The Earth Scientist

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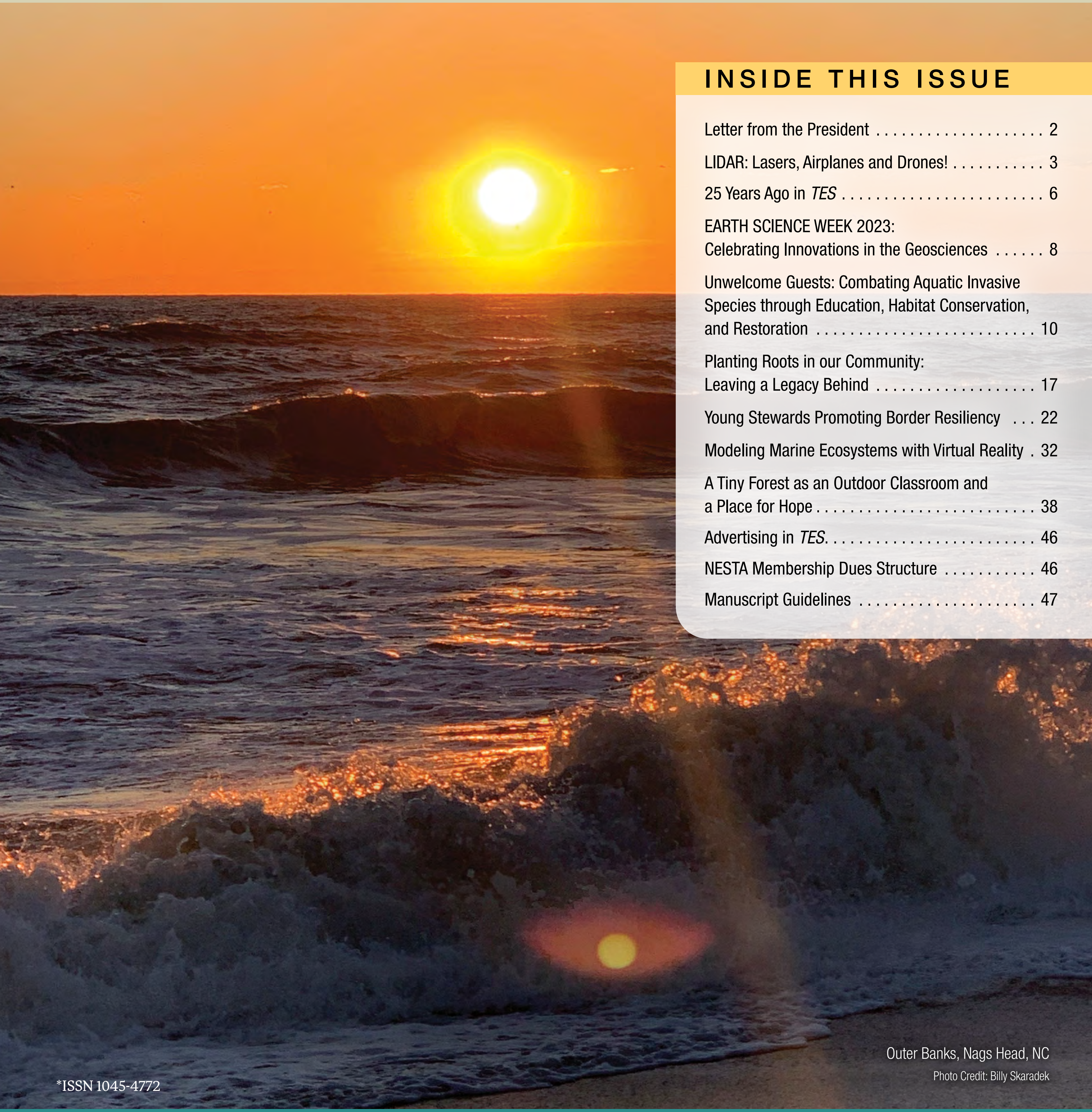

INSIDE THIS ISSUE

Outer Banks, Nags Head, NC
Photo Credit: Billy Skaradek

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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 Natalie Macke, NESTA President 2022-2024 | @NESTA_US

The 2023-2024 school year is upon us, and I'm keenly focused on ideas to improve the learning experience for each of my students. To that end, I will strive to create an environment where every student's uniqueness is celebrated, each one emotionally and academically supported, and with inclusion a cornerstone. This NOAA Planet Stewards sponsored issue of *The Earth Scientist* is a perfect reminder about the transformative power of Project-Based Learning (PBL) – a pedagogical approach that not only educates but also nurtures a culture of diversity, equity, and inclusion. I hope you can take inspiration from the successes of our colleagues to plan for PBL experiential learning in your own classroom this year.

I like to think about PBL as a collaborative canvas on which every student's unique background, perspective, and set of experiences are collected and built upon to support educational learning objectives. These guided projects have unique potential to reflect the cultural, linguistic, and cognitive diversity within our classroom by drawing from multiple viewpoints and designing solutions to real-world challenges faced by diverse communities.

Equity in our classroom may seem simple enough. But the challenge to ensure that every student has an equal opportunity to succeed is often wrought with barriers that educators may fail to perceive. PBL opens a door to uniquely address students' individual needs, catering to their strengths and interests. When we design projects that offer various entry points, students of all abilities are allowed to engage in meaningful ways. By focusing on local issues, we bridge the gap between classroom learning and real-life application, making education relevant to every student.

Inclusion, the heart of our classroom, is nurtured through collaboration and empathy. PBL fosters an environment where students work together, combining their skills, backgrounds, and perspectives to tackle real-world challenges. This allows students opportunities to share their unique stories and experiences, fostering a deeper connection and understanding among peers. With PBL, we lay the foundation for a classroom where everyone's voice is heard, fostering a sense of belonging and unity.

I applaud the educators that have put the time and effort to showcase the impacts of their stewardship projects in this Summer 2023 issue. Using these examples as inspiration for our own classroom and communities, together, we can create an environment where every student thrives, regardless of their background, and where the seeds of positive change are sown.

With enthusiasm and dedication,

Natalie Macke

NESTA Regions

Region I - ME, MA, NH, RI, VT	**Region III** - DE, MD, NJ, PA, VA, DC, WV	**Region V** - IN, KY, MI, OH	**Region VII** - AZ, CO, ID, MT, NV, NM, OK, TX, UT
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Lidar: Lasers, Airplanes and Drones!

By Galen Scott, NOAA's National Geodetic Survey

The Geologic Map Day poster: Applications of Lidar that accompanies this issue of the Earth Scientist highlights the uses of lidar, **Li**ght **D**etection **A**nd **R**anging. NOAA scientists are using lidar to produce more accurate shoreline maps, make digital elevation models for use in geographic information systems and as well as understand and respond to natural hazards and disasters.

How Does it Work?

Lidar instruments shoot millions of laser pulses per second, which bounce off a surface or object to measure distances and directions to the object. Using the known speed of light, we can figure out how far away any object is by measuring how long it took for the laser to leave our instrument, hit the object, and bounce back to the instrument. We can also tell something about the composition of objects or the surface that the laser bounced off because different types of materials absorb different amounts of laser light energy. By looking at the strength, or intensity of the light that bounces back, we can distinguish pavement from grass, and sand from water.

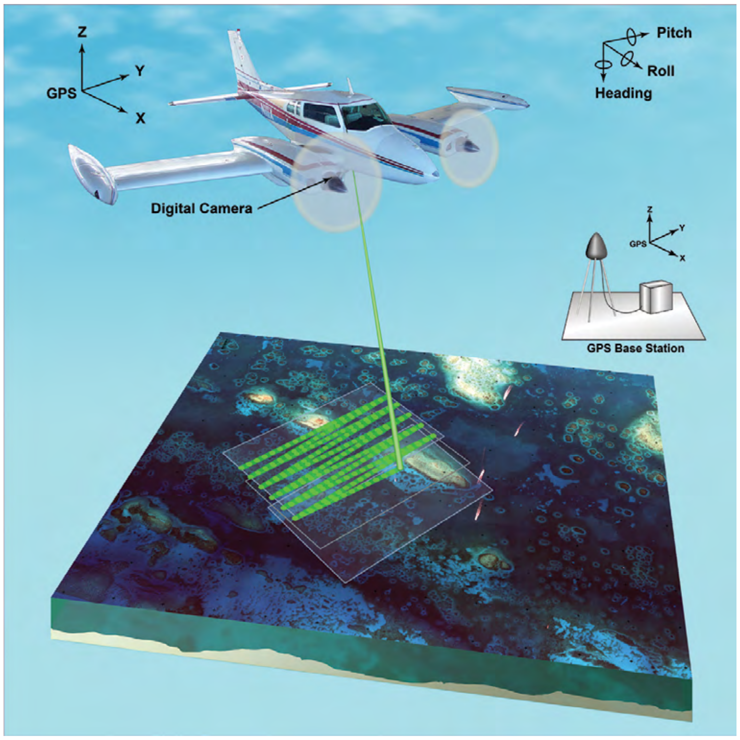
By shining lasers at targets from different angles, lidar can create detail-rich, 3-dimensional collections of data points. These "point clouds" can then be processed to create digital elevation models (DEMs) of the Earth's surface that are accurate enough to determine which way water flows and can be used by researchers and decision makers to understand and predict environmental changes such as stream levels or flooding.

With a camera added to the system, imagery can be combined with the lidar data to create immersive, 3D, photo-realistic, digital environments that can be explored, measured, and interacted with on a browser, on a laptop or cell phone, or using a virtual reality headset.

This system works well when the instrument stays in one place, but it gets more complex when you want to move the instrument to collect data across larger areas. This is where GPS, or the Global Positioning System comes in. By pairing a GPS receiver with a lidar unit, we can compute precise coordinates for where the instrument was when a particular laser pulse was sent, and where the instrument was when it received the same pulse after it bounced back from the target. This makes it possible for lidar units to be mounted on vehicles in the air, on the ground, or on the water, and collect data in many different environments and for many different purposes.

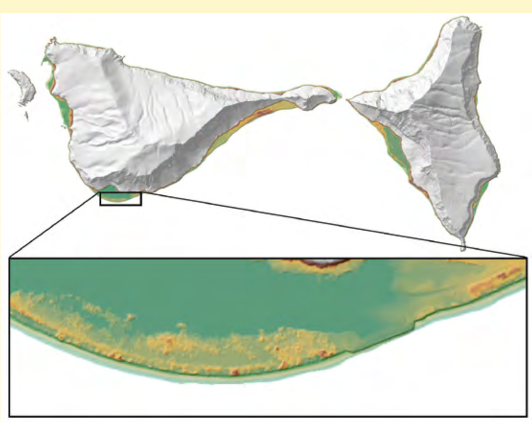
How is Lidar Used?

Surveying and mapping professionals use lidar and GPS every day to digitally capture geospatial data. At construction sites, surveyors use aerial and ground-based lidar and GPS before, during, and after construction. They collect high-precision data to inform each building phase of a project and provide "as-built" information to manage a site once construction is complete. Lidar units mounted on cars and trucks map roads, highways, signs, hydrants, phone and light poles, and other transportation infrastructure. This critical data helps to inform transportation planning, emergency response, and even the maps we



Airborne lidar system. Lidar, short for light detection and ranging, is a remote sensing detection system that works on the principle of radar, but uses light from a laser. The quick light pulses measure the distance from the plane to the surface and back. This illustration depicts the equipment used, including the plane with digital camera mounted underneath, and the GPS base station, but does not show the satellites used to obtain the coordinates. Illustration: USGS

On the small islands of Ofu and Olosega in American Samoa, researchers used high-resolution lidar to locate archaeological sites and learn more about how island settlers thousands of years ago responded to sea level fluctuations and other environmental changes. High-resolution lidar data covering the immediate coastline and interior of Ofu and Olosega enabled the research team to model terrain in key locations, identify ancient beach ridges reflecting sea-level change, extract landscape and structural features, and predict and locate archaeological coastal settlements. The lidar data led to the discovery of an archaeological site on Ofu Island that appears to have been inhabited at, or shortly after, initial colonization thousands of years ago. Lidar-derived elevation data of the excavation site enabled researchers to model the landscape and paleoenvironment during periods of past sea-level change.



Lidar-based map of Ofu and Olosega islands, American Samoa, with close-up of the Vaoto Plain showing traces of ancient beach ridges in yellow and red.

use every day to navigate in our cars. Lidar is becoming so prevalent that many new model cars are equipped with lidar to support cruise control and automatic braking systems. Some newer cell phones even have lidar to help their cameras focus, and have apps that allow you to use lidar to scan objects and create 3D models.

Aircraft, both crewed and uncrewed, are also equipped with lidar, GPS, and digital cameras to map and measure land elevations across large areas of the Earth.

These data sets can then be used to categorize the mapped areas into specific land-use and land-cover categories, measuring biomass for example, which informs agricultural, forest, and mineral resource assessments as well as land management decisions. The U.S. Geological Survey uses lidar data to manage water resources and identify areas prone to landslides and other geological hazards, and lidar elevations are used by the Federal Emergency Management Agency (FEMA) to create floodplain maps to better understand flood risks.

