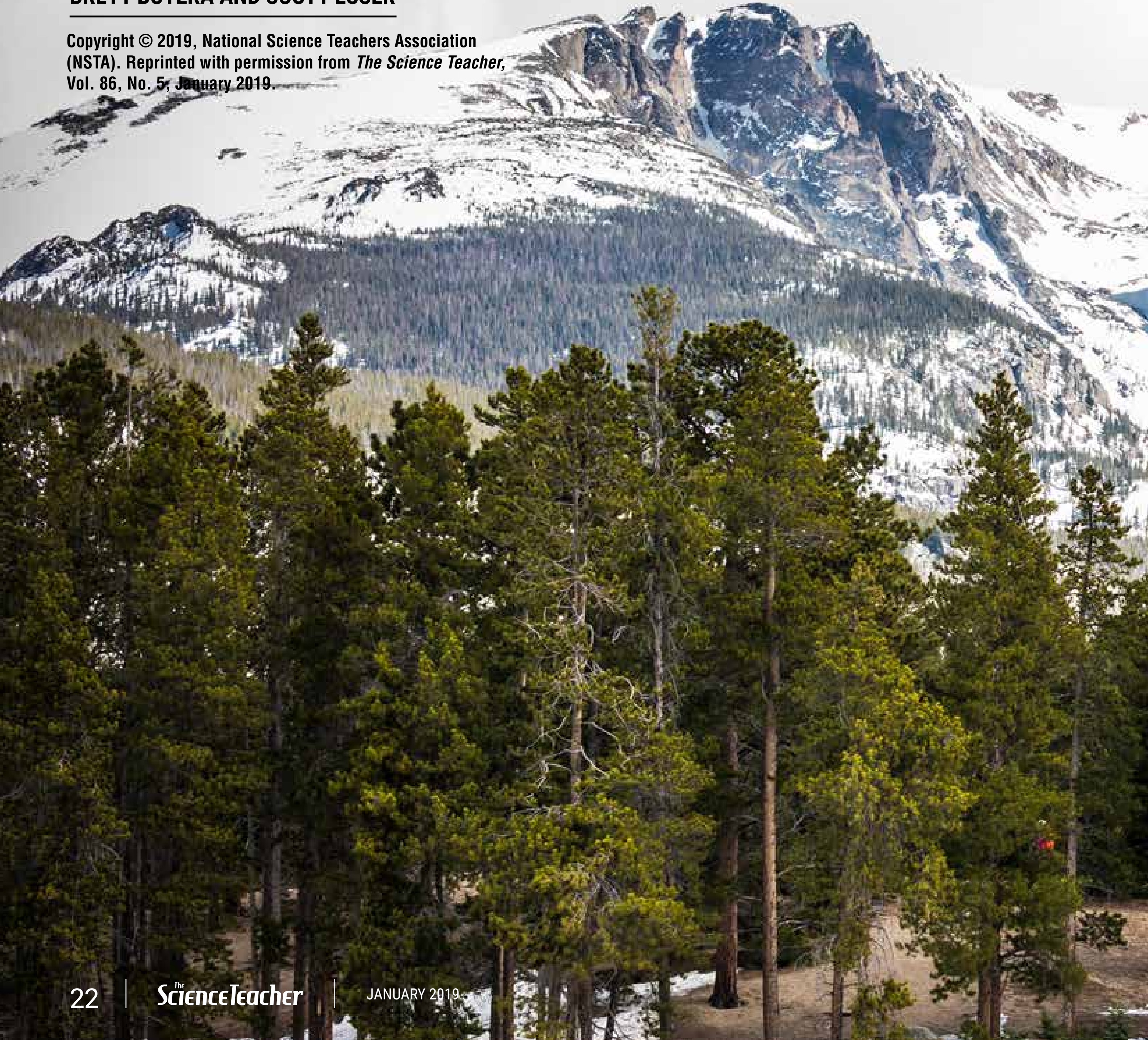
A Forest in Motion

Student citizen scientists investigate how trees respond to changing mountain climate

BRETT BUTERA AND SCOTT ESSER



“It’s one thing to talk about how the Earth is changing in the classroom. It’s another thing to see it and measure it for yourself.” A student’s reflection on a field trip to Rocky Mountain National Park (RMNP) to conduct a forest inventory demonstrates the impact citizen science can have as a tool for place-based field learning. The field trip is part of an ongoing project in which students collect and analyze data to monitor changes in the ecological structure of forest communities. The data will help RMNP scientists better understand how tree species are adapting to a changing mountain climate.

