
ELSA GODTFREDSEN

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PROFILE

Dedicated and creative botanist focused on physiological and ecological research with emphasis on climatic adaptation, drought response and alpine ecology. Passionate about the integration of science into education of all levels in order to create equal opportunities, knowledgeable conservation and adept policy making.

EDUCATION

NORTHWESTERN UNIVERSITY, EVANSTON, IL

PhD Candidate, Plant Biology and Conservation, joint program with Northwestern University and the Chicago Botanical Garden, September 2020-Present

- GPA: 4.0/4.0
- *Advisor/Laboratory:* Amy Iler, Global Environmental Change: Population and Community Ecology Lab
- *Working Dissertation:* “Susceptibility of the Subalpine: New Realities of Plant Phenology, Physiology, and Demography Under a Changing Climate”

COLORADO COLLEGE, COLORADO SPRINGS, CO

Organismal Biology and Ecology Major

Graduation Date: May 2019

- GPA: 3.78/4.0
 - *Thesis:* Flower Color, Anthocyanin, UV Damage and Functional Traits in *Ipomopsis aggregata*
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AWARDS & GRANTS

- 2018 Student Undergraduate Research Grant by Colorado College: **4,000**
- 2019 Richard G. and Reba Beileman Award by Colorado College
- 2020 University Fellowship by The Graduate School at Northwestern University **34,500**
- 2021 Karling Graduate Research Award by Botanical Society of America: **1,500**
- 2021 Colorado Mountain Club Foundation 2021 Fellowship: **2,000**
- 2021 Rocky Mountain Biological Laboratory Snyder Graduate Fellowship: **1,300**
- 2021 Northwestern Plant Biology and Conservation Award for PhD Students: **1,500**
- 2022 Alumnae of Northwestern University Research Grant: **2,000**
- 2022 Colorado Native Plant Society John Marr Fund Grant: **750**
- 2022 Rocky Mountain Biological Laboratory Graduate Fellowship: **2,000**
- 2022 Lewis and Clark Field Scholars Fellowship: **5,000**
- 2022 Northwestern Plant Biology and Conservation Award for PhD Students: **750**
- 2022 Colorado Mountain Club Foundation 2021 Fellowship: **1,000**
- 2022 Sigma Xi Grant in Aid of Research: **989**
- 2022 Northwestern Plant Biology and Conservation Travel Award: **500**
- 2022 Honorable Mention in NSF Graduate Research Fellowship Program
- 2023 Dr. John N. Nicholson Fellow at Northwestern University **36,960**
- 2023 Northwestern Plant Biology and Conservation Travel Award: **600**
- 2023 Northwestern Graduate School Conference Travel Grant: **600**

PUBLICATIONS

- Mooney, E., M. Mullins, J. Den Uyl, S. Trail, P. Nguyen, J. Owens, **E. Godtfredsen**, S. Heschel. 2020. Early snowmelt reduces aphid abundance (*Aphis asclepiadis*) by creating water-stressed host 11 plants (*Ligusticum porteri*) and altering interactions with ants. *Arthropod-Plant Interactions*
- Dibiase, C., **E. Godtfredsen**, A. Shapiro, K. Brown, J. Dahl, S. Heschel. 2021 Maternal Flower Color, UV Protection, and Germination in *Ipomopsis aggregata* (Polemoniaceae). *Population Ecology*

