Investigating the Consequences of an Invasive Species to the Ecological Integrity of the Community

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Abstract: In this open-ended investigation spanning four lab periods, students explore the ecological consequences of the introduction of two invaisve plant species, Autumn Olive (*Elaeagnus umbellata*) and Myrtle (*Vinca minor*) at nearby field sites, each lab section focusing on one of the two species. In a modified jigsaw framework, six teams from each lab section design, implement, analyze and present experiments to answer six different, but integrated, sub-questions, each deriving from a single "big picture" question: What are the consequences of an invasive species to the ecological integrity of the biological community?"

Introduction

In this open-ended investigation, students explore the ecological consequences of two invasive plant species, Autumn Olive (*Elaeagnus umbellata*) and Myrtle (*Vinca minor*) at nearby field sites, each lab section focusing on one of the two plant species. At our four-year liberal arts college, four lab periods are devoted to this investigation at the conclusion of the semester. This exercise constitutes the capstone of a non-science major's general education laboratory science course (GEMS 153: Populations in Changing Environments). In a modified jigsaw framework, six teams (3 or 4 students each) from each lab section design, implement, analyze and present experiments to answer six different, but integrated, sub-questions, each deriving from a single "big picture" ecological question: What are the consequences of an invasive plant species to the ecological integrity of the biological community?

The sub-questions are: 1) What is the effect of the invasive plant on the growth/germination/survival of other plants? 2) What is the effect of the invasive plant on the light characteristics in the immediate environment? 3) What is the effect of the invasive plant on the soil nutrient characteristics in the ecosystem? 4) How do herbivores respond to the invasive plant as compared with natives? 5) What is the effect of the invasive plant on the soil seed bank? 6) What is the effect of the invasive plant on the leaf litter arthropod community?

Teams meet with their "counterpart" group (the student team investigating the *same* question with the *other* plant species) periodically during the combined lecture, and each team meets with the instructor for a progress interview. Students present their results orally, with a portion of the evaluation being peer assessment of the counterpart group's effectiveness at answering the shared sub-question, as well as the "big picture" question. The structure of this lab, as well as the longer time devoted to it, encourages student ownership of the research project and maintains a level of cohesiveness among projects because different student groups are linked by invasive plant species (within lab section) and by sub-question (among lab sections), as well as by the "big picture" question (all students in all sections).

Student Outline

Objectives

1. To enhance your knowledge and experiential familiarity with living ecosystems, and ecological interactions within living ecosystems.
2. To help you better understand what constitutes scientific evidence, how it is evaluated, and how evidence challenges us to re-evaluate, improve, or change our prior conceptions and knowledge.
3. To help increase your appreciation, awareness and understanding of our role in natural ecosystems and the value of natural ecosystems to us as human beings.
4. To improve your scientific literacy about ecological issues such as the impact of invasive species, especially those in our own regional area.
5. To improve your skills in organization of data, scientific (mathematical) analysis, and in oral presentation skills.
6. To better appreciate the role of scientific communication (e.g. communication within and between research teams working on similar problems) in the scientific endeavor.

Introduction – What are the consequences of an invasive species to the ecological integrity of the community?

Non-native species are those that evolved elsewhere and have been purposely or accidentally relocated. Such species are often also called introduced, alien, or non-indigenous species. Invasive species may be defined in terms of *impact*, e.g. "alien species whose introduction does or is likely to cause economic or environmental harm or harm to human health" (President Clinton's Executive Order on Invasive Species, Order 13112, 3 February 1999). Myrtle *(Vinca minor)*, Purple Loosestrife (*Lythrum salicaria)*, Garlic Mustard (*Alliaria petiolata)*, and Autumn Olive (*Elaeagnus umbellata*) are common examples of invasive plants in the Great Lakes region. Non-native species might be introduced either deliberately or accidentally. Both focal species in our investigation, Myrtle and Autumn Olive, were most likely introduced deliberately – Myrtle for it's use in landscaping and gardens, and Autumn Olive for use in soil stabilization on reclaimed mines and for wildlife cover.

