Testing Hypotheses in Aquatic Habitats
A Field Study

Overview
Students use classic ecological sampling methods to investigate human impacts on a nearby ecosystem to present data-driven and evidence-backed conclusions about their research. This lesson is adaptable to a variety of natural ecosystems and includes a range of optional project extension activities.

Lesson objectives
By the end of this activity, students will be able to:
-design a testable hypothesis and research study
-explain human impact as it relates to eutrophication, destruction of habitat, and overconsumption
-explain the role of climate, water quality, light, etc, in characterizing biomes
-explain the abiotic and biotic factors which influence communities aquatic ecosystems

NGSS standards

Directly addressed in student project:
HS-LS2-2. Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.

HS-LS4-5. Evaluate the evidence supporting claims that changes in environmental conditions may result in: (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.

Addressed in class discussion:
HS-LS2-6. Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.

HS-LS2-7. Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.

HS-ESS3-4. Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.

Contents

Brief Introduction for Teachers

As humans, we highly value aquatic ecosystems as sources of food, water, and recreation. However, our activities shape these ecosystems, typically in a negative way. When this lesson was written during Summer 2015, advocacy against plastic pollution in the ocean was a hot topic - as well as the deadly effects our trash was having on oceanic organisms as small as plankton and as big as birds and whales. Any ecosystem features a complex set of interactions between a multitude of abiotic and biotic factors. Although human activity can take a variety of forms including the aforementioned pollution, as well as introduction of invasive species, habitat destruction, changing water flow (dams, etc), overfishing, and disruption of nesting sites, these activities need only to affect one of these biotic or abiotic factors to alter the balance of interactions, damaging the ecosystem.

In this lesson, students will use classic ecological sampling methods to investigate human impacts on a nearby ecosystem to present data-driven and evidence-backed conclusions about their research. The crux of this lesson is seated in the class discussion of collected data and its possible implications for the ecosystem. This lesson is adaptable to a variety of natural ecosystems and includes a range of optional project extension activities. A STEAM component is included in the form of field notebooks that students will keep throughout this activity.

There are two tracks that this 3+ day lesson could take. In Track 1: Exploration and field observations, the students will visit the field site at least twice, once to explore and generate experiment ideas, and once to collect data (more visits for a long-term project). In Track 2: One-off field survey, the teacher will provide students with information about the sites in lieu of an exploration field trip. The students will visit the field site once to collect data.

An extensive directory of background information, project design, instructions for sampling methods and data analysis, class discussion points, and possible extensions is included in the Teacher's Guide section.

Related research

From the authors:

I got my MS in biology at the Oregon Institute of Biology in Coos Bay, Oregon in 2012. This field station is perched on the sandstone cliffs of the Pacific Ocean and is surrounded by a wide variety of marine habitats, from salt marshes and estuaries to rocky shores and sandy beaches. While I was a student at OIMB I became fascinated by the sheer diversity of invertebrates that inhabit the marine habitats of the pacific northwest and their vastly different body plans and life histories. In my first plankton tow off of the dock I found beautifully delicate organisms that were unlike anything I had seen before, but turned out to be the larval stage of the very organisms I found living in tide pools and growing on the sides of floating docks.

My MS research project focused on a kind of marine invertebrate called a bryozoan. In its adult form, my study species can be found growing as a brittle orange crust on the surface of mussel shells. Upon further investigation with a dissecting microscope, this crust is a network of glass boxes that each housed a delicate fan of tentacled mouths flicking in and out. Each box houses an individual animal that together with its genetically identical neighbors forms the bryozoan colony. Speckled throughout the colony are rounded brood chambers for housing the developing larva. Once the larva is mature, it exits the brood chamber and swims freely in the ocean, where it will settle on a new hard surface and found a new colony. My preliminary research with bryozoans involved looking at the settlement preferences and behaviors of these larvae as they searched for new places in which to settle and start new colonies.

This line of research led me to think more critically about the way that marine species are spread about in the ocean, particularly how non-indigenous species arrive in new places. A bryozoan colony is sessile, it stays glued onto the same surface for the duration of its life. However, every single larva released by the colony (and there can be hundreds to thousands of larvae) can swim and be carried by currents to colonize new surfaces, whether they be a rocky bottom, the shell of a hermit crab, a floating buoy or the hull of a boat. The second part of my project involved surveying submerged settlement plates in the south slough estuary to examine how a changing salinity gradient affected the settlement of species, with a focus on non-indigenous species.

- *Kira Treibergs*

My research on marine ecology and human impacts began in high school, through after-school and summer programs at Project Oceanology, a local organization that monitors the health of many locations in Long Island Sound on the Connecticut shoreline. Project Oceanology is unique in that the majority of their “researchs” are school kids. By spending one night a week for a couple of semesters, and several full weeks during the summer, on a boat,

doing water quality tests and animal surveys, I began to realize how each of my very different local water systems were all shaped in some way by humans.

On one particularly memorable Tuesday night, I was part of a survey along a river feeding into the Sound - a river on which manufacturers like Electric Boat were located - our trawling net came back incredibly heavy - we had caught a “ghost” lobster trap (a trap whose marking buoy has been lost). It was full of spider crabs, a long-legged crab that eats decaying tissue. While spider crabs were not out of the ordinary in these surveys, the number of crabs in this trap, whose trapdoors had long since decayed away, was astonishing. The species distribution in that small patch of the river had been drastically altered by human negligence.

