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Biodiversity Beyond the Four Walls

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Introduction

It is already hot and humid by mid-morning as a small group of elementary students hike through the weedy field of a state park. They are following a deer trail looking for the tell-tale signs of animal movement and trying hard not to leave too many of their own signs. Along the way their teacher points out bent stems and droppings. They stop to briefly gather some pods, already cracked open, spilling seeds on silken threads. They gently examine the plants closely for insect activity before moving on. The girl in the lead stops suddenly and motions the others to stop also. The teacher moves calmly ahead, identifies the large black snake to the students before gently encouraging it to move on with the help of his walking stick. As the group moves forward, he describes the snake's diet and defenses. The students take it all in, some asking questions, others pausing briefly to check for more nature clues.

They have their sights set on the line of trees up ahead, ready to welcome the shady temperature drop while noting other changes as they transition out of the open field. New plant species are pointed out, some to avoid, others to rub gently to learn their unique smell that leads to identification. When they break for a moment under the leafy canopy, they are encouraged to listen for the bird calls they've learned should be there, hushed excitement ensuing with each recognition. They know that there will be time to discuss and examine the day's experiences once they are back in the classroom. The classroom back at school is actually in a separate building from the main school, tucked back in the woods, resembling more of a nature center than a classroom. The returning students unpack their findings and settle into closer observations with lenses and comparisons to field guides.

Throughout the next two weeks the students will continue daily trips to the various parts of the park. They will wear old sneakers and wade through the creek, picking up rocks to study what is under them. Another day those old sneakers will find themselves in pond muck where the creek has spread and deepened allowing the organic material to settle out before the water trickles over rocks, continuing its way to larger water systems. There in the pond the students will cast seining nets, walking nervously across before tipping the nets up and transferring their catches to buckets. They will only keep them a short time for observations and identifications before releasing them. Lots of fish and amphibians in the net, are happy recompense for the smell of decaying pond plants and the occasional lost shoe. All the experiences and learning will be discussed in light of understanding the ecosystems and how to care for them.

Near the end of the two weeks the students will watch *The Lorax* movie and relate all they have learned to the importance of preserving nature and avoiding destroying it with greed the way the Onceler did. Those two weeks' outdoor experiences will empower them to speak for the trees… and the fish… and the birds… and all the other creatures they encounter directly or indirectly.[1]

The students will be so enthralled that they will return to that course and eagerly seek out similar experiences. The teacher will expand units to include a two-week stream study canoeing course, and a two-week marine ecology extended stay course held in other parks across the state. Multiple students will engage in all three learning experiences, returning yearly and recruiting others to join. All stake holders in this diverse educational ecosystem win.

From the summer after third grade through high school, these types of courses were how I chose to spend my summers. I was fortunate that my school district at the time did not just offer summer school for remediation but offered a multitude of enrichment courses. These special experiences shaped my life-long interest in, and deep respect for nature. They are my most memorable science instruction that engaged me as a life-long learner and ignited my desire to teach. I became personally connected to each of the environments and ecosystems that I encountered.

While my experiences took place outside the regular school year, it is still possible to create similar opportunities for today's students within the school year. What we need to do is move our students beyond the four walls of the classroom. We need to foster students' connections within the environments around them. Engagement builds meaning and understanding that are the foundation for sympathy and empathy. We must literally show them the interconnections, so they are more likely to care.

Demographics

I teach at Keene Elementary school in the Christina School District. Christina has historically been the largest district in Delaware and is spread out between the City of Wilmington, Suburban Newark, and the nearby region of Bear.

Our school is considered a Title 1 school and has over 70% of our students receiving free or reduced lunch. The majority of our students come from non-traditional households. Many of our families are single parent, or another relative as caregiver (grandparents, aunt or uncle, older sibling). It is not unusual for a family to have transportation and technology issues. We also have a large population of English Language Learners from a variety of cultures: Asian, Hispanic, Middle Eastern and the Caribbean. Despite this wide range of differences, Keene is a close-knit family.

I am dual certified, so I have Special Education students assigned to my room. These students' IEPs range from Speech Therapy only, to Occupational Therapy, Learning Disabilities, Autism, and Severe Oppositional Disorders. There are also children with 504 Plans for Attention Deficit Disorder. I do have a full time Special Education teacher that pushes in every other day and a paraprofessional that comes in on the interim days. We find ways to motivate and engage these students by providing as many hands-on opportunities as possible. Using a Project-based approach to content helps keep the students vested in their own learning

Location

William B. Keene Elementary School is located in a region known as “Bear” in New Castle County, Delaware. The school address is technically “Newark, Delaware” but our location is far from the bustling college town of that name. Despite the school’s proximity to some of its feeder neighborhoods, its location between a major highway, and a strip of woods, means that all students are either bus riders, or car riders, not walkers. This corridor of the highway has a very transient population and many of our students come and go throughout the K-5 grade span of the school.

Neighbors

Our location is next to the Troop Two State Police Barracks, which is a mixed blessing. We have the benefit of quick security response but proximity to the comings and goings of criminals. These issues clearly impact the school, and local, community in outdoor activities.

We are very fortunate in our other two neighboring resources. One of which is the Glasgow YMCA, and the other is Glasgow Regional Park. The YMCA has multiple programs, and also runs the Before and Aftercare program at our school. They have both indoor and outdoor swimming pools and a large amount of outdoor green space for various activities. There are pavilions with tables for gathering, as well, one of which is directly adjacent to our school parking lot.

