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Urban Ecology: Inquiry-based and Experiential Laboratory Exercises for Urban Ecosystems

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Many universities are located within urban areas, not commonly recognized as complex and dynamic ecosystems. This module was created to introduce students to these ecosystems, provide them with techniques used commonly by ecologists to assess ecosystem diversity and health, and gain a better understanding of both positive and negative human impacts on urban environments. This lab has been designed to be flexible and has been executed both as a 3-hour module and a three-day, 18-hour module, and with indoor contingencies in place in case of inclement weather.

Keywords: scavenger hunt, invasive species, water quality, pollution, modular, human impacts, ecosystem health

Introduction

The Urban Ecology module was created, and later redesigned, to allow high school (HS) students to complete undergraduate level ecology laboratory exercises that display techniques used by field ecologists. The redesigned module exploits the competitive nature of students by asking them to quickly and accurately complete a variety of tasks. During the redesign process, the module was designed to fill both a three-hour lab and an 18-hour lab over three separate days (Rycroft and Seliga, 2013). A small graduate student to HS student ratio allows volunteers to effectively guide HS students through inquiry-based procedures and discussion. The redesign also created an indoor contingency that was lacking in the initial version of the module. Each component of this module has been incorporated into undergraduate-level laboratory courses, both introductory and upper-level.

The three-hour module is broken down into five separate activities (Table 1). The 18-hour module replicates the same basic activities at each of three unique locations and allows students to compare and contrast between sites. The 18-hour version also adds several activities that take place at the forested park field site in downtown Boston, the Fens. The Fens is a managed park area with a dammed river system flowing into the Charles River. The park is a component of the Emerald Necklace, originally designed by Frederick Law Olmstead, encircles much of Boston and connects several larger park areas including the Arnold Arboretum and the Esplanade. The park is managed and maintained by the City of Boston and exhibits substantial biodiversity along with several invasive species and numerous examples of positive and negative human impacts.

Biology Inquiry and Outreach with Boston University Graduate Students (BIOBUGS) is an outreach program to encourage local HS students to become excited about science. This will be accomplished by implementing the following three objectives: 1) exposing them to sophisticated scientific equipment and techniques, 2) providing interaction with graduate students who utilize that equipment in their research, and 3) introducing them to a university campus and laboratory environments.

Participation in this program also benefits BU's graduate students by providing opportunities to develop pedagogical techniques critical to their success as graduate students and as future science, technology, engineering, and mathematics (STEM) faculty members.

Table 1. Activities in the three-hour module.

Activity	Description
Mass Invaders Game	A card based game that teaches students the impacts of invasive species through competitive imbalance.
Matching Game	A game intended to teach students how to quickly and accurately identify different animal species that they may see in the field. The game uses model specimens.
Scavenger Hunt	A set of 9 tasks spread across a variety of sites that cover topics including tree species identification, animal species identification, and a multifactorial assessment of ecosystem health.
Urban Water	Identification of microorganisms found in water samples using microscopes.
Tough Stuff Here to Stay	Assessment of human waste impacts by collecting and analyzing litter.

In addition to the aforementioned objectives shared by all BIOBUGS modules, the Urban Ecology module is designed to foster interest in field ecology by exploring the urban environment and human impacts on the ecosystem, which aligns with Massachusetts Department of Education STEM Curriculum Frameworks for Biology, specifically 6.1 (explain how biotic and abiotic factors cycle in an ecosystem (water, carbon, oxygen, and nitrogen)) and 6.4 (analyze changes in an ecosystem resulting from natural causes, changes in climate, human activity, or introduction of non-native species) in the ecology broad concept.

Graduate students at BU have the potential to be assigned to teach any biology laboratory or discussion course. Graduate TAs face many challenges (e.g. unknown subject matter, unclear expectations from faculty, difficult students, etc.) and are not necessarily given the tools to overcome these challenges. Teaching and volunteering with a BIOBUGS module provides additional teaching skills to the graduate students via experiential learning in three ways. First, graduate students are in a classroom with a demographically unfamiliar and diverse audience, which forces them to explore new teaching techniques and introspectively assess previously used methods. Second, graduate students are asked to present material that is novel or unfamiliar as the topics are outside of their research or coursework backgrounds. Third, since many of our graduate students teach or volunteer in successive BIOBUGS semesters, participation affords them to opportunity to refine their methods in a lower risk, lower pressure environment relative to their roles as TAs. By gaining experience teaching novel material to diverse populations, graduate students are forced to reassess pedagogical methods that need improvement and actively pursue development in those areas.

Currently, BIOBUGS has five separate modules representing a spectrum of broad topics in biology (genetics, anatomy, forensics, microbiology, and ecology). Each BIOBUGS module is run once a day over a weeklong period bi-annually during the final exam periods of each fall and spring semester when the classrooms are available. The program recruits graduate students to act as BU teachers and additional undergraduate and graduate students to act as BU volunteers throughout the week. For each day, there are one or two BU teachers whose responsibilities include background lecture, time management, and supervising the BU volunteers. There are four or five BU volunteers who are directly in charge of up to six HS students. The BU volunteers are responsible for ensuring the HS students complete the lab activities properly and answer any questions that come up. For additional information, visit the BIOBUGS' website (http://www.bu.edu/lernet/biobugs/).

Since its redesign in late 2012, Urban Ecology's three-hour-long version has been run four times. Each time the module was run it was done over a weeklong period with a new group of students participating each day. The 18-hour version has been run once with one group of students participating each of three days. The indoor contingency module has also been run on multiple occasions, as the weather has required. The students that have participated have been 10^{th} to 12^{th} grade biology students from Boston Public Schools with various experiences and abilities in biology ranging from students without microscope experience to those that are in their second year of biology education and have already studied ecology.

In the appendices we have included the worksheet packets given to each student at the beginning of the three-hour module with both outdoor and indoor

contingencies. The worksheets do not have detailed protocols for each task; those are provided to the BU volunteers working at each task's station and are also included in the appendices. Background information is also omitted from the worksheets but is provided to the students in the form of a PowerPoint presentation given by the BU teachers. The background PowerPoint can be found on the BIOBUGS website.

Student Outline

The following section provides an abbreviated version of the materials given to students. Outlined here are the activities completed during the three-hour version. To see the full materials handed out to students, look to the Appendices referenced for each activity below.

Activity 1: Mass Invaders Game

1.1 Activity Objective

In this activity, we create a metaphor for competition in nature using playing cards and pennies. The purpose of this game is to compare an ecosystem in competitive balance with one that has been impacted by an invasive species where competition is no longer balanced. Pennies represent resources such as food or shelter and the goal of the game is to "win" by obtaining the maximum number of pennies. At the same time, the student is attempting to avoid losing all of their pennies and "going extinct." This activity functions in both indoor and outdoor versions of the module.

1.2 Protocol and Discussion Questions

For detailed protocol and discussion questions, please see the MASS Invader Personal Card in the Appendix A. For an example of a set of species cards, please see the example set of Species Cards in Appendix K.

Activity 2: Matching Game

2.1 Activity Objective

The purpose of this activity is to have HS students practice using the customized field guides on plant, bird, and mammal specimens from the Boston University Biology Museum's collection that are also found in the field. Students are provided with field guides that contain images and descriptions of both plant and animal species seen in the field. These guides were created after visiting the chosen field sites and identifying the local flora and fauna. Representative images and descriptions of species were found online. A dichotomous tree was created and included in the field guide to speed student identification of plant species, which is generally more challenging than identification of animal species. This activity functions in both indoor and outdoor versions of the module.

2.2 Discussion Questions and Student Work

For discussion questions, please see the Matching Game Volunteer Card in Appendix B. For student work, please see the Student Worksheet (Outdoor) in Appendix I or the Student Worksheet (Indoor) in Appendix J. For an example of a species page from the field guide, please see the Species Identification Card in Appendix N.

Activity 3: Scavenger Hunt

3.1 Activity Objective

In this multi-station activity, the students complete a series of tasks in order to learn how to assess ecosystem diversity and health, and gain a better understanding of both positive and negative human impacts on urban environments. The scavenger hunt is built around the time allotted and the field site. Each BU volunteer is given a unique title (i.e. Dr. Dolittle, Tree Hugger, Invader, etc.) and tasked with leading discussion at one of five locations that function as the sites of one or more tasks. Tasks include general site description, identification of invasive species and their impacts, examination of a cut tree to predict historical environmental conditions, plant and animal species identification, assessment of tree health, and evaluation of how humans directly impact the environment through infrastructure and pollution.

In the event of inclement weather, the stations were recreated indoors using a combination of station-specific, volunteer guided PowerPoint presentations. During the scavenger hunt, students complete the student worksheet (Appendices, "Student Worksheet (Outdoor)" and "Student Worksheet (Indoor)"). Students are guided through the scavenger hunt with these worksheets and locate each station using the map included in their field guide (see Appendices, "Field Map" and "Indoor Map"). Throughout this activity, students are asked to collect non-dangerous or illicit litter found on the ground or in the water for use in a later activity.

3.2 Discussion Questions and Student Work

For discussion questions, please see the Scavenger Hunt Volunteer Cards in Appendices C-G. For student work, please see the Student Worksheet (Outdoor) in Appendix I or the Student Worksheet (Indoor) in Appendix J.

Activity 4: Urban Water

4.1 Activity Objective

This activity occurs immediately after students return from the field site. The purpose of this exercise is to allow students to observe aquatic life under a microscope. Students are given the chance to discover the quantity and diversity of life that exists in urban bodies of water. Students discover how humans interact with and impact urban water systems and discuss these interactions with the BU volunteer stationed at their table (Appendices, "Urban Water Personal Card").

4.1 Discussion Questions and Student Work

For discussion questions, please see the Urban Water Volunteer Card in Appendix H. For student work, please see the Student Worksheet (Outdoor) in Appendix I or the Student Worksheet (Indoor) in Appendix J.

Activity 5: Tough Stuff Here to Stay

5.1 Activity Objective

The purpose of this activity is to allow HS students to discover how much and what type of trash is left at the Fens. During the Scavenger Hunt activity, students collected trash, sorted, counted, and estimated relative degradation times. Then, through a discussion with the BU volunteers, students reflect on how they could personally minimize their impacts on the environment.

5.2 Discussion Questions and Student Work

In this activity volunteers are asked to discuss how students can reduce their family's, their school's, and their own impact on the environment. Students asked whether they feel that their field site was a healthy ecosystem based on the factors that they observed while in the field. Finally, students are asked how they feel like a natural ecosystem would differ from the fens in terms of the factors that they observed. For student work, please see the Student Worksheet (Outdoor) in Appendix I or the Student Worksheet (Indoor) in Appendix J.

Materials

Table 2. Activity 1: Mass Invaders Game.

Item	**5 days (24 students/day)**
Set of 6 sequential playing cards (i.e. 9, 10, J, Q, K, A)	6 sets
Set of 6 species cards with 5 native and 1 invasive (Appendix 11)	6 unique sets
3 pennies per student	72

Table 3. Activity 2: Matching Game.

Item	**5 days (24 students/day)**
Biology Museum Specimens • 24 different plants, birds, and mammals in 2nd classroom	
Timer (for teachers)	2
Field Kits	8
Clipboard (students will share)	8
Worksheet (students will share)	8
Writing utensils	8
Customized Field Guide (on a ring): • The map of the Fens (Appendix L) • Dichotomous Tree (Appendix M) • Bird ID cards of species found at the Fens (Appendix N) • Mammal ID cards of species found at the Fens • Plant ID cards of species found at the Fens • Plant Fact Sheet	8 sets
Matching Game Personal cards (Appendix B) • Cheat-sheet instructions for volunteers	6

Table 4. Activity 3: Scavenger Hunt.