The examples kept on coming: on another trip, we were counting seabird eggs on a tiny island, where the birds are forced to nest, away from human disruption. On still another trip, I saw first-hand how drainage of salt marshes by humans attempting to eradicate mosquitoes (ironically, mosquitoes don’t brood in the salt water found in a salt marsh!) destroyed the animal communities, whereas nearby healthy salt marshes served as nurseries for all sorts of life.

These trips significantly shaped the way I think about the relationship between humans and the ocean, and has served as a theme in all of my subsequent research. As an undergraduate at Roger Williams University, my research focused on studied the physics of jellyfish feeding, with the ultimate goal of helping to improve our understanding how the currently rising populations of jellyfish and increasing occurrences of jellyfish blooms will affect marine communities in years to come.

While I now study fish swimming performance and physiology as a PhD candidate at Harvard University, I hope to apply this work to understanding the pressures driving fish evolution, and how overfishing, changing water temperatures, etc, are changing these pressures.

- *Kelsey Lucas*

A highlight from current biological research:

California’s Elkhorn Slough wetlands system

A very recent (June 30, 2015) study published in the *Proceedings of the National Academy of Sciences* examined how agricultural run-off related to hypoxia in an important fish nursery, the Elkhorn Slough wetlands in California. What was particularly interesting about this research was that it also investigated how low survival of baby food fish in this nursery decreased landings of adult fish by fishing boats in the ocean. Although this pattern of recruitment is a widely-accepted concept in fisheries science, it has rarely been demonstrated so thoroughly. Below is an excerpt from the student reading assignment based on this study.

> [California’s] Elkhorn Slough is a critical nursery for several types of food fish, which hide in the sheltered wetlands until they are big enough to move into the ocean.

Water from the mainland drains to the ocean through the Elkhorn Slough. Because the area is surrounded by farms, a huge amount of fertilizer is constantly being swept into the Slough in run-off. This build-up of fertilizer increases the amount of nutrients like nitrogen and phosphorous available to algae. You can think of these algae as being plant-like: they use the nutrients and photosynthesis to make their energy. But, at night, when there is no sun, the algae stop photosynthesizing and use cellular respiration for energy, consuming oxygen in the water. When there is too much algae, it can consume nearly all the available oxygen in the water (making "hypoxic" or low-oxygen water), causing the growing fish to suffocate.

While the death of the fish changes the food web in the Elkhorn Slough itself, it also causes the ocean environment occupied by the adult fish to change: no new fish ever arrive! Slowly, this oceanic ecosystem changes as the top-predators are fished out without being replaced.

About the scientific study:
Title: Climate mediates hypoxic stress on fish diversity and nursery function at the land–sea interface
Journal: *Proceedings of the National Academy of Sciences*

Workshop Activity

Overview of lesson

Today we're going to test hypotheses about a nearby pond. We'll brainstorm some hypotheses and testable questions about the site, focusing on human impacts on ecosystems. Next, we'll take samples and measurements at three different locations in the pond. Finally, we'll bring our samples back to the lab and pool together our data for some preliminary analyses in an attempt to draw conclusions about our hypothesis. We'll close with a discussion of the lesson in small groups, with a focus on ways that this lesson can be adapted to each teacher's local aquatic habitat.

Today's goals

-generate class-testable questions about a nearby aquatic habitat
-practice biological illustration in the field
-collect biological and physical data about three different sites within this habitat
-discuss ways to apply this lesson to each teacher's local aquatic habitat

Materials

-dip nets
-quadrat
-plankton net
-wide neck sample jars
-secchi disc
-glass jar + white card
-dip strips (ammonia and 6-1 test strips)
-field notebooks and sketch pencils
-salinity meter

Procedure

1. (classroom)Introduction to site, discussion of lesson & brainstorming testable questions (5 minutes)
2. Gather field equipment and walk to pond (5 minutes)
3. Data collection in groups, at 3 pond sites (30 minutes)
    a. quadrat sampling
    b. plankton tows
    c. water measurements: turbidity, color, quality, salinity
4. Walk back to classroom (5 minutes)
5. Clean up/change clothes/rinse off mud (5 minutes)
6. Data analysis and group discussion
    a. How will you apply this lesson to *your* local aquatic habitat? (15 minutes)
        i. discuss in groups of 2

    ii. share with group
b. Data analysis (~7 minutes)
    i. KL or KT will work assembling data into preliminary figures for discussion
    ii. Look at our plankton samples under the microscope
c. Group discussion & wrap-up (~7 minutes)
    i. What went well? What didn't go well?
    ii. How will you apply this lesson?
    iii. What difficulties do you anticipate?

Data analysis

During teacher discussion, KL and/or KT will work on pooling together the data we collected during our field study to calculate measures of diversity at our sampling sites, along with other figures displaying the data we collected.

Discussion & adapting the lesson

At the end of the lesson, teachers will do a 'think-pair-share' exercise where they meet in groups of two to discuss their local aquatic habitat, and then share their discussion with the class. Groups will address questions such as:

What human influences affect this ecosystem?
How do these influences affect this ecosystem?
How might we be able to measure these effects using the tools we learned today?
What are some challenges we anticipate in bringing a class to this ecosystem?

While teachers are discussing lesson adaptations, KL or KT will calculate summary statistics and measures of diversity from the data we collected. If we have time, we'll get a chance to explore the results of our field study and discuss how they apply to our hypothesis, and perhaps draw some conclusions about the pond ecosystem. If we don't have time, we can write the results and share them in an email.We will also take some time to discuss what went well and what did not go well, as well as propose future studies that we could conduct in this habitat.

