Hummingbird Citizen Science

Students become citizen scientists to contribute to research that may help declining populations of hummingbirds

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Pollinators such as hummingbirds are critical to the reproduction of many flowering plants. Hummingbirds help maintain genetic diversity of local plant populations because they travel farther than other pollinators, spreading pollen between distinct plant populations (Cronk and Ojeda 2008). Hummingbirds can pollinate in cold, wet conditions when most insect pollinators remain inactive (Cronk and Ojeda 2008).

Flowers and hummingbirds offer striking examples of coevolution between plants and pollinators. For example, in Costa Rica, researchers (Betts, Hadley, and Kress 2015) found that pollen grains in a keystone tropical plant species, *Heliconia tortuosa*, germinated only after nectar was extracted by violet sabrewing (Figure 1, p. 26) and green hermit hummingbirds. These two species have long bills that match the shape of the flowers and travel farther distances than other local pollinators (Betts, Hadley, and Kress 2015).

Unfortunately, hummingbird populations are declining due to habitat destruction and fragmentation (Sauer et al. 2012). This decline typically happens when habitat is converted to construction projects, agricultural crops, or intensively managed forests where pesticides and herbicides eliminate food for hummingbirds. In their travels, hummingbirds might also avoid landscapes converted into roads or agricultural fields (Volpe et al. 2014). The decline in hummingbird populations and shifts in their movements may adversely affect their role as pollinators and, in turn, plant biodiversity (Allen-Wardell et al. 1998). For example, Hadley et al. (2014) discovered that larger fragments of forest correlated with larger hummingbird populations and more seeds of *H. tortuosa* being produced.

OSU Citizen Science Hummingbird Project

Citizen science engages people to collect, organize, and analyze scientific data at a scale beyond the capabilities of a single research lab. Due in part to the explosion of connectivity technology and social media, research projects using citizen science have increased dramatically, and citizen scientists have contributed to furthering understanding in a wide range of fields, from ecology to computer science (Bonney et al. 2014; Rosner 2013). Working as citizen scientists, students can collect and report data for projects beyond the classroom and actively contribute to furthering scientific knowledge (Jones et al. 2012). Contributing to a cause often inspires students to find more relevance and purpose in their learning (Hiller and Kitsantas 2014).

To support hummingbird conservation, the Oregon State University Citizen Science Hummingbird Project (OCSHP) uses student citizen scientists to better understand the populations and habitat preferences of rufous hummingbirds and other common hummingbird species in Oregon (Figures 2 and 3, p. 28). The OCSHP aims to determine whether—like the tropical species examined by OSU researchers—temperate hummingbirds are sensitive to deforestation and forest fragmentation. Several species of tropical hummingbirds prefer large patches of connected forest and tend to travel in forested habitat while avoiding open areas (Volpe et al. 2014).

The OCSHP was started in 2012 through a National Science Foundation (NSF)–funded research project. The principal investigators of the study partnered with the Oregon Natural Resources Education Program to include citizen science studies in Oregon that paralleled the research questions of the NSF-funded study. The goal of the OCSHP is to have students build a data set to help determine whether changes in forest cover and human development lead to hummingbird decline.

Rufous hummingbirds

The OCSHP focuses on rufous hummingbirds (*Selasphorus rufus*). Though widespread and common in North America, their populations have been declining by about 3% per year over the last 30 years (Sauer et al. 2012), possibly as a result of intensive forest management and climate change

FIGURE 1

The size and shape of the violet sabrewing hummingbird's bill (A) matches the *Heliconia tortuosa* flower (B), giving it more access to nectar and simultaneously triggering the flower to release more pollen than with other pollinators (Betts, Hadley, and Kress 2015).