Item	**5 days (24 students/day)**
The same materials from Table 3 (except the museum specimens)	
Gloves	24 pairs/day
Plastic streamers for the site, neon-colored • Tied visibly onto 11 trees for tasks #4 and 5 (tree ID and tree health)	
Trash bags • Small plastic shopping bags, 1 double-bag per team	8
Plastic specimen containers	8
Plastic mm rulers	8
Outdoor Personalized cards (Appendices C-G) • Cheat-sheet instructions for volunteers (Invader, Dr. Dolittle, Tree Hugger, Woodcutter, and Traveler)	5

Table 5. Activity 4: Urban Water.

Item	**5 days (24 students/day)**
Stock of Muddy River water (can last for a week at room temperature without aeration). 10 gallons collected several days prior to the start of the lab. Best samples include sediment and detritus and are kept in a tank at room temperature with constant aeration. This stock of water can be used for both indoor and outdoor versions.	
Teacher microscope with camera connects to monitor via USB • Moticam camera (fits on any compound microscope) • Make new slide sample every day (using pre-sampled water or rotifers provided by a research lab)	
Transfer pipets	1 box
Microscopes, 1 per team (2 at a bench)	8
Depression slides, 1 per team (2 at a bench)	8
Cover slips	1 box
ProtoSlo • Carolina Biologicals ($6/bottle)	1 bottle
Urban Water Personal Cards (Appendix H)	6
Water Samples • HS Students collect samples at Task 4 in the previous activity or from the pre-collected class sample	

Table 6. Activity 5: Tough Stuff Here to Stay.

Item	**5 days (24 students/day)**
Large trash bags	
Pre-collected trash from the classroom buildings (general and recycling bins) for possible use in indoor version • Enough for 4 separate bags, particular attention to Styrofoam, glass, and useless trash • Stored in cold room	
Gloves	24 pairs/day
Recycling bins for ultimate disposal of recyclable waste	

Notes for the Instructor

The techniques used to create this module were outlined in a prior ABLE presentation and were published in the 2013 proceedings (Rycroft and Seliga, 2013). For specific notes on design and implementation, please refer to that publication.

Table 7. Schedule of 3-hour module.

Time	Activity	Activity Overview
Hour 1	Mass Invaders Game (~30-45 min)	• Ecology background • 1st half of game (native species) • 2nd half of game (invasive species)
	Background/procedures for field lab (~15 min)	• Scavenger hunt rules • Distribution of field kits
Hour 2	Matching Game (~15 min)	• Match photos of birds and mammals with BU's museum collection
	Travel to site (~10-15 min)	• Gather trash en route
	Scavenger Hunt (~35 min)	• 9 tasks spread across site • BU Volunteers at specific tasks
Hour 3	Travel to classroom (~10-15 min)	• Gather trash on route
	"Urban Water" (~15 min)	• Microscope ID
	Field Conclusions (~15 min)	• Share team data, compare to known info
	"Tough Stuff Here to Stay" (~15 min)	• Amount of trash • Relative degradation rates
	Conclusion	• Human impacts

Activity 1: Mass Invaders Game

1.1 Activity Protocol

The game is easy to set up and very simple to run. Students are divided into groups of up to 6 (minimum of 4). Initially, each group is given a set of 6 playing cards of the same suit (it is easiest if these cards are sequential such as 9 through Ace). Also, each student is given 3 pennies. A BU volunteer leads each group and is responsible for moderating both the conversation and managing the game-play.

The game is comprised of two rounds; the first round has all students as equally competitive. In this round, the volunteer deals one upside-down card to each student. Once each student has a card, they simultaneously flip the cards revealing their value. The student with the lowest card gives the student with the highest card one penny. The students then pass the playing cards back to the BU volunteer who shuffles the cards and repeats the process for a minimum of 5 rounds (this can be increased to fill time but should not be decreased). During the course of play, the volunteer will ask the students a variety of questions related to the game in an attempt to give a biological context to the non-biological pennies and cards (see Appendix A: "MASS Invaders Personal Card").

In the second round, the BU volunteer hands out the species cards, upside down, and instructs the students to not turn them over. Five of the cards have green dots on the back (native species) while one has a red dot (the invasive species). The student with the red dot has the opportunity to pick three cards before the rest of the group gets theirs and to choose the highest. The student then returns the two lower cards to the BU volunteer who shuffles them back into the set and deals to the remaining students. This provides the student with the red dot a competitive advantage as they will never have the lowest card and will have a much higher probability of having the highest.

After each round, the BU teachers poll the students to identify the number of students with 0, 1, 2, 3, 4, 5, and 6+ pennies. The teacher plots the number of students with each number of pennies on a graph on the board and discusses the results with the students. Ideally, the first

round results in a normally distributed plot and the second results in a skewed plot with the students given the red card having obtained a significant number of pennies and a greater number of students that have lost most if not all of their pennies. If the plots did not produce the expected results, the instructor should ask students as to what was expected versus what was observed. The key to the activity is that students recognize that the first round had equal competitive ability while the second had unequal competitive ability with the invasive species having a competitive advantage.

1.2 Notes for the Instructor

For this game, we chose to include species that are proximate to Boston or New England. The sets of 6 species cards are created by finding one invasive species and then five others that are impacted, in some way, by that species (Appendix K). Prior to the game, students are not given any background on invasive species so as to not color the view of each round of the game and allow the questions posited by the BU volunteers to lead them to the conclusion that they are modeling competitive interactions between organisms. The game takes approximately 15 minutes as written; however, there is room for this game to be lengthened to fill more time if needed. The simplest way is to increase the number of rounds students play, this will also benefit the game as it will make it more likely that the result of the first round will be a normal curve and that the student with the red dot will have a significant advantage in the second round. It is very important that the BU volunteers are active during this game and ask questions that force students to think about the system that they are modeling. We provide the BU volunteers with the personal cards (Appendix A "MASS Invaders") to help them start the conversation with their groups. The student with the red dot card will have the competitive advantage in the second round and it is possible to have a bit of fun in selecting that student. Sometimes the BU volunteer will choose the student who had the lowest number of pennies in the first round, or to the quietest student, or sometimes to the loudest most energetic student. It is the BU teacher's role to encourage conversation between volunteers and students, to keep track of time, and to alert the BU volunteers as to how much time they have remaining in each round.

Activity 2: Matching Game

2.1 Activity Protocol

Prior to the lab, a secondary room is set up with plant, bird, and mammal specimens are separated into 8 sets and each set is placed one of 8 stations around the perimeter of the room. Each student group is asked to walk to a station and not touch the specimens while waiting for further instruction. BU Volunteers are stationed such that each is managing one or two stations. The volunteers remain at their stations throughout the activity and are provided with an instructional sheet (Appendix B, "Matching Game"). Students rotate through every station having 2 minutes at the first station and 1 minute at every subsequent station. The activity is intended to be short and to focus on the student's ability to quickly recognize species. Volunteers work with the students to help guide their use of the field guide and dichotomous tree (Appendix M, "Dichotomous Tree" and Appendix N, "Species Card").

2.2 Notes for the Instructor

This is possibly the most challenging activity in terms of feasibility. Boston University has a large museum of specimens collected over many years that the design team was able to choose from when creating this activity. Specimens were chosen because they represented species that are commonly seen in Boston and are likely to be seen in the field. If taxidermy specimens are not available, it is also possible to use photographs or videos to show particular species of interest. To avoid damaging the specimens, we arrange them on the outer edge of the room and in groups of no more than three or four per station (Appendix O). The students are also instructed on multiple occasions to not touch the organisms. Students are told to use their field guides to help identify each organism. The instructor's major role is to keep time and to ensure that students are rotating to the next station efficiently.

Activity 3: Scavenger Hunt

3.1 Activity Protocol

The scavenger hunt has the overarching purpose of providing students with the means to explore the urban ecosystem and to identify human impacts. The scavenger hunt is comprised of 9 major tasks:

3.1.1 Task 1: General Site Description

This task asks students to count the number of large trees, small trees, bushes, birds, and mammals at three stations and attempt to identify those that they observe. They will also check in with the "Invader" volunteer (Appendix D, "Invader Personal Card") at one location who will ask them a series of questions and will sign off on their successful answering of those questions.

3.1.2 Task 2: Invasive Species

This task asks students to identify invasive species and answer questions provided by the "Invader" volunteer (Appendix C "Invader Personal Card") who will then sign off on their worksheet.

3.1.3 Task 3: Woodcutter

This task asks students to examine a cut tree. The students count the number of rings in the section and discuss with the "Woodcutter" volunteer (Appendix D,

"Woodcutter Personal Card") how they can estimate environmental conditions based on their analysis. Students will also collect samples of water from the local body of water.

3.1.4 Task 4: Tree Hugger

This task asks the students to use the dichotomous tree and field guide to identify pre-selected and marked trees. They are asked to briefly write about the benefits of the local flora. The "Tree Hugger" volunteer (Appendix E, "Tree Hugger Personal Card") leads the task and provides the training for the students in how to use the dichotomous tree and field guide to identify trees.

3.1.5 Task 5: Tree Health

This task gives the students the opportunity to assess the health of trees in the urban ecosystem. The "Tree Hugger" volunteer also leads the discussion of tree health while providing the training necessary for the students to complete Task 4.

3.1.6 Task 6: Traveler

This station asks students to evaluate how humans impact the environment through the construction of solid structures such as a bridge. The station is located at a derelict bridge that is no longer in use and has fallen into a state of disrepair. The "Traveler" volunteer (Appendix F, "Traveler Personal Card") asks students questions about the human impacts in this location and others in an urban environment.

3.1.7 Task 7: Leaf Analysis

This task asks students to draw leaves from two marked trees and to compare and contrast between the leaves using descriptive vocabulary such as shape and venation pattern.

3.1.8 Task 8: Trash

For this task, students are asked to make observations of the presence of trash and recycling bins in and around the field site. Students are also asked to assess how full those bins are.

3.1.9 Task 9: Dr. Dolittle

For this task, students are asked to listen to the sounds at three different sites. At the first location, students interact with the "Dr. Dolittle" volunteer (Appendix G, "Dr. Dolittle Personal Card") who asks the students questions about the sounds that they hear and about how man-made sounds might impact local organisms.

3.2 Indoor Alternative

Each task has been recreated for an indoor-friendly version of the module. In order to accommodate for the lack of an outdoor field site, the tasks were replicated on PowerPoint presentations that the volunteers at that task moderated. For ease of training, the volunteers had nearly identical responsibilities at each station and similar questions. Indoor versions of the personal cards were created to accommodate for the differences that did exist and provide the answers to the task-specific questions.

3.3 Notes for the Instructor

The creation of this lab was lengthy and a design committee was convened specifically to create this component of the module. The details of the design process are explained in the ABLE publication noted above (Rycroft and Seliga, 2013). Of most critical importance to the success of this activity are the specific assignments for each volunteer, the personal cards or cheat sheets for each volunteer's role, the development of more tasks than could possibly be completed in the time allotted to ensure that students are never sitting and waiting for others to finish, and the creation of the indoor contingency. Additionally, it is important to train each volunteer for each of their tasks and ensure that the volunteers understand the purpose and goals of each of their responsibilities. One of the more challenging components of the design was finding the field sites and developing tasks specific to those sites. For any individual interested in the development of a module such as this, the first steps should be identifying viable field sites and then creating tasks specific to the ecosystems at those sites.