Teacher's Guide

This guide contains the resources needed to implement this lesson. In this section, you will find some suggestions for study sites and comparison options at these sites, a detailed set of instructions on how to conduct this lesson, details on sampling and data analysis methods, and information/resources on how to extend/adapt this lesson.

Potential study sites and within-site comparisons

Potential study sites:

Pond

Compare a more polluted section to a less polluted section
Compare a section of the pond that is closer to 'human activity' (parking lot, roadway, swimming beach) to a more remote section of the pond?

Stream

Compare an area of high flow to an area of low flow
Compare a deep/wide section of the stream to a shallow/narrow section
Compare two different bottom substrates (ie. silty bottom area to a pebbled one)

Beach

Compare a sheltered area to an area with a lot of human activity (ex: near the breakwater - sheltered - vs in the recreational area)
Compare a beach that is combed/groomed/has sand delivered, vs a natural beach
Rocky coastline
Are there more species in an area with a lot of rocks, compared to a more open area (like the parking lot/beach)?
Is there evidence of pollution? Compare an area near a drainage pipe to an area far away, or an area with a lot of trash build-up to a cleaner space.

Vernal pools

Compare a pool that is closer to human activity to one that is more remote
Compare a large vernal pool to a small vernal pool

Measurements for within-site comparisons:

Biological measurements

Number of species

-classify organisms to the lowest level as possible

-species abundance & diversity will be estimated via quadrat sampling

-from these measurements we will calculate species richness and eve

Organism Abundance

-transect or quadrat sampling (depending on density/size of organism

Organism Presence/absence

Plankton community

-use microscopes to sort plankton samples and measure presence/absence or abundance

Physical measurements

Habitat dimensions: length, width, depth etc.

Temperature: air, water, sun, shade

Flow rate

-measured using a floating object, timer and measuring tape

Turbidity & water color

-secchi disc

-sample in a jar with a white background

Litter/Trash/Pollution

-presence/absence or abundance measurement along a transect

Water quality

-tested using dipstick style test kits

-pH, ammonia, nitrite, nitrate, hardness etc.

Salinity

-hydrometer

Choosing a lesson track

This lesson is designed to take at least 3 days to complete and follows this general structure.

(Step 0: preliminary homework assigned)
Step 1: learn about the field sites and design experiments
Step 2: complete field survey
Step 3: data analysis and discussion/critical thinking activities

There are two forms that the lesson could take.

Track 1: Exploration and field observations will take 4+ days to complete, and is suited for more in-depth student projects. This track can optionally be extended to create a long-term field project including several, but regular, sampling dates over the course of weeks or months.

In this track, the students will visit the field site at least twice. During the first visit, they will explore the area, make observations, and generate experiment ideas. During the second (and optional subsequent) visits, students will collect data required to test their hypotheses.

Track 2: One-off field survey will take 3 days to complete, and is designed for a classroom with limited time for field trips.

In this track, instead of an initial field trip to explore the study sites, the teacher will provide students with information about the sites during the first day of classroom work. Later, the students will visit the field site once to collect data.

Refer also to the instructions for all field sampling methods and data analysis methods.

Notes for shorter lessons:

To shorten the lesson for a 1-2 day activity, consider making measurements at one field site only, and comparing your results to baseline, healthy environmental parameters. Alternatively, a small, single field site could be surveyed in completion (count every animal in a vernal pool, etc).

What if I don't have access to a field site, or can't go on a trip?

If you do not have field site access near the school, or can't go on a trip, consider having students collect their own water samples to bring into the classroom. In this case, you would still be able to perform water quality, color, turbidity, and salinity tests, and examine any plankton found in the samples.

To do this, you will need to provide each of your students with a clear jar of a standard size - for example, collecting jars, baby food jars, etc. Have each student bring the jar home and collect a water sample from the environment near their home (ex: local pond, stream in the woods near their home, etc).

Students can collect samples by dipping the jar in the water source, and filling the jar halfway. Cap the jar tightly for transit. Have students label their jars with their name. Also have students record any relevant details about their sampling site, including:

- Time of collection
- A description of the environment, such as moving or standing water, smells, sounds, plant coverage, sediment type, etc

Ideally, students would collect their sample in the morning before school. However, if they need to collect the night before, have students keep their jars in the fridge, with the lid loosely attached, overnight.

Students should deliver their jars to their teacher as soon as possible in the morning. The teacher will store jars in a refrigerator or cold room, again, with the lids loosely attached, until the class meets.

Directions for teachers

There are two tracks that this 3+ day lesson could take. In Track 1: Exploration and field observations, the students will visit the field site at least twice, once to explore and generate experiment ideas, and once to collect data (more visits for a long-term project). In Track 2: One-off field survey, the teacher will provide students with information about the sites in lieu of an exploration field trip. The students will visit the field site once to collect data.

Refer also to the instructions for all field sampling methods and data analysis methods.

