Knowledge Gleaned From the First Great Georgia Pollinator Census[1]

B. Griffin[2], A.G. LaTora, U. Bhattarai, and S.K. Braman

University of Georgia, Department of Entomology, 413 Biological Sciences Building, Athens, Georgia 30602 USA

J. Entomol. Sci. 57(1): 39–63 (January 2022)

Abstract In August 2019, Georgians were provided the opportunity to participate in a pollinator census, called the Great Georgia Pollinator Census (https://GGaPC.org). This initiative evolved from two pilot projects conducted in 2017 and 2018. Citizen scientists counted insects and placed them into one of eight insect categories: (1) carpenter bee, *Xylocopa* sp. (Hymenoptera: Apidae); (2) bumble bee, *Bombus* sp. (Hymenoptera: Apidae); (3) honey bee, *Apis mellifera* L. (Hymenoptera: Apidae); (4) small bee (Hymenoptera); (5) wasp (Hymenoptera: Vespidae); (6) fly (Diptera); (7) butterfly or moth (Lepidoptera); or (8) other insects. This project was a yearlong effort that included assisting Georgians in creating sustainable pollinator habitat and increasing participant knowledge of insects and insect-mediated ecosystem services. A sustainable education effort involved the use of a website, newsletters, social media, University of Georgia Extension personnel, and project partners. Over 4,500 participants recorded over 151,000 insect counts in 135 Georgia counties, including 134 schools. Data analysis indicated a significant difference between pollinator counts in rural and urban areas (e.g., carpenter bees were more abundant in urban than in rural areas). Analysis also showed a significant influence of the local presence of honey bee hives on relative proportion of other pollinators as represented in the survey counts.

Key Words pollinator conservation, citizen science, community science, bees, pollinator education

Worldwide pollinator decline emerged as an important issue for policymakers and the public in recent years (Baldock 2020; Potts et al. 2010, 2016; Powney et al. 2019). Pollinator declines first came to public attention following widespread European honey bee, *Apis mellifera* L., colony losses in 2006–2007 and the description of colony collapse disorder, a syndrome characterized by rapid honey bee die-off within hives (vanEngelsdorp et al. 2009). However, declines also have been documented for bumble bees (*Bombus* spp.), monarch butterflies (*Danaus plexippus* L.), and other native pollinators (NRC 2007). Urbanization, land-use change, and habitat loss are primary causes of pollinator declines and reductions in biodiversity (Baldock 2020; McKinney 2008; Potts et al. 2010, 2016). Habitat loss and fragmentation isolate species from their food and nesting resources and can

[1]Received 22 January 2021; accepted for publication 11 April 2021.

[2]Corresponding author (email: beckygri@uga.edu); UGA-Georgia Mountain REC, 195 Georgia Mountain Experiment Station Road, Blairsville, GA 30512.

lead to population declines and extinctions (Hines and Hendrix 2005, Potts et al. 2005, Rathcke and Jules 1993, Richards 2001).

Bees are the primary pollinators and the most frequent flower visitors in most ecosystems (Neff and Simpson 1993). The European honey bee is the best-known species, and hives are generally purchased or rented and managed by humans (Barfield et al. 2015). Wild bees including bumble bees (*Bombus* spp.), ground-nesting bees (species of Andrenidae and Apidae), and wood-nesting bees (species of Megachilidae) are also effective pollinators of many crops and native plants (Delaplane et al. 2010). At least 271 bee species have been reported in Georgia (GBIF 2020a); some are listed as endangered. Based on U.S. Geological Survey designations (GBIF 2020a), *Bombus variabilis* Cresson is critically endangered, while *B. affinis* Cresson is imperiled and seven other species (*B. pennsylvanicus* (De Geer), *B. fraternus* (Smith), *B. fervidus* (F.), *B. terricola* Kirby, *Megachile rubi* Mitchell, *Nomia maneei* Cockerell, and *Ashmeadiella floridana* (Robertson)) are vulnerable. Flies (Diptera), butterflies and moths (Lepidoptera), wasps and ants (Hymenoptera), and beetles (Coleoptera) are other common insect pollinators (Bernhardt 2000, Winfree et al. 2011). At least 2,185 species of butterflies and moths are found in Georgia (GBIF 2020b). Twelve lepidopteran species are considered imperiled, and 45 species are vulnerable (GBIF 2020b). A survey among flowering ornamental plants on the University of Georgia Griffin Campus (Griffin, Spalding Co., GA) identified at least 30 species of insect pollinators representing 16 families, including European honey bees, bumble bees, other native bees, wasps, flies, beetles, moths, and butterflies (Harris et al. 2016).

In response to documented pollinator declines, federal policy has been created in recent years to increase conservation efforts (Griffin and Braman 2018). To date, four federal bills related to pollinator conservation have been passed by the U.S. Congress, and 110 laws involving pollinator conservation were passed by 36 states between 2000 and 2017 (Hall and Steiner 2019). The main goals of these laws were to create pollinator habitat, increase research and monitoring, revise pest management practices, reduce pesticide use, and increase education and awareness (Hall and Steiner 2019). Designating state insects and instituting "Pollinator Weeks" have also been popular policy tools for increasing awareness. A "National Pollinator Week" was created by the U.S. Congress in 2006 (U.S. S.Res. 580, 2006), and all states have since created their own pollinator weeks (Hall and Steiner 2019). Georgia also has developed a state-level, nonregulatory conservation plan called Protecting Georgia's Pollinators, which provides factual information about pollinators, promotes communication among stakeholders, and encourages conservation actions (Georgia Department of Agriculture, http://agr.georgia.gov/protecting-georgias-pollinators.aspx, last accessed 01 December 2020).

Policy creation and media attention involving honey bee and monarch butterfly losses have increased public interest in pollinator conservation and education (Baldock 2020, Semmens et al. 2016, vanEngelsdorp et al. 2009). In a recent U.S. survey, 99% of participants considered bees "critical" or "somewhat important" (Wilson et al. 2017). However, despite interest in pollinators, information gaps exist in pollinator identification, pollinator-friendly habitat development and establishment, and implications of pesticide use affecting pollinators (Griffin and Braman 2018). Wilson et al. (2017) found that 79% of survey participants significantly underestimated the number of bee species in the United States, and respondents could correctly distinguish bees from nonbee insects only 70% of the time. These discrepancies offer an opportunity for states and localities to increase pollinator literacy through educational programming. Cooperative Extension systems, especially, can have a significant impact on public understanding of pollinator diversity, conservation, habitat creation, and pesticide use by providing training and educational resources (Griffin and Braman 2018, Sponsler et al. 2019). Many extension systems have already begun to offer educational programs focused on pollinator conservation. The Pollinator Spaces Project (PSP), an outreach program developed by University of Georgia Cooperative Extension Service, addressed these knowledge gaps among Georgia residents and demonstrated public interest in pollinator conservation (Griffin and Braman 2018). The PSP sought to increase public understanding of pollinators and encourage pollinator habitat creation by providing no-cost tools, training materials, seed packets and discounted plants, and workshops (Griffin and Braman 2018). This project met the need for a ready-to-use, adaptable program that could be implemented by extension agents throughout the state. In all, agents led 22 workshops with 621 attendees and held over 9,000 face-to-face contacts with Georgia residents (Griffin and Braman 2018).