SEMINARS & TALKS

- 2019 *Flower Color, Anthocyanin and UV Damage in Ipomopsis aggregata*: Seminar at Organismal Biology and Ecology Day, Colorado College
- 2019 *Flower Color, Anthocyanin and UV Damage in Ipomopsis aggregata*: Poster at Research and Internship Symposium, Colorado College
- 2022 *Earlier Snowmelt, Earlier Flowering, and Increased Drought: New Realities of Subalpine Plant Reproduction under Climate Change*: Seminar, Plant Biology and Conservation Department, Chicago Botanic Garden
- 2022 *Earlier Snowmelt, Earlier Flowering, and Increased Drought: New Realities of Subalpine Plant Reproduction under Climate Change*: Graduate Student Seminar, Rocky Mountain Biological Laboratory
- 2022 *Earlier Snowmelt, Earlier Flowering, and Increased Drought: New Realities of Subalpine Plant Reproduction under Climate Change*: Talk, Ecological Society of America Meeting, Montreal UBC
- 2023 *Drought and Daily Flowers: The Effects of Reduced Precipitation on the Reproduction of a Subalpine Plant Species*: Seminar, PBC Department, Chicago Botanic Garden
- 2023 *Drought and Daily Flowers: The Effects of Reduced Precipitation on the Reproduction of a Subalpine Plant Species*: Graduate Student Seminar, Rocky Mountain Biological Laboratory
- 2023 *Drought and Daily Flowers: The Effects of Reduced Precipitation on the Reproduction of a Subalpine Plant Species*: Talk, Ecological Society of America Meeting, Portland USA
- 2024 *Is earlier better in a changing world? A meta-analysis on the effects of phenological shifts on demographic vital rates across taxa*: Seminar, Plant Biology and Conservation Department, Chicago Botanic Garden
- 2024 *Earlier Snowmelt & Earlier Flowering: New Realities of Subalpine Plant Reproduction under Climate Change*: RMBL Seminar, Rocky Mountain Biological Laboratory
- 2024 *Is earlier better in a changing world? A meta-analysis on the effects of phenological shifts on demographic vital rates across taxa*: Graduate Student Seminar, Rocky Mountain Biological Laboratory

MENTORSHIP, TEACHING & ACADEMIC SERVICE

- 2021 Mentor at the Rocky Mountain Biological Laboratory REU program
- 2021 Mentor at the Chicago Botanic Garden REU program

- 2022 Manuscript Reviewer for Polar Ecology
- 2022 Co-Instructor and Creator of Statistics Course at Northwestern University: *Analytical Toolkit for Ecologists and Evolutionary Biologists*
- 2022 Mentor at the Rocky Mountain Biological Laboratory REU program
- 2022 Panelist at Rocky Mountain Biological Laboratory Graduate Application Workshop
- 2023 Instructor of Record of Statistics Course at Northwestern University: *Analytical Toolkit for Ecologists and Evolutionary Biologists*
- 2023 Abstract Reviewer for Physiological Ecology Section of ESA
- 2023 Mentor for the Rocky Mountain Biological Laboratory REU program
- 2023 Mentor for Northwestern University SURG research program
- 2024 Manuscript Reviewer for Ecological Monographs
- 2024 Panelist at Rocky Mountain Biological Laboratory Graduate Application Workshop
- 2024 Mentor for the Rocky Mountain Biological Laboratory REU program
- 2025 Teaching Assistant for Practical Statistics Course at Northwestern University

SCIENCE COMMUNICATION & OUTREACH

- 2020 Author of Field Notes: Newsletter of Mountain Area Land Trust
- 2021 *Mountains, Science and Me*: Skype a Scientist Presentation to Brownie Group of Girls: Saskatchewan
- 2022 Science Spotlight in Budburst Newsletter
- 2022 Print Interview, “*Early Snowmelt Means Earlier Blooms*”, Northwestern Magazine
- 2023 *Susceptibility of the Subalpine: New Realities of Plant Life under a Changing Climate*: Presentation to Undergraduate Field Ecology Class at Allegheny Univ.
- 2023 Experimental Design Consultant and Spotlight Scientist for Rocky Mountain Biological Laboratory Youth Programs
- 2023 Young Voices of Science Fellow, Hubbard Brooks Foundation
- 2024 Scientists for Migrant Learning & Education Science Fair Panelist
- 2024 Spotlight Scientist for Rocky Mountain Biological Laboratory Youth Programs
- 2024 Print Interview, “*Plants and their pollinators are increasingly out of sync*”, Grist Magazine
- 2025 Panelist for Mentorship Opportunities for Research Engagement (MORE) Showcase at Plant Science Colloquium at Lindblom Math and Science Academy (Chicago Public School)
- 2025 Volunteer Coordinator and Supervisor at Chicago Botanic Garden for Impacts of Snowmelt Timing on Seed Production project

LEADERSHIP

GRADUATE STUDENT COORDINATOR

Rocky Mountain Biological Laboratory (RMBL), Gothic CO, September 2021-April 2025

- Acts as a liaison with RMBL admin and organizes and communicates needs of graduate students

- Organizes and hosts the weekly RMBL Graduate Student Speaker Series which hosts attendances of 45-60.
- Serves as both a social and logistical resource for new graduate students to RMBL, providing safety and informational documents and organizing question and answer sessions prior to field season
- Plans, designs posters and advertises social events which foster a feeling of community and belonging for students of various backgrounds at RMBL

