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CONSERVING BIODIVERSITY: POLLINATORS PROJECT

FINAL REPORT 2017-2020

THE UNIVERSITY OF ARIZONA
COLLEGE OF AGRICULTURE & LIFE SCIENCES
Entomology

MICHELLE TOSHACK CATCHING AND RELEASING BUTTERFLIES FOR THE PROJECT OUTSIDE OF BOZEMAN, MT

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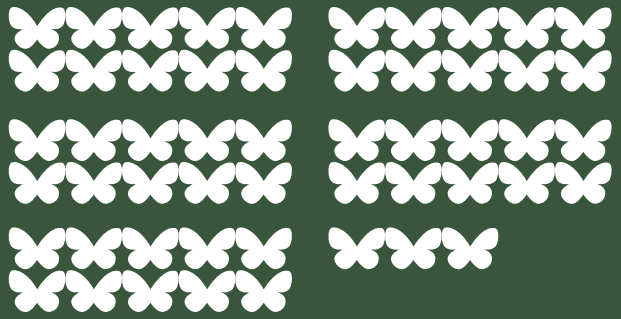
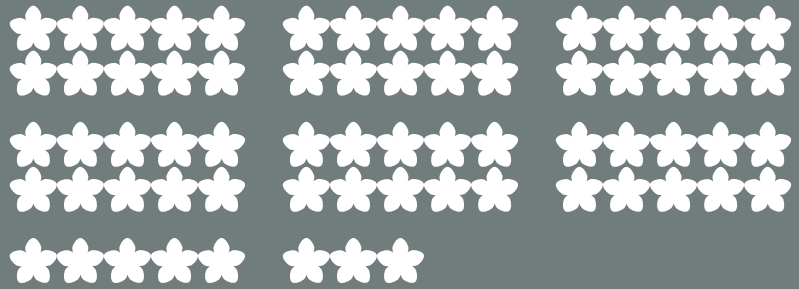


526

volunteer-submitted
observations of butterflies



676

volunteer-submitted
observations of wildflowers

70

butterfly species
identified

94

volunteer crew
members

126

wildflower species
identified

CONSERVING BIODIVERSITY: POLLINATORS PROJECT

PREPARED BY MICHELLE TOSHACK, MARIS FESSENDEN, AND ISABELLA PRITCHARD
ADVENTURE SCIENTISTS

SUMMARY

Adventure Scientists' Conserving Biodiversity: Pollinators Project provides data on pollinator abundance and diversity from remote areas where data gaps limit scientists' and land managers' ability to protect species and habitats at risk. In collaboration with Dr. Katy Prudic from the University of Arizona, the project launched in 2017 in 37 field sites across the western United States managed by the U.S. Forest Service (USFS). Volunteers with the project conducted butterfly and wildflower surveys in subalpine habitats from 2017 - 2020. At each site, volunteer teams conducted three surveys from May through October. Each team caught and released butterflies and recorded wildflower phenology (life phases such as flower, fruit, seed, or leaf). In 2018 the project added 31 more field sites in the western United States.

AN ANISE SWALLOWTAIL (PAPILIO ZELICAON) OPENS ITS WINGS BEFORE BEING PHOTOGRAPHED AND RELEASED

In 2019 and 2020 the project expanded to a more opportunistic site selection model where volunteers contributed butterfly and wildflower observations across the globe. Over the life of the project, volunteers accessed 107 remote field sites and collected observations of 1,997 individual butterflies representing 151 species and 3,751 wildflowers from 612 species.

Dr. Prudic and her lab investigate biodiversity loss according to different climate change scenarios. The data set will inform land managers of conservation priorities. All data is integrated into state Natural Heritage databases and NatureServe where it can be accessed by USFS land managers. USFS land managers can utilize the data for restoration projects and for long-term forest planning.

This project contributed baseline data in remote areas that have limited or no data on butterfly diversity.

VOLUNTEER KATIE GUETZ COLLECTS DATA ON A WILDFLOWER IN MONTANA

PROJECT IMPACT

Many wild pollinators, including butterflies, are experiencing declines due to habitat loss, pesticides, and climate change (Potts et al. 2010, Goulson et al. 2015). Although some species such as monarchs and honeybees are well studied, the conservation status of many pollinators is unknown. Butterflies and moths (Order Lepidoptera) are an incredibly diverse group of insects, comprising over 250,000 species globally (Merckx et al. 2013). Butterflies serve as important biodiversity indicators for ecosystem health. They also provide food for many organisms, such as migrating birds. Remote backcountry areas are often considered biodiversity hotspots (Dobrowski and Parks 2016) yet these remote areas lack data that could be used to inform management decisions. The U.S. Forest Service manages 193 million acres, including many high-elevation areas which provide ideal butterfly habitat. Baseline data collection is required in order to further refine research questions around butterfly species diversity and distribution.