Citizen science, also known as community science, has become a common practice for conducting biodiversity and conservation research (Dickinson et al. 2010, Druschke and Seltzer 2012). Citizen scientists are generally volunteers who collect data using standardized experimental protocols with guidance from professional scientists (Birkin and Goulson 2015, Dickinson et al. 2010). Volunteers may submit their collected data, which are often measures of species diversity, weather, and habitat characteristics, by mail or to online databases (Dickinson et al. 2010). Engaging the public in ecological data collection allows research to be conducted at larger spatial and temporal scales and increases the amount of data that can be collected (Birkin and Goulson 2015, Dickinson et al. 2010, Druschke and Seltzer 2012, Gardiner et al. 2012, Martin et al. 2012). Citizen science projects may also have lower operating costs than conventional scientific research (Gardiner et al. 2012). Citizen science has been especially useful in studying population ecology, habitat fragmentation, and the effects of global climate change on animals (Canterbury 2002, Greenwood 2007, Repasky 1991, Root 1988).

While some citizen science projects test hypotheses using experiments, most involve relatively broad, long-term monitoring activities (Dickinson et al. 2010). Long-term pollinator monitoring is crucial for documenting changes in species composition, population growth, and overall health (Klein et al. 2007, Potts et al. 2016). These data are often used to develop conservation plans and establish extension program priorities (Hall et al. 2017, Miller-Rushing et al. 2012). As of now, relatively few long-term studies have monitored pollinator populations, leaving an incomplete understanding of how populations have changed over time and whether certain species need protection (Winfree et al. 2011). Pollination is a proximal service, meaning the most valuable benefits are observed in the same location as the pollinators; thus, urban pollinator conservation plans must possess an understanding of pollinator ecology within a specific area or city (Baldock et al. 2019, Haines-Young and Potschin 1982). Monitoring native bees and other pollinators has been a policy focus for some states, like Minnesota, which created a Native Bee Atlas citizen science program to document all native bees found in the state (Hall and Steiner 2019).

The educational goals of a citizen science project are as important as the research goals (Druschke and Seltzer 2012). Citizen science can be one of the most effective ways to engage the general public in conservation science (Bonney et al. 2009). In addition to data collection, citizen science offers opportunities to create pollinator habitat, educate residents, and increase awareness of conservation issues (Cohn 2008, Deguines et al. 2012, Dickinson et al. 2010, Martin et al. 2012, Saunders et al. 2018). Citizen science can connect individuals to the scientific process, engage participants in scientific thinking, and create a local awareness and appreciation of research objectives (Cooper et al. 2007, 2008; Irwin 2001). Citizen scientists often feel a personal stake in the projects in which they participate (Miller-Rushing et al. 2012). The increased awareness, knowledge, and skills gained through participation in citizen science often increases positive attitudes toward science and inspires proenvironmental and conservation behaviors (Chawla and Cushing 2007, Kelly et al. 2019).

Examples of pollinator-focused citizen/community science projects in the United States include Bumble Bee Watch, which takes place across the United States, the Monarch Larva Monitoring Project in Minnesota, the Great Sunflower Project in San Francisco, the Chicago Area Pollinator Study, and Monarchs Across Georgia (Druschke and Seltzer 2012, MacPhail et al. 2020, Oberhauser and Lebuhn 2012, Potter and LeBuhn 2015). The Urban Pollinators Project, the Bumblebee Conservation Trust "Beewalks," the Great British Bee Count, and Bees 'n Beans are all citizen science projects developed in the United Kingdom (Birkin and Goulson 2015, Westphal et al. 2008).

Georgia's Extension Service has identified several pollinator conservation priorities. The first was to collect baseline pollinator population data, which would inform conservation and management plans developed by policymakers (Sponsler et al. 2019). Most long-term pollinator monitoring programs have occurred in Europe, and there is a dearth of population data on nonbee pollinators in the United States, specifically (Baldock 2020, Klein et al. 2007, Winfree et al. 2009). Beyond baseline population data, descriptive natural history, especially of different pollinator functional guilds, is a valuable component in understanding pollinator dynamics and conservation needs (Klein et al. 2007, Tewksbury et al. 2014). Observing and measuring insect visits to flowering plants is a useful monitoring approach that is employed in research projects conducted by both professional and citizen scientists (Frankie et al. 2002).

The second priority was to educate community members on pollinator health. Central to urban pollinator education is changing the paradigm that urban centers are biological "deserts" and encouraging the view that cities can support healthy pollinator communities (Hall et al. 2017). Some bee taxa even seem to thrive in urban environments (Baldock et al. 2019, Deguines et al. 2012). A key teaching objective is that residents have an opportunity to support pollinators and increase biodiversity with their landscaping and management decisions and practices (Baldock 2020, Burghardt et al. 2009). Residential and community gardens are some of the most ideal habitats for pollinators in urban environments and can make up 22–35% of a city's area (Baldock et al. 2019, Kaluza et al. 2016, Levé et al. 2019, Loram et al. 2007, Matteson et al. 2008). In providing floral resources that offer nectar and pollen, and reproductive resources, like larval host plants or nesting materials, backyard gardens have the potential to offset some negative effects of habitat loss and urbanization on wild pollinators (Frankie et al. 2005, Majewska and Altizer 2020, Matteson et al. 2008, McIntyre and Hostetler 2001, Scheper et al. 2014, Wratten et al. 2012). In an urban pollinator survey, Baldock et al. (2019) saw the greatest bee and hover fly (Diptera: Syrphidae) abundance in residential and community gardens, with up to 52 times more bees in gardens than in other land-use types. The authors estimated that residential gardens support 54–83% of the pollinators in a city. Native bee species, including *Lasioglossum imitatum* Smith and *Halictus ligatus* Say, were observed in a survey of ornamental plantings in Griffin (Spalding Co.), GA, also demonstrating that gardens can support native pollinators (Harris et al. 2016). Increasing access to floral resources and "forage" is the action that may have the widest impact on pollinators (Hall et al. 2017, Hennig and Ghazoul 2012). Floral resources are a limiting factor for pollinators across any landscape, and changes in floral resource availability, whether positive or negative, tend to be reflected in pollinator populations (Winfree et al. 2011). Increasing forage with butterfly gardens, wildflower strips, and "bee pastures," and offering nesting habitat with bee houses and "hotels" are ways residents can make landscapes more favorable to pollinators (Baldock et al. 2019, Delaplane et al. 2010, Hostetler and Main 2010, Tipton et al. 2019, Wratten et al. 2012).

The Great Georgia Pollinator Census (GGaPC), a citizen science project launched by the University of Georgia Extension Service in 2019, sought to meet these extension priorities. The primary goal of the project was to generate snapshots of pollinator populations throughout the state using volunteer-collected monitoring data. The GGaPC asked participants to count and identify insects visiting a single plant over a specified time period, just as the Audubon Society's Great Backyard Bird Count does with birds (Van Vliet and Moore 2016). A secondary goal of the project was to encourage residents to create pollinator habitat in home gardens by installing plants that provide forage and nesting resources. Gardeners are interested in creating sustainable habitat that can withstand Georgia summer droughts, attract few pest insects, and flourish in Georgia's climate (Griffin and Braman 2018). This goal was addressed by making research-based plant recommendations available to gardeners through flyers, a social media campaign, extension workshops, and partner trainings (Harris et al. 2016). Plants that would bloom during the dates of the Census were emphasized. Another secondary goal was to increase Georgia residents' entomological literacy and encourage positive attitudes toward insects. We wanted gardeners to appreciate insect biodiversity in their gardens and learn that most of those insects are not pests. This was a fundamental part of the GGaPC and one that has not been achieved by other citizen science projects (Druschke and Seltzer 2012). University of Georgia pilot projects conducted in 2017 and 2018 demonstrated that it was possible to increase Georgians' insect knowledge and understanding (B.G. and S.K.B. unpubl. data). In the Chicago Area Pollinator Study, Druschke and Seltzer (2012) reported a significant reduction in participants' fear of bees and an increase in the number of bee types that participants could name. Both were results of increased familiarity with bees following participation in a citizen science project. The GGaPC required the involvement of educators and schools to achieve its goal of increased entomological literacy. The Census was crafted to encourage the participation of school groups, especially in schools with science, technology, engineering, and math (STEM) programs and those working toward STEM certification. The GGaPC provided project materials to Title 1 and low-income schools at no cost to remove financial barriers to participation.

