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MILLIONS OF MONARCH BUTTERFLIES AND THE QUEST TO COUNT THEM

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YOUNG REVIEWERS:

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AGE: 14

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OWEN,
THEO
AGES: 9–11

Monarchs are capable of amazing feats! They transition from caterpillars to beautiful butterflies. During migration, they fly for thousands of miles—from the northern part of the United States and southern Canada to Mexico. But monarch butterflies are in trouble. In the past 25 years, citizens and scientists have reported fewer and fewer of them. There were less than half as many monarchs in 2020 as in 2019. Parks across the United States, like Rocky Mountain and Indiana Dunes National Parks, host the monarchs along their migration paths. The park rangers are helping scientists track monarchs through "capture, tag, and release." With this method, anyone who sees a tagged butterfly can report when and where they saw it. By tracking monarchs along their migration paths, we expect to learn where they run into problems. Scientists are also using new technology to count monarchs in their winter habitats.

WHY MONARCHS?

Have you seen orange wings fluttering by? Or maybe you have seen a green caterpillar eating a milkweed plant? Certain caterpillars transition into the popular orange-and-black monarch butterflies (Figures 1A,B). Monarchs do important work in the ecosystem. While these insects feed on nectar, they also move pollen between plants. **Pollination** helps plants reproduce (Figure 1C). When pollination is successful, there is more food available for all types of animals, including people! While monarchs help create food for us, they are also a good source of food for birds, other insects, and small animals (though they have ways of defending themselves according to https://monarchwatch.org/biology/pred1.htm).

POLLINATION

Transfer of dust-like pollen particles from the flower of one plant to another (or to a reproductive part of the same plant). Pollination is essential for plant reproduction.

Figure 1

Figure 1

(A) Monarch butterfly. **(B)** Monarchs clustering on cold winter day to keep warm. **(C)** Monarchs pollinating a milkweed flower.

There are two different populations of monarch butterflies. One population spends winters in California (United States) and travels through state and national parks west of the Rocky Mountains; the other population, called the Eastern population, stays east of the Rocky Mountains. We will focus on the much larger Eastern population. These butterflies travel thousands of miles every year, from southern Canada all the way to Mexico. This event is called **migration** [1]. Imagine traveling thousands of miles (up to 4,000 km, which is 2,500 miles) under your own power! That is almost like traveling from New York to Los Angeles! Butterflies make the trip only once in their lifetimes. This makes monarchs very interesting to scientists—how do monarchs know where to go if they have never been there?

MIGRATION

Movement of wildlife or people to find a location that is optimal for finding food and safety for the next generation. For birds and insects, migration is often seasonal.

Since these creatures are helpful to ecosystems across North America, it is very important to keep track of their population sizes. The best way to count Eastern monarchs is in Mexico in the winter, when all Eastern monarchs snuggle together in the trees of protected **cloud forests**. The rest of the year, monarchs are spread out across the United States and Canada and are too difficult to count. Mexican cloud forests have the perfect temperature and humidity for monarchs. Areas further north are too cold; monarchs can freeze to death. Areas further south are too warm for the plants monarchs depend on for food. Monarchs crowd into these few places in Mexico during the winter because conditions are just right.

CLOUD FOREST

Cloud forests are like rain forests: they exist in tropical areas. Cloud forests are all at high elevations where low clouds filter through the trees and produce precipitation.

TRAVELING TO MEXICO

As they migrate to Mexico, monarchs must rest along the way. Some of their rest stops are in Indiana Dunes and Rocky Mountain National Parks in the United States, where staff and visitors have been monitoring monarchs for 15 years. Monarch monitors catch monarchs with butterfly nets, gently put little tags on them, and release them. This method is called "capture, tag, and release." The tags look like little stickers with numbers on them (Figure 2). Anyone who sees a monarch with a tag can write down the number and report it online to an organization called Monarch Watch. The stickers work like car license plates—you can tell which state a car came from no matter where it is seen. This way, researchers can piece together the path of that specific monarch. If the butterfly does not make it to Mexico, researchers can figure out where it was last seen and maybe even why it ran into trouble. Anyone, including you, can help researchers collect this information! Whenever you see a monarch with a tag, write down the number and report it to MonarchWatch.org! On this website you can see how the number of butterflies goes up and down. The numbers go up as more monarchs are sighted, and they go down if the monarchs get caught in storms or fires.

