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Life Responds: Citizen Science to Document Behavior Changes in Plants and Animals During the 2017 Total Solar Eclipse

Alison N. Young, Rebecca F. Johnson, Elise Ricard, and Ryan Wyatt
California Academy of Sciences, San Francisco, CA 94118

Abstract. There is a rich historical record demonstrating the cultural and scientific impact of solar eclipses on humans, but much of the information regarding plant and animal reactions is anecdotal. The *Life Responds* project was designed to formalize those anecdotes, mobilizing citizen scientists to collect data during the 2017 eclipse. While people prepared for and observed the eclipse, we hoped they would also take a couple moments to experience a connection to the life around them, as they witnessed first-hand that all life is influenced by celestial events. With extensive outreach and media coverage, over 600 people participated in *Life Responds*, submitting more than 2,500 observations of plant and animal behavior during the eclipse, creating the largest collection to date of response to a solar eclipse.

1. Introduction

In anticipation of the August 21, 2017 total solar eclipse, the California Academy of Sciences (Academy) in San Francisco, California, sought to find a meaningful way to engage people across the country in the "Great American Eclipse." The Academy is a natural history museum, planetarium, and aquarium and includes teams of researchers, science communicators, and educators with the collective mission 'to explore, explain and sustain life.' We sought to harness this expertise and make new and interesting connections for our guests and larger community by connecting the solar eclipse to the rest of the natural world. Anecdotal evidence and limited research indicate evidence of living things responding to previous solar eclipses. By mobilizing our expertise and previous experience we endeavored to aggregate, archive, and increase the quantity and quality of such observations. The Academy Citizen Science Department uses iNaturalist, a free app designed for anyone to document and share observations of biodiversity anywhere in the world, as the platform for all of their work. A cross disciplinary team from Citizen Science, Planetarium and Public Programs, and Education came together to create, and then promote, a project using the iNaturalist app that would allow eclipse viewers across the country to document changes noted in animal or plant behavior during the event. *Life Responds*, hosted on the iNaturalist platform, asked participants across the United States to record and submit observations of plants and animals to answer the question: does non-human life respond to a total solar eclipse?

Anecdotal evidence of both human (e.g., Herodotus 440 BC) and other life responding to previous solar eclipses is both long-standing and abundant, while evidence-based records and research are less prolific. Many who have witnessed an eclipse have shared stories of animal and plant behavior changes, such as birds ceasing foraging and returning to roost (Murdin, 2001), pasture animals returning home (Rudder et al.,

2001), orb-weaving spiders destroying their webs (Utez et al., 1994), a drop in photosynthesis in legumes and grains (Economou et al. 2006), diurnal reef-fishes seeking shelter (Jennings et al., 2005), zooplankton displaying night time vertical migration (Economou et al., 2006), changes in cicada song (Sanborn and Phillips, 1992), captive baboons decreasing activity (Gil-Burmann & Beltram, 2003). While interesting and important, most of these observations are limited in both scope and scale: restricted to a few species and made within a small geographic area.

Recognizing that a large-scale study of plant and animal responses to a solar eclipse requires many observers spread across the path of totality, there have been a couple notable efforts to get volunteers to submit their observations. Harvard myrmecologist William Morton Wheeler launched a well-coordinated campaign to get volunteers to monitor animal behavior during the 1932 total solar eclipse. Working with his colleagues on the 'eclipse behavior committee' of the Boston Society of Natural History, Wheeler recruited the general public via local newspapers and radio broadcasts in part of the path of totality (New England) to take part in a survey asking them to share their observations of behavior change during the eclipse. The committee also worked with New England game wardens to share and consolidate reports that were generated by well-known naturalists and naturalist clubs (Wheeler et al., 1935). More recently, a citizen science effort called EclipseWatch recorded animal observations during the 2010 annular solar eclipse, which passed over India. One hundred participants recorded the reactions of sparrows, kites, crows, pigeons, geckos, bats, and dogs across 30 cities experiencing between 40% and 96% Sun coverage during maximum eclipse. The study reported noticeable changes in bird flight and call patterns that were stronger in regions with greater Sun coverage (EclipseWatch, 2018).

These studies seem to indicate that a variety of animal life could react to the environmental changes caused solar eclipse, such as the decreases in temperature and light, which are factors that plants might respond to as well, and that there could be a minimum amount of Sun coverage necessary for life to notice. The August 21, 2017 solar eclipse presented the opportunity to design a citizen science project to gather observations of plant and animal response to the eclipse on the widest geographic scale yet: the entire continental U.S.