Biological invasions can produce severe, often irreversible impacts on agriculture, recreation, and our natural resources because invasive species compete with native species for limiting resources; invaders may even interrupt or alter evolutionary processes in the biotic community (Cronk and Fuller 1995, Rhymer and Simberloff 1996, Vitousek et al. 1996, Ecological Society of America 2000). In animals, this competition may be very direct and very easy to observe. For example, European Starlings *(Sturnus vulgaris)* compete directly with native hole-nesting bird species for cavities in trees and other suitable nest holes. Sea lampreys *(Petromyzon marinus)* directly parasitize native fishes in the Great Lakes (Mills et al. 1994). Among plants, the competition for resources is less visible to humans because plants are competing for sunlight, water, space, and nutrients in the soil. Nonetheless, the effects can be just as devastating. In this way, successful invaders upset the balance of native ecosystems, and they may seriously alter the way that species in that ecosystem interact with one another. Alteration in these interactions can change major ecosystem functions, such as the ways in which nutrients or water are cycled within the ecosystem. Invasive species can promote local extinctions of native populations. The introduction of invasive species is considered by ecologists to be second in its importance as a threat to native ecosystems in the continental United States only as compared with outright habitat destruction or conversion (e.g. logging, road-building, wetland destruction, etc.) (Ecological Society of America 2000).

Autumn Olive is a non-native shrub that was introduced to the United States from Asia in the 1830s. It has been planted in the eastern and central United States for re-vegetation of disturbed areas as a method of "reclamation, erosion control, and interplanting in agroforestry" (Catling et al. 1997). Later, Autumn Olive was promoted as a suitable wildlife cover and forage (e.g. Allan and Steiner 1965). Autumn Olive has since escaped controlled cultivation, having spread to many parts of the U.S. and Canada, and is now considered to be an invasive plant species (Ebinger and Lehnen 1981, Sather and Eckardt 1987). Autumn Olive competes with native plants because it contains nitrogen-fixing root nodules that negatively affect the nitrogen cycle of native vegetation that rely on infertile soil (Sather and Eckardt 1987). As a result, Autumn Olive presents a threat to the native biodiversity (the different kinds and relative abundances of native plants) in the habitats where this plant is found. Some of the characteristics that are related to Autumn Olive's high competitive ability include: 1) a rapid growth rate, 2) production of abundant fruits that are dispersed by many species of animals, 3) the presence of nitrogen-fixing root nodules, allowing it to be able to thrive in poor soil, 4) it resprouts vigorously after cutting or burning, and 5) larger Autumn Olive plants create heavy shade which may suppress the growth of plants that require direct sunlight. Once Autumn Olive becomes established in unwanted areas, it is difficult to control or eradicate because of its habit of forming root shoots that can re-grow following burning or cutting. Efforts at control have included mowing of seedlings and sprouts, cutting or girdling of stems, burning and herbicide application (Szafoni 1994). The Nature Conservancy (Sather and Eckardt 1987) has suggested that research questions should include: How well does *E. umbellata* compete with and displace native vegetation? What is the affect on growth and reproduction of repeated burning over several years?

Vinca minor, commonly called Myrtle or Periwinkle, imported from Eurasia during the European settlement of North America, is common in the eastern United States (Wyman 1956, 1977, MacKenzie 1989). Myrtle propagates as a trailing evergreen vine, facilitated by vegetative reproduction, establishing itself especially well in moist soils enriched with organic matter (MacKenzie 1989). Only recently have biologists considered the species as a potential forest invader with possible serious consequences (Schulz and Thelen 2000, Darcy and Burkhart 2002). Darcy and Burkhart (2002) studied the pattern of invasion by Myrtle in the dune forest of the Hope College Nature Preserve, including an investigation of the potential mechanisms whereby Myrtle inhibited the establishment of native trees. They gathered several lines of evidence suggesting that Myrtle affects tree species at the seedling growth rather than at the seed germination stage, and that it has a profound depressing effect on native tree establishment. Survivorship rates of transplanted Sugar Maple (*Acer saccharum*) seedlings suggested that light obstruction by Myrtle has a significant inhibitory effect on the seedlings; additional experiments they conducted suggested that Myrtle may also produce chemicals that are allelopathic to tree seedlings (Darcy and Burkart 2002).

During the last four weeks of this course, your time will be devoted to the design, implementation, analysis, and presentation of a group research project. All of the group research projects are integrated in the sense that they are all sub-questions derived from the "big picture" question: *What are the consequences of an invasive species to the ecological integrity of the community?* Thus, your group will choose or be assigned to one of these questions, but you will have a great deal of freedom in constructing an experimental design, and in deciding upon a methodology to answer your question.

There are six possible sub-questions, with a 1:1 correspondence between groups and sub-questions. There will be one research team from Lab Section 1 working on each sub-question from the perspective of Autumn Olive (*Elaeagnus umbellata*) as the focal invasive plant, and one team from Lab Section 2 working on each of the six sub-questions from the perspective of Myrtle (*Vinca minor*) as the focal invasive plant. Time will be set aside during a few lectures for the two lab section teams working on the same sub-question to meet and discuss their progress. The six sub-questions are listed below with a short description of what each will involve.

