The Earth Scientist

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INSIDE THIS ISSUE

A young girl is tidepooling in a marine reserve off the University of California, Santa Barbara campus, during an exceptionally low king tide.

Photo credit: Claire Fackler, NOAA National Marine Sanctuaries

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NESTA'S MISSION
Champion Excellence in Earth & Space Science Education for ALL through a community of support.
One Earth. Our Future.

Letter from the President

By John-Henry Cottrell, NESTA President 2022-2024 | @NESTA_US

Summer day memories fly through my mind while reading this issue of *The Earth Scientist*. It's exciting to read many San Diego schools are getting out of classrooms for community research, taking me back in time. I grew up in San Diego, surfing at age 12; member of Scripps Institute of Oceanography young scientists; the beach was my second home. San Diego has a different approach; no private or city-controlled beaches, instead they belong to every San Diegan. Feeling like one long beach with no boundaries stirs deeper emotion than a public beach; personal ownership and care placed on each of us. The beach is not to visit, rather something you are a part. NOAA Planet Stewards projects like these, help instill these emotions into the next generation, something we should pass to all students: Curating the beauty that surrounds us, rather than prescriptive labs verifying topics in a textbook.

This past summer was special: My first invitation to a former student defending a doctoral thesis. How could I possibly say no? So, my wife and I made a road trip from SoCal to Stanford, a good 9-hour drive by freeway. Of course, stopping to watch otters in Moro Bay, searched for Moonstones at Moonstone Beach, and visiting a few other places. Being able to witness Jose achieve his dream brought me to proud tears. He showed promise to his parents at a very early age living in Costa Rica. Though his parents did not share his early interest in science and fearing limitation in the Costa Rican education system, they sent him to the US. During the after-party, I talked with his mother, her tears for missing much of his life struck home. The sacrifice they made for this day was heartbreaking and warming at the same time. As he moves on as lead chemical engineer for a carbon sequestration company creating new plastics, I hope that there was something I implanted. The many Earth Science-based chemistry labs; discussions of climate issues in physics; science fair project on climate remediation that won him medals; somewhere had impact. As a teacher it is easy to lose the forest for the trees. Students seem to arrive into class less prepared than previous years; discipline on the same trajectory; labs/projects become harder to complete. Alas, do not go easy into that good night. It is the labs and projects that make the science class. Often, we never know the impact of our labs/projects; teaching critical thinking and problem-solving skills, while strengthening scientific literacy. Spend too long in the classroom, those terms become education jargon unlinked from reality. However, my closing remark at the after-party, "I may have assisted in Jose's accomplishment in some small way, but I think I was rewarded the most, as it is he that rekindles the flame of hope within my heart for teaching, watching him achieve his dreams" It need not be a doctoral achievement, it is in the achievements of all our students. May you soon have similar relighting of passion, a reminder that labs/projects have impact.

So as you flip through this issue of *The Earth Scientist*, I implore you to imagine how impactful these projects are to the students. Find one to inspire you. If you have completed a great project, please contact our Editor to inform our membership. For it is teachers like you that *NESTA* exists, let us celebrate you and your successes to share with a community of passionate Earth Science educators. Let's help rekindle others fires as well.

One Earth. Our Future.

John-Henry Cottrell

Letter from the Guest Editor

By Bruce Moravchik, Coordinator, NOAA National Ocean Service Education

As I write this, another heat wave is forecast for the southern United States. Multiple heat waves this past summer have contributed to record drought conditions across the globe. Other parts of the world have experienced record breaking rains causing life threatening flooding. Hearing about, or worse, experiencing these types of events along with ever present news about melting glaciers, human caused plastic pollution in our oceans, the war in Ukraine, Covid-19, monkeypox, the state of the national/world economy, and state of political discourse across the globe make so many of us – particularly young people, feel helpless, powerless, and hopeless. But there is hope.

In this issue of *The Earth Scientist* you'll read about projects supported by NOAA Planet Stewards that have been developed and carried out by educators who have inspired real hope and made a difference with their students, schools, and communities. These educators have restored native prairie and woodland habitats, abated stormwater runoff, sequestered atmospheric carbon, reduced carbon footprints, and cleaned our ocean and coastal habitats of marine debris. These educators recognize that developing minds and changing mindsets comes through education coupled with action, and have shown young people, their peers, families, and communities that they are not powerless, that they can make a difference affecting real issues concerning their communities and the world.

This summer I received a long and uplifting email from a NOAA Planet Stewards educator who has been working on a marine debris removal program at her school. I can't share the whole letter with you – it was pretty long, but I will share a few snippets:

> *"I want to say thank you for a wonderful opportunity. Having NOAA Planet Stewards funding has been a transformative experience for me, our students, and our school."*
>
> *"…our students are excited. They really want to make a difference in the world...They loved learning about marine science, STEM careers, and actions they can take to make a difference. I know this because they are doing things of their own volition."*
>
> *"Teachers recognized the excitement and asked for a Planet Stewards theme for the yearbook."*
>
> *"Parents emailed to thank me for encouraging stewardship at our school and at home. They asked me questions about where to recycle and shared anecdotes of things their kids were doing to clean up their neighborhoods."*
>
> *"The trash cans made by students using marine debris art were lightning rods. Parents, teachers, and staff were thrilled and our city hall asked to showcase them in April. Two other schools heard about what we did and copied us. I think our custodian was genuinely thrilled."*
>
> *"So many good things happened as a result of this project and I really want you to know that we are transformed and so excited to do more."*

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I welcome you to be the change you want to see in the world. I hope you read these articles and are inspired to learn more and do more; to educate through action. Subscribe to the NOAA Planet Stewards Newsletter: *The Watch* (https://oceanservice.noaa.gov/education/planet-stewards/the-watch-archive.html) and discover new and exciting opportunities for you and your students, as well as free education resources, articles on science, stewardship, and education. Join our monthly book club (https://oceanservice.noaa.gov/education/planet-stewards/upcoming.html#bookclub1) and discuss timely environmental fiction, nonfiction and Young Adult fiction with your peers. When you feel ready, consider designing your own stewardship project and applying to NOAA Planet Stewards for funding (https://oceanservice.noaa.gov/education/planet-stewards/psep-supporting.html). I look forward to you joining us.

Bruce Moravchik
(https://oceanservice.noaa.gov/education/)

NOAA PLANET STEWARDS

oceanservice.noaa.gov/education/planet-stewards/

Science for Sustainability

EARTH SCIENCE WEEK 2022

By Geoff Camphire, Lindsay Mossa, and Lauren Brase

Educators have the capacity to inspire students to work toward making a sustainable world — one where people meet their needs in the present without compromising their ability to do so in the future. Earth science education is key to help students understand what can be done for a sustainability society. This is why the 25th annual Earth Science Week (www.earthsciweek.org) is gearing up to celebrate the theme of "Earth Science for a Sustainable World" on October 9-15, 2022.

This year's theme emphasizes the essential role of Earth science in helping people make decisions that maintain and strengthen the planet's ability to support thriving life. Individuals of all backgrounds, ages, and abilities are being engaged in how the entire planet is challenged to provide for human health, safety, and prosperity, while preserving environmental integrity.

The weeklong celebration, organized by the American Geosciences Institute (AGI) in partnership with dozens of organizations, provides materials, activities, resources, and opportunities for audiences in both formal and informal education settings to learn about sustainability.

Pursuing Vital Goals

To ground instruction about sustainability in real-world applications, Earth Science Week 2022 engages educators and students with the United Nations' 17 Sustainable Development Goals (SDGs, https://sdgs.un.org/goals). The SDGs are concrete, actionable goals that tackle some of the biggest challenges humans face today, such as energy, climate change, hunger, natural hazards, industrial production, and economic opportunity for all. A number of the materials in the Earth Science Week 2022 Toolkit call on students to conduct learning activities that not only foster geoscience understanding but also connect directly to the SDGs, as well as the Next Generation Science Standards (NGSS, https://www.nextgenscience.org/). Making

		No Poverty	Zero Hunger	Good Health and Well-Being	Quality Education	Gender Equality	Clean Water and Sanitation	Affordable and Clean Energy	Decent Work and Economic Growth	Industry, Innovation, and Infrastructure	Reduced Inequalities	Sustainable Cities	Responsible Consumption and Production	Climate Action	Life Below Water	Life on Land	Peace, Justice, and Strong Institutions	Partnerships for the Goals
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
ESS2.A	Earth Materials and Systems		■				■	■						■	■	■		
ESS2.B	Plate Tectonics and Large-Scale System Interactions		■	■	■		■	■	■	■		■	■	■	■	■		
ESS2.C	The Roles of Water in Earth's Surface Processes			■			■							■	■	■		
ESS2.D	Weather and Climate		■					■						■	■	■		
ESS2.E	Biogeology														■	■		
ESS3.A	Natural Resources		■				■	■	■	■		■	■		■	■		■
ESS3.B	Natural Hazards											■		■				
ESS3.C	Human Impacts on Earth Systems	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
ESS3.D	Global Climate Change		■				■					■		■	■	■		■

Table 1. Alignment of the SDGs to the Earth-Space Science Disciplinary Core Ideas (DCIs) from NGSS. The content of the DCIs was compared with the Targets and Indicators of each SDG to assess for overlap.

Lindsay Mossa, Lauren Brase, Brenna Tobler, AGI.

The Earth Scientist

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these connections will help students understand how work being done in the Earth sciences helps achieve the goals set by the SDGs, as well as inspire them to be part of a global network of people working toward a sustainable future.

Educators can introduce their students to the SDGs in a way that sparks interest and passion not just in science but also in using science to take action and make positive changes to many aspects of our world. Learning about the SDGs allows students the opportunity to discuss global issues and actions that can be taken to improve the standard of living for everyone around the world. The SDGs can be easily tied to what you already teach, based on your state's unique standards or the NGSS. Educators may already be teaching components of the SDGs. Use the resources that AGI has created and compiled as a guide for connections between the SDGs and what you already cover in your Earth science teaching.

For example, as in past years, the Earth Science Activity Calendar features classroom investigations, authored or recommended by program partners, that help students understand various facets of how the geosciences relate to the SDGs. The U.S. Geological Survey's (USGS) "Wetland in a Water Bottle" activity, for instance, enables students to learn about life in water (SDG 14) and on land (SDG 15). And the American Association of Petroleum Geologists' "Solar Updraft Tower" activity sheds light on energy technologies (SDG 7) as well as industry, innovation, and infrastructure (SDG 9). These activities can help foster discussions on the SDGs and how even small steps toward sustainability are beneficial.

This year's Earth Science Week Poster (https://www.earthsciweek.org/sustainable-world) features a world map showing specific places around the globe where initiatives are addressing SDGs focused on issues like hunger, climate, and affordable and clean energy. On the back of the poster are a handful of activities inviting students to, for example, learn more about those initiatives through ArcGIS StoryMaps (https://www.earthsciweek.org/sustainable-world), explore how geoscientists' work applies to SDGs, and create displays about SDGs in their communities. The highlighted initiatives can call attention to work being done around the world to let students know that actions being taken locally can have regional and global effects.

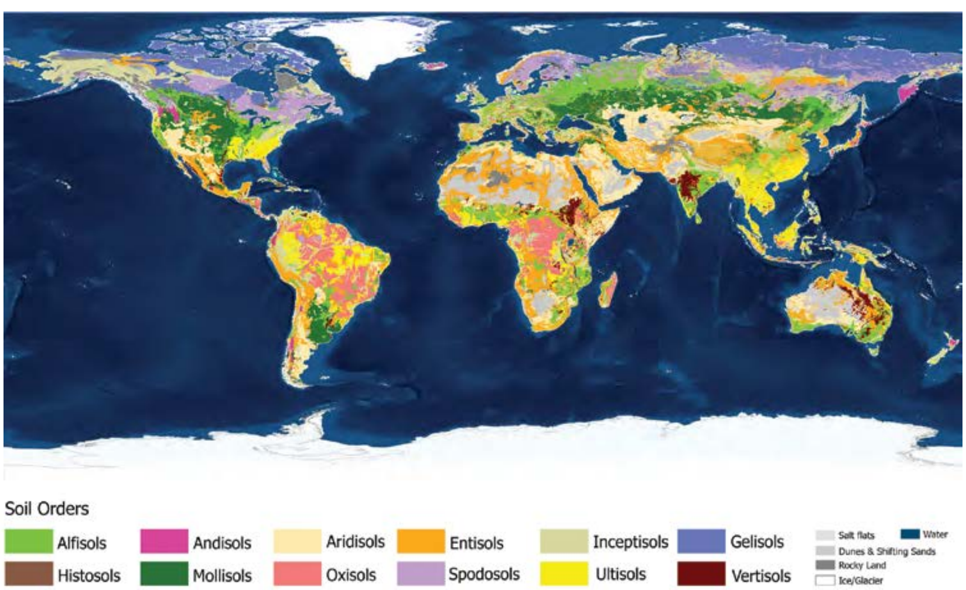

Figure 1. Global Map of Soil Regions

Paul Reich (USDA-NRCS) AGI

This year's Geologic Map Day Poster paints a detailed picture of how "Soils Sustain the World," showing the global distribution of 12 soil orders, as classified by the U.S. Department of Agriculture. The poster's learning activities explore soil classifications, profiles, textures, and related SDGs. One activity, for example, encourages students to consult online resources to learn about the type and uses of soil in their area. Many scientists believe that maintaining and improving soil health is *the* key to a sustainable future, since soil is the basis for food production and environmental health and stability.

Studying Sustainability

The Earth Science Week Toolkit once again includes dozens of posters, worksheets, and additional materials that take a range of approaches. Look for NASA resources on climate change and agriculture science, Geoscientists Without Borders® activity sheets, a National Park Service resource on paleontology, an item on resources from the Soil Science Society of America, Mineral Education Coalition material on metals and sustainability, a community resilience activity booklet, and much more dealing with subjects such as seismology, climate, energy, gems, caves, karst, groundwater-dependent ecosystems, and the critical zone.

The Earth Science Week Webinar Series (https://www.earthsciweek.org/content/earth-science-week-webinar-series) will also occur again this year, tackling sustainability-related geoscience topics. AGI invites educators, students, and geoscience enthusiasts to participate throughout the week and beyond. This webinar series covers an array of thought-provoking, timely issues relating to the science of sustainability. Aimed at the general public and education community, the series features presentations hosted by scholars and experts. Selected on-demand webinars occurring during Earth Science Week have a live question-and-answer period with presenters. Webinars are available in many languages, with multilingual captioning.

