A Laboratory Activity to Engage College Students in Habitat Suitability Analysis to Teach Conservation, Ecology, and Evolution

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ABSTRACT

Solving conservation problems requires students to apply their knowledge of ecology and evolution. We present the Endangered Species Conservation through Habitat Suitability Analysis Laboratory Activity, in which students perform habitat suitability analyses for endangered freshwater species, compelling application of ecological and evolutionary principles. Students gather natural history information for endangered species native to Illinois, synthesize publicly available GIS/map data and habitat requirements for an endangered species, and present evidence-based proposals identifying geographical regions that should be set aside for protection. Students discuss current freshwater conservation issues and develop conceptual understanding of evolution, ecology, and conservation principles and processes. Students are prompted to consider human inclusion in freshwater ecosystems and its consequences. This laboratory investigation is effective in highlighting naïve conceptions of ecology, evolution, and conservation because students are prompted to provide rationale for their management decisions and engage in scientific discourse as they conduct their habitat suitability analyses.

Key Words: conservation education; ecology education; habitat suitability analysis; place-based learning.

Introduction

Conservation biology seeks to maintain functional ecosystems and prevent species endangerment and extinction, which requires application of evolutionary and ecological knowledge. Core evolutionary mechanisms like natural selection, adaptation, and extinction are applicable to conservation, because these determine ecological niches and life histories of organisms. Due to rising rates of extinction resulting from human activities, students will be continuously called upon to use ecological and evolutionary knowledge to solve conservation problems.

Freshwater ecosystems provide opportunity to explore conservation, ecology, and evolution simultaneously. Freshwater resources are withdrawn to serve drinking water needs, and freshwater species are threatened by withdrawal rates (Abell et al., 2008; Maupin et al., 2014). Limiting factors for species in freshwater habitats include hydrologic characteristics (e.g., stream velocity), water quality parameters (e.g., amount of dissolved oxygen), micro-habitat availability (e.g., availability of a sandy substrate), habitat heterogeneity (i.e., the consistency of the required habitat across space), connectivity (i.e., the degree to which different bodies of water are accessible from each other), invasive species presence (e.g., presence of Zebra mussels in the Great Lakes, an introduced species that outcompete native mussels), and overharvesting (Abell et al., 2008; Brönmark & Hansson, 1998). The juxtaposition of humans and threatened or endangered species’ participation in aquatic ecosystems in the lab activity presented in this article illustrates the complexity of conservation problems while providing opportunity to engage students in place-based learning (Gruenewald, 2003).

This article presents the Endangered Species Conservation through Habitat Suitability Analysis Laboratory Activity (Habitat Suitability Analysis lab) in which students perform habitat suitability analyses for a local endangered freshwater species, compelling application of ecological and evolutionary principles to solving a conservation problem. This lesson seeks to encourage students’ metacognition about conservation issues by prompting reflection on the factors that limit a species’ population size and identifying habitat locations that are likely to best support the species’ conservation (Duit & Treagust, 2003). The activity is set in Illinois riverine ecosystems, and students with whom the activity was piloted were from Illinois. Focal species were not charismatic, well-known species, but rather, students examined lesser known aquatic vertebrates, one invertebrate, and one plant species.

The species profile of the alligator snapping turtle (Macrochelys temminckii) illustrates how application of ecological and evolutionary principles can be applied to solving the problem of its endangerment in Illinois (INHS, 2012). Historically, alligator snapping turtles were overharvested due to their desirable meat (INHS, 2012). Their endangered status in Illinois places a ban on harvesting alligator snapping turtles, but they are also threatened by habitat alteration (INHS, 2012). Alligator snapping turtles are ambush predators that
sit on the murky bottom with their mouth open to reveal their worm-like tongue and await their prey (INHS, 2012). Their prey are fish that are attracted to their lure of a tongue. Due to their predation strategy, they require slow-moving waters that are typical of the backwaters of large river systems (INHS, 2012). However, due to the channelization of large rivers in the Mississippi River basin, such microhabitats (i.e., slow-moving waters in large riverine systems) are no longer common, thereby limiting available habitat (INHS, 2012). Although alligator snapping turtles live for decades, they do not reproduce until 11 years of age, so populations can be slow to replace themselves (INHS, 2012). This case exemplifies how both ecological and evolutionary concepts must be applied to conduct conservation of alligator snapping turtles. Over-harvesting and human alteration of their habitat, through river channelization, has caused their endangerment (INHS, 2012). This conservation problem is exacerbated by their evolutionary adaptations (i.e., predation strategy, time to reach reproductive maturity), reducing their ability to participate in organismal interactions (i.e., predatory-prey relationships) that maintain their survival.