Ecological Sub-questions about the impacts of the invasive plants

1. *What is the effect of the invasive plant species on the growth/germination/survival of other plants growing near it?* Teams focusing on this sub-question will be concerned with how the focal invasive plant is impacting the other members of the plant community. Plants could affect each other through direct or indirect competition (Muller 1966, Whittaker 1970). Some plants, for example, produce inhibitory chemical compounds into the air or soil near them, or plants may simply use up all the resources in a way that makes it unlikely for other plants to grow nearby. Possible dependent variables could include, but are not limited to: abundance, diversity, and/or health parameters of plants already growing beneath or near the invasives, germination rates of seeds planted by the researchers, and/or survivorship of seedlings transplanted by the researchers. This project is a good research focus for people who like seeds, growing things, plants, counting, measuring and thinking about competition!

2. *What is the effect of the invasive plant species on the light characteristics in the environment around it?* How a particular plant species modifies the light environment can be of utmost importance to the survival and growth of other plants and animals. Plants are particularly sensitive to any changes in the amount of light received, since with levels too low or of poor spectral quality, photosynthesis will be limited. If the rate of photosynthesis decreases, the entire community may ultimately suffer. For this research project, the main dependent variables will be amount and quality of light. This project is a good research focus for people who like measuring things with instruments, integrating physical science with ecology, and thinking about the importance of sunshine to plants and the rest of us!

3. *What is the effect of invasive plant species on the soil nutrient characteristics in the ecosystem?* Changes in the soil nutrient composition and/or pH of the soil could potentially have a serious impact on native plants, and subsequently, on animal communities as well. Plants, in particular, are highly sensitive to levels of nutrients in the soil (e.g. phosphorus, nitrates, nitrites, calcium, etc.), low levels of metal ions (e.g. copper, aluminum), a wide variety of toxic substances, and soil pH (acidity). It is also well-known that certain plant species can significantly alter some of these factors in the soil, thereby increasing or decreasing the suitability of the soil nutrient composition to the growth of other plant species (for just a few examples see Lovett and Mitchell 2004, Nilsson and

Wardle 2005). Potential dependent variables for this project include nutrients, pH, and physical soil characteristics that can be measured with basic soil sampling materials. This project is a good research focus for people who like carefully mixing and measuring things, playing in dirt, chemistry, working with test kits, and thinking about nutrient flow in ecosystems.

4. *How do herbivores respond to invasive plant species as compared with natives?* In most ecosystems, herbivores (primarily insects, but also deer, rabbits, etc.) are one of the things that limit plant growth and reproduction the most, since herbivores can decrease the survivorship and reproduction of plants greatly. One of the potential problems with invasives is that, since they are not native to the local area, they may not be limited by local herbivores to the same extent that the native flora is, since there is no history of interaction between the two. The outcome of such a scenario could represent a "double-whammy" – not only are invasives using up some of the resources the "natives" need, but they may not experience natural population controls to the same extent that the "natives" do. This research project will involve making a comparison of the extent to which the invasive plants have suffered herbivore damage as compared with native plant species in the same location. Dependent variables will be measured by scoring plant damage in ways that you will devise to best represent the most important aspects of herbivory. This question is a good research project for people who like thinking about the ways that insects and other herbivores eat, munch, and basically wreak havoc on the lives of plants, creating methods of measurement from scratch, and lots of detail work.

5. *What is the effect of the invasive plant species on the soil seed bank?* The soil seed bank is the part of the community that is represented by ungerminated seeds "hiding out" in the leaf litter or the soil, waiting for the right time to germinate. Essentially, the soil seed bank is where the next plant community will come from when the plants aboveground complete their life cycle and die. The soil seed bank is a big chunk of the future habitat! Does the presence of invasive plant species impact what is present in the soil seed bank? This is a big mystery – we have no idea what the answer to this might be, but we're very interested because if invasives not only wreak havoc on the above-ground community, but also on the below-ground seeds, there's the potential for another "double-whammy". This research group will use methods for extracting buried seeds from the soil to find an answer to this question. This is a good research focus for people who like thinking about how current events impact the future, seeds, soil, digging holes, sorting small items, and lots of painstaking detective work.

6. *What is the effect of the invasive plant species on the leaf litter arthropod community?* Similar to the question posed in #5, invasive plants potentially impact below-ground processes, not just what's happening in the most obvious, above-ground species interactions. For example, the type of leaf litter produced by invasives is likely to be chemically and physically different from the leaf litter produced by the natives – if this is so, then are there consequences for the composition of the leaf litter arthropod community? Could those consequences affect nutrient cycling and decomposition in the leaf litter? (If it does – there are then trickle-down impacts on what kinds of nutrients the native plants will or won't be getting, and at what rate.) People working on this research question will have dependent variables that include species diversity and composition measures for leaf litter arthropods. This is a good research focus for people who like thinking about why biodiversity is important, small, strange litter critters, identification and categorization, microscopes, and lots of detail work.