The goal of the Academy's *Life Responds* project was to build a robust, crowdsourced, observational dataset of non-human response to solar eclipses, achieved by:

- Capitalizing on planned Academy educational outreach and intense media interest about the eclipse to solicit participation in *Life Responds*.

- Asking participants to observe any plant or animal, with the intention of increasing 1) the number of participants and 2) the likelihood that an animal or plant could be recorded reacting or something reacting in a new and unrecorded way—which could inspire future research.

- Encouraging participation from anywhere in the country regardless of the percent Sun coverage to help determine the minimal Sun coverage needed to witness responses.

2. Methods

2.1. Project Design and Set-Up

Inspired by the Boston Society of Natural History's 'eclipse behavior committee' and their campaign to solicit observations of behavior change in a variety of animals and plants during the 1932 total solar eclipse, we designed a project using the global biodiversity recording platform, iNaturalist.[1] The iNaturalist app is designed to record and share observations of species; it automatically tags observations made on smartphones and tablets with geolocation, date, and time, and although observations can be supported with photos or sound, they can also be recorded without that information. Observations can also be made from photos taken with digital cameras and uploaded directly to the website.

Our project, *Life Responds,* was created on iNaturalist.[2] Instructions on how to participate were included on the project page. Participants were asked to:

1. Download iNaturalist onto a smartphone or tablet (if they were not using a smart device they could skip to Step 2 on a computer).

2. Create an iNaturalist username.

3. Join the *Life Responds* project.

4. Practice making observations using iNaturalist.

5. If possible visit the location where they will be during the eclipse and "scout out" possible animals or plants to observe.

6. On the day of eclipse, make observations of plants and animals and upload them to iNaturalist app, add them to the *Life Responds* project, and fill in the required fields about how close in time the observation was made to totality (or the maximum extent of the eclipse at your location). The options were: more than 30 minutes before totality, 30 minutes before totality, between 30 minutes before & totality, during or close to totality, between totality & 30 minutes after, 30 minutes after totality, longer than 30 minutes after totality.

The instructions let participants know that we were hoping they would make three observations: 30 minutes before totality, during or very close to totality, and 30 minutes after totality, but they could make observations at other times as well.

In addition, we created a *Life Responds* webpage on the California Academy of Sciences website.[3] This website included background and more information about how to participate.

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[1] https://www.inaturalist.org/

[2] https://www.inaturalist.org/projects/life-responds-total-solar-eclipse-2017

[3] https://calacademy.org/citizen-science/solar-eclipse-2017

2.2. Outreach and Recruitment

In order to get the word out about our project, we printed 3,000 postcards and a digital poster with information about participating in the *Life Responds* project. These materials were distributed by numerous partners, including the National Park Service and Oregon State Parks. Postcards were also included in 300 Eclipse Preparation Kits assembled by the Astronomical Society of the Pacific and distributed to the Night Sky Network Amateur astronomers.

Through the Academy's Teacher and Youth Education Department programs, information about *Life Responds* was included in various eclipse trainings to schools. Academy educators hosted both student and teacher programs for the eclipse including an in-person teacher workshop for 23 Bay Area teachers, three one-hour teacher webinars that reached 1,520 teachers and others and as part of a two-part distance learning module developed especially for the eclipse, 3,566 3rd–8th grade students from 121 classrooms in the path.

In addition, we did considerable outreach in the citizen science and astronomy communities. *Life Responds* project leads participated in an ASP Astronomy from the Ground Up, which focused on eclipse citizen science and apps, were featured panelists on the #CitSciChat Twitter conversation about eclipse citizen science projects, and served on a panel at an eclipse-focused meeting of the AAAS Science Fellows Citizen Science Interest Group. We presented and shared information about the project at the 2016 Astronomical Society of the Pacific Conference, the 2016 Association of Science and Technology Centers (ASTC) Annual Meeting, the 2017 Citizen Science Association Meeting, and the 2017 American Astronomical Society Conference. We also promoted the project at special members-only Academy planetarium shows over the summer of 2017.