Located across the highway with more than 250 dedicated acres, Glasgow Park has plenty of green space, an almost 3-mile paved trail, gravel trails, a catch and release pond, a skate park, large and small bark parks, tennis courts, basketball courts, playgrounds, pavilions, activity and information stations, and even a sledding hill. This park is the most accessed outdoor space for our student population. They and their families go there for playdates, picnics, community events, the farm market, and all the other amenities.

Rationale

The outdoor classroom inspires lessons across all disciplines. This unit provides necessary background knowledge, resources, and lesson ideas for teachers at any grade level to adapt for taking their own students to outdoor learning spaces. When engaging with outdoor learning spaces, it is important to consider the best ways to utilize and manage the spaces while limiting the environmental impact. There is significant need to study the existing flora and fauna, especially as these spaces are functioning in the local ecosystem. This should include learning about resources to identify native species, but also looking at the role invasive species may be filling in the existing environment. We need to consider any potential benefits being supplied by nonnative species that have become naturalized to an area, and the potential drawbacks to simply removing a species because it is nonnative. We must also explore the roles of various plant species in supporting native insect and animal populations.

Learning Objectives

The NGSS framework has three main components: Cross Cutting Concepts (CCCs), Disciplinary Core Ideas (DCIs) and Science and Engineering Practices (SEPs.), that are used to explore and understand observable events known as “phenomena.” I am interested in developing a unit that identifies phenomena and applies the NGSS standards to interdisciplinary lessons for outdoor spaces. Students will address CCCs (patterns; cause and effect; scale, proportion, and quantity; systems and system models; energy and matter; structure and function; and stability and change) and utilize SEPs (scientific inquiry - the formulation of a question that can be answered through investigation, and engineering design - the formulation of a problem that can be solved through design.)

Background Content

Historical Biodiversity

In our Yale National Initiative Seminar, *Caretakers versus Exploiters: Impacting Biodiversity in the Age of Humans,* our seminar leader Paul Turner defines biodiversity as “earth’s living variety, in all its forms and interactions.”[2] He goes on to elaborate that this diversity ranges from genetic codes, across species and communities, and includes the lifeforms and landforms that shape one another.[3] It may be diversity of interactions that is the most crucial for the continued success and longevity of our planet. The ever-changing adaptations, roles and shifts of our planet’s biota, or region-specific living organisms, are traceable through history. We can use the fossil record to study the rise and fall of many organisms from microscopic to mega sized, noting major events that created large scale changes. While there have been many periods in earth’s history that indicate extensive die-off of species, there are five catastrophic events that define our geographic record known as “The Big Five” mass extinctions. These events are identified through markers in the fossil record and the earth’s crust. Ecologists and Geologists continue to study cause and effect relationships related to major extinction events but are simultaneously realizing that we may be in the midst of a sixth mass extinction.[4]

If we only glean our understanding of mass extinctions from movies and the disappearance of dinosaurs, the idea of our currently living in a period of mass extinction is almost impossible to imagine. Most people’s working understandings of extinction are limited, (Spoiler alert: The end of the dinosaurs was not the biggest extinction event!) In fact, conceiving the extent of earth’s history overall is challenging. Extinction events, even the catastrophic ones, take place over millions of years.

One of the most compelling analogies is to put earth’s history in the context of a 24-hour clock. When illustrated that way, it is eye-opening to discover that humans have only been around for about 4 seconds. A quick Google search will provide you with multiple examples of a geologic time clock. Given humankind’s egocentric view and the rapid rate of our reproduction, coupled with the drastic rate of our destruction to earth’s ecosystems taking place in that itty bitty slice of time, the only thing that seems hard to believe about a sixth mass extinction is that it will take millions of years.

While the extinction of dinosaurs does not provide deep enough representation of extinction, they have been a common entry point of understanding. In her book, *The Sixth Extinction-An Unnatural History*, author Elizabeth Kolbert points out that very young children often play with toy dinosaurs and quickly grasp the concepts that the toys represent creatures that were very much larger, and that those same creatures no longer exist.[5] Adults reinforce the concepts by using dinosaurs as a point of reference for both something from "a long time ago", and something that is "all gone." By the time they reach school-age, most children can readily explain these concepts without great difficulty. So common is this understanding that you may find yourself as surprised as I was to learn that the notion of extinction wasn't developed until the end of the 1700's by a naturalist at the Paris Museum of Natural History by the name of Cuvier.[6]

I never considered how people came up with extinction as an occurrence, and prior to Cuvier's work, no-one seemed to consider that an animal species might cease to exist. Even in the early 1700's when large bones and fossils began to be found and studied, there was still an assumption that the animal which they represented was still "out there somewhere" waiting to be discovered alive. Cuvier instead explained that there were species that had somehow become "lost" due to an unknown, overwhelming disaster.[7] There is significant correlation between the loss of additional species and the introduction of humans and their predecessors leading most scientists to believe that human actions are an overwhelming, extinction-inducing disaster.

All the mass extinction events are believed to be a combination of global climatic changes and loss of biodiversity which brings us back to the present and our supposed sixth extinction. With global warming, land and water degradation, and world-wide biodiversity losses, the evidence for another mass extinction event is mounting. Our current COVID-19 global pandemic only strengthens concerns and the call to action.