Citizen science can provide insightful data to inform decisions, while also serving to enhance ecological awareness and foster environmental stewardship among participants (Bonney et al. 2009). It has evolved into a practical way to identify developing ecological patterns in response to climate change (Dickinson, Zuckerberg, and Bonter 2010). By conducting citizen science projects within communities or adjacent to public lands, students can make tangible connections to natural areas that provide direct benefit to their communities. These connections with nature are the primary benefit of place-based learning programs.

How is climate changing in the Rockies?

During the past 100 years, the average annual temperature in RMNP has increased 1.9°C (3.4°F), compared to a 0.9°C (1.6°F) global increase (NPS 2018; NASA 2018). Rocky Mountain forests have become hotter and dryer, with an overall reduction in spring snowpack and spring snowmelts beginning as much as three weeks earlier than historical averages (NPS 2018; Funk et al. 2014). Changes in climate are also altering forest disturbance types and frequency; fires are expected to become more prevalent, beetle outbreaks more severe, and forest pathogens may spread.

How do tree species respond to climate change?

Research shows that several tree species may struggle to adapt to changing environmental conditions, which could result in smaller ranges, or even population die-off. The predominant view is that species in mountainous areas will need to migrate upslope to track suitable climate (Aitken et al. 2008). As Rocky Mountain forests become hotter and drier, lower-elevation montane tree species may migrate into higher-elevation subalpine ecosystems (Figure 1) (Bell, Bradford, and Lauenroth 2014).

Changes in Rocky Mountain forests correlate directly to the *Next Generation Science Standard* core concept, "Ecosystem Dynamics, Functioning, and Resilience," (HS-LS2.C), the idea that ecosystems sustain relatively consistent communities of organisms in stable environments; however, changing conditions can result in new and different ecosystems (see *NGSS* connections box). To this end, we planned this scaffolded sequence of lessons as part of a unit on terrestrial ecology for Advanced Placement Environmental Science (APES) classes. This guided scientific inquiry allows students to answer the research question: *How are tree species responding to disturbances brought on by a changing mountain climate?*

Project overview

Ecologists, researchers, and educators at RMNP's Continental Divide Research Learning Center (CDRLC) collaborated with teachers from Thomas Jefferson High School (Denver Public Schools) to develop this citizen science forest monitoring project. The project focuses on 68 sites sampled in 1972 and 2013 by park ecologists and academic researchers (Figure 2, p. 26). Each site covers an area of 1,000 m^2 (20 m × 50 m) and is located within subalpine coniferous forests throughout RMNP. In collaboration with the CDRLC, APES students embark on a field trip to RMNP in early fall each school year to conduct a forest inventory of one of these sites.

Conducting a forest inventory and analyzing the data over time

To begin this investigation, students learn the field methods they will use in RMNP and how to analyze the data they collect; this is accomplished in two 50-minute class periods. The forest inventory lesson is given in a public park adjacent to the high school campus. Prior to the lesson, the teacher maps out three 1,000 m^2 rectangular study plots, containing various species of mixed-age trees, and records the coordinates in a set of handheld GPS units.

Student groups use the handheld GPS units to locate and mark their plot with utility flags. Once marked, students move systematically through the plot, identifying tree species using a field guide and measuring diameter at breast height (DBH) to classify tree size. Teachers advise students on trees that need to be identified, measured, and recorded, and act as safety guides by calling out any hazards they see.

The following day, students use the collected data to generate bar graphs of the distribution of trees by DBH in size classes (small, medium, large, and giant). Their graphs represent population size and age structure; smaller trees correlate to younger trees and larger trees are correspondingly older. Additionally, students create pie charts illustrating species composition or relative abundance of tree species observed in the park (Figure 3, p. 26).

As a formative assessment, students answer several questions connected to one of the central questions of this investigation: "How can collecting and analyzing data be used to track change over time in biological populations and communities?" (Figure 4, p. 27).

Learning about Rocky Mountain forest communities

To begin this 50-minute lesson, students receive a worksheet that models the structure of a scientific paper and provides supports such as: guide questions, graphic organizers, and data tables. Students use this worksheet throughout the investigation. As a warm-up, students read selections from field guides and other resources about the ecosystems of RMNP (see "On the web").

Students answer the prompt, "Identify the tree species found in the montane and subalpine ecosystems of RMNP and describe the environmental conditions of each ecosystem." After a teacher-led class discussion about the trees of the montane and subalpine forest ecosystems of RMNP, students engage in a tree species identification lab (Figure 5, p. 27).

