Bringing the Urban Environment Into the Classroom: Learning From an Estuarine Mesocosm*

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Abstract

As the United States and the world become increasingly urbanized, human populations exert a more concentrated impact on their local environments. The effects of human activity extend well beyond the geographical borders of cities, to almost every remote area. This worldwide urbanization has the additional impact of distancing urban youth from pristine habitats and making it difficult for them to connect with the natural world. This paper describes an inquiry-based educational unit that is designed for an environmental science class, biology class, or general science class and can be taught at a variety of grade levels (grades 6–12) with slight modification. In the unit, which supports National Science Education Standards (Appendix A), small groups of students observe an estuarine mesocosm. Each mesocosm is seeded with one common macroinvertebrate that inhabits urban salt marshes. Students research their organism through observation and literature review and present their findings to the rest of the class. The purpose of the unit is manifold: 1) to allow students to reconnect with the natural world; 2) to introduce the concept of adaptation to the urban biome; 3) to allow students to understand that many commonly encountered organisms may have economic or recreational benefits to human society as well as value independent of human concerns; and 4) to increase students' knowledge base regarding salt marsh ecosystems and the natural histories of four salt marsh–inhabiting organisms. Requiring the students to conduct independent research and report their findings to the class engages them in peer teaching and also forms a basis for formative and summative assessment. In addition, because the unit may require the use of multiple computer programs by the students, it reinforces or introduces the use of such tools in a format that is likely to maintain their interest.

Keywords: urban ecology, lesson plan, secondary school, education, starlet sea anemone, banded killifish, grass shrimp, periwinkle

* Published online November 16, 2005

Introduction

As of April 1, 2000, 79% of Americans lived in urban environments (U.S. Census Bureau, 2002). Worldwide, urban populations are growing rapidly, in both absolute and relative terms. The percentage of the world's population living in urban areas is expected to rise to 58% by 2020 (McDevit, 1996). The recent increase in density and size of urban areas is attributed to increased fertility, decreased mortality, and population redistribution. As the United States and the world become increasingly urbanized, human populations exert a more concentrated impact on their local environments. The effects of human activity extend well beyond the geographical borders of cities, to almost every remote area. This worldwide urbanization has the additional impact of distancing urban students from pristine habitats and making it difficult for them to connect with the natural world.

It is imperative that students be introduced to urban ecology as part of an environmental science or biology curriculum. Urban students are already superficially familiar with the urban biome through their own experience. An academic investigation of this familiar biome provides an opportunity to teach many fundamental concepts of biology and environmental science. In this way, this lesson in urban ecology exemplifies a "place-based education" schema. The lesson can easily be integrated as a curriculum piece in an ecology, biology, or environmental-science class. Teaching students about the natural histories and biology of urban organisms helps them to understand biological concepts that extend well beyond those organisms (for example, the challenges of maintaining homeostasis in an urban aquatic environment). Teaching students about how organisms adapt to the urban biome, such as through pollution resistance, provides a natural transition into population genetics, Hardy-Weinberg equilibrium, and evolution in a broader sense. In addition, showing the economic or recreational benefits of certain organisms allows students to understand how many environmentalists and environmental economists support conservation interests (Cropper & Oates, 1992).

This lesson unit serves as a venue for open dialogue about the philosophical value of ecosystems and the organisms they harbor. Numerous researchers have argued that biophilia (and its corollary, personal environmental responsibility) is a direct result of bonding with natural systems and organisms during childhood (Flicker, 2002; Kellert & Wilson, 1993). This connection with the natural world is difficult for urban children to forge (Pyle, 2002). In addition to its science content, this unit is designed to encourage students to reconnect with, and foster stewardship for, the natural world (Pyle, 2003).

Estuaries often provide nearby cities with protected harbors as well as inland access through rivers (Figure 1), which makes these habitats particularly susceptible to the dangers of human population. According to a 1999 population census, six of the ten largest urban areas worldwide are located on estuaries (Table 1). Their high productivity, the temporal and spatial variability in salinity, water depth, and temperature (Nixon & Oviatt, 1973; Roman, Jaworski, Short, Findlay & Warren, 2000), in conjunction with high rates of human disturbance, makes estuaries an ideal candidate for an urban ecology lesson.

In the lesson, groups of students observe mesocosms of a salt marsh environment. Each group is assigned one organism (killifish, *Fundulus heteroclitus*; starlet sea anemone, *Nematostella vectensis*; grass shrimp, *Palaemonetes pugio*, or periwinkle, *Littorina* species). The assigned organism is seeded in the group's mesocosm, and students observe the organism and conduct independent research. The students then present their findings to the rest of the class, with particular emphasis on the pressures of living in urban environments and the adaptations that might allow these species to thrive in them. Students are challenged to describe the value of each organism: its value to human society and its intrinsic value. A prepared reference sheet about each organism (Appendices C–F) may be given to the students at the discretion of those implementing this lesson. By requiring a presentation, this unit allows students to develop observational, literature-research, and presentation skills.

This inquiry-based unit follows the National Science Education Standards (Appendix A; National Research Council, 2000) and is designed to actively engage students by allowing them to pursue their own questions as well as those posed by the instructor(s).