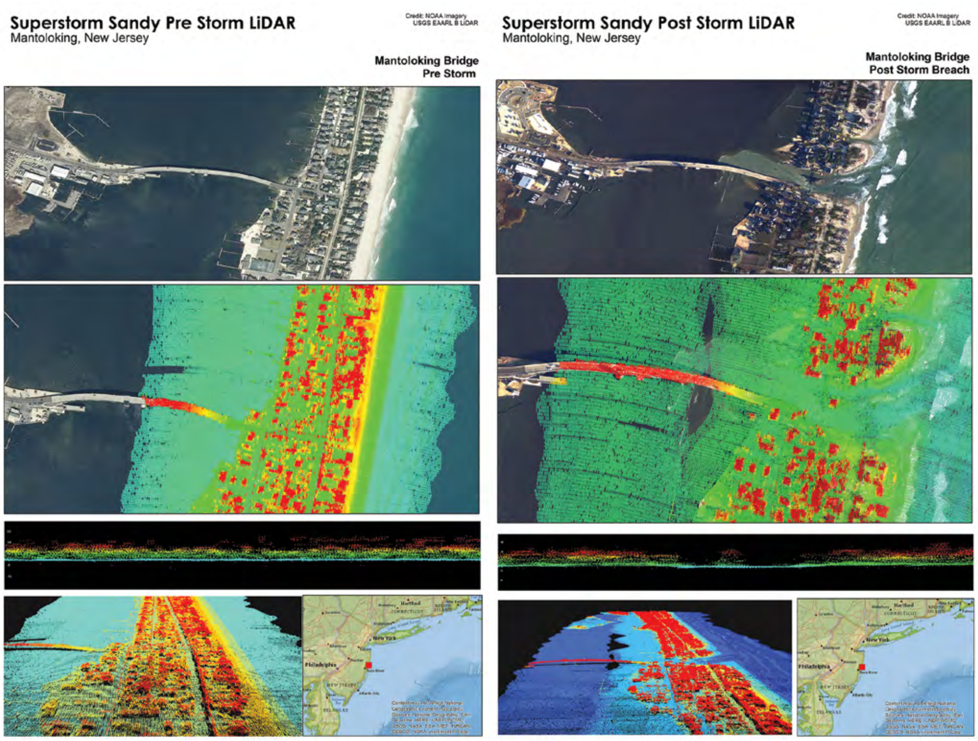
How Does NOAA Use Lidar?

NOAA uses data sets created with lidar in a wide range of critical monitoring activities, including:

- hazard mitigation
- ecosystem management
- habitat research
- coastal and marine spatial planning
- shoreline mapping
- community preparedness

NOAA's bathymetric lidar systems use frequencies of light that penetrate water for mapping clear rivers and shallow coastal bathymetry much more safely and efficiently from the air than the historic method of sending survey crews out into difficult and dangerous environments. Beyond providing data for nautical charts, underwater lidar data is used to map the marine environment's benthic habitats (the ecological region at the lowest level of a body of water) for fishes, sea turtles, marine mammals, and seabirds.

Lidar data collected from NOAA aircraft is used to determine the National Shoreline, and is combined with sonar data from NOAA ships to create the United States' official nautical charts. Ships from around the world move $1.5 trillion worth of products in and out of U.S. ports every year and rely on these navigation charts to do so safely.



This visualization was designed by the UNH/Marine Program to illustrate the use of lidar data in a storm response scenario. Using a combination of NOAA photogrammetry data and US Geological Survey EAARL-B lidar data, the before and after displays illustrate the damage caused to the Mantoloking Bridge (Mantoloking, NJ) due to a barrier island breach caused by Super storm Sandy.

NOAA's Weather Service and other partners point a lidar's lasers to the sky and use lidar to measure clouds and different types of particles in the atmosphere to better predict the weather and understand our changing climate.

The availability of lidar and other geospatial data is growing faster than ever, but the number of people that know how to harness and apply it is still low. This means that there is a great need and high demand for people with the skills to collect and apply this technology. The geospatial technology job market is hot, and there are plenty of opportunities to work on critical issues. So, if you like working outside, solving

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To become a member of NESTA visit nestanet.org.

To get more information about NESTA or advertising in our publications, contact, nestaearthscientist@gmail.com.

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About the Author

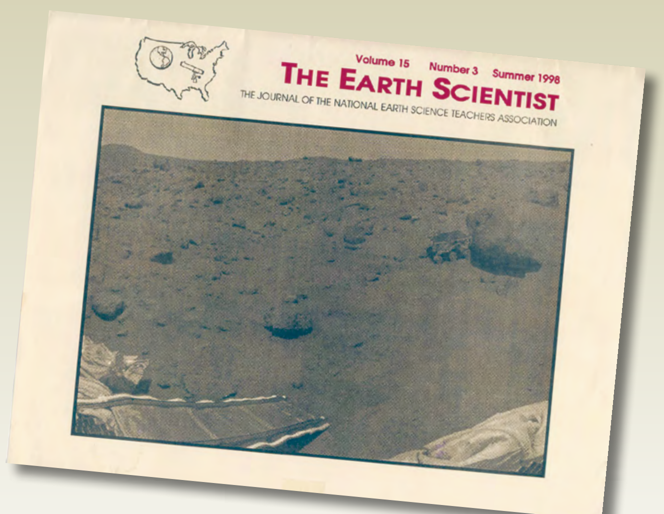
Galen Scott began federal service in 2003 as a Presidential Management Fellow for NOAA's National Geodetic Survey. Starting off in the NGS Front Office as a geek translator, he explained the complex science and critical applications of geodesy for non-technical audiences, particularly in the strategic planning and budgeting process. Since 2004, Mr. Scott has worked with coastal scientists and managers to build the geospatial infrastructure necessary to obtain accurate coastal elevations and water levels for long-term ecosystem monitoring and coastal management decisions. He has forged diverse partnerships to help coastal communities use NOAA's authoritative data, services, and tools to understand and address impacts of sea level rise. He currently serves as the NGS Constituent Resources Manager, responsible for engaging stakeholders about NGS products and services, and generating feedback to better serve our users' needs. Mr. Scott leads the NGS GPS on Bench Marks program, a crowd-sourced data collection effort to help the geospatial community prepare for the Modernization of the National Spatial Reference System. He holds Master's Degrees in Environmental Science, Policy, and Management from Johns Hopkins University and the University of Rhode Island. Galen can be reached at galen.scott@noaa.gov.

puzzles, and playing with cool technology, consider a career (or even some classes) in surveying and mapping!

Here are some links to additional lidar resources:

- https://coast.noaa.gov/digitalcoast/data/
- https://oceanservice.noaa.gov/facts/lidar.html
- https://coast.noaa.gov/digitalcoast/training/intro-lidar.html
- https://noaacrest.umbc.edu/crest-lidar-network/
- https://www.ncei.noaa.gov/products/coastal-elevation-models
- https://oceanservice.noaa.gov/podcast/mar21/nop45-lidar.html
- https://psl.noaa.gov/technology/instruments/floe/
- https://www.neonscience.org/resources/learning-hub/tutorials/lidar-basics

25 Years Ago in TES



The focus of the Earth Scientist in 1998 was geology with articles on Utah – Reading the Geologic History Book, Constructing Road Logs for Field Trips, Collecting Quartz, and Industrial Minerals of South Carolina. Several articles provided information about the Agate Fossil Bed National Monument, Dinosaur Valley Museum and the National parks of Utah. A short discussion about Geologists Salaries was reprinted from the Explorer Magazine. The average starting salary for a geoscientist with a Bachelors degree and little or no experience was $48,100. (Masters, $49,700 and Ph.D, $56,000) The salaries and job opportunities were tied to the oil and gas industries. Finally, a precursor to the open resources we find today was an effort called Educational Object Economies where participants designed and shared information with others on the Internet. It fostered communities of scholars and was established by Apple. Teachers and faculty members used applets to share their lesson plans, activities and multimedia products.

Review by Peg Steffen, Editor


Boat Building Challenge
What You Will Do
Design a boat hull that is able to float a specified weight. Then, design a way to propel your vessel using wind power
Discover Your World with NOAA
An Activity Book
NOAA's Building Blocks

EARTH SCIENCE WEEK 2023: Celebrating Innovations in the Geosciences

By Lindsay C. Mossa, Lauren E. Brase, Edward C. Robeck

The American Geosciences Institute (AGI) invites all Earth science educators and others around the world to celebrate the 2023 Earth Science Week theme "Geoscience Innovating for Earth and People." New theme-related resources, activities, and programs are being made available to promote public understanding of innovations in the geosciences and how the Earth is studied. Special focus is given to how the geosciences can help address critical issues faced by humanity, as defined by the United Nations' Sustainable Development Goals (SDGs, https://sdgs.un.org/). These goals address topics such as access to energy and clean water, increased gender equality, and responsible use of resources.

Earth Science Week 2023 will take place October 8-14 and is coordinated by AGI in cooperation with many partner organizations – including the National Earth Science Teachers Association (NESTA), NASA, the U.S. Geological Survey, and the National Oceanic and Atmospheric Administration (NOAA). AGI and its partners create media of many kinds, such as posters, instructional activities, and other materials that are collected into a toolkit and can be used in a variety of educational settings. These materials can introduce students to Earth science concepts, especially how innovations have advanced data collection and processing in ways that lead to a greater understanding of Earth's processes. Copies of the Earth Science Week 2023 Toolkit are available for the cost of shipping and handling (https://bit.ly/2023ESWToolkit). AGI also hosts an ESW website where many of these and other resources can be accessed for free (https://www.earthsciweek.org/geoscience-innovating).

Drones are highlighted on this year's Earth Science Week Poster. This image shows a student from Alcorn State University taking part in a certification course to become a drone pilot. There are many programs around the United States for people aged 16 and older to become certified in piloting drones and other Unmanned Aircraft Systems (UAS). Credit: Alcorn State University School of Agriculture and Applied Science.

This year's toolkit includes more than two dozen items, such as the Earth Science Activity Calendar that features one learning activity for each month of the year. Each activity focuses on an innovative technology or geoscience practice and engages students in the many ways in which the study of Earth science has changed or been updated. Many of the activities involve students in hands-on investigations to encourage them to consider how innovations can reduce human impacts on the environment. For example, NOAA's activity, "From Trash to Terrarium", introduces students in grades 3-7 to how they can innovate ways to reuse materials to reduce the amount of trash they produce, which then reduces the amount of debris getting into the oceans. To provide a real-world context, each activity in the calendar is related to specific SDGs. The NOAA activity is connected to SDG 12 (Responsible Consumption and Production) as well as SDG 14 (Life Below Water). Dimensions of curriculum standards including disciplinary core ideas, crosscutting concepts, and science and engineering practices are also identified for each activity, so they can be easily integrated into material you are likely to address with your students.

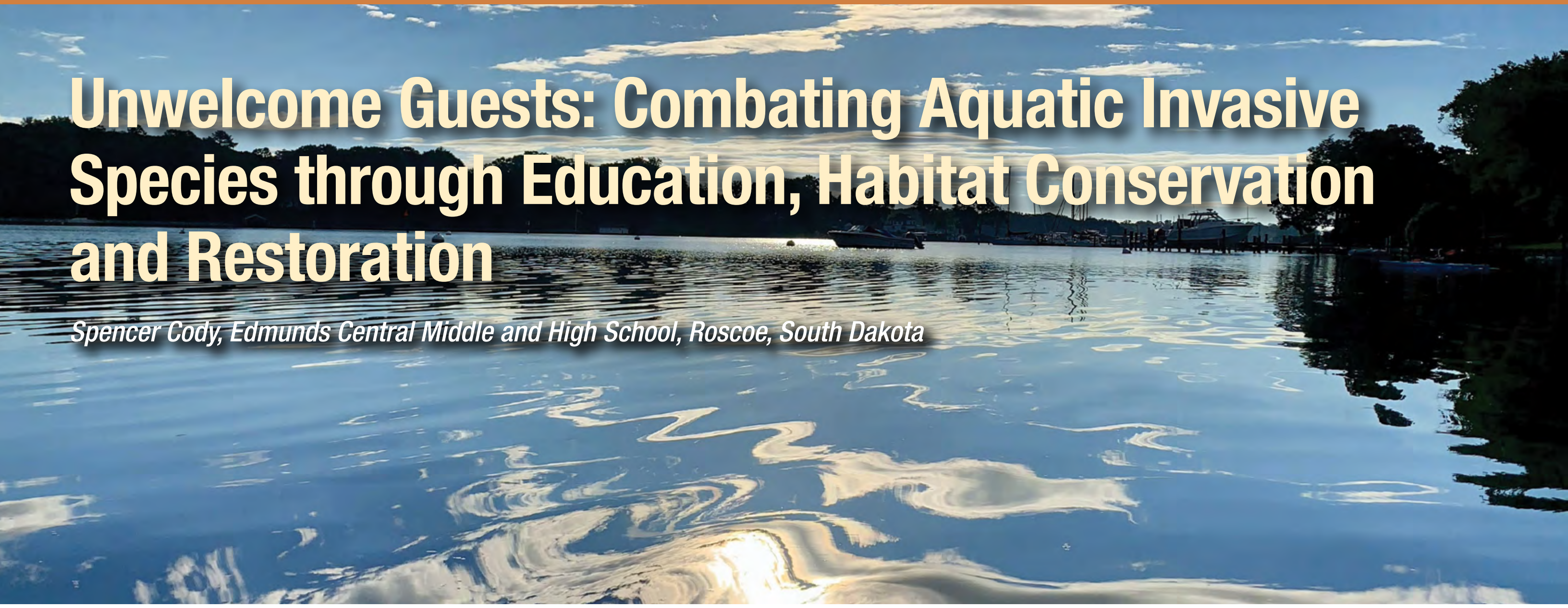
This year, too, AGI is sponsoring its four traditional contests in video production, photography, visual arts, and essay writing. As always, students, geoscientists, and the general public around the world are invited to participate in the "Geoscience Innovation Worldwide" video contest. Teams and individuals can submit brief original videos that show how new Earth science technologies and practices are helping create more sustainable communities. People of all ages in the U.S. are invited to participate in the "Innovation Right Here" photo contest. Entries must be composed of original, unpublished material, and show how new geoscience-related technologies or practices affect local communities. This year's visual arts contest, "Earth Science Innovations", is open to U.S. students in kindergarten through grade five. Submissions should illustrate how Earth science innovations improve people's interactions with the Earth. Essays by older students (grades 6-9, U.S. only) must address the idea of "Geoscience Innovations Solving Problems".

In the winning submission for the 2017 ESW Visual Arts Contest **David De Costa of Alexandria, Virginia,** depicted how humans interact with Earth's spheres.