AGI is sponsoring four contests honoring this year's theme. The visual arts contest encourages students from kindergarten through grade five to explore "Our Sustainable World." "Geoscience for Sustainable Development Goals" is the subject of the essay contest, targeting grades six through nine. The photo contest, which is open to all ages, asks participants to bring attention to on "Sustainability in Action." Teams and individuals of any age and anywhere in the world are invited to submit brief videos that show viewers their perspective on "Striving for Sustainability Globally." These contests allow both students and the general public to participate in the celebration, learn about Earth science, and compete for prizes.

Throughout the quarter-century that Earth Science Week has grown to become one of the premier outreach efforts in the geosciences in the U.S. and across the world. Many partners and sponsors have collaborated to support the program's success. Some provide financial support, while others contribute materials for the Toolkit. Still others lend their expertise to the media that AGI develops, such as the USGS and Natural Resource Conservation Service adapting maps for the Earth Science Week and Geologic Map Day posters and accompanying online media. Specific partners are acknowledged on the media, and a complete list of partners and sponsors can be found on the Earth Science Week website. AGI is grateful to all the sponsors and partners as well as the Earth science educators in the U.S. and internationally who use Earth Science Week as a vehicle for building geoscience awareness.

For more information, visit www.earthsciweek.org or email info@earthsciweek.org.

Help shape the future of Earth Science Week! Complete the survey at: https://bit.ly/ESWtoolkitsurvey.

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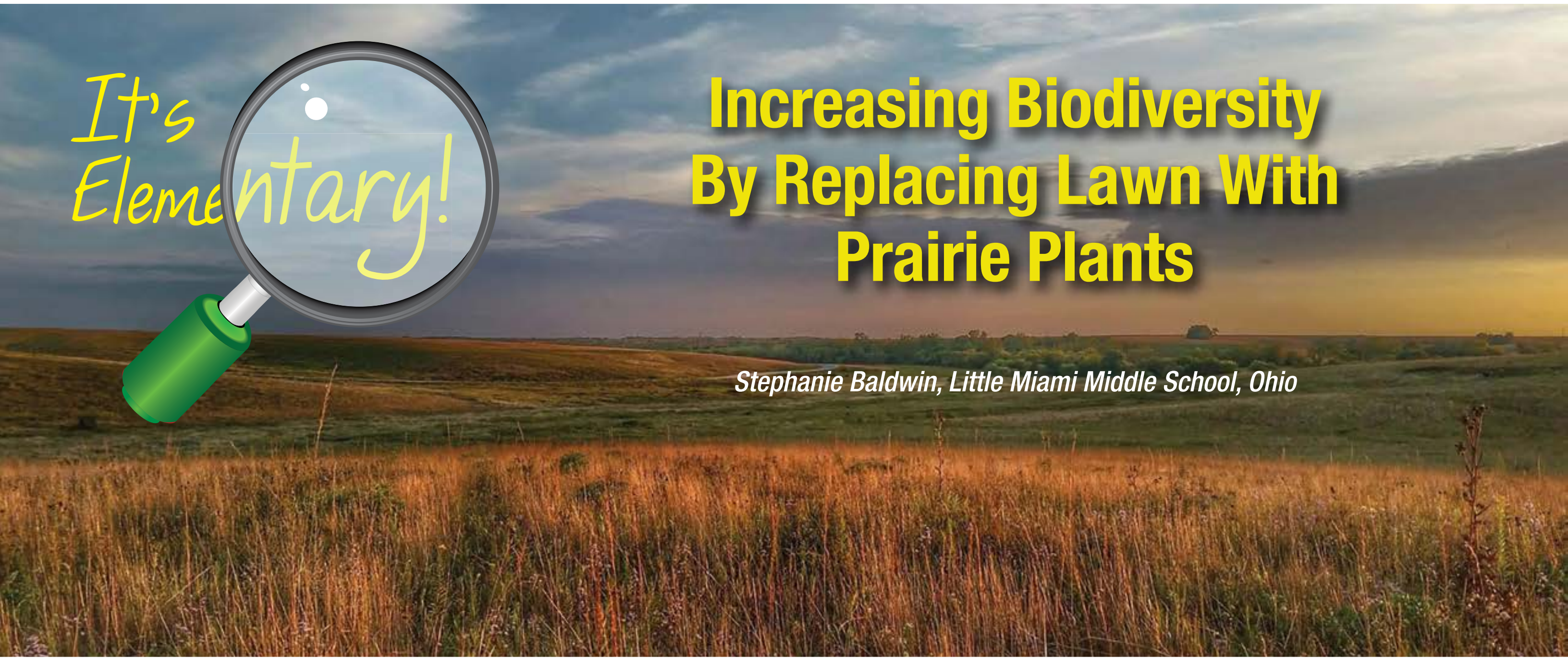


Increasing Biodiversity By Replacing Lawn With Prairie Plants

Stephanie Baldwin, Little Miami Middle School, Ohio

Prairie Sunset at Neal Smith National Wildlife Refuge in Iowa
Photo Credit: Doreen Van Ryswyk - USFWS

Abstract

Prairies are defined by unique soil characteristics, grasses, and wildflowers. They provide native habitat for birds, butterflies, insects, reptiles, and other small wildlife. This middle school project, supported by funding from NOAA Planet Stewards, created a native prairie landscape on a school-site yard where there was once only a 2.75-acre lawn. Students worked with community members to research planting and maintenance of prairie plants. After installation, students were able to track an increase in biodiversity of plants and animals over a four-year span. They also compared the biomass of lawn and prairie and calculated the savings of carbon emissions due to a reduction of mowing.

Figure 1. Baldwin Prairie area before restoration.
Photo credit: Stephanie Baldwin

Introduction

Native prairies require little maintenance, are long lasting, and do not need fertilizers or pesticides and they are perfectly adapted to the midwestern climate. Prairie root systems are drought resistant, hold soils in place, absorb water, *slow runoff, reduce soil loss, and lessen the severity of flooding.* (https://tallgrassprairiecenter.org/) The benefits of restoring prairie in previous lawns can be substantial, maintenance that uses less water and no fertilizer, and an ecosystem that supports wildflowers and wildlife. (Kessler, 2021)

In the spring of 2017, my students watched with wonder each day as a mother killdeer tended to her chicks that had been born on the grassy lawn beside the playground. We used safety cones and communicated with our groundskeeper to keep them safe, but what if there were other nests we had missed? My students worked together to find a way we could encourage wildlife be on our school grounds.

The Project

This project had 2 anticipated outcomes:

- Eliminate carbon dioxide gas produced by lawn mowing.
- Increase biodiversity by planting more species of plant instead of turf grass.

Finding community helpers was key to our success. Students worked closely with our district groundskeeper to develop a plan. We had local master gardeners look over our plans and they helped us pick plants and connected us with the Ohio Prairie Nursery where we sourced our seeds.

A representative from the Greenfield Plant Farm taught students how to select native plants that would grow well in our local soil and attract the largest number of pollinators to our site. Warren County Master Gardeners explained to students how to clear our site and maintain the young plants for the most successful plant growth in the Spring. Local gardeners and high school student volunteers helped students learn the proper way to dig, transfer and water new plants.

The groundskeeper was happy to stop mowing the new prairie during the school year and also had a brush cutter available to cut down the tall prairie plants once each fall to prevent our grass species from being taken over by newly growing trees. Funds for our plants, new benches and signs came from NOAA Planet Stewards and the Ohio Department of Natural Resources WILD school sites grant (https://ohiodnr.gov/discover-and-learn/education-training/environmental-education/wild-school-sites). A local greenhouse manager came to our school on planting day and brought mature plants to plant along with our seeds.

Species Planted

Grasses

- *Schizachyrium scoparium* - Little Bluestem
- *Bouteloua curtipendula* - Side-oats Grama

Wildflowers

- *Chamaecrista fasciculata* - Partridge Pea
- *Heliopsis helianthoides* - Ox Eye Sunflower
- *Gaillardia pulchella* - Indian Blanket
- *Echinacea purpurea* - Purple Coneflower
- *Monarda citriodora* - Lemon Mint
- *Coreopsis lanceolata* - Lanceleaf Coreopsis
- *Senna hebecarpa* - Wild Senna
- *Rudbeckia hirta* - Black-eyed Susan
- *Ratibida pinnata* - Yellow/Grey-headed Coneflower
- *Liatris spicata* - Dense Blazingstar
- *Asclepias syriaca* - Common Milkweed
- *Asclepias tuberosa* - Butterfly Milkweed
- *Asclepias incarnata* - Swamp Milkweed
- *Monarda fistulosa* - Wild Bergamot
- *Tradescantia ohiensis* - Ohio Spiderwort
- *Penstemon digitalis* - Foxglove Beardtongue

Figure 2. Students planting native species.

Photo credit: Stephanie Baldwin

School year timeline

August

- A local businessman tilled the soil that would become the prairie
- Prairie seeds were ordered
- Students installed 2 benches at the prairie site

September

- Students planted the prairie seed
- Students collected data on how much carbon our school mower emits per hour and calculated a carbon footprint for our current school yard maintenance practices
- Students planted 100 native plants

October-March

- Students in the school's nature club weeded the new prairie area weekly

Figure 3. Butterflies on newly restored prairie.
Photo credit: Stephanie Baldwin

April

- Students continued weekly weeding
- Students completed a quadrant frame measurement of biomass.

May

- Students calculate new carbon footprint data for our schoolyard maintenance practices

We installed signs designating the area as a National Wildlife Federation Certified Wildlife Habitat. In subsequent years we have added bluebird boxes, bat houses and walking trails to the area. It is well used by both students and the neighboring community.

Data Collection and Results

The students gathered four types of data over the course of the project. For biomass calculations, students collected all the plants from a 1x1 foot grid and let the plants dry. Students then weighed the dried grass from each grid to show change.

Table 1. Project data collection types and results

Type of Data	Data Collection Method	Amount
Carbon sequestered	Biomass comparison of lawn vs. prairie	Students measure 400% more biomass in our prairie plants as compared to the maintained lawn areas of our school.
Carbon released by typical lawn mowing	Students calculated the amount of gas used to mow the school lawn where the prairie would be planted.	Students calculated a savings of 1,062 lbs of carbon per year from our prairie.
Types of plants observed	Plant survey comparison of lawn vs. prairie	Students recorded 20 types of plants in our prairie area compared to 3 types of plants in our lawn areas.
Animal diversity observed	Animal survey comparison of lawn vs. prairie	Students took an original survey of 30 animals found on our school grounds. After prairie planting the list has grown to 45 species of animals observed.

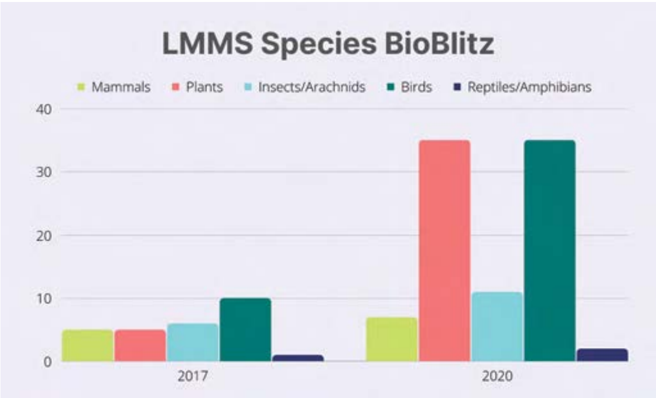


Figure 4. Comparison of numbers of animal species before and after restoration at Little Miami Middle School (LMMS).

iNaturalist (https://www.inaturalist.org/pages/teacher's+guide) is an app that provides a way for citizen scientists to share their observations of organisms with their community. It works well as a way to collect data for a biodiversity discovery project, such as a BioBlitz, a short (often 24 hours or less) inventory of living organisms found within a specified geographic area. (https://www.nationalgeographic.org/projects/bioblitz/) A BioBlitz may be conducted on all organisms or confined to a single taxonomic group or habitat. I took students out weekly for a month each Spring and Fall to get a tally of species found in our prairie. Students recorded any species they could find by snapping a picture using a smartphone and using the iNaturalist app to help identify the species. Using the iNaturalist community we were able to delete duplicate species and have community members check the accuracy of our species identification. Once our observations were verified by the iNaturalist community we added the species to our bioblitz list.