The lesson is written for urban classes that have access to a salt marsh from which to remove sediment and sample for organisms. However, it may be easily modified to accommodate schools without easy access to a salt marsh: The animals used in the lesson can be ordered from biological supply companies and housed in tanks containing dilute artificial seawater (e.g., Instant Ocean), with or without the addition of sediment. Alternatively, the lesson may be modified for aquatic or terrestrial mesocosms seeded with organisms from local biomes.

This curriculum was designed explicitly for the school and group of students for which it was piloted and is presented with details of its implementation, but educators can modify it to meet their own particular goals, both in terms of overall structure and detail. For example, while the use of the Internet for research and Microsoft PowerPoint for presentations is suggested here to increase the interdisciplinary value of this unit, educators can substitute other research methods or assessment techniques at their discretion.

The curriculum was designed in the summer and fall of 2004 and piloted in the fall of 2004 at Odyssey High School, South Boston, Massachusetts, in two classes (Figure 2). Odyssey High School is a racially heterogeneous (Table 2) urban public high school with diverse learners.

Prerequisite Knowledge and Skills

Prior to coming into this unit, students should acquire a basic working knowledge of their urban environment through maps, walking tours, discussion of local history, and introductory biology lessons. They should understand that every habitat has been affected in some way by anthropogenic disturbance, but that despite the human impacts, urban areas may harbor a high biomass. Students should have a rudimentary knowledge of estuarine environments in general and the role that salinity fluctuation plays in shaping the diversity in them. Familiarity with the Internet and Microsoft PowerPoint is helpful; otherwise, this lesson can be combined with an introduction to these tools.

New Learning for Students

The content of new material the students will learn follows:

A. Specific Content

Students will learn the i) habitat, ii) range, iii) life cycle, and iv) natural history of the following organisms, which are common inhabitants of both pristine and heavily disturbed salt marshes/estuaries:

- Banded killifish (*Fundulus heteroclitus*)
- Starlet sea anemone (*Nematostella vectensis*)
- Grass shrimp (*Palaemonetes pugio*)
- Periwinkle snail (*Littorina* species)

Each small group of students will become content expert on one species. Upon comp letion of observational and literature research, peer-to-peer teaching will be used to share findings and form the basis for evaluation.

B. Skills

Through implementation of this unit, students will learn to frame scientific questions, construct a mesocosm, perform careful observations, record data, review scientific literature, and present scientific findings.

C. Concepts

Students will learn that many pressures, including human disturbances such as habitat destruction and pollution, threaten the survival of urban organisms. The lesson will illustrate both common and unique strategies for survival in response to these disturbances. The effect of invasive species upon ecosystems will also be examined. Students will also learn that many organisms influence the economic or recreational value of urban environments (Cropper & Oates, 1992).

Performance Objectives

1. Each group of students will create a mesocosm using water and sediment removed from a salt marsh pool.
2. Each group of students will perform background research and assemble a presentation using Microsoft PowerPoint software on the organism they have been assigned. This presentation will include the following content:
   - Title slide
   - Natural history information
   - Observations
   - Content specific to urban ecology:
     i. How the organism is affected by/survives in spite of human disturbance
     ii. The value of the organism intrinsically and to human society
     iii. At least two original interesting facts on or aspects of the organism "discovered" by the group during its research.

   In addition, each group will give a "tour" of its mesocosm to the other students in the class. As an alternative to the use of PowerPoint, a presentation using printed or hand-drawn transparencies or poster presentations may also be appropriate.
3. During the presentation, groups will be expected to competently answer questions posed by other students and the instructor(s).

Materials

Materials are as follows:

- Salt marsh picture(s) (Figure 1)
- Mesocosm picture(s) (Figure 3)
- Ten-gallon aquarium per group
- Water aerators
- Five-gallon buckets
- Waders
- Shovel
- Salt marsh brackish water or Instant Ocean artificial seawater

- Project introduction sheet (Appendix B)
- Fact sheets for each organism (Appendices C–F), including a list of active websites for Internet research
- Computers with Microsoft PowerPoint software
- Projector and screen for student presentations

Procedure

Part I: Introduction to the Unit

This introduction requires two 50-minute classes. Time may be saved if students are not required to conduct the sampling, or if sediment is not included as part of the lesson.

The lesson begins with a highly engaging topic: mud. Literally and figuratively, sediment forms the base of the mesocosm. Mud is an engaging place to begin the discussion because most students will enter the class with the preconceived notion that mud is "gross." The students will likely be surprised to learn of its complexity and its importance in a functioning estuarine ecosystem.

1. Students are given the opportunity to view, smell, and feel a sample of highly organic sediment, though they should not be forced to smell or touch it if they don't want to (Bixler & Floyd, 1999). The instructor(s) should be aware of the quality of the sediment and ensure that all proper safety precautions are taken if the sediment is likely to be contaminated.
2. The belief that odorous sediment is "dirty" and indicates an unhealthy ecosystem should be drawn out conversationally. Questions (to ask students): "What do you think of the smell?" "Does the fact that it smells gross mean that the pool/river from which it came is unhealthy? Polluted? Dead?" (Explanations: "The highly organic nature of the sediment is responsible for the odor. The sediment is full of decomposing plants and animals," etc.)
3. After students understand the reason for the odor of the sediment, introduce the concept of a mesocosm, and provide a picture(s) of examples (Figure 3). Tie in the sediment to the picture of a mesocosm and explain that they will be developing a mesocosm of a salt marsh pool.
4. Explain the purpose and scope of the unit, providing a time line for the students if possible.
5. Brainstorm with the students to develop a list of both biotic and abiotic factors that influence the biodiversity of a salt marsh ecosystem. Make sure that students are aware that their mesocosms will contain only a small subset of the organisms that inhabit the salt marsh.
6. Formalize the list of biotic and abiotic elements of the salt marsh ecosystem. Students may be assigned homework to research and define each of these elements.
7. Brainstorm with the students to create a materials list and a procedure for sampling the sediment.
8. Formalize the materials list and procedure.