In addition to participating in ESW contests, we encourage you to get involved in Earth Science Week by facilitating and/or attending associated events! Many individuals, museums, schools, communities, and organizations around the world host Earth Science Week events that offer talks, interactive activities, and other informal educational opportunities that highlight the year's theme. You can also take part in activities emphasizing various areas of the geosciences during "Focus Days." For example, activities on National Fossil Day, Tuesday, October 11, engage students and teachers with paleontology and its educational and scientific value. Friday, October 13, 2023, is Geologic Map Day, which promotes awareness of the importance of geologic mapping for education, science, business, and policy. This year's Geologic Map Day poster focuses on the use of lidar to enhance geologic mapping. AGI will also host an Earth Science Week webinar series from October 9-13. Each webinar will cover a different innovation, such as photogrammetry, the use of drones in the geosciences, and others. Many of the talks will include segments directly relevant to teachers and students in grades 6-12. Please see the Earth Science Week website for more information on the webinar series, focus days, resources, and information on how to plan events.

www.earthsciweek.org

Lindsay C. Mossa and Lauren E. Brase are Education Specialists at the American Geosciences Institute (AGI). Edward C. Robeck is the Director of Education and Outreach at AGI.



Unwelcome Guests: Combating Aquatic Invasive Species through Education, Habitat Conservation and Restoration

Spencer Cody, Edmunds Central Middle and High School, Roscoe, South Dakota

Photo credit: Billy Skaradek

Abstract

Aquatic invasive species are an environmental threat throughout the entire continent, and students in a landlocked, rural South Dakota school district also find themselves at the forefront of the struggle against invasive species. A NOAA Planet Stewards project in the 2021-22 school year for middle and high school students on aquatic invasive species resulted in a substantial attitudinal change along with increased content understanding. While the issue of aquatic invasive species presented its own logistical problems, these challenges were, for the most part, successfully navigated to meet stewardship goals resulting in a remarkable learning experience for both students and teachers alike.

Introduction

Pole of inaccessibility...no doubt this is an obscurely known reference to most. *Pole of inaccessibility* is an old navigation reference that refers to the farthest point from land in an ocean or on land, the farthest point from the ocean. South Dakota is the pole of inaccessibility for the North American continent. It is more than a geographical oddity; it can also serve conceptually in many minds as a seemingly pervasive sense of isolation, perhaps, even a sense of security from the rest of the world's problems. When it comes to aquatic invasive species, South Dakota was one of the last places in North America that had to deal with the budding issue, but as time has progressed, these threats edged closer and closer to our front door step. Once they became evident in our state, it was apparent that we were no more immune than the rest. Now South Dakota has invasive Asian carp as far up the Missouri River as Gavins Point Dam and the entirety of the James River and most of the Vermillion River. Asian carp, specifically bighead carp, grass carp, and silver carp can starve any trophic level above producers by consuming large quantities of algae each day. The impact can be quite dramatic for a fishery. For example, even though these exotic carp species have only been present in the United States since the 1970s, they are now pound-for-pound the dominant fish species in terms of population density throughout the Mississippi River and its connecting tributaries leading to the decimation of local native fish stocks and having a negative impact on recreational fishing. Asian carp not only harm our aquatic ecosystems, but they can physically harm recreationalists (Atwal 2012). As a cautionary tale to all for introducing a new species to an environment, silver carp have taken on an unusual characteristic of jumping out of the water when startled. This is a rarely observed characteristic among this same species in its native China, but in America boaters have suffered severe injury due to, up to a 100 lbs., silver carp hitting them in the face making recreation on infested waters dangerous for boaters (Vetter and Mensinger, 2016). Just as we have faced a threat of aquatic invasive species migrating up our rivers through Asian carp, we soon realized the growing frontlines in aquatic invasive species with the presence of zebra mussels in dozens of South Dakota bodies of water. Zebra mussels and their close relative quagga mussels pose an equally devastating ecological problem for our bodies of water. Zebra and quagga mussels can cause great ecological harm to plankton communities, therefore, negatively impacting the entire food chain in a freshwater ecosystem. Zebra and quagga mussels were both likely brought to North America through untreated ballast water dumped into the Great Lakes during the late 1980s. Through untreated ballast water, they were able to make a trip all the way around the world from their native Caspian Sea range to infest the waters of America. Once infesting the Great Lakes, they entered the Mississippi drainage system through the Chicago River. Now recreation boaters are the unwitting spreaders of these mussels to water bodies that are not connected to the Mississippi drainage system (Prather, 2009). While South Dakota awaits its first confirmed quagga infestation, zebra mussels continue to expand their range in South Dakota. With such a daunting set of ecological challenges facing South Dakota concerning aquatic invasive species, we decided to take action through our project made possible by funding from NOAA Planet Stewards.

Racing to Keep Up with the Frontlines of the Invasion

Our project was designed to help combat aquatic invasive organisms by attaining three goals; curriculum development and education, habitat conservation through stewardship, and habitat restoration through stewardship. In order to meet our habitat conservation and habitat restoration stewardship goals, we planned to engage 60 students to complete stewardship activities, inspect and/or clean 500 boats/watercraft, inspect and/or clean 500 bait buckets, inspect and/or clean 500 live wells, inspect 50 aquariums, remove 500 kg of Asian carp, and 10 kg of invasive mussels. During the fall semester of 2021, students were engaged in habitat conservation stewardship by engaging in boat inspections/cleanings, bait

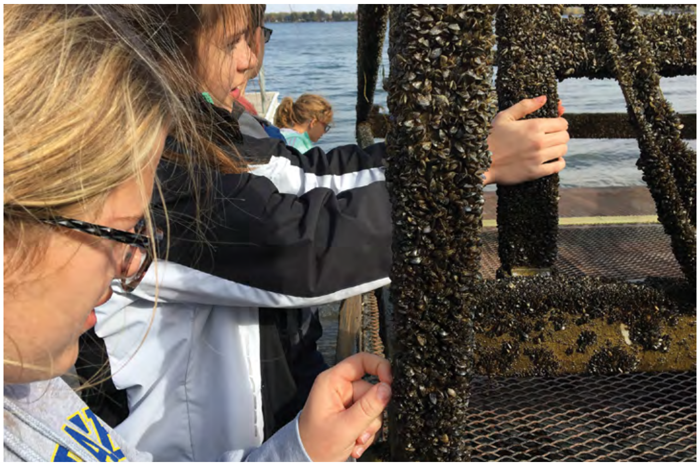


Image 1: Edmunds central students learning about zebra mussel removal while inspecting a boatlift infested with zebra mussels on Pickerel Lake. At the time of our visit, zebra mussels had colonized most hard surfaces in the lake even though the first confirmed zebra mussel in the lake was only discovered 15 months prior to our survey visit. Photo credit: Spencer Cody

Image 2: Edmunds Central students inspecting riprap at Enemy Swim Lake for zebra mussels. Invasive mussels can easily spread from lake to lake as hitchhikers on boats and recreation equipment. Enemy Swim was only a couple of miles from a lake with a known zebra mussel infestation at the time of our survey. While we did not find any zebra mussels on our stop in October of 2021, by July of 2022 zebra mussels were confirmed in the lake. Photo credit: Spencer Cody

bucket inspections/cleanings, live well inspections/cleanings, and aquarium inspections along with site visits to inspect lake accesses for possible infestations for documentation.

Students were also engaged in habitat restoration through stewardship through site visits to known infested waters to work on removing mussels. The inspection and cleaning numbers and restoration removal amounts required students to not just complete these inspections and removals on their own watercraft and equipment and shorefront but branch out to neighbors, friends, businesses, and other local contacts associated with fishing and watercraft, thoroughly, permeating our local area with our message. While we exceeded our goal in mussel removal due to our fortune of working with a watercraft company in the fall of 2021 for boat lift removal during a fall zebra mussel survey of lakes in Northeastern South Dakota, mussel removal opportunities since that point in time were few and far between.

Image 3: Edmunds Central inspecting docks at Bitter Lake for zebra mussels. Docks are often one of the first places where zebra mussels are noticed frequently when docks are pulled in the fall before ice on.

Photo credit: Spencer Cody

In South Dakota invasive mussels can be removed, but they cannot be transported. This makes removal very tricky and getting permission trickier. Additionally, known infested waters are not locally close to our school district making these opportunities for removal more difficult for our students to access. The same problem was experienced with the Asian carp removal. They cannot be transported and removal is difficult since flying silver carp are dangerous to boaters attempting to retrieve them, and infestation locations are not near our school. Not to be deterred, we expanded our removal efforts to include common carp to some degree of success. Our numbers for inspections and cleanings assumed that our arrangements made in the fall for inspection points would be carried out in the spring and summer of 2022. This was not the case. We had been working with a lake association to help staff their zebra mussel check point with our students, but confrontations became so tense that the state took the checkpoint over in the spring of 2022. No one wants zebra mussels in their lake, and no one wants to be caught with them. It seemed as if we were racing to keep up with the frontlines of an ecological invasion. Unfortunately, the lake in question recorded its first zebra mussels in July of 2022; consequently, the inspection point had been completely disbanded shortly after the discovery of the infestation. The battle lines against aquatic invasive species had shifted yet again.

A Thought-Provoking Book Study

The curriculum development portion of our project centered on the reading of *The Death and Life of the Great Lakes,* (Egan, 2018). The student book study worked nicely with our grades 6-12 as students were further engaged in stewardship activities throughout the school year highlighting the different ways in which stewardship can combat invasive species even as the fishing seasons changed. The student book study was paired with a teacher book study and curriculum development workshop that ran through the spring semester. The curriculum development aspect led to a field trip of site visits corresponding to *The Death and Life of the Great Lakes* that was documented from the perspective of South Dakota students/teachers coming face-to-face with zebra/quagga/Asian carp-infested waters on a scale not seen in South Dakota to document and bring back the importance of keeping these invasive organisms out of South Dakota waters.

In addition to seeing firsthand what lies in store for South Dakota in terms of the severity of the oncoming invasion, we made site visits referenced in the book looking for potential solutions to what we are facing. The goal was to recruit at least 30 teachers with the requirement that they would implement stewardship activities in their classroom through the reading of the book and going through the South Dakota-focused curriculum that was presented on invasive organisms with the opportunity to interact with site visits discussed in the book virtually during our live virtual teacher field experience of aquatic invasive species. Unfortunately, we fell a little short of this goal at only 26 teachers of which only 22 took the course for credit. However, 17 of these teachers participated in the virtual field trip in July of 2022 with another 7 of them completing it for additional credit.

An Inspiring Field Experience

The July field experience was the culmination of the project. Students and cohort teachers came together in a unique field experience for everyone. We took a bus load of students in grades 6-12 and endeavored to visit as many sites mentioned in the book study that we could during a week-long field experience covering all the Great Lakes. As we traveled from South Dakota up through Minnesota and the UP of Michigan, our students explored Lake Superior posting videos for our cohort teachers to engage virtually with the student field experience. Students posed questions from the book from sites such as the Great Lakes Aquarium and the Duluth harbor for participating teachers to reflect on and discuss topics on native versus introduced species and how shipping has opened the Great Lakes up to aquatic invasive species. The field experience progressed onto Lake Michigan with a stop at Beaver Island in the middle of the lake to learn about the impact of aquatic invasive species on the Great Lakes at Central Michigan University's Biological Station.

Image 4: While piloting Central Michigan University's remote operated vehicle (ROV), students were able to observe invasive quagga mussels along the shores of Beaver Island in Lake Michigan while searching for a sunken car that has been submerged for decades in the harbor.
Photo credit: Spencer Cody

After our visit, we headed farther east all the way to the end of Lake Erie and looped back through Chicago to probe the problem of entry points for aquatic invasive species through site visits along the Erie Canal and Niagara Falls and exit points for invasive species through the Chicago River.

Having internet access for a virtual field experience, combined with a student in-person experience, constantly presented logistical issues of having enough time to lead a field trip while uploading and recording enough content for a simultaneous virtual field experience. Overall, both aspects of the field experience proved valuable to teachers and students. The teacher cohort found the student interaction to be engaging in discussion and reflection while the students took their tasks of relaying information and developing thought-provoking questions for the teachers with a heightened sense of duty. Altogether, running a field experience in tandem with its virtual counterpart proved to be logistically challenging, but it produced a more meaningful learning experience for students than those field experiences that we have done that lacked such a virtual component.

Image 5: Learning about how opening up the Great Lakes via canals helped pave the way for aquatic invasive species as Edmunds Central students ride on a ferry on the Erie Canal in Lockport, New York.
Photo credit: Spencer Cody

If you are interested in recreating this experience in your classroom, you can utilize our teacher-friendly study guide: https://docs.google.com/document/d/1FFuAbVAvJL7jv7JMTZr_eP5uAhYVdPJj/edit

This includes slideshows for each chapter in the book including a whole host of interesting discussion questions and media, and as a special treat, we have included original video discussion questions from our students from the Great Lakes field experience. This book study guide paired with *The Death and Life of the Great Lakes* might be woven into lessons that would help students demonstrate understanding from the Next Generation Science Standards (NGSS, 2013). Disciplinary Core Ideas of **LS2.A**: Interdependent Relationships in Ecosystems and **LS2.C**: Ecosystem Dynamics, Functioning, and Resilience are strong in the lessons and are connected to these Performance Expectations:

NGSS Middle School Life Science

- MS-LS2-1: Analyze and interpret data to provide evidence for the effects of resource availability on populations of organism in an ecosystem.
- MS-LS2-2: Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems.
- MS-LS2-4: Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.
- MS-ESS3-3: Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment

NGSS High School Life Science

- HS-LS2-6: Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.
- HS-LS2-7: Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.
- HS-LS4-5: Evaluate the evidence supporting claims that changes in environmental conditions may result in: (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.
- HS-ESS3-3: Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity.
- HS-ESS3-6: Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity.

Conclusion

In total 82 students in grades 6-12 logged 297 stewardship and project involvement hours totaling a wide variety of stewardship activities involving both habitat restoration and conservation. Our habitat conservation activities involving preventative measures to reduce the spread of aquatic invasive species included the following:

- 43 boat inspections
- 22 boat cleanings
- 108 bait bucket inspections and 19 bait bucket cleanings

- 34 live well inspections
- 57 dock inspections
- 72 riprap locations inspected for zebra mussels
- 32 boatlift inspections
- 37 boat trailer inspections
- 12 aquarium inspections

Habitat restoration opportunities were more limited but were also performed: 72 kilograms of zebra mussels were removed, 5 kilograms of quagga mussels removed on Beaver Island, and 42 kilograms of common carp removed. These stewardship activities contributed to marked shifts in student views and understanding as are referenced in Figure 1.