PBC GRADUATE ORGANIZATION VICE PRESIDENT AND SCRIBE

Plant Biology & Conservation Department, Northwestern University, September 2022-April 2025

- Manages all student organization documents, budget and student email list serv
- Assist in organizing all student meetings, takes notes and serves as a resource for other student groups for administrative needs
- Oversees the transition of other student government roles between years of students
- Serves as a student elected representative at staff and departmental retreats

DEI OUTREACH CHAIR

RMBL DEI Committee, Gothic CO, May 2022-September 2024

- Designed posters to advertise and disseminate information about DEI events to larger community
- Created outreach opportunities and resources for DEI committee including visitor center guides, resources for the REU undergraduate program and DEI events

BOARD MEMBER

Student Organization of Sexual Safety, Colorado College, September 2017-May 2019

- Provided education, support, and referrals on issues of sexual violence and harassment
- Focused on creating engaging events for students that promote self-care and mental health
- Encouraged a feeling of safety and well-being at Colorado College

RESEARCH EXPERIENCE

FIELD TECHNICIAN

Mountain Area Land Trust, Candi Galen Laboratory, Alma, CO, June 2020-August 2020

- Independently conducted ecological surveying on Pennsylvania Mountain including audio bumble bee monitoring, floral counts and phenological assessments.
- Communicated to the larger community of the land trust through weekly field note sections
- Created and conducted data collection on an independent research question focusing on increased frequency of drought's effect on floral duration.

FIELD TECHNICIAN

United States Department of Agriculture (ARS), Lauren Porensky Laboratory, Fort Collins, CO, May 2019-January 2020

- Independently managed ecological field work on the Conservation Reserve Program (CRP) in Fort Collins area
- Performed fitness counts on floral blooms as well as pollination observation to assess success of individual plots
- Worked with landowners to promote and understand projects being enacted on their lands
- Assisted on grazing projects in David Augustine's lab at ARS which included collection of fecal samples from cattle and participating in a prescribed burn

RESEARCH ASSISTANT

Colorado College Department of Organismal Biology, Shane Heschel Laboratory, Colorado Springs, CO, May 2018 – May 2019

- Conducted multiple weeks of field research in remote settings
- Mastered physiological instruments including a Porometer, Fluorometer, and SPAD meter
- Performed hormone analysis using ELISA technique
- Collaborated with Emily Mooney's lab at Rocky Mountain Biological Laboratory on *Host plant mediated effects of snow cover on an ant-aphid mutualism*

HERBARIUM DIGITIZATION INTERN

Carter Herbarium, Colorado College Department of Organismal Biology, Colorado Springs, CO, May – October 2018

- Designed a system to digitize the Carter Herbarium for usage on SEINet Portal
- Barcoded and transcribed information for 11,000 specimens

WORKSHOPS & TRAININGS

- 2016 *Wilderness First Responder Course and Certification*, (Certification maintained)
- 2017 *Wilderness Safety and Skills Training*, Overland Summers
- 2019 *Python Half Block Course*, Colorado College
- 2020 *R Fundamentals Bootcamp*, Northwestern University IT Department
- 2021 *Mentoring Workshop*, Chicago Botanic Garden REU Program
- 2021 *Identity-Based Field Safety Workshop*, Rocky Mountain Biological Laboratory
- 2022 **Instructor of Hiking Safety**, Rocky Mountain Biological Laboratory
- 2023 **Instructor of Hiking Safety**, Rocky Mountain Biological Laboratory
- 2023 *Implicit Bias Training*, Rocky Mountain Biological Laboratory
- 2023 *Phys Fest 4: Training Workshop on Plant Eco-Physiology* at Sevilleta National Wildlife Refuge (NM)
- 2023 *Young Voices of Science Communication Training*, Hubbard Brooks Foundation
- 2024 *Building Neuro-inclusive Learning Environments: Best Practices to Support and Empower Neurodiverse Learners in STEM*, Center for the Integration of Research Teaching and Learning (CIRTL)
- 2024 *The College Classroom: Exploring inclusive, learner-centered teaching theories and practices*, CIRTL
- 2024 Certified as CIRTL Associate from the Searle Center for Advancing Learning & Teaching at Northwestern University

PROFESSIONAL ASSOCIATIONS

- DEI Committee, Rocky Mountain Biological Laboratory
- The Society for Ecological Restoration Northwestern University Chapter Member
- Colorado Native Plant Society, Denver Chapter
- Chicago Women in STEM Initiative
- Blue Key Honor Society, Colorado College Chapter
- Ecological Society of America Member

SKILLS

COMPUTER: Introductory Understanding of GIS Programming and competent knowledge of Python coding language, R programming and Arduino IDE use; Proficiency in Microsoft Excel, Word, PowerPoint, Outlook as well as JMP; Competent in constructing and manipulating phylogenetic trees using Geneious, Competent in use of Canva and Adobe Illustrator to create graphics and design visuals.