Preserving Biodiversity

While the bad news is that humans have historically been a major agent of change affecting biodiversity, conversely, the good news is that humans have been a major agent of change affecting biodiversity. Many of the same traits that have brought negative impacts to biodiversity are the same that have motivated those seeking to preserve it. So, we are both exploiter and caretaker, but we need to decide on which side to expend our energies. We have made grave and careless mistakes, unintentional mistakes, short-sighted mistakes, but we are trying to improve. I am a firm proponent of the philosophy "Do the best you can until you know better. Then when you know better, do better." which is attributed to Maya Angelou by Oprah Winfrey[8]

Dynamic Biodiversity

The teeming coral reefs with all the bright colors and schools of fish reversing directions, or the dripping rainforest with chattering animals, rainbow plumage, and iridescent insects are classic representations of biodiversity. Many people however won't see these places in person. Students we teach might live in a concrete jungle or cookie cutter suburbia, but the biodiversity is there, nevertheless. The diversity might be muted, corrupted, or interrupted but we can teach students to find it and nourish it. Biodiversity is geographically specific (local) but globally connected (worldwide) so we need to help students understand that preserving it means starting with our own immediate surroundings.

The Language of Biodiversity

When considering language, it is important to note that it is "a body of words and the systems for their use

common to a people who are of the same community or nation, the same geographical area, or the same cultural tradition,"[9] hence the *diversity* of languages.

Why is this important to note? Words can be subjective based on cultural, political, religious, and economic factors. Words chosen to describe things often have different connotations or value and they have the potential to become buzzwords or trigger words if so employed. The subtleties and subjectivity of language is seen in the variation of terms throughout our own federal government's handling of species management through terms like exotic, alien, invasive, and non-native.

The National Invasive Species Council (NISC) and the Invasive Species Advisory Committee (ISAC) were formed in 1999 by Executive Order 13112 under the Clinton presidency. This order superseded the earlier Carter Executive Order 11987 that had restricted the import of exotic (non-native) species to federally owned lands or the export from those lands of native species to be introduced outside of the U.S. in an effort to protect ecosystems.[10] The purpose of NISC and ISAC is not only to control importing and exporting of species for federally owned land but for the nation overall, in addition to controlling existing invasives and ecosystem restoration. To direct their goals a national management plan, The National Invasive Species Management Plan, was released in 2001, last updated 2016.[11]

Executive Order 13112 included a short set of definitions to establish common understanding of purpose but in 2006 the NISC published a paper to further define and clarify terms related to species management. The purpose of the paper was "to provide a non-regulatory policy interpretation of the term invasive species by identifying what is meant and, just as important, what is not meant by the term."[12] Intended as a document to educate those involved in the processes of species management and to provide conflict resolution, specifically providing "insight into those areas where societal judgments will be necessary to implement effective public policy."[13]

For many generations plants and animals fell into two basic categories, good or bad. An animal was either a meal or a varmint, plants were either a flower/crop or a weed. These mutually exclusive descriptors were sufficient cause for increasing numbers in the good category and eliminating those in the bad. Even the more recent terminology of native and non-native have a positive versus negative connotation. Reality (and biodiversity) is much more nuanced than that. While the consensus is that native is best, there are other scientists that argue otherwise. There are arguments that claim that the view of all non-natives as villains is unscientific and borderline xenophobic.[14] There is research that says some non-natives may fill an important niche in an existing ecosystem, and that some ecosystems are strong enough to prevent even aggressive non-natives from becoming established.[15] Despite differing views on the specifics, all scientists agree that species management in ecosystems is highly dependent on the location of the ecosystem and must be done with careful consideration for long-term results..

Having been a life-long environmental enthusiast, educator, and gardener, I thought I had a pretty good handle on "the good, the bad, and the ugly" of ecosystems. My research has been an eye opener. Sometimes I felt like the more I discovered; the more complicated things became. As one of my resources stated, "As a rule, ecological terminology is messy; discrete ecological categories rarely exist."[16] I think the language of biodiversity is just as dynamic as the topic due to its local adaptations, increased understanding, and continued developments. Across the United States there are state and regional guides that might further clarify your specific area's terminology. For the purposes of background content, I will present the most universal terms as I have come to understand them from multiple resources. Keep in mind that all of these

terms are geographically dependent.

- **Native/Indigenous**: Regional/Ecosystem specific. Species originating within that area/system and naturally established over extensive time. For example, only plants that existed in North America prior to the arrival of Europeans are considered native.
- **Non-native** (Alien, Exotic): Regional/Ecosystem specific. Any species, including any aspect allowing reproduction or propagation, that has been introduced by human activity to an area/system where it does not naturally occur. Introduction may be accidental or intentional but is often without human understanding of consequences. Exotic is used to describe species non-native to a whole continent. Some non-native species are dependent on human intervention for survival or continuation. Other non-native species are able to make it on their own in their new environment.
- **Naturalized**: Any non-native species that has succeeded in becoming established (reproducing) within an area/system without human intervention. Many naturalized species have existed for long periods of time and may not even be recognized as non-native if they have not had a negative impact on the environment or economy. Perception of impact as positive or negative may be regionally/culturally specific. However, the term is typically applied to species that have neutral impact, while the next term is applied to those that have negative impact.
- **Invasive**: Any naturalized non-native species that causes environmental harm by depleting resources for native species, altering ecosystems physically or chemically, even at the micro-level, disrupting the reproduction/survivability rate of native species, and rapid reproduction even across geographical boundaries. Typically, these impacts also happen at a much faster rate than local species processes or adaptations which then decreases biodiversity. Invasive species that impact the human species' health, economics, and activity usually attract the most attention and management efforts.
- **Invasive Watchlist**: Regional/Ecosystem specific. A list of invasive species that are occurring nearby and are a threat to another specific region. Often these are published by states or counties in an effort to enlist public assistance in identification, tracking and management. A current example is the Spotted Lantern Fly that is causing significant tree damage. Last year it was on my state's watchlist and this year it has officially become an issue for the northern part of our state.
- **Aggressive/Opportunistic Native**: A native species that spreads faster than other local species within an ecosystem when that system has been disrupted. Disruptions frequently occur from human activity but may also occur from natural causes such as storm damage, flooding, drought, and more.
- **Nuisance**: Any species, native or non-native, that is considered undesirable in relationship to human activity. Highly subjective and often controversial.
- **Noxious**: Any species that can harm human health or activity, or harm other species or environments integrated into human activity such as plant cultivation/harvesting, domesticated animals and land or water usage. For example, poison ivy, the bacteria that causes Lyme's disease, or the virus species that cause COVID, specifically COVID19.