Positive outcomes of this activity were due in part to the familiarity and relevance of the local ecosystems to students’ lives. This lesson provides opportunity to engage students in place-based education, which potentially builds on students’ connections with specific locations, while also cultivating a greater appreciation of their local environment (Woodhouse & Knapp, 2000). We conclude this article with guidance on how a similar activity can be developed for other locales.

**Objectives**

Objectives of the Habitat Suitability Analysis lab are:

1. Engage students in solving conservation problems by applying ecological and evolutionary principles.
2. Familiarize students with types of data used for conservation.
3. Compel students to think critically and problem-solve in the context of conservation.

This lab activity creates opportunity for instructors to observe students’ ecological and evolutionary understandings in action, as applied to a conservation problem, thereby enabling instructors to identify common naïve conceptions. Naïve conceptions that are likely to be unearthed through this activity are (a) that organisms can adapt to meet the demands of any environment or habitat, (b) that all conditions within a habitat type (i.e., aquatic habitats) can equally meet the needs of a species adapted to that habitat, and (3) that although humans are responsible for many negative environmental impacts, humans cannot mitigate them. Additionally, students use evolutionary terms such as “adapt” or “evolve” in unscientific ways, and they tend to be overly focused on predator-prey relationships at the expense of other important organismal interactions. Thus, this laboratory activity would best be situated within a curricular unit on ecology or evolution as an introduction to the unit, allowing instructors to formally assess prior knowledge as it is brought to bear during problem-solving. Ideally, students would be able to revise the habitat protection proposal that they create during this lesson to demonstrate constructed knowledge over the course of the ecology or evolution unit.

**Methods**

**Details of Activity**

The Habitat Suitability Analysis lab is designed to be implemented over a single two- to three-hour laboratory period. The pre-lab assignment is estimate to take students about one to two hours to complete, and the lab activity could be prefaced by a field trip to a local zoo or stream. Although optional, the field trip serves to emphasize the place-based nature of this activity as well as to engage students in an exploration of the concepts addressed in the lab activity. Table 1 provides a breakdown of the curricular phases, instructional goals, and examples of how students engage with key concepts.

Required materials include an introductory presentation on local aquatic habitats and limiting factors, a pre-lab handout, a field trip handout, the laboratory activity handout, and a map packet that includes species information for the packet’s focal species, watershed quality 303(d) listings (IL EPA, 2014b), and the following five maps printed on transparencies for each group of two (or three) students, divided equally across the species to be examined:

1. Base map with watershed boundaries of the state (IL EPA, 2014a)
2. Land cover (Luman et al., 2007)
3. Major rivers and lakes (IL DNR, 2014)

All handouts are available as Online Supplementary Material. The accompanying presentation file is available by contacting the corresponding author.

The map packet is not made available through this article due to use of copyrighted maps, but authors are available to provide guidance in locating maps for locations. We strongly suggest the map packet be adapted for the home state in which it will be taught, in order to both build upon the students’ connections to the local region as well as expand students’ appreciation and conceptualizations of their local environment and ecosystems. Place-based learning theory describes how students’ prior knowledge is connected to a larger conceptual landscape, which may include the literal geographical landscape (Karrow & Fazio, 2010). Therefore, this lesson can potentially help students overcome a discrepancy that commonly exists between students’ preconceived conceptual landscape and the context of their science classroom, exploring issues that are unique to each place and relevant to students’ lives (Woodhouse & Knapp, 2000; Zandvilt, 2014). Thus, in the Preparation section below, we describe how an instructor would locate and prepare materials to adapt this activity for the state or region in which it will be taught.

**Preparation**

We implemented this lab in Illinois, so our materials pertain to Illinois endangered species and aquatic ecosystems. To adapt our materials for another state, instructors should first identify about five locally endangered or threatened aquatic species using the United States Fish & Wildlife website (www.fws.gov/endangered/) and state Fish & Game or Departmental of Natural Resources (e.g., Illinois DNR) website. It is important that sufficient information is
available on state websites and/or the International Union for Conservation of Nature and Natural Resources (IUCN) Red List website (www.iucnredlist.org) to construct a species profile for each selected species.

Once the focal species are identified, instructors should then locate regional or statewide maps from the Maps, Imagery, and Publications webpages of the USGS website (www.usgs.gov). Instructors should select maps that illustrate spatial and environmental limiting factors.
factors needed for focal species. For example, if the instructor chose a species that requires a high amount of dissolved oxygen, a map showing stream flow rate should be included. By incorporating several different maps, instructors can tailor the lab to investigate a local ecosystem. We recommend four primary maps for the lab activity that are relevant to most aquatic species’ habitat requirements: a map of statewide or regional watersheds, a map of major waterbodies including lakes and rivers, a map of stream discharge rates, and a map of statewide or regional land use.