Activity 4: Urban Water

4.1 Activity Protocol

In this activity, water samples that were gathered at the field site are examined under the microscope. Students look for organisms and attempt to draw and identify any that they observe. ProtoSlo is used to reduce the mobility of the specimens under the microscope. Adding ProtoSlo according to the manufacturer's instructions is important, as is the 10-minute wait between adding the chemical and placing the slide under the microscope. A camera setup on the teacher's microscope allows the teacher to display and explain specimens to the entire class. The Urban Water personal card (Appendix H) explains the protocol and the responsibility of the volunteers during this exercise.

4.2 Indoor Alternative

To accommodate for the water sampling that cannot be completed during the trip to the field site, a 10-gallon sample of water was collected beforehand. The water is stored in a sunny location with an air stone to provide oxygen to the tank. Students can then use this water to complete the activity. Additionally, in the event that the students do not have significant amounts of visible life in their water samples, the students can supplement their samples using water from this tank. When collecting samples, it is very important to obtain not just water from

the surface but also some sediment or detritus from the bottom of the water body. Many organisms hide in these areas during the day or lay their eggs in these areas.

4.3 Notes for the Instructor

The most challenging aspect of this activity is the identification of freshwater invertebrates. Often, it is very challenging and therefore helps to have somebody on staff that is knowledgeable of freshwater organisms. Students often struggle to collect water samples with significant numbers of organisms present. For that reason, it is often necessary to supplement student collections with the previously collected 10-gallon sample in the lab. If the sample is kept in a clear glass tank, it is possible to see the invertebrates swimming in the water and becomes a bit easier to collect specimens for observation under the microscope. Once the water sample is obtained, it can be held in the lab for over a week as long as a bubbler is added to maintain oxygen levels.

Activity 5: Tough Stuff Here to Stay

5.1 Activity Protocol

At the beginning of this exercise, students put on gloves and dump the trash that they collected during the scavenger hunt activity on the lab desk. Students, with the assistance of the BU volunteer at their station sort through the trash and group pieces based on material and size. The students then attempt to estimate the total amount of trash and how long each item would take to decompose.

5.2 Indoor Alternative

To accommodate for an indoor version of this lab, students are asked to sort through pre-collected trash. This pre-collected trash can be obtained beforehand from trash bins within the building or collected from the field site at an earlier date, sealed, and stored in a cold room until needed.

5.3 Notes for the Instructor

This is one of the easier activities to prepare for and execute. The most critical note for the instructor to convey to volunteers and students is the awareness of dangerous objects and the instruction to not touch any drug paraphernalia or broken glass.

Literature Cited

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Derek Stefanik earned his PhD from Boston University. He is currently a Postdoctoral Researcher at The University of Pennsylvania. Research interests

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Mission, Review Process & Disclaimer

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Appendix A
Mass Invader (Main Classroom)

ALL VOLUNTEERS (EXCEPT DR. DOLITTLE) CHOOSE A BENCH. THIS IS YOUR GROUP OF 6 FOR THE DAY!

The purpose is to introduce students to how invasive species impact native species. Choose a bench and lead your 6 students through at least two rounds (1st as native species, 2nd with one invasive species introduced).

Basic Protocol

1. Round 1: have 6 playing cards and 18 pennies, 3 pennies each
   a. Shuffle the playing cards and deal one to each student.
   b. The student with the lowest card pays one penny to the student with the highest card.
   Note: If a student loses all pennies, they are still in the game. If they are given the lowest card when they have zero pennies, no pennies change hands and the game continues.
   c. Recollect the playing cards and shuffle them again.
   d. Repeat for 5 rounds. Indicate to the teacher when you finish.
   e. Have students count how many people have 0 pennies, 1, 2, 3, 4, 5, and 6+.
   f. Remember or write the data as such:

# of pennies	0	1	2	3	4	5	6+
# students							

2. Round 2: WAIT FOR TEACHER! same setup as above, plus invasive cards (the card with the red spot on the back represents the invasive species which has a competitive advantage over native species)
   a. Reset the pennies so that each student has 3 pennies again.
   b. Pass out the invasive cards face down.
   c. Shuffle the playing cards and deal three to the student with the red card.
   d. The student with the red card will choose the highest of the 3 cards and will return the lower 2 to you.
   e. Deal the cards out to the other students.
   f. Similar to Round 1, lowest pays the highest one penny, recollect, shuffle, and repeat for 5 rounds. Indicate to the teacher when you finish.
   g. Have students count how many people have 0 pennies, 1, 2, 3, 4, 5, and 6+.
   h. Remember or write the data as before.

Sample Q&A

Round 1: Around the 2nd or 3rd deals of the cards, ask probing questions:

- Q: What do the pennies represent? Think about plants and animals. What do animals or plants need to live? Are there equal amounts? What happens if there is not enough food? Use anecdotes or analogies.
- A: resources (food, water, territory, mates, etc.). Students may remember vocabulary such as survival of the fittest, endangered, extinct, adaptation, but they may not remember precisely. Incorporate adaptation specifically into your discussion (relevant for next activity).

Round 2: Around the 2nd or 3rd deals of the cards, ask probing questions:

- Q: What's happening with the student with the red dot? What happened to the other players? How was this different from the first time you played the game? Why did the red dot player win?
- A: Some of the green dots "died." More of them "died" than in round 1 (may not be necessarily true for all groups—see class data). The red dots were able to get more resources. You want to guide the students to saying that they outcompeted the green dots

After Round 2: Have students flip over the cards and have them read aloud what organism they are to their group)

- Q: Why did the (fill in name of organism) win the game? What traits of the (organism) allowed it to win the competition? Why did the other organisms lose the competition (allow students to go around and share info)

- A: Because they are an invasive species. Winners are specific to cards (no natural predators/parasites, use resources more quickly than native species, faster reproduction time, etc.). Losers are specific to cards (predation, not enough food, lose habitat (highlight the indirect interactions: how a plant might change the habitat or an animal, or how another organism might lose its food source). The take home is that some of these interactions are not directly between the invasive and the native species. You can also bring up how many species are impacted by a single invasive.

Transition

- Elect a speaker of the group to prepare to answer any of the teacher's questions
- Remember the 2 students who "lost" (became extinct first, or fewest pennies after round 2)

Appendix B
Matching Game (2ND classroom)

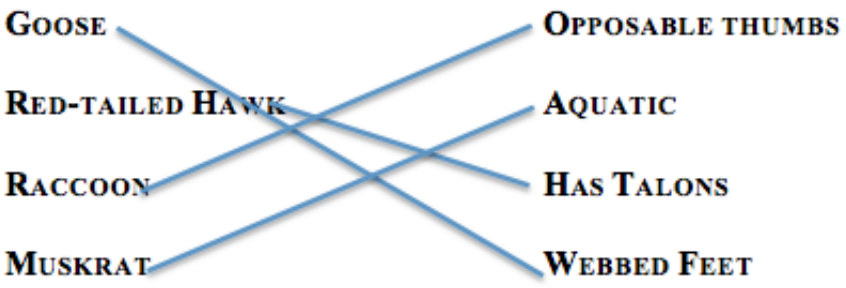
The purpose is to instruct students how to identify birds and mammals from the BU museum.

Basic Protocol

1. Split your group of 6 into two groups of 3.
2. Give each team a Field Kit:
   a. Separate the 2 students who "lost" at Mass Invaders, assign as Trash Collectors for their teams (important for the next tasks)
   b. Assign Data Collectors (holds clipboard and records data)
   c. Assign Grunts (responsible for Field Kit contents)
3. Bring your students to the 2nd classroom and choose two Animal Matching stations near each other (do not congregate by the door).
   a. TELL STUDENTS THEY SHOULD NOT TOUCH THE SPECIMENS.
4. For 2 minutes, help your 6 students in two separate teams and these first stations ID the specimens.
   a. Point out how the Field Guide cards are organized and ask questions.
   b. Answer key is the back of this page.
5. Students will rotate to the next station and have 1 minute to ID the specimens while you stay at your station and help the next group.
6. If the group finishes early, help them with the adaptations on the back of this page, particularly if this specimen is at your station.

Answer Key for Student Worksheet:

A	pigeon/rock dove	B	red squirrel
C	mallard ducks	D	robin
E	opossum	F	woodpecker
G	house sparrow	H	rat
I	chipmunk	J	herring gull
K	cottontail	L	starling
M	muskrat	N	hawk
O	Canada goose	P	cardinal
Q	gray squirrel	R	raccoon
S	mouse	T	red-winged blackbird



Appendix C
Invader (Tasks 1 and 2 at Site A/ISP)

You will have two primary tasks: have the students ID the types of birds and plants for Task 1 (Site A; ask when no students at ISP) and for Task 2 (ISP; can have up to 2 teams here simultaneously). For both, show students how to use the Field Guide. Initial and insert points (out of 5) on the worksheet if answers are satisfactory. (Note: On the back of this guide, we include images of the most common invasive species in the region)

Invasive Species Patch (ISP):

The purpose of this site is to extend the discussion from the classroom.

Q: Which species in the patch are invasive and which are native?
A: Have them point out each one to you (see back of page for samples).

Q: Which of the species can you identify here?
A: This may be fast or slow depending on the students.

Q: Why are these species so common?
A: Because they are invasive.

Q: Think back to the invasive species card game. What characteristics of invasive species make them so successful?
A: rapid reproduction, no native competitors/parasites, etc.

Q: How do you think these species got here?
A: Knotweed – decoration; Phragmites – accidently carried from Europe

General Identification and Counting (Site A)
Q: What do you see? What types of organisms are here?
A: plants, birds, mammals, insects, water, etc.

Q: How can you measure how many (ex. Trees) are here? Don't count!
A: Estimate. Talk about measuring one area and then extrapolating to the rest

Q: Do you notice human impacts? What are they?
A: people, road, etc.

Answer Key for Student Worksheet

Type	Number	Species ID
Large Trees	4	Swamp oak (the major tree in the middle)
Small Trees/Bushes	0	
Birds	Varies	Possible: Geese, grackle, robin, starling, pigeon, red-winged blackbird, field sparrow, red-tailed hawk, mourning dove, cardinal, mallard, chickadee
Mammals	Varies	Possible: Squirrels, muskrat, field mouse

Figure 1. Japanese Knotweed. Introduced: Decoration

Figure 2. *Phragmites australis*. Introduced accidentally from Europe. Impact: Spreads rapidly and overwhelms native species

Figure 3. European starling. Introduced: Sixty were set free in Central park in 1890 by Shakespeare admirers. They are now one of the most common birds in America. Impact: Take up shelters that would normally be used by native birds which decrease native birds' ability to reproduce.

Appendix D
Woodcutter (Task 3 at Site T)

You will have two primary tasks: help students examine a tree trunk that has been cut and collect a water sample with their plastic specimen cups.

Tree Trunk
Q: How do you tell how old a tree is? How old is the tree? (questions in student worksheet)
A: Count the rings (there are 44-45)

Initial and insert points (out of 5) on the worksheet if answers are satisfactory.
Q: What do the thick rings and the thin rings mean?
A: Thick = strong growth year, Thin = weak growth year. Thick rings could indicate a wet summer or short winter season. Thin rings could indicate drought, a hot (or cold) summer or a long winter.