In the weeks prior to the lab investigation, teachers gather samples of tree species from montane and subalpine forests within nearby national forests, in accordance with national forest collection guidelines (see "On the web"). In this lab activity, students work in pairs, rotating through stations, each with a sample of a different tree species from montane or subalpine forests. Students use field guides to identify tree species and note distinguishing characteristics and habitat/niche requirements in the worksheet.

Examining data, discussing scienitifc literature, making hypotheses

In the final lesson before the field trip to RMNP, students examine baseline data for their site from 1972 and write comparative

FIGURE 1

A description of montane, subalpine, and ecotone forest communities.

The montane forest is characterized by open sunny areas dominated by ponderosa pine on south facing slopes, while north facing slopes are dominated by dense stands of Douglas fir mixed with ponderosa pine. The montane ecosystem generally occurs below 2,600 m of elevation (8,500 ft).

Subalpine forests are characterized by dense stands of Engelmann spruce and subalpine fir. The elevation range of the subalpine ecosystem is 2,600 to 3,500 m (8,500 ft to 11,500 ft). At lower elevations, a mix of spruce, fir, lodgepole pine, and aspen is evident. Higher elevations include spruce, fir, and limber pine. This ecosystem has much cooler temperature and higher precipitation levels than the montane.

PHOTOS COURTESY OF BRETT BUTERA

Ecotone: The ecotone is the transition zone between two ecosystems. This is the area where species that dominate the Montane are at their highest elevation ranges and the species that dominate the subalpine are at their lowest elevation ranges. Ecotones are great places to observe changes due to climate since the individuals that can live at the edges of their range already possess adaptations to potential new climates. Site 5A (Figure 9) is in an ecotone.

questions (Figure 6, p. 28). Students then read selections from scientific papers (Funk et al. 2014; Aitken et al. 2008), discuss what they learned from reading the selections, collaborate to write hypotheses, and share their hypotheses in a class discussion (Figure 6).

Data collection in Rocky Mountain National Park

After completing the necessary preparations on campus, students take a field trip to RMNP to put their skills to use. Once in the park, students and teachers are joined by RMNP staff members and proceed to the location of the plot to be surveyed, at an elevation of about 2700 m (about 9,000 ft). Following introductions and a safety briefing, teachers and park staff facilitate a tree identification tutorial for students to build upon their classroom exercise (Figure 7, p. 29). Once confident about their tree identification skills, teams of students (accompanied by teachers and RMNP staff), walk to their sites.

Using handheld GPS units and forestry open-reel tape measures, students locate and mark the corners of the 1,000 m^2 site, then divide it into four equal sections. Within each section, a team of two or three students (heterogeneous grouping) and one teacher or RMNP staff member conducts an inventory (Figure 7). To promote equity, teachers and park staff regularly prompt students to switch roles, from data recording, to tree identification, and DBH measurement.

To strengthen the reliability of the data collected, teachers and park staff use Socratic questioning for quality control purposes. For example, if a teacher observes that a student thinks a tree is a Douglas fir when it is actually a subalpine fir, the teacher may ask, "How would you distinguish a Douglas fir from a subalpine fir?" Through such questioning, students are more likely to identify trees correctly.

Connecting field observations to ecological concepts and forest management

After data collection is complete, teachers and park staff conduct a facilitated dialogue with students about their observations and what some of the ecological drivers for those observations may be. These discussions connect student observations to APES topics such as ecological disturbance, succession, and the general ecology of forest communities (Figure 8, p. 30).

FIGURE 2

Area of study.