Four-week Plan

Week 1 – Introduction and team organization. Introduction to the field site and the invasive plant(s), establishment of research teams, research teams select sub-question projects, teams are assigned species (Myrtle or Autumn Olive) and the field site in which to study that species. Research teams collect observational data and brainstorm experimental design and methodological ideas. Begin writing of proposals (see Appendix A: Group Research Proposals). At the end of the week, your group's research proposal is due. One day prior to the second field trip (the beginning of week 2), the proposals will be returned to each team by the instructor. Each team will make changes, additions, corrections and re-submit to the instructor so that you will be ready to start by the date of the second field trip (Week 2). First meeting (in lecture) for counterpart teams from different lab sections who will be working on the same sub-question with different plant species.

Week 2 – Data collection, field and/or lab. Groups with approved proposals will have materials provided to commence work on projects in the field. Groups without approved proposals may use the lab period to improve proposals and assemble materials. The instructor will assist/coach teams in the field as needed. Modify lists of materials as needed and submit to instructor at end of lab period. Second meeting (in lecture) for counterpart teams from different lab sections who have been working on the same sub-question with different plant species.

Week 3 – Data collection and progress interviews. Work on projects in the field and/or lab. During this week, each team will schedule a progress interview meeting with the instructor (see Appendix B: Progress Interview for Research Project). Make sure you sign up for a time for which all members of your group can be present. For the progress interview, please bring: all raw data collected in your field notebooks or a lab book, all references and/or scientific journal articles you have collected that relate to your project, your original, graded research proposal, with modifications indicated directly on the proposal, and your initial thoughts on how you will analyze the data you have. During the progress interview, the instructor will make suggestions for appropriate inferential statistical analysis for your particular data set, since what is appropriate for various teams will be different. For most groups, this will be the last lab period for data collection and analysis.

Week 4 – Analysis and preparation of oral presentation. This week is reserved primarily for you and your team members to work on final organization and statistical analysis of your data and to plan your oral presentation to the class. Groups who have not completed field or lab data collection may use the lab period for those purposes, but will then need to complete data analysis and presentation planning outside of class time.

End of Week 4 – Oral presentations and evaluation. At the end of this week, your team will give an oral (e.g. Powerpoint) presentation to the entire class, with all group members speaking for part of the time. Appendix C includes a sample grade sheet for the oral presentation - use this as a guide for what is expected to be included. Following each presentation, members of each counterpart team (same sub-question, different plant species) will fill out an evaluation/question form for their counterpart team and will write additional questions for each presenting group. Each student will also write a short essay in response to the "big picture" question: What is the impact of invasive species on the ecological integrity of the community? Appendix D (Questions for Oral Symposium on the Impacts of Invasive Plant Species) contains an outline of what you will write during and following the oral presentations.

Evaluation

There are five graded components to this research project, some of which are graded as a group endeavor, and some of which you must do individually. Your team will also evaluate one another according to each person's contribution.

1. Research Proposal (Appendix A). Your group will submit a written outline of your proposed investigation: questions, hypotheses, and experimental design, including how you will statistically evaluate your hypotheses. Your proposal must be approved by the instructor before you can commence work on the project. This is a group grade.
2. Progress Interview (Appendix B). Each group will meet with the instructor to discuss progress on their research project and to discuss methods of data analysis and presentation. This is a group grade with one individual component.
3. Oral Presentation (Appendix C). Each group will give a 10-minute presentation at the end of the last week of the project. Paper copies of all information (raw data and printouts from statistical analyses) will be submitted at the time of the presentation. This is a group grade with individual components.
4. Question Quality (Appendix D) – Each student (not group) will submit written questions during the research presentations; you will be graded on the scientific/mathematical quality, significance, and depth of your questions, and in particular, on your insights to the counterpart group's presentation, since their study is the most similar to your own. You will also respond to an open-ended question pertaining to your understanding of the "big picture" ecology question. This is an individual grade.

Notes for the Instructor

Invasive Plant Species

Several invasive plant species are bound to be common at a local field site near you! The investigation ideas presented in this laboratory are easily transferable to many other species that may be problematic on or near your campus. For an excellent start on resources on invasive species you might find in your area, refer to

- Institute for Biological Invasions: http://invasions.bio.utk.edu/resources/index.html
- Union of Concerned Scientists: http://www.ucsusa.org/invasive_species/
- Global Invasive Species Database: http://www.issg.org/database/welcome/
- The Nature Conservancy http://www.nature.org/initiatives/invasivespecies/

Because invasive often infiltrate human-altered landscapes, their study does not require long-distance field trips to pristine habitats. Instructors should become familiar with any potential outdoor hazards in the study area and relate that information to students (wasp nests, poison ivy, suggested use of insect repellent, etc.).