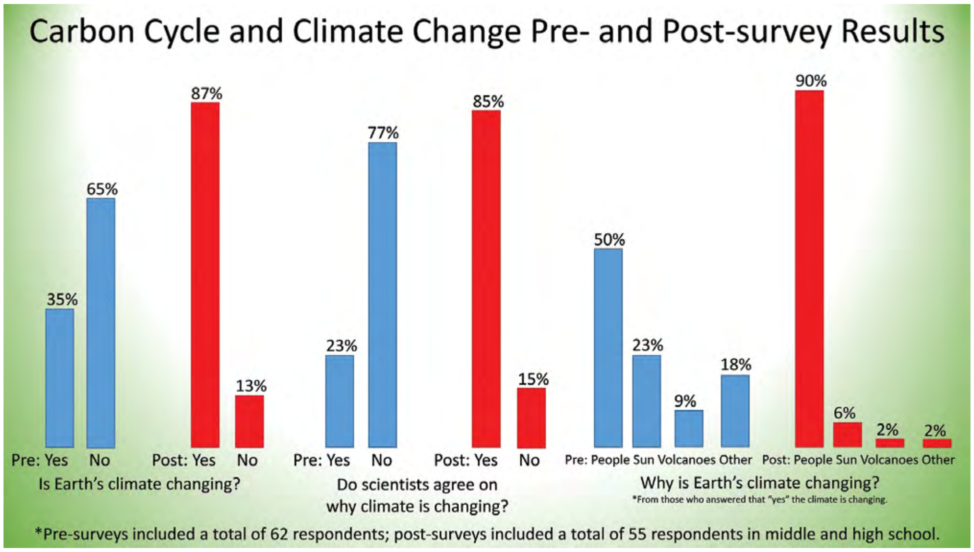


Figure 1: Data collected from pre- and post-surveys from the project's participating students indicate a significant shift in views about the spread of AIS. These shifts were somewhat surprising considering the degree to which aquatic invasive species have been in the local media.

Teacher involvement included 26 teachers in our aquatic invasive book study with 22 teachers completing the course for graduate credit through the University of Sioux Falls. Additionally, 17 of these teachers participated in our summer virtual field experience with another 7 of them taking it for credit. This curriculum development opportunity also led to smaller shifts in teacher perception and understanding as are referenced in Figure 2.

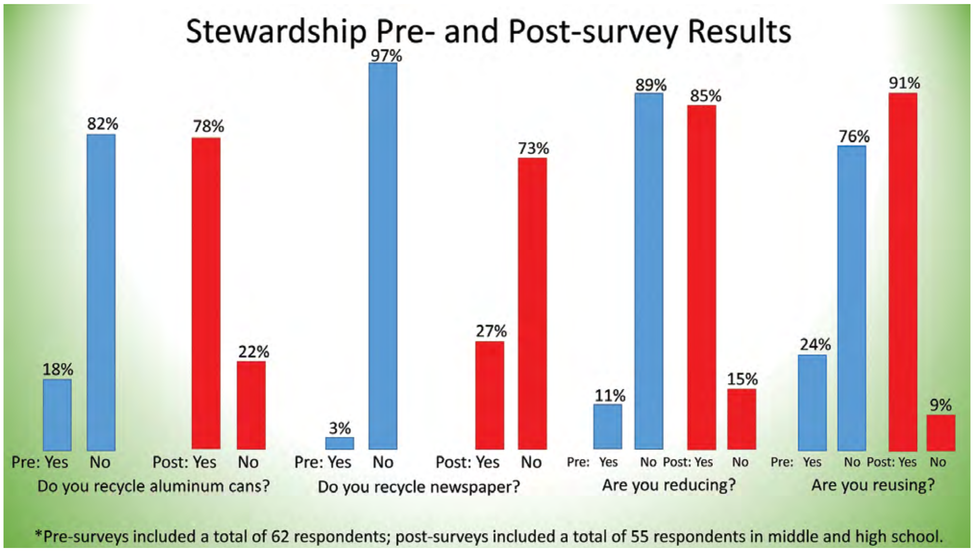


Figure 2: Data collected from pre- and post-surveys from the project's participating teachers indicate a smaller shift in views and understanding on the issue of aquatic invasive species than was exhibited by participating students. Participating teachers had a wide range of backgrounds and, in most cases, did not teach any content concerning aquatic invasive species.

While the issue of aquatic invasive species presented its own logistical problems, these challenges were, for the most part, successfully navigated to meet stewardship goals resulting in a remarkable learning experience for both students and teachers. This NOAA Planet Stewards project produced substantive attitudinal changes paired with documented increases in content understanding proving that South Dakota students on the forefront of our struggle against aquatic invasive species can greatly benefit from project-based, stewardship-centric learning.

About the Author

Spencer Cody teacher 6-12 Science at Edmunds Central Middle and High School in the Edmunds Central School District in Roscoe, South Dakota. He holds a BA degree in Middle School and Secondary Biology Education from Concordia College in Moorhead, Minnesota, and an MS degree in Chemistry Education from South Dakota State University in Brookings, South Dakota. He has taught for 15 years in the middle and secondary sciences and is the recipient of numerous awards for his teaching including the 2018 Sanford Inspire Teacher of the Year for South Dakota, 2020 North Central Section Outstanding Earth Science Teacher, 2020 EPA Presidential Award for Environmental Education, and 2021 Region Four Teacher of the Year for South Dakota. Spencer can be reached at Spencer.Cody@k12.sd.us.

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Planting Roots in our Community: Leaving a Legacy Behind

Julie Houck, Defiance Elementary, Defiance, Ohio

Abstract

This NOAA Planet Stewards project was designed to reduce the carbon dioxide in our environment through tree planting around the Defiance, Ohio area. Locations included a nature preserve, a therapeutic riding center called Lily Creek Farms, and the Defiance Elementary School, along with local church grounds and backyards. The project was responsible for planting 112 trees with a calculated 1,322 pounds of carbon absorbed for the first year which will continue to grow in years to come. Once the trees are fully grown, they will remove 5,555 pounds of carbon dioxide from the atmosphere each year. Students involved in the project showed an increase from pretest to post-test about their desire to do science, choose a STEAM- related (Science, Technology, Engineering, Arts, Math) career for their future job, and take care of the environment.

The Project

The concentration of carbon dioxide has increased in the world especially after the industrial revolution. Earth's global average surface temperature in 2020 statistically tied with 2016 as the hottest year on record, continuing a long-term warming trend due to human activities. Yearly surface temperature compared to the 20th-century average from 1880–2022.

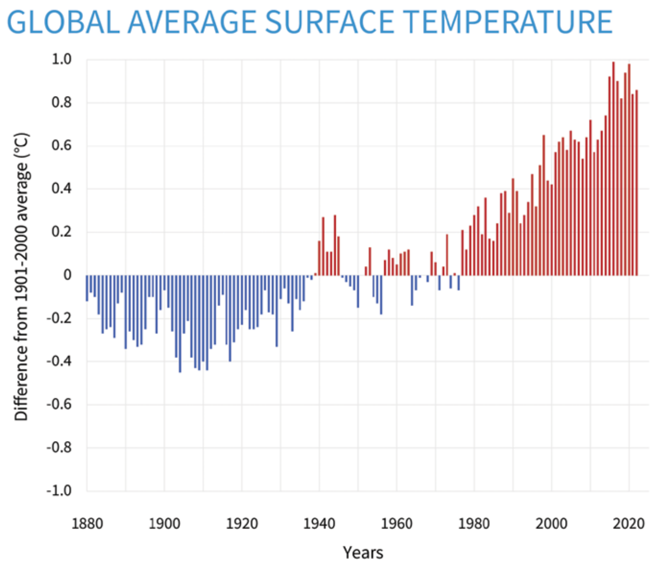
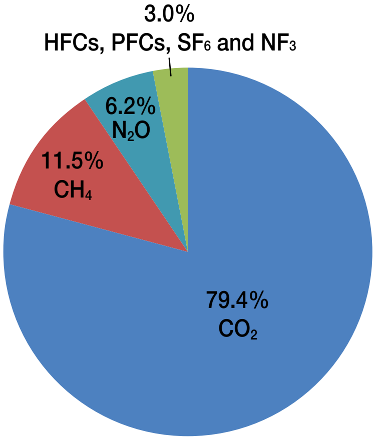


Figure 1. Blue bars indicate cooler-than-average years; red bars show warmer-than-average years. NOAA Climate.gov graph, based on data from the National Centers for Environmental Information.

The town of Defiance, Ohio has a strong interest in reducing carbon dioxide to mitigate the risks of global warming. Defiance City has been recognized by the Arbor Day Foundation for planting trees and is aware of the impact trees have on our community as a whole. Defiance was awarded the Tree City USA Growth Award in 2020. Knowing this information made it easy to decide to focus on planting more trees to help to improve our air quality. In 2020, it was estimated that about 79% of the greenhouse effect is caused by carbon dioxide, a heat-trapping gas that prevents the releasing the heat into space. (EPA, 2021) This excess

Figure 2. Total U.S. Emissions in 2021 = 6,340 Million Metric Tons of CO_2 equivalent (excludes land sector). Percentages may not add up to 100% due to independent rounding. Land Use, Land-Use Change, and Forestry in the United States is a net sink and offsets 12% of these greenhouse gas emissions. This net sink is not shown in the above diagram. All emission estimates from the Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2021.



U.S. Environmental Protection Agency (2023). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2021

greenhouse gas creates a phenomenon known as the "greenhouse effect." Heat from the earth is trapped in the atmosphere due to high levels of carbon dioxide and other heat-trapping gasses that prohibit it from releasing the heat into space.

One way to help reduce carbon dioxide is to plant trees because they act as carbon sinks. We were able to partner with our Soil and Water Department and many other community partners to help with this project, including Defiance Dream Center, YELP, Defiance City Schools, Defiance College, Defiance City, Lily Creek Farm, Defiance Soil and Water, Paulding Soil and Water, and Toledo University GLOBE B-WET.

Image 1. Getting ready to plant trees at Lily Creek Farms, a therapeutic riding center providing healing opportunities through the use of equine-assisted activities. Photo credit: Julie Houck

Image 2. Student at Lily Creek Farm Riding Center. Photo Credit: Julie Houck

Students were a part of a leadership organization called YELP, Youth Engaged Leadership and Philanthropy. This group consisted of students grades 4 – 7 who had an interest in helping in their community. We found a local nursery in the town that helped the students select native trees to plant at an equestrian center called Lily Creek (http://www.lilycreekfarms.org/) where they had trees die along their sensory trail for students with special needs. We planted trees in October and then we were able to go back to measure the trees and do a field trip where the students got to learn about careers on the farm and ride the horses.

Another tree-planting location was a 78-acre nature preserve in Defiance called the Penney Nature Center (https://www.defianceswcd.org/penney-nature-center.html). It consists of wetlands, woodlands, and prairie land. It has an outdoor classroom and provides a nature camp to students over the summer. We were able to partner with the Defiance Soil and Water Department to plant trees there in April with volunteers from our County Commissioner's office and other local volunteers.

Image 3. Penney Nature Preserve in Defiance Ohio where over 100 trees were planted with Defiance Soil and Water.
Photo credit: Julie Houck

Defiance Elementary School was the focus of May tree planting. The local nursery helped students to analyze the soil to determine the best trees to plant and each grade level planted a tree. We collected data using the GLOBE protocols for trees, measuring the height of the trees and the diameter of the trunks. We also estimated how much carbon has been sequestered over the time of the project and the prediction of how much it will sequester over the next 5 years. The students learned about the importance

Table 1. Connections to the Next Generation Science Standards (NGSS, 2013)

Performance Expectation

3-5-ETS1-1 Define a simple design problem that can be solved through the development of an object, tool, process, or system and includes several criteria for success and constraints on materials, time, or cost. (3-5-ETS1-1)

3-5-ETS1-3 Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials considered. (3-5-ETS1-3)

Dimensions	Classroom Connections
Science and Engineering Practices	
Developing and using models • Modeling in 3–5 builds on K–2 experiences and progresses to building and revising simple models and using models to represent events and design solutions.	• Students create a model of a tree (tower) and then measure it using blocks. They will relate how they measure the blocks to find the height of the tower to how they can count the size of themselves to measure a tree height.
Disciplinary Core Idea	
ETS1.A: Defining and Delimiting Engineering Problems **ETS1.B: Developing Possible Solutions** **ETS1.C: Optimizing the Design Solution**	• Students create a model and design a way to measure using nonstandard measurements. They are creating a possible solution and designing a way to measure the height of a tree.
Cross-Cutting Concepts	
Scale Proportion and Quantity • In considering phenomena, it is critical to recognize what is relevant at different size, time, and energy scales, and to recognize proportional relationships between different quantities as scales change.	• Students see the connections between the proportional relationships of the tree to themselves. They also compare nonstandard units to the tower and how these relationships change.

of planting trees, how to measure trees, taking air and surface temperatures, and different STEAM careers. This lesson series provided many ties to the Next Generation Science Standards (NGSS, 2013).

Students created their own class book titled, "What They Want to Be", about their aspirations when they grow up. Students went through the writing process and chose a career that was of interest to them. They peer-edited each other's work and completed final copies were sent off to the publisher. They were very interested in STEAM careers and several picked careers that we had explored during our class career explorations.

Image 4. Student recording her data after measuring the surface temperature and tree data.

Photo credit: Julie Houck

Image 5. Defiance Elementary School tree planting.

Photo credit: Annabelle Houck

Lesson: Engineering for Height https://docs.google.com/document/d/1fjsWBjDTS2CHw0N_TmEGtub-Wt0dX6LUtQPNfNJ4kz4/edit?usp=sharing

Images 6 and 7. Trees were planted at Hebron Ministries in Defiance Ohio. Photo credit: Julie Houck

Additional trees were planted in areas around the community, including a local church and ministry. Native plants and apple trees were planted at Hebron Ministries by volunteers. The apple trees were selected specifically to help with their food outreach program. Trees were also planted in neighborhoods and yards.

During the summer, we were able to share this project with Honor Academy students who represented four different counties (Defiance, Henry, Fulton and Williams) at a week-long camp in Archbold, Ohio. These students also learned about GLOBE protocols and the importance of trees, conducted air and surface temperature measurements, met with a scientist from Toledo University, and went outdoors each day. We used a Terra Rover to collect temperature measurements and compare them to our data.