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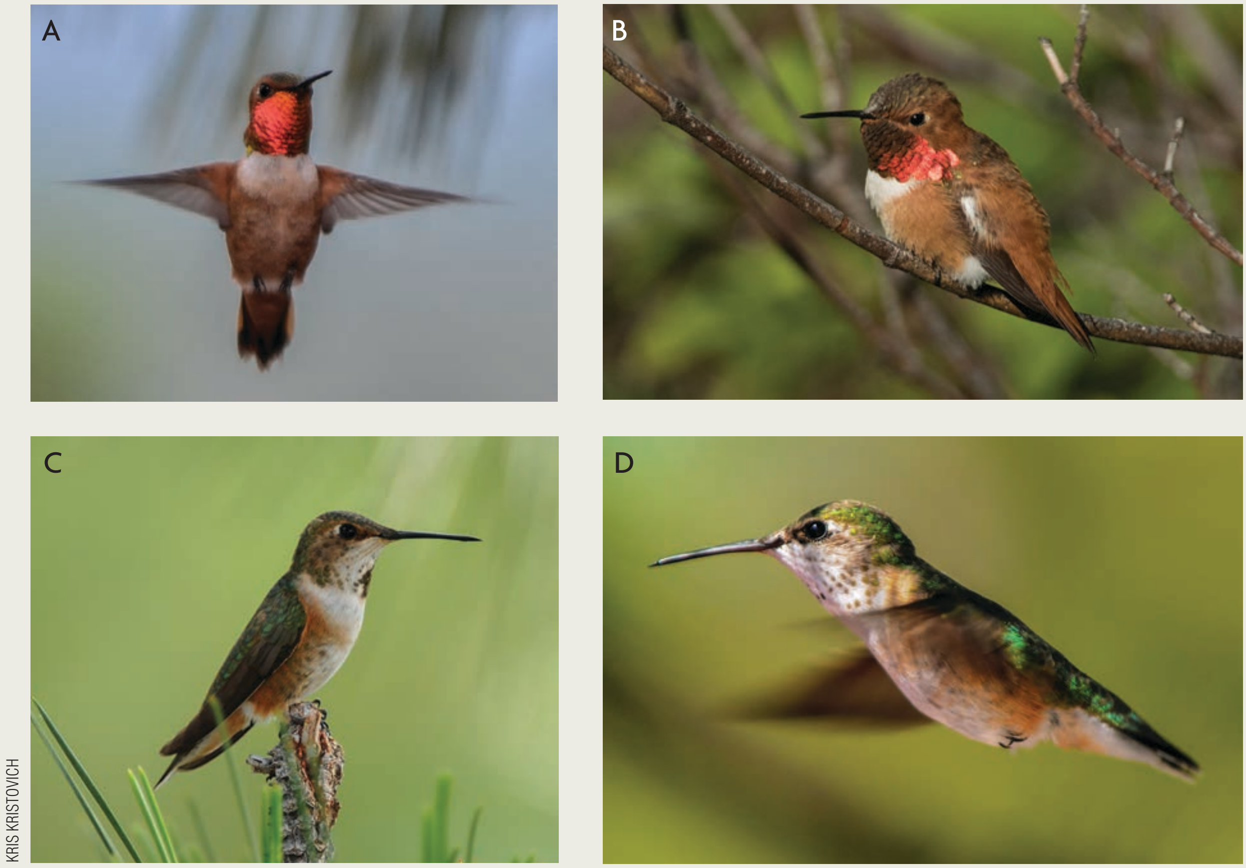
FIGURE 2

Rufous hummingbirds, male (A) and (B), female (C), and juvenile male (D).



(Betts et al. 2013; Gutiérrez Illán et al. 2014). Rufous hummingbirds migrate farther than any other bird, after accounting for body mass (Moran et al. 2013); each year they move from their wintering grounds in central Mexico to their breeding grounds as far north as Alaska. Rufous hummingbirds play a critical role in pollination of native plants but are confronting increasing rates of native habitat loss, fragmentation, and degradation (Arizona-Sonora Desert Museum 2015).

Capitalizing on the beauty of hummingbirds (Figures 2 and 3, p. 28), the OCSHP calls on educators and students to collect data to help address the driving question: "How does forest loss and fragmentation affect the presence/abundance of rufous and other hummingbird species?" Specifically, the OCSHP asks:

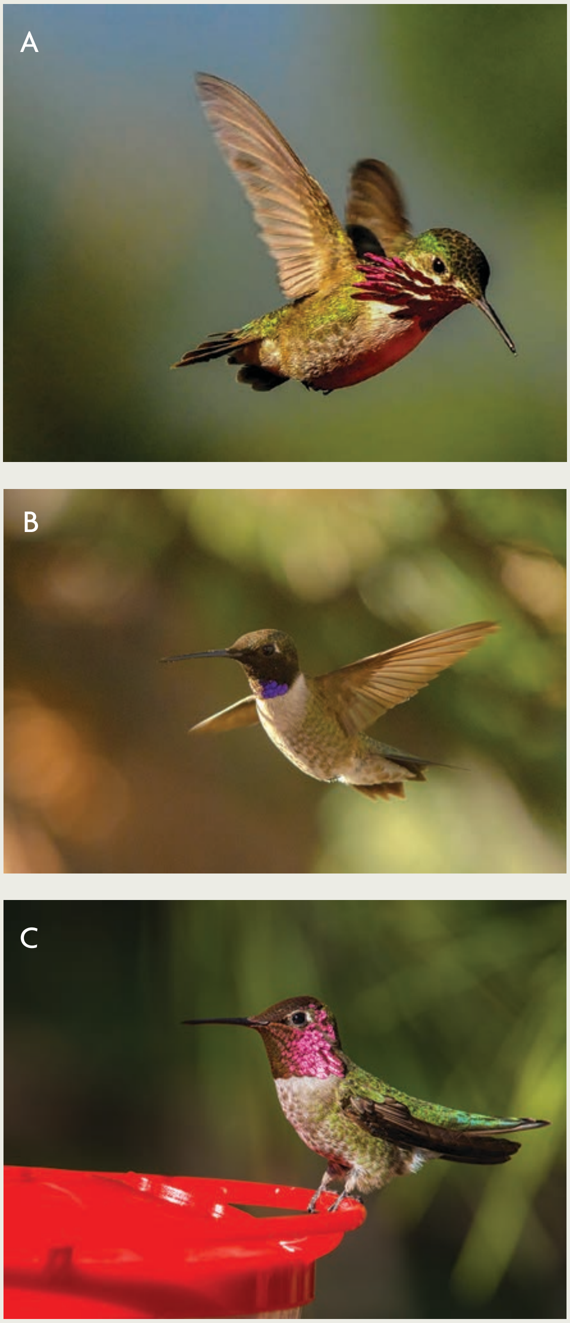
1. What landscape cover types (e.g., native forest, agricultural land, urban development) have the highest rates of hummingbird visitation rates?
2. Do visitation rates differ depending on the surrounding landscape (e.g., amount of surrounding native forest, agricultural land, or urban development)?
3. How are visitation rates affected by local flowering communities and surrounding hummingbird feeders?

Through participating in the project, students learn about the importance of pollinators for food and ecosystem sustainability, declines in pollinators in Oregon and the potential consequences of this decline, methods to study hummingbirds and monitor habitat, and the value of citizen science in collecting data to better understand hummingbird populations.

The OCSHP began as a one-day teacher workshop that covered content and resources about pollinators, student protocols (see "On the web"), and tips for engaging students in citizen science projects. Teachers provided feedback about the protocols and feasibility of the project. Other teachers from Oregon have since joined the project, and potential exists to broaden its scope.

FIGURE 3

Calliope hummingbirds (*Selasphorus calliope*) (A); black-chinned hummingbirds (*Archilochus alexandri*) (B); and Anna's Hummingbirds (*Calypte anna*) (C) occur in Oregon and are monitored in the OCSHP.



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Teachers are provided with data sheets for students to use and special hummingbird feeders (Figure 4) with graduated cylinders for measuring nectar. Undergraduate interns visit classrooms to demonstrate protocols and introduce the research project to students. Participating classes set up hummingbird feeders in their school yards for all students to monitor and send home study information and protocols inviting students and their families to do the study in their yards or nearby natural areas. Teachers and students follow the protocols to

1. monitor nectar consumption rates from graduated feeders as a measure of hummingbird abundance,
2. observe hummingbird visitation, and
3. make observations about the habitat around their feeder.

Students set up the graduated feeders two weeks before collecting data to give hummingbirds time to discover them. Then they make observations every three days for four to eight weeks, cleaning the feeder every two weeks or sooner if mold or insect contamination occurs. Students return their data sheets or

FIGURE 4

Hummingbird caught in action during feeder monitoring.

Red duct-tape "flowers" are added to attract the birds. Students record nectar volume every three days to measure amount consumed.