To calculate the carbon dioxide emissions of the original plot of land my students began by interviewing our school grounds keeper. He reported that his riding mower used 1.5 gallons of gas per hour. The 2.75-acre site took him 2 hours to mow and he mowed the site twice a week from April to October. First, students used this data to determine the amount of gas used on mowing the site. They calculated:

> Gas used in a year of mowing the school grounds (168 gallons) = [hours of mowing per week (4 hours) + number of weeks mowed per year (28 weeks)] @ 1.5 gallons per hour

According to the U.S. Energy Information Administration, the motor gas used in the school lawn mower produces 19.37 pounds of carbon dioxide for each gallon burned. Using this information my student calculated that:

> Carbon footprint of maintaining our school lawn (3,254.16 lb.) = 19.37 pounds carbon dioxide per gallon x 168 gallons

Conclusion

Our goal of increasing biodiversity and giving wildlife a safe space to live in our school yard were met. We found an increasing number of species each year the prairie continued to grow. We had the most increase in plant species and bird species. Where we once only had fescue grass, there are now wildflowers and tall grass species. Birds attracted to prairies like red winged blackbird and meadowlark are now plentiful in our space where we had not seen them previously. By turning a portion of lawn to prairie we gave schoolyard wildlife a place to be safe and thrive. Over the years my students have tracked the increasing biodiversity of the area and enjoyed the new species our space has attracted. Educators who are interested in developing native species areas can find additional information in the *National Wildlife Federation Schoolyard Habitats Planning Guide.* (https://www.nwf.org/Eco-Schools-USA/Pathways/Schoolyard-Habitats/schoolyard-habitat-planning-guide)

Link for the BioBlitz activity

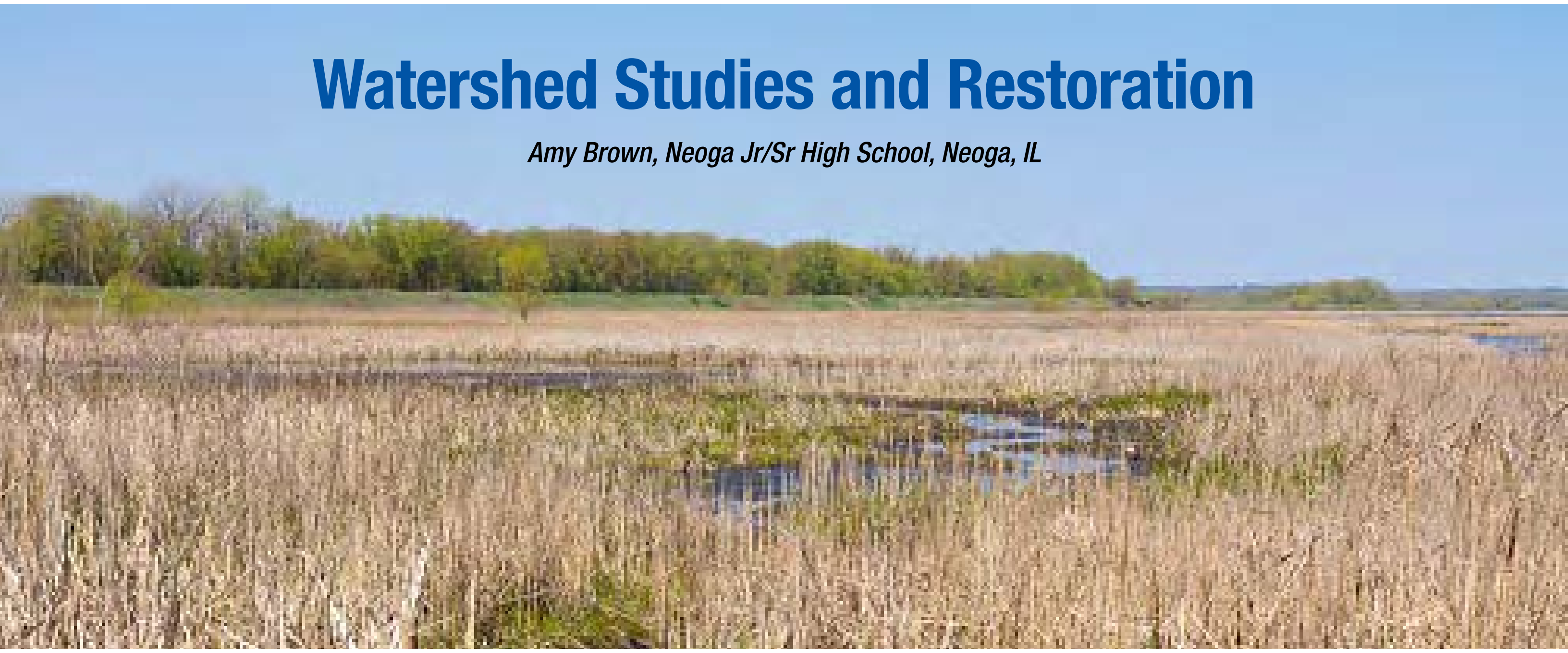
https://docs.google.com/document/d/1QkygYtnR4N7oTiFGyPjbXatfN4-l0N3DgccIJQm39b0/edit?usp=sharing

Reference

Kessler, Rebecca, 2021. Yale Environment 360. https://e360.yale.edu/features/in_us_midwest_restoring_native_prairie_ecosystems_kessler

About the Author

Stephanie Baldwin is a sixth grade language arts and science teacher at Little Miami Middle School in Ohio. She holds a BA degree from DePauw University in Biology and an MS degree in Curriculum and Instruction from the University of Cincinnati. She has taught for 18 years in the middle school sciences and received the Warren County Soil and Water Conservation Teacher of the Year award in 2018. Stephanie can be reached at sbaldwin@lmsdoh.org.



Watershed Studies and Restoration

Amy Brown, Neoga Jr/Sr High School, Neoga, IL

Abstract

Students in a rural Illinois high school Earth and Space science class were challenged to consider how to better manage our land in central Illinois to positively impact water quality. The students learned about watersheds, their local Little Wabash River and how our land use choices affect all of the bodies of water it empties into. They mapped the watershed, determined its threats, and gained an understanding of the effects of different land uses on the Little Wabash and all the watersheds downstream to the Gulf of Mexico. Students collected and analyzed water quality samples. They also used online tools to determine how changing a specific land use practice could impact runoff, siltation, and nutrient pollution. Students proposed and implemented a tree planting project to reduce runoff from part of an agricultural field of a local landowner. Students prepared detailed reports and showed improvement from pretest to post-test about their knowledge of watersheds. Results from this project will be used with future classes as the tree planting matures.

Introduction

Water pollution is a global problem. Everyone has seen sad pictures of animals swimming around and ingesting plastics in the ocean, and many in coastal communities have been impacted by beach closures at various times. My students in central Illinois may have seen these things as well, but they don't feel personally connected to them. We live in the very center of the continent, far from the ocean. Some students live on or near a local lake, Lake Mattoon, and sometimes they will describe the water as polluted, or "gross," but when pressed to explain what that means, they do not have much knowledge about what could be polluting the lake. Students rarely consider the river that feeds the lake and drains our farmland and towns, the Little Wabash River. Water pollution is an everyone problem. We all produce sewage. We all eat the food and use the products produced by farming. We all want the rainwater to drain from our yards and properties as soon as possible, and not flood our homes. But we all also want clean water to drink. We want clean water for recreation.

And we don't often make any connection between our lifestyle and land use choices and the quality of our water.

Project Implementation

The challenge we attempted to address with a NOAA Planet Stewards grant was "How do our land use choices affect the Little Wabash River and all of the bodies of water it empties into, including its estuary, the Gulf of Mexico, and how can we better manage our land in central Illinois to positively impact water quality?" The impairments in the Little Wabash River can be attributed to grain and livestock farming, and sewage treatment by several small towns along its length. (Illinois Environmental Protection Agency, 2008) Siltation and excess nutrients are the primary concerns, and these are tied directly to stormwater runoff and the associated erosion of soil from agricultural lands. (NOAA, 2019) As the Little Wabash makes its way downstream into the Wabash River, the Ohio River, and the Mississippi River, these same pollutants continue, until they are released into the Gulf of Mexico, which develops a dead zone every year (NOAA, 2021). In 2019, NOAA predicted the yearly dead zone in the Gulf of Mexico to be one of the largest ever, due to excessive amounts of agricultural runoff associated with increased rainfall throughout the Mississippi watershed during the year. Spring is the most significant season for the increased nutrient load, and in 2019, the USGS was estimating that 156,000 metric tons of nitrate and 23,300 metric tons of phosphorous was being discharged into the Gulf in May alone (NOAA, 2019). Some of these nutrients are coming from the Little Wabash watershed and the farmland in our school district. On a small scale, this project showed students in the Neoga Community School District and their families and community that land use changes can have an impact not just on local water quality, but on global water quality because of the effect in the Gulf of Mexico. This project involved installing a riparian forest area on the edge of an agricultural field currently experiencing significant erosion.

Figure 1. Runoff from site of riparian restoration before tree planting. Photo credit: Amy Brown

This erosion is the result of stormwater runoff, which also carries agricultural chemicals into the adjacent creek. The goal of the tree planting was to reduce erosion and runoff from the agricultural field, and improve the quality of the stream) therefore improving the quality of all downstream waters in the process.

Riparian restorations are valuable tools in maintaining or improving water quality, with the added benefit of removing carbon dioxide from the atmosphere. (Climate Literacy and Energy Awareness Network, 2016)

Figure 2. Creek on restoration site showing silt runoff. Photo credit: Amy Brown

Students in Earth and Space science class were challenged to first learn about watersheds, in general. We spent time identifying our watershed, the Little Wabash River. Students researched information about the watershed and impairments to it, and drew detailed maps of the area. We learned about pervious and impervious surfaces, and the impact those might have on runoff and infiltration. We mapped our school property, and identified areas of runoff from the property, as well as where it leaves the property. We also mapped the site about 10 miles from school, where a landowner had asked to have a riparian forest planted.

Table 1. Water quality results from Wikiwatershed analysis

	Load, agricultural use (kg)	Load, forest cover (kg)	Average concentration, agricultural use (mg/l)	Average concentration, forest cover (mg/l)
Total suspended solids	42.215	4.098	203.3	42.4
Total Nitrogen	1.505	0.096	7.2	1.0
Total Phosphorus	0.209	0.012	1.0	0.1

Table 2. Runoff results from Wikiwatershed analysis

	Depth, agricultural use (cm)	Depth, forest cover (cm)	Volume, agricultural use (m^3)	Volume, forest cover (m^3)
Runoff	4.355	2.029	207.67	96.76
Evapotranspiration	0.605	0.526	28.83	25.07
Infiltration	3.04	5.445	144.95	259.62

Students used tools on Wikiwatershed Model my Watershed (Stroud Water Research Center, 2022) to calculate runoff, infiltration and nutrient loss from the approximately 2-acre site, and then used the tool to change the land use on the site, and compare the differences in all parameters before and after the tree planting. Results from this analysis are displayed in Tables 1 and 2. Load and concentration data refer to the amounts of those contaminants expected to be in the runoff as simulated in the Wikiwatershed tool. (Stroud Water Research Center, 2022) Runoff was simulated based on an 8cm precipitation event. The depth measurements show how much of the 8cm runs off, infiltrates, or gets processed by the plants to eventually evapotranspirate. The volume data refers to total volume of water for each outcome. This simulation showed a significant reduction in runoff and pollutants between the current agricultural land practice and forest land use.

Figure 3. (top left) Students planting trees on the pull behind tree planter. Photo credit: Amy Brown

Figure 4. (top right) Students sort and prepare trees for planting. Photo credit: Amy Brown

Figure 5. (left) Students and volunteers measure and plant tree seedlings. Photo credit: Amy Brown

Figure 6. (right) Student using a dibble bar. Photo credit: Amy Brown

On a cool spring day in March, 2021, a group of intrepid students and volunteers planted approximately 1800 trees and shrubs on the restoration site. We used dibble bars (hand-held tree spades) and a pull-behind tree planter. Conditions were very muddy, which made tree planting easier, but walking and carrying muddy equipment harder.

We also collected water quality samples from the creek on the tree planting site and another site further downstream.

These were analyzed for typical freshwater quality parameters, including dissolved oxygen, ammonia, nitrites, pH, carbon dioxide, chloride, hardness, and alkalinity.

Results from the analysis of these water samples is shown in Table 3. Future classes will use these results to compare future water quality as the trees in the planting mature.

Figure 7. Student collecting water quality samples in the creek below the field.

Photo credit: Amy Brown

Figure 8. Student conducting water quality analysis.

Photo credit: Amy Brown

Students were given a pretest before beginning the activities in the unit, and after completing the unit to find out their knowledge about watersheds, both in general as well as about their own specific watershed and its impairments. Students showed a 49.7% increase in scores after completing the unit, reflecting the learning about watersheds as a result of the lessons. Students also prepared detailed reports of the results of our watershed study. These reports included recommendations for further land use changes that could improve water quality, both in the Little Wabash River and in the Gulf of Mexico. Some of these recommendations included more riparian tree planting restorations, installing saturated buffer strips along agricultural fields, and bioreactors to absorb excess nitrogen and phosphorus from field runoff.

Table 3. Water quality test results

Test name	Clear creek downstream 10/20/2020	Emmerich Farm tree planting site 10/23/2020
Alkalinity (ppm $CaCo_3$)	200	200
Ammonia nitrogen (ppm NH_3)	1.8	2.4
Carbon dioxide (ppm)	26	17
Chloride (ppm)	0.10	0.3
Dissolved oxygen (ppm)	10	3.5
Hardness (ppm $CaCo_3$)	320	300
Nitrite nitrogen (ppm NO_2-)	0.06	0.1
pH	7.5	8.0
Turbidity (NTU)	120	120

Conclusion

Real world problems provide actionable phenomena for students to engage with science. This project introduced students to their local watershed and concerns with its quality. Students quantified the water quality concerns, and learned about methods to improve some of the land management practices causing pollution issues. Students then proposed and carried out a tree planting project on former agricultural row crop acreage. Students produced positive quantitative and qualitative results, and were able to articulate how the land use changes would positively impact not just their own watershed, but all those downstream, as well. Students showed learning improvement through pre and post-test scores, as well as comprehensive lab reports that included detailed background information about the watershed, its impairments, and the improvements in water quality the land use changes would provide.

