All six butterflies were placed, one at a time, in a wind tunnel that uses fans to move air at specific speeds. In order to precisely observe how air flows around the butterfly, smoke made of tiny droplets of oil was added to the air blown into the tunnel. The fans were set to move the air just enough to keep the smoke evenly distributed, and a laser was used to light up a layer of smoke behind the butterfly.

For each trial, a butterfly was placed on a feeding station in the middle of the tunnel. Four high-speed cameras were set up around the feeding station to capture the movement of the butterfly and the smoke as the butterfly was taking off. Recording commenced when the butterfly took flight on its own, and the researchers were able to create a 3D picture of the air movement as the insect flapped its wings.

They analyzed a total of 25 takeoffs by the six butterflies, and each analysis included three wing-beats after takeoff. They noted that the butterflies are more likely to clap their wings together during the first few wing-beats, rather than later in flight. The recordings showed air swirling around a central point as their wings moved. This swirling of air or water around a central point, like a whirlpool, results in a vortex.



Butterfly in the wind tunnel. Photo: Christoffer Johansson.

The photos also showed that during the downward strokes of the wings, air was being pushed down creating a force that pushed the butterfly up. When the wings moved upward to clap, an air pocket was created that created a strong jet of air. This jet of air shot out between the wings behind the butterfly and propelled the insect forward. Both these forces created by the wings cause the “fluttery” flight. That is, the butterflies rise as their wings move down, and shoot forward as their wings move up to clap.

The researchers noticed that the wings formed the puffed-out pocket just before clapping. They set out to check if the pocket, along with the flexibility of the wings improved the jet propulsion created by the clap. For this, they made two models of butterfly wings – a rigid one made from balsa wood, and a flexible set made from a sheet of latex. Each set was attached to hinges and rods that moved to mimic the flight of a butterfly.

The rigid model did not form an air pocket. It created two vortex rings instead- which takes more energy to create and would therefore make flight “less efficient” in an actual butterfly. The flexible wing model created a stronger jet of air and only one vortex, behaving like true butterfly wings.

Johansson and Hinningson’s research has resulted in a better understanding of how butterflies fly – proving that their large and flexible wings are good at clapping which traps air and creates a strong jet. Furthermore, this study has generated awareness among researchers who study the mechanics of insect movement, especially to help design small drones and flying vehicles.

Read more: https://royalsocietypublishing.org/doi/10.1098/rsif.2020.0854

A message from Angangueo, Michoacán, México

by Estela Romero

Dear friends,
As in all nations of the world, we continue to face crucial times due to the COVID-19 pandemic, even after one-and-a-half years of semi-confinement. With schools closed this past academic year, we found ourselves missing both our classrooms and our classmates.
In this unusual time, two main aspects of our lives became apparent: the awareness of our environmental conditions and our education system.

During the past monarch overwintering season, the Symbolic Migration program, through its conservation lessons, managed something extraordinary. It brought us together as a social and school community with our families, teachers, and even our local religious leaders to get much closer to our natural surroundings. We were reawakened to the importance of the conservation of our unique local natural reserve, our Oyamel forests and their rich surrounding ecosystem. We were re-inspired by its extraordinary resilience and the delicate equilibrium in which monarchs overwinter every year since ancestral times. We felt blessed that all of this exists right where we live with our families. We were reminded to continue discovering, restoring, conserving, and raising awareness.

Technology, a highly incipient resource to education in our small mountain villages, has been a great challenge for students, teachers, and parents during the pandemic. The lack of expertise of our teachers to coordinate distance learning, in addition to the lack of financial resources of our families to acquire wi-fi signal and the necessary implements to operate it, has signified a highly challenging time in the progress of our academic education. For many, it was simply a year lost.

The Symbolic Migration program and its conservation lessons were richly enhanced with the book donations by the Monarch Butterfly Fund and the Monarchs Across Georgia Mexico Book Project to our local schools and teachers. These books, our “traditional learning tools” are now more than ever being awaited as an extremely important complement to our education. Our local families, teachers, and nearly 2,000 students in the region anticipate this opportunity to read, learn, and witness the importance of the conservation of our forests and local ecosystems -- a natural treasure and essential to our planet’s equilibrium.

Thank you for all of your efforts to conserve the habitat of the monarchs during their spring and summer generations. We shall continue doing our part to guarantee their overwintering sanctuaries here.

With decades of history, our lives and local culture could not be explained without monarchs and their incredible migratory phenomenon. We look forward to receiving more inspiration in the form of books through the Mexico Book Project to further our joint efforts in fostering conservation, friendship, and cultural association.