FIELD RESEARCH: Capable of on sight identification of 11 plant families, 134 genera and 50 species of the West; Experienced using a dichotomous key in order to identify to a species level adept in usage and maintenance of physiological instruments; Capable of identifying western bees to mono-type on sight; Practiced in taking Frequency, Density, LPI, Canopy Cover and Robel Pole measurements in vegetative samples; Knowledgeable of prescribed burn protocols and experienced in burn suppression and safety practices

LAB: Trained in the operation of light and fluorescent microscopes; proficient in setting up, cloning, and purifying a PCR; isolating protein from E. coli; using SDS-PAGE and Western blot techniques to examine proteins as well as isolating plant tissue for the purpose of hormone analysis using the ELISA technique; and identifying various western seeds for weighing and density calculations

CERTIFICATIONS: Wilderness First Responder (trained to recognize and treat various medical conditions, such as asthma, diabetes, shock, and wounds), Adult & Child CPR & Airway management and Epinephrine Auto-Injector

Godtfredsen Writing Sample
Sourced from Grants Written for Botanical Society of America which was funded in 2023

Biographical Sketch

My first botany class reminded me of the day I received my prescription glasses. All of the trees turned from amorphous buildings of green to intricate structures of leaves. Suddenly the outside world was filled with a whole new host of characters, in an entirely new landscape. This fresh lens came from PowerPoint slides in a dark room and the immense excitement of my first plant biology professor. I learned not only to see the internal world of plants but how the world surrounding them was changing. In that dark room, a classroom of future ecologists listened to a re-uttering of a tale as old as our childhoods: climate change. I dove deep into topics such as ecosystem collapse, species extinction and vast climatic alteration that was occurring not only at that moment, but had been building in intensity for most of my life. I walked from that room not only determined to pursue a career in plant biology but with a staunch belief that plant based research was the key to saving our biological world.

I pursued research opportunities with Dr. Shane Heschel at Colorado College, the same professor that taught that first class. I spent nearly every day that first summer measuring the physiology of a small montane herb, *Ipomopsis aggregata* in the field in order to produce an undergraduate thesis. This work involved untangling the relationship between floral color and UV-radiation. During that same time, I assisted on a project with Dr. Emily Mooney that focused on the consequences of climate change at the Rocky Mountain Biological Lab (RMBL). This work revolved around how snow melt, which is in flux in alpine Colorado, influences the relationship between ants and aphids on *Ligusticum porteri*. I was captivated by plants physiology and reactions to environmental cues. I was thrilled to be involved with both of these projects through their conclusions. The RMBL study was published in 2020 in *Arthropod-Insect Interactions* while my thesis work has been submitted to the journal *Population Ecology*. Through these projects, I became enraptured with the process of science and the possibilities physiological research had to understand and therefore combat a changing climate. My next step was exploring pollination and land restoration at the Agricultural Research Service of the United States Department of Agriculture. I worked on the Conservation Reserve Program, which creates restored farmlands with pollinator attractive plant species on local farm owners land. This project was a fascinating insight to pollination research and its ecological importance not only to natural areas but also to agriculture. I began to see the possibility for a combination of this applied work in pollination with my academic experience in physiology.

I dove into this intersection in the summer of 2020 at Pennsylvania Mountain, a 13,000 foot mountain in Colorado. I worked with the Mountain Area Land Trust and Dr. Candi Galen on conducting phenological monitoring of plants and bumble bee populations. I also conducted my own research project focusing on the reaction of floral duration to drought and its pollination consequence. The work I did in this fragile and captivating alpine ecosystem lit a fire in me to focus my research interests on these high risk areas. I brought these ideas into the first year of my PhD at the Plant Biology and Conservation program in Amy Iler's lab. I am fascinated by the intersection of phenological change, physiological reaction to drought and subsequent pollination consequences in high elevation settings. My dissertation will investigate these factors by manipulating snowmelt timing and assessing plant community response. I intend to continue to investigate these topics eventually as a professor at a research institution. It is a dream of mine to offer the revelatory experience I had as an undergraduate to others and to educate future climate ecologists. I intend to continue to pursue these research topics both as an educator and mentor in order to promote informed conservation of alpine areas and adept scientific education about pollinator and plant species.