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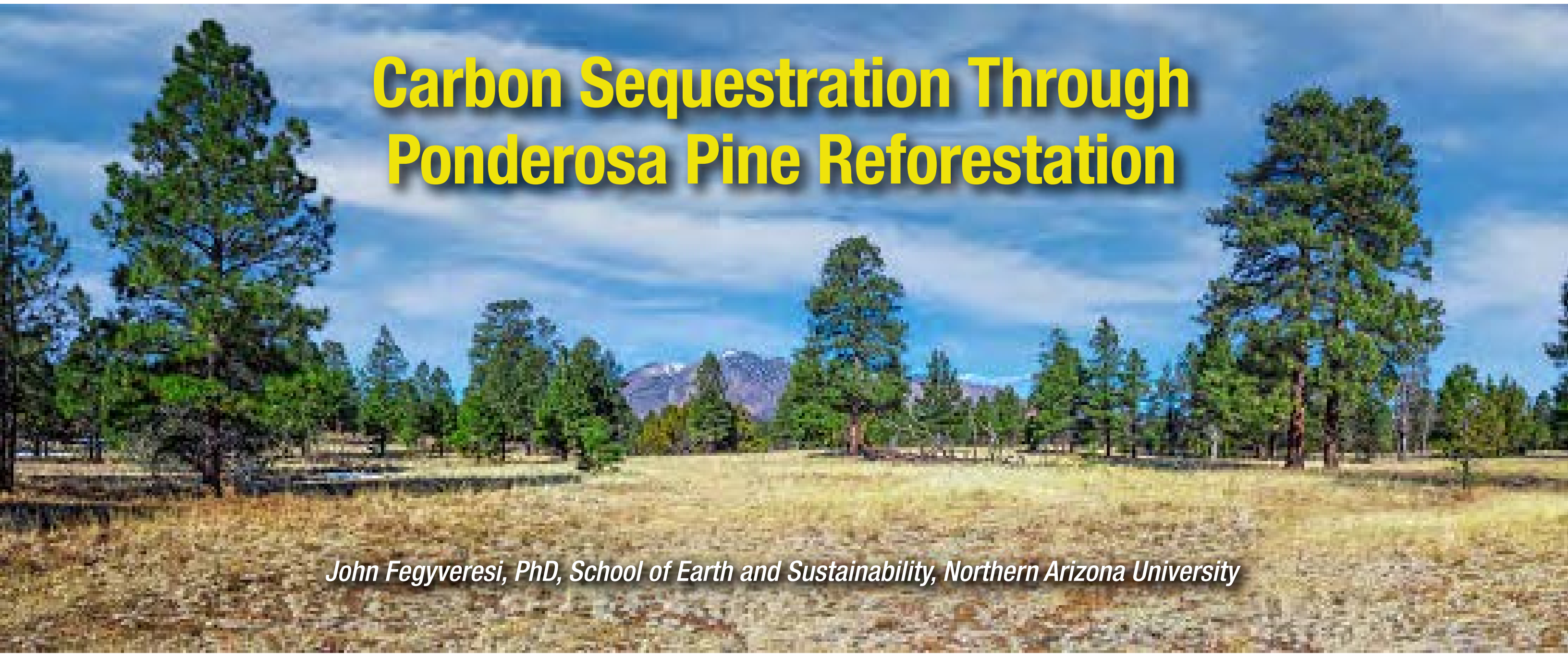
About the Author

Amy Brown is a high school biology and earth science teacher at Neoga Jr/Sr High School, in Neoga, IL. She has taught junior high and high school there since 2004. Amy earned her Bachelor of Science degree in Zoology (Wildlife Biology) from Southern Illinois University at Carbondale, and worked for the Illinois EPA for a few years in the early 1990's. She then spent a few years as an independent contractor contacting riparian landowners along the Embarrass, Salt Fork and Spoon Rivers in Illinois to promote healthy riparian management. Amy received her teacher certification through Eastern Illinois University, and later completed a Master of Science program at the same institution. For the past few years, Amy has also been part of a team working on writing NGSS storyline units with Dr. Barabara Hug of the University of Illinois at Urbana/Champaign College of Education. Amy is very interested in ecology and conservation, and has always strived to bring real world issues into her classroom. She can be reached at abrown@neogacusd3.net.



Carbon Sequestration Through Ponderosa Pine Reforestation

John Fegyveresi, PhD, School of Earth and Sustainability, Northern Arizona University

Abstract

Reforestation efforts are often cited as one of the 15 most important and effective strategies that can be implemented to reduce atmospheric CO_2 (Hawken, 2017). The project detailed here, is a small-scale, proof-of-concept initiative for a much larger and future reforestation campaign in Northern Arizona. This project allowed for broad student involvement in what will ultimately be a multi-year effort for sequestering CO_2. In addition, this project serves as a first step in a potential larger Carbon Offset initiative that would be sponsored and championed by all three of the State Universities of Arizona (ASU, UofA, and NAU). As part of this NOAA Climate Stewards funded project, two-dozen graduate students from the NAU Climate Science and Solutions (CSS) graduate program successfully completed a small-scale (2-acre) Ponderosa Pine reforestation initiative in the Fall of 2020. These students planted ~200 Ponderosa Pine saplings on previously burned National Forest land. Future graduate students will subsequently monitor survival rates and carbon sequestration. It is hoped that the long-term project will ultimately result in over 1 million total newly planted trees (approximately 10,000 acres) in the next five years.

Introduction

Global climate change is not a single-solution problem to society and has even earned the nickname, "the wicked problem" (Murphy et al., 2012). As crucial players in the global CO_2 cycle, forests and trees can help offset emissions by naturally increasing carbon sinks. In a CRS Report to Congress (Gorte, 2009), tree planting was deemed to have a greater carbon sequestration potential than other land use practices, and serves multiple purposes when implemented in areas where tree biomass has been lost. Specifically, it is estimated that on average, reforestation can result in the sequestration of between 1.1 and 7.7 metric tons of CO_2 per acre, per year (Table 1; Brown et al., 1996).

Among the different terrestrial ecosystems, conifer forests are considered major carbon reservoirs. Their contribution to climate change mitigation is established in their large

Table 1. Estimated Sequestration Potential for Selected U.S. Land Use Practices. Adapted from Brown et al., 1996
(in metric tons of CO2 per acre per year)

Activity	EPS (2005)	USDA (2004)
Afforestation (previously cropland/pasture)	2.2 - 9.5	2.7 - 7.7
Reforestation	1.1 - 7.7	—
Riparian or conservation buffers (non-forest)	0.4 - 1.0	0.5 - 0.9
Reduced/conseration tillage	0.6 - 1.1	0.3 - 0.7
Grazing management	0.1 - 1.9	1.1 - 4.8

Sources: EPA: U.S. Environmental Protection Agency, Office of Atmospheric Program, *Greenhouse Gas Mitigation Potential in U.S. Forestry and Agriculture,* EPA 430-R-05-006, Washington, DC, November 2005, Table 2-1, https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P100GO8M.TXT. **USDA:** Jan Lewandrowski, Mark Peters, and Carol Jones et al., *Economics of Sequestring Carbon in the U.S. Agricultural Sector,* USDA Economic Research Service, Technical Bulletin TB-1909, Washington, DC, April 2004, Table 2.2, https://www.ers.usda.gov/webdocs/publications/47467/17126_tb1909_1_.pdf.

storage capacity and their ability to uptake carbon dioxide from the atmosphere through photosynthesis (Laclau, 2003). As such, one common species of tree found in the forests of Northern Arizona, is the Ponderosa Pine.

Based on the EPA's Carbon Footprint Calculator (https://www3.epa.gov/carbon-footprint-calculator/), an average American household in Flagstaff produces between ~8-12 metric tons of CO2 per year. Thus, an acre of Ponderosa Pines planted as part of a reforestation strategy in Flagstaff could nearly offset the carbon output of an entire single-family home. The projected 10,000 acres of planned new growth as part of this greater project, could offset approximately 21% of all carbon emissions from Flagstaff county homes. Furthermore, Ponderosa Pine stands at full maturity, could sequester up to 175.1 metric tons of CO_2 per hectare. In addition to significant biomass loss due to the various local and regional wildfires in Coconino County (e.g., the 1996 Horseshoe Fire), the already delicate Ponderosa Pine forests near the margins of the Colorado Plateau are losing several thousand additional acres per year due of the impacts of climate change and average warmer temperatures. This project aimed to address a portion of these losses. Data collected by future graduate classes will also be shared with the School of Forestry and the National Forest Foundation in order to inform the larger reforestation project, as well as evaluate the success, feasibility, and efficiency of the project.

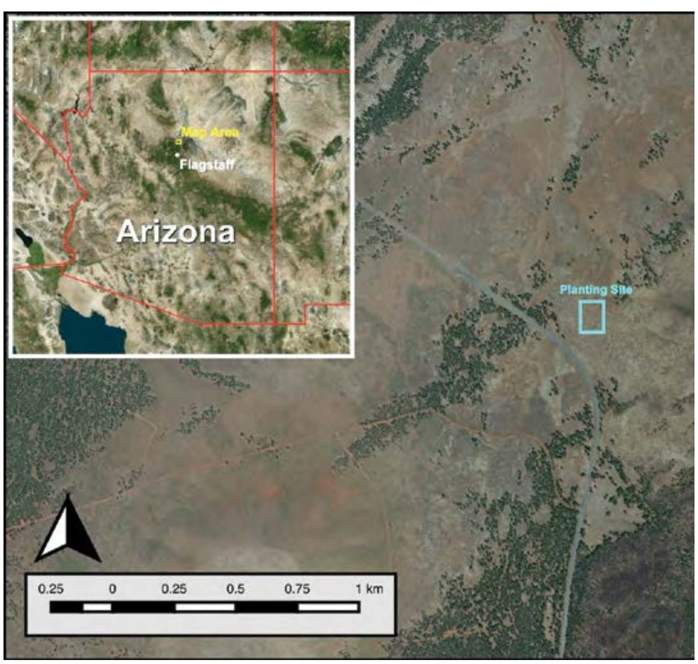


Figure 1. Field location map created in QGIS by the author, using open-source satellite imagery.

At the onset of this project, Northern Arizona University Graduate students within the CSS program took a required class specific to Climate Change Mitigation in the Fall of 2020 (course: ENV 675). As part of their class project, they were broken up in to seven specific teams for the purposes of project preparation, field methods and operations, data collection, and report synthesis (as detailed in subsequent sections below). These teams were: *Literature Review, Site Summary, Outreach and Fundraising, Aerial Drone Imagery, Automatic Meteorological Station, GPS Tagging, and Soil Sampling.*

Background and Site Summary

The planting site is located within the Horseshoe Fire (1996) burn scar (Figure 1), approximately 25 miles NNW of Flagstaff, Arizona. It is characterized by high elevation (~8,000 ft), mean annual precipitation of ~20 inches, moderate humidity (<50%), and four distinct seasons (with wide ranges in diurnal temperatures).

The growing season in this area is relatively short, with the final spring freeze often occurring as late as June, and the first fall freeze as early as September. There are two main seasons of precipitation in the area, a summer monsoon (rainy) season, and a winter precipitation, or snowfall season (Staudenmaier et al., 2014).

Low precipitation conditions in the area may become the new normal as climate change increases the mean annual temperatures of the region, and decreases annual precipitation. The 4th National Climate Assessment indicates that the Southwest U.S. should expect intensifying droughts all while the population increases in the region, and already limited water resources continue to diminish (Gonzalez et al., 2018). Based on projections from the U.S. Climate Explorer Toolkit (https://toolkit.climate.gov/tool/climate-explorer-0), the planting site should expect a mean daily max temperature increase of nearly 10˚F by the end of the 21st century if as a society we continue on the "business as usual" pathway (IPCC – SSP5-8.5 scenario) of emitting greenhouse gases around the globe (Figures 2, 3). Based on these predicted changes in temperature and precipitation for the region, it is imperative that we regularly consider the suitability of Ponderosa Pine to inhabit this historically Ponderosa-dominated landscape in future planting initiatives.

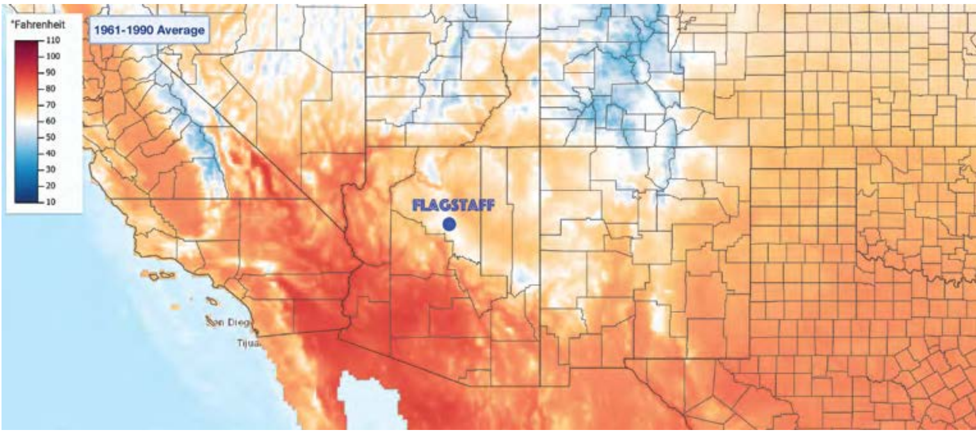


Figure 2. Historical 1961-1990 mean daily max temperature for Northern Arizona.
U.S. Climate Resilience Toolkit. https://toolkit.climate.gov/tool/climate-explorer-0

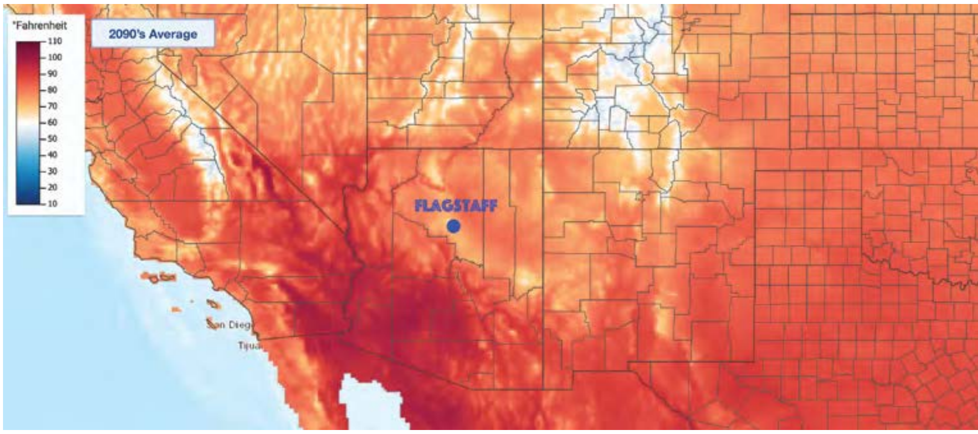


Figure 3. Projected 2090 mean daily max temperature for Northern Arizona under the high emissions (SSP5-8.5) scenario. U.S. Climate Resilience Toolkit. https://toolkit.climate.gov/tool/climate-explorer-0

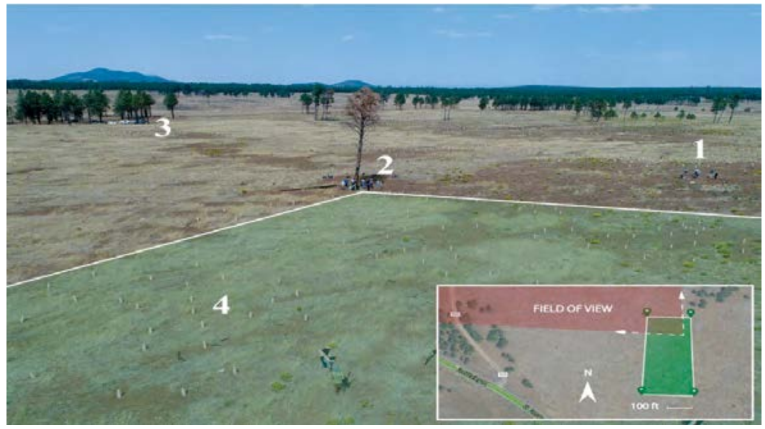
Initial Site Data and Observations

Many aerial photographs and videos of the planting site were taken during the planting campaign (Figure 4). During the on-site tree planting, the ambient temperature, soil moisture, solar radiation, soil pH, and soil nutrient level were all measured by various team members. In addition, a Meteorological (*ONSET*) data logger weather station were configured to continually monitor local conditions at the site.