Start Here (both tracks)

Before Day 1:

1. Assign your students the preliminary homework (contained in the Introduction for Students section).
    a. Optional - visit the special collections at Harvard's Ernst Mayr Library with your students to look through several field notebooks in person. Note that several field notebooks are available online, and links have been provided with the student assignment.
2. Choose two field sites that will be compared (some suggestions can be found in the Potential field sites & within-site comparisons guide). These sites should be similar in all areas except for some human impact. Decide which of the following options you will take.
    a. Track 1: Exploration and field observations (2+ site visits)
    b. Track 2: One-off field survey (1 site visit)

Track 1: Exploration and field observations

Day 1 - field trip 1:

1. Provide an overview of the project.
2. Provide a description of the field sites.
3. Discuss field notebooks, the homework, and expectations.
4. Visit the field sites. Have students explore, observe, and fill out their field notebooks with their impressions. Encourage creativity - drawings are awesome!
5. Homework - brainstorm ideas for study topics

Day 2 - classroom prep:

1. Based on their observations in the field, have the class brainstorm potential interesting things to study, and keep a record on the board.
2. Discuss the initial homework assignment, especially topics related to experimental design/writing testable hypotheses.
3. Have students break into small groups (3-4s). Each group should generate a testable hypothesis that they are interested in studying at the field site.
4. Have student groups come up with a list of things they will need to measure at the field site to test their hypothesis.
5. Homework assignment: have students write about their proposed study and hypothesis in their notebooks.

Day 3 (& beyond as needed) - field trip 2+:

1. At each field site, have students work with their groups to measure relevant parameters. These may include things like a pH test, turbidity, species abundance, plant cover, conducting a plankton tow, sediment sampling, etc. Make sure students get replicate measures.
    a. *Based on available time, you may need to have students divide and conquer tasks (ex: two groups need pH and turbidity data. Have one group collect pH data and the other turbidity, then share).
    b. Have students take notes about their methods and data, as well as any potential mistakes or any other relevant observation, in their field notebooks.
    c. Have students create some sort of visual in their notebooks - a map of the study sites, a diagram of their tools, a drawing of something they found interesting, etc. Based on available time, this could be put into the homework.
2. If this is a long term study, repeat visits to the field site to collect more data regularly.
3. Homework assignment - students should write a complete description of their methods, and a paragraph or two response about the trip (think diary/journal entry, with limited guidelines. Some ideas: what was fun, what wasn't, what didn't they expect, what cool critters did they see, etc)

Day 4 (& beyond as needed) - classroom:

1. Pool the class data.
2. Have students work in their groups to calculate species richness, abundance, and diversity index for each of the field sites (see Data analysis methods). As a class, compare results (make sure everyone got the same thing).
3. Have students work in their groups to explore data relevant to their hypotheses. Student groups should create some graphs showing relevant data, perform some basic statistics (optional depending on class background), and should start to discuss how that fit or did not fit their expectations.
4. Have each student group informally present their findings to the rest of the class - use chalk-talk format - each group gets 2-3 minutes total.
    a. Groups should cover what their hypothesis was, what things they measured, what they found, and if their results supported their hypothesis or not.
5. As a class, discuss the broader impacts of the field study. Some guiding questions are provided below. Students should respond with their opinions backed by evidence from the study and relevant material they have learned in the course. Teachers should generate a list of keywords on the board.
    a. Discussion questions:
        i. Does human activity affect biological and physical parameters at our study site? What kinds?
        ii. What human activities appear to be more harmful than others?
        iii. What kind of management plan might you recommend for this site? What other information might you need and why? How might you get that information?
        iv. What biotic factors might have influenced what we saw? How would you study this?
        v. Are there refuges here? Would there be a huge effect of disturbance?
6. Homework assignment (due in a week) - students should take home their field notebooks and write about the following:
    a. Their results, including the graphs they made in class.
    b. Discuss their conclusions (support or refute hypothesis), and why they may have seen what they saw.
    c. A response to the broader impacts discussion. What pieces were relevant to their own part? What were they surprised about, or now think about differently? (etc)

Track 2: One-off field survey

Day 1 - classroom prep:

1. Provide an overview of the project.
2. Provide a description of the field sites.
3. Discuss the homework assignment, especially topics related to field notebooks and experimental design/writing testable hypotheses.
4. Have the class brainstorm potential interesting things to study, and keep a record on the board.
5. Have students break into small groups (3-4s). Each group should generate a testable hypothesis that they are interested in studying at the field site.
6. Have student groups come up with a list of things they will need to measure at the field site to test their hypothesis.
7. Homework assignment: have students write about their proposed study and hypothesis.

Day 2 - field trip:

1. At each field site, have students work with their groups to measure relevant parameters. These may include things like a pH test, turbidity, species abundance, plant cover, conducting a plankton tow. Make sure students get replicate measures.
    a. *Based on available time, you may need to have students divide and conquer tasks (ex: two groups need pH and turbidity data. Have one group collect pH data and the other turbidity, then share).
    b. Have students take notes about their methods and data, as well as any potential mistakes or any other relevant observation, in their field notebooks.
    c. Have students create some sort of visual in their notebooks - a map of the study sites, a diagram of their tools, a drawing of something they found interesting, etc. Based on available time, this could be put into the homework.
2. Homework assignment - students should write a complete description of their methods, and a paragraph or two response about the trip (think diary/journal entry, with limited guidelines. Some ideas: what was fun, what wasn't, what didn't they expect, what cool critters did they see, etc)

Day 3 (& beyond as needed) - classroom:

1. Pool the class data.
2. Have students work in their groups to calculate species richness, abundance, and diversity index for each of the field sites (see Data analysis methods). As a class, compare results (make sure everyone got the same thing).
3. Have students work in their groups to explore data relevant to their hypotheses. Student groups should create some graphs showing relevant data, perform some basic statistics (optional depending on class background), and should start to discuss how that fit or did not fit their expectations.