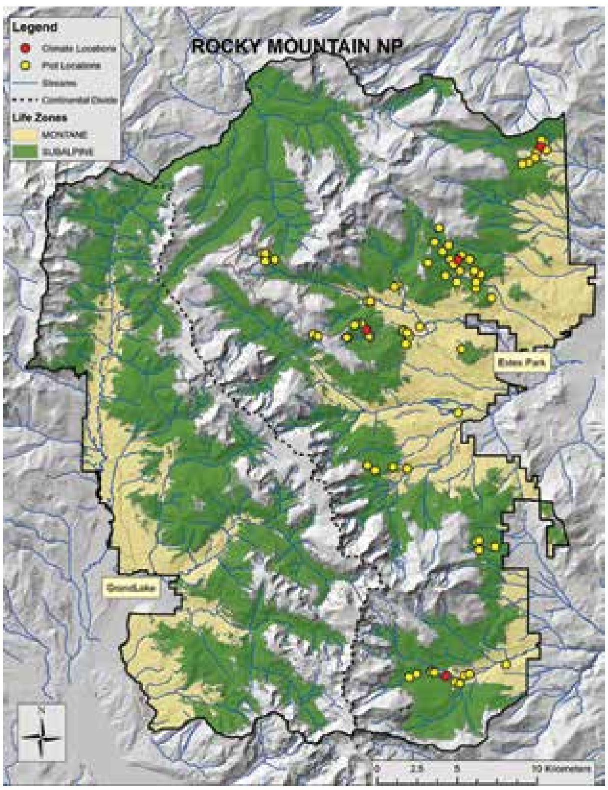
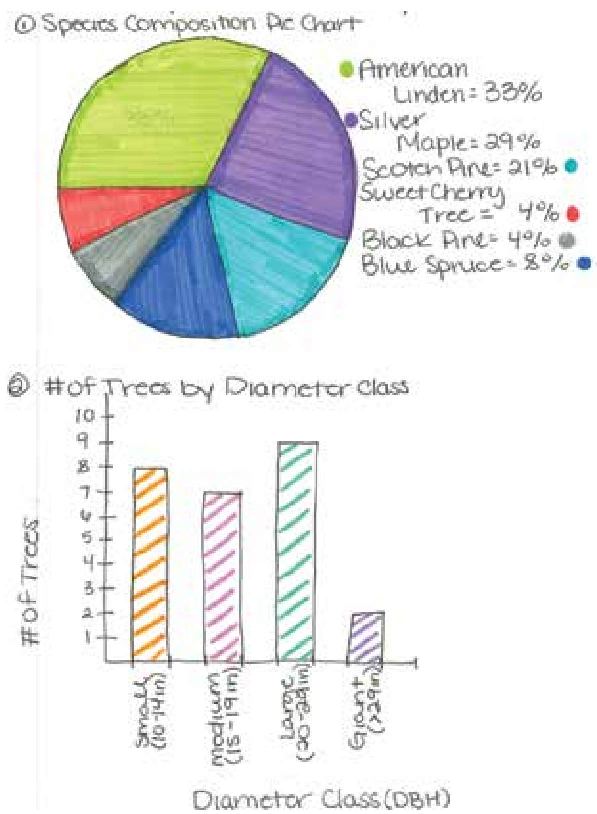


FIGURE 3

Student-created charts illustrating species composition or relative abundance of tree species.



Students also learn how forests are managed to mitigate fire intensity and beetle outbreaks. Teachers explain that data collected by student-citizen scientists can reveal the density of understory growth, from which the amount of *ladder fuels* (living or dead vegetation that allows a fire to climb up from the forest floor into the tree canopy) and potential pathways for beetles to travel from tree to tree can be estimated and managed through thinning and selective cutting. After the facilitated discussion, students head back to the bus, data in hand, and begin the journey back to school.

Advanced planning and collaboration

Collaboration and advanced planning are the foundations of this burgeoning citizen science project. Each year, three to four teachers from the school participate in the project, as well as two to three RMNP staff. The school team consists of the lead environmental science teacher, a certified athletic trainer who is also certified in CPR and first aid, a biology teacher, and an athletic coach. The participating teachers have relationships with most of the students, which helps mitigate management issues that can arise in the field.

During the summer that precedes each fall trip, teachers and park staff meet in RMNP to assess potential sites. Sites are preselected based on proximity to the road, slope, prevalence of dead and fallen trees, the distribution of rocks and boulders, and other safety considerations. Weather is the primary concern, because wet weather can create slick conditions that could cause injurious slips, trips, and falls. The wind is also a major hazard as it can blow down trees. To minimize the risk of injury, forest inventories are conducted only in ideal conditions.

FIGURE 4

Sample student responses to assessment questions.

How can relative abundance be used to track change over time of forest ecosystems? What can researchers learn from these data?

Relative abundance can be used to show the diversity of trees in the area and researchers can decide which species can thrive in certain climates and how climates could or are changing.

Consider this scenario: you come back for a visit in 15 years and I show you a graph that breaks down trees in the park by diameter class. It shows fewer giant trees (than 15 years ago) and fewer large trees, yet more small and medium trees. What could you infer from these data? Explain.

This could explain that the larger trees have an increase in mortality and are being replaced by smaller, new growth trees.

