Teaching complex ecological concepts through a demonstration garden: Biodiversity, invasions and conservation in practice

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Abstract:

Biodiversity encompasses the variety within and between species in an environment. Native communities host a diverse array of species and interactions between members. Invasions by non-native species reduce biodiversity and a community's ability to support diverse assemblages, and are one of the largest drivers of modern species extinctions. The Keep It Native Demonstration (KIND) Garden demonstrates the differences between invaded and intact plant communities. Utilizing this resource, we developed an inquiry-based activity for grades 5-7 that focused on observational data. Student groups recorded the number of animal and plant species in multiple habitat types. We then compiled data from the separate groups and averaged the number of species observed in each habitat type. The results were graphed to enable students to visualize the differences in species diversity among habitats. This exercise illustrated differences in species richness and diversity between invaded and native plant dominated areas and allowed students to begin initial data interpretation. We provide methods for this activity, strategies for implementing the activity on other sites, and adaptations to accommodate different grade levels and the associated Next Generation Science Standards.

Keywords: *Biodiversity, conservation, invasive species, demonstration gardens, ecology.*

Biodiversity includes the full extent of diversity of organisms at all scales, from the diversity of ecosystems in a biome to genetic diversity of a single population of species (Gregorius et al., 2003). Ecosystem goods including food, fiber, fuel and services such as flood mitigation, disease resistance and soil regeneration, which all tangibly benefit humanity, are dependent upon high levels of biodiversity (Pejchar & Mooney, 2009; Tilman et al., 2011).

Habitat loss and invasive species rank highest among factors affecting species loss and threats to biodiversity (Brook et al., 2008; Pejchar & Mooney, 2009; Simberloff, 2001; Wilcove et al., 1998). Wilcove et al. (1998) estimated that 49% of imperiled species were impacted by non-native invaders. Introduced predators may directly impact native species through increased rates of consumption, while non-native plants may alter habitats to exclude native herbivores and outcompete native plants (Gurevitch & Padilla, 2004; Simberloff, 2001). Invasive species are responsible for nearly $120 billion of environmental damages and economic losses annually in the United States (Pimentel et al., 2005). Even perceived advantages of invasive species, such as increased habitat for a single native species, may be ephemeral and are actually negative in the long term (Pejchar & Mooney, 2009).

The Intergovernmental Panel on Climate Change and other governing and advisory bodies have expressed steadily increasing concern about the state of the environment (Cardinale et al., 2012; Collins et al., 2013; Intergovernmental Panel on Climate Change, 2014). A decline in biodiversity and ecosystem productivity is particularly worrisome to scientists (Hooper et al., 2012; Isbell et al., 2013). Preventing invasions is the best means of reducing the negative effects of invasive species, because maintaining high levels of biodiversity within populations,

communities and ecosystems increases ecosystem function and resistance to invasions (Benayas & Bullock, 2012; Tilman et al., 2012; Walker, 1992).

As recognized in the Belgrade Charter of the United Nations Educational, Scientific, and Cultural Organization (UNESCO), environmental education is a critical component to developing a world population that has the knowledge, skills, and attitudes to solve current problems and develop solutions to new ones (UNESCO, 1975). Landscape and ecosystem scale conservation efforts require significant expenditures and buy-in from the public and governments. This buy-in is based on perception, communication to the public and opportunities for the public to participate in conservation activities (Schenk et al., 2007). Public support for such efforts is difficult to obtain when much of the general public is not familiar with core ecological principles (McBride et al., 2013). In addition to a working knowledge of ecological concepts, a feeling of connectedness is pivotal to the type of attitude that people develop towards the environment (Louv, 2008; Schultz et al., 2004). Several studies spanning multiple generations concluded that early childhood interaction with the environment through leisure and structured activities influence adult attitudes towards the environment (Awert et al., 2005; Corcoran, 1999; Tanner, 1980; van Weelie & Wals, 2002). These findings influenced the 2013 Next Generation Science Standards (NGSS). The NGSS for the life sciences focus on several core ideas, including biological evolution: unity and diversity.