Part II: Development of Unit

Four to six 50-minute classes will be necessary for the development of the project. Class time dedicated to the project may be reduced by requiring the students to perform work outside class hours.

At this point, the students understand what a mesocosm is; they have compiled a materials list and created a written procedure; and they know the purpose of the unit. Once any needed parental permissions have been obtained, they are ready to go to the field site.

The development of the lesson follows:

1. Students are taken to an appropriate field site. They should be divided into groups and briefed on what to expect beforehand to ensure that their educational experience in the field is not compromised by poor behavior or distractions (Crimmel, 2003). The collection site's water should have a salinity of between 5 and 15 parts per thousand (‰) to ensure survival of the species to be studied. Students are instructed to make observations about the pool from which the sediment is to be drawn and record any life forms spotted in or around the pool in their individual notebooks. They

will also measure and record the water-column depth.

An instructor enters the pool (wearing hip or chest waders) and removes sediment using a shovel. (This step will require an instructor with sufficient dexterity and strength. He/she should be aware of the proper safety precautions for the particular type of waders being utilized.) Sediment is collected in a five-gallon bucket.

Additional five-gallon buckets are filled with brackish water on site by the instructor or, preferably, by the students (safety and individuals' ability permitting).

Alternatively, if a field site visit is precluded, artificial seawater can be prepared by the instructor with a salinity of between 5‰ and 15‰.

2. Sediment and water samples are brought back to the classroom or laboratory. Each student group lines the base of an aquarium with about three inches of sediment. Water from the field site (or artificial seawater) is then added to a depth of about seven to ten inches. A small aerator can be placed in each aquarium.
3. Before distributing the organisms (collected from the field or ordered) to students, the instructor engages them in a discussion of the intrinsic value of the organisms. If the organisms are collected from the field, appropriate accommodations must be made to house the organisms at the conclusion of the lesson. (*Note*: Some *Littorina* species are not native to North American estuaries and have invasive tendencies, and *Nematostella vectensis* may also be nonnative. Do not release these animals into the wild, even if they were collected from a local estuary.)

   If they are ordered from a supplier, the instructor must be prepared to maintain the developed mesocosms. The importance of making these accommodations is discussed with the students to ensure that they realize they are stewards of their mesocosms.

   Each group is given one (or preferably more) specimen of one type of organism to study. The specimen(s) is distributed to each group in a 50 ml conical tube or some other small clear container. Ask the students to make observations about the organisms in the tubes, where they can view them in more detail than later, when the animals are in their larger environs.

   At this point, ask students questions such as "What does the organism breathe? How does the organism breathe?" These types of general questions will help focus the students on looking at systems (i.e., respiratory) analogous to their own, and will also dovetail later on with urban environmental threats (i.e., deoxygenation through anthropogenic eutrophication).

   Do not hand out the fact sheets yet. Allow students to formulate and record their own questions about the organisms. Later, they will research these questions.
4. After sufficient observation (less than 15 minutes), allow the students to place the organisms in the tanks. (Note: Before the class starts, make sure the water in the aquarium and the containers holding the organisms are roughly equal in temperature.) If using the fact sheets (Appendices C–F), hand out them out and allow the rest of the period for observations and independent reading. Depending upon the scope of inquiry the instructor wants to foster, he or she might consider not using these fact sheets at all and allowing all research and direction to be driven by the students.
5. During the next class, allow the assigned groups to organize their time, and if possible, provide students access to computers. Each student should have read the fact sheet on the organism the group has been assigned as homework or during the class before. The group needs to:
   - Conduct research (Internet, library, interviews of scientists) on the research questions/guidelines for the presentation and questions posed by the students themselves
   - Continue to make observations of the organisms
   - Develop a presentation

If the groups are not able to work independently, the time frame for each of these tasks can be scheduled. Otherwise, groups may be allowed to allocate their own resources.

Part III: Closure of Unit

Lectures or discussions of the pressures upon organisms in urban environments are presented, specifically addressing their adaptations to survive in an urban ecosystem, and students should be introduced to the idea of stewardship. To conclude the unit, students make a presentation on their mesocosm, which includes accepting and answering questions formulated by both other students and their instructor(s). A final homework sheet may be handed out to the students to gauge the effectiveness of the lesson and to be used in student evaluation.

Evaluation

Throughout the project, the instructor challenges the students informally with questions to check student interest and encourage participation. Students are graded on their presentation based on written guidelines established by the individual educators and their school systems. The instructor can direct the questions during the presentation toward specific group members to aid in individual evaluation. Individual evaluation can be further determined by self-evaluations or group-peer evaluations. A homework sheet can also be used for evaluation.