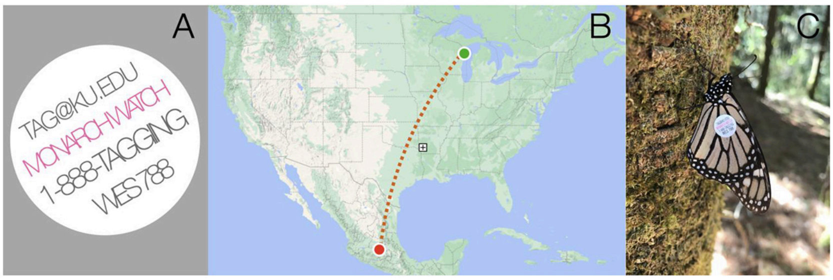

Figure 2

Figure 2
(A) To track its migration route, a monarch butterfly was tagged by Monarch Watch on September 20, 2016 and released from Egg Harbor, Wisconsin, USA. **(B)** The monarch traveled 2,300 miles in 5 months. **(C)** This picture of the tagged monarch was taken on February 20, 2017, in Zitácuaro, Mexico (for more on tagging, see https://monarchwatch.org/tag-event).

COUNTING MILLIONS OF BUTTERFLIES

Monarchs cluster together on fir trees high in the cloud forests of Michoacán, Mexico [2]. Scientists have been wondering how to accurately count so many monarchs. The problem is that monarchs come in extremely large numbers, and they hang on to the trees in very dense groups. If you did not know you were among butterflies, you might think you were walking through trees with blankets tossed over them! This has made it very difficult for scientists to be sure they are getting correct numbers. Picture it this way: you are asked to estimate the number of M&Ms in a giant jar in front of you. When they are all clumped together in the jar, it is difficult! If you could line them up, it would be much easier.

What if you had super eyesight and could count the shapes of the hidden butterflies to get your answer? Scientists have that technology

LIDAR

Light detection and ranging. A technique in which a camera-like device directs a beam of light into a space and measures the distance to the first solid object it hits.

SVE

Subtractive Volume Estimation. A method for estimating the number of animals in dense groups by analyzing the shape and volumes of these groups when scanned with LiDAR.

today! It is a laser-beam technology called **LiDAR**, for **li**ght **d**etection **a**nd **r**anging. LiDAR technology uses a laser scanner, which is like a camera. But instead of making a two-dimensional image (like a drawing of a square on a piece of paper), it makes a digital, three-dimensional model (like a Rubik's cube). To generate the model, the LiDAR scanner sends out millions of laser beams to record the positions and distances of objects in the environment. Two scientists, Louise Allen and Nickolay Hristov, decided to use LiDAR to estimate large populations of animals that cluster together. To find out how many monarch butterflies were in the forest, the scientists scanned the forest two times: first when there were no butterflies, and then when the butterflies were covering the trees. Since the laser scans show detail in three dimensions, they can be used to figure out how much space something in the image takes up (its volume). They subtracted the volume of the bare trees from the volume of the covered trees, to get the volume of just the butterflies (laser **SVE**) (Figure 3, Video 1). Since scientists can estimate the typical volume of one monarch, they can divide the total volume by the volume of one butterfly, to estimate the total number of monarchs in the forest [3].

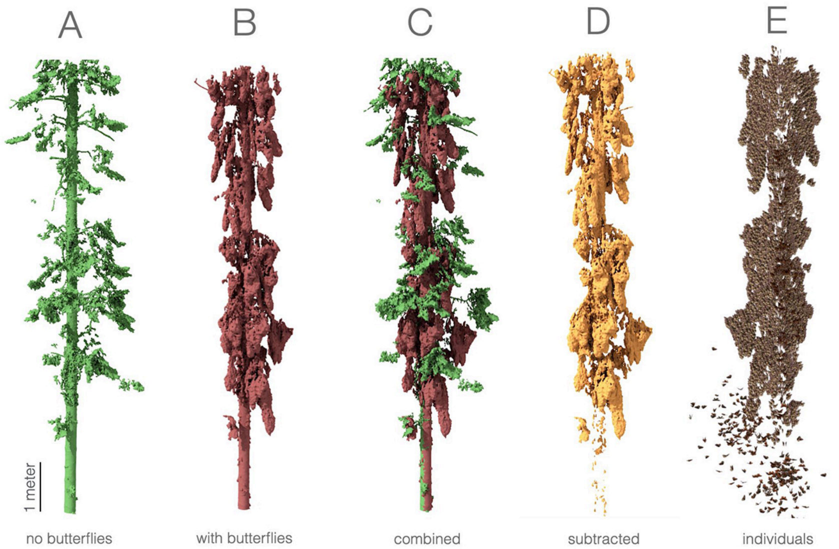

Figure 3

Figure 3

Three-dimensional models of Oyamel fir trees in central Mexico, based on LiDAR. **(A)** A tree without butterflies. **(B)** The same tree with butterfly clusters. **(C)** The combination of **(A,B)**, to show the shapes of the tree with and without butterflies present. **(D)** Only the roosting butterflies, created by subtracting **(A)** from **(B)**. Notice that the trunk and branches of the tree are missing. **(E)** Conversion of the volume of butterflies from **(D)** into estimated individual monarchs.