Conclusion

Over 600 elementary students and 30 volunteers from four local counties (Defiance, Henry, Fulton and Williams County) were involved in this project. The students calculated that this project reduced the amount of carbon (1,322 pounds of carbon for the first year) and the amount will continue to grow in years to come. Once the trees are fully grown they will remove 5,555 pounds of carbon dioxide from the atmosphere each year. Over the span of 40 years there will be over 100 tons of carbon sequestered from this project.

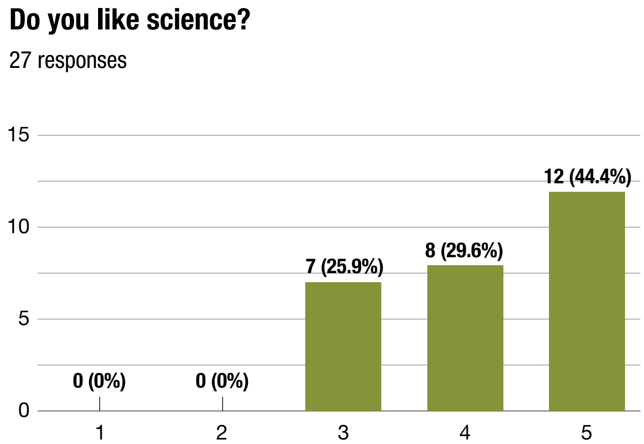


Figure 3. In the year-end survey, 20 out of 27 students selected at or above 4 out of 5 for liking science. At the beginning of the year, 10 students listed liking science at 3 or below.

Students showed an increase from pre-test to post-test about their desire to do science. In the end of year survey, 20 out of 27 students selected at or above 4 out of 5 for liking science. At the beginning of the year, 10 students listed liking science at 3 or below.

Students also grew in their knowledge about the importance of planting trees and in STEAM careers. Multiple presenters such as Joshua Hall, a computer programmer, visited throughout the year in-person or virtually to highlight what they did in their specific job and answer questions from the students. In their book about future jobs, 14 out of 21 students picked a STEAM career.

As a result of the Planet Stewards funding and seeing the impact it could make on my students, I was encouraged to try for an Ohio Environmental Education Fund grant in 2023. The superintendent of my school reached out to me to work on it and I was amazed at the number of community partnerships I had already created. It was fairly easy to continue in my environmental endeavors because I had the experience through Planet Stewards. I do not believe I would have had the courage to write the grant had I not had such a wonderful experience. I also think the community support and ability to partner together made it more manageable to take the next step and my school was selected to receive the Ohio Environmental Education Grant.

I was able to share the results and the impact of this Planet Stewards project on my students and my teaching practice at the 2023 GLOBE (Global Learning and Observations to Benefit the Environment) Annual Meeting in Denver Colorado.

STEAM Careers Presented to Students

- Nurse
- Eye Doctor
- Computer Programmer
- NASA Scientist
- Civil Engineer
- Environmental Specialist
- Candy Maker
- Astronaut
- Equestrian Trainer

Image 8. Joshua Hall sharing about his job as a Computer Programmer.

Photo credit: Julie Houck

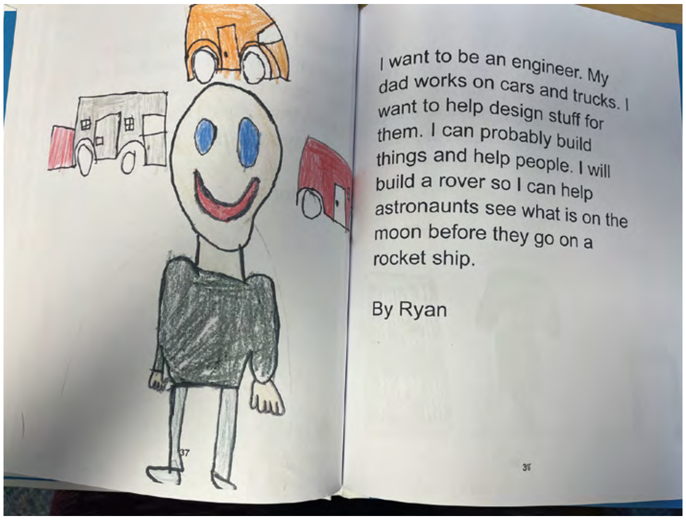


Image 9. Student book page of STEAM career.

From *What We Want to Be* by Mrs. Houck's 2021-2022 Class (Published by Student Treasures https://studentreasures.com/)

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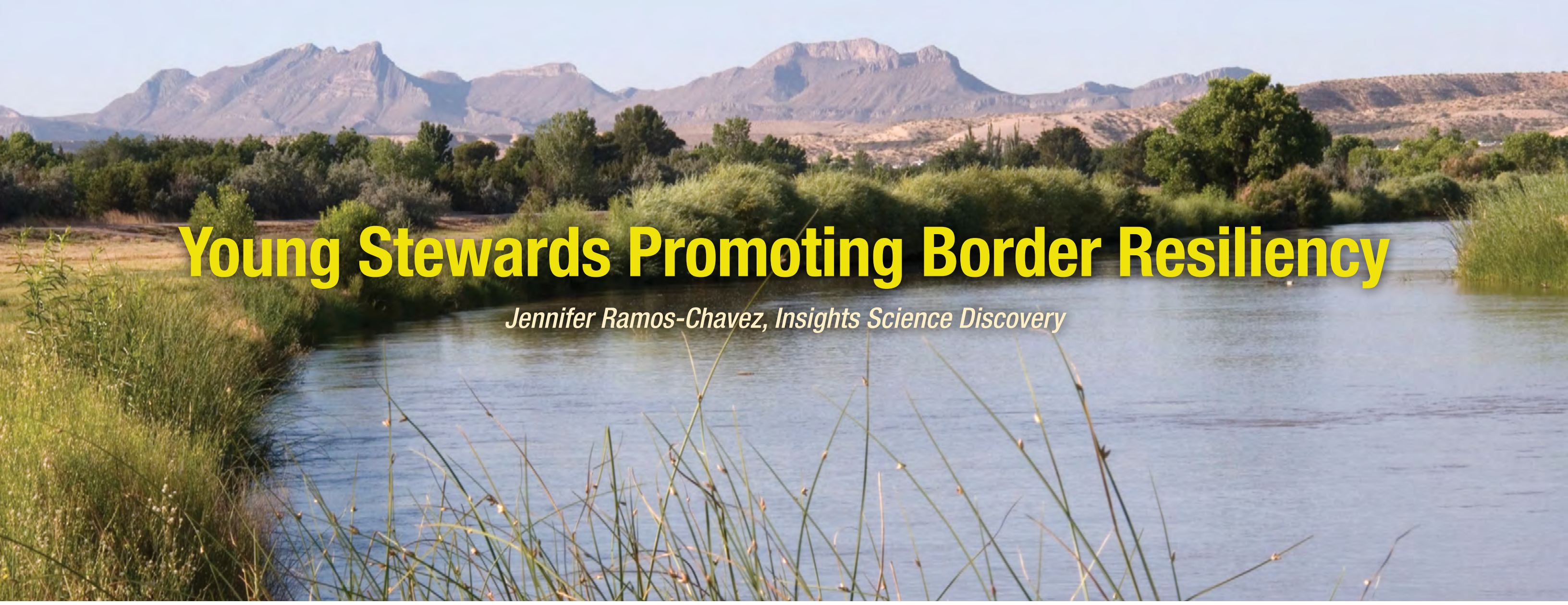
About the Author

Julie Houck became a NOAA Planet Steward in 2021. She is a K-5 STEAM Teacher at Defiance Elementary in Defiance, Ohio. She has been teaching for 20 years and has also taught students in Australia, Germany, and China. She earned her Bachelor of Early Childhood Education from Cedarville University and her masters from Regent University. She has been a part of GLOBE Mission Earth for three years and is also a GLOBE trainer. She is a My NASA GLOBE product reviewer, an NSTA member, and an Ohio STEM Learning Network Fellow. Julie can be contacted at jhouck@defianceschools.net.



Young Stewards Promoting Border Resiliency

Jennifer Ramos-Chavez, Insights Science Discovery

Abstract

The city of El Paso is uniquely located along the Rio Grande River and borders of Mexico and New Mexico, all of which are situated in the Chihuahuan Desert. The region faces a variety of environmental threats, including habitat loss due to urbanization, deterioration of freshwater resources and climate change. The Border Region (82% Hispanic and poverty rate of 22%) is also very much an underserved community. Working in partnership with the Rio Bosque Wetlands Park and with funding provided by the NOAA Planet Stewards program, Insights Science Discovery (Insights) created the Young Stewards Promoting Border Resiliency project. The goal of this project was to arm high school students from underserved communities with the knowledge and skills to restore one acre of riparian wetland habitat. The project also fostered career development within STEM fields by providing students with opportunities to learn and engage with STEM experts. The students' efforts of removing invasive species followed by the transplanting of native vegetation within the wetland, helped restore a small portion of this river-valley environment while instilling a greater sense of conservational awareness among the next generation of decision makers.

Introduction

The Border Region of West Texas, Southern New Mexico and Northern Chihuahua is uniquely situated along the Rio Grande River and in the critical ecoregion of the Chihuahuan Desert which faces a variety of threats, including habitat loss, deterioration of freshwater resources and climate change. According to the National Park Service (https://www.nps.gov/im/chdn/ecoregion.htm), the Chihuahuan Desert is considered one of the most diverse deserts of the world, and a critical reservoir for conserving biodiversity. Unfortunately, the Chihuahuan Desert Ecoregion is also one of the most endangered regions in the world (Briggs et al., 2019).

The El Paso Border Region in west Texas is one of the nation's fastest growing metropolitan areas. With a steady annual population growth rate of an average of 0.7% per year between 2010 and 2021 (U.S. Census, 2021), El Paso City and County planners have primarily focused on tapping into the binational workforce unique to this region and have thus dedicated projects and funding to commercial, industrial and residential growth. Unprecedented rates of urban sprawl have farmers and environmentalists at odds with government planners.

Wetlands and riverside forests once dominated the banks of the Rio Grande in the Border Region. They were the most productive natural habitats in the area. Historically, the floodplains of the river used to stretch up to 8 miles wide when flooding of the Rio Grande occurred during spring and early summer. Native riparian vegetation such as screwbean mesquite, willows and cottonwood trees were once dominant in these habitats. However, today these historical riparian forests and wetlands are virtually gone as a result of channeling and damming of the Rio Grande, land conversion, border fence building, and stressors such as the introduction of invasive salt cedar (*Tamarix spp.*) (Howe & Knopf, 1991).

Wetlands serve as a vital habitat for plants and animals, act as a natural filter for water, decrease erosion and promote land stability, provide aesthetic value, and play a crucial role in combating climate change. It is well established that riparian wetlands play a significant role in carbon sequestration (Tan et al., 2020). Though quantitative measures in riparian wetlands within the El Paso Border Region are limited, if Rio Bosque's sequestration potential is anything comparable to its functioning as a flourishing habitat in areas that have been since restored, then the Rio Bosque Wetlands in El Paso, Texas is confidently a considerable environment for carbon sequestration. This not only has a positive impact on local environmental health, but globally as well as we face environmental and climate change.

Though the Border Region faces multiple environmental challenges, a number of adult organizations are actively engaged in environmental stewardship, but few youth programs exist. With an 82% Hispanic population and poverty rate of 22%, El Paso, Texas is an underserved community as a whole (U.S. Census, 2022) West Texas is geographically isolated from the state's environmental education services in based in central regions of the state. Moreover, the Chihuahuan Desert and its environmental issues cross city, state and national boundaries in the Border Region.

Background and Site History

Rio Bosque Wetlands Park is part of El Paso's city park system and is managed by the University of Texas at El Paso's Center for Environmental Resource Management (CERM). Since 1997, partnerships among the University of Texas at El Paso, the City of El Paso, the International Boundary and Water Commission (IBWC), Ducks Unlimited and El Paso Water Utility have worked to rebuild the wetland.

The park spans 372 acres. Early wetland restoration efforts involved re-building the old river channel through the park and creating a system for diverting water from this channel into two large shallow wetland cells designed to recreate shallow-water emergent wetland habitats.

Active restoration establishing native species and controlling exotic species (Watts et al., 2002), along with natural regeneration responses to exceptionally wet years of 2006 and 2008, has slowly transformed the wetland park into a habitat

Figure 1. Map of Rio Bosque Wetlands Park. The yellow star indicates the project's restoration site.

resembling what was once present with the historical meandering Rio Grande. In the years since, wildlife has increased in diversity and density, and natural progression of vegetation has reclaimed several of the previously cleared areas.

In the early years of the wetland project at Rio Bosque, the only available source of water was treated wastewater from El Paso Water's Bustamante Wastewater Treatment Plant, located immediately north of the park. It was often only available for 3 to 3.5 months in late fall and early winter (Watts et al., 2002). The rest of the year, including throughout the growing season, the park was completely dry. In recent years, the park's water availability has increased thanks to El Paso Water and El Paso County Water Improvement District No. 1. Today, the park relies on three different water sources: treated wastewater, groundwater, and irrigation water from the Rio Grande. The availability of water during the growing season has greatly accelerated the development of wetland and riparian ecosystems at Rio Bosque.

Project Goals/Objectives

The Young Stewards Promoting Border Resiliency project aimed to build a strong environmentally conscious future for the Border Region by providing young community members, many of whom come from underserved communities, with skills and experiences to promote a new generation of conservational awareness. The project's overarching goal was to advance efforts that combat land conversion and shrinking wild habitats by restoring approximately one acre of the wetland by clearing invasives and replanting native vegetation.