Jigsaw and Organizing Large Numbers of Students

"Jigsaw" is a cooperative learning strategy used by teachers (K-College) who have, as a learning goal, that students will help each other in achieving a synthesis of complex concepts or interactions through an exercise in which each student first becomes an "expert" in one part of the overall problem. In the investigation of the impacts of invasive species, our objective is that students will come to understand the complex ecological interactions that occur in biological communites, and the many ways in which invasive species can alter those interactions, by first becoming an "expert" investigator for one, very focused question on one particular aspect of invasive species ecology. For an explanation of "Jigsaw" with other examples, please refer to: Teaching Issues and Experiments in Ecology: http://tiee.ecoed.net/teach/teach_glossary.html and http://tiee.ecoed.net/teach/tutorials/jigsaw.html

In typical "jigsaw", the class of focused "experts" is then rearranged into a second set of groups so that each second team has someone who is expert on each sub-component (e.g. for each part of the research project, in our example). Students in the second group teach one another, and with all the jigsaw pieces now available to the entire class, the students are challenged to put them together to solve the "puzzle". We have referred to our construction of this particular exercise as a "modified jigsaw" because we don't re-shuffle all students or groups on the second round. But we do bring "counterpart groups" (same sub-question, different species) together to help problem-solve their particular experiments, and the final oral presentation, attended and presented by the entire class, is the "solving the puzzle" component for our "big picture" question: What are the consequences of the invasive plant species to the ecological integrity of the community?

This exercise is used for a (freshman through senior) non-science majors course that is one elective that can meet a general education laboratory science requirement at Hope College. The typical enrollment is 48 students in one combined lecture and two lab sections of 24 students each. When our students begin this project, they have already completed eight weeks of other ecological investigations in the field, and are therefore well-versed in transportation punctuality, (very) basic statistics and computer graphics, sharing tasks while working in a group, and collecting data in a field setting. Nonetheless, coordinating six sub-projects can be challenging and the "bottleneck" consistently occurs between the first trip to the field site (Week 1 – assignment of sub-questions and the formation of groups) and the following week, when proposals are due (with a quick turnaround required of the instructor just before the second week out to the field site), when materials for six sub-projects must be assembled, and inevitably, when some members of some groups have failed to communicate well about who is doing what. Note that our Week 2 plan has a built-in contingency for groups who just don't "have their act together" yet, and although those groups do suffer a consequence of being somewhat "behind", they still have a reasonable 2 weeks left in which to actually collect and analyze data. As mentioned in the Materials section, the high cost of prepping six sub-questions during Week 2 is more than offset by a very minimal preparation time needed for the remaining weeks of the project, allowing instructors to devote a large amount of "quality time" to what some of us like to do best – coaching research-based projects!

Progress Interview

Accountability, dialogue, and coaching the statistical analyses are our main goals for the progress interviews. Students know that they must bring ample evidence of having made good progress on their project goals to the interview. In our experience, students are eager to relate how things are going, and of course, all of the methodological problems they might be having. Being able to dialogue with students 4-on-1 is tremendously valuable. The instructor will gain much insight into the group dynamics and will be able to help the team trouble-shoot data collection problems *before* the last weeks of the project (such that students have the opportunity to shift gears in protocol details, and often do). It is also a much-needed time for the instructor to see what student data sets look like, so that s/he may make group-specific suggestions on statistical analyses, graphs to produce, and/or other aspects of the study that need to be considered within the allotted time frame. Students often convey a strong sense of ownership and pride in "their" projects and almost universally respond positively to encouragement and suggestions. We allot 20 minutes per group.

Alternative Sub-Questions

An instructor lacking the instruments or materials for one or more of the suggested sub-questions is encouraged to consider substituting any alternative that s/he has an interest in, or perhaps an investigation that would constitute a novel application for a piece of instrumentation that s/he has available. That's precisely how we got started on these six ideas! Additional comparisons to make between invaded vs. non-invaded communities could include: microbial functional diversity, species diversity (and abundance) of insects found on the plants, species diversity (and abundance) of birds in the community, success rates of predatory web-building spiders, associations with particular species of invasive vs. non-invasive animals (e.g. earthworms), comparisons of "used" bird nests, or animal tracks, or other animal signs found in each community, comparison of temperature and moisture gradients etc.!