Case Studies

With the above terminology in mind, let's look at a few real-world examples to witness the complexity of biodiversity, human interactions and becoming caretakers.

Case Study #1 - A Carbon Conundrum

Most of us are aware that global warming is a scientifically established issue attributed to the increase of certain gases in our atmosphere, especially carbon. Carbon is an integral part of our planet's systems and is constantly cycling through species living and dead, plus the earth, water and air. It is most notably exchanged between the flora and the fauna of our planet. When human activity impacts the biodiversity of a species or region on a large scale, one of the negative consequences has been the disruption of the carbon cycle resulting in excess carbon present in our atmosphere. As humans have begun to better understand the negative consequences of some of our activities, there have been efforts to restore or replace affected species.

Deforestation where large sections of forest were either harvested or destroyed has been addressed by the practice of replanting trees in those areas. It was a simplistic initial solution that was better than doing nothing at all, even though most trees take years to grow to maturity. Fortunately, environmentalists and scientists didn't stop there but have continued to look at other ways to address the problem. They keep doing the best they can, and as they study more, they must decide which practices are better, and for whom.

In a research article published in the May 2020 issue of *Science*, results of a New Zealand experiment showed that exotic (invasive) plant species interact differently with micro and macro organisms in the soil resulting in a higher level of carbon release.[17] Two of the researchers published an additional article discussing their findings in layman's terms. They explained that the presence of the exotic plants as a new element of the ecosystem, particularly within the soil, acted as a stimulus to the existing soil species. The increased soil activity resulted in increased response from the exotic plants with better use of nutrients and faster growth/maturity. That part isn't exactly surprising based on the benefits of rotating crops for better soil health and plant growth. But the faster maturity resulted in the exotic plants having a shorter life span than their native predecessors. Once dying or dead, the exotic plants were also decomposed more quickly and completely by those same stimulated soil systems than their native counterparts. The sped-up dynamics of the altered ecosystem resulted in a greater release of carbon from the soil in a shorter time frame.[18]

While the above research was conducted on exotic plants, there are similar concerns when planting regular non-native species. Many times, non-natives have been chosen for reforestation in third world regions with the largest tracts of deforestation based on economic resources and needs. Overall, reforestation programs are focusing on ways to reestablish diverse native species by providing appropriate support systems to young plants.

Case Study #2 – Hurry up, then Wait

Reforestation done right is a slow, thoughtful, research, and labor-intensive process. In her book, *Braiding Sweetgrass*, author Robin Wall Kimmerer shares stories of places through both ancient indigenous and modern-day interactions. She highlights the beautiful and fulfilling experiences that take place when humans interact respectfully and responsibly with nature.

In the Pacific Northwest giant forests grew between the Pacific Ocean and the Cascade Mountains. Over a hundred inches of rain annually classifies them as rainforest and they boasted all the biodiversity one typically associates with the rainforest. Indigenous people lived there and made the most of the bounty available from both the ocean and the forest. They dubbed the massive cedar tree "The Tree of Life" and they incorporated it in every aspect of their existence. Most notably they made use of the tree without killing it by harvesting only small portions from multiple trees: branches, roots, long single strips of bark and even single planks from

living trees. Larger items such as canoes and even coffins were fashioned from fallen trees, possible because cedar is highly resistant to rot. They even clothed themselves in The Tree of Life with fibers created by beating and scraping the bark strips. So, the trees continued to grow strong, healthy and massive and the forest thrived.

The forest was already an old growth forest when America's European settlers arrived at this particular area in what is now known as the state of Oregon.[19] The native people were the first to suffer from the non-native invasion. By the mid-1800s diseases and violent encounters with settlers had wiped out most of the population. In 1855 the indigenous people were forcibly removed to reservations and the land ceded to the federal government.[20] The logging began in the 1880s and it would take weeks to cut down the giants with a two man saw. They thought it was an endless supply of trees so over time they took them all, including the second generation.[21]

Flashforward to the late 1900s and the arrival of Franz Dolp to forty acres on Shotpouch Creek, near Burnt Woods in the middle of Oregon's Coast Range. The land was ravaged by clear cutting which allowed the opportunistic plant species to take over. These plants rely on rapid spread to make the most of the disturbed soil and open sunshine resulting in an explosion of stems, leaves and vines and no investment in hardwood growth. They are in a competitive race to monopolize all the available resources which earns them another apt moniker, "pioneer species." Eventually trees will regrow, and the forest ecosystem will rebalance and increase in diversity, but this takes a very long time.

Franz' forty acres along with most of the surrounding area was considered timberland rather than forest. The Oregon Department of Forestry was focused on planting quick growing Douglas fir, an industrial forest. Even though the Douglas fir is native to the region it was unnaturally planted thickly to maximize harvest potential and chemicals were used to control understory competition. Franz referred to the patches of industrial monoculture as fir lawns which were not his objective. His objective, his dream, was to instead rebuild the old growth forest.