Q: Why are the thick rings sometimes different thicknesses?
A: Water/nutrient availability, temperature, etc. If you have a longer better growing season you have thicker rings

Q: Are the rings symmetrical (the same around the tree)? Why or why not?
A: No. The tree grows larger on one side or another because of where the sun is, where other trees are, the slope that it is on (grows up the slope faster than down it), where the water is.

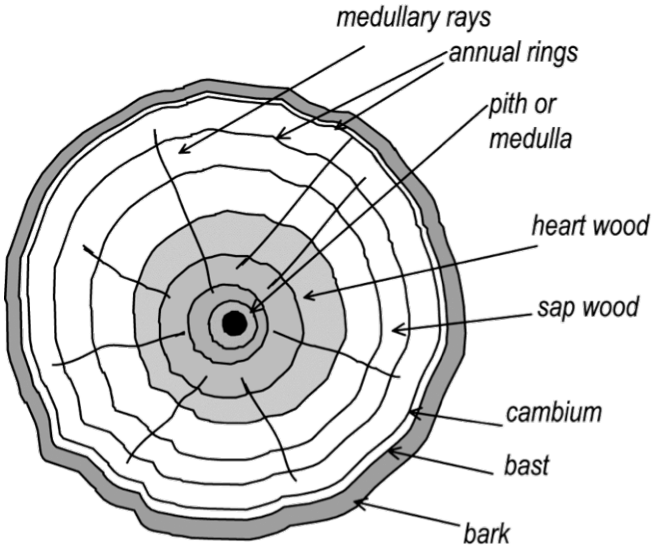
Q: What does the color of the rings indicate?
A: Dark – late wood (growth from later in the year), light – early wood (growth from early in the year)

Ask them about the vocabulary on the next page. Tell them what each thing is and ask them what its function might be. Ask them to point out these features on the cut tree.

Water Collection

When the kids are collecting water, make sure that they fill their bottle completely. Ask the kids if they need to wear the gloves that were provided in their field kit. MAKE SURE THE KIDS DO NOT ENTER THE WATER OR ACCIDENTALLY FALL IN.

Note: Here we include an image of the cross-section of a tree along with labels identifying each of the following features.



The tree trunk showing growth rings

Figure 4. Tree trunk cross section.

Pith, or **medulla**, is a tissue in the stems of vascular plants. Pith is composed of soft, spongy parenchyma cells, which store and transport nutrients throughout the plant.

Heartwood is wood that as a result of a naturally occurring chemical transformation has become more resistant to decay. Heartwood formation occurs spontaneously (it is a genetically programmed process). Once heartwood formation is complete, the heartwood is dead.

Sapwood is the younger, outermost wood; in the growing tree it is living wood, and its principal functions are to conduct water from the roots to the leaves and to store up and give back according to the season the reserves prepared in the leaves.

Medullary rays, also called pith rays or wood rays: these formations of primarily parenchyma cells allow the radial transmission of sap and are essential in the process of tylosis.

Annual rings are visible rings that result from the change in growth speed through the seasons of the year, thus one ring usually marks the passage of one year in the life of the tree. The rings are more visible in temperate zones, where the seasons differ more markedly.

Appendix E
Tree Hugger (Tasks 4 and 5 at Example Tree)

You will have two primary tasks: help students identify trees based on the physical characteristics and explain how to identify healthy and unhealthy trees. There is a 5-minute limit for each group at the Example tree (home base). But ask the questions about tree health to prepare them for Task 5 on their own. For both tasks, show students how to use the *Field Guide.*

Tree Identification

HOW TO ID A LEAF: (Note: On the back of this card, we provide a guide to identifying each of the following features of a leaf, students also have a similar guide within their *Field Guides*)

1) Is the leaf simple or compound? This is based on the number of leaves originating at the Axillary bud (most difficult part)
2) What is the shape of the leaf?
3) What is the venation pattern?
4) Are the leaves on a branch opposite or alternate?
5) Are there any unique features of this leaf? (i.e. thorns, fuzzy stems, etc)

Determining the Health of a Tree

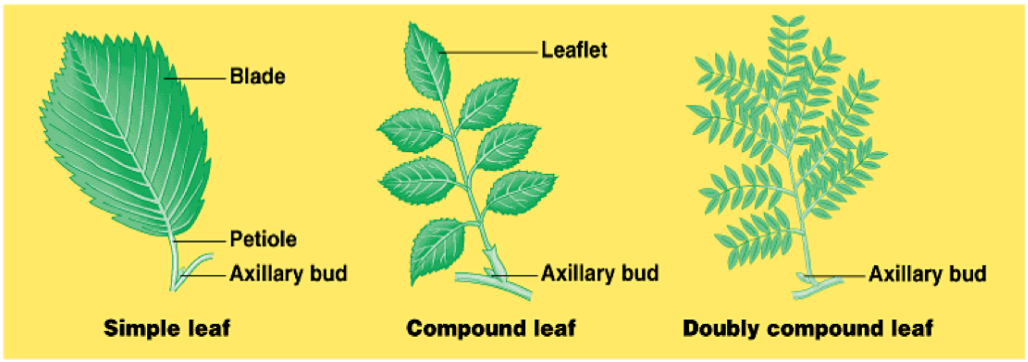
Q: This is a healthy tree. What tells you it's healthy?
A: height, number of leaves, branches, healthy bark cover, color of leaves, lack of herbivory (chew holes)

Q: What might an unhealthy tree look like?
A: no leaves, leaves discolored, rotting, bare branches/trunk, webworms/tent caterpillars

Q: Why might there be unhealthy trees in a city?
A: pollution, lack of nutrients, human destruction, invasive species, etc.

Answer Key for Student Worksheet

(Example) ____Ashleaf maple
Tree A_____Downy Juneberry
Tree B _____Swamp oak
Tree C_____ Staghorn sumac
Tree D _____Black Locust
Tree E_____Sugar Maple
Tree F _____Red maple
Tree G_____Green Ash



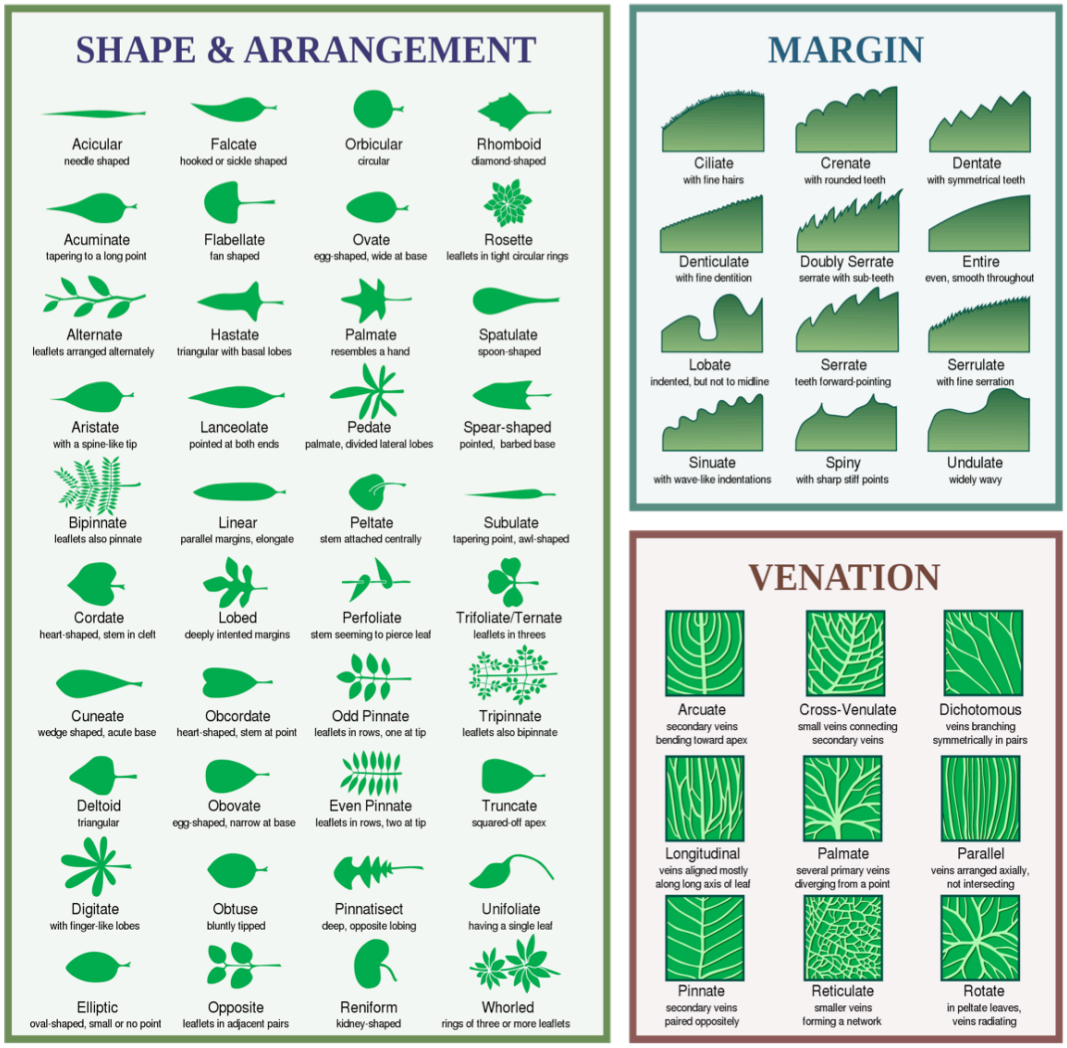


Figure 5. Leaf types, shapes, arrangement, margins, and venation.

Appendix F
Traveler (Task 6 and 9 at Site C)

You potentially have two primary tasks: for Task 6, look at human impacts on the ecosystem (Site C), for Task 9, listen for animal sounds (if no Dr. Dolittle volunteer; grab Dr. Dolittle's personal card, but complete tasks at Site C).

Bridge

Make sure the kids look at the bridge closely. *DO NOT ALLOW THEM TO CLIMB ON THE BRIDGE*

Things That Determine Environmental Impact of a Bridge:

- Footprint – how much of the ecosystem was destroyed to place the bridge
- Construction of the bridge – how long it took to put it together (from the beginning to the end)
- The supplies used on the bridge (i.e. steel worse than concrete worse than wooden).
- Where the bridge is placed (wetland vs barren rock)
- What is the bridge used for? (Cars can leak oil or antifreeze, people can throw things off the bridge, cars and trains produce CO_2, etc.)
- How long will the bridge last? (i.e. will it need to be replaced? At what cost? Based on weather and materials)

Initial and insert points (out of 5) on the worksheet if answers are satisfactory.

Q: What do you notice about this bridge?
A: no longer in use, heavily rusted, falling apart, no clear function, etc.

Q: How is the bridge impacting the environment?
A: rust can go into environment, water supply, not safe for people, animals, eyesore

Q: What should the city do about the bridge?
A: tear it down, repair, leave it. Let the students discuss pros and cons.

Q: What other human impacts are there in the Fens?
A: car exhaust, runoff, trash, paved path, dogs, in general urban effects.

Q: What can we do as individuals or as governments to manage our effects on the environment?
A: Controlling pollution, using public transportation, recycling, etc.