Materials

Because these are largely open-ended investigations, we try to be flexible, as much as possible, in basic materials that will be on-hand for students to complete various projects. When writing their research proposal, each student team is asked to provide the instructor with a detailed list of the equipment and supplies that will be needed (See Appendix A) to complete their project, and we use a heavy hand in modifying that list, asking for additional details, and/or making suggestions for substitutes/alternatives during the proposal evaluation process. Although the preparation for the first

"Data Collection" Week (Week 2) is thus quite involved (prepping for six different projects), it is compensated for by the low-level prep that is required for the remaining 2 weeks. This list is provided to help guide you on the items that we have available for students to complete these projects. Many substitutions in materials would be appropriate, given the experiments that the students propose to do. Usually, not all items are needed for each listed experimental group. Numbers and amounts given below are per team of four students, but will vary depending on the specifics of student proposals.

1. *Plant survivorship/germination team*

- Shovel
- 2 garden spades
- 6 5-gallon buckets with handles
- 50 to several hundred sunflower seeds
- 200 radish seeds
- 200 lettuce seeds
- 20 gallons of potting soil
- 2 pairs of work gloves
- 6-20 planting pots or greenhouse planting trays
- 12 inch ruler marked in cm
- 100 golf tees OR seedling rings OR surveyor's flags (used for marking the position of seedlings in the field)
- 2 50-m tape measures
- 12-36 plastic zipping bags for field-collecting plants
- plant species identification books (e.g. Thieret, J.W. 2001. "National Audubon Society Field Guide to Wildflowers: Eastern Region: Revised Edition", Alfred A. Knopf, New York, New York, 879 pp.).
- sheets of Rite-in-Rain paper (available from www.forestry-suppliers.com) with pencils
- roll of string
- blender (for making extracts for allelopathy experiments)
- graduated cylinders (2- 10 ml, 2-50 ml)
- distilled water source
- 100 petri dishes
- paper towels
- 2 pairs of forceps
- 4-8 500ml or 1 liter plastic or glass jars (screw tops) for storing plant extract

2. *Light environment team*

- 2 light ceptometers with instructions and fresh batteries (e.g. Decagon Accupar from www.decagon.com) or alternative light meters
- 2 clipboards
- 20 surveyor's flags
- two-way radios (e.g. Motorola Talkabout); used for synchronizing light measurements for control vs. experimental conditions, and extra batteries
- several sheets Rite-in-Rain paper with pencils

3. *Soil nutrient and pH team*

- 4 garden spades
- 12 inch ruler marked in cm
- 20 small plastic zipping bags with sharpies for collecting soil samples
- water source
- measuring cup (1 cup)
- Soil Sample Test Kit (with reagents and instruction booklet, e.g. LaMotte model SIH-14 or similar model for wide range of nutrients and pH, available through www.forestry-suppliers.com)

4. *Herbivory team*

- 12 small and/or 12 large plastic zipping bags for field collection of leaves/plant parts
- 1 pair of plant clippers or scissors
- 1 pair of garden gloves
- 1 50-meter tape measures
- 40 surveyor's flags
- 1 clipboard and pencils
- several sheets Rite-in-Rain paper
- small grid (e.g. mm) graph sheet transparencies for quantifying area of leaf damage on leaves
- herbivory field guide handout (e.g. "Signs of Animals Eating Plants", pp. 360-361 copied with permission from Hogan, K. Eco-inquiry: a guide to learning experiences for the upper elementary/middle grades. 1994. Institute of Ecosystem Studies, Millbrook NY, published by Kendall/Hunt Publishing Co., 4050 Westmont Drive, Dubuque, Iowa, 52002).
- optional: any digital image analysis software system (e.g. Scion for Apple) that will quantify surface area

5. *Seed bank team*

- soil extraction devices (our home-made extraction devices are hollow PVC tubes of approx. 5 cm diameter, and cut to a length of 25 cm; a nail is inserted at the 10 cm length mark, and blunted, to form a guide for sampling a soil "core" at a 10 cm depth; standard soil coring devices (available from www.forestry-suppliers.com) are also useful; all that is necessary is a device to collect a standard volume of soil at a standard depth)
- 6 5-gallon buckets with handles
- shovel
- several sheets of Rite-in-Rain paper and pencils
- 2 small garden spades
- sectioned Petri dishes (useful for sorting seeds under magnification)
- 100 vials (2 dram – 8 dram size) for storing seed vouchers collected from soil
- 4 pairs forceps
- soil sieve set (we use #10 and #18 sieves)
- source of water
- large plastic or enamel trays to water-sieve soil samples
- 4 hand magnifiers (10X)
- 4 dissecting microscopes and light sources
- 12-36 1 or 2 gallon size plastic zipping bags for transporting soil samples