Franz was already in his fifties when he embarked on his ambitious reforestation project. He knew he had to accelerate the natural forest succession process. To begin he looked to remaining sections of old growth forest to understand plant growth in relation to location. Eschewing chemical use for the preservation of biodiversity, he hand-cleared the overgrown pioneer species and preserved existing trees. He planted hemlock, fir, and cedar by the thousands. He tended his new forest, replacing trees lost to natural causes like beavers and deer. When health set him back, he hired others to help. Franz's forty acres is now home to some thirteen thousand trees, old growth children.

Franz knew that the jumpstart he provided his forest was important, but he also knew that its value was in its longevity. His work at Shotpouch focused on reforestation but he discovered that his communion with the land was personally restorative. Franz knew that his dream would live on by sharing his forest and old growth philosophies with others. To ensure future generations would benefit from and continue his work, he established a partnership with Oregon State University to create the Spring Creek Project. He dedicated his cabin at Shotpouch as a retreat for writers, philosophers, scientists and artists to exchange thoughts and experiences inspired by their own communes with nature there.[22] Like the indigenous people that long preceded him, Franz Dolp exemplifies what it means to be a caretaker.

Case Study #3 - Farmers' Friend/Forest Fiend

Have you ever seen any of the "I was today years old when I learned…" memes on social media? Sometimes I read them and think, "Well yeah, I thought everyone already knew that." and other times, "Huh, hadn't thought of that one!" Every once in a while, I am truly surprised by learning some unexpected fact. The ones that I appreciate the most are little known facts about everyday stuff, so I offer you this: I was today years old when I learned that earthworms are not native to North America.

What?! But they are everywhere, and they've been here for ages and ages, and they help the soil, and they help organic material decompose! Oh wait, they must be naturalized non-natives. Phew, okay, no need to completely question everything I've taught students about earthworms across my entire career! Good thing I went to Yale to learn this new tidbit, though. But I also learned to question all my previous understandings of native and non-native species, so I did more research. This is where the regional/system specific factors come into play when analyzing the role a species fills in a particular ecosystem.

For years I have taught about earthworms in conjunction with teaching about soils. In addition to identifying the three components of soil (sand, clay, humus), we study how the different proportions of the components affect plants' growth. We talk about the factors of composition, permeability, water retention and nutrient availability. Earthworms are nicknamed "Farmers' Friend" because they are seen as positively affecting soil quality on each of those factors. It makes perfect sense in our region where our soils contain a high level of clay and worms contribute to the mixing of organic materials into the clay and their tunnels allow water to travel through its denser composition. It had never occurred to me that the beneficial earthworms in my region would cause a problem elsewhere.

In a 2007 interview with National Public Radio, Peter Groffman, senior scientist at the Institute of Ecosystem Studies in Millbrook, New York shared information about the impact of earthworms in northern regions of North America. He explained that there are native earthworm species in the lower regions of North America, but they aren't the ones we typically see and associate as earthworms. The earthworms we commonly know came over with European settlers like so many other non-native species. In addition to the European earthworms there has also been a rapid spread of Asian earthworms that are classified as invasive. It is believed that native earthworm species in the northern portion of North America were driven extinct in the last ice age. Above the glacial boundary, forests are characterized by a heavy floor layer of humus mostly made up of leaf litter. As non-native earthworms' territories expand northward, or humans transport them, they are causing significant changes to the forest ecosystems. When these earthworms become established in the northern forest ecosystems, they are depleting the existing thick layer of the forest floor which damages the native species habitat, allows opportunistic species to gain a foothold, or leads to erosion and root exposure. These drastic changes take place in an alarmingly short time.[23]

Additional articles echo the findings above but add further dimension by identifying species such as understory plant species, fungi, microorganisms, invertebrates, and vertebrate species such as salamanders that suffer from the loss of the thick humus layer.[24] The role of humans in spreading the invasive earthworms is further complicated by the prevailing notion that earthworms are good for the soil. People add them to gardens and compost piles believing they are beneficial, but they can eventually spread to the forests. The direct transport to the forest typically happens when leftover bait worms are dumped by fisherman. Repeated education about the problems of invasive earthworms are required to change the existing mindset towards earthworms. Alternative procedures must also be taught to change the way people handle earthworms.[25]

In his NPR interview, Peter Groffman "joked" that the problem with earthworms is "Global worming" but then explains that the relationship between worms and global warming goes beyond wordplay.[26] That notion is further supported in a 2019 New York Times article about the movement of earthworms into the most northern forests, known as boreal forests. These forests are found circling the northern end of the planet, so it is a global concern. Boreal forests are characterized by a cold, wet climate and possess an even thicker layer of leaf litter. The earthworm colonies they are finding established there are devouring the leaf litter, but they are not burrowing and mixing those nutrients into lower layers of the soil which means they release all the carbon from the leaf litter directly back into the atmosphere. Much like findings from the Carbon Conundrum case study, this increased release of carbon back into the atmosphere will contribute to global warming. In keeping with the cyclical nature of ecosystems, global warming is contributing to the earthworm's invasion further and further north, all the way to the permafrost line. Damage to forests at the permafrost line hastens melt. While the boreal forest has been a major storage sponge for carbon, damage to that system can result in irreversible carbon release to the atmosphere and accelerated global warming.[27]

Rethinking our relationship to earthworms and their relationship to ecosystems is necessary to the preservati9on of biodiversity.

Case Study #4 - Worn-out Welcome

I've always associated the return to school with the coming of Autumn. The transition in temperatures and the changing length of day are a signal to many species to begin their migratory journeys. The call of geese overhead flying in their V-formation is a classic herald of the coming season. So, several years ago when we returned to school to discover large flocks of Canadian geese grazing across the school grounds, we were understandably surprised and confused.