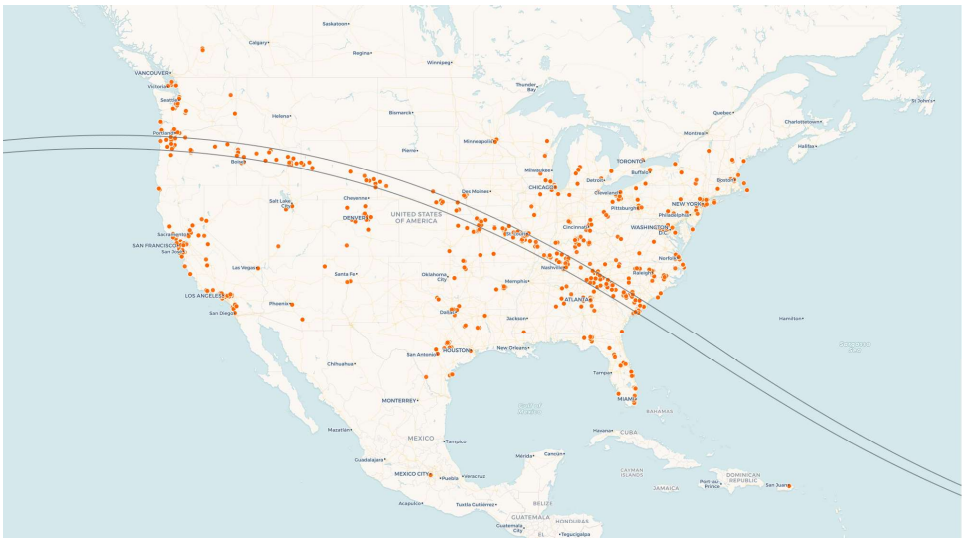

Figure 1. Map of the locations of the observations submitted to *Life Responds*. Double lines are the path of totality of the solar eclipse.

2.3. Media and Website Traffic

There was intense media interest in the 2017 eclipse. We fielded over 40 interview requests and *Life Responds* was featured in more than 35 stories that ran in local, national, and international outlets including *KQED*, *The Mercury News*, *NBC News Bay Area*, *National Geographic*, *The Washington Post*, *The New York Times*, *Scientific American*, *Discover Magazine*, *Forbes Online*, *The Los Angeles Times*, *NPR*, *The Guardian*, *The Daily Mail*, *Africa News*, and more (see Media Links). This media coverage and reach ended up being the main way participants found out about our project and how to take part. All of the media coverage of *Life Responds*, in combination with our other outreach strategies, drove visitorship to our website. In July 2017, we had 1,629 unique page views and visitors spent on average 6:23 minutes on the *Life Responds* page, and in August 2017 there were 28,502 unique page views with an average of 5:08 minutes on the page, making it the 6th most visited page on the entire Academy site. Overall, Academy webpages have a 1:24 minute average time on page.

3. Results

In total, 645 people uploaded 2,795 observations taken on August 21, 2017, of 437 species to the *Life Responds* project on iNaturalist. People made observations in 40 U.S. states, Puerto Rico, two Canadian provinces, and one state in Mexico. Almost half of the observations were made within the eight U.S. states included in the path of totality (1386 observations, 49.6%), with an obvious concentration of observations being made along the path of totality itself (see Figure 1).

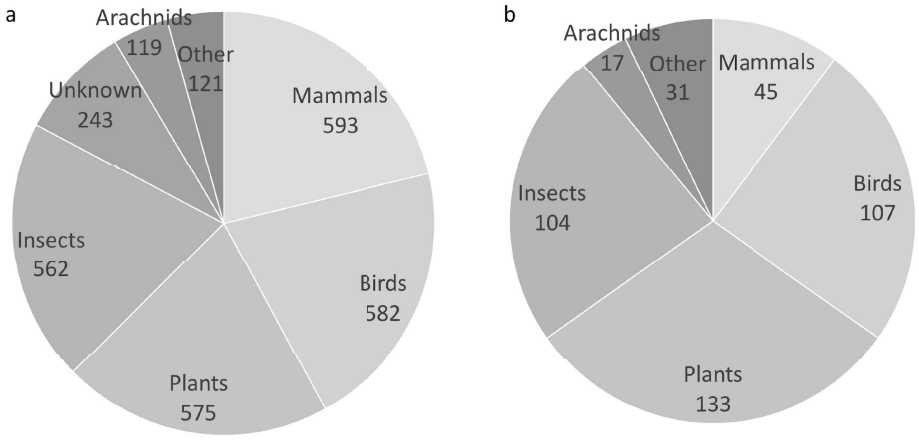

Figure 2. (a) Breakdown of the 2,795 observations made for *Life Responds*, by taxon. (b) Breakdown of the 437 species documented by the observations made for *Life Responds*, by taxon.