Anecdotal Results From the Lesson Pilot

While resource constraints precluded us from piloting this lesson plan in more than one school, we qualitatively found that the lesson was successful at engaging students and teaching the prescribed content. Students were surprised and intrigued by the organisms, particularly because many of them had believed that there was nothing alive in the urban estuary from which our samples were collected. There was much variation in the quality of the concluding presentations (see Figure 4 for an example of a student presentation).

Follow-up Lessons

The presence of these organisms in the classroom/laboratory allows the opportunity to teach many other aspects of biology and environmental science. Discussions of population genetics and evolution naturally follow from discussion of adaptive resistance to toxins, which is particularly well supported in the case of *Fundulus* (Oleksiak, Churchill & Crawford, 2002; Elskus, Monosson, McElroy, Stegeman & Woltering, 1999). Interspecific competition can be illustrated between *F. heteroclitus* and *P. pugio* (Cross & Stiven, 1997). Morphology of bilaterians and radially symmetrical animals can be discussed in the context of *Nematostella vectensis* (Finnerty, 2003; Martindale, Finnerty & Henry, 2002). The same species can be used to lead an inquiry-based lesson on regeneration and/or asexual reproduction (Hand & Uhlinger, 1992; for this lesson plan see http://www.nematostella.org/Resources_Classroom_JS02.html). Other basic biology lessons utilizing this organism may be retrieved from http://www.nematostella.org/Resources_Classroom.html. Allopatric speciation can be discussed in reference to habitat fragmentation. The effects of invasive species can be illustrated by the extremely successful *Littorina* family, especially in reference to the role of humans in their dispersal (Bertness, 1984; Brenchly & Carlton, 1983).

This list of follow-up lessons is not exhaustive. Perhaps the best follow-up lessons will be those devised by students. Having aquariums in the classroom allows students to design controlled experiments to test many hypotheses. A few suggestions include predator/prey interaction experiments, growth-rate experiments, and niche-partitioning experiments.

Acknowledgments

This work was funded by a GK12 grant fromthe National Science Foundation (NSF DGE-0231909) designed to enrich high school curriculum in science, technology, engineering, and math by partnering graduate students in classrooms with K–12 teachers. Additional support was provided through a National Science Foundation grant (IBN-0212773) to John R. Finnerty. We thank Jean Francoise for assistance with animal collection and Cynthia Brossman, Lance Pearson, and three anonymous reviewers for insightful comments regarding both the scientific content and educational merit of the lesson plan.

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Glossary

Abiotic: Nonliving chemical and physical parameters in an environment.

Allopatric speciation: The formation of new species from ancestral species as a result of geographical separation or fragmentation of a breeding population.

Anthropogenic: Resulting from human activity.

Bilaterian: Bilaterally symmetrical organism, with body parts arranged in two halves that are mirror images of one another.

Biotic: Pertaining to the living organisms in an environment.

Biomass: The total mass of living organisms, commonly of those in a particular population or ecosystem.

Biophilia: A word coined by Harvard biologist Edward O. Wilson to describe the deep need that people have for natural habitats and species; the love of nature.

Estuarine: Present in an estuary, an area where a freshwater river meets seawater and is subject to tidal fluctuations and fluctuations in salinity.

Eutrophication: Process by which bodies of water age and become more productive. Anthropogenic eutrophication can lead to algal blooms and deoxygenation.

Formative assessment: All those activities undertaken by teachers and/or their students that provide information to be used as feedback to modify and improve the teaching and learning activities in which they are engaged.

Hardy-Weinberg equilibrium: The law or principle that states that in an infinitely large, interbreeding population in which mating is random and there is no selection, migration, and mutation, gene frequencies will remain the same between the sexes and constant from generation to generation, with no overlap between generations.

Homeostasis: State in which the internal processes of an organism tend to remain balanced and stable.

Interspecific competition: Competition between species.

Macroinvertebrate: Invertebrate animal large enough to be seen without a microscope.

Mesocosm: A biological system used for conducting experiments.

Niche partitioning: The coexistence of two or more species that partition one or more resources in a habitat.

Radially symmetrical: With body parts arranged symmetrically around a central axis.

Summative assessment: The process of evaluating (and grading) the learning of students at a particular point in time.

Figure 1. An estuary in Eureka, California

Figure 2. Students at Odyssey High School (South Boston, MA, 2004)