What was believed to be a brief respite on their journey turned into a veritable siege that lasted for weeks. The geese interfered with school traffic, intimidated pedestrians going from cars into the building, took over the playground preventing normal recess, and covered all horizontal surfaces with endless goose poop. We daily wondered when on earth they would leave. Eventually they did leave but the scenario has repeated itself every year since, with the geese staying longer and returning intermittently throughout the school year.

A 2016 study by the University of Delaware explains human actions that have led to the scenario described above. First, Canadian geese from other parts of the country were brought in to stabilize/increase the existing Mid-Atlantic population. This translocation happened in the 1930's and 40's by well-intentioned wildlife biologists. Second, the development of suburban sprawl in the following decades created such an inviting environment that many of the swelling geese population had no need to migrate. These geese capitalized on the easy food source of cut grass lawns, open greenways of parkland, recreational areas, or commercially owned and maintained properties. The same geese turned to manmade bodies of water such as retention ponds and reservoirs for their nesting sites. All the human activity in these feeding and nesting areas kept them relatively predator free so survival and reproduction rates increased. Those individuals that did not migrate passed those behaviors on to their offspring which over time created a subspecies of geese that had adapted to a nonmigratory existence. This subspecies of geese is now known as resident Canadian geese.[28]

The very same factors that drove the adaptations of Canadian geese cause them to often clash with humans and their activities. Despite any negative impacts, Canadian geese are not an invasive species because they are native to North America, and even though they choose not to migrate they are still protected by migratory bird laws.[29]

A 2004 fact sheet published by Rutgers Cooperative Research and Extension explores the pros and cons of resident geese populations. In addition to the kinds of problems shared in my school's experience, geese have also been determined to contribute to crop damage, erosion issues and water contamination. Not only are water sources often found to have illness inducing bacteria from goose feces, but they can cause oxygen depleting algae blooms that damage the water ecosystem. On the pro side, resident geese contribute to the local ecosystem through seed dispersal, plant control and as a food source. Recreational hunting and birdwatching are also listed as pros along with the interesting quality of aesthetic benefit, the enjoyment of their mere presence or existence.[30]

Because they are native, and human reactions to their presence may be positive or negative, these resident Canadian geese are more appropriately described as a nuisance species. While they may be described in some less kind terms around our school when fire drills result in slimy shoes (even the most careful of students and teachers can't avoid it) or we are on our third week of indoor recess because the playground and the parking lot are equally covered in goose goop, we still respect that they are living creatures that are now a part of our ecosystem. Accordingly, we turned to Wildlifehelp.org that promised "civilized solutions" through the use of deterrents.[31] We will examine those recommendations more closely in our classroom activities.

Conclusion

There is a lot of gray area but ultimately the pattern that appears is that when humans interact with other species there are consequences for the species involved, which brings us back to the question of whether we chose to behave as caretakers or as exploiters.

If we educate others, particularly our youth, about the importance of diversity within ecosystems/regions, and the consequences of human actions, we can improve the likelihood of caregiving. If we allow students to grapple with the gray areas, explore benefits and drawbacks, identify the viewpoint and roles of species beyond themselves, they become more vested in the process of caretaking. If they learn to respect, appreciate and care for the species and biodiversity around them, they are more likely to value biodiversity elsewhere around the earth.

Teaching Strategies

As represented in the case studies above, scientists have been struggling to understand the repercussions of environmental problems and finding ways to make reparations to damage already done, while still seeking to make better environmental choices. There is a lot of information, some of it conflicting, and much of it "unconnected" to our student's daily lives. One of the best ways to hasten our progress is to open our student's eyes to environmental concerns by building connections and modeling responsibility. In the classroom we often seek to improve reading comprehension by encouraging students to build text-to-self, text-to-text, and text-to-world connections. Exploring phenomena in the environment surrounding school will help teachers and students become active caretakers by supporting environment-to-self, environment-to-environment, and environment-to-world connections. The term phenomena, as defined by the Next Generation Science Standards (NGSS.), refers to relevant, real world observations of occurrences or problems that drive inquiry-based learning.[32]

At my school we established an outdoor classroom a few years ago. Each year we have sought to improve upon the classroom's set up and usage. We have found that one of the factors frequently cited by teachers is that they aren't sure how to use the space beyond one or two formal science lessons. The purpose of the outdoor classroom should be to connect students to the environment around them which is the beginning of learning to be an environmental caretaker.

One of the ways to encourage use of this valuable resource is to empower students' (and teachers') familiarity with the space and the types of things they might encounter there. By participating in introductory tours for all the outdoor spaces of a school, students have the opportunity to begin building connections and ownership for those spaces. Using the outdoor spaces for less formal lessons such as independent or partnered reading, fine arts classes, and general data collection will further grow students' connections to their surroundings.

Another way to encourage inquiry in the outdoor spaces is to provide easily accessible support materials such as reference charts, hand lenses, and even binoculars. Students can keep field journals to record observations. A school camera can generate excitement for documenting experiences. Inviting students to establish and maintain these support materials will encourage caretaking of supplies.

Teach the language of biodiversity. Primary children don't need cutesy names for living things only to have to learn their proper ones later. Teach them common terms and names so that they may share a common language. Older students should learn scientific names as they apply. Resist the urge to attribute descriptors like good or bad, instead introduce the gray areas and the idea that a species may fulfill different roles depending on its location and the type of ecosystem.