Animal Listening

If there is no Dr. Dolittle volunteer today, grab that Outdoor Volunteer Personal card and engage students at your Site C.

Appendix G
Dr. Dolittle (Task 1 and 9 at Site B)

You will have two primary tasks: Task 9 is listening for animal sounds and Task 1 is general identification of plants and animals at Site B (can have up to 2 teams here simultaneously). For both tasks, show students how to use the *Field Guide*.

Animal Listening

The purpose of this station is for the students to listen to the world around them and attempt to identify the animals that make them.

While Identifying:

- Point out an animal - what sound would you expect that animal to make?
- Can you replicate that sound (check "how to identify sounds" below)?
- Ask "is it just one animal or is it a group of them?"
- If students are stumped, start with "is it a bird or mammal?"
- Then, if bird, ask "is it a bird of prey, song bird, or goose?"

Once Identified

Q: Why do animals make sounds?
A: Communication, warning, to find mates, just sounds of movement, etc.

Q: What might a warning call sound like? A mating call?
A: Warning call might be loud, scare away etc. Mating call is specific to a species.

General Identification and Counting

Q: What do you see? What types of organisms are here?
A: plants, birds (geese, grackle, robin, starling, pigeon, red-winged blackbird, field sparrow, red-tailed hawk, mourning dove, cardinal, mallard, chickadee), mammals (squirrels, muskrat, field mouse), insects, water, etc.

Q: How can you measure how many (ex. Trees) are here? Don't count!
A: Estimate. Talk about measuring one area and then extrapolating to the rest

Q: Do you notice human impacts? What are they?
A: people, road, etc.

How to Identify Sounds

Q: Is it repetitive, rhythmic and sustained?
A: draw attention to itself

Q: Is the call erratic, maybe consisting of a few sounds and then silence?
A: This could be an alarm signal

Some of the Sound Types You Might Hear

- Warble - Sing softly and with a succession of constantly changing notes
- Whistle - A clear, high-pitched sound
- Quack - The characteristic harsh sound made by a duck
- Caw - The harsh cry of a crow or similar bird
- Cackle – The raucous clucking cry of a bird such as a hen or goose
- Trill - A quavering or vibratory sound
- Chatter - A rapid series of short, inarticulate, speech-like sounds
- Click - A short, sharp sound as of two hard objects quickly making contact
- Squeak - A short, high-pitched sound or cry
- Chitter - Make a twittering or chattering sound
- Chirp - A short, sharp, high-pitched sound

Common Animals for Student Worksheet (with descriptions to help students):

1. Red-tailed hawk - Adults make a hoarse, screaming "*kee-eeeee-arr*". It lasts 2-3 seconds and is usually given while soaring
2. Robin - It's a string of 10 or so clear whistles assembled from a few often repeated syllables, and often described as *"cheerily, cheer up, cheer up, cheerily, cheer up."*
3. Beaver – generally hear a loud splash as it slaps its tail against the water
4. Chickadee - the song is a simple, pure 2 or 3-note whistled "*fee-bee"* or "*hey, sweetie"*, make their "*chickadee-dee-dee"* call using increasing numbers of "*dee"* notes when they are alarmed
5. Canada goose - Various loud honks, barks, and cackles. Also some hisses
6. Grackle - make a variety of squeaks, whistles, and croaks. The typical song, made by both males and females, is a guttural "*readle-eak"* accompanied by high-pitched, clear whistles.
7. Starlings - warble, whistle, chatter, make smooth liquid sounds, harsh trills and rattles, and imitate meadowlarks, jays, and hawks. The songs tend to consist of either loud whistles or softer, jumbled warbling
8. House sparrow – has a rather simple song of one or a series of "*cheep"* or "*chirrup* notes"
9. Mourning dove - The song (or "*perch-coo*") is given mainly by unmated males from a conspicuous perch. It's a soft *coo-oo* followed by two or three louder coos
10. Cardinal - The song is a loud string of clear down-slurred or two-parted whistles, often speeding up and ending in a slow trill. The songs typically last 2 to 3 seconds. Syllables can sound like the bird is singing "*cheer, cheer, cheer"* or "*birdie, birdie, birdie"*.
11. Blue Jay – "*jeer"*, most often considered a song is the "whisper song," a soft, quiet conglomeration of clicks, chucks, whirrs, whines, liquid notes
12. Pigeon - Song is a rolling series of throaty coos

Appendix H
Urban Water (Main Classroom)

To allow students to discover how humans impact urban water systems. In the previous activity, students collected water samples and will bring to the lab to identify microorganisms living at the Fens.

Basic Protocol

1. Each team of students will use one microscope and their water sample (try to spread out the work among the team).

2. Instruct one student in each team to pipet several drops (not too much) of their water from the sediment into the depression slide.
   a. "Dr. Dolittle" and the teacher will add 1 drop of ProtoSlo to each of team's slides when ready (takes about 10 minutes to work more effectively).

3. Instruct a different student to place a cover slip onto the depression slide.

During Background

1. Set up each microscope to observe the organisms at 10X (scan the sample for the students and find a "live" area on each scope).

After Background

1. Have students sketch up to three organisms in student worksheets.

2. Help students identify each organism to the best of your abilities using the common organisms identification guide on the back page.

3. Have students observe the organisms at 40X.
   a. The students should try to draw the same organism as before (or try to draw new ones that you couldn't see before).
   b. If it is a new organism, try to identify it.

Sample Q&A

Once you get each team set up to view a particular organism, keep them interested but ask probing questions to help them draw and identify what they see.

- Q: What general shape is the organism? Is the organism moving? How is the organism moving? Can you see parts of the organism at 40X that you couldn't see at 10X?
- A: Oval, long, or round. If Diatom, probably not. If other organism, then it is probably moving around. Using its legs, cilia (imagine having little rowing oars all over your body to help you move around), and body movements. Rotifers and nematodes, look elongated, and worm-shaped at times, but rotifers move like a slinky (i.e., expand and contract along the length of their body), whereas nematodes basically thrash about using side-to-side undulations of their body – very spastic little creatures). Maybe internal body structures, or feeding appendages around their mouths.

If the Students Identify and Draw Quickly, or More Time is Left, etc, Ask the Following:

Q: Do you think there is any correlation between the abiotic conditions and the types of species that you found at The Fens?

A: Yes. The worse the abiotic conditions, the less diversity that would be observed

Q: Create a hypothesis for how the organisms or abiotic factors are influenced by humans: For the organisms? For the abiotic factors?

A: Varies – can say that the more urban it is, the fewer organisms**.** Varies – can say that the more urban it is, the worse the abiotic factors

Q: Propose an experiment or environmental monitoring program to test this hypothesis.

A: Depends on their answer to the last question. Possible answers include:

Experiment: Create an urban wildlife preserve to see whether the organisms or abiotic factors change Monitoring: Regularly collect water samples and regularly observe organisms to determine whether things are changing. Test this against a non-urban (i.e. rural or natural) ecosystem.

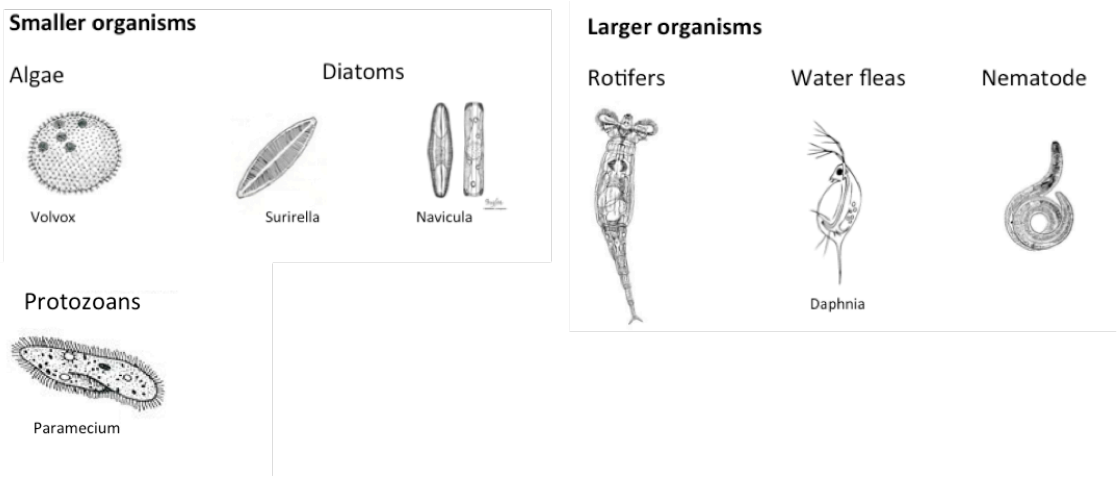


Figure 6. Common organisms in water.

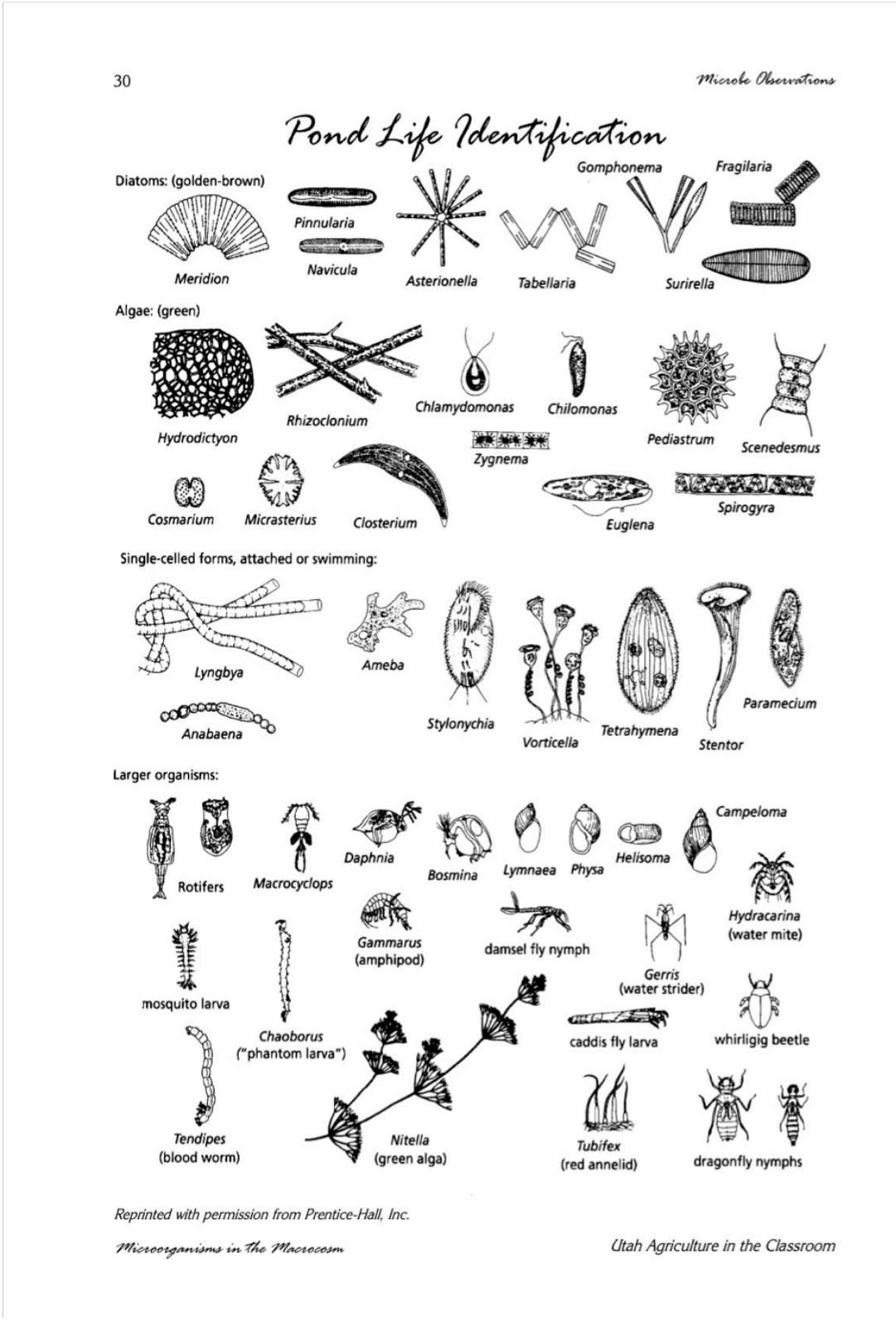
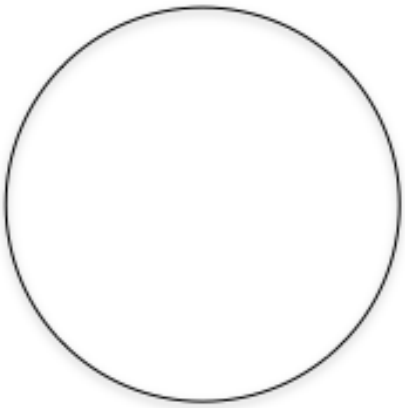