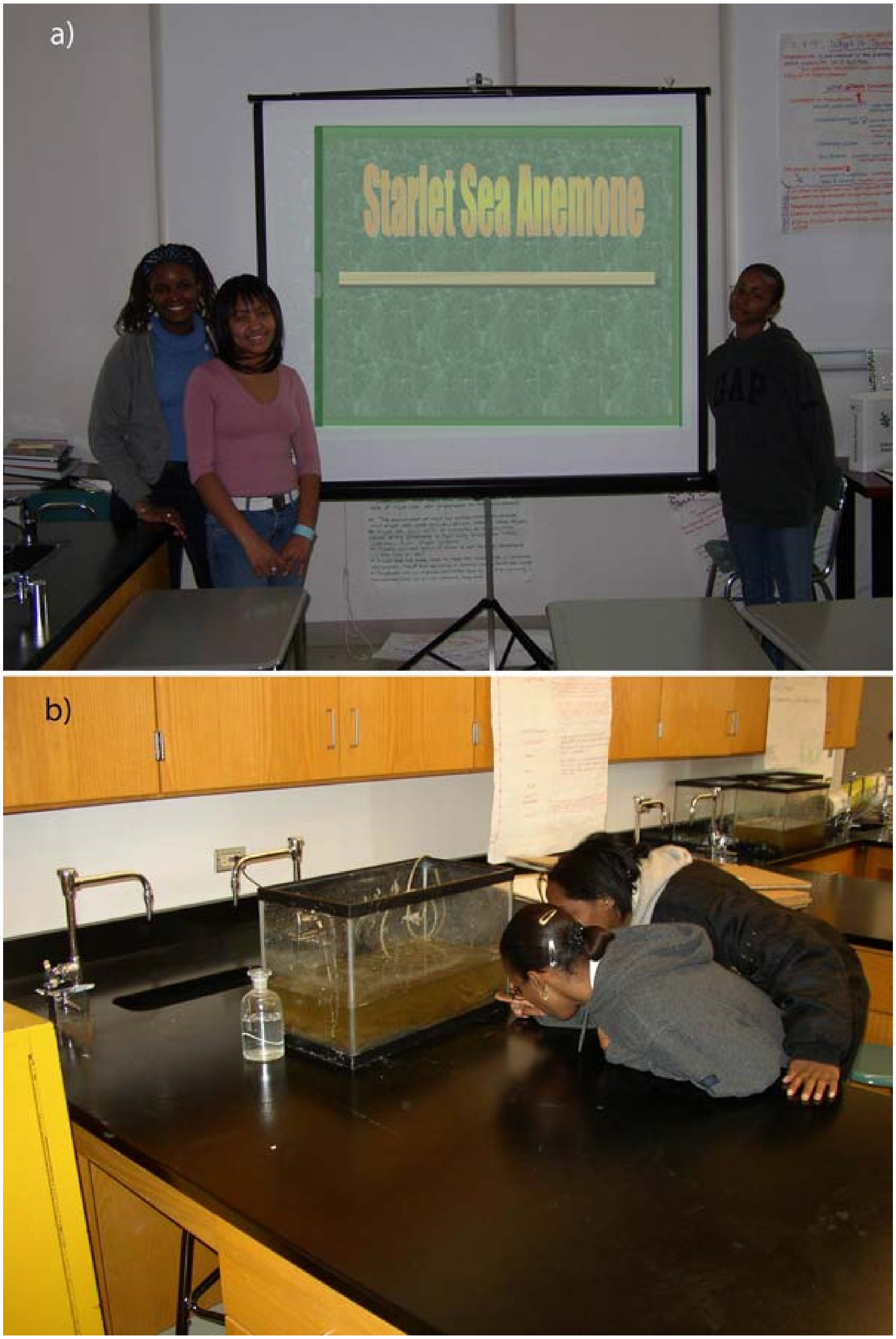

Figure 3. Terrestrial (a) and marine coral reef (b) mesocosms

Figure 4. Sample of pilot presentation done using PowerPoint software (Odyssey High School, South Boston, MA, 2004)

Table 1. The ten largest urban areas worldwide. Urban areas located on estuaries are in boldface type (Park, 2005).

Rank	Urban Area	Population in millions (1999)
1	**Tokyo, Japan**	**28.8**
2	Mexico City, Mexico	17.8
3	Sao Paulo, Brazil	17.5
4	**Bombay, India**	**17.4**
5	**New York, United States**	**16.5**
6	**Shanghai, China**	**14.0**
7	Los Angles, United States	13.0
8	Lagos, Nigeria	12.8
9	**Calcutta, India**	**12.7**
10	**Buenos Aires, Argentina**	**12.3**

Table 2. Racial demographics of Odyssey High School, Boston, MA, during the 2004–05 year

Grade	Black	White	Asian	Hispanic	Native American	Total	Row %
9	81	36	7	58	0	182	41.8%
10	42	20	11	34	0	107	24.6%
11	37	25	5	15	0	82	18.9%
12	31	11	9	13	0	64	14.7%
Total	191	92	32	120	0	435	
Column %	43.9%	21.1%	7.4%	27.6%	0.0%		

Appendix A. National Science Education Standards

This appendix indicates that this lesson meets the National Science Education Standards (National Research Council, 1996). Italicized text from *Inquiry and the National Science Education Standards* (National Research Council, 2000) is followed by a plain text description of how this lesson plan supports the specific standard.

Standard A—Teachers of science plan an inquiry-based program for their students. In doing this, teachers

- *Select science content and adapt and design curricula to meet the interests, knowledge, understanding, abilities, and experiences of students.*

By teaching general concepts of biology and environmental science through urban organisms and ecosystems, the lesson utilizes preexisting knowledge of the students' surroundings. By requiring students to conduct observational and literature research, the lesson utilizes the abilities of the students and leads to understanding and knowledge of the lesson content.

- *Select teaching and assessment strategies that support the development of student understanding and nurture a community of science learners.*

The students are given an excellent starting point for their independent work through the prepared fact sheets (Appendices C–F). By requiring independent research to complete the performance objective, teaching and assessment strategies are utilized that will greatly enhance student understanding. By requiring groups that have become student experts on one organism to teach other students during presentations, a community of science learners is developed.

Standard B—Teachers of science guide and facilitate learning. In doing this, teachers

- *Focus and support inquiries while interacting with students.*

This lesson enables students to be the primary scientific investigators through their own data collection and literature reviews. In this inquiry, teachers play a supportive role working alongside, not in front of, the students.