Pollinator conservation in urban centers will only be achieved with community participation. Education and access to science-based information is integral for encouraging Georgians to participate in pollinator conservation efforts (Baldock 2020, Potts et al. 2016, Wilson et al. 2017). Community members must be engaged and have a basic understanding of pollinator needs, especially the needs of native species and non–honey bee insects (Wilson et al. 2017). The extension system is primed to help community members invest time and resources in environmental action and to facilitate skill building (Chawla and Cushing 2007). Nature-based experiences are especially powerful tools for encouraging environmentalism in children. Educators, like Cooperative Extension professionals, can encourage proenvironmental attitudes in young people by providing learning opportunities and teaching actionable skills (Chawla and Cushing 2007).

Materials and Methods

The first Great Georgia Pollinator Census took place on 23–24 August 2019. Participants were asked to count the insects that landed on a pollinator plant of their choosing within a 15-min period. A pollinator plant was defined as one on which participants had noticed a high level of insect activity. Participants grouped insect visitors into one of eight taxonomic categories: (1) carpenter bee, (2) bumble bee, (3) honey bee, (4) small bee, (5) wasp, (6) fly, (7) butterfly/moth, or (8) other insect. Participants were asked to upload their count data to the project website. Because a count was recorded each time an insect landed on the pollinator plant, participants were actually tallying insect visits as opposed to the true number of insects present. A challenge was to establish Census counting criteria that were within participants' skill levels but still effective for gathering accurate data. Working with project participants, University of Georgia Cooperative Extension agents, Master Gardener Extension volunteers, entomologists, horticulturists, and other experienced gardeners during the 2017 and 2018 pilot projects helped to fine-tune the counting criteria.

The project was housed on a WordPress website, https://GGaPC.org. This allowed the project coordinator to manage this statewide project from one geographic area. The website contained the details of how to successfully participate in the Census; a portal to sign up for a monthly educational newsletter; resources for educators wanting to use this as a no-cost STEM project, and; a list of public pollinator events. The website was fluid and changed over time, adding resources as developed. The social media campaign centered on the Georgia Pollinator Census Facebook page (https://www.facebook.com/groups/1775862132659278/), where we shared educational information and encouraged participation of all group members. Starting in January 2019, our outreach methods emphasized best management practices and plant selection when building a successful pollinator garden (i.e., the use of trees and shrubs in pollinator habitat, use of host plants including native milkweed (*Asclepias* spp.) providing nesting materials for nesting bees and wasps, or providing larval food sources for native butterflies).

Later in the spring, we emphasized the insect identification process using pictorial memes, links to more detailed information, and #FunFactFridays, where we provided more technical information. In-person programming on insect identification from project partners as well as Cooperative Extension offices increased during this time. The Facebook platform was useful for interaction among participants and entomologists. Participants could ask questions and show photos of their pollinator gardens and insects on Facebook, and entomologists could answer them in real time. The Facebook platform also promoted workshops and events of our partners under the “Events” tab.

We used social media and newsletters for insect identification quizzes in the weeks just prior to the Census. We promoted this as preparation for the actual Census. During the Census dates, the project coordinator as well as several entomologists were available through social media, cell phone, and email to answer any questions.

University of Georgia Cooperative Extension agents were an integral part of the project. Agents were provided with a “grab-and-go” program with PowerPoint presentations, news release templates, social media memes, programming ideas, and publications. They were encouraged to hold events in their counties, working within the frame of their existing programs. Agents hosted several opportunities for train-the-trainer sessions so that they could share Census information with Master Gardeners, garden club presidents, and community leaders. They greatly expanded the reach of the Census project.

Partners outside the university were recruited to help promote the project and to host counting events and assist in insect education. They included Georgia Institute of Technology, Emory University, University of North Georgia, Georgia Association of Water Conservation Districts, Bee City USA, Georgia Department of Natural Resources, North American Butterfly Association Georgia Chapter, Monarchs Across Georgia, and others.

Schoolteachers were recruited to participate with their students. As the use of school gardens is increasing in Georgia, creating pollinator habitat can assist school gardeners in creating successful and beautiful gardens (Food Well Alliance 2017). Providing an avenue like the Census to tie the garden to school curriculum would be an important service to teachers who may not have an entomology background. Teaching citizens, especially youth, about native pollinators can lead to increased pollinator conservation (Chawla and Cushing 2007). Many schools held practice counts and created curricula and school events centered on the Census. Special training sessions were held for educators, and the project coordinator was available for consultation.

News outlets assisted in promoting the project by interviewing the project coordinator and other partners and including them in news articles. A multimedia campaign resulted in pollinator characters that could be used on flyers, signs, and on social media (Griffin et al. 2021). This multipronged, yearlong campaign furthered the goal of educating as many participants as possible.

Insect identification education. Accurate counting of data was essential for the success of the project. Past citizen science project work identifies some barriers to the generation of usable data when working with insects. Recruiting of participants who are interested and have some experience with insects can improve the quality of data generated (Birkin and Goulson 2015). For this project, effective recruitment to the project and training in insect identification using multiple educational outlets was imperative to project success (Ratnieks et al. 2016). The design of the project is a compromise between creating an ideal statistical model of collecting data and making the project sufficiently straightforward to recruit the citizen scientists who are comfortable with the project objectives and methods (Pocock et al. 2015). The insect categories were defined so that the participants could increase their insect knowledge without feeling the counting requirements were too difficult. The crux for the education was the definition of categories found in the *Great Georgia Pollinator Insect Counting and Identification Guide* (https://ggapc.org/wp-content/uploads/2021/02/GGaPC-Counting-Guide-2021.docx, accessed 01 December 2020). This guide is a comprehensive booklet centered on the insect identification needed to successfully participate in the Census. It contains detailed insect category descriptions along with many example photographs. Housed on the website, it was easily downloadable and printable.

During insect identification training, we taught participants to identify several bee categories, including carpenter bees, bumble bees, and honey bees. Carpenter bees were denoted as 14–19 mm in length with a lumbering flight pattern, wide head on a stout body, dense hair covering the head and thorax, and hairless/shiny abdomen. Our goal was to have participants recognize Georgia's common large carpenter bee species, *Xylocopa* spp. This bee is often thought of as a pest due to the nesting habit of excavating holes in untreated wood, but this species is considered an effective pollinator (Keasar 2010). During the Census we hoped to bring attention to the positive pollination services this bee provides. To distinguish between carpenter bees and bumble bees, we taught participants that bumble bees have "hairy rears" while carpenter bees have "shiny heinies." We also taught that a carpenter bee is a "Mack truck" while a bumble bee is more of a "pickup truck." Carpenter bees are one of the first to emerge in the spring and would still be visible in August during the Census. Carpenter bees were an insect that we could teach participants to confidently identify.

Bumble bees were described as 10–19 mm in length, having small heads on a larger thorax and abdomen, and covered with dense hair. We taught the concept of buzz pollination, how bumble bee hairs are designed to be pollen attractors, and how they move pollen (Amador et al. 2017). Participants were encouraged to advance their bumble bee identification skills by participating in The Bumble Bee Watch project (https://www.bumblebeewatch.org).