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upload their data to the Google form (see "On the web") to be analyzed by researchers at the Betts Landscape Ecology Lab at OSU. Data analyzed from the previous year are distributed to participating schools the following spring (Figures 5 and 6, p. 30) so students can compare results with data they collect. So far, results indicate a correlation of larger hummingbird populations in areas with less development and more forest cover.

Integrating hummingbird citizen science in general biology

The OCSHP described above presents the opportunity to integrate genetics, evolution, and ecology standards in general biology (grades 9–10), while engaging students in learning outdoors in the spring. To prepare for the hummingbird study, students read articles, write reflections and summaries, hold small-group and class discussions, engage in lab and field activities, give presentations, review worksheets, and view documentaries (see "On the web"). This preparation increases their understanding of the following concepts, which connect to the *NGSS* life science standards involving ecosystems (HS-LS2), heredity (HS-LS3), and evolution (HS-LS4) (see box, pages 31–33):

1. Hummingbirds play a vital role in pollination (sexual reproduction) of many plant species, perpetuating plant biodiversity.
2. Genetic variation in different hummingbird species has provided diverse adaptations, enabling them to fill different ecological niches.
3. Flowers have many structures, each with a vital role in reproduction.
4. Different flower structures attract different types of pollinators.
5. Genetic traits determine structure and are inherited by offspring through reproduction.
6. Rufous hummingbird populations have been steadily declining since 1966.
7. Biodiversity of hummingbirds affects other species in ecosystems, including humans.
8. Conservation of hummingbird habitat is critical to maintaining hummingbird populations.

At the end of the unit, students analyze the data collected by all students in their class, writing conclusions and providing peer feedback, and are assessed on their understanding. Class data are then sent to the Betts Landscape Ecology Lab at OSU to be analyzed by researchers who will provide the results to future classes.

Teacher reflection

The OCSHP helped students connect genetics concepts to ecology and evolution standards. Reviewing the previous day's activities at the beginning of each class helped students internalize the material and answer questions. Discussing the different evolutionary and behavioral adaptations of hummingbirds helped lead to discussions on pollination (i.e., pollen transfer, flower morphology, and reproduction).

FIGURE 5

Comparison of nectar consumption to amount of forest near feeder.

This figure shows the data collected by OCSHP students and their families in 2014. Each data point represents the nectar consumed in one feeder. It shows the relationship between how much nectar was consumed from each feeder and the amount of forest cover within 500 meters of the feeder. Nectar consumption increases slightly in more forested areas, suggesting that hummingbirds prefer forested areas over more developed areas. Ants and leaky feeders may have caused outliers. These data were shared with the 2015 OCSHP participants.