FIGURE 5

Students conducting a tree species identification lab.

On days when the roads are clear but conditions in the forest may not be suitable for field work, we have developed an inclement weather lesson plan. The lesson starts in an RMNP conference room during the morning hours while forest conditions are still cold and wet. In this lesson, students analyze data from a previous inventory, and discuss trends in the data. Then, as conditions improve, students and staff embark on a bus tour to visit accessible sites.

The sites characterize the ecological principles that are revealed in the data analysis, such as tree species migration, and provide students access to the same learning outcomes as the field work. Additionally, in the case that a student has a physical impairment or disability that would prevent the entire class from conducting an inventory, the backup lesson serves to accommodate such a student's needs while delivering the same learning outcomes.

FIGURE 6

Samples of student comparative questions and predictions.

Comparative questions

- What is the difference in species composition in the subalpine forest from 1972 to 2017?
- What is the difference in age structure of the subalpine forest from 1972 to 2017?

Predictions

- The subalpine in 2017 will consist of more species generally characteristic of the montane forest such as ponderosa pine and Douglas fir.
- The age of the forest will have increased overall, but the younger population will have a higher percentage of montane species and the older tress will mostly be subalpine firs and Engelmann spruce.

Analyzing data

After the field trip, the teacher organizes the data into a more usable form and shares it online through the citizen science website CitSci.org (see "On the web"). Students navigate CitSci.org to view the data and complete a data table in the worksheet, then design and create bar graphs to present the data. Many students use Google Sheets to create graphs (Figure 9, p. 31); however, other students prefer drawing their graphs by hand.

To wrap up the investigation, students engage in two 50-minute lessons that focus on data analysis and writing scientific explanations. Students pair up, examine their graphs, and discuss the following questions:

- Did any species decline significantly in abundance during the study period?
- Did any species increase substantially in abundance during the study period?
- Were there any shifts in abundance of trees between size classes?

The teacher circulates the room, engaging students in brief discussions that serve as informal assessments. Most students in the fall 2017 class could point out obvious changes, such as the increase in abundance of the Douglas fir population, while others noticed more subtle changes such as the increase in Engelmann spruce population or the increase in aspen saplings (Figure 9).

The teacher then asks students to discuss *why* the forest community has changed over time by asking questions such as: "What are some possible ecological and environmental drivers responsible for the changes in the forest communities over time?" After students discuss possible explanations, the teacher introduces and models the components of a scientific explanation: claim, evidence, and reasoning (McNeill and Krajcik 2008; see "On the web"). Students write scientific explanations that account for the observed changes, including claims that cite the data as evidence and refer to known ecological concepts as reasoning.

Finally, as a summative assessment, each student writes a brief report that models the structure of a scientific paper. The report includes a section with results and discussion, which incorporates

FIGURE 7

Collecting data in Rocky Mountain National Park.

Student using a Biltmore stick to measure DBH

Students practicing tree identification

Students engaging in a tree identification tutorial their data analysis and scientific explanations (Figure 10, p. 32). In written discussions, students referred to known ecological concepts as reasoning to explain the ecological drivers responsible for observed changes in the forest community over time. For example, Anika wrote, regarding the change in aspen populations between 1972 and 2017: "With aspen—who are shade intolerant—some of them probably found a little bit of light and shot up to the sky as other trees died and opened up part of the canopy on site 5."

Anika also wrote regarding the change in the Engelmann spruce population between 1972 and 2017: "There was a significant increase in their population. … This shows us that there could have been some sort of change in the environment that helped stimulate their growth. I believe that this was because they are shade tolerant. Through all those years there was a constant number of lodgepole pine that created a canopy over the site which would help the growth of the Engelmann spruce." In the 2018 classes, some students wrote research questions that directly addressed climate change. For example, Camden wrote: "Is climate change facilitating the migration of montane tree species to the subalpine forests?" In his written discussion he answered this question by stating:

> A younger age structure and an increase in the population of Douglas Firs is certainly a telling sign in the migration of trees upslope. A species will almost always migrate towards more suitable habitat, and while Douglas Firs can live in nearly any ecosystem in the park, they tend to live in the montane and warmer regions. In conjunction with rising temperatures in the park, it becomes evident as to why their population increased (at the subalpine study site). The migration of these trees is significant because it shows that global warming is significantly changing the forest forever.

Through this project students observe and explain how Rocky Mountain forests are in motion; i.e., species ranges are shifting in response to climate change.