Honey bees were described as 12–55 mm in length, showing definite body stripe patterns, and having less hair on their abdomens than bumble bees. Participants were educated on the structure of the honey bee hive and the social behavior of these insects. Conservation efforts centered on the honey bee were also emphasized using Protecting Georgia's Pollinators as a reference for conservation in Georgia (Georgia Department of Agriculture, http://agr.georgia.gov/protecting-georgias-pollinators.aspx, last accessed 01 December 2020).

Small bees were defined as any bee that is smaller than a honey bee. This is the size of many non-*Bombus* native bees (Schlueter 2019). Prior to the Census, our interviews indicated many people were unaware of the quantity and types of native bees in Georgia. Our educational process stressed the different types of native bees and their benefits. One popular workshop taught how to create sustainable bee boxes. Other workshops emphasized leaving nesting sites for ground-dwelling bees and hollow spent flower stems for cavity-nesting bees and wasps.

Flies were identified in comparison to bees. For this study, a fly had two wings, had no pollen-gathering structures, small antennae, and eyes that were placed towards the top of their head. We taught the participants about bee mimics and how many flies were beneficial predators and parasitoids.

Wasps were identified as sleek insects lacking hair, usually having a small waist and no pollen-gathering structures. Educational efforts centered on these insects as predators or as parasitoids. Most participants felt comfortable identifying insects in the butterflies/moths category, having previously noticed them in their gardens. Educational components discussed nontraditional Lepidoptera, like ermine moths (Lepidoptera: Yponomeutidae) providing habitat for all phases of butterfly life cycles, and migratory butterflies. Participants were encouraged to register their gardens as part of the Monarch Watch Program (https://monarchwatch.org). The "other insect" category included any insect that did not fall into any of the seven categories, including beetles (Coleoptera), mantids (Mantodea), ants (Hymenoptera), etc.

Statistical analyses. Data were analyzed using SAS 9.4 software (SAS Institute 2014). The PROC FREQ procedure in SAS was used to construct the contingency tables to perform chi-square test. A chi-square test of independence was performed to determine the association between honey bee hive presence and the type of insects observed. Similarly, a chi-square test was performed to analyze the relationship between location (rural/urban) and the type of insects observed.

Results

There were 4,698 counts uploaded to the website from 134 of the 159 Georgia counties. No results were recorded from 25 counties. Insect visits recorded totaled 131,844. Results listed in Table 1 represent insect category counts for each Georgia county. DeKalb (394 counts), Fulton (379), and Gwinnett (332) counties reported the highest number of counts. Appling (0.50%), Lumpkin (0.34%), and Twiggs (0.32%) reported the highest number of counts per resident population.

Counts were held at 135 Georgia schools, and 1,100 participants indicated that they counted as part of a STEM event. A total of 934 participants reported that they created or added to a pollinator garden as part of the Census. Plants observed during counting included abelia (*Abelia* × *grandiflora* (Rovelli ex André) Rehder), Autumn Joy sedum (*Sedum telephium* L. 'Autumn Joy'), basil (*Ocimum basilicum* L.), black-eyed Susan (*Rudbeckia hirta* L.), butterfly weed (*Asclepias tuberosa* L.), butterfly bush (*Buddleia daviddi* Franch), common boneset (*Eupatorium boneset* L.), lantana (*Lantana camara* L.), mountain mint (*Pycnanthemum muticum* Persoon), purple coneflower (*Echinacea purpurea* L.), and zinnia (*Zinnia elegans* L.).

Honey bee influence. As participants uploaded their counts, they were asked if honey bee hives were present within 8 km (5 mi) of their garden. The purpose of the question was to explore whether the presence of honey bees influenced the presence of other pollinators. Participant choices were "Yes," "No," and "I don't

Table 1. The 2019 Great Georgia Pollinator Census insect counts by Georgia counties.

County	Carpenter Bees	Bumble Bees	Honey Bees	Small Bees
Appling	127	230	162	296
Bacon	0	0	1	0
Baker	1	1	1	12
Baldwin	3	56	1	22
Banks	0	7	0	3
Barrow	52	50	32	97
Bartow	27	165	28	177
Berrien	1	57	63	139
Bibb	80	591	149	454
Bleckley	1	6	23	12
Brooks	1	3	0	0
Bryan	64	10	17	19
Bulloch	12	21	11	51
Burke	0	0	2	0
Butts	3	8	0	4
Calhoun	10	92	20	90
Camden	12	42	52	54
Candler	0	0	0	0
Carroll	231	251	142	447
Catoosa	0	45	1	19
Chatham	308	527	284	646
Chattooga	36	191	68	145
Cherokee	332	330	105	633
Clarke	657	351	155	613
Clayton	4	10	2	39
Cobb	865	442	263	795
Coffee	4	11	0	5
Colquitt	53	81	90	68
Columbia	209	234	63	217
Cook	1	0	1	0

Table 1. Extended.

Wasps	Flies	Butterflies and Moths	Other Insects	Total Insects	Total Counts (*n*)
251	317	362	453	2,198	93
7	0	47	7	62	2
4	12	158	7	196	5
52	74	91	23	322	16
0	0	19	0	29	4
67	104	176	163	741	25
100	107	222	66	892	24
231	69	73	111	744	17
218	327	767	420	3,006	98
7	7	11	5	72	2
1	0	2	0	7	1
69	20	132	19	350	6
47	58	127	57	384	15
3	1	3	2	11	2
22	6	40	7	90	7
33	37	40	114	436	6
52	66	78	39	395	17
0	0	10	11	21	1
147	471	2,453	842	4,984	167
15	5	10	4	99	3
452	401	452	405	3,475	111
91	53	157	83	824	35
459	546	723	491	3,619	156
542	644	648	618	4,228	207
26	49	26	54	210	8
291	490	1,246	809	5,201	235
2	0	12	5	39	1
86	375	61	566	1,380	53
186	230	491	239	1,869	69
2	4	2	1	11	1

Table 1. Continued.

County	Carpenter Bees	Bumble Bees	Honey Bees	Small Bees
Coweta	330	59	13	179
Crawford	0	0	0	0
Crisp	0	0	4	3
Dade	2	5	4	147
Dawson	8	26	6	28
Decatur	26	16	1	7
DeKalb	2,544	2,566	2,069	3,327
Dodge	0	1	0	0
Dooly	0	46	2	5
Dougherty	33	44	62	103
Douglas	132	95	17	137
Early	0	6	2	2
Effingham	10	13	19	68
Emanuel	0	2	2	1
Evans	2	2	1	1
Fannin	23	210	67	377
Fayette	105	33	25	378
Floyd	48	87	47	136
Forsyth	105	89	50	310
Franklin	0	0	0	23
Fulton	1,115	1,680	1,124	1,519
Gilmer	6	10	5	47
Glynn	99	23	14	77
Gordon	35	30	33	184
Grady	4	13	48	71
Greene	1	5	1	47
Gwinnett	1,197	938	475	1,138
Habersham	6	8	7	49
Hall	300	233	80	284
Hancock	2	0	0	0
Haralson	4	6	0	4

Table 1. Extended, Continued.

Wasps	Flies	Butterflies and Moths	Other Insects	Total Insects	Total Counts (*n*)
358	249	607	467	2,262	72
0	1	18	1	20	1
3	3	10	8	31	3
4	25	43	18	248	7
21	8	15	15	127	8
18	40	18	44	170	7
2,978	1,472	3,050	2,365	20,371	394
5	8	3	3	20	1
51	4	8	1	117	3
66	76	167	163	714	53
111	81	577	166	1,316	52
0	1	0	0	11	1
28	7	71	20	236	9
11	6	6	9	37	4
4	7	10	1	28	5
306	214	275	251	1,723	26
78	369	918	296	2,202	103
106	149	225	303	1,101	67
260	275	339	344	1,772	98
6	2	43	4	78	3
760	966	1,759	1,376	10,299	379
43	23	56	53	243	15
70	91	61	145	580	17
81	170	114	217	864	45
55	42	18	69	320	8
17	14	63	4	152	3
842	986	2,345	1,594	9,515	332
81	13	102	31	297	13
152	215	1,012	284	2,560	103
4	0	22	0	28	3
12	7	78	5	116	4

Table 1. Continued.