Looking at what people chose to observe, overall roughly 80% of all the observations were equally divided between mammals (593 observations), birds (582 observations), plants (575 observations), and insects (562 observations). The remaining 20% of observations were arachnids, other taxa, or "unknowns"—meaning that no identification has been assigned to them. The species represented by these observations

broke down differently, with plants having the greatest number of species observed (133 species), followed by birds (107 species), insects (104 species), mammals, (45 species), arachnids (17 species), and other taxa (31 species) (see Figure 2). The most-observed species on *Life Responds* was *Canis familiaris*, the domestic dog, with 206 observations, followed by *Gallus gallus domesticus*, the domestic chicken, with 106 observations (see Figure 3). Out of the ten most-observed species, four are domestic animals, two are species introduced to the United States, two are native species, and one is humans.

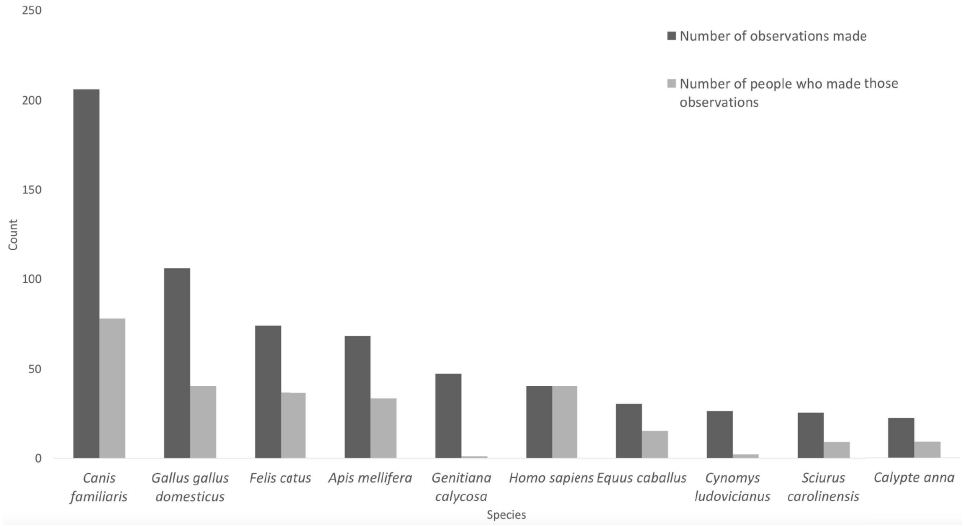

Figure 3. The ten most-observed species for *Life Responds*. Darker bars depict the number of observations made of each species, lighter bars represent the number of people who made those observations.

The majority of people (61.4%) participating in *Life Responds* submitted one, two, or three observations, with the median number of observations being three. 31.2% of participants made between four and ten observations, and the remaining 7.4% of people made more than 11 observations, with the greatest number of observations submitted being 64 (see Figure 4). Of the 2795 observations submitted to the *Life Responds* project, 1,389 (49.7%) were made before totality, 721 (25.8%) were made during or close to totality, and 678 (24.3%) were made after totality. 37.5% of participants made an observation before, during, and after the eclipse as per the instructions in the project.

For classifying behavior of plants and animals during the eclipse, we looked for observations that recorded activity from before totality to during totality itself. In many cases, no response was documented or the evidence submitted was inconclusive. However, there were quite a few interesting and varied observations of behavior change documented:

- swallows or swifts starting to flock and fly during the eclipse;
- ants slowing down or stopping movement entirely;
- domestic hens gathering together or roosting and getting quiet during the eclipse and roosters starting to crow during the eclipse;

- at active bird feeders in yards, birds, especially hummingbirds, stopped feeding for the entirety of totality;
- frogs starting to call during the eclipse;
- flowers closing up or partially closing (see Figure 5); and
- cicada and crickets starting or stopping their calls during the eclipse: often cicadas stopped their singing and crickets started, which then reversed once totality/maximum coverage was over.