In many endangered species’ cases, stream velocity may be more relevant to microhabitat requirements than stream discharge, but stream velocity map data are not as readily available as stream discharge data from the USGS. Thus, we recommend choosing local species for which microhabitat parameters can be described and explored with the locally available data. Although maps are downloadable from the USGS website, permission for map duplication for educational purposes should be obtained from the USGS, which we found to be uncomplicated. Maps should be copied on transparencies. Sufficient transparency copies should be made of each map to provide one of each map (i.e., a “map packet”) to each student pair. Additionally, supplemental water quality maps and associated impaired waterbody listings for each watershed in the state/region (also known as 303(d) listings) should be downloaded from the state EPA website and copied on regular paper. These should be provided in a binder for reference to students as they work through the activity; we made enough copies to provide one binder to each student pair.

Prerequisite Knowledge

In our course, prior to engaging in the Habitat Suitability Analysis lab, students received ecology and evolution lectures in the course, which presented evolution concepts including natural selection and adaptation, and ecology concepts including populations, communities, interspecific relationships, abiotic factors, and food webs. These lectures may have increased students’ familiarity with vocabulary used in the activity, but we acknowledge that substantial conceptual development is unlikely to occur during lecture. We suggest that students only need be familiar with the vocabulary in this activity before engaging in it.

We also expected that students could read maps and have familiarity with the regions in the state, including rough spatial estimations of rivers, lakes, and general principles of freshwater connectivity (i.e., if an organism is going to move from one water body to another, there must be a waterway connecting them that is navigable by the organism). However, we learned that our post-secondary students would have benefitted from a review of local geology prior to beginning the activity. Further preparation might also include arranging a field trip to a local zoo that participates in conservation programs. Our community has access to a zoo that prompted discussion of the ecological and evolutionary aspects of conservation decisions, but an equally relevant field trip would be to a local stream where students could survey macroinvertebrates and observe and discuss microhabitat parameters that are relevant to individual species.

Laboratory Investigation

During the laboratory investigation, students synthesize multiple pieces of data to identify a region that should be preserved to protect their focal endangered species; student pairs then propose their plan for where the preservation should be to the class, backing up their proposal with evidence from their analysis.

The field trip reflections should be collected at the beginning of the lab activity, but the lab instructor should check pre-lab assignments for completion and initial each student’s pre-lab assignment before the lab activity begins, allowing them to keep it for reference throughout the lab activity. At the beginning of lab, the lab instructor gives a brief presentation (see Supplement) introducing the goals of the lab, and then facilitates a discussion about the use of Geographic Information Systems (GIS) in conservation science. The lab instructor also demonstrates how maps layers can be overlain to identify regions that fulfill multiple criteria (e.g., slow-moving water and good water quality), similar to how conservation scientists use GIS software to layer digital maps. The lab instructor assigns groups of two (or three) students to an endangered species, guided by students’ preferences, and each group receives a map packet for their endangered species. Each packet contains transparency map layers, supplemental maps on regular paper, watershed quality 303 (d) descriptive listings (IL EPA, 2014b), and a dry-erase marker.

To engage in the lab activity, students then review their species’ life history traits, limiting factors, range, and habitat requirements, which were documented in the pre-lab assignment, and use the map layers to facilitate discussion of protection of their endangered species. During this time, the instructor circulates to answer questions and challenge students’ reasoning. During these discussions, students will commonly focus only on predator-prey relationships,
so instructors should prompt them to think about other types of organismal interactions that might be relevant to the focal species’ conservation.

There will also be a generalization of aquatic habitats, resulting in students reasoning that as long as there is water to live in, any aquatic species can live there (e.g., “They just need clean water.”). This reasoning reflects a lack of distinction between microhabitats that are relevant to endangered species’ conservation, so the instructor will need to ask probing questions that challenge this overgeneralization, such as, “Humans are a terrestrial species, but does that mean all you need is land to survive? Can you just as easily live in a prairie and on top of Mt. Everest; they’re both terrestrial?”

Similarly, students will use the terms “adapt” and “evolve” in ways that indicate they believe that individuals can evolve or that adaptation is a matter of choice or free will. Again, the instructor will need to ask probing questions, such as, “If you were forced to live on Mt. Everest, would you be able to, for example, extract more oxygen from the air, by trying really hard?”

When misconceptions such as these are common, the instructor will likely need to pause the small group discussions to hold question-driven, whole-class discussions that pose these types of questions to students and compel clarification ecological or evolutionary concepts that are relevant to the discussions. The power of this Habitat Suitability Analysis lab for developing students’ concepts about ecology and evolution lies in these small-group and whole-class discussions, interspersed with instructors’ probing questions that challenge ecological and evolutionary misconceptions. The manipulation of maps to identify a region to protect for a particular endangered species is simply the activity that necessitates exploration of ecological and evolutionary ideas, which is what allows for conceptual development.