This four year project extensively surveyed high elevation butterflies and their host plants throughout the western U.S. This dataset is unique in filling in data gaps in remote regions, which are often locations of high biodiversity.

FIELD SITES INCLUDE HIGH ELEVATION MEADOWS SUCH AS THIS ONE IN MT BAKER-SNOQUALMIE NATIONAL FOREST

PROJECT DESIGN

Field protocols

Dr. Katy Prudic co-developed protocols and tested them in the field alongside Adventure Scientists staff. The collaboration yielded protocols based on the methods used in Prudic et al. (2017) and Taron and Ries (2015).

Volunteers adopted a field site to survey multiple times throughout the butterfly flight season (May - October, depending on region). Site selection criteria included high elevation subalpine meadows on U.S. Forest Service land.

Adventure Scientists loaned project participants one butterfly net for each team of two. We purchased collapsible butterfly nets ideal for backpacking from Bioquip, Inc. We provided each volunteer team with field guides (plant and butterfly identification), forceps for handling butterflies, power packs to extend the battery life of cell phones, and CLIF bars to fuel their field work.

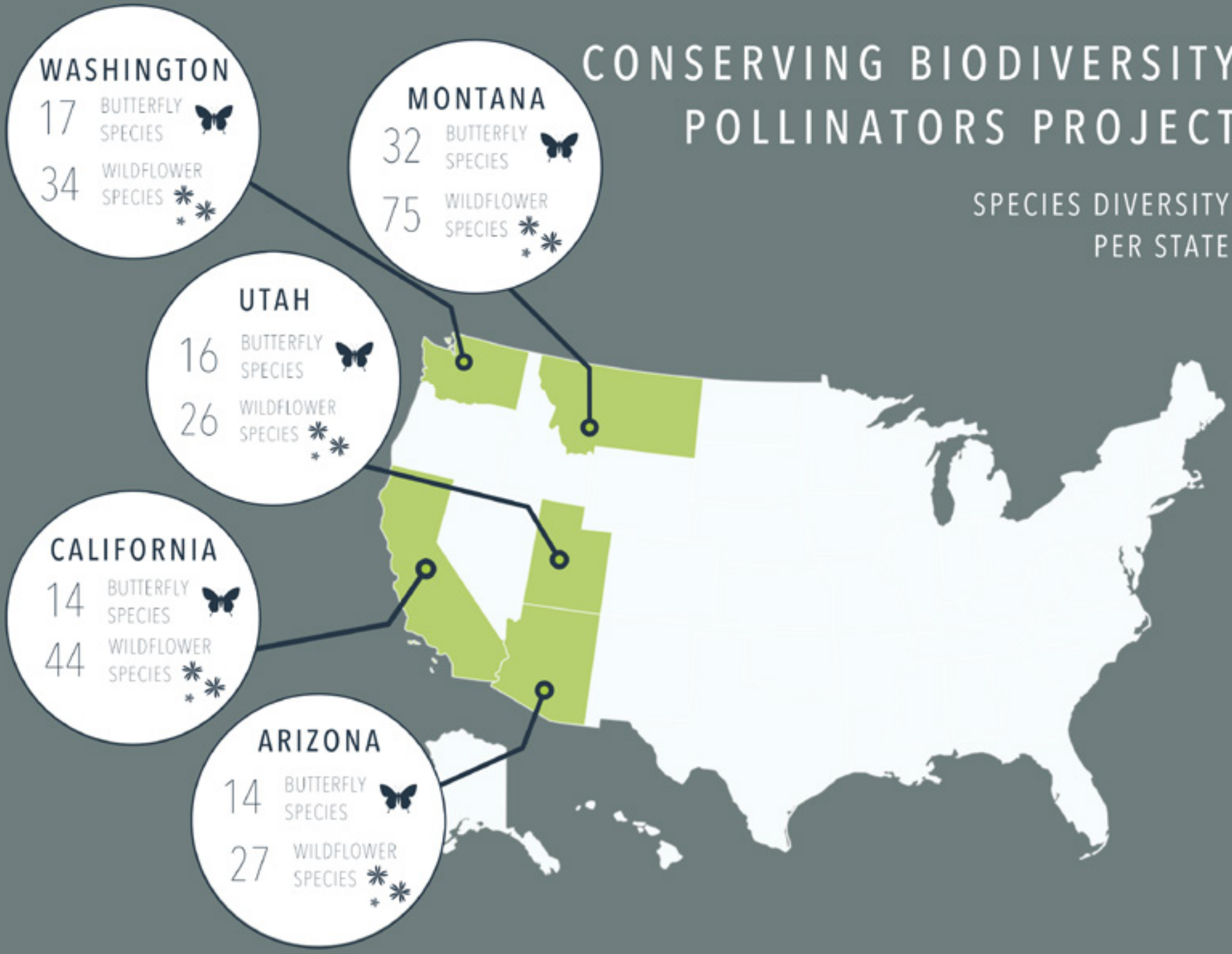
We provided all volunteers with a written protocol that included example photographs and screenshots of data collection apps. The objective of this detailed protocol was to remind volunteers before, during, and after their field visits about project equipment and technology, details of catching and handling butterflies, and how to record plant phenology data. In end-of-season surveys, volunteers expressed that Adventure Scientists provided the necessary training resources to be successful as a volunteer (across all years: 48.3% strongly agreed, 40.5% agreed, 9.3% neutral, 1.9% disagreed). High quality training products resulted in high-quality data submitted by volunteers.