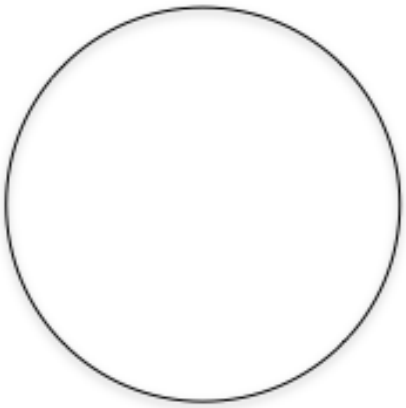
Figure 7. Pond organisms.

Please draw and identify three organisms in your water sample. (15 pts)
Organism #1 (5 pts): Name:_____

10X

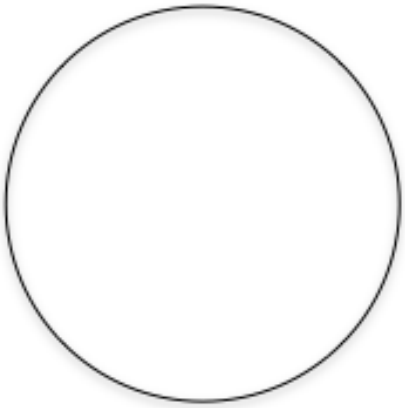


40X

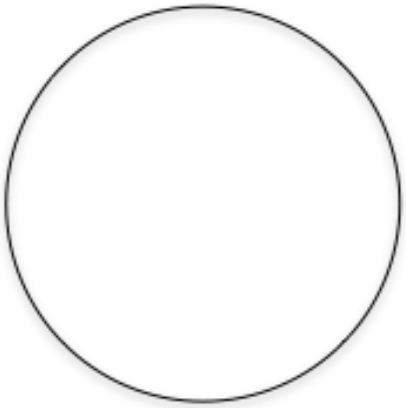


Organism #2 (5 pts): Name:_____

10X

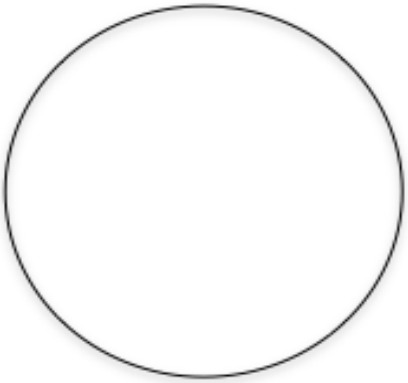


40X



Organism #3 (5 pts): Name:_____

10X



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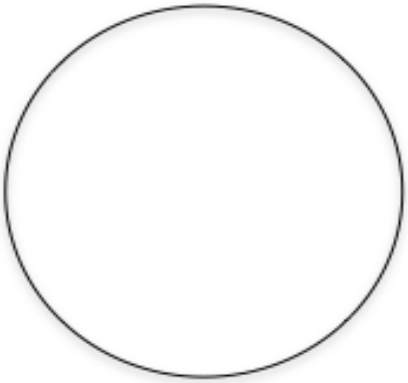


Summary of Results: (10 pts)

1. How many different types of organisms did you see (5 pts)?
   Class data
2. What were the abiotic (i.e., weather) conditions at The Fens (5 pts)?
   Gathered using class data

Appendix I
Urban Ecology Student Worksheet (Outdoor)

Team Name:

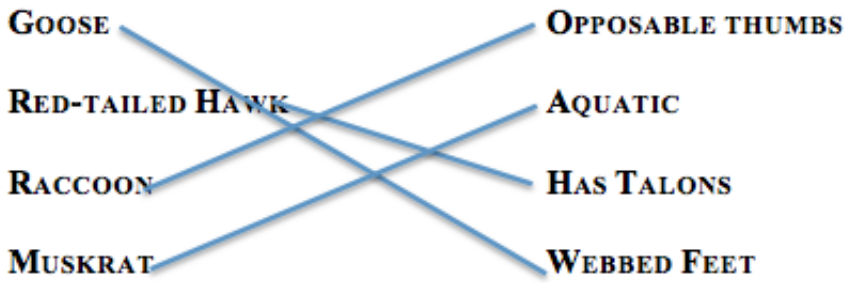
Team Members:

Matching Game (25 PTS)

In front of you are birds and mammals from BU's museum collection that you could see in the field today. Each specimen is labeled with a letter. Use your *Field Guide* (ringed cards) to match as many specimens with the correct name as you can in 10 minutes (**1 pt each**).

A pigeon/rock dove	B red squirrel
C mallard ducks	D robin
E opossum	F woodpecker
G house sparrow	H rat
I chipmunk	J herring gull
K cottontail	L starling
M muskrat	N hawk
O Canada goose	P cardinal
Q gray squirrel	R raccoon
S mouse	T red-winged blackbird

Match the animals below with the correct adaptation(s). (**5 pts**)



Field Tasks

Rules

1. Move around the designated area indicated by your map and correctly complete as many tasks as possible.
2. No more than 1 team per task at the same time.

Task 1 – 20 pts

Go to "SITE A" on your map. Count the number of bushes, trees, birds, mammals, and people in SITE A. Use your *Field Guide* to help with correct identification. At each site there is a Volunteer to help and to check your work before moving on to the next site. If you have time later, return to these sites and attempt to identify the plants or animals that you counted.

Site A (5 pts total):

Type	Number (3 pts)	Can you ID birds and mammals? Write below (2 pts)
Large Trees	4	
Small Trees or Bushes	0	
Birds	Varies	Possible: Geese, grackle, robin, starling, pigeon, red-winged blackbird, field sparrow, red-tailed hawk, mourning dove, cardinal, mallard, chickadee
Mammals	Varies	Possible: Squirrels, muskrat, field mouse

Site B (5 pts total):

Type	Number (3 pts)	Species ID (2 pts)
Large Trees	8	
Small Trees or Bushes	4	
Birds	Varies	Possible: Geese, grackle, robin, starling, pigeon, red-winged blackbird, field sparrow, red-tailed hawk, mourning dove, cardinal, mallard, chickadee
Mammals	Varies	Possible: Squirrels, muskrat, field mouse

Site C (5 pts total):

Type	Number (3 pts)	Species(2 pts)
Large Trees	5	
Small Trees or Bushes	2	
Birds	Varies	Possible: Geese, grackle, robin, starling, pigeon, red-winged blackbird, field sparrow, red-tailed hawk, mourning dove, cardinal, mallard, chickadee
Mammals	Varies	Possible: Squirrels, muskrat, field mouse

After you complete the numbers for sites A, B, and C, you can go to the Volunteer at Site A, who will ask you some questions about these sites.

Volunteer's Grade: _____ **(5 pts)** Volunteer's Initials: _____

Task 2 (15 pts)

Use your map to find the Invasive Species Patch (labeled ISP on map).

1. Use your *Field Guide* to ID any invasive species that you see (**10 pts**)

   Phragmites, Japanese knot weed, Starlings

2. A volunteer at this Task will ask you some questions about invasive species.

Volunteer's Grade: _____ **(5 pts)** Volunteer's Initials: _____

Task 3 (15 pts)

Use your map to find the tree trunk (labeled Ton map).

1. Starting from the center and going to the farthest outside edge, approximately how many rings do you count? (**3 pts**)

44-45

2. What does this tell you about the tree's age when it was cut? (**5 pts**)

That it was around 45 years old, therefore it was in the approximately the middle/first quarter of its life (since we don't know the species) therefore something was either wrong with the tree or it was removed to create a view of the river.

A volunteer at this Task will ask you some questions about this tree.

Volunteer's Grade: _____ **(5 pts)** Volunteer's Initials: _____

While at this station, take the plastic container from your field kit and take a water sample to bring back to the classroom for analysis (more points!). The volunteer at the station will guide you through this process. **(2 pts)**

Task 4 (30 pts)

Use your *Dichotomous Tree* and *Plant Fact Guide* to correctly identify the trees (labeled on your map with letters on a leaf shape). You can choose to ID as few or as many (all 4) as you want, but you must start with the Example Tree (labeled as Example on map). A volunteer is at the example to help and to check your work before you move on. Each correct ID is worth **3 pts**.

(Example) Ashleaf maple
Tree A Down Juneberry
Tree B Swamp Oak
Tree C Staghorn Sumac
Tree D Black Locust
Tree E Sugar Maple
Tree F Red Maple
Tree G Green Ash

1. How do these trees benefit animals in the Fens? List two ways. (**3 pts**)

Shelter, Food, Shade, Protection, oxygen

2. How do these trees benefit people in the Fens? List two ways. (**3 pts**)

Shade, oxygen

Task 5 (10 pts)

On your map, you will see a mix of healthy and unhealthy trees (labeled on your map with letters on a leaf shape) that have been impacted by humans and/or diseases. Label which ones you think are healthy and unhealthy. (**2 pts each**)

Tree H _____ Tree I _____
Tree J _____ Tree K _____

1. Which tree(s) do you think suffer from human-made causes? (**2 pts**)

Task 6 (10 pts)

1. A volunteer at this Task will ask you some questions about the bridge.

Volunteer's Grade: _____ **(5 pts)** Volunteer's Initials: _____

Task 7 (10 pts)

Draw a leaf from Tree F and Tree L (labeled on your map with letters on a leaf shape) in the boxes on page 5. You must draw both (**3 pts each**). Look at your *Plant Fact Guide*. How are these leaves different? In the boxes, also write what venation pattern and shape each leaf shows (**1 pt for each correct answer**)

Plant 1	Plant 2
Venation pattern: Shape:	Venation pattern: Shape:

Task 8 (10 pts)

1. As you walk around, count how many trashcans you see in the Fens. **(2 pts)**
   3
2. Circle how full they look. (**3 pts**)
   Completely full ¾ full ½ full Mostly empty

3. How many recycling cans do you see in the Fens? **(2 pts)**
   0
4. Circle how full they look. (**3 pts**)
   Completely full ¾ full ½ full Mostly empty

Task 9 (15 pts)

In this task you will be listening to animal sounds. First, find a spot at Site "B" and listen to the sounds around you. Answer the following questions.