Biodiversity can be an abstract concept that is challenging for teachers to convey and students to comprehend (Lude, 2010). We conducted a hands-on, investigative activity to expose middle-school students to differences in biodiversity between native and invaded landscapes. We hypothesized that:

1. students would observe more plant species in the native than invaded landscape, and
2. as a result of higher primary producer diversity, students would observe more primary and secondary consumers in the native habitats.

Creation of the KIND Garden

A demonstration garden was created at the USDA-ARS Invasive Plant Research Laboratory in Fort Lauderdale, Florida, USA. The garden was designed by Eileen Pokorny to fulfill requirements of her Master Gardener's certification program. The Keep it Native Demonstration (KIND) Garden showcases native Florida plant communities and highlights differences between these habitats and one dominated by some of Florida's most problematic non-native invasive weeks (Figure 1). Installation of the KIND Garden began in 2010 and it is continually evolving. New plantings and ongoing maintenance are performed by USDA-ARS employees, Master Gardeners, boy scouts, and student interns. The KIND Garden is used for a variety of outreach activities to educate the public about native plants and engage them in a discussion of the impacts of invasive plants.

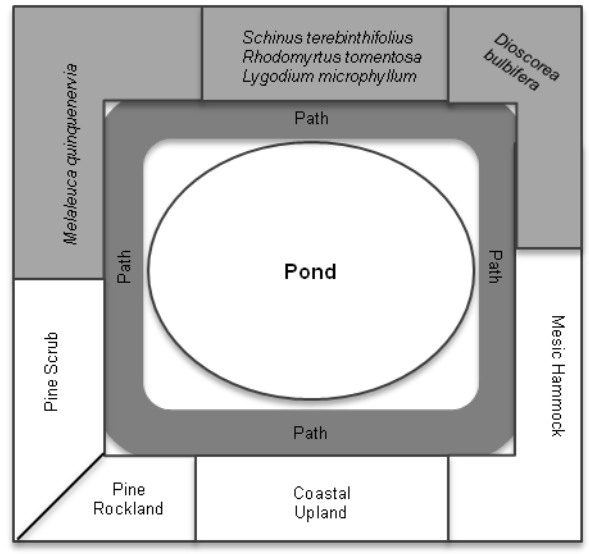

Figure 1: The Keep it Native Demonstration (KIND) garden layout. Invasive plant species are shaded and native communities are described using the Florida Native Plant Society designations (http://www.fnps.org/natives/native-plant-communities) (Left). An aerial view of the KIND garden (26.083806°N, -80.240612°W, Google Earth, 22 August, 2016) (Right).

Methods and results: biodiversity exercise

Twenty-five school children (grades 5-7) participating in a science-based summer program visited the KIND Garden in August 2015. The activity began with a brief classroom introduction about the importance of native organisms, diversity, invasion of habitats by exotic organisms, and how these topics are related. Specifically, we surveyed the class using a show-of-hands to gauge impressions regarding biodiversity and invasive species. The students were then split into small groups (4-5 students) and each group was given a hand lens, tally counter, data sheets, and a clipboard. Each group was paired with a USDA-ARS scientist or technician and asked to visit the four native habitats plus the invaded habitat in the KIND Garden. Within each habitat students collected data on the number of tree, shrub, and herbaceous plant species they encountered, as well as the number of invertebrate and vertebrate animal species present. After recording data in the five different habitats, the students gathered in a classroom to examine the data.

Each group totaled the number of species recorded in each habitat they surveyed. Species in each trophic level were lumped together into one group (total species). They then reported the number of species they encountered in each habitat to an instructor who created a table on a dry erase board. Each group's report was treated as a separate "replicate". The mean number of species found in each habitat was calculated and graphed on the dry erase board in front of the students (Figure 2). The students were then asked a series of questions to facilitate a discussion to interpret the graph and synthesize their observations:

1. Which habitat type had the highest diversity? Why?
2. Which habitat type had the lowest diversity? Why?
3. How does the number of plant species present in a habitat influence animal diversity?