Learning Topic	Presenter's Profession
Land conservation and preservation	Wildlife Biologist and Land Trust/ Conservation Administrator
Ecological Restoration and Rain Water Harvesting	Biologist and Restoration Expert
Invasive Species	Botanist/Ecologist
Wetland vegetation and the importance of wetlands	Biologist and Botanical Curator
History of El Paso water and the Rio Grande River	Hydrogeologist and Professional Engineer
Wetland water; Water of the Rio Bosque; groundwater	Hydrogeologist and Geochemist
Wetland birds, particularly resident and migrant birds of the Rio Bosque	Wildlife Biologist and Avid Birder (Audubon Society President)
Burrowing owls, conservation efforts for the species and the role Rio Bosque plays for the owls	Urban Wildlife Biologist
Desert wildlife tracking and monitoring	Ecology and Evolutionary Biology PhD students
Native desert pollinators and the importance of pollinator gardens/native vegetation	Texas Master Naturalist
Science communication, citizen science, participatory science, and the importance of diverse and inclusive science and research	Ecologist and Environmental Scientist

Table 1. Project's priming lesson topics and the corresponding presenter's profession. Priming lessons served as a means to provide information and knowledge students would need to understand field trip objectives, as well as a means of career exposure and development.

This project was a partnership with Insights Science Discovery (http://www.insightselpaso.org/), a local non-profit with the mission of providing equitable access to Science, Technology, Engineering, Arts, and Math (STEAM) education, the University of Texas at El Paso's CERM, and the Rio Bosque Wetlands Park. Keeping in the spirit of youth empowerment and environmental ownership, we enlisted students from a nearby high school, Mission Early College High School, many of whom had never visited nor heard of the wetlands despite being located only six miles from their school campus. Forty students worked side by side with restoration experts and researchers to understand the process and importance of habitat restoration.

Since the project administrators and volunteers had limited time with the participating students, the project was designed to provide monthly learning lessons on different wetland topics and issues before each field trip over the course of the school year. For these lessons, we employed the help of local experts who presented on the topic and also highlighted their experience in their career field, as well as their journey to reaching that point. Several of these guest speakers attended in-person field trips and served as mentors to the high school students. The students would then participate in stewardship activities (invasive removal and native planting) and hands-on lessons relating to the correlating topic during the subsequent field trip at the site. In total, eleven priming lessons, which included providing introductory information for the respective field trip, a deeper dive into the respective field trip topic by a STEM expert, and material preparation for hands-on activities, (Table 1) were given and seven of the eight planned field trips took place. Due to constraints related to the Covid-19 Pandemic, some activities were rescheduled or canceled altogether.

Data Collection

This project included a number of data collection activities. Students learned to collect physical data within the restoration area as well as at a control site (where no stewardship activities were conducted) at several intervals within the project timeframe. The control site served as a comparison for environmental assessments. The project administrator also collected data on student perceptions and learning outcomes.

Environmental Monitoring

In an effort to enhance student learning and understanding of habitat restoration, environmental measures including vegetation assessments, soil and water analyses, pollinator surveys and bird counts were conducted by the students under the guidance of experts and volunteers and served as a means to illustrate how habitats can be monitored, and restoration efforts guided based on the results. The number of native plants installed and amount of invasive biomass were also monitored and recorded.

Vegetation assessments included pre and post-linear transects. Linear vegetation surveys (LVS) were conducted along a 50 m transect parallel to a water channel within the restoration and control sites.

Image 1. Students conducting linear vegetation transects to measure and record present species and calculate the most dominant species at the site.

Photo Credit: Dr. Ramos-Chavez

Image 2 (left). Students learned about soil dynamics within wetland/riparian habitats and conducted soil analyses to compare nutrient levels between the control and restoration sites.

Photo Credit: Dr. Ramos-Chavez

Image 3 (right). Participating students learned that the diversity of wildlife can indicate habitat health. During the project, students learned to identify and survey wetland bird species.

Photo Credit: Dr. Ramos-Chavez

Species data was collected at random points along the transect both at 1 meter towards the water channel and 5 meters away from the water channel. This double, simultaneous LVS allowed for a more robust understanding of the vegetation along the varying ecotones within the riparian habitat.

We had intended to conduct pre and post assessments but the second half of the project year was faced with pretty severe drought conditions. Water that was planned to be delivered to the wetland was diverted to farmers downstream in Socorro and San Elizario, Texas and elsewhere further down river. The wetland was bypassed by two upstream river releases in February and April and remained dry during the duration of the second half of the project. Despite this, students did learn how to conduct the assessments and learned how these measures are used to determine habitat health and the relationship between water quality/quantity and vegetation along with the presence of wildlife.

Student Learning and Perceptions

To assess student learning and perceptions of riparian wetland restoration, we utilized two abstract survey techniques. The Draw-an-Ecosystem Approach (Sanford et al., 2017) consists of a pre-test and post-test in which students draw and label an ecosystem and is graded based on a rubric (https://ncsce.net/the-draw-an-ecosystem-task-as-an-assessment-tool-in-environmental-science-education/) including eight categories (abiotic/biotic mass transfer, energy input, trophic interactions, human activities, hydrologic cycle, atmosphere, system/environmental issues) each with a 0–3 score, where 0 represented no display of that category and 3 represents a comprehensive response. We also investigated the effects of hands-on educational programing on student's environmental perceptions using Bogner and Wiseman's Model of Ecological Values using an Environmental Perception (ENV) scale (Bogner and Wiseman, 2004). Multiple choice questionnaires regarding wetland habitats were scored on a 5-point Likert scale ranging from "strongly agree" to "strongly disagree". The pre-test for both methods were administered before students were introduced to any habitat restoration concepts, and the post-tests were administered upon completion of the project.

Images 4, 5, 6. Part of the project's restoration efforts included removal of invasive species. Students remove an invasive tree tobacco; remove tumbleweed growing along the water channel, and students amass a large pile of invasives during one of the project workdays.

Photo Credit: Dr. Ramos-Chavez

Results

Environmental Monitoring

As a result of the students' stewardship efforts, approximately one acre of riparian wetland habitat was improved and well on its way to natural regeneration. The restoration site was dramatically improved and cleared of many invasive species.

	West - Restoration	West - Control	East - Restoration	East - Control
# of species @ 1m	5	3	6	5
# of species @ 5m	5	4	7	7
Total # of species	6	5	9	9
Most frequent species @ 1m	Tumbleweed; Coulter's horseweed	Bare ground; Tumbleweed	Tumbleweed	Bare ground; Lamb's quarters
Most frequent species @ 5m	Tumbleweed	Indian rushpea	Bush seepweed; Tumbleweed	Fall tansyaster; tumbleweed; Lamb's quarters
Most frequent overall	Tumbleweed	Tumbleweed	Tumbleweed	Tumbleweed; Lamb's quarters

Table 2. Linear Vegetation Survey pre-assessment. Transects were conducted on both sides of the water channel (East and West), and both in the restoration and control sites. Pre-assessments show that Salsola kali (tumbleweed) was the dominant species within the restoration and control sites.

	West - Restoration	West - Control	East - Restoration	East - Control
# of species @ 1m	2	3	2	2
# of species @ 5m	3	3	5	5
Total # of species	5	4	6	6
Most frequent species @ 1m	Bare ground; Hoary tansyaster	Indian Rushpea; Tumbleweed	Bare ground; Bush seepweed	Bare ground; Tumbleweed
Most frequent species @ 5m	Bare ground; Willow baccharis	Tumbleweed	Bare ground; Willow baccharis	Tumbleweed
Most frequent overall	Hoary tansyaster	Tumbleweed	Bush seepweed; Narrowleaf Globemallow	Tumbleweed

Table 3. Linear Vegetation Survey post-assessment. Transects were conducted on both sides of the water channel (East and West), and both in the restoration and control sites. Post-assessments illustrate that native wetland vegetation like willow baccharis (*Baccharis salicina*) and hoary tansyaster (*Machaeranthera canescens*) became more established within the restoration site, while the control sites remained dominated by tumbleweed.

Vegetation pre-surveys showed that invasive tumbleweed (*Salsola kali*) was the dominant plant species within the site (Table 2).

After invasive removal, native wetland vegetation like willow baccharis (*Baccharis salicina*) and hoary tansyaster (*Machaeranthera canescens*) became dominant and established in areas where tumbleweeds were removed (Table 3).

A total of $65.2m^3$ of invasive plant material (including tumbleweed, tree tobacco (*Nicotiana glauca*) and Johnson grass (*Sorghum halepense*)) was removed from the site. 72 native plants and seedlings, including Rio Grande Cottonwood (*Populus deltoides wislizenii*), Gooding Willow (*Salix gooddingii*), Broom snakeweed (*Gutierrezia sarothrae*), and Sand sagebush (*Artemisia filifolia*) to name a few, were transplanted while three dozen seeds were germinated offsite for future transplantation.

Student Learning and Perceptions

According to the pre-assessment survey multiple choice questionnaire a majority of the students had existing positive and strong beliefs about environmental science and awareness of their environment. This was reflected once again in the post-assessment survey. However, some students felt that the same beliefs and awareness may not be shared by their school and community. More than half the students felt unsure as to whether their school/community shared the same beliefs after stewardship activities were conducted.

Image 7. Students work to install native plants where invasive tumbleweeds were removed. Photo Credit: Dr. Ramos-Chavez

Image 8. A student works alongside the park assistant manager to plant a native willow tree in November 2021. Photo Credit: Dr. Ramos-Chavez

Image 9. Students plant wolfberry seeds to germinate plants that will be installed at the site once matured. Photo Credit: Dr. Ramos-Chavez

The Student's Environmental Perceptions and Behavior pre-survey (https://docs.google.com/document/d/18F2lW1wthTGNrUKqjO1iNw1c8CVry5vnykT4NwvmGik/edit?usp=drive_link) illustrated little connection and knowledge about wetlands among students, particularly in desert ecosystems like the Chihuahuan Desert. However, the post-survey showed much higher correct responses to specific wetland concepts. For example, the pre-survey indicated that 30% of students were unsure about migratory species' connections to desert wetlands. However, the post-survey showed 93.8% of student respondents understood these connections. This is directly attributable to lessons and stewardship activities as a part of this project. Finally, as a result of the activities and interactions incorporated in this project, more students have indicated that they would like to pursue a career in STEM fields (pre-survey: 72.5% agreed, post-survey: 100% agreed) and perhaps one that incorporates scientific research (pre-survey: 52.5% agreed, post-survey: 65.7% agreed).

Score	Pre-assessment # of Students	Post-assessment # of Students
0	1	0
1	13	0
2	12	1
3	9	4
4	2	3
5	0	4
6	0	2
7	0	0
8	0	2
9	0	1
10	0	5
11	0	2
12	0	1
13	0	1
14	0	1
15	0	1

Table 4. Draw-an-Ecosystem pre and post-assessment student scores. Thirty-seven total students participated in the pre-assessment, while 28 students participated in the post-assessment. The highest possible score is that of 24; no students scored higher than 15 on either assessment.

The Draw-an-Ecosystem pre-assessment mirrored results from the questionnaire which illustrated the students' lack in understanding/knowledge of desert wetland ecosystems. The rubric provides that an individual can obtain an overall score of 0 to 24. Comparing the pre/post assessments showed a stark increase in student scores. Most students scored between 1 and 2 on the pre-assessment, however, most students obtained a score between 5-10 on the post-assessment (Table 4). The highest score obtained on the pre-assessment was a score of 4 (n=2). The highest score obtained on the post-assessment was 15 (n =1, though 6 students scored eleven or higher).

The pre-assessment drawings were rudimentary depictions of desert habitats displaying very basic manifestations of the following categories: External energy input (a sun), Geosphere (rocks/mountain features), Trophic levels/organism interrelationships (predator/prey), and Hydrologic cycle (a water source).

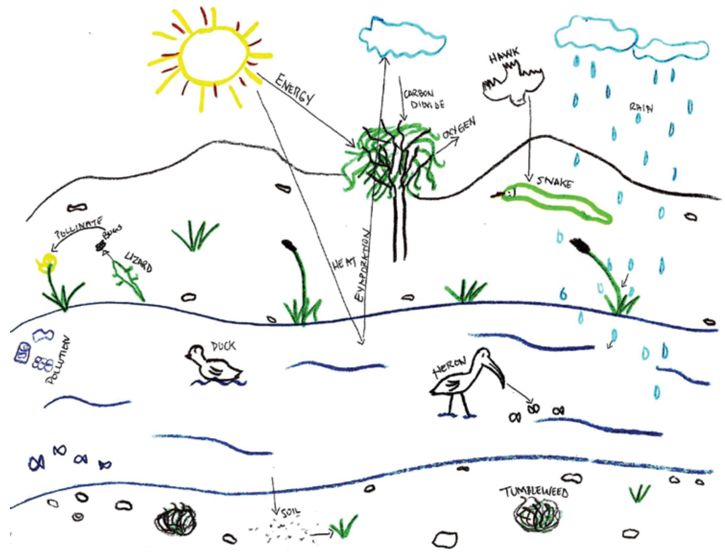


Image 10a (left). Student example of Draw an Ecosystem Preassessment shows very basic and elemental depictions of a wetland ecosystem illustrating the lack of knowledge and/or experience/exposure to these habitats.

Image 10b (right). Student examples of Draw-an-Ecosystem post-assessment. Overall, the post-assessment drawings were clear portrayals of what they had learned and experienced during their interactions with the project activities.

None of the students included any representation of the following categories: Nutrient cycling/Abiotic and biotic mass transfer, Human activities, Atmosphere, and Systems and environmental issues on the pre-assessment drawings. There was evidence of student learning in the above-mentioned categories as depicted in post-assessments drawings except 'Nutrient cycling' where only a few students obtained 1 point for that category. The teacher agreed that this tends to be where most students struggle as these concepts were only briefly discussed in class. Though we did discuss nutrients and nutrient cycling in one of the lessons and field trips, it is illustrated here that this is a challenging concept for these students.

Conclusion

This project helped restore a small portion of this river-valley environment and it inspired young community members, a majority of whom (93%) are minorities, to be stewards of their environment far beyond the duration of this project. It also provided the skills and knowledge needed to make real environmental improvements to their own communities and beyond. The two-pronged approach of hands-on, practical experiences coupled with career development via expert mentors provided a unique and perhaps singular opportunity for many of the participating students.

In all, students helped rehabilitate approximately one acre of desert wetland/riparian habitat by removing invasive species and planting native vegetation. Though carrying out this project in the middle of a global pandemic was challenging, we feel this project was quite successful and can serve as a model for future hands-on, participatory projects with the intention of including young people from diverse experiences, backgrounds and cultures. We found that these in-person and hands-on experiences connected with the students far more than any other classroom lesson could.