Figure 4. Aerial drone imagery of the project planting site on the Horseshoe Fire burn scar. Photo credit: John Fegyveresi

Aerial Drone Methods and Data

A designated drone team gathered aerial imagery of the site in an effort to create high-resolution figures of the planting area. Images gathered were made available to all other project teams in order to combine and/or



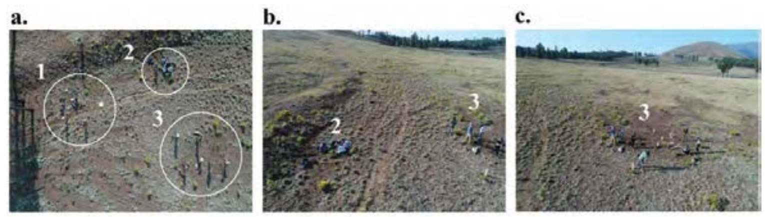


Figure 5A. (top) DJI Phantom 4 drone and components used for aerial imagery and site surveying. Photo credit: John Fegyveresi

Figure 5B. (bottom) Students preparing DJI Phantom drone for flight and image capture. Photo credit: John Fegyveresi

Figure 6. View from the NW corner of the planting site. 1) Location of drone deployment; 2) Location of ONSET Weather Station and main rendezvous point; 3) Parking area; 4) Partial view of tree cluster #1. Photo credit: John Fegyveresi

Figure 7. (a) Examples of three different student teams near the NE corner of the planting site; 1) Original location of Drone Team; 2) Soil/Solar Team collecting sample; 3) Tree Planting Team. (b) Soil/Solar Team (left) and Tree Planting Team (right). (c) Tree Planting Team working cluster #1. Photo credit: John Fegyveresi

incorporate them with their gathered data sets (See also Figures 5 – 7). The obvious advantage of using a drone for the site imagery, was that it was capable of giving a more complete picture of the specific site location as compared to traditional ground-based imagery. Additionally, larger-scale aerial images give a better sense of scale for the burn scar and planting area.

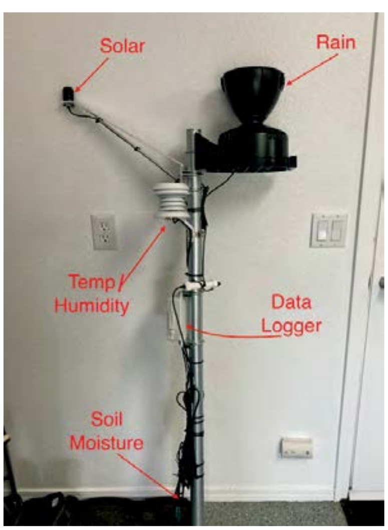


Figure 7. ONSET Meteorological Station installed at the planting site. Data logger and individual sensors are identified.
Photo credit: John Fegyveresi

ONSET Meteorological Station Methods and Data

Introduction

The *ONSET* Sensor Station team installed and configured an automated meteorological sensor station and data logger at the planting site (Figure 8). This team was responsible for downloading all collected sensor data from the planting day, as well as data captured over a 10-day period following the planting in order to evaluate any possible longer-term trends. The *ONSET* sensor Station included sensors for detecting rainfall (inches), soil moisture content (m^3/m^3), solar radiation/Insolation (W/m^2), temperature (°F), and humidity (%). The station was positioned near an existing snag (dead tree) at the primary planting area rendezvous point, and was programed to continuously record data at 1-minute intervals.

GPS Methods and Data

The GPS Measurement team gathered and documented all location specifics for the two-acre planting site through GPS latitude and longitude waypoints (e.g., Table 2). These measurements included GPS Coordinates bounding the entire site itself, as well as coordinates for all individual planted trees, any on-site instruments installed (i.e., the *ONSET* station), and any direct measurements made (i.e., soil measurements).

Soil Methods and Data

The Soil Measurements team set out to gather various data relevant to the health and condition of the soil in the planting area. In order to get an accurate and in-depth analysis of current soil conditions at the planting site, they used four different instruments. These included the *Rapitest* Soil Test Kit, *Rapitest* Digital 3-way, the Atree 3-Way Meter, and standard Toulifly pH strips. Four sampling sites were selected to best represent the integrated soil composition and conditions across the planting site. Measurements of nitrogen, phosphorus, potassium, and soil pH, were carried out using the *Rapitest* Soil Test Kit (Figure 9).

At each site, the GPS coordinates were recorded before the soil analysis, and soil was sampled from a depth of approximately six inches.

Table 2. GPS Site Locations

Site Identifiers	Longitude	Latitude
Site Corner 1	35.445203	-111.761341
Site Corner 2	35.446414	-111.761267
Site Corner 3	35.445178	-111.760622
Site Corner 4	35.4464	-111.760671

Instruments	Longitude	Latitude
ONSET Sensor Station	35.446517	-111.761240

Soil Sample Identifier	Longitude	Latitude
Sample 1	35.446389	-111.760639
Sample 2	35.445667	-111.761333
Sample 3	35.445639	-111.760972
Sample 4	35.446278	-111.760861

Figure 9. Students in the Soil Sampling team taking soil chemistry and pH measurements at the planting site.

Photo credit: John Fegyveresi

Ponderosa Pine Growth

Fortunately, Ponderosa Pines are fairly tolerant of varying soil conditions, however they still do prefer soils with a pH of between 6.0 to 7.0, and growing best in zones with 30 to 60 cm average annual precipitation on well-drained soils. Once established Ponderosa Pines can also survive in hot and dry conditions, exhibiting medium drought tolerance (Ganey and Vojta, 2011). When compared to other species of pines, Ponderosa Pines are able to tolerate less fertile soils, requiring lower soil nitrogen and phosphorus in order to survive. In addition, though higher potassium levels are not necessary for growth and survival, there is some evidence that potassium fertilization can lead to decreased mortality in ponderosa pine (Garrison-Johnston et al., 2005). The biggest concern for the soil conditions is that the annual rainy ("monsoon") season did not bring adequate rain totals for the year, leaving the soil conditions exceptionally dry. And though an established Ponderosa Pine tree can survive in such dry conditions, a young sapling needs additional moisture to properly establish. These dry conditions may ultimately lead to a higher mortality rate.

It is reasonable to conclude that our saplings can grow with the available nutrients of nitrogen, potassium, and phosphorus and the pH recorded for the planting site. Mean pH reading across all sampling sites and methods, was 5.7. This value is just under the ideal threshold of 6.0 (slightly more acidic). The nitrogen reading found in each testing location also showed that the levels were depleted. Our phosphorus readings varied at each testing site from depletion, to adequate, with two readings not clear enough to record an accurate interpretation. Though nitrogen levels were depleted and phosphorus readings were not consistent, it is still likely that the conditions are sufficient for tree growth. Lastly, two of our testing locations found a surplus of potassium while the other two found an adequate level of potassium. Despite the dry conditions, and based on the collected data however, the results should indicate a relatively satisfactory survival rate among the saplings (at least 20-30%).

Conclusions

In total, ~200 new Ponderosa Pine saplings were planted and catalogued on a previously burned portion of National Forest land, ~26 miles north of Flagstaff Arizona, within the Coconino National Forest. At the planting site, several measurements were made, and many instruments were used in order to document an ensemble of relevant data. These included drone photography, soil moisture and pH measurements, GPS waypoints and coordinates, and various meteorological and solar data. As a part of this campaign, a fundraising and social outreach effort was also carried out in an effort to raise awareness and funding for future project support. In total, over $500 dollars were raised through these efforts. In future years, this planting site will be further monitored by CSS graduate students to estimate overall tree survival rates, as well as total sequestered carbon. It is hoped that through this experience, and with the collaborations and partnerships built through it, that this initial proof-of-concept, small-scale planting campaign, will evolve into a much larger and continual reforestation and carbon mitigation effort. Following the project, the NAU School of Earth and Sustainability and School of Forestry, have teamed up to promote a larger tree-planting fundraising campaign on the NAU campus. We have established a NAU Foundation charitable fund through the University that will allow for open donations to this campaign. Long term, the multi-year extended plan for this project is to plant over 1 million trees over the next five years (~10,000 acres).

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About the Author

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Contributions to this article were made by the following MS graduate students in the NAU Climate science program under the supervision of John Fegyveresi, PhD:

Anabeth Avila Arenas; Bryce Beck; Jamie Blatter; Samuel Blustein; Caitlin Brogan; Dylan Chandler; Jenna Decker; Katie Dickinson; Jack Dugan; Katherine Dunlap; Sebastian Espinosa; Jillian Goulet; Stephannie de Souza Fernandes; Brianna Lovato; Christopher Moreno; Marie Nabors; Xuechen Niu; Mitchell Riner; Bennett Rosenow; Crystal Routhe; Maya Shimoni; Virgil St Aime; Chelsey Trejo; Ryan Tsingine; Hailey Weinberg; Isabelle Wilhelm; Alex Wilson; Iris Wu; Taylor Wyum

Gardening for Carbon Sequestration

John Herrington, East Syracuse Minoa Central High School, East Syracuse, NY

Abstract

Anthropogenic Climate Change is the challenge of our time. Unfortunately, most educational experiences leave students in a state of despair, missing the opportunity to capitalize on action. In order to affect positive change for our collective future, students must not only understand the mechanisms of climate change, but be empowered to create positive change now within their sphere of influence (Hayhoe 2021). In this project, sponsored by NOAA Planet Stewards, high school students learned about plant growth, biodiversity, and ecosystems before investigating how their consumer choices and actions can impact individual carbon emissions. Finally, students worked to solve this challenge through the creation of a school community garden.

Introduction

It can be a daunting task for students to grasp the magnitude of climate change, attribute it to human causation, and enact meaningful change that will have a lasting impact. With funding from the NOAA Planet Stewards Project, high school students in central New York created a school community garden. This project had two phases. In Phase 1, students assessed, created, and improved the habitat in an enclosed courtyard at our high school. The project responsibilities were divided into student teams. One team researched what were the best trees and shrubs for our soil and climate with the goal of not only carbon sequestration, but to attract birds and other potential pollinators. A second team of students researched birdhouse designs and types of feeders to attract a variety of bird species. Students then selected and planted trees, shrubs, and installed bird houses and bird feeders.

During Phase 2, students created an organic vegetable garden in the same courtyard with the improved habitat. The goal of Phase 2 was to learn the skills and knowledge about the art of gardening, as many had never been exposed to gardening at home and to empower students to translate this skill into their own context in the future. Students gathered information on what vegetables would be best for the school garden; then students planned, designed, planted and maintained the vegetable garden while incorporating other school groups in their endeavors. They created meals from their vegetables and used these meals as a basis for calculating the carbon cost of food.

Implementation

The project was set to start in February 2020. Students took the Carbon Footprint Calculator (https://www3.epa.gov/carbon-footprint-calculator/) as a presurvey and started researching and gathering information for the implementation of the school garden. Then March 16, 2020 happened and virtual teaching became the new rave. Even with plans scrapped for creation of the outdoor garden, some good was salvaged from the craziness. Through online discussions and videos, 11 students created a vegetable garden for the first time at their homes.

In August 2020, a few students met with an arborist from a local nursery to discuss the best trees and shrubs for attracting and creating habitat for birds and that are best adapted for our soil, drainage and climate. We also received supplemental funding from the State Farm Teacher Assist grants. Planting took place in September and October of 2020. Coordinating the planting was a monumental task but I had both a Boy Scout (future Eagle Scout) and a Girl Scout (future Gold Award) involved in this project and they were tasked with recruitment and task management. They were able to engage their prospective athletic teams, field hockey and baseball, in the physical manpower necessary to plant all the trees and shrubs and to move 12 yards of soil and 12 yards of mulch. Phase 1 was complete.

Image 3. Students working hard preparing the courtyard for planting of shrubs and trees. Photo Credit: John Herrington

Image 4. After planting the vegetables, students work the garden to remove weeds and keep the soil loose and watered. Photo Credit: John Herrington

In March of 2021, students started with the building and placement of birdhouses and bird feeders in the courtyard. Students researched what type of birdhouses would best for our courtyard and shared plans with our schools' production class and had 10 birdhouses built. In May 2021, the organic vegetable garden was tilled and planted. Over the next 6 weeks, students maintained weeding and watering of the garden. The cross-country team wanted to leave a legacy gift, and asked the production class to also build benches so that students could use the outdoor classroom for a mental health respite while also to make seating available for classes that wished to be outside. COVID had really cramped everyone's style at that point, and the addition of benches enhanced the use of the outdoor space.

Image 1. Student showing off some of the produce from the organic vegetable garden. Photo Credit: John Herrington

Image 2. The finished product was a mini ecosystem with bird houses and feeders. Students are able to use the courtyard for science projects and to relax and appreciate the outdoors. Perfect during COVID. Photo Credit: John Herrington

This project would not have been possible without the involvement of many partners. We were surprised how many local businesses were willing to donate, offer at a reduced price, or offer services in kind when the project was explained and they were asked if they could help our budget go further. Materials needed were soil, seeds, containers, wheel barrow and mulch, shovels, rakes, gloves, hose and water and online access for plant research or library resources. Local phenomena were highlighted and student engagement enhanced through Engineering Design Challenges. (NGSS, 2013) and (New York Board of Regents, 2016) Local phenomena included organic gardening using no pesticides and fertilizers and connecting it to reduced local harmful algal blooms. Our project focus was primarily on decreasing fossil fuel usage, but we spent a lot of time discussing and showing how large commercial farms had a negative impact on the environment. Traditional ecological knowledge was incorporated into our garden planning. One of our engineering design challenges was to create a water catchment system to collect rainwater from the flat roof of our high school and water the garden at the roots to limit evaporation and conserve water.

Table 1. NGSS performance expectation

Performance Expectation
HS-LS2-7 Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity. [Clarification Statement: Examples of human activities can include urbanization, building dams, and dissemination of invasive species.]
Science and Engineering Practice
Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. • Design, evaluate, and refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.
Disciplinary Core Idea
LS2.C: Ecosystem Dynamics, Functioning, and Resilience • Anthropogenic changes (induced by human activity) in the environment—including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change—can disrupt an ecosystem and threaten the survival of some species. **LS4.D: Biodiversity and Humans** • Biodiversity is increased by the formation of new species (speciation) and decreased by the loss of species (extinction). (secondary) • 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 overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. **ETS1.B: Developing Possible Solutions** • When evaluating solutions it is important to take into account a range of constraints including cost, safety, reliability and aesthetics and to consider social, cultural and environmental impacts. (secondary)
Cross-Cutting Concept
Stability and Change • Much of science deals with constructing explanations of how things change and how they remain stable.