Using citizen science data to support the curriculum

When students successfully complete an inventory, the data is added to the citizen science database on CitSci.org. The online database holds additional historical data from forest plots that were inventoried in 1972 and 2013 that have not yet been inven-

FIGURE 8

Connecting field observations to AP environmental science concepts.

Ecological succession: Succession is an idea that one community succeeds to the next community and ultimately results in a climax community that is stable. Recent science suggests that the idea of a stable climax community is inaccurate and that forests are continually shifting or *in motion* due to disturbance and changes in climate.

Pioneer species: These are species that are able to colonize quickly and easily after a disturbance occurs. These species set the stage for the future forest composition.

Tolerance/species life history: Each species has a life history strategy or a way of living in concert with the other species with which they co-exist. This is expressed in some tree species being tolerant of specific environmental conditions such a light level (i.e., shady vs. sunny), drought (i.e., wet vs. dry), fire (i.e., fire tolerant vs. not), and other variables such as seed size, how much seed they produce and how long they live.

Example: Shade tolerance allows young trees to grow below a closed canopy (e.g., Engelmann spruce) whereas shade intolerant species (i.e., sun-loving) generally cannot reproduce or flourish under a closed canopy (e.g., lodgepole pine).

Disturbance: Disturbance type matters in the impact to and outcomes in forest communities after the disturbance. Fire, beetles, and climate change will all result in a different outcome or dominant forest community.

Example: A forest impacted by a beetle outbreak will result in growth of the already established trees of the understory and a shift toward trees species that are tolerant of shade since the beetle killed trees are still standing and casting some shade.

Example: A forest impacted by fire will usually result in germination and establishment of fire-tolerant and shade-intolerant species. This is due to the canopy being opened up as the forest was burned by the fire. Fire tends to lead to aspen- and/or lodgepole-dominated forests. Both species can thrive in sunny and dry conditions, grow fast, and are short-lived. These species close the canopy which allows only shade tolerant species to persist in the understory. Once the short-lived species begin to die off, the shade tolerant species are poised in the understory to grow quickly into the newly formed canopy gap. Over time the dominance of the forest shifts from aspen/lodgepole to more spruce and fir until the next disturbance comes.

toried by students. These data are useful in subsequent lessons. For example, students use the database to investigate the biological diversity in RMNP using the Shannon diversity index (a statistical measure of biodiversity). Also, students examine the impact of the mountain pine beetle epidemic on one of the RMNP study sites located within a lodgepole pine stand.

Developing a high school citizen science project

While this project is regionally specific, the need to gather data to inform conservation management decisions is global. City and county open space/park managers, as well as state and national park managers, are often seeking to develop educational outreach programs to engage students as citizen scientists. Teachers aspiring to develop a citizen science program for their classes should consider reaching out to a local or regional land management organization, such as an open space or park, to inquire about potential research and educational outreach opportunities.

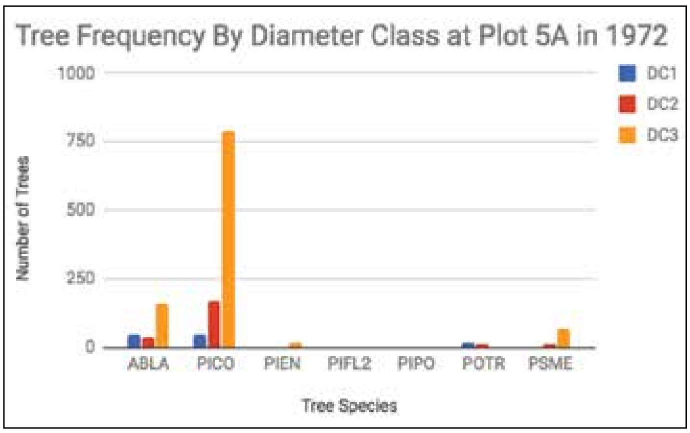
If a contact and area of research are established, it may be necessary to complete a research and collections permit for the park or open space; such was the case for this project. Once granted permission to conduct research within a park or open space, the lead teacher can begin to assemble a team and become familiar with the relevant ecological and logistical aspects of the area. With regard to funding, corporate field trip grants are available online by application (see "On the web") and school PTOs may also be able to provide financial support. Finally, SciStarter (see "On the web") is an online database of citizen science projects where teachers can discover existing citizen science projects, get ideas for their own projects, connect and collaborate with scientists and educators, and contribute to existing projects.