4. Have each student group informally present their findings to the rest of the class - use chalk-talk format - each group gets 2-3 minutes total.
    a. Groups should cover what their hypothesis was, what things they measured, what they found, and if their results supported their hypothesis or not.
5. As a class, discuss the broader impacts of the field study. Some guiding questions are provided below. Students should respond with their opinions backed by evidence from the study and relevant material they have learned in the course. Teachers should generate a list of keywords on the board.
    a. Discussion questions:
        i. Does human activity affect biological and physical parameters at our study site? What kinds?
        ii. What human activities appear to be more harmful than others?
        iii. What kind of management plan might you recommend for this site? What other information might you need and why? How might you get that information?
        iv. What biotic factors might have influenced what we saw? How would you study this?
        v. Are there refuges here? Would there be a huge effect of disturbance?
6. Homework assignment (due in a week) - students should take home their field notebooks and write about the following:
    a. Their results, including the graphs they made in class.
    b. Discuss their conclusions (support or refute hypothesis), and why they may have seen what they saw.
    c. A response to the broader impacts discussion. What pieces were relevant to their own part? What were they surprised about, or now think about differently? (etc)

Sampling methods

Water quality

Dip Strips

Dip strips such as these test for chlorine, ammonia, nitrate, nitrite, GH, KH and pH all at once. To measure each water parameter, the strip is dipped directly into the water and then after a period of time, colors are compared to a chart where value estimates can be made. Dip strips can be thrown away in the regular trash, and can often also be purchased in the aquarium department of your local pet store.

Meters

Electronic meters for measuring various water parameters including pH, dissolved oxygen content, salinity, temperature, and conductivity (often all at once) do exist, but they can be *very* expensive. If your school has a budget for obtaining supplies like this, YSI sells many high-quality meters (https://www.ysi.com/products/sampling-handhelds?Page=1).

To use a meter, follow these steps:

1. Make sure the meter is calibrated according to the manufacturer's instructions. This will need to be done in advance.
2. Power on the control box.
3. Cycle through the displays until the parameter you are interested in is on screen.
4. Dip the sensor in water sample. Make sure that the probe is complete submerged.
5. Wait several seconds for the display to update, and the values to become stable.
6. Record the stable values.

Plankton Towing

Student plankton nets can be purchased online or can be made inexpensively from common household materials. Traditionally, plankton net mesh sizes can vary from 50 µm to 300 µm. The size of the mesh openings will determine the size range of the plankton that you collect. Zooplankton in temperate regions are commonly collected with a 200µm net. If you are building your own net, keep in mind that a stocking has a mesh size of around 250µm.

To conduct a plankton tow:

1. Make sure that the cables are untangled.
2. Make sure the collection cup at the bottom of the net is attached/closed off.
3. Stand on the edge of the body of water with the plankton net. Hold the end of the towing cable in your non-dominant hand, and the opening rim of the plankton net in your dominant hand.
4. Using a motion like tossing a frisbee, cast the plankton net over the water surface. Be sure to hold on to the towing cable!
5. Reel in the towing cable slowly.
6. As the net reaches you, lift the net vertically to keep the water sample in the collecting cup.
7. If available, rinse down the sides of the plankton net with water from a squirt bottle. (Note that for this lesson, this step isn't crucial, unless you plan on publishing results in a journal).
8. Transfer the sample to a jar.
    a. If you have a net with a container-style end (usually on a purchased plankton net), unscrew the container and pour the contents directly into the collection jar.
    b. If you have a net with a bottle-cap style end (on the DIY net), make sure you have a wide-mouthed collection jar. Hold the end of the plankton net over the jar. Carefully unscrew the bottle cap so that the water drains into the jar.
9. Label your jar with the study site, time, and date.

To analyze a plankton sample in lab later, you will need:
-a microscope (dissecting scopes are sufficient, but some things may be seen better in a compound scope)
-plastic Petri dishes (can be reused)
-a dropper or pipette
-your sample jar
-an empty sampling jar or beaker

Analysis steps:

1. Decide on an ending criteria for analysis. For example, will you survey the complete contents of the collecting jar? Thirty pipette-fulls?

Assuming complete sampling,

2. Start by pouring your sampling jar's contents into the empty jar or beaker. Do you see anything moving? Are there any macroscopic organisms? If you can, identify any of these things, and transfer them to the original sampling jar using the pipette.
3. Use the pipette to suck up an interesting-looking speck (things that are moving, things that are drifting, look like an animal, etc). Transfer the contents of your pipette to a dry Petri dish. Try to expel the fluid from the pipette so that it ends up in a small droplet.
4. Place the Petri dish on the table of the microscope, and search the speck for any critters. Identify and count anything you can. When done, transfer the animals back into the original sampling jar.
5. Repeat steps 3 & 4 until you empty the beaker or confidently believe you've seen everything.

Assuming a set number of pipette-fulls,

2. Start by pouring your sampling jar's contents into the empty jar or beaker.
3. Stir up the sample using the pipette.
4. While small particles are still suspended, dip the pipette into the water sample and suck up a small amount of water. Transfer the contents of your pipette to a dry Petri dish. Try to expel the fluid from the pipette so that it ends up in a small droplet.
5. Place the Petri dish on the table of the microscope, and search the speck for any critters. Identify and count anything you can. When done, transfer the animals back into the original sampling jar.
6. Repeat steps 3-5 until you reach the set number of pipette-fulls.