County	Carpenter Bees	Bumble Bees	Honey Bees	Small Bees
Harris	66	88	82	272
Hart	36	2	12	16
Heard	12	2	0	0
Henry	12	24	14	47
Houston	48	94	63	185
Irwin	0	0	0	0
Jackson	85	62	5	146
Jasper	16	24	19	30
Jeff Davis	0	4	0	4
Jenkins	5	8	21	33
Jones	1	12	1	166
Lamar	7	48	6	207
Laurens	2	14	0	18
Lee	20	18	164	27
Liberty	23	11	13	47
Lincoln	0	0	0	0
Long	0	0	0	1
Lowndes	22	41	54	103
Lumpkin	177	348	115	194
Macon	8	20	14	22
Madison	5	11	13	35
Marion	0	5	11	7
McDuffie	0	4	5	8
McIntosh	4	8	5	22
Meriwether	13	14	8	13
Mitchell	3	5	9	10
Monroe	8	4	0	6
Morgan	16	11	20	52
Muscogee	20	18	15	36
Newton	28	103	63	170
Oconee	84	192	166	477

Table 1. Extended, Continued.

Wasps	Flies	Butterflies and Moths	Other Insects	Total Insects	Total Counts (*n*)
210	295	623	645	2,281	67
77	34	37	29	243	10
0	0	2	0	16	2
32	35	213	74	451	28
146	175	146	180	1,037	51
1	3	5	1	10	1
303	178	307	69	1,155	26
18	42	77	67	293	9
2	4	6	12	32	4
23	18	25	37	170	10
68	49	241	101	639	6
58	76	184	31	617	21
71	71	35	78	289	9
35	45	78	125	512	20
8	51	5	105	263	18
0	0	0	40	40	1
0	0	0	1	2	1
60	43	90	100	513	25
146	266	477	438	2,161	113
36	36	161	49	346	21
43	45	40	49	241	8
10	11	70	8	122	6
21	16	35	20	109	4
5	3	33	21	101	11
5	12	32	11	108	4
2	4	25	2	60	6
17	11	32	9	87	9
45	54	92	40	330	17
13	10	13	20	145	7
85	143	309	263	1,164	54
586	379	478	411	2,773	98

Table 1. Continued.

County	Carpenter Bees	Bumble Bees	Honey Bees	Small Bees
Oglethorpe	10	87	195	229
Paulding	78	87	31	79
Peach	0	3	5	1
Pickens	21	35	7	13
Pierce	0	0	3	1
Pike	19	30	8	28
Polk	0	14	0	5
Pulaski	8	5	0	8
Putnam	37	26	25	39
Rabun	8	83	70	79
Randolph	3	26	9	20
Richmond	165	525	214	351
Rockdale	96	76	40	118
Schley	0	2	0	4
Screven	5	53	3	46
Seminole	0	0	5	7
Spalding	22	24	4	260
Stephens	9	10	3	20
Sumter	3	33	15	28
Talbot	1	1	0	0
Taliaferro	0	3	0	0
Taylor	8	11	9	5
Terrell	75	12	47	23
Thomas	18	114	58	292
Tift	4	49	40	95
Toombs	0	0	0	6
Towns	34	167	72	212
Troup	10	4	0	32
Twiggs	0	0	0	0
Union	179	371	122	854
Upson	77	144	16	311

Table 1. Extended, Continued.

Wasps	Flies	Butterflies and Moths	Other Insects	Total Insects	Total Counts (*n*)
152	169	304	247	1,393	19
77	145	241	163	901	38
3	15	44	155	226	5
31	13	91	15	226	7
7	6	0	20	37	2
5	55	59	72	276	13
2	2	0	1	24	2
1	16	60	6	104	2
20	23	50	18	238	7
31	27	144	135	577	34
28	16	75	15	192	15
232	336	179	274	2,276	98
334	90	547	60	1,361	29
2	1	13	1	23	2
66	40	108	70	391	11
3	8	8	3	34	2
176	140	133	86	845	30
7	17	16	18	100	7
15	47	113	96	350	24
0	0	2	1	5	1
0	4	1	3	11	1
11	0	134	6	184	9
26	18	9	26	236	4
260	338	521	444	2,045	84
235	98	60	118	699	36
2	6	4	5	23	1
77	80	279	97	1,018	26
29	29	136	39	279	15
0	0	0	1	1	27
345	177	415	139	2,602	47
146	49	570	81	1,394	49

Table 1. Continued.

County	Carpenter Bees	Bumble Bees	Honey Bees	Small Bees
Walker	0	4	1	83
Walton	186	171	43	436
Ware	0	1	0	2
Warren	1	2	0	3
Washington	0	0	3	12
Wayne	17	50	89	40
White	5	20	18	58
Whitfield	0	2	2	6
Wilcox	9	2	0	11
Wilkes	2	3	1	28
Worth	4	14	9	131
Total	11,066	13,517	7,979	20,039

know." Data from participants who answered "I don't know" were excluded from analysis. Counts totaling 2,257 (73,601 insect visits) were submitted from gardens with honey bee hives nearby (Table 2), while 378 counts (8,946 insect visits) were from gardens with no honey bee hives nearby. Chi-square test analysis indicated a

Table 2. Insect numbers from gardens with or without honey bee hives present within 8 km (5 mi).*

Identification Group	With Honey Bee Hives	Without Honey Bee Hives
Carpenter bees	6,399	763
Bumble bees	8,057	600
Honey bees	5,768	250
Small bees	11,417	1,251
Wasps	8,302	556
Flies	7,650	1,135
Butterflies and moths	15,432	2,826
Other insects	10,576	1,565
Total number of insects	73,601	8,946
Total number of counts	2,257	378

* Chi-square statistics: df = 7; $P < 0.001$.

Table 1. Extended, Continued.

Wasps	Flies	Butterflies and Moths	Other Insects	Total Insects	Total Counts (*n*)
12	16	44	19	179	11
501	262	486	313	2,398	54
18	13	0	9	43	4
5	6	18	9	44	4
0	2	7	2	26	4
63	89	99	63	510	25
40	14	27	27	209	10
1	10	12	4	37	4
12	10	25	31	100	7
24	48	32	11	149	26
32	14	83	28	315	9
15,151	14,555	29,692	19,845	131,844	4,698

significant ($\chi^2 = 1{,}120.14$; df = 7, Y; $P < 0.001$) association between the type of insect present and whether or not there were honey bee hives present nearby. When honey bee hives were present within 8 km (5 mi), wild bees were 80% of total bees reported. When hives were absent, wild bees were 90% of the total bees observed.

Urban versus rural counts. Pilot projects leading to the Great Georgia Pollinator Census indicated that there could be a difference in pollinator populations between urban and rural gardens (Griffin and Braman 2021). The U.S. Census Bureau criteria for urban (more than 50,000 residents) and rural (fewer than 50,000 residents) distinctions were used in the data analysis (U.S. Census Bureau 2019). Georgia counties considered as urban were Barrow, Bartow, Bibb, Bulloch, Camden, Carroll, Catoosa, Chatham, Cherokee, Clarke, Clayton, Cobb, Columbia, Coweta, DeKalb, Dougherty, Douglas, Effingham, Fayette, Floyd, Forsyth, Fulton, Glynn, Gordon, Gwinnett, Hall, Henry, Houston, Jackson, Liberty, Lowndes, Muscogee, Newton, Paulding, Richmond, Rockdale, Spalding, Troup, Walker, Walton, and Whitfield. The 2019 population of these counties was listed as 8,217,149 out of a total Georgia population of 10,617,423 (U.S. Census Bureau 2019). Chi-square analysis indicated that there may be some dependency between location (urban or rural) and type of insect present ($\chi^2 = 1{,}498.21$; df = 7, Y; $P <$ 0.001; Table 3). Carpenter bees, for example, represented 10% of the total insects and 24.1% of bees in urban samples, while they accounted for 3% of total insects and 11.2% of total bees in rural counties.