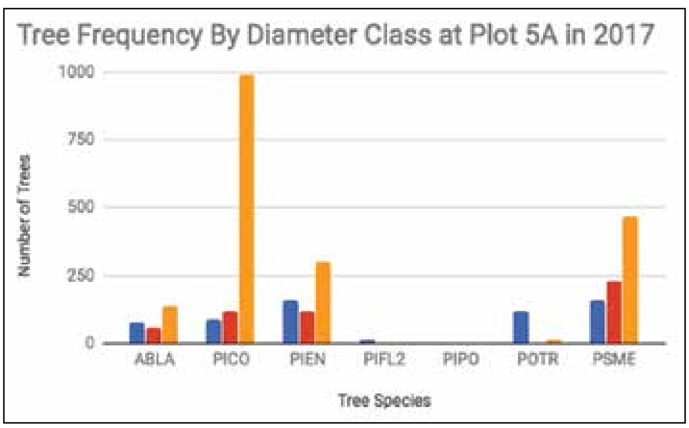
Conclusion

Facilitating this kind of place-based citizen science experience requires a significant amount of advance planning and preparation both in the field and the classroom. Nevertheless, it is well worth the effort. Through this experience students gain appreciation for scientific methods and what it takes to conduct science in the field, while contributing to the citizen science database. Students practice critical skills such as analyzing scientific texts and data, as well as evidence-based writing.

FIGURE 9

Student-created graphs.





Diameter Class 1 (DC1): < 2.5 cm
Diameter Class 2 (DC2): 2.5 - 7.5 cm
Diameter Class 3 (DC3): > 7.5 cm

Species codes:
PICO – lodgepole pine, *Pinus contorta*
ABLA – subalpine fir, *Abies lasiocarpa*
PIPO – ponderosa pine, *Pinus ponderosa*
PIEN – Engelmann spruce, *Picea engelmanii*
PIFL2 – limber pine, *Pinus flexilis*
PSME – Douglas fir, *Pseudotsuga menziesii*
POTR – aspen, *Populus tremuloides*

*Data has been scaled up from trees per 1,000 m^2 to trees per hectare.

1,000 m^2 =1/10th of a hectare; 10,000 m^2 = 1 hectare; 1,000 m^2 x 10 = 10,000 m^2 or 1 hectare

As a result, students connect to the natural world around their communities and gain a greater awareness of the impact that climate change and disturbance are having on Rocky Mountain forests. They also gain a greater respect for nature and the preservation of public lands. This was evident in Zainab's post-project reflection: "Learning how our local environments are changing is truly inspiring. It is awesome to learn, hands-on, that our environment is changing and needs our help." Finally, capturing the essence of this citizen science project in his report, Camden concluded: "If we value our national parks we need to put more effort into preserving them and the first step to preserving them is to understand them." ■

FIGURE 10

Sample student discussion and conclusion.

Discussion

Global Warming's Impact on Rocky Mountain Subalpine Ecosystems

In the past 45 years, the ecology of the Rocky Mountain National Park has changed. Expanding on the research, we have found various trends in the age, species, and mortality composition of the park, supporting the hypothesis that global climate change is contributing to the ecosystem's change and species migration. As can be seen in the attached graphs, the Douglas fir species has increased 975% since 1972, along with Engelmann spruce, who has increased by a massive 2800%. A possible reasoning behind this result would be that as global climate change continues to make the mountains hotter and dryer, more like the montane ecosystem, where Douglas firs live, that ecosystem is encroaching into the subalpine forest, what is called species migration, as the new climate is more conducive to Douglas fir growth. Thus, as Douglas firs began to grow extremely tall in recent years, the Douglas firs tend to lose their lower branches, as I learned, as the lower branches have much less sunlight reaching them, and therefore produce less energy. This created new space, which Engelmann spruces were able to take advantage of, given their shade tolerance, and thus, the two species increased their populations hand in hand.

Conclusion

Before our trip I made two predictions about our data and the subalpine ecosystem. There will be more montane trees in the subalpine ecosystem since 1972, the environment will have younger montane trees and older subalpine trees. Overall, I was right. In the subalpine ecosystem we collected data from we observed an increase to nearly 800 Douglas fir trees since 1972. The primary amount of trees that were older were the subalpine trees, while the younger trees were mainly Douglas firs.