Because plankton IDing can be a time-consuming process, you may consider looking to identify types of species, and no counts. Be sure to consider the meaning of each species present. For example, several species of plankton and insect larvae are "health indicator" species - meaning, they are only present if the water system is healthy.

Plankton Identification resources:
Image-based freshwater plankton key from the University of New Hampshire
How to ID zooplankton, from Missouri State University
Ocean Data center, marine phytoplankton ID
UCLA Plankton Guide
Marine zooplankton ID guide, University of Georgia

Animals students might see in the pond or plankton tow:
Fishes -
http://www.eregulations.com/massachusetts/huntingandfishing/fishes-of-massachusetts/
Amphibians
Insects - http://penobscotswcd.com/publications/insects.pdf

Zooplankton - http://cfb.unh.edu/cfbkey/html/begin.html

http://flocculate.missouristate.edu/zooplankton/Default.htm

Meroplankton (organisms that spend part of their life as plankton):

- Polychaete larvae
- Crab larvae
- Mollusk larvae
- echinoderm larvae

Holoplankton (organsims that spend their whole life as plankton):

- copepods
- jellyfish medusae
- isopods
- amphipods
- pelagic flatworms
- comb jellies

Looking for indicator species

Because some animals are more sensitive to water quality changes than others, the presence or absence of different species in a plankton or dip net sample can provide a rough sense of how health the ecosystem is.

In any habitat, a large species richness or good biodiversity index suggests a more healthy environment. But, we can get more specific.

The presence of different types of Insect larvae are a particularly good way to identify health of an aquatic environment. To catch insect larvae, use a plankton tow or a dip net (students have aquatic nets; they pass them through the water and check out what they caught).

IDing insect larvae

The New Hampshire Department of Environmental Services has a great text-only guide to some common insect larvae found in aquatic environments. This can provide an overview of different insects you may find.

Although this guide is from California, it provides an excellent description of biomonitoring. Pages 7-9 will be most useful for your students; these pages have short descriptions and drawings of different insect larvae they might find in the water. These drawings are also divided up into “sensitive,” “intermediate,” and “tolerant” species categories.

If Internet access is available while looking at insects, this great picture-based, interactive key can help students categorize different critters - not just insects! - that they collect from the aquatic environment, using easily-visible features on the animal’s body.

Quadrat sampling & percent coverage estimations

Quadrats

Ecologists use quadrats to quantitatively sample a habitat. Quadrats are usually made from a square frame (most commonly being 1 m^2). This tool gives us a standard size of space from which we can collect meaningful data from a small portion of the environment and then extrapolate it to generate an estimate for the whole environment. We can also use a quadrat to make meaningful comparisons between different environments, because it gives us a way to make sure we are unbiasedly sampling the same amount of space.

Make your own quadrat

Quadrats can be made from PVC pipes, PVC elbows, PVC glue and rope. You can find more instructions on how to make your own 1 m^2 quadrat here.

How to use a quadrat

For this field study, we'll be using quadrat sampling to measure a small part of our ecosystem. There are other more involved methods for habitat-sampling you can learn about here, but we won't have time to get into them for this lesson.

1. To start, you place the quadrat on the habitat from which you'd like to sample. Ideally the spot where you place the quadrat will be selected randomly, but we'll probably choose a spot based on logistics (ie. a spot that is away from poison ivy, a place easily accessible, minimal mud).
2. Count all of the animals found within the region of your quadrat.
    a. Field guides can be useful tools for identifying unknown organisms, but for this study, we will go with 'operational taxonomic units', or OTU's. This means, we'll classify each organism we find into the most specific category we can, to the best of our ability.
    b. It helps to set rules ahead of time as to 'what counts' as inside the quadrat. For example: a frog may be half inside and half outside the margins of your quadrat.
        i. one helpful rule is: "If the animal/plant/object touches the upper edge or left-most edge of the quadrat square, we count it, and if it touches the lower edge or right-most edge of the quadrat we don't count it."
3. Estimate % cover of the different kinds of plants found in your quadrat. Since our quadrat is a 5x5 grid of 10cm x 10cm squares, each square is 1/25th (or 4%) of the total quadrat.
    a. Go through each of the squares and determine if your plant of interest fills all, half, or none of the square.
        i. If it covers all of the square, add 4% to a running total of percent cover. If it covers half of the square, add 2% to a running total of percent cover.
        ii. if it is not present in the square (or present in less than half of the square), continue on to the next square and repeat each step until you've checked all squares of your quadrat.

4. Repeat this sampling method for at least two other sections of our habitat, for a minimum of 3 quadrat samples per site.
    a. Later we will use these data from these three measurements along with the estimate of the total area of the habitat to estimate ecological measures for the habitat.

Flow rate

Flow rate measures are relevant where water is moving, as in a stream or river. Measures are typically taken at a few points along the width of river, since the flow rate in the middle is faster than near the shore. Measurement mid-river require waders. If waders are not available, shoreline measurements will suffice.

A flow-rate measurement requires at least two people, one upstream and one downstream.

Materials:
-meter stick or tape measure
-stopwatch
-orange
-waders (helpful but not required)

Procedure:

1. Have the two people stand a known distance apart. This can be accomplished in two ways:
    a. Have each person stand at either end of a meter stick (1 m apart).
    b. Have the downstream person hold the dispenser of a tape measure at their side. Have the upstream person hold the end of the tape. Try to keep the tape as level as possible. Note the reading off of the tape measure.
    c. The measuring tool can be placed to one side now, as long as the two people don't move from their spots.
2. Have the downstream person ready to catch.
3. Have the upstream person hold an orange at the surface of the water. If the orange was released, it should move along without dropping.
4. Have the upstream person be ready with a stopwatch.
5. When the downstream person (or a third party) says, "go,":
    a. The upstream person releases the orange, starts the stopwatch, and removes their hand from the water.
    b. When the orange reaches the downstream person, the upstream person stops the stopwatch, and the downstream person catches the orange.
6. Repeat these measurements several times.
7. For each trial, divide the known distance by the recorded time to get flow rate in m/s.