- *Challenge students to accept and share responsibility for their own learning.*

In addition to questions posed by the instructor(s), students are expected to develop their own questions to research about the organisms. In addition, because students are expected to peer teach the rest of the class on the group's independent work, each group is held responsible by the rest of the class.

- *Recognize and respond to student diversity and encourage all students to participate fully in science learning.*

This lesson plan is written for classes with a wide range of skill levels. The observational and group nature of the lesson plan encourages all students to participate; for example, students who might have strong observational skills but have difficulty conducting a literature review may be aided by other students who might have poor observational skills yet strong research skills.

Standard C—Teachers of science engage in ongoing assessment of their teaching and of student learning. In doing this, teachers

- *Use multiple methods and systematically gather data about student understanding and ability.*
- *Guide students in self-assessment.*
- *Use student data, observations of teaching, and interactions with colleagues to reflect on and improve teaching practice.*
- *Use student data, observations of teaching, and interactions with colleagues to report student achievement and opportunities to learn to students, teachers, parents, policymakers, and the general public.*

As part of the lesson, the instructor(s) is expected to continuously monitor and probe student progress through questioning. Furthermore, the culminating presentation, the use of self-assessment or peer assessment, and the use of a homework sheet to integrate concepts allows instructors to utilize a wide range of assessment strategies. Completion of the performance objective also creates a result that can be archived electronically to allow instructors to refine the lesson plan to better serve their needs.

Standard D—Teachers of science design and manage learning environments that provide students with the time, space, and resources needed for learning science. In doing this, teachers

- *Structure the time available so that students are able to engage in extended investigations.*
- *Create a setting for student work that is flexible and supportive of science inquiry.*
- *Make available science tools, materials, media, and technological resources accessible to students.*
- *Identify and use resources outside the school.*
- *Engage students in designing the learning environment.*

The inquiry-based and student-designed nature of the project fulfills this national standard. By allowing groups to organize their own time between the tasks of observation, literature review, and presentation development, the lesson "create(s) a setting for student work that is flexible and supportive of science inquiry." By including as part of the fact sheets (Appendices C–F) Internet websites as resources and providing the students with computers that they can use to search those sites, technological science tools and outside resources are made available to the students. By asking that students design as a class the sampling procedure, and allowing individual discretion as to pertinent topics to be covered in group presentations, the students are engaged "in designing the learning environment."

Standard E—Teachers of science develop communities of science learners that reflect the intellectual rigor of science inquiry and the attitudes and social values conducive to science learning. In doing this, teachers

- *Display and demand respect for the diverse ideas, skills, and experiences of all students.*
- *Nurture collaboration among students.*
- *Model and emphasize the skills, attitudes, and values of scientific inquiry.*

This lesson relies heavily upon group work conducted by the students. As such, they must be collaborative. Within groups, each student is likely to posses a different "competitively advantageous" skill. That is, since the project requires observational work, literature review, and technical proficiency with Internet exploration and Microsoft PowerPoint software, the lesson "display(s) and demand(s) respect for diverse ideas, skills, and experiences of all students." By necessitating collaboration and rewarding a diverse skill set, the lesson also emphasizes the "attitudes and values of scientific inquiry."

The Essential Features of Classroom Inquiry

- *Learners are engaged by scientifically oriented questions:*
- *Learners give priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions.*
- *Learners formulate explanations from evidence to address scientifically oriented questions.*
- *Learners evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding.*
- *Learners communicate and justify their proposed explanations.*

In this lesson, students are engaged by scientifically oriented questions posed by the instructor(s) as well as by each other during their observation. They collect their own evidence to answer some of these questions during observation and perform literature reviews to research other questions. As per the performance objective, students are required to communicate and justify their research results through an oral presentation.

Appendix B. Project Introduction Sheet

Mesocosm Project

Purpose

The purpose of this project is to collect and examine sediment and organisms from an urban salt marsh and learn about these organisms and their place in their ecosystem.

Objective

At the conclusion of this project, each group will present information in the form of a PowerPoint presentation to the other groups regarding one of the following:

a. The Banded Killifish

b. The Starlet Sea Anemone

c. The Periwinkle Snail

d. The Grass Shrimp

Information will be provided via fact sheets containing information and Internet-based resources. Students are encouraged to research their organism using the Internet.

Presentation Format

The PowerPoint presentation will consist of between 7 and 10 slides and take the following format:

a. Title slide with group members' names

b. 3 slides containing information about your organism: These slides should include information about the geographic range of your organism, its habitat, its life cycle, what it eats, what eats it, and any other information you deem important.

c. Between 1 and 3 slides of your observations: These slides should include any observations that you make about your organism (how it swims, how it eats, etc).

d. 3 slides about your organism and urban ecology: These slides should include information about how your organism is affected by humans and how your organism contributes to humans.

Appendix C. Fundulus heteroclitus Fact Sheet (to be handed out to students)

Note: For the purposes of uninterrupted reading by students, references are not placed in the body of the fact sheet. References may be found in Literature Cited.