ACKNOWLEDGMENTS

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ON THE WEB

Student investigation worksheet: *www.nsta.org/highschool/connections.aspx*

Ecosystems of Rocky Teacher Guide: *www.nps.gov/romo/learn/education/upload/Ecosystems-of-Rocky-Teacher-Guide.pdf*

Rocky Mountain Forests at Risk Confronting Climate-driven Impacts from Insects, Wildfires, Heat, and Drought: *www.ucsusa.org/sites/default/files/attach/2014/09/Rocky-Mountain-Forests-at-Risk-Full-Report.pdf*

Adaptation, migration or extirpation: climate change outcomes for tree populations: *https://onlinelibrary.wiley.com/doi/full/10.1111/j.1752-4571.2007.00013.x*

CitSci.org—RMNP Forest Monitoring Project: *www.citsci.org/CWIS438/Browse/Project/Project_Info.php?ProjectID=979&WebSiteID=7*

National Forest plant and animal collection guidelines: *https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fsm91_054415.pdf*

How to Write a Scientific Explanation: *https://bscs.org/sites/default/files/_media/about/downloads/scientific_explanation_tool.pdf*

SciStarter: *https://blog.scistarter.com*

Target field trip grants: *https://corporate.target.com/corporate-responsibility/community/philanthropy/field-trip-grants*

REFERENCES

Aitken, S.N., S. Yeaman, J.A. Holliday, T. Wang, and S. Curtis-McLane. 2008. Adaptation, migration or extirpation: Cimate change outcomes for tree populations. *Evolutionary Applications* 1 (1): 95–111.

Bell, D., J. Bradford, and W. Lauenroth. 2014. Mountain landscapes offer few opportunities for high-elevation tree species migration. *Global Change Biology* 20 (5): 1441–51. *https://doi.org/10.1111/gcb.12504*

Bonney, R., C.B. Cooper, J. Dickinson, S. Kelling, T. Phillips, K.V. Rosenberg, and J. Shirk. 2009. Citizen science: a developing tool for expanding science knowledge and scientific literacy. *BioScience* 59 (11): 977–84.

Dickinson, J.L., B. Zuckerberg, and D.N. Bonter. 2010. Citizen science as an ecological research tool: Challenges and benefits. *Annual Review of Ecology, Evolution, and Systematics* 41: 149–72.

Funk, J., S. Saunders, T. Sanford, T. Easley, and A. Markham. 2014. Rocky Mountain forests at risk: Confronting climate- driven impacts from insects, wildfires, heat, and drought. Report from the Union of Concerned Scientists and the Rocky Mountain Climate Organization. Cambridge, MA: Union of Concerned Scientists

McNeill, K.L., and J. Krajcik. 2008. Scientific explanations: Characterizing and evaluating the effects of teachers' instructional practices on student learning. *Journal of Research in Science Teaching* 45 (1): 53–78.

National Aeronautics and Space Administration (NASA). 2018. Climate change: How do we know? *https://climate.nasa.gov/evidence*.

National Park Service. 2018. Climate Change. *www.nps.gov/romo/learn/nature/climatechange.htm*.

NGSS Lead States. 2013. *Next Generation Science Standards: For States, by states*. Washington, DC: National Academies Press.

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

Standards

HS-LS2: Interdependent Relationships in Ecosystems

HS-LS4: Natural Selection and Evolution

Performance Expectations

- The chart below makes one set of connections between the instruction outlined in this article and the *NGSS*. Other valid connections are likely; however, space restrictions prevent us from listing all possibilities.
- The materials, lessons, and activities outlined in the article are just one step toward reaching the performance expectations listed below.

HS-LS2-6. Evaluate claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.

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.

DIMENSIONS	CLASSROOM CONNECTIONS
Science and Engineering Practices	
Engaging in Argument From Evidence Engaging in argument from evidence in 9–12 builds on K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current scientific or historical episodes in science.	Students analyze the data they collected in the field and compare it to baseline data to observe and describe changes in ecological structure of forest communities over time.
Disciplinary Core Idea	
LS2.C: Ecosystem Dynamics, Functioning, and Resilience If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability.	Students analyze and interpret data from an ecological data set that they collected in the field to make observations on how a specific forest community has changed or stayed the same over time.
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 and distinct species as populations diverge under different conditions, the decline—and sometimes the extinction—of some species.	Students will understand that changes in the physical environment contributes to the expanded range of some species in forest communities and the decline in population of other species.
Crosscutting Concept	
Stability and Change Much of science deals with constructing explanations of how things change and how they remain stable.	Students will understand that assemblages of tree species in forest communities may stay the same over long periods of time under stable conditions and that they will respond to changing environmental conditions in a variety of ways.

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