6. *Leaf litter team*

- 8 Berlese funnels with light bulbs (for construction of Berlese funnels for the extraction of leaf litter arthropods from a bagged leaf litter sample, please see: Murray, K.G., K. Winnett-Murray and L. Hertel. 2002. Species diversity, island biogeography and the design of nature reserves. Pages 125-143, in Tested Studies for Laboratory Teaching. Vol. 23 (M.A. O'Donnell, Editor). Proceedings of the 23rd Workshop/Conference of the Association for Biology Laboratory Education (ABLE), 392 pp.)
- 4 5-gallon buckets with handles
- 4 blunt knives (for outlining overturned perimeter of bucket when placed on forest leaf litter)
- 1 50-meter tape measure
- 30 freezer-size plastic zipping bags and sharpies
- 4 liters of 70% (by volume) ethanol, for preserving arthropods killed in Berlese funnels
- 8-30 500-ml screw-cap, wide-mouth collecting jars (placed under the Berlese funnels to catch arthropods)
- 8 plastic disposable pipettes
- 4 pairs insect forceps
- 8-24 sectioned Petri dishes (useful for sorting insects with microscope)
- 4 dissecting microscopes and light sources
- identification guides for arthropods found in the local leaf litter are useful, but not essential (for a sample of a local guide, please refer to: http://www.hope.edu/academic/biology/leaflitterarthropods/)

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Appendix A

Group Research Proposal

Group Members:____ **Lab Day:**____________________

1. **Question**: State the question and then describe why it is an important one - that is, why is it worth investigating? (5 pts.)

2. **Hypothesis:** (5 pts.). Remember to state this as a *testable* statement. Include the independent variable(s) and the dependent variable(s) in the statement.

3. **Prediction** (5 pts.). This is a re-wording of your hypothesis as an if-then statement. A prediction (or hypothesis) can also be represented *graphically*. Sketch your graphical prediction and then write it as an if-then statement. Include the names of the independent and dependent variables on the axes of your graph.

4. **Test of the Hypothesis = Protocol for your Experimental Design. (10 pts.)** Explain exactly how you expect to do this. First, draw a schedule or flow-chart or a step-by-step diagram on the following page showing which week you expect to do what kind of work. For example, actual data collection (explain what data are to be collected and how), data analysis, preparation of report, library research, etc. Then provide an explanation of each step. In addition, fill in these details:

Dependent variable(s): ____

How measured quantitatively: ________________________________

____

____

Independent variable(s): ____

Controlled variable(s):____

Treatments: (the nature of the test groups, e.g. presence or absence of invasive, concentration of test extract, etc.).

Number of Replicates per Treatment: (e.g. 10 seeds subjected to each extract concentration).

Space for Schedule Chart and explanation:

Week 1:

Week 2 :

Week 3:

Week 4:

5. **Mathematical Evaluation of Results: (5 pts.)** Carefully explain here how you will evaluate your data (results). Will you use a mathematical model to represent your results and provide predictive applications? If so, what mathematical model, and why? You will test the significance of your results with an inferential statistical test. Consult with your instructor to determine which one(s) and why that one in particular is used. Write the name of the test here, for further reference.

6. **Conclusions.** How will you know if your results provide support for your hypothesis, or not? (5 pts.). This is not a trivial, circular question. Whether you know if your hypothesis is supported or not, at the conclusion of the experiment, will depend on how well you designed your experiment. In this question, you should address *<u>how the design will effectively exclude other possibilities and test what you really think you are testing</u>*.

7. Materials. (10 pts.). In a neat, legible list, specify exact amounts, concentrations, and identification of all materials you will need for your investigation. For any piece of equipment specify the dates and times your group will need it. Example of inadequate description: "beakers". Example of adequate description: "12 50-ml beakers". Example of inadequate description: "some alcohol". Adequate description: "100 ml of 70% ethyl alcohol in a squirt bottle". Inadequate: "ceptometers". Adequate: "2 ceptometers needed on 17 November from 12-3 pm and 1 ceptometer needed on 18 November from 10-11 a.m.)".

Appendix B

Progress Interview for Research Projects

Group Members: ____
Interview Time & Date:____
Title of Project:____

Grade/20 pts.:__________

1. To the Group: "Summarize what you have been trying to find out and what you have learned so far."

2. Does the group have a neat, coherent and well-organized summary of data, showing all values for treatments, environmental variables that could influence the outcome (e.g. weather, date and location information), and units for all measurements (e.g. eggs eaten per 7 day period, relative humidity in %, etc.)?

3. Has the group made good use of the time available to do as many replicates as possible? For the week of the progress interview, is the group finished with data collection, or close to it? How many more replicates or visits to the field site are needed?