The unit was presented in a 5E (Engage, Explore, Explain, Elaborate, Evaluate) format.

Engage: In the fall, the high school Biology and Environmental Science Students took a carbon footprint and attitudinal survey related to climate change and then connected with special education students to harvest vegetables and create a meal together. Pumpkins and apples were harvested to cook some creative fall recipes. The interactions between these students can be powerful. Students were then challenged to create a "local slow food meal" as school was beginning and local harvests are abundant. They were presented with a focus question: How do consumer choices impact climate change? Students were allowed to source their food out of the school garden, local grocer, or local farmer's market. Favorite recipes were discussed and samples were shared. Students presented their findings on how buying local produce or growing produce at home has a positive impact. In the spring an area for an organic vegetable garden was tilled and weeded, seeds were started in the classroom and eventually planted in the garden.

Explore: Students calculated the food miles (carbon footprint) of their meal (https://www.foodmiles.com/food/calculator), and compared that to an alternate, remotely sourced version. Students also investigated the food miles of their favorite foods (how carbon costly is your guacamole at Moe's)?

Explain: Throughout the year, the concepts of ecosystem composition, nutrient cycling, photosynthesis, growth, biodiversity, and anthropogenic climate change were explored. Students mapped out the courtyard describing the different mini ecosystems present and related them to biodiversity and specific bird habitats. Also, with the use of compost bins, students traced the path of energy through an ecosystem using the compost as a 'fertilizer' for the shrubs and garden.

Elaborate: This portion of the experience happens in late winter/early spring. Students engaged in an engineering design challenge, "What actions can you take to reduce carbon emissions through personal food choices?" One of the student challenges was to design a garden at home (space, sun, soil and water collection) and determine which vegetables would best suit their family. Next students created an action plan to purchase locally grown produce either from local farmers markets or from the handful of local farms in our district that sell produce directly.

Evaluate: This portion of the experience happened in the late spring. Students retook the survey from the beginning of the year. Students presented and implemented their Community Garden ideas and their organic vegetable garden was planted.

Results

Phase 1: Students calculated that approximately 430 lbs. of carbon dioxide is sequestered each year from the trees and shrubs that were planted. National Tree Benefit Calculator (https://www.arborday.org/calculator/)

Phase 2: Students calculated that approximately 900 - 1000 lbs of carbon dioxide is saved from the vegetables and fruit harvested from our garden (food miles eliminated) each year.

The graphs that follow (Figures 1-5) show the Climate Change Pre and Post Student survey results.

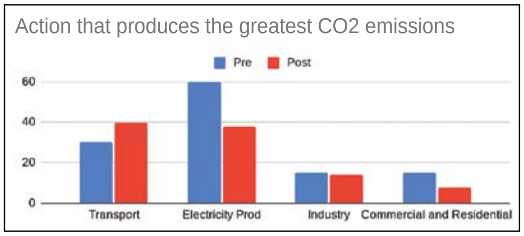

Figure 1. Graph indicates a better student understanding of the cause of the increased carbon dioxide in the atmosphere.

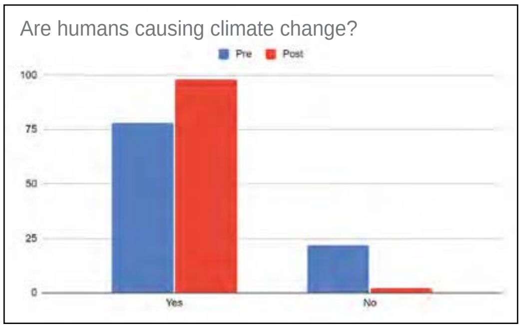

Figure 2. Graph shows an increase in student understanding of the human investment and moral obligation to take action against climate change.

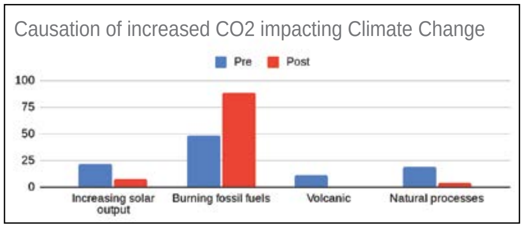

Figure 3. This project focused on the impact gardening and decreasing food miles through buying local produce. Understanding the role transportation plays in the addition of carbon dioxide to the atmosphere is crucial in making changes.

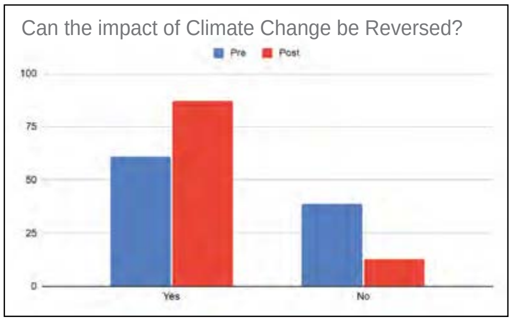

Figure 4. Graph shows a change in attitude about whether climate change can be reversed.

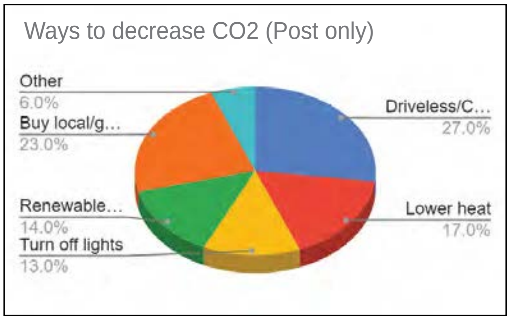

Figure 5. Graph shows what students feel are important ways to decrease carbon dioxide input. The project focus was on ways to drive less and buy local; decreasing fossil fuel emissions.

Discussion

This "Community Garden" project has become self-sustaining thanks to NOAA Planet Stewards and other locally sourced matching funds. The courtyard has created a unique space for student utilization and the student learning that has occurred in this space has been priceless. Students truly enjoy being outside and able to experience firsthand baby birds being fed by their parents, understanding the importance of growing a vegetable garden, recycling of nutrients in a compost bin and making connections between climate change and actions they can take to help reduce the impact of carbon emissions. Science projects and activities allow students to utilize the space to study bird houses/nests and types of birds that feed at the feeders. The garden is a point of focus in our Locavore Unit and the space is used as a place to read and do work. Other teachers in the school take their classes outside to have discussions or work time. A future project is to have the art club create a 3D piece of art from recycled material.

Central New York is home to a state regional farmers market, where students and their families can purchase local foods every week throughout the year. It is famous for apples, not too far away from the Finger Lakes Region (grapes), and only ten minutes from the Onondaga Nation, so the opportunity to infuse traditional ecological practices such as the practice of the Three Sisters from indigenous traditions for soil amendment and crop efficiency on acreage.

Through our partnership with S.U.N.Y Environmental Science and Forestry, a professor visited to talk with students about Traditional Ecological Knowledge (TEK). These ideas were incorporated into students' final projects. Students have tried different ideas at home such as the Three Sisters (Native Seeds, 2016) using no pesticides, using compost as fertilizer and supplying rainwater to their gardens.

East Syracuse Minoa Central School District is a founding member of the CNY STEM HUB and Cleanwater Educational Research Facility (CERF) in the Village of Minoa, NY. Because of these connections, students have the opportunity to engage those visiting our school, participating in "Learning Tours," on their project. Future students also have the opportunity to learn from the original cohort of students and expand the project at CERF, where we have a greenhouse available, courtesy of a previous NOAA Climate Stewards grant. This will extend the season growing and include the practices of aquaponics and aquaculture into this project-based learning unit.

Implementation Tips for other schools that want to start a project like this.

- Involve the entire school community (several teams needed community service hours for graduation or club participation). The first year is labor intensive!
- Diversify funding sources
- Recruit other programs for summer maintenance and to reduce waste
- Create a space for mental health breaks
- Include social media shout-outs for donations from local businesses

Resources

Hayhoe, K. (2021). Saving us: a climate scientist's case for hope and healing in a divided world. New York, NY : One Signal Publishers/Atria Books.

Native Seeds (2016) https://www.nativeseeds.org/blogs/blog-news/how-to-grow-a-three-sisters-garden

NGSS Lead States. (2013). *Next Generation Science Standards:* For States, By States. https://www.nextgenscience.org/search-standards

New York Board of Regents (2016). New York State Science Learning Standards: http://www.nysed.gov/common/nysed/files/programs/curriculum-instruction/hs-science-learning-standards.pdf

About the Author

John Herrington is a 24 year veteran teacher with East Syracuse Minoa Central High School located in Central New York. John has received the NNSTOY New York STEM Fellowship, the Technological Alliance of Central New York award for innovative teaching, is a NOAA Planet Steward, and has been appointed as an adjunct instructor for State University of New York Environmental Science and Forestry. John holds a BS in Environmental and Fisheries Biology from SUNY ESF and an MS in Education from LeMoyne College. As an environmental enthusiast, John co-advises the Outdoor Adventure Club, coaches cross country, and baseball. John can be reached at jherrington@esmschools.org.

Pamela Herrington contributed to this project and article. She is a former NOAA Planet Steward and is the STEM and science instructional specialist for East Syracuse Minoa Central School District.

Water and Climate Stewards of San Diego Bay

Sandra Lebrón, Elementary Institute of Science, San Diego, CA

Abstract

In partnership with the Climate Science Alliance, the San Diego Coastkeeper education team developed new climate change lessons and activities to demonstrate the connection between human activities and greenhouse gases and climate change impacts in our oceans. Thanks to the generous support from NOAA Planet Stewards, the project was able to bring a Water and Climate Stewards program to approximately 944 4th-12th grade students at eight schools within San Diego County. Through one-on-one meetings with teachers and students, classroom presentations, online lesson plans, free supplies and action projects, students gained a better understanding of San Diego's ecology and the threats that our environment and community face from pollution and climate change. Students developed a sense of stewardship towards San Diego's habitats and wildlife and learned specific actions they can take to protect our natural resources, reduce their single-use plastic consumption, and create positive change in their communities. Teachers gained free access to standards-aligned lesson plans that meet Next Generation Science Standards and Common Core State Standards, enhancing their curriculum with environmental science education.

Introduction

San Diego Coastkeeper (https://www.sdcoastkeeper.org/) is a non-profit organization based in San Diego, California with the mission to protect and restore fishable, swimmable and drinkable waters in San Diego County. The education team has been providing hands-on water education for years, and have reached thousands of students and teachers with our education programs. In order to make our programming more relevant and local we have been building partnerships with San Diego environmental education organizations and the Climate Science Alliance, a non-profit organization with the mission of safeguarding natural and human communities in the face of a changing climate (https://www.climatesciencealliance.org/). With these connections and the knowledge and resources that community partnerships bring, we felt empowered to start incorporating meaningful climate education into our existing curriculum.

One of the key science education content standards that California has adopted to guide K-12 science education is the principle that people influence natural systems. The goal of our climate action project was to deepen student knowledge and to find practical solutions for two issues: climate change and marine debris. New climate change lessons and activities were developed that included tools for understanding which human activities produce greenhouse gases, presentations on the ways in which climate change is impacting our oceans, games that help illustrate links between human behaviors and climate outcomes, and resources full of tips for how students can reduce their climate impacts in their own lives and empower their families and communities to do the same.

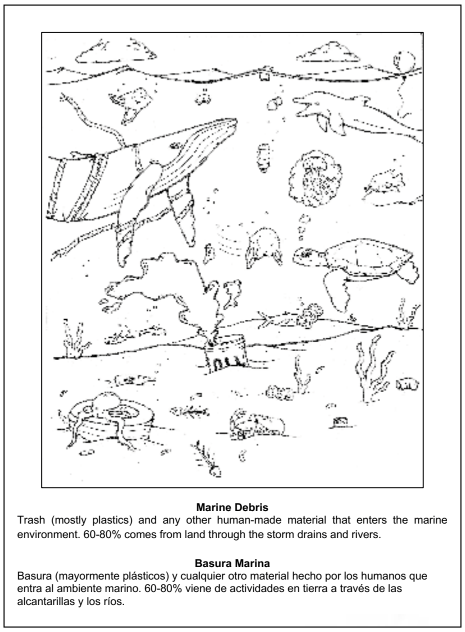

Figure 1. Example of bilingual science illustrations.

Funds provided by NOAA Planet Stewards (https://oceanservice.noaa.gov/education/planet-stewards/psep-supporting.html) allowed us to purchase supplies to build the education kits we distributed to local classrooms. Through a partnership with the Port of San Diego's environmental education grant program, we were able to expand the program into the San Diego Bay Watershed communities of Coronado, Imperial Beach, and Chula Vista in addition to San Diego. Spanish language versions of our climate lesson further improved our ability to connect with more students and more educators in our region.

Project Implementation

During this grant period, we hosted numerous classroom presentations and field trips through partnerships with the Climate Science Alliance and the Earth Discovery Institute (https://earthdiscovery.org/). These partnerships allowed us to leverage a larger number of students and allowed us to present a holistic view of climate and water science. Through our hands-on trash decomposition and greenhouse gases activities, students learned about the relationship between plastic consumption and climate change. We offered classroom presentations to help teachers integrate the Climate Change and Marine Debris lesson plan into their curriculum and conducted climate stewardship action projects in three schools.

The following schools in San Diego County participated in the project:

1. Bayside Elementary in Imperial Beach.
2. Harborside Elementary in Chula Vista.
3. SAY San Diego an after-school program at Innovation Middle School in San Diego.
4. Logan K-8 School in San Diego.
5. Marston Middle school in San Diego.
6. Mission Bay High School in San Diego.
7. Silver Gate Elementary school in San Diego.
8. Silver Strand Elementary school in Coronado.