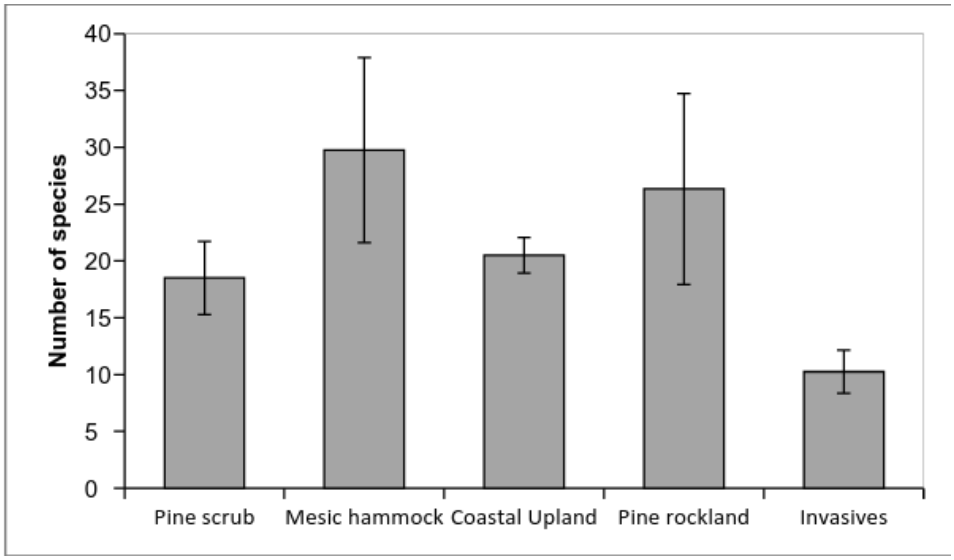

Figure 2. Species richness (average number of species ± s.e.) in each habitat type. Overall, students observed fewer species in the invaded habitat than in the native habitats.

The group immediately recognized from the graph of their data, that species diversity was much higher in the native habitats than in invaded areas. The invaded habitat is physically the largest region of the KIND Garden, but the students observed the lowest number of species in this habitat. We discussed the ability of invasive plants to outcompete natives and how invasive weeds often form monocultures, decreasing biodiversity.

Discussion

The invaded habitat of the KIND Garden features weeds that have been the targets of USDA-ARS Invasive Plant Research Laboratory biological control programs. The majority of arthropods observed in this habitat were biological control agents. This reduction in arthropod (and other animal) diversity in areas invaded by exotic plants is common, as illustrated in a meta-analysis on the impacts of invasive exotic plants. In this analysis, exotic plants decreased the abundance of animal species by 17.3%, on average (Vilá et al., 2011).

Several recent studies have sought to quantify the impact of non-native plants by evaluating community composition in habitats dominated by native versus non-native plants. Although the current student exercise used a very coarse estimate of biodiversity, with species from all trophic levels lumped together, our results are consistent with these studies. Insect communities were more diverse on native plants compared to non-native plants in early successional communities (Ballard et al., 2013), forest thickets (Fickenscher et al., 2014), and experimental landscapes consisting of native and non-native woody congeners (Burghardt & Tallamy, 2013). Furthermore, landscapes dominated by native plants support increased diversity at higher trophic levels, including avian diversity (Burghardt et al., 2009).

Lessons and activities that teach about biological invasions and their impacts on biodiversity are directly applicable to several of the Next Generation Science Standards. The KIND Garden biodiversity activity, although designed for grades 5-7, can be modified to fulfill the standards for other grade levels (Table 1). Modifications for middle-school students include comparing diversity at different trophic levels or feeding guilds, and creating food webs. Students could then be challenged to predict the results of perturbations to these food webs. For high school students, modifications focus on more sophisticated data collection and analysis, such as calculating diversity indices and synthesizing what they have learned to create a restoration plan for a site. There are also opportunities to integrate this activity with other disciplines such as math, health, economics, and history. For example, students could research the role of acclimatization societies in moving organisms around the world and the consequences of this global movement.