4. Has the group encountered any problems with their original protocol, and if so, how have they managed to trouble-shoot these problems (or not)?

5. Has the group given *any* thought as to how they will test their *original working hypothesis statistically*? Refer to the graded Group Research Proposal. What statistical tests will be used and why? What is the null hypothesis for each test? Working hypotheses? For t-tests, ask if the working hypothesis is unidirectional (e.g. group 1 has a greater mean than group 2) or non-directional (the means are different). For chi-squared tests, ask the group *how expected values will be calculated*. Make a sample chart of what values will be used for the tests.

6. The instructor will most likely go over the statistical tests with the group using a graphing calculator or statistical computer software. Do the group members know how to interpret statistical values that are generated by this test? Do they have any questions about the mechanics of running the test, or it's interpretation?

7. Does the group have appropriate literature cited resources and have they documented all of these sources correctly?

8. The instructor will go over the grade sheet for oral presentations (Appendix C) and the Question form to be filled out during and following the Oral Symposium (Appendix D). Does the group have any questions about constructing their presentation or the grade sheets?

Appendix C

Oral Presentation Grading Sheet

Names: ____

Time and Instructor: ____

Research Title: ____

Category	Possible	Score	Comments
"Substance"	****	****	
Introduction	****	****	
* Clear statement of question	3		
* Background including basis for hyp.	4		
* Clear statement of hypotheses tested	3		
Experimental Design and Methods	****	****	
* Clear identification of dependent & independent variables	4		
* Adequacy of experimental design	4		
* Proper controls included?	4		
* Ambitiousness	8		
Results	****	****	
* Accurate measurements	5		
* Presenters' understanding of data	5		
* Adequate presentation of data in summary form (tables, graphs)	6		
* Appropriate & accurate statistics	6		
* Interpretation of statistics	6		
Discussion	****	****	
* Interpretation of results relation to original hypotheses & questions	7		
* Comparison of results to those of other studies (scientific literature)	7		
* Clear understanding of biological phenomena underlying results	6		
* Discussion of next steps to take to refine answers, suggestion of next study, etc.	4		
"Style"	****	****	
* Clarity of presenters	4		
* Clarity of visual aids	4		
Appropriate Citations	6		
Quality of Question(s) Asked	4		
Total	100		

Appendix D

Questions for Oral Presentation Symposium on the Impacts of Invasive Plant Species

YOUR NAME:____________________
Your Group's Species and Your own Research Project:_______________________________________

Part A. "Best" Question for the "Counterpart Group" (1%). This is from your entire group, so should read the same on each group member's sheet. Write your ONE most scientifically pertinent question for the counterpart group's presentation. You have 1 minute after *their* presentation to discuss, then ask the question. Please write what you asked, and their response, in the space below.

Part B. (2%) Individual questions that you have for each presentation group except your own. Do not discuss these questions with other students; simply write at least one question during each presentation (except your own). If there is time between presentations, please ask your question! Write the team names in the blank next to each number.

1. ________________________________.

2. ________________________________.

3. ________________________________.

4. ________________________________.

5. ________________________________.

6. ________________________________.

7. ________________________________.

8._________________________________.

9._________________________________.

10._________________________________.

11._________________________________.

You will be graded on the ***scientific quality and relevance*** of each question – does it convey understanding of the research problem? Relevance to the problem? Is it trivial or is it indicative of your critical thinking about the research outcomes? Do the questions focus on minute details (e.g. why did you use a sample size of 7 plants instead of 8?) rather than relevant interpretation (If Brown and Jones, 1994, as you cited, found a significant positive effect of the invasive on the soil seed bank species diversity, why do you think your study demonstrated the opposite result?) or adding insights and/or additional relevant questions to be explored? (Example: Do you think that transplanting sunflower seedlings to patches of myrtle in the summer would have shown a different result than your results from the fall, and if so, how?)

Part C. The "Big Picture" Question: What is the impact of invasive plant species on the ecological integrity of the community? Please write a short essay on your current state of understanding of this question, as enlightened by all of the research presentations, as well as by your own study. Please include abundant comparisons of different teams' results. Are the impacts of invasive plant species consistent from one kind of plant community to another? Consistent from one species to another? Consistent from one method of exploring the same question to another method? According to our investigations, what types of ecological interactions are these two plant species (Myrtle and Autumn Olive) most likely to alter? And last, but not least, what *recommendations* do you have for the organizations managing these field sites with regard to: 1) controlling the spread of the invasives, and 2) further research on the impact of the invasive plants that would be beneficial in improving control methods and/or decreasing the invader's impact on the native community.