Students learned about marine debris; what happens with our trash—specifically single-use plastics—when it reaches our storm drains, where it ends up if not properly disposed of, and its detrimental effects on our local waterways, the San Diego Bay, and the Pacific Ocean. Students discovered how long it takes for plastics to decompose and were surprised to learn

Image 1. 88 4th-5th grade students from Bayside Elementary learned about the San Diego Bay tidelands and pollution sources during an outdoor field trip with the Earth Discovery Institute to Imperial beach. Photo credit: Sandra Lebrón

that some single-use items can take hundreds of years to break down into smaller pieces, making them more accessible to become part of the food chain and ultimately never degrade. Students were deeply concerned about the effects of marine debris on our marine life when exploring real pictures of aquatic and marine animals with their stomachs filled with plastic items.

Link to NGSS Lesson Finding Solutions to Climate Change and Plastic Pollution: (https://docs.google.com/document/d/184LF9U3EOCI2BRBAkod_IcTSyDt6LcNi9T5KdLxBnVw/edit?usp=sharing).

Innovative games engaged students in learning about different causes of climate change, the sources of greenhouse gases as well as practical solutions an individual can take to reduce plastic consumption and pollution and decrease their carbon and water footprint.

The team piloted new lessons at Pacific Beach Elementary School over the course of five weeks in 2017—reaching every single student in grades K-5 at the school—and received positive feedback. We also worked with 6th grade students from Harborside Elementary and the students showed an increase in understanding about solving the pollution problem from 22% to 84%.

Topics at the schools varied depending on the needs of the curriculum. Students from Marston Middle School, Mission Bay High School and Silver Gate Elementary participated in hands-on marine debris decomposition activities and greenhouse gases games.

Image 2. Students learning about marine debris and watersheds.
Photo credit: Sandra Lebrón

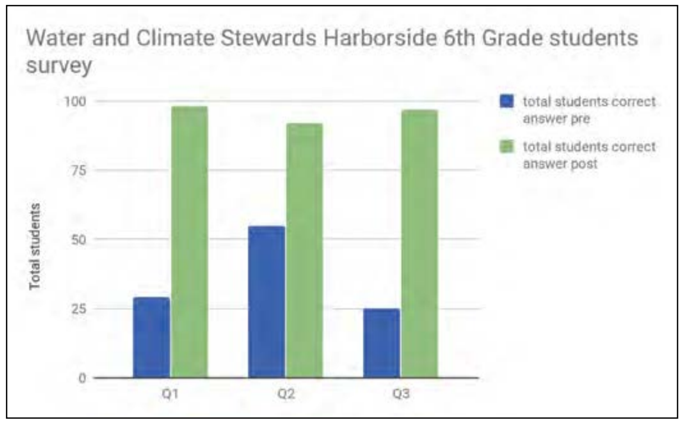

Table 1. Before: 25 of the 115 (22%) students answered correctly. After: 97 of the 115 (84%) students answered correctly.

Image 3. Mission Bay High School students analyze trash during decomposition activity.
Photo credit: Sandra Lebrón

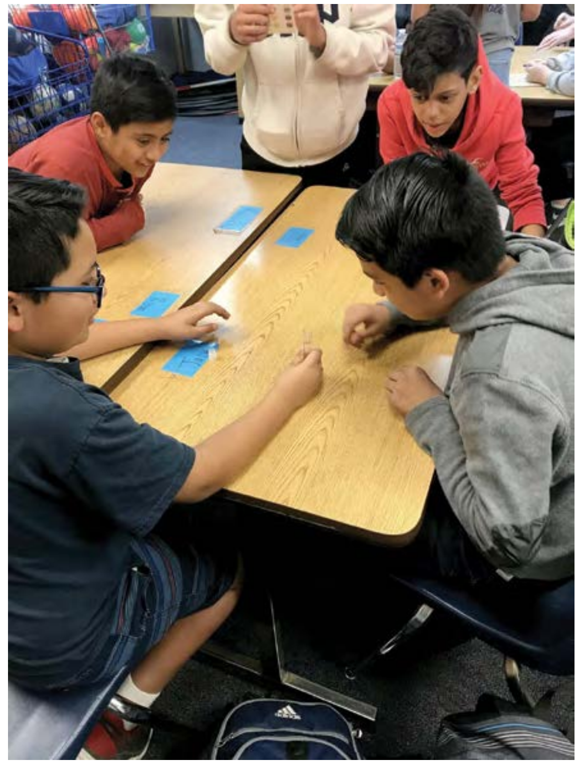

Image 4 and 5. San Diego Coastkeeper interns work with Innovation Middle 6-8th grade students at an afterschool program. Photo credit: Sandra Lebrón

The afterschool program at Innovation Middle School learned about ways to monitor and minimize pollution in our watersheds, learned about ocean acidification effects to our ocean, and practiced pH testing. Students discussed ways to monitor and minimize pollution in our watersheds, learned about ocean acidification effects to our ocean, and practiced pH testing.

The focus at Logan K-8 School was water quality, measuring pH, ocean acidification, and CO_2, and ways to reduce greenhouse gases and plastic pollution as well as the effects of ocean acidification on our marine animals and habitats.

Image 6. Students from Silver Strand Elementary School in Coronado.
Photo credit: Sandra Lebrón

Image 7. Marston Middle students during trash collection and assembly.
Photo credit: Sandra Lebrón

Student Action Projects

Climate action projects were started at three schools to help students understand their carbon and water footprints on the local environment, their daily plastic consumption, and encourage simple actions to reduce their daily single-use plastic consumption. 6th grade students at Marston Middle School in San Diego conducted a plastic inventory and implemented measure to refuse, reduce, reuse, and ultimately recycle. Their climate stewardship action project included:

- Public service announcement (PSA) to increase awareness about single-use plastics. https://youtu.be/Z-L1Eb2GwGg and https://youtu.be/1Hf68hCnSyY.
- Each week from January-June, posters highlighting a different plastic pollution problem were hung around the school.
- A school-wide assembly highlighting the problems caused by plastic pollution with over 200 students and teachers in attendance.
- A spirit week with each day dedicated to reducing the consumption of a specific plastic item, such as straws and single-use plastic water bottles.
- The Gifted and Talented Education (GATE) class created e-posters to highlight a specific plastic pollution problem and its solution.
- Alphabet coloring books for elementary school students. (https://drive.google.com/drive/folders/19cqHBk3Q54NKJiVnlnQW6H-76wuIm2DX)

The Marston Middle School students presented their climate action project at the 14th Annual CCTE Showcase, an initiative from San Diego Unified School District's Ignite College, Career & Technical Education. They were the only 6th grade students in the competition and offered an outstanding presentation to the judges. (https://drive.google.com/file/d/1nO1UUGonXAPOpEmicnq7iT4u0QdIcmDN/view). Photo at https://drive.google.com/file/d/12maRQOAHhKB9cV0KhQm3sVncBkMxs_mO/view?usp=sharing.

The 5th grade class from Silver Strand Elementary tracked their plastic usage for one week, then discussed as a class which plastics they could reduce and/or refuse to decrease the number of single-use plastics consumed. During the second week, they tracked their single-use plastic consumption.

The student's data showed the highest reduction during the second week with the following items: plastic water bottles (61%), plastic plates (57%), cereal bags (46%), straws (40%), and plastic baggies (38%).

2 week Plastic Usage Data: After tracking plastic usage for one week the 35 5th Graders discussed which plastics they could reduce and/or refuse to lower the amount they used. Then tracked their usage for another week. Here are the results.

ITEM	WEEK 1	WEEK 2
Styrofoam bowl	2	4
Styrofoam cup	7	11
Styrofoam plate	18	19
Styrofoam tray	80	63
Plastic utensils	75	62
Plastic cup	36	24
Plastic plate	37	16
Straw	55	33
Straw cover	24	21
Yogurt cup	9	22
Candy wrappers	41	46
Juice container	11	12
Bread bag	23	16
baggies	82	51
Cereal bag	13	7
Water bottle	51	20
Soda bottle	11	8
Milk jug	7	6
Meal container	16	12
Snack wrapper	109	79

Figure 2. Example of chart comparison between the first (previous behavior) and the second week (implementing environmental stewardship).

5th Grade
Silver Strand Elementary School
Coronado

Keeping my plastic diary was really eye opening. I was very surprised of how many pieces of plastic I used. Also there are 5 people in my family which means that my family used a lot of plastic. Next time I will try to use a lot less plastic and recycle. The thing I used most was snack wrappers.
--Sophia Gates

After we had done two weeks of keeping a plastic log I was surprised at how much plastic I used. After the first week I made a goal not to use as many plastic straws. Now I know not to use as many plastics and when I do I will recycle when I need to. I will also reuse when I can.
--Mason Walton

I've never kept track of how much plastic I use so this was new for me to do. I never realized that I never really used much plastic during the week and I thought that I would have used more. SO on the second week I decided to commit to using less plastic straws and lunchable containers. And I did just that, I used less plastic straws when I was drinking and packed less lunchables for my lunch and instead packed my own lunches for myself for school. As I finished the second plastic diary, I found out that it was actually easy to use less plastic during the week. This plastic project helped my see how much plastic I use and how I can use less plastic.
--Hana Rose Ty

I have learned that plastics can affect the ocean and the waterways on the Earth. They kill turtles and stuff. And pollution on the atmosphere can affect temperature and cause droughts on some areas and floods in others.
--Rich Zhang

The plastics diary taught me alot! It taught me that we use a lot more plastics than we think. This is a big deal in the world because of pollution. We might want to think about not using as much plastics. Plastics are a huge deal in life, we use them every day and every hour. Just try to imagine the whole world using plastics every hour and that making a giant group of plastic. That all makes a huge pollution group.

--Will Sevigny

Using a plastic diary made me think before using plastic because it was sometimes hard to remember but it was mostly easy because i kept it right behind my homework. I thought it was a good idea to do that so we could see how much plastic we used. I was somewhat surprised with the amount of plastic I used, I use a lot of plastic so it didn't surprise me that much, I use most of my plastic for snacks and other stuff like that. I don't really use plastic forks or straws so I only used one or two of them. That was a great experience that made me think about the Earth more.
--Isabel Moses

Figure 3. Examples of the responses from the 5th graders after their second week of the climate stewardship action project.

The teacher from the 4th grade class at Bayside Elementary School provided feedback on how it was initially challenging to conduct the action project due to the limited time allocated to science class. However, after participating in the action project, students expressed that this project was "very eye-opening" and that it increased their awareness of environmental stewardship. Additionally, the class was excited about the action project and will be implementing it next school year with the entire school.

Conclusion

This project was a hands-on learning opportunity to help students understand their environmental impact on the local community and then to implement climate action projects. Our goal was to partner with at least two schools to encourage the students to implement climate action projects. We worked with 8 schools, and ultimately helped to pilot the climate stewardship action project at three schools: Marston Middle School, Silver Strand Elementary School, and Bayside Elementary School. 125 students from these three schools challenged themselves to reuse and reduce single-use plastics. Our students were able to conduct an investigation, learn from experts, and find solutions to prevent and minimize pollution in our beaches and watersheds and understand the connection to plastics and our carbon footprint. This project provided an opportunity for students to take action and to be part of the solution to marine debris and climate change. We appreciate the teachers, informal educators, interns, NOAA Planet Stewards, and The Port of San Diego for all their support to our students. Additional information about the project can be found at Climate Stewards - San Diego Coastkeeper (https://www.sdcoastkeeper.org/education/climate-stewards) and "How Community Partnerships Empowered Coastkeeper's Education Team to Take on Climate Change" (https://www.sdcoastkeeper.org/blog/environmental-education/community-partnerships-empowered-coastkeepers-education-team-take-climate-change)

About the Author and Collaborators

Sandra Lebrón, MS in Marine Science, University of Puerto Rico Mayaguez, is the former San Diego Coastkeeper Education Manager. She is the current Director of Education at the Elementary Institute of Science (https://eisca.org/) where she serves the Southeast San Diego schools to provide STEM opportunities for underrepresented students in STEM. Sandra has been working in science education for 20 years with organizations like the National Estuarine Research Reserve, NOAA's Sea Grant College Program, Birch Aquarium at Scripps, and the Living Coast Discovery Center. She is passionate about environmental education and STEM equity. She enjoys spending time with her 15-year-old son, friends, and family, and enjoys the beach as much as possible! Sandra can be reached at slebron@eisca.org

San Diego Coastkeeper Education Interns

- **Victoria Dickey,** BS in Oceanography, Hawaii Pacific University
- **Robyn Gillium,** BS in Environmental Systems: Ecology Behavior and Evolution and B.A. in Political Science, University of California, San Diego
- **Melissa Pennington,** BA in Sustainability, San Diego State University

Climate Science Alliance

- **Amber Pairis,** PhD in Environmental Studies. Founder and Lead Advisor, Climate Science Alliance, Associate Research Professor-Western Regional Climate Center at the Desert Research Institute
- **Laura Hampton,** BA in Physical Geography, San Diego State University. Former Program Manager, Innovative Community Engagement Initiative at Climate Science Alliance- South Coast California. Department of Fish and Wildlife & Center for Climate Change Impacts and Adaptation at Scripps Institution of Oceanography

Environmental Stewardship on St. Paul Island, Alaska

Veronica Padula, Ecosystem Conservation Office, St. Paul Island, Alaska

Abstract

The Planet Stewards Program is invaluable for connecting teachers and informal educators who are passionate about instilling the value of environmental stewardship in students. A team from the Aleut Community of St. Paul Island Tribal Government developed a curriculum for middle school students at the St. Paul Island School in Alaska about marine debris issues that helped them find small-scale solutions within their community. We created original lesson plans that utilized materials from marine debris experts around the world, and coordinated with them to provide virtually visits to students from the school to talk about their work. Piloting this curriculum required high levels of communication and collaboration with teachers at the St. Paul Island School and the Covid-19 pandemic provided challenges. As a result, our first attempt to deliver the curriculum was done in a hybrid format in which the teacher was in the classroom with the students on St. Paul Island, and presenters visited the classroom virtually via video conference to talk to students and lead classroom activities. We learned many valuable lessons about working with teachers and students in a small rural Alaskan community, and hope to pass along those lessons for teachers and informal STEM educators in other parts of the country.

Our story

Our staff within the Ecosystem Conservation Office, the research and resource management department within Tribal Government, consists of talented scientists and resource managers. Within the Tribal Government, we assist teachers in their efforts to offer the best education and opportunities possible to their students. As informal STEM educators working for an Alaska Native Tribal Government, we are particularly grateful for the opportunity to connect with and learn from other teachers – their input and creativity helped us to develop and propose a project that could hopefully engage and inspire the students of St. Paul Island, Alaska. We work closely with teachers at the St. Paul Island School and recognize that as a small public school in rural Alaska, teachers' resources are limited.