Statement of Purpose:

Introduction: Climate change is altering global precipitation and temperature trends, causing drastic changes in ecosystems across the globe ¹. In high-elevation ecosystems, which are more sensitive to climatic change, rising temperatures and lower precipitation have resulted in earlier snowmelt and more frequent drought conditions ². Snowmelt acts as an important moisture source and phenological cue for high-elevation plants, and therefore changes to both snowmelt timing and precipitation can fundamentally change survival and reproduction, and over time, population persistence, of subalpine plants. Despite this risk, the reproductive consequences of early snowmelt and lower precipitation have only been assessed for a small number of subalpine plant species, and the specific mechanisms behind these changes are under investigated. **This project will help fill this gap in knowledge by experimentally testing the effects of early snowmelt and reduced precipitation on phenological, physiological,**

and demographic traits of subalpine plants to identify both mechanisms and impacts of climate change on high-elevation plant species.

Snowmelt serves as both a major moisture source and a phenological cue for the timing of emergence and flowering in subalpine plants and therefore can have numerous impacts on plant reproduction and survival. Earlier snowmelt is generally shifting flowering timing to an earlier date, which can expose plants to novel conditions such as lower temperatures, altered moisture conditions, and decreased synchrony with pollinators, all of which can alter plant reproduction^{3,4}. Specifically, earlier snowmelt increases the time between the influx of snowmelt moisture in the spring and the onset of the monsoon rains in mid-summer. The lengthening of this gap, as well as decreased moisture due to reduced precipitation, can lead to inadequate water sources for plants attempting to flower. Drought conditions while flowering can prompt plants to reduce floral number and size as well as decrease production of floral rewards (nectar & pollen)^{5,6}. In turn, changes to floral traits can reduce pollinator visitation and inhibit plant reproduction⁷. Drought can also cause reduced survival due to plant desiccation (hypothesized in Iler et al. 2019). Reduced pollination, along with diminished survival, could threaten the long-term persistence of plant populations.

Although the negative effects of early snowmelt and decreased precipitation, such as decreased survival and lower flower abundance, have been observed on a small number of species^{8,9}, it is unclear what aspect of early snowmelt is driving these reproductive changes and how severe they may become. Both changes in phenological timing and moisture availability can alter plant reproduction, and my research will tease the effects of these two factors apart. Without a mechanistic understanding of the ways in which early snowmelt and decreased precipitation affect plant reproduction, our ability to predict and forecast future responses of the plant community is limited.

My study will utilize multiple approaches of plant monitoring (phenological, physiological, demographic) to assess the reproductive impact of early snowmelt and reduced precipitation on subalpine plant species. Specifically my field work in the summer of 2022 will be the second out of a four-year snowmelt and precipitation manipulation where I will measure flowering phenology, physiological responses, demographic vital rates, floral morphology, and pollination of four subalpine plant species. I will ask: **Q1)** How does early snowmelt and reduced precipitation influence physiological drought stress of subalpine plants? **Q2)** How does early snowmelt and reduced precipitation affect flowering characteristics (phenology, floral size, and reward) in subalpine plant species? **Q3)** How does early snowmelt and reduced precipitation affect pollination frequency, plant survival and seed set?

Methods: I will conduct my field work at a subalpine meadow near the Rocky Mountain Biological Laboratory (RMBL) in Gothic, CO, USA. RMBL is an ideal setting for my work because the area is experiencing direct consequences of climate change through shifts to earlier snowmelt timing and changes to summer precipitation that are only forecasted to become more severe over time^{2,10}. I will study four animal pollinated plant species that flower at different points across the season and represent various floral morphologies and families: *Delphinium nuttallianum* (Early Season, Ranunculaceae), *Linum lewisii* (Mid-season, Linaceae), *Hymenoxys hoopesii* (Late/Mid-Season, Asteraceae) and lastly, *Delphinium barbeyi* (Late Season, Ranunculaceae).