The city of El Paso is at a critical point in its development and in order to ensure that natural, open spaces are conserved for future generations, it is imperative that we delegate the leadership and solution development to the young people that will soon inherit the responsibility of legislative, community, and environmental decision-making. Furthermore, arming high school students in this region with the knowledge and resources necessary to

Image 11. Students work alongside volunteers to level out a water channel to allow for more water flow and bank inundation once water is released into the wetlands. Photo Credit: Dr. Ramos-Chavez

affect environmental change empowers not only student participants, but an entire community of traditionally economically, environmentally, and educationally disenfranchised citizens.

Acknowledgements

This project was made possible through funding provided by NOAA Planet Stewards. Significant contributions to the success of this project were made by the various volunteers involved including those from the University of Texas at El Paso's (UTEP) Center for Environmental Resource Management (CERM), Friends of the Rio Bosque, The Frontera Land Alliance, The Green Hope Project, El Paso TransPecos Audubon Society, UTEP BEE Grads, and UTEP faculty from the Departments of Biology and Geology. Last, but certainly not least, there would not be a project without the teacher, Mrs. Carlye Flores, and students from Mission Early College High School and Cathedral High School who worked so diligently and gave up many Saturday mornings to work on this project.

About the Author

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Additional Resources

Lesson – Conservation Wetland: Impacts of Human Activities on the environment and biodiversity (https://docs.google.com/document/d/1cDAOk7U-ovmT204IQGgrToEDls7hATktTj9iU88QY2M/edit)

Additional Chihuahuan Desert Educational Materials Developed by Insights (https://www.insightselpaso.org/sesi-teacher-resources)

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Modeling Marine Ecosystems with Virtual Reality

Dr. Randy Russell, STEM Consultant

Wild salmon migrating upstream in the Columbia River, Oregon
Photo credit: Dave Alan, Getty Images

Abstract

Modeling Marine Ecosystems with Virtual Reality is a series of three-lesson modules that use a computer-based simulation of marine environments to provide high school students with minds-on explorations of scientific modeling concepts and techniques. Scientists at NOAA (National Oceanic and Atmospheric Administration) Fisheries (https://www.fisheries.noaa.gov/) developed a Virtual Reality software environment called VES-V (Virtual Ecosystem Scenario Viewer) (https://nmfs-fish-tools.github.io/VES-V/) to help fisheries stakeholders visualize marine environments and the organisms living within them. The software provides a "virtual SCUBA diving" experience. Educators at NOAA realized that the VES-V software had great potential for use in educational settings, and developed modules that use VES-V to help students learn about scientific modeling.

Module Development

The overarching goal of these modules is to provide high school students, as is encouraged by the Next Generation Science Standards (NGSS, 2013), opportunities to **develop** and **use** scientific models. The education team that created these modules shares the belief that students need to move beyond **learning about** scientific modeling to engage in the **use** and **development** of such models. Active engagement with models is a central, unifying theme in the Modeling Marine Ecosystems with Virtual Reality modules.

Scientists who were part of the development process were very supportive and helpful. However, due to their unfamiliarity with the strong modeling emphasis in the NGSS, they initially were curious as to why teachers might be interested in a seemingly obscure topic. However, as scientists who use models extensively, they were very much in tune with the importance of the topic. They readily understood the nuances about modeling that we hoped to convey through the modules (topics such as model resolution, differences between models and observations, and the relationship between trophic levels and biomass).

The scientists were instrumental in identifying datasets (geographic regions, specific marine species, observational vs. modeled datasets) included with the VES-V software that contained exemplars of the concepts the team hoped to convey. The expertise of the NOAA

Image 1. Students use the scientific data and models employed by NOAA scientists to explore changes in ocean ecosystems and the impacts these changes have on the animals in those ecosystems.

Image 2. All modules (https://oceanservice.noaa.gov/education/marine-ecosystem-modeling-vr/) include student worksheets, NGSS alignment, and presentation graphics. The modules feature the Virtual Ecosystem Scenario Viewer, an interactive virtual reality model that NOAA scientists use to visualize changing ocean ecosystems.

scientists and education staff was crucial throughout the iterative design process; the scientists even added features to VES-V software updates specifically to support the lesson modules. Also, it really helped that all members of the development group were on the same page in terms of the desire to convey the importance of modeling as a key idea via data from marine environments. The result is a series of "minds-on" activities that enable students to work with these concepts and not simply learn "about" them.

The Lesson Modules

The three modules in the Modeling Marine Ecosystems with VR suite are: Ocean Food Webs, Observations and Models, and Predators and Prey. Each module includes 7 or 8 activities, each of which requires one or two class periods to complete. These modules build upon each other and are meant to be used together, though they can be used individually if time constraints or other considerations require. Each module begins with a brief tour of the VES-V virtual environment, to spark student interest, before delving into the scientific modeling topics explored in that module.

The VES-V software includes numerous geographic regions, data from both observations and models, data spanning varied time periods, and model runs with varying conditions (more or less fishing, changing ocean temperature or acidity, etc.). Many species of marine organisms are represented in the datasets, and students have the ability to highlight a species in order to view its population graph over time.

Each module begins with a slight variant of the same "Big Question", which provides relevance to students and anchors the rest of the module. In each case, students consider whether the modeling techniques learned in the module can help individuals, communities, or governments accurately predict the health of marine environments and the future supply of seafood. Students revisit the "Big Question" during the wrap-up discussion at the end of each lesson.

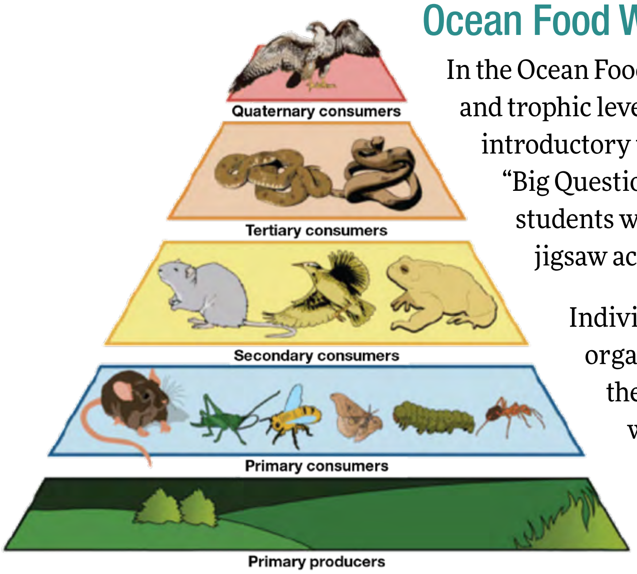

Image 3. Ocean Food Webs – Students use the concepts of food webs, trophic levels, and biomass to explore populations of marine organisms. They research an organism and combine their data in a jigsaw activity to produce a food web diagram for that habitat. Students then collect biomass data during "virtual dives" to determine the relationship between biomass and trophic levels.

Ocean Food Webs

In the Ocean Food Webs module, students use the concepts of food webs, biomass, and trophic levels to explore populations of marine organisms. After an introductory tutorial in the VES-V environment and being introduced to the "Big Question" about predicting future populations in marine environments, students work together to build a food web diagram as part of a whole-class jigsaw activity.

Individual students or small groups each research a species of marine organisms from the Gulf of Maine in the Atlantic Ocean. Then, they combine their data with their classmates to construct a food web diagram for that ecosystem. This diagram is used during a whole-class discussion about trophic levels and their relationship to biomass.

During a virtual "dive" using the VES-V software, students collect biomass data about herring and cod (which eat herring) in the Gulf of Maine, which they then graph. Based on this data, students form a hypothesis about the relationship between trophic level and biomass. On a second virtual "dive", this time in a kelp forest in Monterey Bay in the Pacific Ocean, students collect biomass data for sardines, sea lions and orcas. After graphing their data in relation to trophic level for each species, they test and refine their hypothesis about the relationship between biomass and trophic level. Using their newfound knowledge of this relationship, students predict how a change in one species' biomass might affect the biomass of another species that eats it. Students apply their biomass and trophic level relationship knowledge to the initial "Will there be enough seafood?" question in a third case study, this time from the Gulf of Mexico. Students use data about changing mackerel biomass to predict the biomass of tuna, which feeds on mackerel and is an important human food source.

Observations and Models

This module explores the distinction between data derived from observations versus data generated by models. Students build simple conceptual models for temperature based on geography, analyze temperature graphs depicting a mix of observational and model-based data, and learn how scientists use sampling to estimate populations too large to count.

Students construct a simple mental model to estimate the temperature at a place halfway between two towns where the temperature was measured. First, using simple interpolation in an inland locale with relatively featureless terrain; then taking geographic features into account in a coastal setting.

Students construct another simple model to estimate temperature in a location between Hawai'ian islands, using observational temperature data from different times of day on the two bracketing islands. Next, students compare observational data at the modeled location in the ocean with predictions from their simple model to validate and calibrate their models.

Students analyze several local and global temperature graphs to learn the distinctions between observational data, model-generated data, and datasets that blend the two types of data. This comparison of model-generated data and observational data is done first with the familiar concept of temperature, then applied later in the lesson to data about populations of marine organisms.

The next activity explores the use of sampling when observing populations that are too large to count. Students first consider how to estimate whether a garden has enough berries for a pie without directly counting all of the strawberries. They consider the challenges of counting creatures that move about, and the data biases that can be introduced when sampling a population, by discussing how the birds spotted at a feeder might or might not represent the local bird population. Students then discuss how marine biologists use sampling to estimate fish populations, as well as the potential problems associated with such sampling.

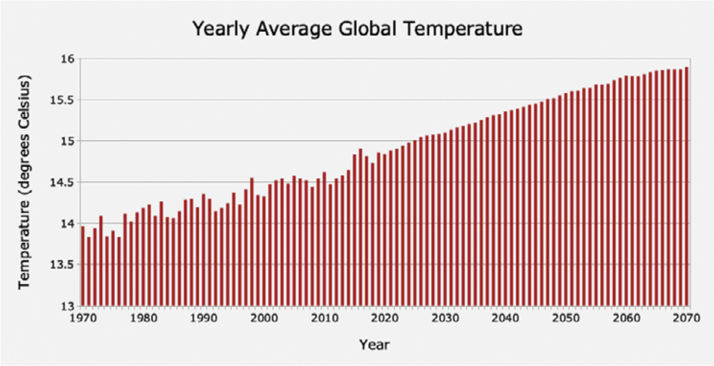

Image 4. Observations and Models – Students learn about data derived from observations and data produced by models, including how to recognize each, and how each type is used to make predictions. Students also explore methods to estimate the size and composition of populations. Students then observe simulated marine habitats generated by models and observational data to estimate future populations of tuna and of lobster.

During a virtual "dive" using the VES-V software, students collect lobster population data from two different datasets. Using the understandings that they have gained in comparing model-based and observational temperature data earlier, students attempt to identify the marine data as observational or model-based. During another virtual "dive", students compare data from a model with data from observations, using the same marine species and time span in each case. They assess the validity of the model based on how well it mimics observations. Finally, students revisit the "Will there be enough seafood?" question, analyzing a mix of observational and model-based data about tuna and lobster populations.

Predators and Prey

This module explores population dynamics in a predator-prey system, first using a classic example from a simple ecosystem on land, then delving into a more-complex aquatic example. Teachers can choose between three options for this module: students can build and run a model using spreadsheet software, can simply run a provided model, or can simply analyze data produced by the model. After observing how modeled populations of predators and prey rise and fall in comparison to each other, students compare modeled data with historical observations to validate the model. The observational data represents a real predator-prey system of Canada lynx and snowshoe hares in Canada in the 1800s.

Image 5. Predators and Prey–Students work with models that predict changes in populations of organisms. Students first analyze a simple predator-prey system, optionally building and "running" a simple, spreadsheet-based model. They compare population graphs produced by the model with historical data from a similar, simple predator-prey system. Students then collect data in simulated marine habitats, gathering biomass data for predators and their prey in complex marine food webs, comparing changes over time to the dynamics in simpler systems with a single predator and its lone prey.

Students collect biomass data for mackerel and cod (which eats mackerel) on a virtual "dive" in VES-V. They compare biomass trends for cod and mackerel over time to see whether the patterns from the terrestrial predator-prey system are evident. Students learn that ecosystems with complex food webs can exhibit much different dynamics that a simple two-organism ecosystem.

Challenges

The wide range of computer expertise among high school students makes development of "minds-on", computer-based activities challenging. We didn't want to make most activities too hard for students with limited expertise; but also didn't want to diminish the richness of the activities for more computer-literate learners. In some cases (Predator-Prey module) we offered options to build and run models (for more tech-skilled students) or to just analyze data from such models (for less tech-adept students). We emphasized data analysis of graphs, whether student-produced or provided by scientists. Students are able to construct several simple models that require only lightweight arithmetic skills, not complex calculations requiring a computer.

There are many real datasets that ship with the VES-V software, covering several regions and many species. Even with the help of experts, it took considerable effort to identify good case studies for which appropriate data was available. Some case study examples proposed by NOAA educators turned out to not have the required data in VES-V. Real ecosystems are complex, so it was difficult to find cases that illustrated principles, such as the relationship between the population of a predator and one of its prey species, in a way that was simple and "clean" enough for students to readily see the key patterns. Overall, the development team is hopeful that these modules will provide students with opportunities to explore models and data rich representations of systems to better understand scientific processes critical to understand our changing world.

Acknowledgements

Jason Link, NOAA Fisheries Senior Scientist for Ecosystem Management, and Howard Townsend, NOAA Fisheries Cooperative Oxford Lab Ecologist and Systems Modeling, led the project to develop the VES-V software for use by fisheries stakeholders and were very supportive of this effort to develop lessons to extend its use. They guided the education team to appropriate scenarios and datasets within the software. NOAA educators Bruce Moravchik, Bart Merrick, and Lisa Hiruki-Raring provided a clear vision for the goals of the project; were integrally involved in planning, reviewing, and improving the lessons; and provided excellent suggestions and support throughout the editorial process.