Targets for sampling

The conservation status of many pollinators is unknown. As a result, we targeted field areas that included remote, subalpine regions on U.S. Forest Service (USFS) land throughout the western United States: Arizona, California, Montana, Utah, and Washington.

CONSERVING BIODIVERSITY POLLINATORS PROJECT

SPECIES DIVERSITY PER STATE



We selected field sites using a combination of spatial modeling and expert guidance. The site selection model used environmental data and recent climate trends data based on the date and location of previous observations gathered from iNaturalist and GBIF (Global Biodiversity Information Facility). Additional criteria for site selection included: US Forest Service Land, accessible by a trail, more than 3 miles from a trailhead, above 6,000 ft, wildflowers present (suitable butterfly habitat), and less than a 2-hour drive from cities selected for recruitment (Tucson, AZ, San Francisco, CA, Bozeman, MT, Salt Lake City, UT, and Seattle, WA). For further details on the site selection process refer to Appendix A.

From this model's output, we initially selected 10 sites per region for Utah, California and Washington, for a total of 30 suitable field sites. The remaining sites were selected by our project partner at the University of Arizona, Dr. Katy Prudic, and Adventure Scientists' Project Manager, Michelle Toshack, based on their geographical knowledge of suitable butterfly habitat. We encouraged volunteers to provide feedback about whether the model-assigned sites were located in suitable butterfly habitat.

In 2019, the project expanded internationally. Volunteers selected their own field sites based on their understanding of high-quality butterfly habitat, which varied across different habitats across different continents. With this more opportunistic approach to data collection, the project gained more field locations across diverse landscapes.

A PINE WHITE *(NEOPHASIA MENAPIA)* PERCHES ON VOLUNTEER KATIE GUETZ'S FINGER

VOLUNTEER MANAGEMENT

Twenty-two volunteers had previously been involved in Adventure Scientists projects.

Volunteer recruitment began in early June of each year. Thirty community members who previously participated in Adventure Scientists' Microplastics Project expressed interest in the project and helped to fill the sites in Montana. We distributed information about the project through the Adventure Scientists' newsletter, blog, social media, and by directly contacting organizations who could reach a wide network of potential volunteers including SciStarter, native plant societies, outdoor groups, and others.

Potential volunteers filled out an application form on our website, which included screening

VOLUNTEER TEAMS USE MAPS AND GPS APPS TO NAVIGATE TO DESIGNATED FIELD SITES

DOMINIC OAKES

questions such as their level of experience in outdoor settings and whether they have any experience handling insects (experience preferred, but not required). We screened, accepted, and trained 323 volunteers who ultimately contributed to the project.