This year will represent the second of a four year snowmelt timing and precipitation manipulation to understand how snowmelt timing and reduced precipitation *specifically* impacts plant reproduction either through the increased drought exposure for plants or the alteration of the temporal landscape of flowering. I will work within a series of 21 plots arranged in seven treatment blocks in an open meadow habitat. Each block will consist of a control plot, an early snowmelt plot and a rain reduction plot. I will stimulate early snowmelt by covering the early snowmelt plots with black shade cloth when there is approximately 1 m of snow remaining in the spring, translating to approximately a 10 day earlier snowmelt date¹¹. I will use rain out shelters to reduce water availability across the growing season in the rain reduction plots. I will measure soil moisture weekly across the season in all plots to quantify the effect of snowmelt timing and reduced precipitation on water availability.

For my plant measurements I will study 360 plants (90 of each species) evenly distributed across all plots for the entirety of the season. **Physiological data (Q1):** I will collect physiological drought response data (stomatal conductance & photosystem efficiency) (1x/week). **Floral trait data (Q2):** I will collect flowering phenology data (3x/week) and floral trait data (nectar volume, nectar sugar concentration, flower size; 1x/week). **Demographic data (Q3):** I will monitor the size, survival to the end of the season, number of flowers, and number of seeds of each individual plant. To further quantify plant reproduction I will observe pollinator behavior by recording the number of pollinator visits and the identity of pollinators during biweekly observation sessions in all plots.

In 2021, I successfully completed my first year of snow manipulations and was successful at measuring the above data on 240 plants. Preliminary results indicate that earlier snowmelt prompts a phenological shift to an earlier peak flowering date in all four species monitored ($p < 0.05$ for 3 species, $p < .8$ for 1). I also observed significantly lower pollinator visitation rates for plants in the early snowmelt plots compared to the control ($p < 0.05$). Certain species had significantly reduced floral size and smaller plant size in the early snowmelt plots, which

may contribute to the lower pollinator visitation, but more years of data collection are needed to understand the specific effects of snowmelt timing and drought on plant reproduction.

Conclusion: The proposed study will contribute to our understanding of how earlier snowmelt affects high elevation plant species in an area of the Rocky Mountains where snowmelt timing is actively changing to an earlier date¹⁰. By including data on multiple facets (demographic, physiological and reproductive) the dataset will produce a rigorous picture of how four different subalpine plant species may be affected by earlier snowmelt and reduced precipitation. This project represents a dynamic and multi-year study that will produce valuable data that can be used to understand the threats of a severely changing climate on the natural world.

Work Cited

1. Cook, B. I., Smerdon, J. E., Seager, R. & Coats, S. Global warming and 21st century drying. *Clim. Dyn.* **43**, 2607–2627 (2014).
2. Pederson, G. T. *et al.* Climatic Controls on the Snowmelt Hydrology of the Northern Rocky Mountains. *J. Clim.* **24**, 1666–1687 (2011).
3. Forrest, J. R. K. Plant–pollinator interactions and phenological change: what can we learn about climate impacts from experiments and observations? *Oikos* **124**, 4–13 (2015).
4. Gezon, Z. J., Inouye, D. W. & Irwin, R. E. Phenological change in a spring ephemeral: implications for pollination and plant reproduction. *Glob. Change Biol.* **22**, 1779–1793 (2016).
5. Caruso, C. M. Plasticity of inflorescence traits in *Lobelia siphilitica* (Lobeliaceae) in response to soil water availability. *Am. J. Bot.* **93**, 531–538 (2006).
6. Waser, N. M. & Price, M. V. Drought, pollen and nectar availability, and pollination success. *Ecology* **97**, 1400–1409 (2016).
7. Galen, C. & Newport, M. E. A. Bumble Bee Behavior and Selection on Flower Size in the Sky Pilot, *Polemonium viscosum*. *Oecologia* **74**, 20–23 (1987).
8. Iler, A. M. *et al.* Reproductive losses due to climate change-induced earlier flowering are not the primary threat to plant population viability in a perennial herb. *J. Ecol.* **107**, 1931–1943 (2019).
9. Inouye, D. W. Effects of Climate Change on Phenology, Frost Damage, and Floral Abundance of Montane Wildflowers. *Ecology* **89**, 353–362 (2008).
10. Ogilvie, J. E. *et al.* Interannual bumble bee abundance is driven by indirect climate effects on floral resource phenology. *Ecol. Lett.* **20**, 1507–1515 (2017).
11. Steltzer, H., Landry, C., Painter, T., Anderson, J. & Ayres, E. Biological consequences of earlier snowmelt from desert dust deposition in alpine landscapes. *Proc. Natl. Acad. Sci. U. S. A.* 11629–11634 (2009).