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A Tiny Forest as an Outdoor Classroom and a Place for Hope

Dr. Patrick Walsh, Catlin Gabel School, Portland, Oregon

Microforests are small, dense patches of forest plants native to the location of the forest and are being used as a climate change solution.
Photo Credit: Witney Tree Keepers.

Abstract

According to experts, such as psychotherapist Caroline Hickman (Hickman, 2020), climate anxiety in young people can be countered by engaging them in collaborative work that binds them to the environment and demonstrates for them the power of collective action. Inspired by such work at schools in Brazil, China, and Malaysia, and thanks to funding from the NOAA Planet Stewards program, our pre-K-through-twelfth-grade school built a so-called "Tiny Forest" on our campus in 2022. Tiny Forests are dense plantings of native plants in a space about the size of a tennis court. Students took key roles in writing the proposal to the school, choosing the plants, preparing the ground, and planting. A year later, the Tiny Forest has become an outdoor classroom, offering a site for age-appropriate lessons about topics ranging from carbon capture to nature poetry. By sharing the positive effects of reforestation and species diversification, students could articulate the possibility of making small but meaningful impacts on environmental problems. At the Tiny Forest we hope our students might experience empowerment rather than anxiety.

Image 1. Students from the Environmental Action Team, preparing the soil, early 2022. Photo Credit: Patrick Walsh

The Tiny Forest Project

Portland, Oregon, home to my school, Catlin Gabel, has made worldwide headlines over the past two years, first because it briefly had the worst air quality in the world due to catastrophic forest fires, and second, because of a deadly heat wave in 2021. For students, these events came in conjunction with the Coronavirus pandemic and many were stuck in houses, learning on Zoom, unable to go outside because of hazardous air quality. Like teachers everywhere, I have noticed rising worry and anxiety about climate change and the disruption it brings. As Anthony Leiserowitz, Director of the Yale Program on Climate Change Communication, has noted, "worry" can be a motivator, but "anxiety" can become "overwhelming and debilitating." (Yale 2023)

Hoping to counter my students' climate anxiety, and inspired by a story I heard on the BBC during lockdown, I decided to build a Tiny Forest at my school. A grant from the Planet Stewards program made this possible. A Tiny Forest is a dense planting of 600 native trees and shrubs in an area the size of a tennis court. Begun in Japan and now popular in Malaysia, Brazil, China, Tiny Forests offer opportunities for communities and especially kids to reconnect with nature while improving water, soil, and air quality. Tiny Forests create a carbon sink, an outdoor learning space, and a way to reintroduce a diverse range native plants and the animals they attract. Because the soil is prepared and the trees are planted closely together, the trees grow up to ten times faster than usual. Most importantly, Tiny Forests are a space for hope and reflection for students.

Image 2. Students help plant the 600 trees and shrubs on February 21, 2022.

Photo Credit: Tea Bear

My students, colleagues, and I followed the "Miyawaki Method" of planting, named for the Japanese botanist Akira Miyawaki (https://daily.jstor.org/the-miyawaki-method-a-better-way-to-build-forests/). This way of planting involves specific steps; first, learning about the plants native to the specific area of the proposed forest and assembling a plant list based on a four-layer model of canopy, understory, shrubs, and herbaceous plants or groundcovers; and second, preparing the soil, making it loose and rich with no chemical fertilizers and by turning it over down to a meter deep.

With the generous support of NOAA and a local water district, I purchased 600 native trees, shrubs, and groundcovers. After the school grounds crew turned over the soil with a tractor and dumped compost on the site, middle-school and high-school students further broke up the soil and mixed in the compost. A pair of sophomore girls pounded fence poles into the soft earth. I divided the site into twenty small sections with rope and short poles; an online sign-up sheet netted almost 200 volunteers. I divided these folks into small groups and gave each one a time and a section for our planting day, so the space wouldn't be crowded, and to make sure the volunteers didn't compact the soil by walking on it too much.

On February 22, 2022, the volunteers—students, parents, alumni, staff, and faculty—came in waves, each group staying for an hour or so while they made a small hole and slipped in their sapling or other plant. In accordance with the Miyawaki method, they didn't tamp down the soil, leaving it loose and ready for quick growth. By late afternoon, the forest was planted and the final work group helped quickly erect a four-foot metal fence. We wore masks and braved a little drizzle, but the mood was light and the morale high. Numerous people told me it felt so good to feel like they were doing something to help the earth after almost two years of the Covid crisis.

Later that spring, seniors in my elective honors course, "American Environmentalism," made sets of guides for the Tiny Forest, one appropriate for second graders and one suitable for eighth graders. Each guide contained information on about twenty species, including Indigenous uses for the plants, as well as photos of the Seniors in the Tiny Forest, puzzles, and games.

Image 3. A Student Identifies Plants at the Tiny Forest, 2023.

Photo Credit: Teresa Walsh

Image 4. "Beaked Hazelnut." Watercolor by student Eve Cody, 2022.

In the approximately eighteen months since planting day, the Catlin Gabel Tiny Forest has grown quickly. While many of the pine and fir trees are still only two to four feet tall, some of the understory species, including Black Cottonwood and Red Alder, are already well over ten feet high.

Many Academic Uses

The Tiny Forest has quickly become a place on campus where students can connect with Oregonian flora. This school year, second graders investigated different habitats on campus and compared the living things they saw in them. Third graders used the Tiny Forest to learn how to spot toxic plant species. Fifth graders investigated which types of plants they might successfully grow in our small greenhouse, and visited the Tiny Forest to learn about native plants. Tenth graders partnered with first and third graders, meeting in the Tiny Forest, choosing a plant to observe closely and, then, together writing poetry about it.

A Tiny Forest Lesson: the Cross-Grade Tour

Another cross-grade use of the Tiny Forest was led by middle-school teachers Berkeley Gadbaw and Christa Kaainoa. The idea behind the assignment was to link students' experience with the climate fiction they had read in Christa's seventh-grade English classes with the climate change unit in Berkeley's eighth-grade science course. The science students ultimately led their younger peers on tours of the Tiny Forest and of some woodland nearby. For all the students, the same key goals were in place:

- Connect student classroom learning with experiences outside.
- Engineer experiences in which students teach students about fighting climate change.
- Encourage students to bond deeply with the natural environments on campus.

In order to prepare for the tours, Berkeley's eighth-grade students began with what she calls "Wonder Walks." For several days, part of their classroom time was spent outside, sitting and sketching the plants they saw. Berkeley's goal is to establish a connection with nature before students are compelled to learn "facts" about the plants. Berkeley then instructed them in the layers of the forest; students used Tiny Forest guides (made by high school students in the Spring of 2022) to learn how to identify most of its forty-plus species. From the guides, they also learned about the interdependence between species in various layers of the forest as well as Indigenous uses for many of the plants.

Next, students returned to the Tiny Forest with the goal of calculating carbon capture during its early years. All the eighth graders measured the circumference of existing trees in established forest, specifically Western Red Cedar, Douglas Fir, and Big Leaf Maple. They tagged twenty individual trees for measurements in future years. Using a great handout from the New York Sea Grant (NYSG) and the Paleontological Research Institution (https://drive.google.com/file/d/1UV_HNr-EwD4I_xZM9QfMRNVeQUx4oRVL/view?usp=sharing), students derived the trees' biomass from their measurements. Students read a graph that shows a species' diameter to biomass ratio, and then divided the biomass by two to discover how much of the tree was carbon. From this they derived the amount of carbon dioxide. They then practiced online graphing tools to indicate their findings.

This baseline of data will be used for the future, something the students could feel proud of. Finally, the eighth graders learned about heat islands and their links to historic racial inequality. (Portland is among the cities with the greatest heat differences between neighborhoods.) With a new understanding of the connection between the built environment and heat, the eighth graders grabbed clipboards and digital thermometers and measured the temperature in several places on campus, including the main parking lot and the Tiny Forest. They cataloged their results and then discussed where in Portland the next Tiny Forest might be planted to most effectively lower the temperature and provide shade where it is most needed.

Importance of forests

By the end of the unit, the eighth graders had been in the forest every single day for three weeks. First, they had had outdoor, direct instruction from Berkeley. "Being out there exceeds anything I can do in the classroom, even if I don't have a particular agenda," Berkeley said. Students then had time to sit in a different place every day, always with a physical journal to take notes and record reflection. In those weeks, they learned about the importance of forests in regulating the earth's temperature and harboring its biodiversity. They became experts on their own campus; they can point out a number of the trees and shrubs that shade the school, and they have found favorite places outside of the classroom to sit and write.

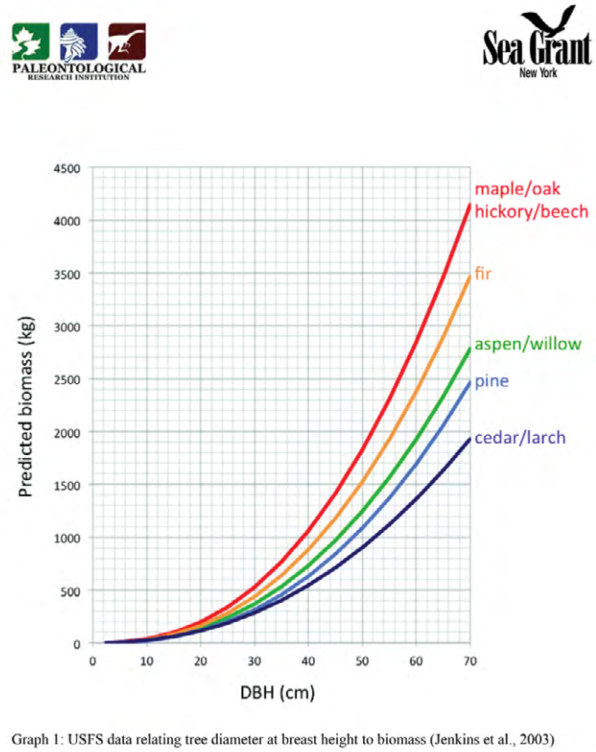

Image 5. Relative Predicted Biomass for a Number of Key Tiny Forest Species. Source: NYC Stem Summer Institute: Climate to Go!

Image 6. Beginning a Baseline. Photo Credit: Patrick Walsh

Results

In the spring of 2023, eighth-grade students from the Catlin Gabel Middle School learned about topics relevant to the Tiny Forest: the Greenhouse Effect, biodiversity, native plants, and heat islands. After three weeks of outdoor instruction and observation, the students led small groups of seventh graders on nature walks, through campus and to the Tiny Forest, in order to share what they had learned.

In many ways, the cross-grade tour was really the culmination of the assignment. This was the best and most meaningful forum for the students to demonstrate their knowledge. The conversation during the tour was the assessment, the transfer task. But since the instructor couldn't be present during the entirety of every tour, and because the interaction between students of different grades has a value a classroom test does not, she was satisfied with feedback from the seventh-grade students after they have been led around the Tiny Forest by the eighth graders and relevant areas of the broader campus. Each guest on each tour had a checklist so the instructor could see if any topics were omitted. She also asked the tour guides to turn in all their documentation. Eighth graders were required to fill out and hand in a guided note sheet (https://docs.google.com/document/d/1m8D6gNgcaQMhnqZUolTA0RNYr7jXO8qaAJw2Fz98YuU/edit?usp=sharing). Later, Berkeley quizzed the students on the content of the tour.

Berkeley and Christa were not with the students on their walks and couldn't correct errors from student tour guides or make sure every student remained focused on the task at hand. Yet entrusting students to teach their peers has more than enough value to offset the lack of teacher control. By having the eighth graders become "tour guides," Berkeley and Christa compelled them to take "ownership" of the Tiny Forest and share its value with younger members of the community.

Connections to the Next Generation Science Standards (NGSS, 2013)

Performance Expectation

MS-ESS3-3. Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

Disciplinary Core Idea

- ESS3.C: Human Impacts on Earth Systems: Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. Changes to Earth's environments can have different impacts (negative and positive) for different living things.

Cross-Cutting Concept

- Influence of Science, Engineering, and Technology on Society and the Natural World: All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment. (MS-ESS3-4)

Conclusions

The activities surrounding the Tiny Forest provided students with ways to experience how human activities have altered the biosphere and to provide avenues for positive action.

As Berkeley shared with me, it's hard to teach climate change and not be pessimistic, "even," she noted, "with a pageful of solutions." She's right: showing students how shifting diets away from red meat or creating a national market on Greenhouse Gas emissions can often exacerbate student anxiety because of our inability, working individually, to make the shifts necessary to prevent catastrophic changes during our students' lifetimes. Berkeley went on to explain that this project was a viable way of lessening climate anxiety by connecting kids to nature and to give them time and structure to notice how learning about their environment feels empowering and motivating. The lesson links students to particular plants at the school. Understanding the positive impact of careful reforestation through the calculation of carbon captured by trees in the Tiny Forest gives students the opportunity to appreciate the importance of beauty on the campus in a new way and affords their teachers the chance to tell the kids it's not too late to make meaningful change.

Learning about Indigenous uses for native plants, and then sharing that knowledge with other young people, potentially offers hope in the form of a historical connection to Nature. Realizing that other civilizations have flourished in the same place suggests there are other ways to live besides our shared American culture and its reliance on fossil fuels. More importantly, perhaps, is the lesson that climate change can best be addressed through collective action, such as the construction of a Tiny Forest. By planting trees in historically underserved areas which are so often also heat islands, communities can make a real difference in how their neighbors, especially people of color and those with the fewest economic resources, will experience their daily lives in the decades to come.

Image 7. The Catlin Gabel Tiny Forest, June 2023, Sixteen Months Since Planting.
Photo Credit: Patrick Walsh

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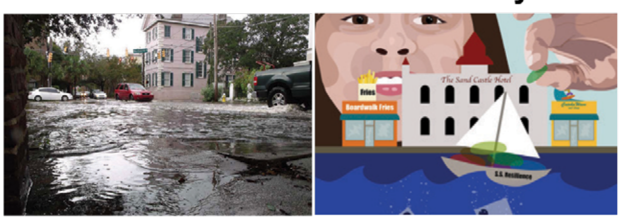

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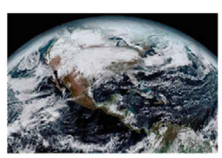

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