Admit what you don't know or share beliefs that have changed as you learned new information. Acknowledge that our understanding of earth and its inhabitants is an ever changing, growing body of knowledge as this reflects the dynamic nature of biodiversity. Model engaged responsibility in the outdoor and indoor spaces of the school. Be an explorer alongside your students, share your wondering and concerns along with theirs in reflective community discourse.

Activities/Lessons

Developing this unit in the midst of the COVID-19 pandemic presented a unique set of challenges. No-one is sure when, if, or how, we will return to the classroom for instruction in the next school year. I have included suggestions for virtual adaptations accordingly.

Activity 1 - Concentric Circles

When I teach children about their place in the world both socially and geographically, I use a bullseye type graphic. Capitalizing on their still egocentric viewpoint, I place them in the middle of the bullseye then build out the surrounding rings such as: me. class. grade-level team, pod, school or me, home, building/street, neighborhood/complex, town/region/city, county, state, country, continent, hemisphere, and so on. As a group we discuss our roles in each of those circles while I emphasize that we are still a part of each circle. We don't cease to be a part of one circle as we move to the next, we just become part of a larger whole. This same graphic can then be used to consider the different roles other species may fill in an outward expanding ecosystem.

(Virtual Adaptation: This is an activity that can be completed simply on Zoom with the teacher and students creating their bullseye graphics on paper. For a more tech involved adaptation, the graphics can be completed using other online platforms such as Jamboard or Whiteboard.fi. It is important to hold the group dialogue to process the idea of embedded relationships, the graphics are just the visual representation of those relationships.)

Activity 2 - Eye for Biodiversity

As mentioned above, dynamic biodiversity is easy to recognize in some ecosystems and more challenging in others. To help children develop a discerning eye for biodiversity they should be exposed to many variations. While the eventual goal is to have them make these observations in actual outdoor settings, students can be primed by practicing these skills using images or videos. Beyond just recognizing the biodiversity, capture the students' natural observations and curiosity, encouraging them to think about the relationships that might exist. Have students place wonderings on a class chart or in their field journals. Start with easier images as a whole group activity, modeling as necessary. Move on to more challenging or less obvious images as a whole group prior to having students work in small groups, with partners, or independently. You can even set up an activity center for this using old calendar pages. Add additional complexity by comparing/contrasting images and having students hypothesize cause and effect scenarios. When able to, have these students apply these observation and inquiry skills to their outdoor spaces.

(Virtual Adaptation: Easily screen share images during a Zoom, have students search for their own image examples to share. There are many live cam streaming sites through zoos and other conservation organizations that might be useful but precheck before sharing. I also took photographs and video of our actual school spaces in the event we are online only. If unable to access school spaces, use outdoor spaces around your home in live or recorded sessions.)

Activity 3 - Seasonal Shifts

Have students use their field journals to record observations about their outdoor spaces at the beginning of the school year and write predictions about what changes they expect to happen across the school year. Schedule regular returns to the spaces to make new observations, analyze previous predictions and possibly make new ones. Class dialogue about their journals is essential to help students share their thinking and grow their understanding. Provide support materials for students to do research to support their thinking. If possible, have students draw or take pictures to document and compare throughout the year.

(Virtual Adaptation: Our quarantine experience this past spring was that many students were not able to get outside much during the day. First, the teacher should select a specific area outside of their own home to allow students to make their observations. Ideally use a combination of livestreaming and still images. Second, have students pick a view out one of their windows to document changes across the school year. If possible, students or a family member could take pictures of the view. Prior to making this request of students, share examples of a variety of views and model potential observations/predictions. Recognize that some students might not have much of a view or be embarrassed about their view. Offer ahead of time to supply a window view to anyone on request, making sure it is separate from the whole class' observation site.

Activity 4 - One Small Square Survey

Activity inspired by the *One Small Square* science series by Donald Silver and Patricia Wynne. Working independently or with a partner, students will plan their own investigation survey for a square foot area. They

will create/construct an open square foot out of their chosen materials (rulers, paper, cardboard, straws, etc) They will plan an area to survey, and predict what they will observe. Observations will be recorded in their field journals, data recorded on a data table, and a graph representation created. They may change their location only two times if they are unsatisfied with their initial survey results but must document the reasons. Students will analyze their findings and present to the rest of the class.

(Virtual Adaptation: Explain the investigation to the whole group on Zoom, sharing video of your available outdoor spaces to survey, then utilize breakout rooms to create groups of 2-4 students to complete all the planning phases of the investigation. Set up recorded small group Zoom sessions for you to construct the open square foot according to their specifications then video its placement in a location of their choosing - no changing possible in this version. Because it is a recorded session, students can take their time to make observations and record their data. May require multiple Zoom sessions for students to small group collaborate then share their investigation findings with the whole group.)

Activity 5 - A Fowl Situation

This is an activity directed at problem solving a very real issue for our school. Perhaps you can relate, otherwise look for other problems/challenges directly impacting your own school community that highlights the complexities of human/natural interactions.

Case Study #4 above recounts a problem we have been having at our school, and shares pros and cons related to the particular geese species involved. As with most established species that are altering an ecosystem in some undesirable way, total eradication is not an option which leaves us to look instead to management options. The Wildlife Help website offers multiple suggestions of various difficulty. Students will review the issue at hand, determine if there is a problem, and if so what is it specifically. Students will analyze the various control options for feasible use and expected level of improvement. If determined necessary, we will implement the controls and track the results. This may require engaging other stakeholders in the school community for financial or physical support.

(Virtual Adaptation: This could possibly work with video and image documentation, but it would lack the community effort/involvement possible in person. Given the residential adaptations of the geese I suspect the situation will still exist once COVID precautions subside. Then the geese are going to want to find ways to manage the pesky humans suddenly invading their space!)