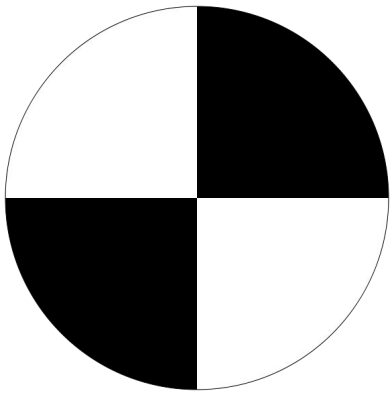
Turbidity measurement

Secchi disk

A secchi disk is a tool used to measure turbidity, which is a measure of water clarity. Water clarity depends on how much material (soil particles, algae, plankton, microbes etc.) are suspended in water, resulting in a decreases in the passage of light through the water.

To make your own secchi disc:

1. Draw an X with black sharpie across a round white flat object such as a lid or a white frisbee (yogurt container lids work great for this). Color in two of the "pie quarters" to obtain a black-white pattern.



2. Drill a small hole through the center
3. Using a ~2M length of line or thick string, tie several heavy metal washers to the center of the disc, so that it can be lowered down below the surface of the water.
4. Use a meter stick to make measurement markings along the length of the rope so that you can measure how submerged the disc is when you lose sight of it.

To use your secchi disc:

1. Lower the disc into the water until you can no longer see it. Record the depth of the disc using the marks on your rope.
2. Raise the disc until it appears again. Record the depth of the disc.
3. Take the average of these two numbers to find the water turbidity measurement.

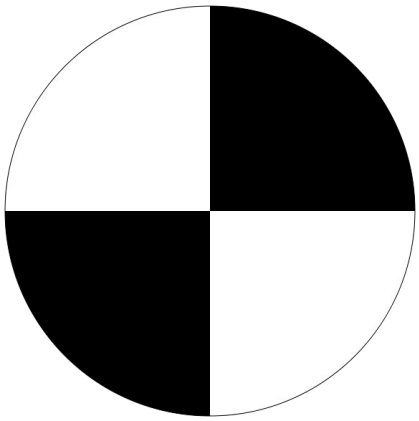
Note that secchi disks are successful only when the water is murky enough that the bottom cannot be seen. If the water is fairly clear, or the disk can hit the bottom of the water before disappearing from sight, use a turbidity tube or water color measurement instead.

For very clear water, such as water coming out of a faucet, note that the water is "clear," and make no measurement. A water color measurement may still be applicable.

Turbidity tube

A turbidity tube is similar in concept to a secchi disk and takes a measure of turbidity, or water clarity. Water clarity depends on how much material (soil particles, algae, plankton, microbes etc.) are suspended in water, resulting in a decreases in the passage of light through the water.

Turbidity tubes can be made in the classroom. To make a turbidity tube, draw the secchi disk pattern (pictured below) on a sheet of paper.



Place a clear, glass, flat-bottomed tube on top of the pattern on the sheet of paper. Look down into the tube and verify that the pattern is visible.

Slowly pour water from your sampling site into the tube until the pattern just barely disappears. Using a metric ruler, measure the height of the water in the tube. This number is the turbidity measurement.

For very clear water, such as water coming out of a faucet, note that the water is “clear,” and make no measurement. A water color measurement may still be applicable.

Water color measurements

Take a clear plastic jar-full of pond water and hold it up to the light with a white card behind it. Describe the color of the water as objectively as possible. If the color isn't saturated enough to register a color, you can record the same observations using your plankton sample. Keep in mind that this is a highly concentrated sample.

When discussing water color, you may also want to consider the amount of suspended sediment and visible zooplankton in your sample. You may also want to discuss the types of microalgae that might be present. Microalgae comes in three colors - brown (can be yellowy), red, and green.

There is an alternative way to measure water color using your secchi disc and a smartphone app. You can read about this method here.

Salinity measurement

Water salinity can be measured three different ways.

1. Hand-held refractometer-- This tool measures how much light bends, or refracts, when it enters the liquid. The more salts (and other material) dissolved in the water, the more resistance the light will meet and the more it will bend.
2. Hydrometer-- This tool measures the specific gravity of a liquid compared to pure water. Water with salt in it is more dense than pure water.
3. Conductivity meter-- Conductivity meters measure salinity by sending an electric current through the water and measuring how resistant the water is to the flow of the current. Since salts increase conductivity, the less resistant the water is to the flow of the current, the higher the conductivity and the higher the salinity.

This measurement is a particularly important one if you are working in an marine or estuarine area, but it could also be worthwhile to check the salinity in a pond, lake, or stream. Keep in mind that ocean water salinity is 35 ppt* (parts per thousand) and freshwater salinity is on average 0.5 ppt*. In an estuary (region where freshwater and saltwater meet) brackish water can fluctuate from 0.5 - 35 ppt in a single tidal cycle! [*Think about how salinity fluctuations like these could affect the ecosystem!*]

*A note about the units for salinity: Technically the calculation of salinity is a ratio, so it is unitless quantity, but out of convenience and convention it is often presented with a unit descriptor. In addition to ppt (also written as ‰), you may also see Practical Salinity Units (or PSU) g/kg, or g/L. These units are virtually interchangeable, and are dependent on how the salinity was measured.