They are also asked to perform many tasks, going above and beyond for their students. We coordinate with teachers to bring our skills into the classroom, sharing our knowledge with students through conducting hands-on activities, and providing mentorship for students as they grow. While the environmental issues facing small, rural communities may vary across the country, we hope that teachers can be inspired by the lesson plans we developed to create curriculum that can inspire their students to find local, small-scale solutions to large environmental problems. We also hope we can share lessons learned for informal STEM educators in how to work with teachers and public schools and small communities.

Figure 1: Scenes from the May 2019 marine debris cleanup, where community members worked together to remove over 19,000 lbs of marine debris from St. Paul Island's shorelines. Photo Credit: Ocean Media Institute

Figure 2: Some pieces of marine debris, such as the trawl net pictured here, were so large and heavy that four wheelers were required to drag them off the beaches. Photo Credit: Ocean Media Institute

Figure 3: The debris removed during the May 2019 cleanup was taken to the landfill and sorted by category before being weighed. Photo Credit: Veronica Padula

Planet Stewards allowed us the opportunity to work with students to take action against marine debris, an issue that threatens the marine ecosystem of St. Paul Island. The Tribal Government conducts major marine debris cleanups, removing almost of 25,000 lbs of debris from the island's shoreline within a single cleanup event.

These cleanup events are critical to the protection of the island, but leave Tribal Government with a new issue, which is the disposal of the collected marine debris. Plastic recycling is not available on a remote island like St. Paul, and plastic either becomes part of the landfill, or we must find a method of barging the waste off the island, which can be expensive and logistically difficult.

Our project set out to make students aware of the plastic waste issue and formulate methods of addressing it directly within their community. Along with lesson plans that provided students with more background about marine debris, plastic waste and their associated negative impacts on the marine environment, we encouraged students to propose solutions that could potentially be achieved within their community. Fortunately, our team was able to travel to St. Paul Island in July 2021, during a brief period of Covid relief. We took advantage of that time on island to conduct cleanups both around the town and along the beaches. The team of students removed more than 200 lbs of litter and debris!

We developed unique lesson plans, but we also pulled resources and materials from various experts to supplement the information provided. We also invited experts to virtually visit

Figure 8: Students examine a sample of sand for microplastics during the July 2021 marine debris camp. Photo Credit: Veronica Padula

Figure 9: Another day of marine debris cleanup during the July 2021 marine debris camp. Photo Credit: Veronica Padula

students and tell them about their work, which was an extremely unique component to this curriculum.

We combined lessons about environmental issues with lessons about technologies that could potentially inspire solutions to the issue. For example, students on St. Paul Island are very interested in emerging technologies, such as 3D printing. We saw an opportunity to harness that interest and develop a project that combined environmental stewardship and technology concepts. While St. Paul Island does not have an active plastic recycling program on site, machines have been designed that can shred plastic items and turn them into 3D printing thread. The project for the students involved learning about marine debris, the problems with plastic and waste management, and challenging them to design solutions to the issues related to marine debris and plastics.

Figure 6: Recycling bins set up for the start of recycling club. Photo Credit: Jessica Fratis

Figure 4: St. Paul Island students learned about how marine debris impacts marine ecosystems during the Bering Sea Days event in September 2019. In the lesson pictured here, students were part of a marine food web where microplastics (another form of marine debris) could be ingested by smaller organisms and get amplified through food web dynamics. Photo Credit: Veronica Padula

Figure 5: Students created art installations to help bring awareness to the marine debris issue. Photo Credit: Veronica Padula

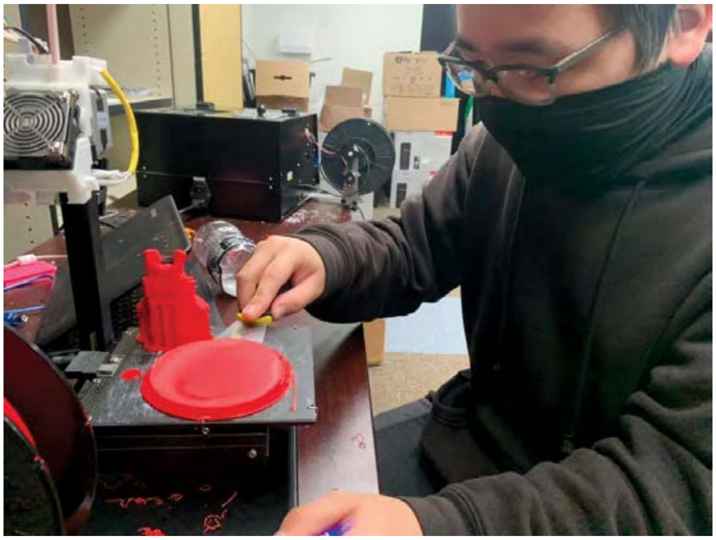

Figure 7: Students experiment with 3D printing.

Photo Credit: Ethan Candyfire

The reward for all of their hard work was to provide them with a ProtoCycler (desktop filament extruder) that could recycle plastic waste items into 3D printing thread and encourage them to create objects from the recycled plastics on 3D printers. Ultimately, we wanted the students to feel empowered to make a difference within their community with regards to plastic waste and protecting their environment.

The Covid-19 pandemic presented many challenges in the execution of this project. We were not able to interact with the students in the way we had hoped – St. Paul Island is a small and remote community, with limited access to health care and a number of Elders that are high risk with Covid-19. Travel to St. Paul was limited, and so we could not visit the island to deliver the lesson plans laid out in this project in person. Classes were remote and this presented its own challenges as internet on St. Paul Island is unreliable, resulting in many students being unable to access learning materials from home. Teachers were forced to rethink and reevaluate lesson plans and teaching methodologies. It would have been too much for us to ask the teachers to conduct these lessons with their students, even remotely. A key lesson we took away from this is that ongoing communication with teachers was critical, but even more critical is showing teachers our support in all ways possible, including showing patience, not placing the goals of our project over those of the teachers in providing quality educational experiences.

We were fortunate that by the winter of 2021, school was back in session for the St. Paul Island students, and we could join their class remotely. We had a marine debris class session every Friday from January to April, where marine debris experts visited students virtually, and the teacher led various activity lessons with the students. The students attempted to use the Protocycler and 3D printers several times, and created several amazing 3D printed objects.

They often had to trouble shoot issues with the technology but the students were very good at finding solutions. A key lesson we took away from this hybrid model of teaching was that we needed to be adaptable within our lesson plans. If the internet was not cooperating and our virtual visitor could not speak to the class, we ensured that the teacher had been provided with enough materials to conduct another lesson with the students, ensuring their progress throughout the marine debris curriculum.

Links to the curriculum:

Module: Introduction to Marine Debris https://drive.google.com/file/d/1GZsQ3xYoYLPklAxbG4c2pyPqdkJkDTK_/view

Link to Marine Debris Module 2 https://drive.google.com/file/d/1BiCaZyHgPCcrp4oH25zbOrxkxSxczTYd/view

Conclusion

The challenges of working with remote communities were certainly highlighted in this project and reinforced during the pandemic. This was our first attempt at sharing the marine debris curriculum with students in a remote fashion, and we spent a good portion of our time trouble-shooting the technology and adjusting the lesson plans. We hope to repeat the effort at the St. Paul Island School in the future and collect data about the impact on students. It is clear that students in remote and rural communities often do not have access to unique educational opportunities or lessons with a local impact. It is up to a coalition of caring adults, from teachers to parents to scientists, to put in the extra effort to ensure students in underserved communities are offered opportunities to enhance their educational experiences. While it may be difficult, and things may not turn out the way one imagines, it is always worth the effort. There may be a student in your orbit that becomes inspired and who may one day find the solution to the world's toughest environmental problems because someone took the time to reach out to their community and introduce them to something new.

About the Author

Veronica Padula is the Assistant Director of the Ecosystem Conservation Office, the research and resource management branch of the Aleut Community of St. Paul Island Tribal Government. Her graduate research focused on the impacts of marine debris in the Bering Sea Ecosystem. She worked with an amazing team of educators to develop the marine debris curriculum discussed here: Haley Edmondson, Herminia Din, Quin Fitzpatrick and Katy Nalvin. Veronica can be reached at vmpadula@alaska.edu.

25 Years Ago in TES

Twenty Five years ago, in 1997, TES was in its fourteenth year of publication. The focus of this Summer issue was "Looking for Weather Patterns". The front cover is a NASA photo of Hurricane Elena, over the Gulf of Mexico, September 1, 1985. The Summer issue led off with a comprehensive 7-page article about Heat Waves and their associated dangers. Next, an article acquainted readers with the facts surrounding the Chicago/Milwaukee Heat Wave of 1995. This was followed by another article about 20th century "great rains" in the Great Plains. Then there was an article which informed the readers about the newspaper accounts of lightning from 1891 to 1895. There was a short article dealing with weather patterns. This was followed by an article dealing with what are now the "early days" of live satellite cams, and how a teacher could actually access them. The final article was a notice of the passing of Eugene M. Shoemaker [1928-1997]. His namesake comet, Shoemaker–Levy 9 was the one that broke apart in July 1992 and collided with Jupiter in July 1994, providing the first direct observation of an extraterrestrial collision of Solar System objects. It generated a large amount of coverage in the popular media, and the comet was closely observed by astronomers worldwide.

By Tom Ervin

NGSS-ESS Working Group

The NGSS-ESS Working Group is a collaboration between the National Association of Geoscience Teachers, the National Earth Science Teachers Association, and the American Geosciences Institute supporting implementation of the Earth and space science Next Generation Science Standards.

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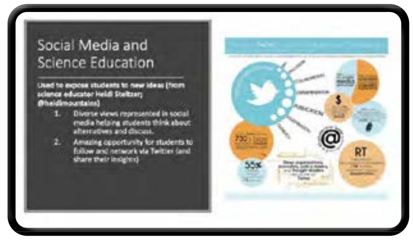

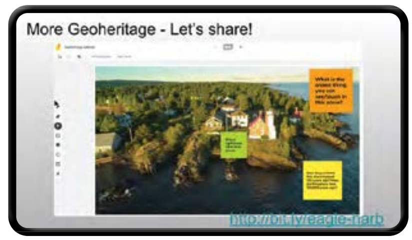

Sample presentation slides from NGSS-ESS Working Group webinars.
Top slide courtesy of Twin Cities PBS, https://www.tpt.org; Bottom: Drone photo by Steve Brimm Photography

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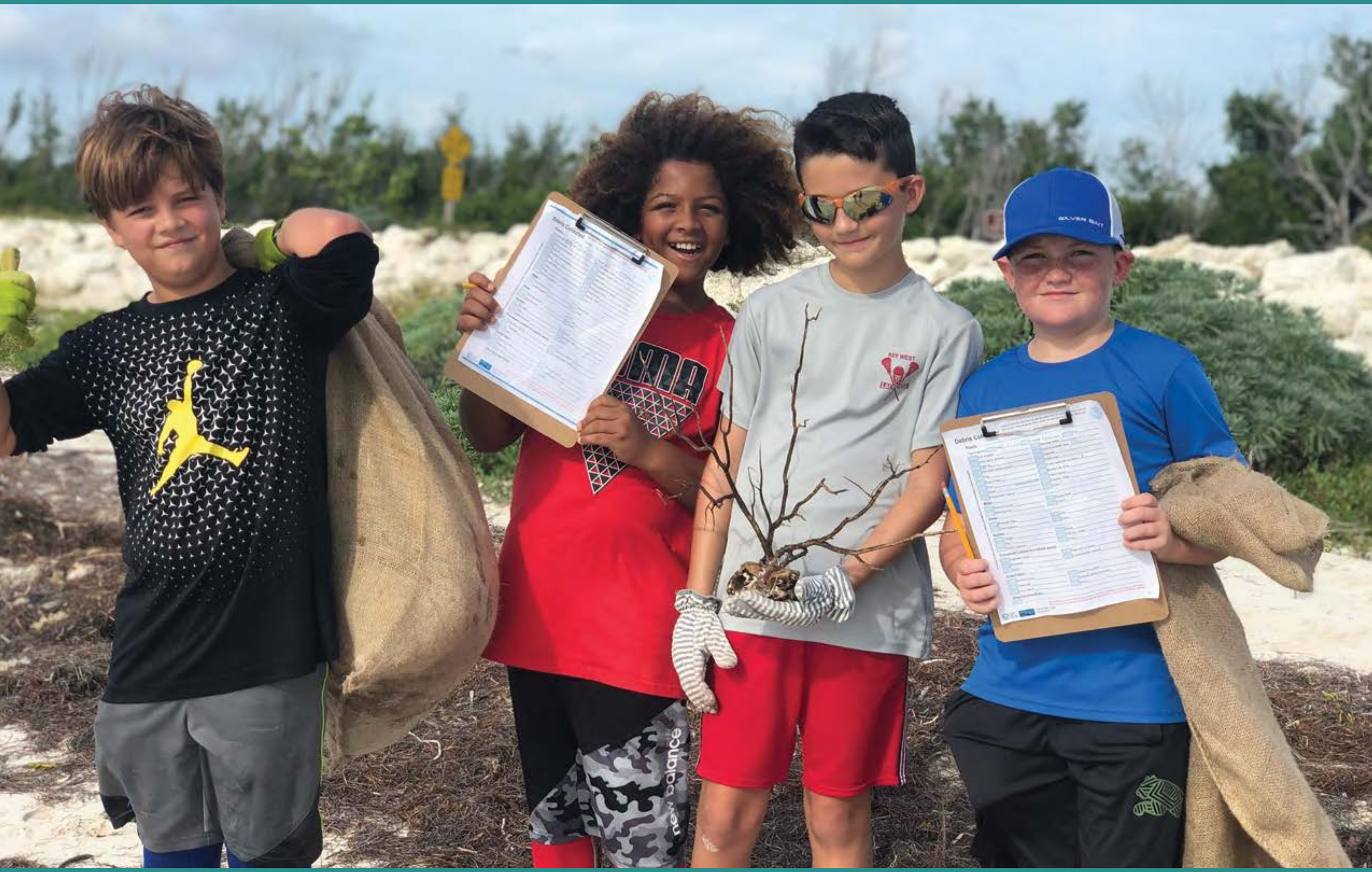

Students participating in a NOAA Planet Stewards project clearing and cataloging marine debris from Florida beaches.

Photo credit: Analisa Duran.