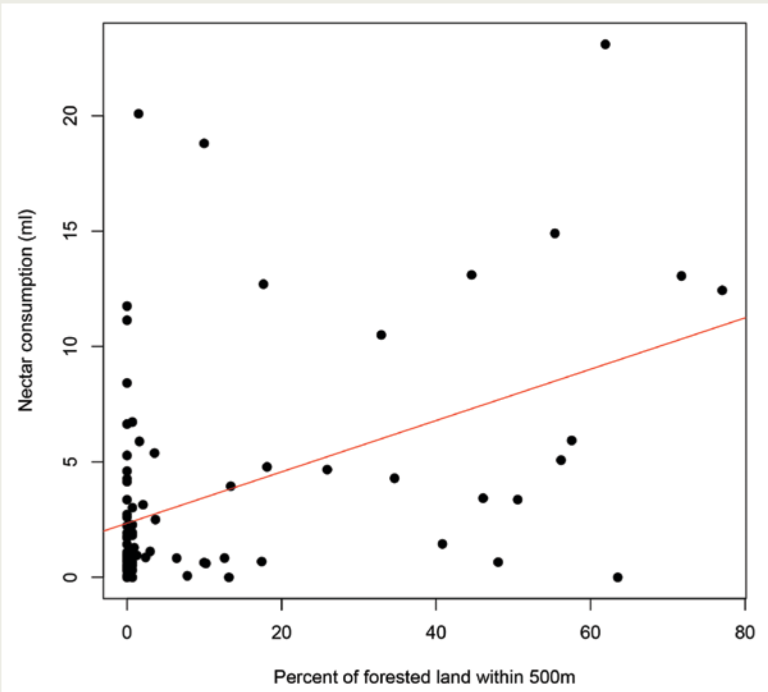
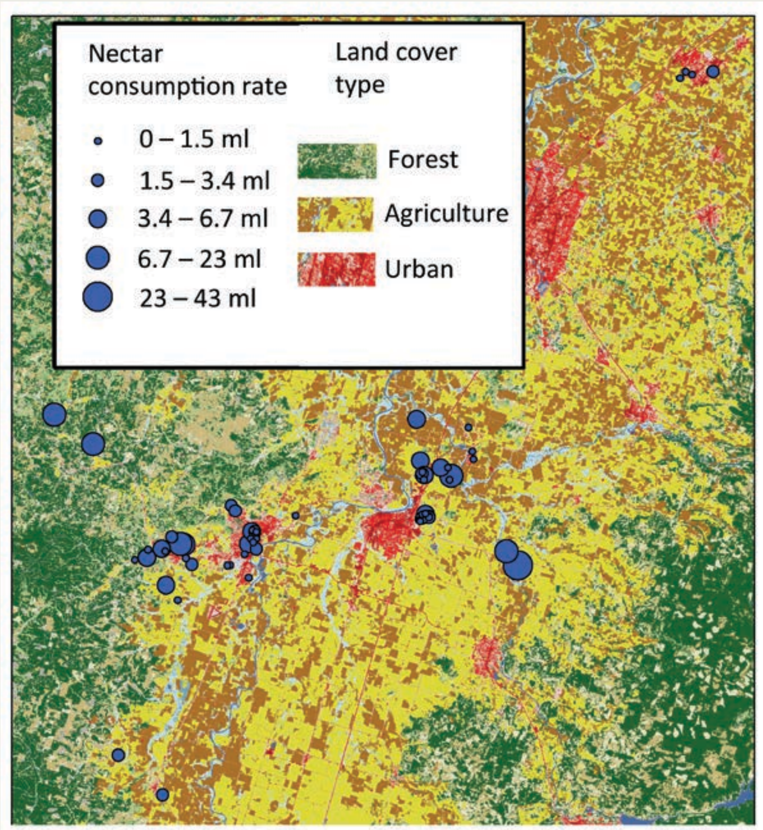


FIGURE 6

Nectar consumption rates in Sisters, Oregon, Spring 2014.

The circles in this map show a trend of how much nectar was consumed at each feeder site. Larger circles demonstrate more nectar consumption, and smaller circles indicate less. Feeders in areas with more forest tended to have slightly higher consumption rates than developed and agricultural areas. These data were also shared with the 2015 OCSHP participants.



When teaching project protocols, giving demonstrations and having students practice at school were important before sending the bird feeders home with students. It was also important to guide students through entering hard-copy data and transferring it to the Google form.

The OCSHP has helped students to connect with their natural environment while contributing data to a larger study with potential to influence conservation policy. The reward was captured in a mother's note reporting that her son was making observations in nature he had not done before. This helped affirm the relevance of the project. Follow-up research will evaluate whether such citizen science efforts enhance student understanding of natural sciences and develop stronger connections to the environment.

Educators can use the OCSHP as a model to develop similar units. See the December 2012 issue of *The Science Teacher* and other articles in this current issue for other examples of student-centered citizen science projects. Incorporating citizen science into the classroom provides a tremendous opportunity for connecting students to real science and addresses the intent of the *Next Generation Science Standards*. ■

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On the web

Detailed lesson plans, data sheets, protocols, and other supporting documents: *www.nsta.org/highschool/connections.aspx*

Sisters High School Biology OCSHP website: *https://sistershummingbirdproject.wordpress.com/*

Betts Landscape Ecology Lab OCSHP website: *http://bit.ly/1EvTSHo*

Google form for data entry: *http://bit.ly/1O3LajA*

Google form for feeder location: *http://bit.ly/1LO6L1S*

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Connecting to the *Common Core State Standards* (NGAC and CCSSO 2010).