Table 3. Counts from urban counties (population >50,000) and rural counties (population <50,000).*

Identification Group	Urban Counties	Rural Counties
Carpenter bees	9,637	1,429
Bumble bees	10,195	3,322
Honey bees	5,877	2,102
Small bees	14,181	5,858
Wasps	10,501	4,650
Flies	10,267	4,288
Butterflies and moths	21,525	8,167
Other insects	13,716	6,129
Total insects counted	95,899	35,945
Total number of counts	3,347	1,351

* Chi-square test statistics: df = 7; $P < 0.001$.

Discussion

The high participation rate in the first 2019 Great Georgia Pollinator Census confirms that there is interest among Georgians in pollinating insects. Over 1,000 participants signed up for a monthly educational newsletter and joined the Georgia Pollinator Spaces Facebook Group. More than 100 educational events were held prior to the Pollinator Census. The enthusiastic participation in these programs confirms that residents were interested in increasing their pollinator insect knowledge. Insects were tallied at events given at public gardens, nonprofit organizations, civic clubs, and businesses.

This project would not have been possible without the involvement of the project partners and University of Georgia Cooperative Extension agents. These partners allowed us to expand the project's reach at a low cost and with limited dedicated personnel (Griffin et al. 2021). Some comments from project participants included:

> "There are many insects attracted to one plant!"

> "That the fear you feel about pollinators decreases as your knowledge increases."

> "It gave me a much better understanding of how important bees are to our gardens."

And from an educator:

"This count was done with my first grade STEM class. My students learned a pollinator must visit more than one flower to help create a seed. They learned about the sticky stigma and the pollen anthers."

The feedback from workshops and the Census participants indicates that people are excited to learn more about pollinators and that learning about these insects gives participants the confidence to learn more. The creation of pollinator spaces by a large number of participants indicates that projects such as these can aid in the improvement of public perception of pollinators and pollinator conservation. The project participants were guided through habitat creation, ensuring that gardeners would use best management practices for insects. The method of placing the insects counted into the eight insect identification categories meant that participants did not feel intimidated by in-depth identification criteria. They indicated that they felt comfortable participating in the counts and that they had provided useful data. We feel the number of participants would decline dramatically if the counting criteria were too specific or relied more heavily on taxonomic categories. Pollinator count data can be used as a baseline to compare to subsequent pollinator Censuses.

Future pollinator censuses, such as the one described herein, could be improved by collecting more demographic information such as age, gender, and the entomological education background of participants. We will encourage participation in counties that were not represented and continue to create more educational content. Plans are in place for this statewide pollinator census to be an annual event.

Acknowledgments

We thank all of the citizen scientists across the state of Georgia who participated in the Great Georgia Pollinator Census. Thank you to the Georgia educators and students who participated. We also thank these partners who fully embraced the project: Bee Cause Project; Bee City USA of the Xerces Society; Callaway Gardens; Environmental Resources Management; Georgia Department of Natural Resources Wildlife Resources Division; The Garden Club of Georgia; Georgia Native Plant Society; Georgia Tech Urban Bee Lab; Monarchs Across Georgia; North American Butterfly Association Georgia (Piedmont) Chapter; State Botanical Garden of Georgia; University of Georgia Honey Bee Program; University of North Georgia's College of Education; and the USDA Natural Resources Conservation Service. This project was funded in part by USDA NIFA EIP Award Number 2017-70006-27202.

References Cited

Amador, G.J., M. Matherne, D.A. Waller, M. Mathews, S.N. Gorb and D.L. Hu. 2017. Honey bee hairs and pollenkitt are essential for pollen capture and removal. Bioinspir. Biomim. 12(2): 026015. doi: https://doi.org/10.1088/1748-3190/aa5c6e.

Baldock, K.C. 2020. Opportunities and threats for pollinator conservation in global towns and cities. Curr. Opin. Insect Sci. 38: 63–71.

Baldock, K.C.R., M.A. Goddard, D.M. Hicks, W.E. Kunin, N. Mitschunas, H. Morse, L.M. Osgathorpe, S.G. Potts, K.M. Robertson, A.V. Scott, P.P.A. Staniczenko, G.N. Stone, I.P. Vaughan and J. Memmott. 2019. A systems approach reveals urban pollinator hotspots and conservation opportunities. Nat. Ecol. Evol. 3: 363–373.

Barfield, A.S., J.C. Bergstrom, S. Ferreira, A.P. Covich and K.S. Delaplane. 2015. An economic valuation of biotic pollination services in Georgia. J. Econ. Entomol. 108: 388–398.

Bernhardt, P. 2000. Convergent evolution and adaptive radiation of beetle-pollinated angiosperms. Plant Syst. Evol. 222: 293–320.

Birkin, L. and D. Goulson. 2015. Using citizen science to monitor pollination services. Ecol. Entomol. 40: 3–11.

Bonney, R., H. Ballard, R. Jordan, E. McCallie, T. Phillips, J. Shirk and C.C. Wilderman. 2009. Public participation in scientific research: Defining the field and assessing its potential for informal science education. The Center for Advancement of Informal Science Education Inquiry Group Report, ERIC #ED519688.

Burghardt, K.T., D.W. Tallamy and W.G. Shriver. 2009. Impact of native plants on bird and butterfly biodiversity in suburban landscapes. Conserv. Biol. 23: 219–224.

Canterbury, G. 2002. Metabolic adaptation and climatic constraints on winter bird distribution. Ecology 83: 946–957.

Chawla, L. and D.F. Cushing. 2007. Education for strategic environmental behavior. Environ. Educ. Res. 13: 437–452.

Cohn, J.P. 2008. Citizen science: Can volunteers do real research? BioScience 58: 192–197.

Cooper, C.B., J. Dickinson, T. Phillips and R. Bonney. 2007. Citizen science as a tool for conservation in residential ecosystems. Ecol. Soc. 12: 1–11.

Cooper, C.B., J.L. Dickinson, T. Phillips and R. Bonney. 2008. Science explicitly for nonscientists. Ecol. Soc. 13: 1–2.

Deguines, N., R. Julliard, M. de Flores and C. Fontaine. 2012. The whereabouts of flower visitors: Contrasting land-use preferences revealed by a country-wide survey based on citizen science. PLoS One 7: 1–9.

Delaplane, K.S., P.A. Thomas and W.J. McLaurin. 2010. Bee pollination of Georgia crop plants. Univ. Ga. Coop. Ext. Bull. 1106: 15.

Dickinson, J.L., B. Zuckerberg and D.N. Bonter. 2010. Citizen science as an ecological research tool: Challenges and benefits. Annu. Rev. Ecol. Evol. Syst. 41: 149–172.

Druschke, C.G. and C.E. Seltzer. 2012. Failures of engagement: Lessons learned from a citizen science pilot study. Appl. Environ. Educ. Commun. 11: 178–188.

Food Well Alliance. 2017. Atlanta's local food baseline report. 1:7. 1 December 2020. (https://static1.squarespace.com/static/543c2e74e4b0a10347055c4d/t/59d66bbdd7bdceaa9c93ba63/1507224523326/FoodWellAlliance_LocalFoodBaselineReport2017_Final.pdf).