1. What kinds of sounds do you hear? Animal? Human-made? (**4 pts**)
   This answer will vary. As they put some decent thought into this, we can give them credit here. Possible sounds include quacks chirps, whistles, clicks, grunts.

2. List at least three reasons animals make these sounds. (4 **pts**)
   Possible: Mating, warning sound, communication, to defend territory, offsping attention.

3. How do you think living in an urban environment affects calling behaviors? **(4 pts)**
   This answer will vary, as long as they put some decent thought into this, we can give them credit here. Volume change, pitch change, proportion of warning calls might increase

Now go to Site "C" and listen again.

1. Do you hear any new animal sounds? How do the sounds differ between the two sites? **(3 pts)**

Trash – Tough Stuff Here To Stay (10 pts)?

In this part of the lab, we want to know how much you know about trash. While out in the fens, collect as much as you can. Which team will collect the most, and whose trash is the toughest? You will get gloves but please do not pick up anything that might be hazardous to you or others (needles, sharp-edged shards etc.). Which is easily avoidable?

Back in the lab, sort your trash according to the groups listed below and weigh each pile. How long will your stuff take to decompose? (Note: we include a table on the presentation that includes predicted decomposition times for each of the following items)

Type	**Count**	**Degradation time**
Plastic bottles, other hard plastics		
Plastic bags		
Paper, cardboard		
Styrofoam		
Glass		
Cans and other aluminum items		
Organics		
Clothes		
Drink cardboard containers		
Other		

Sum up how much of the stuff will still be here in 10/100/1,000 or even 1,000,000 (!) years. Keep in mind: what's still here in 100 years is also here in 10 years…

Still here in…	**Total count**
10 years	
100 years	
1,000 years	
1,000,000 years	

Do you know how to recycle? Check at home! These are the official lists of what can and cannot be recycled in Boston:

Acceptable Materials for Recycling

- Newspaper (with inserts)
- Magazines/Catalogues
- Junk mail (remove free samples; plastic envelope window is ok)
- White & colored paper/brown bags
- Telephone books
- Flattened food boxes
- Paperback books
- Milk and juice cartons
- Juice/soy milk boxes
- Flattened cardboard boxes
- Pizza boxes (empty)
- Glass bottles/jars. (lids and labels ok)
- Tin and aluminum cans, foil, and pie plates (lids and labels ok)
- All plastic containers (caps & lid may stay. No motor oil or chemical containers)
- NEW! cardboard/spiral cans (potato chip, coffee, nut cans, etc)
- NEW! rigid plastics (laundry baskets, buckets, toys, etc)

Unacceptable Materials for Recycling

- Styrofoam
- plastic bags
- motor oil containers
- chemical containers
- ceramics or dishes
- light bulbs
- window glass, mirrors
- yard waste
- food waste
- televisions
- computer monitors

Appendix J
Urban Ecology Student Worksheet (Indoor)

Team Name:

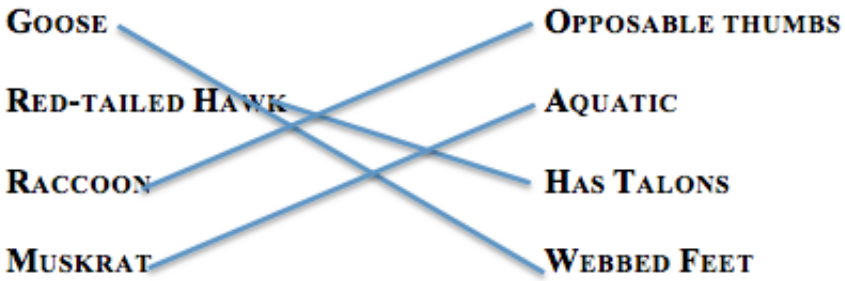
Team Members:

Matching Game (25 pts)

In front of you are birds and mammals from BU's museum collection that you could see in the field today. Each specimen is labeled with a letter. Use your *Field Guide* to match as many specimens with the correct name as you can in 10 minutes (**1 pt each**).

A	pigeon/rock dove	B	red squirrel
C	mallard ducks	D	robin
E	opossum	F	woodpecker
G	house sparrow	H	rat
I	chipmunk	J	herring gull
K	cottontail	L	starling
M	muskrat	N	hawk
O	Canada goose	P	cardinal
Q	gray squirrel	R	raccoon
S	mouse	T	red-winged blackbird

Match the animals below with the correct adaptation(s). (**5 pts**)



Field Tasks

Rules

1. Move around the room and correctly complete as many tasks as possible.
2. No more than 1 group per task at the same time.

Task 1 – Hidden Pictures (20 pts)

Use your *Field Guide* to help with correct identification of the animals and plants on the slide. A volunteer will check your work before moving on to the next site. If you have time, attempt to identify the plants or animals that you counted.

Type	Number (3 pts)	Species ID (2 pts)
Large Trees	At least 4	Swamp oak,
Small Trees or Bushes	1 mass	Japanese knotweed, Phragmites
Birds	12	5 starlings, 5 geese, 2 grackles
Mammals	2	1 gray squirrel, 1 red squirrel

Task 2 – Invasive Species (25 pts)

1. What is an invasive species? **(5 pts)**

   a species that has been transported by natural processes or human activities, either intentionally or accidentally, into a region where it did not occur previously, and reproduces and spreads rapidly into new locations, causing impacts to the economy, environment, or human health.

2. How can invasive species be introduced to a new area? **(5 pts)**

   Either by humans or natural causes.
   Humans: introduction by accident (stow-a-way) or because humans want that species there for pleasure
   Natural causes: pollen travel, climate change causes variation in migration

3. How can invasive species impact native species around them? **(5 pts)**

   cause impacts to the economy (removal costs), environment (out compete native species), or human health.

Using the hidden picture and *Field Guide*, your job is to identify any invasive species that can be found at the Fens. Based on the game we played in the classroom and your conversations with your group leader; answer the following questions.

1. Use your *Field Guide* to ID any invasive species that you see in the hidden pictures (**5 pts**)

   Phragmites, Japanese knot weed, Starlings

A volunteer at this Task will ask you some questions about invasive species.

Volunteer's Grade: _____ **(5 pts)** Volunteer's Initials: _____

Task 3 (15 pts)

1. Look at the picture in front of you, starting from the center and going to the farthest outside edge, approximately how many rings do you count? (**5 pts**)

   19-20

2. What does this tell you about the tree's age when it was cut? (**5 pts**)

   It is approximately 20 years old

A volunteer at this Task will ask you some questions about this tree.

Volunteer's Grade: _____ **(5 pts)** Volunteer's Initials: _____

Task 4 (30 pts)

Use your *Dichotomous Tree* and *Plant Field Guide* to correctly identify the trees. A volunteer will check your work before you move on. There is a 5 minute limit at this station Each correct ID is worth **3 pts**.

(Example) Ashleaf maple
Tree A Downy Juneberry
Tree B Swamp oak
Tree C Staghorn sumac
Tree D Black Locust
Tree E Sugar Maple
Tree F Red maple
Tree G Green Ash

1. How do these trees benefits animals in the Fens? List two ways. (**3 pts**)
   Shelter, Food, Shade, Protection, oxygen

2. How do these trees benefit people in the Fens? List two ways. (**3 pts**)
   Shade, oxygen

Task 5 (10 pts)

On the computer, you will see pictures of healthy and unhealthy trees that have been impacted by humans, animals, and/or diseases. In the spaces below, indicate which trees are healthy or unhealthy and what makes you come to that conclusion (ex. "The bark is peeling off" or "the leaves look healthy") (**1 pt each**).

Tree H Healthy –small insect marks on leaves, not major
Tree I Unhealthy – large section of tree rotted out
Tree J Unhealthy – bark stripped away
Tree K Healthy – healthy leaves
Tree L Unhealthy – dead branches
Tree M Unhealthy – vandalism, bark removed, tree dug
Tree N Healthy – good looking needles
Tree O Healthy – good looking bark

1. Which tree(s) do you think suffer from man-made causes? (**2 pts**)
   Tree M

Task 6 (10 pts)

On the table, you will see pictures of bridges in the Boston area. Rank these bridges from the one that has the least impact on the environment (1) to the one that has the greatest impact on the environment (4). How do they impact their environments?

Longfellow Bridge: 2 – medium size, cars, rusty
Leonard P. Zakim Bridge: 1 – large, lots of cars
BU Bridge: 3 – medium size, cars, no rust
Public Gardens Foot Bridge: 4 – small, stone
A volunteer at this Task will ask you some questions about the bridges.

Volunteer's Grade: _____ **(5 pts)** Volunteer's Initials: _____

Task 7 (10 pts)

Draw a leaf from two of the four example plants in the boxes on page 5 (**6 pts**). Look at your *Plant Field Guide*. How are these leaves different? In the boxes, also write what venation pattern and shape each leaf shows (**4 pts**)

Plant 1	Plant 2
Venation pattern: Shape:	Venation pattern: Shape:

Task 8 (10 pts)

Walk quietly around the 3rd floor.

1. How many trashcans do you see in the hallway on the 3rd floor? **(2 pts)**

2. Circle how full they look. (**3 pts**)

Completely full ¾ full ½ full Mostly empty

3. How many recycling cans do you see in the hallway on the 3rd floor? **(2pts)**

4. Circle how full they look. (**3pts**)

Completely full ¾ full ½ full Mostly empty

Task 9 (25 pts)

A volunteer will play a number of animal sounds for you. Match the sound to the animal that made it. You have 5 minutes to match as many as possible **(2 pts each)**

1. __E___	A: Beaver
2. __D___	B: Sparrow
3. __A___	C: Cardinal
4. __I___	D: Robin
5. __F___	E: Red Tailed Hawk
6. __J___	F: Canadian Goose
7. __H___	G: Mourning Dove
8. __B___	H: Starling
9. __G___	I: Chickadee
10. __C___	J: Grackle

Questions:

1. List at least three reasons animals make these sounds. (**2 pts**)

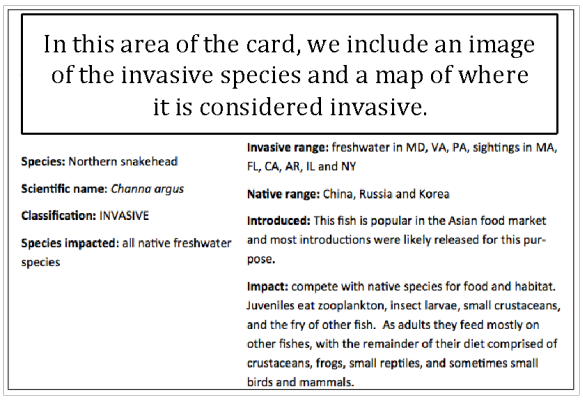
Possible: Mating, warning sound, communication, to defend territory, offsping attention,

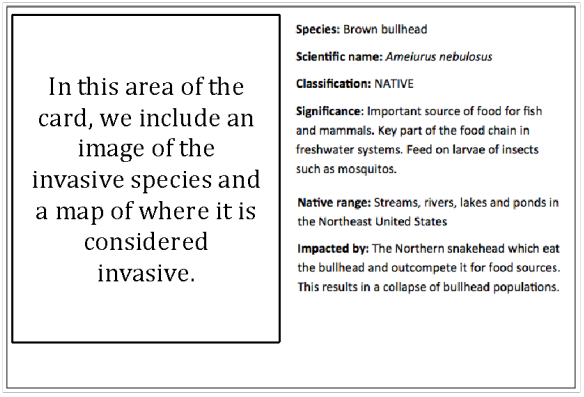
2. How do you think living in an urban environment affects calling behaviors?
(**3 pts**)

This answer will vary; I think as long as they put some decent thought into this, we can give them credit here. Volume change, pitch change, proportion of warning calls might increase

Appendix K

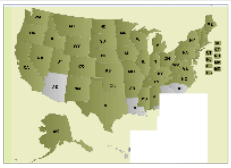
The cards below represent an invasive species card and a native species card. The species included are listed below.