Training for this project followed two methods: in-person field trainings and online training modules. Field training events allow volunteers to practice protocols in the field, and receive feedback from Adventure Scientists staff. However, these trainings require staff time and money that wasn't feasible after the pilot year of the project. We saw this as an opportunity to assess differences in data quality between in-person training and online training. Therefore, we tested both training methods in 2017. We found no difference in data quality from volunteers who had attended in-person training compared to online training sessions, and we therefore decided to discontinue travel for training in 2018 - 2020. We hosted in-person training annually in Bozeman, MT but also required those volunteers to take the online training to ensure consistency.

The data submitted by those who were trained online was as robust as the data from volunteers who were trained in person, which we assessed based on the percentage of properly submitted data.

KATIE GUETZ REMOVES A BUTTERFLY FROM THE NET BY HOLDING IT BETWEEN THE HEAD AND THORAX

DOMINIC OAKES

A VOLUNTEER HANDLES A SULPHUR BUTTERFLY USING FORCEPS TO TAKE HIGH-QUALITY PHOTOGRAPHS EMMA BODE

DATA COLLECTION & RESULTS

All volunteers collected data using the iNaturalist app. We chose to use iNaturalist largely due to the machine learning algorithm, which can assist with identification of butterflies and plants. iNaturalist has a community of observers and identifiers who verify the species ID for each observation. We created three separate projects within iNaturalist: "Butterflies," "Plants," and "Site Observations." All of the data are open source and can be viewed on the iNaturalist website, however only trained observers can contribute to the data set within the three projects created by Adventure Scientists. The data for this project included photos of butterflies and wildflowers, phenology of the plants (timing of the plant's life cycle), and

site information. In total, 323 volunteers submitted 1,997 observations of butterflies, which were identified to 151 species. For wildflowers, volunteers submitted 3,751 observations, which were identified to 612 species.

For this project, 71.1% of the project's butterfly observations are recognized as "research-grade" observations, which means that two or more iNaturalist community members agree with the identification. A total of 28.9% of butterfly observations still need identification or are unable to be identified to species level. For wildflowers, community members identified 34.8% of the project's observations as "research-grade. A remaining 65.2% need identification.

Adventure Scientists' volunteers collected valuable data on species of interest. We detected the iconic monarch (*Danaus plexippus*, 7 observations), whose conservation status is considered "vulnerable" in Canada. In the US, listing of the monarch as endangered or threatened under the Endangered Species Act is warranted, but precluded by higher priority listing actions as of 2020. One volunteer in Wyoming detected one individual Napaea fritillary (*Boloria alaskensis halli*), which is considered imperiled due to its very narrow range with discontinuous habitat patches. One volunteer detected the Gorgon copper (*Tharsalea gorgon*), which is threatened due to habitat degradation and invasive plants.

Butterfly diversity in North America represents approximately 11% of global butterfly diversity (Lotts and Naberhaus, 2017) and by expanding to a global project, volunteers detected a diverse representation of butterfly families.

Volunteers detected two introduced species: The cabbage white (*Pieris rapae*, 6 observations) and the European skipper (*Thymelicus lineola*, 25 observations).