Frankie, G.W., R.W. Thorp, M. Schindler, J. Hernandez, B. Ertter and M. Rizzardi. 2005. Ecological patterns of bees and their host ornamental flowers in two northern California cities. J. Kans. Entomol. Soc. 78: 227–246.

Frankie, G.W., S.B. Vinson, R.W. Thorp, M.A. Rizzardi and L.E. Newstrom-Lloyd. 2002. Monitoring: An essential tool in bee ecology and conservation, Pp. 187–198. *In* Kevan, P. and V. Imperatriz Fonseca (eds.), Pollinating Bees—The Conservation Link Between Agriculture and Nature. Ministry of the Environment, Brasília, Brazil.

Gardiner, M.M., L.L. Allee, P.M.J. Brown, J.E. Losey, H.E. Roy and R.R. Smyth. 2012. Lessons from lady beetles: Accuracy of monitoring data from US and UK citizen-science programs. Front. Ecol. Environ. 10: 471–476.

[GBIF] Global Biodiversity Information Facility. 2020a. GBIF occurrence download. 15 January 2021. (https://doi.org/10.15468/dl.a5w9qh).

[GBIF] Global Biodiversity Information Facility. 2020b. GBIF occurrence download. 15 January 2021. (https://doi.org/10.15468/dl.25dvjt).

Greenwood, J.J.D. 2007. Citizens, science and bird conservation. J. Ornithol. 147(5): S77–S124. doi: 10.1007/s10336-007-0239-9.

Griffin, B. and K. Braman. 2018. Expanding pollinator habitats through a statewide initiative. J. Ext. 56(2): Article 2IAW6. Available at https://www.joe.org/joe/2018april/iw6.php.

Griffin, B. and K. Braman. 2021. School and community garden pollinator census: A pilot project in Georgia. J. Entomol. Sci. 56(3): pp. 287–304. doi: https://doi.org/10.18474/JES20-38

Griffin, B., R. Braman, S. Yaza and M. Griffin. 2021. The strategic use of multimedia in the Great Georgia Pollinator Census citizen science project. Citizen Sci. 6: 1–13. doi: https://doi.org/10.5334/cstp.334.

Haines-Young, R. and M. Potschin. 1982. The links between biodiversity, ecosystem services and human well-being, Pp. 8501–8507. *In* Raffaelli, D. and C. Frid (eds.), Ecosystem Ecology: A New Synthesis. British Ecological Society Ecological Reviews Series, Cambridge, U.K.

Hall, D.M., G.R. Camilo, R.K. Tonietto, J. Ollerton, K. Ahrné, M. Arduser, J.S. Ascher, K.C.R. Baldock, R. Fowler, G. Frankie, D. Goulson, B. Gunnarsson, M.E. Hanley, J.I. Jackson, G. Langellotto, D. Lowenstein, E.S. Minor, S.M. Philpott, S.G. Potts, M.H. Sirohi, E.M. Spevak, G.N. Stone and C.G. Threlfall. 2017. The city as a refuge for insect pollinators. Conserv. Biol. 31: 24–29.

Hall, D.M. and R. Steiner. 2019. Insect pollinator conservation policy innovations: Lessons for lawmakers. Environ. Sci. Policy 93: 118–128.

Harris, B.A., S.K. Braman and S.V. Pennisi. 2016. Influence of plant taxa on pollinator, butterfly, and beneficial insect visitation. HortScience 51: 1016–1019.

Hennig, E.I. and J. Ghazoul. 2012. Pollinating animals in the urban environment. Urban Ecosyst. 15: 149–166.

Hines, H.M. and S.D. Hendrix. 2005. Bumble bee (Hymenoptera: Apidae) diversity and abundance in tallgrass prairie patches: Effects of local and landscape floral resources. Environ. Entomol. 34: 1477–1484.

Hostetler, M.E. and M.B. Main. 2010. Tips to create biodiverse, urban communities. J. Ext. 48: 1–4.

Irwin, A. 2001. Constructing the scientific citizen: Science and democracy in the biosciences. Public Underst. Sci. 10: 1–18.

Kaluza, B.F., H. Wallace, T.A. Heard, A.-M. Klein and S.D. Leonhardt. 2016. Urban gardens promote bee foraging over natural habitats and plantations. Ecol. Evol. 6: 1304–1316.

Keasar, T. 2010. Large carpenter bees as agricultural pollinators. Psyche: J. Entomol. 2010: 1–7. doi: https://doi.org/10.1155/2010/927463.

Kelly, R., A. Fleming, G.T. Pecl, A. Richter and A. Bonn. 2019. Social license through citizen science: A tool for marine conservation. Ecol. Soc. 24: 1–16.

Klein, A.M., B.E. Vaissière, J.H. Cane, I. Steffan-Dewenter, S.A. Cunningham, C. Kremen and T. Tscharntke. 2007. Importance of pollinators in changing landscapes for world crops. Proc. R. Soc. B. 274: 303–313.

Levé, M., E. Baudry and C. Bessa-Gomes. 2019. Domestic gardens as favorable pollinator habitats in impervious landscapes. Sci. Total Environ. 647: 420–430.

Loram, A., J. Tratalos, P.H. Warren and K.J. Gaston. 2007. Urban domestic gardens (X): The extent and structure of the resource in five major cities. Landsc. Ecol. 22: 601–615.

MacPhail, V.J., S.D. Gibson, R. Hatfield and S.R. Colla. 2020. Using Bumble Bee Watch to investigate the accuracy and perception of bumble bee (*Bombus* spp.) identification by community scientists. PeerJ 2020: 1–31.

Majewska, A.A. and S. Altizer. 2020. Planting gardens to support insect pollinators. Conserv. Biol. 34: 15–25.

Martin, L.J., B. Blossey and E. Ellis. 2012. Mapping where ecologists work: Biases in the global distribution of terrestrial ecological observations. Front. Ecol. Environ. 10: 195–201.

Matteson, K.C., J.S. Ascher and G.A. Langellotto. 2008. Bee richness and abundance in New York City urban gardens. Ann. Entomol. Soc. Am. 101: 140–150.

McIntyre, N.E. and M.E. Hostetler. 2001. Effects of urban land use on pollinator (Hymenoptera: Apoidea) communities in a desert metropolis. Basic Appl. Ecol. 2: 209–218.

McKinney, M.L. 2008. Effects of urbanization on species richness: A review of plants and animals. Urban Ecosyst. 11: 161–176.

Miller-Rushing, A., R. Primack and R. Bonney. 2012. The history of public participation in ecological research. Front. Ecol. Environ. 10: 285–290.

Neff, J.L. and B.B. Simpson. 1993. Bees, pollination systems and plant diversity, Pp. 143–167. *In* LaSalle, L. and I.D. Gauld (eds.), Hymenoptera and Biodiversity. Commonwealth Agricultural Bureaux International, Wallingford, U.K.

[NRC] National Research Council. 2007. Status of pollinators in North America, Pp. 307–308. National Academies Press, Washington, DC.

Oberhauser, K. and G. LeBuhn. 2012. Insects and plants: Engaging undergraduates in authentic research through citizen science. Front. Ecol. Environ. 10: 318–320.

Pocock, M.J.O., S.E. Newson, I.G. Henderson, J. Peyton, W.J. Sutherland, D.G. Noble, S.G. Ball, B.C. Beckmann, J. Biggs, T. Brereton, D.J. Bullock, S.T. Buckland, M. Edwards, M.A. Eaton, M.C. Harvey, M.O. Hill, M. Horlock, D.S. Hubble, A.M. Julian, E.C. Mackey, D.J. Mann, M.J. Marshall, J.M. Medlock, E.M. O'Mahony, M. Pacheco, K. Porter, S. Prentice, D.A. Procter, H.E. Roy, S.E. Southway, C.R. Shortall, A.J.A. Stewart, D.E. Wembridge, M.A. Wright and D.B. Roy. 2015. Developing and enhancing biodiversity monitoring programmes: A collaborative assessment of priorities. J. Appl. Ecol. 52: 686–695.