Many schools may already have contrasting communities in place if building landscaping consists primarily of non-native plants and natural areas are present on or near school grounds. These areas are more than sufficient to conduct an exercise such as the one described. Alternatively, teaching gardens like the KIND Garden can be installed in almost any area and can serve as a teaching tool before, during, and after construction. These gardens require planning and research into plant communities and species assemblages, but the planning and implementation could be used as an activity for high school students with the help of Master Gardener groups or County Extension agents. Many nurseries and outdoor stores will donate seeds and plants for non-profit educational projects. Regular maintenance is necessary, but native plant societies, Master Gardener groups, other schools/universities, boy and girl scout groups etc. are often willing to help.

Table 1: Next generation science standards descriptions and expansions for the KIND garden activity.

Next Gen Science Standard	**Our activity**	**Applicable to grades 3-5**	**Applicable to grades 6-8**	**Applicable to grades 9-12**	**Potential modifications to make it applicable to grades 6-8**
LS2.A Interdependent Relationships in Ecosystems	The diversity of each environment/food web can be directly related to the diversity of the plants in that environment.	Yes	Modified	Modified	Record the number of organisms in each trophic level observed in each habitat type. Construct a food web, try to connect all observed members of the community.
LS2.B Cycles of Matter and Energy Transfer in Ecosystems	Diversity of the producers corresponds to an associated increase in the	Yes	Modified	Yes	Record the number of organisms in each trophic level observed in each habitat type. Construct a food web, try to connect

	diversity at higher trophic levels				all observed members of the community.
LS2.C: Ecosystem Dynamics, Functioning and Resilience	Disruptions like human disturbance and the introduction of non-native species can disrupt an ecosystem and can threaten the survival of populations. Healthy ecosystems are diverse.	Modified	Yes	Yes	Compare the most and least diverse habitats. Are there any differences in ecosystem services?
LS4.D: Biodiversity and Humans	Different habitats contain different species. Each habitat is unique and supports a wide variety of life. Changes in those habitats can cause ripples throughout all trophic levels.	Yes	Yes	Yes	Invasive species are human-initiated changes that occur within an environment. Construct an argument that predicts the patterns of interactions among species in invaded and uninvaded communities. Using your knowledge of species interactions, construct arguments, supported by evidence, that changes to an environment from species invasions affect populations.
ESS3.C: Human Impacts on Earth Systems	Humans bring plants and animals into new regions to "recreate home" and for food and fiber. These organisms can often alter their new environments.	Yes	Yes	Yes	Generate a list of foods the students have eaten today that are from a different region of the United States or a different country. What are students wearing? Are the fibers native to the United States? Are they produced here? Where are the plants in their home or school landscape from?

Conclusion

Species invasions and the subsequent loss of biodiversity pose an ongoing threat to native communities and remain two of the most important topics for future environmental policy and ecosystem stability (Hautier et al., 2015). An ecologically conscious general public will play a critical role in combating these threats, but some ecological concepts are abstract and challenging to teach. We offer a tangible exploration of biodiversity and the impacts of non-native species that can be implemented on many school properties. This activity and suggested extensions address multiple Next Generation Science Standards and can be integrated with other disciplines. Engaging school children and the general public in gardens, such as the KIND, forms a foundation for future scientific inquiry, promotes hypothesis-driven science education and reinforces an environmental ethic that may improve efforts to preserve biodiversity and ecosystem function (McKinley et al., 2016).

Acknowledgements

We thank Tracey Wasylik, Alex Chapman, Brittany Knowles, and Ryann Valmonte for their assistance facilitating this activity and the students from Nova Blanche Forman Elementary for their participation. We also thank Michele Parsons and Joanne Korvick for organizing the student's field trip to the Garden. We thank Mike Orfanedes and the many USDA-ARS employees and interns who have contributed to garden construction and maintenance, and all who have donated plants and supplies to the garden construction and maintenance. Mention of trade names or commercial products in this publication is solely for the purpose of providing

specific information and does not imply recommendation or endorsement by the US Department of Agriculture (USDA). USDA is an equal opportunity employer and provider.

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