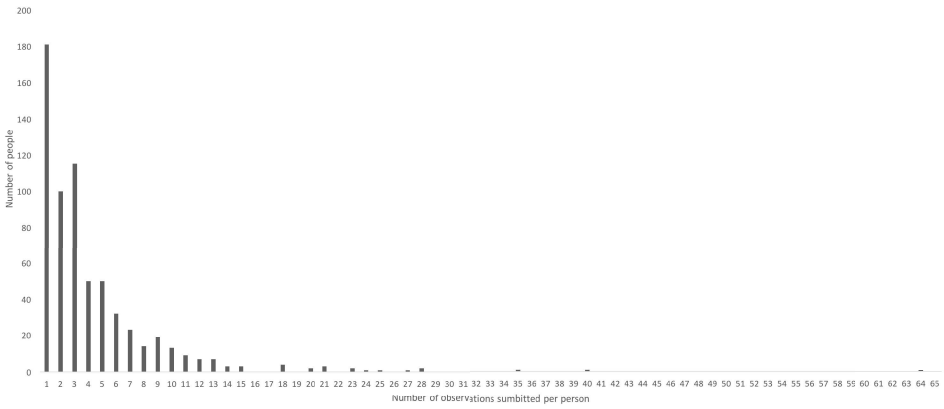

Figure 4. Number of observations per individual submitted to *Life Responds*, by the number of people who submitted that number of observations.

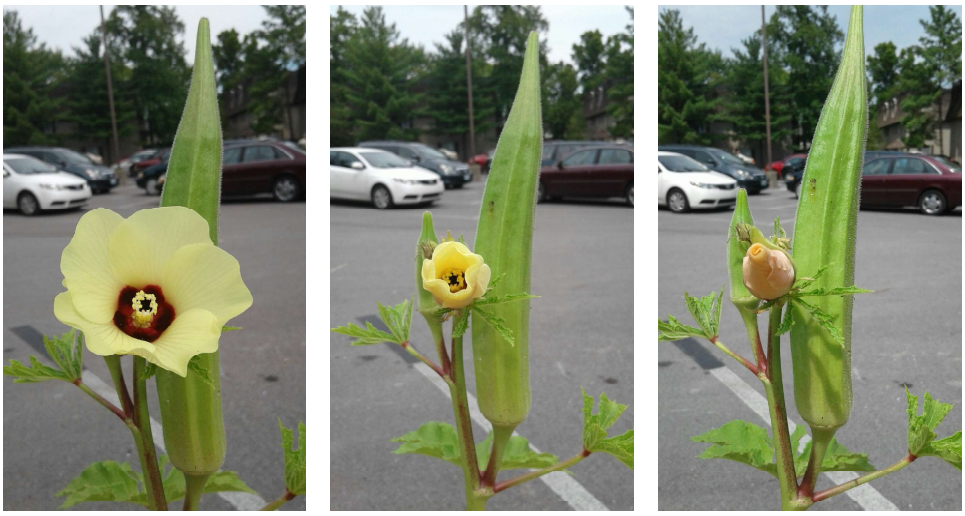

Figure 5. Example of a set of observations submitted via iNaturalist to the *Life Responds* project, documenting an okra (*Abelmoschus* sp.) flower closing up during the eclipse, taken in the path of totality. Observations and photos by David Christopher Owens and Kelly Cristina de Souza Owens.

4. Discussion

4.1. Life Responds Project

The outreach and promotion of *Life Responds* prior to the eclipse appears to have had widespread geographic reach, as seen by the observations that were submitted across the United States and into neighboring countries. It's apparent that people living in or traveling to the path of totality were interested in taking part, though we received observations submitted as far away as 40-50% totality. Interestingly, there is a gap in observations in the middle of the United States, stretching from Montana into North Dakota and then down into northern Texas. This may indicate a lack of promotion reaching this area combined with low population density in these states (Montana, North Dakota, and South Dakota have the lowest population density per square mile in the continental U.S.; Nebraska and Kansas are also in the ten lowest-density states). People were clearly interested in observing species that could be found around their homes, like dogs, cats, chickens, horses, birds at feeders, and spiders. That dogs were the most-observed species may also be indicative of people taking their dogs with them if they traveled to see the eclipse.