The Banded Killifish (Mummichog)

General Info and Habitat

The mummichog, *Fundulus heteroclitus*, is an estuarine species that can tolerate a wide range of temperatures and salinities. It often coexists with another *Fundulus* species, *Fundulus diaphanus*, and is often found in schools of large numbers. Growing up to 5 inches, when found in salt pools, they may be the largest predators; but in tidal creeks and open bays of estuaries, they are preyed upon by many larger fish.

What They Eat

The mummichog is an omnivore that consumes a wide range of organisms. It will eat eelgrass fragments, insect larvae, smaller fish, fish eggs, diatoms, mollusks, crustaceans, and worms in the sediment.

What Eats Them

The mummichog is an important food source for larger fish and wading birds.

Range

The mummichog is found from the Atlantic coast of Florida north through the Gulf of St. Lawrence in Canada.

Life Cycle

The mummichog spawns between April and August. Spawning occurs at high tides with the new and full moons, usually at night. Clutches of eggs, which may number up to 300, are deposited in mussel shells, on the underside of eelgrass leaves, or in other hidden places where they are protected from drying even after the high tide recedes. The eggs hatch after the tides reach them again.

The Urban Connection

This small fish is particularly well adapted to survive in urban environments. PCB's (poly-chlorinated biphenyls) are a type of contaminant that can prevent many organisms from surviving and reproducing. *Heritable altered gene expression* in populations of fish from polluted areas is thought to aide these fish in their survival in heavily polluted estuaries. Because of this genetic change, these fish have been found in heavily polluted harbors such as New Bedford, MA, and Newark Bay, NJ.

The mummichog has also been used in a wide range of scientific studies, because it is a *vertebrate* that is capable of being held in large populations for experimental studies in laboratories. It has been an experimental animal used to study evolution, toxicology, and endocrinology.

But this fish's value to people extends beyond the laboratory. The mummichog is an important food source for larger fish and is important in maintaining their populations. Many fishermen use the mummichog as bait while fishing. And mummichogs are also important for mosquito control. They have even been introduced into ponds and ditches because they eat the mosquito larvae. One mummichog may eat as many as 2,000 larvae a day! This is important not only to prevent urban dwellers (like us) from itching annoying mosquito bites, but may even help prevent the spread of dangerous diseases spread by the mosquitoes, such as eastern equine encephalitis and West Nile virus.

Look It Up!

If you didn't understand something you read above, look it up! A "Google" search is a good place to start (www.google.com). Another good place to start is at the American Killifish Association (www.aka.org). It lists a number of "links" that you can use to navigate.

Appendix D. Nemostella vectensis Fact Sheet (to be handed out to students)

Note: For the purposes of uninterrupted reading by students, references are not placed in the body of the fact sheet. References may be found in Literature Cited.

The Starlet Sea Anemone

General Info and Habitat

The starlet sea anemo ne, *Nematostella vectensis*, is a small anemone that inhabits estuaries. It burrows in soft sediment with only its mouth and tentacles above the surface. It lives in tidal creeks, salt pools, and mud flats. It can tolerate a wide range of temperatures and salinities and has been found in salinities between 2 ppt (nearly fresh water) and 52 ppt (ocean water = 33 ppt). Sea anemones are members of a *phylum* called 'Cnidaria.' Other cnidarians include jellyfish and corals. These are relatively simple animals which possess only two body layers (*diploblasty*).

What They Eat

The anemone has been found to feed upon insect larvae, copepods, chironomid larvae, snails, worms, and almost anything else it can grab with its tentacles. It burrows in the soft sediment, and when anything small contacts its tentacles, the anemone reacts very quickly, drawing the prey toward its mouth.

What Eats Them

Nobody truly knows, but it seems that nothing in the salt marsh eats this small anemone. The anemone is very difficult to find, burrowed into the soft sediment. Additionally, this anemone has stinging cells throughout its body. When attacked by a potential predator (like a killifish or grass shrimp), it releases these stinging cells in self-defense!

Range

The starlet sea anemone ranges from Nova Scotia (Canada) as far south as the Gulf of Mexico. It is also found on the Pacific coast of the United States and in England!

Life Cycle

Like all anemones, the starlet sea anemone can reproduce either *sexually* or *asexually*. In sexual reproduction, females release eggs, which are fertilized by sperm released by males. Fertilized eggs mature into larvae, which change into adult anemones. In asexual reproduction, an adult anemone divides itself into two halves. Each half regenerates the other half of its body. This process is called transverse fission.

The Urban Connection

Like the killifish, the starlet sea anemone has been used in many scientific studies. Because it is a simple organism and easy to maintain in the laboratory, scientists have used it to study development and evolution. It has been used to study how complex body forms evolved; how *bilateral symmetry* evolved from *radial symmetry*.

The fact that this sea anemone can reproduce asexually might allow it to better survive in *fragmented* habitats. In impounded marshes and isolated salt pools, populations of sea anemones have been found that consist of one clonal line!

In Britain, where the sea anemone is found in only a handful of places, it is protected by the government. This limits the commercial development of marshes where the anemone is located.

Look It Up!

If you didn't understand something you read above, look it up! A "Google" search is a good place to start (www.google.com). A good website to find information about the starlet sea anemone is www.nematostella.org.

Appendix E: Palaemonetes pugio Fact Sheet (to be handed out to students)

Note: For the purposes of uninterrupted reading by students, references are not placed in the body of the fact sheet. References may be found in Literature Cited.