VIDEO 1

Visual description of the SVE method showing how the LiDAR scan of a tree with and without butterflies is converted to 3-D models for analysis and estimating the count of individual butterflies.

Before this new method, SVE scientists estimated that, between 2000 and 2020, the monarch population was between 1.6 and 1.5 billion butterflies [4, 5]. That is like saying you either have $70 or $70,000, you are not sure which, but at any time the amount is somewhere in that range. That is a big range. Of course, the number of butterflies changes every year. If the techniques for estimating the numbers of monarchs are not accurate, it is difficult to tell if efforts like milkweed plantings are making a difference. We need the most accurate numbers to understand whether there is a big problem with monarch populations. In the past 2 years alone, the estimated number of monarchs dropped by half according to the area estimations.

With LiDAR, more accurate counts of monarchs in Mexico are possible. Using LiDAR technology, scientists can compare a baseline count taken today to future scans. If future scans show an increase in monarchs, it will tell us that whatever help we are providing for monarchs is successful.

THE CHALLENGES

We know monarch butterflies face many challenges. Besides the storms and fires that kill them, monarchs only eat and lay their eggs on the leaves of the milkweed plant. Milkweeds are getting harder to find because people often kill these plants with herbicides or other chemicals. As we build more houses, stores, and parking lots, we lose space for plants and trees, including milkweeds. The same is true at the end of the monarch migration route in Mexico. More houses, stores, farms, and factories mean fewer trees where monarchs can spend the winter. Mexicans who grew up seeing thousands of monarchs are working hard to preserve the cloud forest habitats, so the monarchs have a place to go. Monarchs have also suffered the effects of changing weather patterns, like more frequent storms, sudden drops in temperature, and excessive rain.

WHY WE CARE

We all benefit from monarchs. They help us by pollinating the plants we eat. We can use new technologies to track and count monarchs, which will help us learn how best to protect them. National parks, both in the United States and Mexico, have a big role to play in protecting monarchs. We can all help decrease the dangers monarchs face by helping to preserve forest areas, limiting the use of chemicals, and leaving milkweed plants in place for monarch habitats. Let us continue the hard work so that we can see larger numbers of monarchs across North America. Help save monarchs! Visit www.monarchwatch.org or www.xerces.org/monarchs to learn more.

AUTHOR DISCLAIMER

Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

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CONFLICT OF INTEREST: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

YOUNG REVIEWERS

HARJAS, AGE: 14

Hey! My name is Harjas and I am 14 years old. My favorite subjects in school are Math and Science. I have been learning Indian classical singing since I was 6 years old. I also love to play cricket in my backyard with my brothers. In my free time I enjoy reading and going on bike rides.

ISLA, PIPER, OWEN, THEO, AGES: 9–11

We are elementary school students. We like to explore outside, be creative, mess around, and think about science.

AUTHORS

SOPHIE PHILLIPS

Sophie Phillips is a graduate student studying energy and environmental policy at the University of Delaware, U.S. She is also a research assistant for the Water Resource Center within the Biden School of Public Policy and Administration. She studied environmental and marine science during her time as an undergraduate, and she worked as a laboratory technician in the Robotics Discovery Lab on University of Delaware's Hugh R. Sharp Campus in Lewes, Delaware. Her research interests include human noise impacts on wildlife, wildlife conservation, environmental justice, and the connection between environmental history and race within the United States. *sophiekp@gmail.com

MARTHA MERSON

Martha Merson has co-led the project Interpreters and Scientists Working on Our Parks, along with Hristov and Allen. Merson was never an outstanding science student, but she was curious about scientists' work. She has worked closely with scientists and park rangers to bring science stories to public audiences.

LOUISE C. ALLEN

Louise C. Allen is a biologist and higher-ed administrator with expertise in undergraduate mentoring. Her research has focused on human impacts on behavior and stress in wildlife, including bats. She also has expertise in science learning inside and outside of the classroom.

NICKOLAY I. HRISTOV

Nickolay I. Hristov is a scientist with interests in information and learning design and population dynamics. His research (done in tandem with Louise Allen) using LiDAR technology has provided more accurate counts of clustering species like monarchs in Mexico and cave-dwelling bats in the south-central United States.