	Card Set #1	Card Set #2	Card Set #3	Card Set #4	Card Set #5
Invasive Species	*Northern snakehead*	*Asian longhorn beetle*	*Asian shore crab*	*Mute swan*	*Purple loosestrife*
Native Species #1	Brown bullhead	American ash	American lobster	Bluegill	Common cattail
Native Species #2	Calico crayfish	American elm	Atlantic mud crab	Canada goose	Long-billed marsh wren
Native Species #3	Green frog	Northern red oak	Blue crab	Common loon	Mallard duck
Native Species #4	Walleye	Paper birch	Eastern oyster	Northern pike	Muskrat
Native Species #5	White bass	Sugar maple	Soft-shelled clam	Wigeongrass	Virginia rail

Appendix L
MASS Invader Set of Species Cards



Species: Purple loosestrife

Scientific name: *Lythrum salicaria*

Classification: INVASIVE

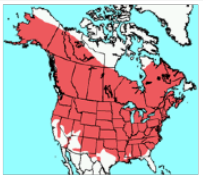
Species impacted: Native wetland plants including grasses, sedges and other flowering plants. Also impact the animals that feed on the plants impacted or use the plants for shelter or reproduction.

Invasive range: 44 states across the US, Canada

Native range: Great Britain, central/southern Europe, central Russia, Japan, China, India

Introduced: Introduced in 1800's for landscaping

Impact: Choke out native species which destroys habitat that hundreds of species depend on for survival. Degrade the health of wetlands by reducing biodiversity



Species: Muskrat

Scientific name: *Ondatra zibethicus*

Classification: NATIVE

Significance: A mammal which uses wetland reeds as food, shelter and nesting. Muskrats provide important food sources for many predators including foxes, coyotes, wolves, bears, snakes and hawks.

Native range: Wetlands throughout the United States and Canada

Impacted by: Purple loosestrife which invades and outcompetes the reeds which the muskrat live in. Without the reeds, the muskrat suffers from reduced habitat which can lead to local extinctions.

Species: Common Cattail

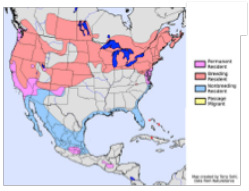
Scientific name: *Typha latifolia*

Classification: NATIVE

Significance: A plant which helps to protect marshlands from erosion. In addition these provide habitats for many species of bird and mammal.

Native range: Coastal and offshore regions from Massachusetts to South Carolina

Impacted by: Purple loosestrife which invades and outcompetes the cattail. This results in a loss of habitat for many species as well as degredation of wetlands.



Species: Virginia Rail

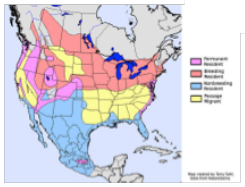
Scientific name: *Rallus limicola*

Classification: NATIVE

Significance: An at risk bird that nests in high reeds alongside wetlands. These birds eat insects and aquatic animals, keeping the populations of these in check.

Native range: Coastal and offshore regions from Massachusetts to South Carolina

Impacted by: Purple loosestrife which invades and outcompetes the reeds which the birds nest in. Without the reeds, the birds suffer from reduced habitat which can lead to local extinctions.



Species: Long-billed Marsh Wren

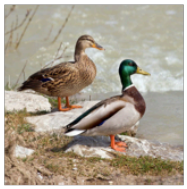
Scientific name: *Cistothorus palustris*

Classification: NATIVE

Significance: A at risk bird that nests in high reeds alongside wetlands. These birds eat spiders and insects keeping the populations of these in check.

Native range: Coastal and offshore regions from Massachusetts to South Carolina

Impacted by: Purple loosestrife which invades and outcompetes the reeds which the birds nest in. Without the reeds, the birds suffer local extinctions and are at risk of large-scale extinctions if the trend continues.



Species: Mallard Duck

Scientific name: *Anas platyrhynchos*

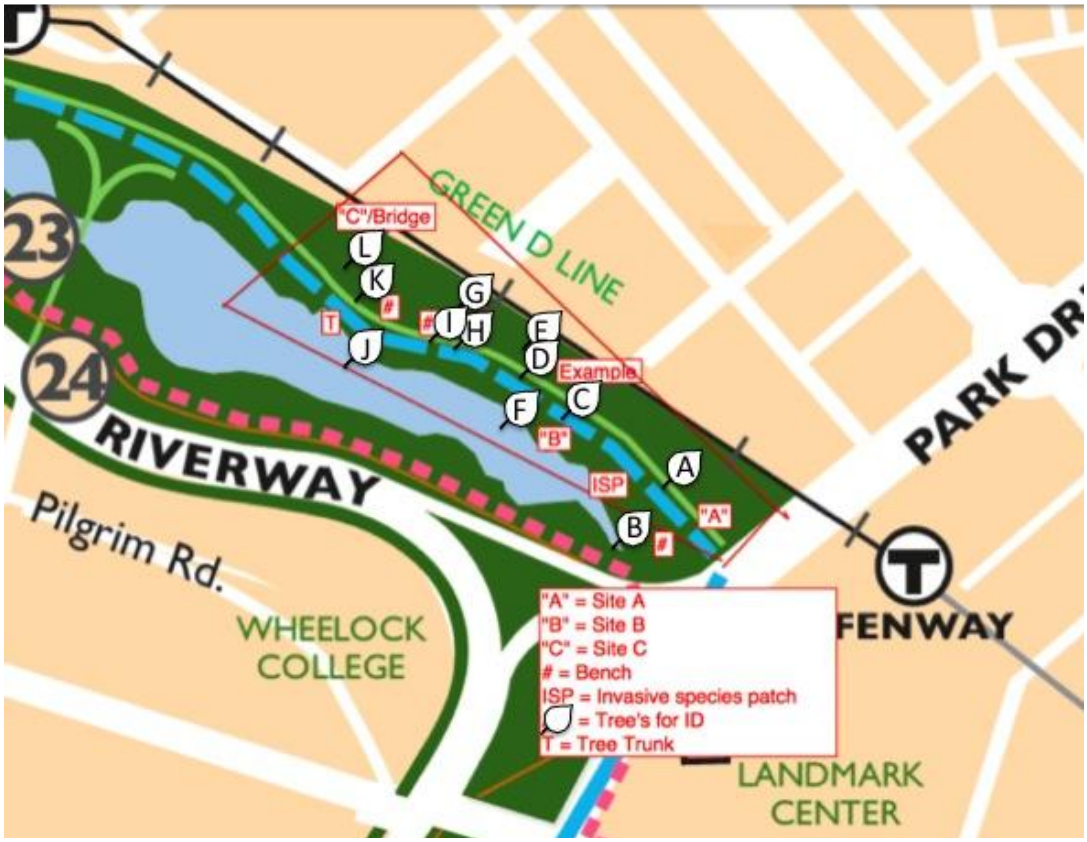
Classification: NATIVE

Significance: A dabbling duck which nests in wetlands and specifically within the reeds which exist on the fringes of the wetlands.

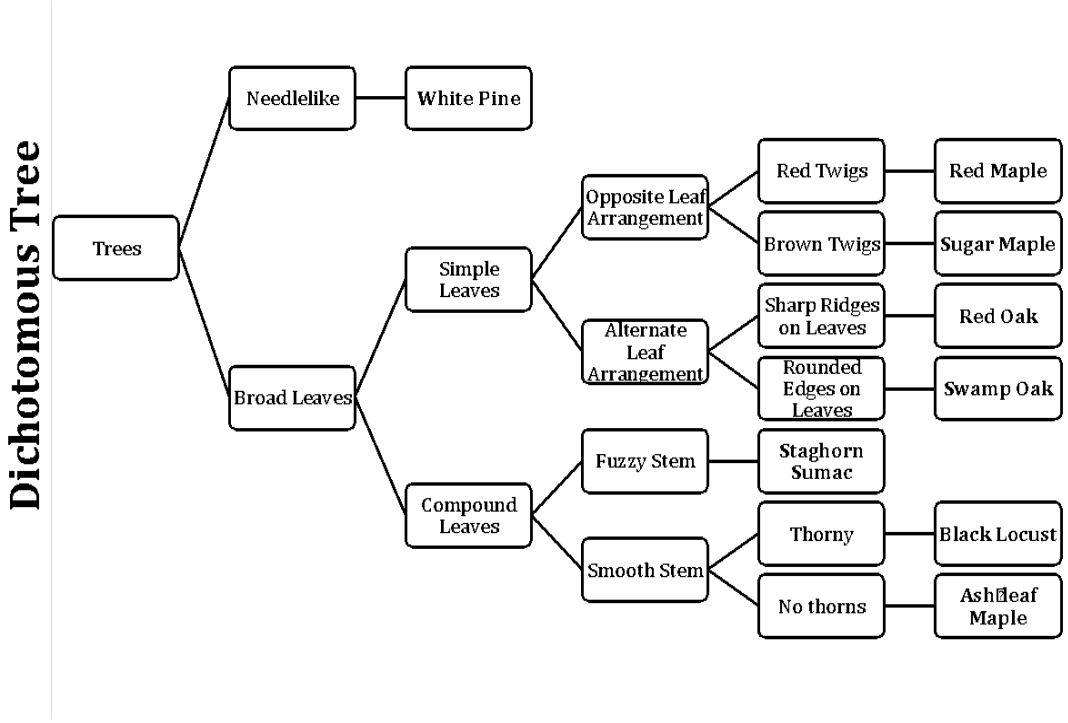
Native range: Throughout the United States and Canada

Impacted by: Purple loosestrife which invades and outcompetes the reeds which the Mallard live in and use for shelter. Without the reeds, the Mallard suffers from reduced habitat which can lead to local extinctions.

Map of the Field Site from the Field Guide

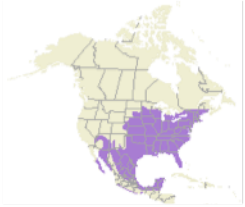


Appendix M
Dichotomous Tree from Field Guide



Appendix N
Example Species Identification Card from the Field Guide

Northern cardinal, *Cardinalis cardinalis*



- One of the most striking songbirds in North America, the cardinal is the state bird of 7 states.
- Males and females are *sexually dimorphic*, meaning that each sex looks differently. Males are bright red with black faces, and females are pale brown with reddish tinges.
- Males and females are extremely aggressive and will even fight their own reflections.
- Eat seeds, fruits, and insects.
- Prefer habitats with dense shrubs, and are often found in forest edges, marshes, fields, backyards, and parks.

Appendix O
Set-up of Laboratory Room for Indoor Contingency