Grass Shrimp

General Info and Habitat

The grass shrimp (*Palaemonetes pugio*) is a small translucent organism inhabiting shallow water in estuaries. This clear shrimp is a crustacean with a well-developed serrated anatomical feature known as a "rostrum," which looks like a horn and extends over the eyes. The front two legs of the shrimp have well-developed claws, which it uses for feeding purposes. The shrimp is an excellent and very fast "swimmer." Like many other inhabitants of estuaries, the shrimp can tolerate a wide range of temperatures and salinities, although it generally avoids the high-salinity waters near the ocean.

What They Eat

Larvae of the grass shrimp feed upon *zooplankton*, *algae*, and detritus. As adults, the shrimp consume a wide variety of food items, including algae, detritus, worms, and crustaceans.

What Eats Them

The grass shrimp is consumed by fish in great numbers. Killifish, as well as commercially important fish such as sea trout, perch, and bass, take advantage of the large numbers of grass shrimp found in estuaries.

Range

Massachusetts is the northern limit of the range of the grass shrimp. It may be found anywhere on the Atlantic seaboard south of Massachusetts through the Gulf of Mexico.

Life Cycle

Grass shrimp spawn in the summer, usually within 10 hours of *molting*. Males fertilize the eggs externally with a *spermatophore* as they emerge from the female. The females then carry the eggs in a brood pouch until they are ready to hatch, after 12 to 60 days, depending upon the temperature. After hatching, the larvae undergo 11 juvenile stages before becoming adults!

The Urban Connection

Grass shrimp have very little intrinsic economic and recreational value, although some fishermen do use these shrimp as bait. They do serve an important ecological role, however, by breaking down dead plants and animals (detritus).

Additionally, grass shrimp serve as food for commercially important fish species such as sea trout, perch, and bass.

The grass shrimp has been found in polluted waters (e.g., New Bedford, MA, and Charleston Harbor, SC). Research is currently being conducted on how this organism survives there. It appears that a genetic change has allowed this species to survive in areas contaminated by heavy metals, such as *chromium*.

Look It Up!

If you didn't understand something you read above, look it up! A "Google" search is a good place to start (www.google.com). A good website to find information about the grass shrimp is www.chesapeakebay.net/info/palaemonetes.cfm.

Appendix F: Littorina Species Fact Sheet (to be handed out to students)

Note: For the purposes of uninterrupted reading by students, references are not placed in the body of the fact sheet. References may be found in Literature Cited.

Periwinkles

General Info and Habitat

Periwinkle refers to a group of snails belonging to the genus *Littorina* and includes the following species: the edible periwinkle (*L. littorea, L. littoralis*), the southern periwinkle (*L. angulifera*), the smooth periwinkle (*L. obtusata*), and the gulf periwinkle (*L. irrorata*). Periwinkles are very common inhabitants of salt marshes, estuaries, and intertidal zones. They are a marine snail and have gills that allow them to breathe underwater. They have a spiraled shell, and the larger species can grow up to 1 inch.

What They Eat

Periwinkles are herbivores, eating algae in the salt marsh. They will also eat cordgrass (*Spartina* species), which have a vital role in supporting the ecosystem of the marsh. They play an important role in breaking down the grasses that have died in the marsh.

What Eats Them

Periwinkles are often present in great abundance. Crabs, fish, birds, and small mammals in the salt marsh all feed upon them.

Geographical Range

Periwinkles are found along the Atlantic coast from Nova Scotia, Canada through the Gulf of Mexico. The edible periwinkle is actually *endemic* to Europe and was introduced to North America.

Life Cycle

Periwinkles reproduce sexually and may reproduce all throughout the year in parts of their range. Mating peaks in late spring or early summer. Fertilization occurs internally. The white, oval-shaped egg masses may contain over 250 eggs and hatch after four weeks. The larvae grow and metamorphose into sexually mature snails after two years. An interesting aspect of the life cycle of these snails is that they can change their sex!

The Urban Connection

Periwinkles play an important role in the ecosystem by breaking down dead plant material. They are sensitive to many types of contamination. Some pollutants affect the ability of the snail to reproduce, while others can change its sex organs! Because of this, scientists use them to study the affects of pollution upon salt marsh species.

Periwinkles are an important food source, not only for organisms like crabs and birds, but for people too! The edible periwinkle is so called because they can be eaten. Europeans have always made use of this commonly abundant food source, but it is not commonly eaten in North America.

Its use as a food source may be the reason why the edible periwinkle was introduced into North America. It first appeared off of the coasts of Nova Scotia and New Brunswick, Canada, in the 1850's. Since then, this very successful species has spread south through Florida and the Gulf of Mexico.

But the introduction of a new species is not always a good thing. Introduced species can disrupt the delicate balance of an ecosystem. A recent scientific study addressed what would happen if crabs, which are commercially harvested, were completely removed from Atlantic marshes. Without the crabs to eat the periwinkles, the periwinkle populations may grow out of control. Unchecked, these populations of periwinkles can devastate the cordgrass (*Spartina*) that forms the base of the salt marsh ecosystem. Without the cordgrass, all of the animals that rely on this highly productive plant cannot survive in the marsh either.

Look It Up!

If you didn't understand something you read above, look it up! A "Google" search is a good place to start (www.google.com). A good website to find information about the periwinkle is www.marlin.ac.uk/species/Litobt.htm. Try to find a recipe that uses periwinkles