monarch, *danaus plexippus*

banded blue pierrot, *discolampa ethion*

postman, *heliconius melpomene*

mormon fritillary, *speyeria mormonia*

banded peacock, *anartia fatima*

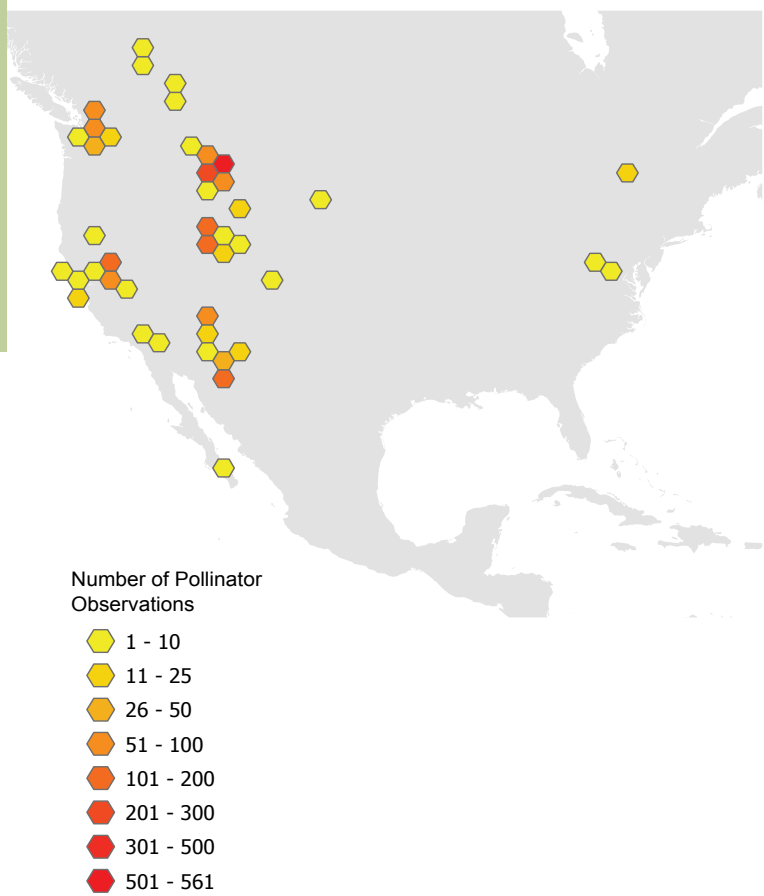
bandless bushbrown, *mycalesis maianea*

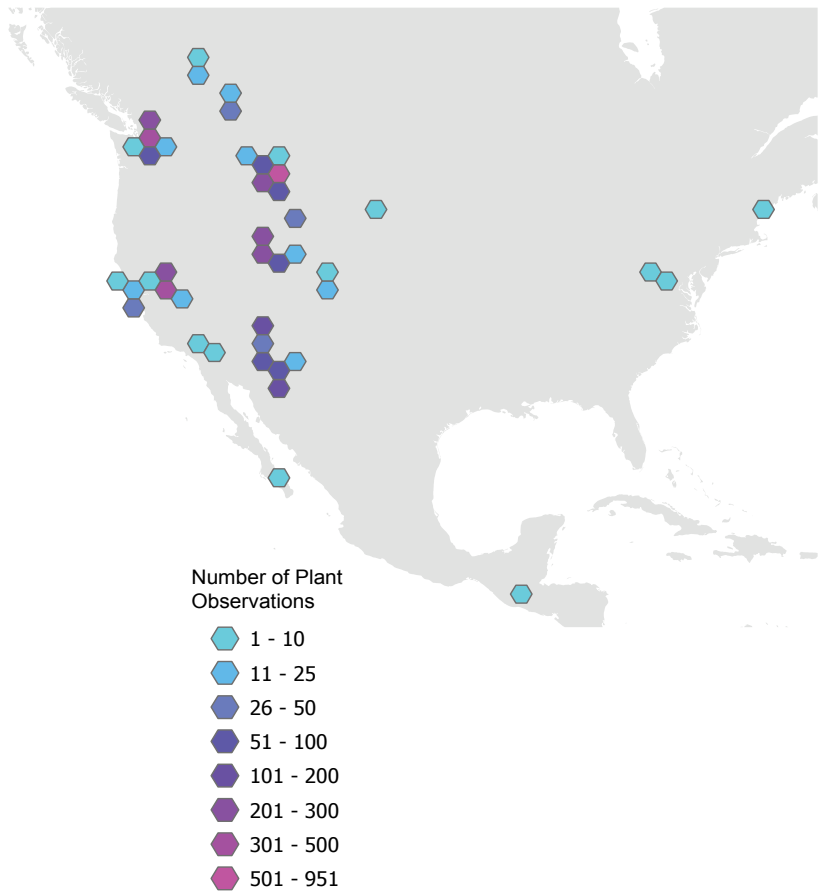
black-tipped archduke, *lexias dirtea*

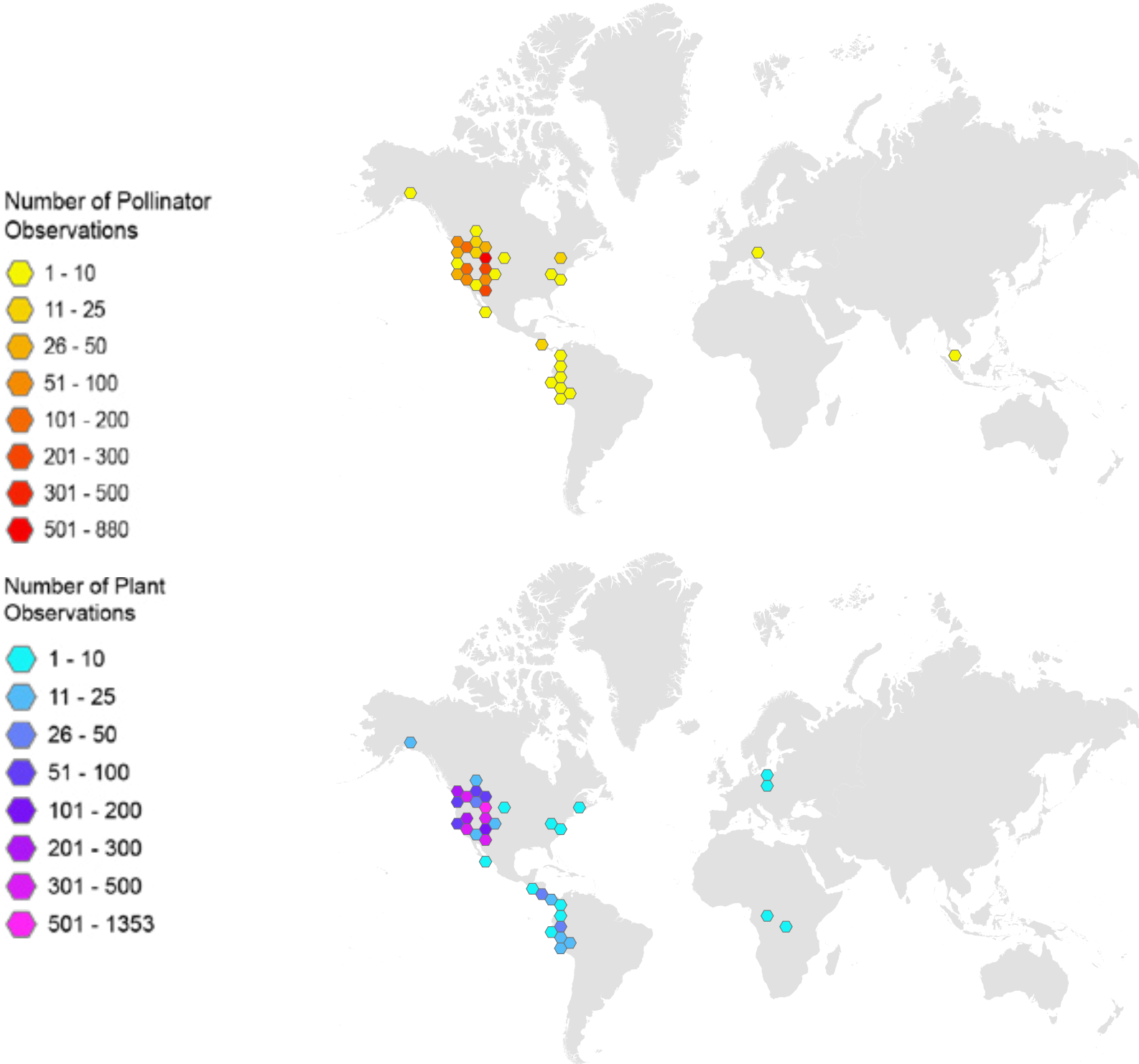
gorgon copper, *tharsalea gorgon*

The three most abundant butterflies volunteers observed were orange sulphur (*Colias eurytheme*, 21 detections), mormon fritillary (*Speyeria mormonia*, 20 detections) and western white (*Pontia occidentalis*, 17 detections).

Volunteers recorded species such as the banded blue pierrot (*Discolampa ethion*, 1 observation) in Malaysia, the banded peacock (*Anartia fatima*, 2 observations) in Costa Rica, the bandless bushbrown (*Mycalesis maianeas*, 1 observation), the black-tipped archduke (*Lexias dirtea*, 1 observation) in Malaysia, the stunning morpho (*Morpho menelaus ssp. amathonte*, 1 observation) in Costa Rica, and the postman (*Heliconius melpomene*, 1 observation) in Ecuador. These species represent just a small fraction of the biodiversity documented in this study. Locations of project observations for butterfly genera are shown on the following maps.