Potter, A. and G. LeBuhn. 2015. Pollination service to urban agriculture in San Francisco, CA. Urban Ecosyst. 885–893. doi: 10.1007/s11252-015-0435-y.

Potts, S.G., V. Betsy, S. Roberts, C. O'Toole, A. Dafni, G. Ne'Eman and P. Willmer. 2005. Role of nesting resources in organising diverse bee communities in a Mediterranean landscape. Ecol. Entomol. 30: 78–85.

Potts, S.G., J.C. Biesmeijer, C. Kremen, P. Neumann, O. Schweiger and W.E. Kunin. 2010. Global pollinator declines: Trends, impacts and drivers. Trends Ecol. Evol. 25: 345–353.

Potts, S.G., V. Imperatriz-Fonseca, H.T. Ngo, M.A. Aizen, J.C. Biesmeijer, T.D. Breeze, L.V. Dicks, L.A. Garibaldi, R. Hill, J. Settele and A.J. Vanbergen. 2016. Safeguarding pollinators and their values to human well-being. Nature 540: 220–229.

Powney, G.D., C. Carvell, M. Edwards, R.K.A. Morris, H.E. Roy, B.A. Woodcock and N.J.B. Isaac. 2019. Widespread losses of pollinating insects in Britain. Nat. Commun. 10: 1–6.

Rathcke, B.J. and E.S. Jules. 1993. Habitat fragmentation and plant-pollinator interactions. Curr. Sci. 65: 273–277.

Ratnieks, F.L.W., F. Schrell, R.C. Sheppard, E. Brown, O.E. Bristow and M. Garbuzov. 2016. Data reliability in citizen science: Learning curve and the effects of training method, volunteer background and experience on identification accuracy of insects visiting ivy flowers. Methods Ecol. Evol. 7: 1226–1235.

Repasky, R.R. 1991. Temperature and the northern distributions of wintering birds. Ecology 72: 2274–2285.

Richards, A.J. 2001. Does low biodiversity resulting from modern agricultural practice affect crop pollination and yield? Ann. Bot. 88: 165–172.

Root, T.L. 1988. Environmental factors associated with avian distributional boundaries. J. Biogeogr. 15: 489–505.

SAS Institute. 2014. Base SAS 9.4 Procedures Guide: Statistical Procedures. SAS Institute Inc., Cary, NC.

Saunders, M.E., E. Roger, W.L. Geary, F. Meredith, D.J. Welbourne, A. Bako, E. Canavan, F. Herro, C. Herron, O. Hung, M. Kunstler, J. Lin, N. Ludlow, M. Paton, S. Salt, T. Simpson, A. Wang, N. Zimmerman, K.B. Drews, H.F. Dawson, L.W.J. Martin, J.B. Sutton, C.C. Webber, A.L. Ritchie, L.D. Berns, B.A. Winch, H.R. Reeves, E.C. McLennan, J.M. Gardner, C.G. Butler, E.I. Sutton, M.M. Couttie, J.B. Hildebrand, I.A. Blackney, J.A. Forsyth, D.M. Keating and A.T. Moles. 2018. Citizen science in schools: Engaging students in research on urban habitat for pollinators. Austral Ecol. 43: 635–642.

Scheper, J., M. Reemer, R. van Kats, W.A. Ozinga, G.T.J. van der Linden, J.H.J. Schaminée, H. Siepel and D. Kleijn. 2014. Museum specimens reveal loss of pollen host plants as key factor driving wild bee decline in the Netherlands. Proc. Natl. Acad. Sci. U.S.A. 111: 17552–17557.

Schlueter, M. 2019. Bees of Georgia. 21 February 2020. (http://native-bees-of-georgia.ggc.edu/).

Semmens, B.X., D.J. Semmens, W.E. Thogmartin, R. Wiederholt, L. López-Hoffman, J.E. Diffendorfer, J.M. Pleasants, K.S. Oberhauser and O.R. Taylor. 2016. Quasi-extinction risk and population targets for the Eastern, migratory population of monarch butterflies (*Danaus plexippus*). Sci. Rep. 6: 1–7. doi: 10.1038/srep23265.

Sponsler, D.B., C.M. Grozinger, C. Hitaj, M. Rundlöf, C. Botías, A. Code, E.V. Lonsdorf, A.P. Melathopoulos, D.J. Smith, S. Suryanarayanan, W.E. Thogmartin, N.M. Williams, M. Zhang and M.R. Douglas. 2019. Pesticides and pollinators: A socioecological synthesis. Sci. Total Environ. 662: 1012–1027.

Tewksbury, J.J., J.G.T. Anderson, J.D. Bakker, T.J. Billo, P.W. Dunwiddie, M.J. Groom, S.E. Hampton, S.G. Herman, D.J. Levey, N.J. Machnicki, C.M. Del Rio, M.E. Power, K. Rowell, A.K. Salomon, L. Stacey, S.C. Trombulak and T.A. Wheeler. 2014. Natural history's place in science and society. BioScience 64: 300–310.

Tipton, J., A. Arthur, Z. Pilgrim, R. Kent and D. Patterson. 2019. A preliminary assessment of native pollinator attraction to bee hotels in northeast Georgia. *In* Proceedings of the Georgia Undergraduate Research Conference; 2019 November 1–2; Gainesville, GA.

U.S. Census Bureau. 2019. Population numbers July 1, 2019. 20 December 2020. (https://www.census.gov/quickfacts/GA).

vanEngelsdorp, D., J.D. Evans, C. Saegerman, C. Mullin, E. Haubruge, B.K. Nguyen, M. Frazier, J. Frazier, D. Cox-Foster, Y. Chen, R. Underwood, D.R. Tarpy and J.S. Pettis. 2009. Colony collapse disorder: A descriptive study. PLoS One 4: e6481.

Van Vliet, K. and C. Moore. 2016. Citizen science initiatives: Engaging the public and demystifying science. J. Microbiol. Biol. Educ. 17: 13–16.

Westphal, C., R. Bommarco, G. Carré, E. Lamborn, N. Morison, T. Petanidou, S.G. Potts, S.P.M. Roberts, H. Szentgyörgyi, T. Tscheulin, B.E. Vaissière, M. Woyciechowski, J.C. Biesmeuer, W.E. Kunin, J. Settele and I. Steffan-Dewenter. 2008. Measuring bee diversity in different European habitats and biogeographical regions. Ecol. Monogr. 78: 653–671.

Wilson, J.S., M.L. Forister and O.M. Carril. 2017. Interest exceeds understanding in public support of bee conservation. Front. Ecol. Environ. 15: 460–466.

Winfree, R., R. Aguilar, D.P. Vasquez, G. LeBuhn and M.A. Aizen. 2009. A meta-analysis of bees' responses to anthropogenic disturbance. Ecology 90: 2068–2076.

Winfree, R., I. Bartomeus and D.P. Cariveau. 2011. Native pollinators in anthropogenic habitats. Annu. Rev. Ecol. Evol. Syst. 42: 1–22. doi: 10.1146/annurev-ecolsys-102710-145042.

Wratten, S.D., M. Gillespie, A. Decourtye, E. Mader and N. Desneux. 2012. Pollinator habitat enhancement: Benefits to other ecosystem services. Agric. Ecosyst. Environ. 159: 112–122.