Common Core State Standards Connections:	Connections to classroom activities
RST.11-12.7 • Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (HS-LS2-7)	Students watch videos, read articles, conduct hands-on investigations, view graphs demonstrating data, and collect data that they input to a Google form so that all data are consolidated. They use information they learn to better understand hummingbird population habitat preferences and apply knowledge toward understanding why hummingbird populations are declining.
WHST.9-12.2 • Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-LS2-2)	Students write conclusions explaining how flowering plants reproduce sexually following a flower dissection inquiry. They write summaries of what they learned when researching hummingbirds, explanations of hummingbird study procedures and feeder locations, and conclusions to explain what they learned from the hummingbird nectar consumption data they collected over six to eight weeks.
MP.2 • Reason abstractly and quantitatively. (HS-LS2-2, HS-LS2-7, HS-LS3-2, HS-LS4-5)	Students analyze data shown in graphs from previous years, and students analyze the data they collect when measuring the volume of nectar consumed by hummingbirds. They interpret what the data means and discuss and write explanations.

Connecting to the *Next Generation Science* Standards (NGSS Lead States 2013).

Standards
HS-LS2 Ecosystems: Interactions, Energy, and Dynamics
HS-LS3 Heredity: Inheritance and Variation of Traits
HS-LS4 Biological Evolution: Unity and Diversity

Performance Expectation(s)

The materials/lessons/activities outlined in this article are just one step toward reaching the performance expectations listed below.

HS-LS2-2. Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.

HS-LS2-7. Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.

HS-LS3-2 Make and defend a claim based on evidence that inheritable genetic variations may result from: (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors.

HS-LS4-5 Evaluate the evidence supporting claims that changes in environmental conditions may result in: (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.

Dimension	Name and NGSS code/citation	Specific Connections to Classroom Activity
Science and Engineering Practice	**Engaging in Argument From Evidence** • Make and defend a claim based on evidence about the natural world that reflects scientific knowledge, and student-generated evidence. (HS-LS3-2, HS-LS 4-5)	Students set up feeders and collect data on hummingbird nectar consumption for six-eight weeks. They write evidence-based arguments based on their analysis of data about hummingbird populations in varying habitats.
Disciplinary Core Ideas	**LS2.C: Ecosystem Dynamics, Functioning, and Resilience** • A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions.... Extreme fluctuations... can challenge the functioning of ecosystems in terms of resources and habitat availability. (HS-LS2-2)	Students measure volume of nectar consumed by hummingbirds in feeders, calculate average volume consumed, and compare amounts in different areas to gain understanding of populations in different habitats. They interpret graphs of data comparing nectar consumption in areas of varying forest cover to determine population response to development.
	LS3.B: Variation of Traits • In sexual reproduction, chromosomes can sometimes swap sections during the process of meiosis (cell division), thereby creating new genetic combinations and thus more genetic variation. (HS-LS3-2)	Students record variations of different adaptations of hummingbirds (e.g., beak shape of specific species matching flower shape, flight capabilities, and metabolism) and they discuss how variations of the adaptions occur through genetic processes such as mutations. They dissect flowers and examine how sexual reproduction can lead to mixing of genes in offspring.

Dimension	Name and NGSS code/citation	Specific Connections to Classroom Activity
Disciplinary Core Ideas	**LS4.C: Adaptation** Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline–and sometimes the extinction–of some species. (HS-LS4-5) **LS4.D: Biodiversity and Humans** Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through...habitat destruction, pollution...(secondary to HS-LS2-7)	Students record variations of different adaptations of hummingbirds (i.e. beak shape of specific species matching flower shape, flight capabilities, and metabolism) and they discuss how variations of the adaptions occur through genetic processes such as mutations. They dissect flowers and examine how sexual reproduction can lead to mixing of genes in offspring. Students participate in a citizen science study working to explain whether changing habitat of hummingbird populations may be leading to population decline. They collect data in habitats of varying forest cover and human development and analyze the volume of nectar consumed in these areas to determine if there is a correlation between habitat type and volume of nectar consumed. Students research environmental threats to hummingbirds (habitat degradation, pesticide/herbicide use, etc.) and consider ways that they can limit negative impacts.
Crosscutting Concepts	**Stability and Change** Much of science deals with constructing explanations of how things change and how they remain stable. (HS-LS2-7) **Cause and Effect** Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-LS3-2, HS-LS4-5)	Students gather data on hummingbird nectar consumption in areas of varying development and forest cover to contribute information on hummingbird habitat preference and to gain insight into why populations are declining. Students discuss and write summaries about current human threats to hummingbird populations (habitat destruction, pesticide/herbicide use, etc.), and they write conclusions based on data collected over six-eight weeks addressing possible correlations between nectar consumed and habitat type.