Number of Pollinator Observations
1 - 10
11 - 25
26 - 50
51 - 100
101 - 200
201 - 300
301 - 500
501 - 880
Number of Plant Observations
1 - 10
11 - 25
26 - 50
51 - 100
101 - 200
201 - 300
301 - 500
501 - 1353

WILDFLOWER DATA IS ENTERED IN INATURALIST AND PROVIDED TO LAND MANAGERS

ADVENTURE SCIENTISTS

DATA END-USE

Adventure Scientists' dataset is unique in filling in data gaps of butterflies and wildflowers in remote areas. Data is available for download through our website, iNaturalist, and the Global Biodiversity Information Facility. We contributed data to state natural heritage programs, which is the official source the USFS utilizes for forest planning purposes. Data in these programs go through a thorough vetting process by USFS botanists and zoologists. Dr. Prudic and her team developed a mapping tool for public land managers which displays species checklist by national forest and shows predicted species range occurrence for future climate change scenarios.

LOUISE JOHNS

Justina Dumont

Botanist, Helena-Lewis and Clark National Forest

"These data will be used to support decision-making, Forest project planning, and land management strategies to promote biodiversity. These data could potentially support monitoring efforts of at-risk plant populations or pollinator populations, future restoration projects, and/or influence native plant material collection and seed mixes. Projects and planning strategies can be altered based on new information, and the additional data on butterfly species present on the Helena-Lewis and Clark National Forest would provide management opportunities to promote biodiversity."

WHITNEY METZGER MOUNTAIN BIKES TO A REMOTE FIELD SITE AT ROSS PASS, MONTANA

GREGG TREINISH

PEER-REVIEWED PUBLICATIONS

FEWER BUTTERFLIES SEEN BY COMMUNITY SCIENTISTS ACROSS THE WARMING AND DRYING LANDSCAPES OF THE AMERICAN WEST

2021 Vol 371, Issue 6533

"[We integrated] expert and community scientist datasets that include decades of monitoring across more than 70 locations ... We found a 1.6% annual reduction in the number of individual butterflies observed over the past four decades, associated in particular with warming during fall months. The pervasive declines that we report advance our understanding of climate change impacts and suggest that a new approach is needed for butterfly conservation in the region, focused on suites of species with shared habitat or host associations."

Science AAAS

EBUTTERFLY: LEVERAGING MASSIVE ONLINE CITIZEN SCIENCE FOR BUTTERFLY CONSERVATION

2017 Vol 8, Issue 2

"[W]e describe eButterfly, an integrative checklist-based butterfly monitoring and database web-platform that leverages the skills and knowledge of recreational butterfly enthusiasts to create a globally accessible unified database of butterfly observations across North America. Citizen scientists, conservationists, policy makers, and scientists are using eButterfly data to better understand the biological patterns of butterfly species diversity and how environmental conditions shape these patterns in space and time."

insects

CREATING THE URBAN FARMER'S ALMANAC WITH CITIZEN SCIENCE DATA

2019 Vol 10, Issue 9

"Identifying and managing the insect biodiversity found on city farms is a complex task ... In this study, we introduced several web-based citizen science programs that can connect growers with useful data products and people to help with the who, what, where, and when of urban insects. Combining the power of citizen science volunteers with the efforts of urban farmers can result in a clearer picture of the diversity and ecosystem services in play, limited insecticide use, and enhanced non-chemical alternatives."

PRESS AND MEDIA

WHY PLANTING WILDFLOWERS MAKES A DIFFERENCE
Christina Nunez - April 27, 2021

NATIONAL GEOGRAPHIC

WESTERN BUTTERFLY POPULATIONS ARE PLUMMETING THANKS TO CLIMATE CHANGE
Eric Betz - April 19, 2021

DISCOVER

450 BUTTERFLY SPECIES RAPIDLY DECLINING DUE TO WARMER AUTUMNS IN THE WESTERN U.S
Liz Langley - March 4, 2021

NATIONAL GEOGRAPHIC

DRAMATIC DECLINE IN WESTERN BUTTERFLY POPULATIONS LINKED TO FALL WARMING
Rozemary Brandt - March 4, 2021

THE UNIVERSITY OF ARIZONA.

HOW TO HELP SCIENTISTS IN YOUR COMMUNITY
Gary Greenberg - April 8, 2019

AARP

WHY ADVENTURERS ARE JOINING SCIENTISTS IN TACKLING ENVIRONMENTAL ISSUES
Simone M. Scully - December 20, 2018

GEEK.COM

TEAM WORK HELPS OVERCOME ENVIRONMENTAL CHALLENGES
Karen Steward PhD - July 31, 2018

Technology Networks

ADVENTURE SCIENTISTS
Katie Christiansen - June 2018

BE JOURNAL

CITIZEN SCIENCE PROGRAM HAS A RESEARCH PAYOFF
Daniel Stolte - May 4, 2018

THE UNIVERSITY OF ARIZONA.