Using map layers, watershed maps, watershed water quality descriptions, and species profiles created on the pre-lab assignment, students aim to identify two regions that they would propose be protected in order to preserve their endangered species. Specifically, students identify the watershed, county, and directional descriptions of landmarks or names of stream segments to include or exclude. For example, a group might conclude, “We recommend the NE corner of ABC County in the XYZ watershed, extending from Shire Creek west to Ironfoot Lake for protection of the alligator snapping turtle.” Students identify the data that supports their decision and then, after synthesizing all available information, create a presentation explaining why they chose the area(s) for protection.

○ Results

Formative Assessment

The pre-lab assignment and field trip reflections provide initial indication of prior knowledge of ecological and evolutionary principles as they are applied to conservation problems. A majority of the formative assessment occurs as the lab instructor circulates during the lab activity, asks probing questions, and facilitates whole-class discussions that challenge students’ thinking about ecological and evolutionary mechanisms.

Pre-lab assignment and in-lab worksheet questions are designed to prompt students to provide reasoning regarding conservation challenges requiring basic ecological and evolutionary knowledge, which allows the instructor to identify naive conceptions and biases about endangered and threatened species, limiting factors and their importance, and conservation. Students are also asked in the pre-lab assignment to explain what they found most interesting or surprising during their information gathering. Interestingly, in our course, many students were unaware that species living in their own state and local ecosystems were endangered (Figure 1).
Summative Assessment
Although the in-lab handout (see Supplement) may be submitted as a summative assessment, we also required students to create a five-minute presentation on the life histories, limiting factors, threats, and habitat requirements of their focal species, their habitat suitability analysis, and their proposal for which region(s) should be protected to preserve their endangered species. Student pairs used the base layer as a visual aid during the presentations, having marked with a dry-erase marker the region(s) they proposed for protection. After student presentations, the instructor led a discussion to identify regions that could be protected to preserve the greatest number of endangered species studied, explicitly prompting students to back up their claims with evidence from the information they synthesized throughout the lab activity.

Discussion

Map Literacy
Our students were not familiar with non-electronic maps. Most students were able to overcome this challenge with individualized guidance. When teaching digital natives, Berk (2009) found that students refer first to Internet searches for information. In an age of GPS-enabled phones, tablets, and digital mapping devices, students may be confused by hardcopy maps.

Our students also struggled with determining if all the map layers were relevant to their species, as not all map layers provided helpful information for every species. For example, some species did not require specific water flow rates, so the water flow map layer did not provide relevant information. Some students assumed that if they did not use information from all the map layers, then they were processing the material incorrectly. We suggest this challenge by mitigating by discussing with students the authentic practice of conservation scientists and how they must continuously decide what information is relevant to the particular problem they are attempting to solve.

No “Right” Answer
A few of our students were left unsatisfied, as there is no single correct answer for conservation challenges. Students provided evidence-based reasoning for why they chose a particular region for protection, but many possibilities would be good candidates, based on the data they synthesized. Students are accustomed to there being a single correct answer, and the experience of thinking like a conservation scientist is an important component to the lesson. To devise a cohesive plan of action and convincingly present it to their peers, we found that this lesson requires students to think critically.

Role of Humans
In the in-lab handout, students are prompted to reflect on how humans participate in aquatic ecosystems. Some students did not link human activity with causes of impairment, and conversely, many students could not identify ways that health of aquatic ecosystems affects humans. If more time can be dedicated to this lesson, it would be worthwhile to examine impacts of pollution and degradation and how knowledge of these effects allows conservation scientists to make management decisions. Furthermore, it would be worthwhile to discuss how threatened species may also serve as sentinels for human health concerns.

Best Practices
The numerous maps, species facts, and activity questions were daunting when students first opened the map packet. Instructors should discuss each map layer and what information is presented, explaining why it was included in the activity. Water quality maps often utilize many codes to designate waterbodies, which requires them to look at a map and then refer to a numerical or abbreviated code to decipher information. Instructors should provide guidance on how to properly reference waterbodies and what type of information can be gathered from the water quality data. Also, as mentioned before, the power of this lesson lies in the instructor’s ability to build on students’ discussions as they synthesize the data. It is these discussions that allow for conceptual development of ecological and evolutionary ideas.

Conclusions
Making sound conservation decisions requires evolutionary and ecological knowledge. Using place-based learning to explore ecological and evolutionary aspects of endangered species management is a novel approach to conservation education. It provides opportunities to discuss human involvement in and dependence on aquatic ecosystems and to teach ecological and evolutionary concepts through problem-solving. The Habitat Suitability Analysis lab necessitates construction of sophisticated ecological and evolutionary concepts, and demonstrates to students the value of conservation as an evidence-based subfield of biology.

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