Appendix on Implementing Next Generation Science Standards (NGSS)

Delaware has been transitioning our science program to the NGSS. In 2014, Delaware and Rhode Island even collaborated in analyzing the alignment of science curriculum kits with the NGSS to determine how existing curriculum materials could be adapted, and what new resources were needed.[33] The important thing to note is that it is much the philosophies involved in the NGSS as the standards themselves that are important.

Specific Standards Addressed

While the standards shown here are specific to the activities described above, there are many additional standards that could be addressed based on grade level and subject focus.

Life Science

2-LS4-1 Biological Evolution: Unity and Diversity – *Unit overall /Activities 1, 2, 4*

Make observations of plants and animals to compare the diversity of life in different habitats.

3-LS4-3 Biological Evolution: Unity and Diversity – *Unit overall*

Construct an argument with evidence that in a particular habitat some organisms can survive well, some survive less well, and some cannot survive at all.

3-LS4-4 Biological Evolution: Unity and Diversity – *Activity 5*

Make a claim about the merit of a solution to a problem caused when the environment changes and the types of plants and animals that live there may change. [Examples of environmental changes could include changes in land characteristics, water distribution, temperature, food, and other organisms.]

5-LS2-1 Ecosystems: Interactions, Energy, and Dynamics – *Unit overall*

Develop a model to describe the movement of matter among plants, animals, decomposers, and the environment.

Earth and Space Science

K-ESS2-2 Earth's Systems – *Unit overall*

Construct an argument supported by evidence for how plants and animals (including humans) can change the environment to meet their needs.

5-ESS2-1 Earth's Systems – *Unit overall / Case study #1*

Develop a model using an example to describe ways the geosphere, biosphere, hydrosphere, and/or atmosphere interact.

K-ESS3-1 Earth and Human Activity – *Unit overall / Activity 1*

Use a model to represent the relationship between the needs of different plants and animals (including humans) and the places they live.

NGSS Terms and Structure

To aid in understanding the NGSS I have organized the terms in the same format as the standards themselves. Be sure to make use of the NGSS website because it is loaded with information and tools. They even have tools for evaluating existing curriculum materials and for developing NGSS aligned lessons and example phenomena.[34]

Title – Core Idea

Performance	*Performance Expectation (PE)* - What students should be able to do by the end of instruction (years or grade-bands)

Three Dimensions Foundations	*Science and Engineering Practices (SEP)* A set of skills and a set of knowledge to be internalized that reflect the major practices that scientists and engineers use to investigate the world and design and build systems.	*Disciplinary Core Ideas (DCI)* Have broad importance within or across science or engineering disciplines, a key tool for understanding or investigating complex ideas and solving problems, relate to societal or personal concerns, and can be taught over multiple grade levels at progressive levels of depth and complexity.	*Crosscutting Concepts (CCC)* Concepts that hold true across the natural and engineered world used to make connections across seemingly disparate disciplines or situations, connect new learning to prior experiences, and more deeply engage with material across the other dimensions.
Coherence	• Connections to other grade level DCIs • Cross grade level DCI connections • Common Core State Standards connections across Content Areas		

Resources

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Case Study #3

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Case Study #4

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Clear terminology source.

Next Generation Science Standards, July 10, 2020. https://www.nextgenscience.org/.

Massive resource for all things related to the science standards including videos, quick references, rubrics and a searchable database.

Paulin, Joseph, Positive Benefits and Negative Impacts of Canada Geese § (2003).

Case Study #4

Schwartz M.W. (1997) "Defining Indigenous Species: An Introduction". In Luken, J. O., Thieret J.W. (eds) *Assessment and Management of Plant Invasions*, 7–17. New York, NY: Springer, 1997. https://doi.org/10.1007/978-1-4612-1926-2_2

Helpful overview of terminology and how it varies. Uses Indigenous rather than native.

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Case Study #4

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Notes

[1] Dr. Suess, *The Lorax*

[2] Paul Turner, *Caretakers versus Exploiters: Impacting Biodiversity in the Age of Humans* 7/14/2020

[3] Ibid

[4] Elizabeth Kolbert, The Sixth Extinction 3

[5] Ibid, 22

[6] Ibid, 28-30

[7] Ibid, 42-46

[8] http://www.oprah.com/oprahs-lifeclass/the-powerful-lesson-maya-angelou-taught-oprah-video

[9] https://www.dictionary.com/browse/language

[10] https://www.invasivespeciesinfo.gov/executive-order-11987

[11] https://www.invasivespeciesinfo.gov/federal-governments-response-invasive-species

[12] https://www.invasivespeciesinfo.gov/invasive-species-definition-clarification-and-guidance

[13] Ibid

[14] https://www.nytimes.com/2016/03/01/science/invasive-species.html

[15] https://link.springer.com/chapter/10.1007/978-1-4612-1926-2_4#citeas

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[18] https://theconversation.com/planting-non-native-trees-accelerates-the-release-of-carbon-back-into-the-atmosphere-139841

[19] Robin Wall Kimmerer, *Braiding Sweetgrass*, 277-80

[20] https://oregonencyclopedia.org/articles/kalapuya_treaty/#.XyV9b25Fw2w

[21] Robin Wall Kimmerer, *Braiding Sweetgrass*, 282-3

[22] Ibid, 282-91

[23] https://www.npr.org/templates/story/story.php?storyId=9105956

[24] https://www.jstor.org/stable/3868431

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[34] https://www.nextgenscience.org/glossary