The instructions for *Life Responds* asked participants to submit at least three observations: 30 minutes before totality, during or close to totality, and 30 minutes after totality, to help capture the change in behavior of the organism they were watching. There were also options to make observations outside of these specific times. However, only slightly more than one third of participants made an observation before, during, and after the eclipse, with almost half the observations submitted to *Life Responds* made before the eclipse. Why did many people not follow through and make three observations? Because totality was short (only 2 minutes 40 seconds), it seems likely that people were caught up in the eclipse and didn't end up making the second observation of their organism. Also noted in some citizen science projects, there can be volunteer bias in not recording zero values or the absence of what they're looking for (Dickinson et al., 2010), so it may be that participants who did not see a response from their organism during the eclipse chose not to document their observations. Furthermore, quite a few people just made one observation after the eclipse, detailing the behavior change they observed in an organism. In these cases, it might be that the participants didn't know what to observe or weren't planning to participate, but when they saw an interesting response from an organism, they then chose to make an observation describing what they saw. While most people only submitted one to three observations, as with many citizen science projects, there was a "long tail" of participation: lots of people do a small amount of work, a few people do a lot (Eveleigh et al., 2014). While practitioners who run citizen science projects are often trying to increase individual participation to give volunteers more depth of experience and even out the "long tail," it was not really a problem in the context of *Life Responds*, since we just wanted people to make three observations. Because totality was short in duration, there was a limited number of observations one could make during it, so in this case an increase in number of submissions from one person may lead to a decrease in quality of those submissions.

Despite the complications of uneven geographic spread and not all participants following the exact protocols of *Life Responds*, the project overall met the goal of gathering and formalizing anecdotal observations of organismal responses to solar eclipses. With more than 600 people participating and over 2,500 observations gathered, it is by far the largest consolidation of observations of plant and animal behavior during a

single solar eclipse. Many of the responses submitted to *Life Responds* also supported compiled anecdotal claims from previous eclipses, such as roosters crowing and going to roost during totality, hummingbirds ceasing to forage, ants slowing their movement, crickets starting to chirp, cicadas going silent, and no consistent or obvious reaction from domestic dogs and cats (Mousley 1932, Wheeler et al. 1935).

4.2. Lessons Learned: Looking toward 2024

A major surprise to all of us was the response to and excitement about the *Life Responds* project. Clearly having an eclipse activity that was *not* astronomy—or environmentally-based garnered quite a lot of media interest, which in turn helped with outreach and promotion of the project across the U.S. and beyond.

Participation in and observations submitted to *Life Responds* for this eclipse definitely illuminated lessons learned that will require some thought if we undertake a similar project for the 2024 eclipse. Because iNaturalist is designed for gathering photos of organisms, some of the behavior people were trying to document for *Life Responds* was difficult to capture in a photo—e.g., birds *not* visiting a feeder during totality, organisms like ants slowing down or stopping their movement. Furthermore, birds in general are difficult to photograph using a smartphone camera. Although iNaturalist has the capability to upload sounds of organisms, the process is quite different from and more complicated than taking photos with a phone, and we did not include instructions on that process in the protocols, in order to avoid confusing potential participants. However, this meant that behavior change in the sounds organisms made (e.g., cicadas stopping their calls, crickets starting to call, roosters crowing) simply had to be described by participants in the notes of their observation.

This is the only citizen science project the Academy has undertaken that relied entirely on individuals finding out about the initiative, reading the protocols, and participating without any chance for in-person interaction with us or our partners, which meant participants had to learn how to use iNaturalist on their own and possibly made their first observations on the platform for the *Life Responds* project. We'd like to re-think how people are trained and participate in 2024, potentially by utilizing a train-the-trainers model and finding regional facilitators, or holding multiple short training webinars open to everyone prior to the eclipse. Totality during the 2024 eclipse is more than double the time of the 2017 eclipse, so it is our hope that the response of organisms, especially within or near the path of totality, will be more marked and thus easily recognized and documented by participants. This, combined with the lessons learned from 2017 and implemented for 2024, will hopefully make a *Life Responds* citizen science project or something similar to it even more successful.

Acknowledgments. First and foremost, a huge thank you to everyone who participated in *Life Responds* and submitted observations during the eclipse—the enthusiasm for this project across the U.S. and beyond was truly inspiring. Thank you to participant David Christopher Owens and Kelly Cristina de Souza Owens for their kind permission in letting us use their photographs. We'd like to thank the media outlets who provided coverage on *Life Responds*, helping us spread the word and reach diverse audiences. And big thank-yous to the Academy staff who promoted the project, worked with teachers and schools, coordinated media requests, and provided valuable input about *Life Responds*: Jacque Benitez, Lindzy Bivings, Haley Bowling, Katie Jewett, Bing Quock, and Josh Roberts.

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