MICHELLE TOSHACK DEMONSTRATES PROPER NET HANDLING TECHNIQUES

ADVENTURE SCIENTISTS

VOLUNTEER EXPERIENCE

We requested volunteer feedback on the project through an end-of-season survey. Overall, we had 90 responses to the surveys. Volunteers spoke positively about their engagement with the project, such as:

"This was a great experience overall, giving a new purpose and direction to outings. Being super attuned to butterflies on non-project outings led to a re-discovery of a place I had hiked or run through many times, but now appreciate on a whole new level."

"What makes me most excited about this project is that I understand the power of data and data collection...I am also excited to help in establishing a database that will ultimately impact how our public spaces are managed. As an extensive public land user I am always excited about active ways to give back."

Across the 4 years of the project, 70.9% of volunteers reported that Adventure Scientists provided adequate resources to explore issues around pollination decline. We provided those resources via our website, social media, emails, blog posts, and events. Volunteers showed interest in receiving additional resources, including scientific journal articles (44.7%), popular media articles/videos (18.5%), and Adventure Scientists produced content such as blog posts, videos, etc. (17.0%). Others responded that they would have appreciated other resources not listed in our survey (2.2%) or no additional resources (17.5%). These results reinforce our understanding that volunteers are likely to become informed ambassadors for the species and places they encountered during their participation in this project.

PARTICIPANTS IN A 2019 POLLINATORS PROJECT FIELD DAY OUTSIDE OF BOZEMAN, MT ZOE GOODWIN

We found that 73.9% of surveyed volunteers stated that they took conservation action as a result of volunteering with this project, such as "pursuing a graduate degree in a conservation-related field," "planting pollinator-preferred plants in my backyard and having conversations with friends and co-workers about pollinators and their importance," and "teaching others what I know by designing K-12 curriculum." In addition, 23.2% of respondents stated that they are more likely to pursue a career in conservation.

In 2017, we held a summer competition over a three-week period for volunteers to collect data, which we called a "butterfly-a-thon." We had competitions for the following categories: most butterfly observations reported, most field sites visited, most unusual butterfly detection, and best team photo. We received positive feedback about this event and hosted a second butterfly-a-thon event in August 2018. We saw an increase of butterfly observations by ~10% per week compared to average observations submitted throughout the field season, suggesting that this competition incentivized volunteers to collect more data during this time frame.

We implemented a number of additional volunteer engagement strategies, including hosting regional meet-ups and hosting a conservation careers webinar with three Adventure Scientists staff. We received high praise for the webinar, such as, "This was super helpful and inspirational! It was great to see smart women doing cool science," and "It helped demystify conservation-oriented graduate school programs and spurred me to explore the options further," and "Love the panel of women in sciences!" In addition, we saw an increase in data collection from volunteers after hosting this webinar.

"We went to places [to] which we otherwise would not have gone. We spent a lot of time in the outdoors and it was great to help with scientific research as part of our recreation."

ADVENTURE SCIENTISTS STAFF HIKE INTO A FIELD SITE FOR DATA COLLECTION

ACKNOWLEDGMENTS

We are so grateful for the enthusiasm and willingness of our trained volunteers. We thank them for participating in this project and providing valuable feedback about how to improve the project for future years. We'd also like to thank the many donor partners of Adventure Scientists without whom this project would not have been possible. The Adventure Scientists team provided tremendous support for getting this project up and running in a short period of time, especially Gregg Treinish (Founder, Executive Director), Nicholas Rustigian (Technology Systems Manager), Jessie Kay (Adventurer Coordinator), Katie Christiansen (Projects Team Lead), Merrill Warren (Development Manager) and Aisling Force (Project Creation Manager). Office assistant Ricky Jones contributed summary stats for this report. Ana Egnew (Assistant Wildlife Program Lead at the USFS) provided support and connections throughout the Forest Service. Celia Whitman at Bioquip Products, Inc. waived shipping fees for butterfly nets. Gaia GPS provided free downloads of their app for navigation purposes to all volunteers. Our corporate sponsors Peak Design, Croakies, Klean Kanteen and CLIF Bar donated cool swag to award to volunteers. Treeline Coffee and Bridger Brewing donated beverages for volunteers.

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NEEDS CAPTION AND CREDIT

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