Ms. Romero is MAG’s environmental educator for the **Symbolic Migration** *program in México, delivering both a conservation lesson to the students in the region of the Monarch Butterfly Biosphere Reserve, and books purchased with donations to our* **Mexico Book Project**. *Please consider a* **tax-deductible donation** *to support this project.*

Complex causes of insect declines

Continued from page 1

monitoring programmes to track the monarch throughout its annual cycle. The authors used data from five monitoring schemes across large parts of the summer breeding grounds of the eastern monarch population — in Ontario, Canada and the Midwestern USA. They also included data from the species' wintering grounds in central Mexico, specifically within the Monarch Butterfly Biosphere Reserve where the monarch forms dense colonies during hibernation. Using a full annual-cycle model, Zylstra et al. simultaneously tested the effects of climate, land cover and herbicide use on both summer and winter population size.

Their findings revealed that annual population sizes of monarch butterflies were best explained by climate conditions during spring and summer. There was a negative association between herbicide use and population size, but this effect was much weaker than the climatic effects. Associations between winter and summer population sizes suggested that changes in migration and overwintering mortality were unimportant.

Overall, the results support climate being a key driver of monarch population size. Moreover, by studying the population dynamics over a broad geographic extent, the authors showed that the climate effects varied regionally — with less-positive effects of warmer summer temperatures in the warmest regions. From this, the authors speculated that these regions may become inhospitable for monarchs as temperatures continue to rise.

A limitation of the study, recognized by the authors, is that it is unclear whether climate is driving long-term trends of the monarch population or is rather more responsible for year-to-year fluctuations. This wasn't separated by their model. As Zylstra et al. pointed out, the steepest decline of monarch populations occurred before 2004, during the period of widespread expansion of herbicide use, but there were less butterfly data available before 2004 for the analysis. Indeed, other studies have concluded that halting and reversing the loss of milkweed plants should be the priority for conservation[13,14]. As with most species, no single factor is probably responsible for the decline of the monarch[15]. Moreover, the relative importance of different pressures may have changed over time. Habitat loss, especially associated with agricultural intensification, and climate change have both been commonly highlighted as leading causes of declines for butterfly species elsewhere[5,16].

One of the greatest challenges for ecologists is overcoming the lack of large-scale monitoring data for insects. While some taxa, such as birds, are relatively well monitored by large-scale and standardized programmes, most insect taxa are sampled only locally, at best[17]. Hence, evidence for insect declines so far mostly comes from data collected at a relatively small number of sites[18,19]. Zylstra et al. show how different data sets can be brought together to examine insect population dynamics at larger scales. This is especially important for migratory species since different monitoring programmes target species at different points in their life cycle. But even beyond migrants, combining multiple sources of data and information can expand the spatial and temporal scale of a study, helping to understand whether declining trends are widespread over a species' range. Greater scale can also help identify causes of declines by encompassing larger gradients in the intensity of pressures and increasing the statistical power to detect their impacts.

Recent advances in integrated modelling offer new ways to combine the information within different data sets to study species' population and distribution dynamics[20–23]. Zylstra et al. provide an example for an iconic insect species but these types of models have so far only been rarely applied to insects[24]. As the statistical tools develop, data integration may help to overcome some of the problems associated with the sparsity of the data available for insects and allow better understanding of the extent and drivers of insect declines. Moreover, data integration could help identify the most effective approaches to tackle insect declines and provide a more robust evidence base for conservation actions[25].

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Continued on page 16

POLLINATOR HABITAT CERTIFICATION

Congratulations to our latest certified habitats

Do you enjoy watching and studying caterpillars on their host plants, searching for chrysalides hidden from predators, or observing butterflies and hummingbirds flitting from flower to flower? Does your schoolyard, workplace, or backyard have bushes, trees, and flowers that provide host plants, nectar, and protection for butterflies, bees, hummingbirds, and other pollinators? Is there a source of water/puddling areas for thirsty butterflies? Are there places for them to roost at night? If so, register your habitat with Monarchs Across Georgia's Pollinator Habitat Program. No garden is too big or too small!

For more details and to download the form, visit thePollinator Habitat Certification webpage.

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- The Rivera Family – Acworth, GA
- Robert and Janice Matthews – Athens, GA
- Hamilton Gardens at Lake Chatuge – Hiawassee, GA
- Betty's Garden, Lavonia Elementary School – Lavonia, GA
- Arcado Elementary School – Lilburn, GA
- Marietta High School – Marietta, GA
- Jim and Brenda Carpenter – Tifton, GA
- Good Nature is Good for All – Decatur, GA
- Kris and Cheryl Maher – Atlanta, GA
- Gold Medal Garden @ Union County Farmers Market – Blairsville, GA
- Euchee Elementary School - Grovetown, GA

Complex causes of insect declines

Continued from page 15

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Competing interests
The author declares no competing interests.