Data analysis methods

Richness index

Species richness is a count of the number of species seen in a certain area and does not account for relative abundances within each species. In this activity, it is likely that students will have found animals that they were only able to ID to the Family or Genus level. That's okay! Do a richness index to whatever level you can.

To find species richness for the field site, have each student group count the number of species report the species (or families, genera, etc) they spotted. Keep a list on the board, and do not include any repeats across groups. Have the students count up the total number of names listed on the board. This is your Richness Index.

Abundance

Abundance is a measure of how many animals, plants, etc you found. Often, because numbers of individuals are counted within a quadrat or in a plankton sample, this number can be generalized to an abundance per square meter or an abundance per sample, respectively. For aquatic surveys, abundance is often focused on animals, with plants/algae estimated as percent coverage instead of abundance.

Abundance is useful in examining one species' populations over time or space, but may be difficult for cross-species comparisons. An alternative form of abundance is "relative abundance of species," which is detailed in the next section. Relative abundance is more useful for determining how proportions of species present shift across environments or time.

Start with the species (or group) list generated in the procedure for Richness Index.

1. Have each student group look at their own data. Each group will:
    a. Determine how many of each of those animals they found in total, across all of their quadrats or samples, at each sampling site.
    b. If normalization is to be used, divide the number of individuals by the total quadrat area or number of samples.
        i. Each quadrat is often a 0.25-m by 0.25-m square, or 0.0625 m^2. If three quadrat samples were taken at one site, then this area needs to be multiplied by three.
    c. Report their result for each animal group, at each site, on the board.
2. As a class:

a. Find the mean abundance for each animal group at each field site.
b. You may find it helpful to rank the results from most to least abundant at each field site for further class discussion.

Relative abundance of species

Like abundance, this is a measure of how many individuals of each species were observed. But, in this case, the metric focuses on the *relative* number of individuals seen - or, the proportion of individuals that belonged to each species.

Relative abundance of species is useful for cross-species comparisons and determining how proportions of species present shift across environments or time. To examine one particular species' populations, a straight abundance calculation (detailed in the previous section) may be more useful.

Start with the species (or group) list generated in the procedure for Richness Index.

1. Have each student group look at their own data. Each group will:
    a. Determine how many of each of those animals they found in total, across all of their quadrats or samples, at each sampling site.
    b. Report these numbers on the board.
2. Have each student group use the class data on the board to:
    a. Add up each group's observations to find the total number of individuals observed for each species, at each site.
    b. Add up these totals to get the grand total - the total number of animals observed.
    c. For each species at each site, divide the number of individuals of that species by the grand total. The result is the relative abundance of that individual at that site.
3. As a class, compare results and make sure everyone got the same thing. Discuss how relative abundances have shifted (or not) between different sites, and why that may be.

Diversity Indices

A diversity index is one number that takes into account both species richness and relative abundance of species. In particular, this index assumes that the relative abundances have already been calculated.

Because the diversity index increases both when the number of species in the area increases, and when the abundances across groups are more equal, a diversity index alone can

sometimes be hard to interpret. Therefore, it is valuable to report and consider both a diversity index and richness/abundance measures.

Diversity indices make a major assumption: that all species living in an environment appear in your samples - meaning, even rare species made an appearance in your samples. They also can be greatly influenced by sampling technique.

There are several different diversity indices, each with its own merits and drawbacks. Two of the most widely-used indices are detailed below.

Shannon Index

The Shannon index is considered an "information" index. The idea behind this index comes from code-breaking. A code with many different letters and an equal number of uses of each of these letters will be more difficult to break because it is less easy to guess the next decoded letter in a text. Roughly, the number of different letters is equivalent to the number of different species, or species richness, and the number of uses is equivalent to the species abundance. A larger index indicates a more complex system, or greater biodiversity. Typical Shannon index values are between 1.5 and 3.5, and are almost never greater than 4.

The strength in this index is its sensitivity and ability to detect differences between sampling sites. But, because it is an information statistic, it does assume that your species numbers represent a truly random sample of the animals in the area. Because some animals live in patchy distributions, this assumption may be violated to some extent.

Shannon's index is given by:

$H' = -\sum p_i \ln p_i$

H' = the index

p_i = the relative abundance of species *i*

Simpson Index

Suppose, at one of your study sites, you pick two animals present at random, and identify them. The Simpson's index measures the probability that these two animals come from the same species (group, etc) out of all the species in the community. Because this measure gives more weight to highly abundant animal groups (there is a greater probability of finding two individuals of the same species if the species is abundant than if the species is rare), the Simpson index is considered a "dominance" index.

The strength in this index is that it weigh species and is not as sensitive as the Shannon index to changes in species richness. A potential drawback is that it can be relatively unaffected by the presence of a few individuals of a very rare species.

The Simpson index, D, takes values in between 0 and 1. As the index increases, the dominance of one species increases, so diversity *decreases.* So that the index and diversity scale in the same direction, sometimes 1-D, called the Simpson Index of Diversity (as opposed to the Simpson index) is often reported instead. The Simpson Index of Diversity is also between 0 and 1, but increases with increased diversity and decreased dominance of one species.

The Simpson Index is given by:

$D = \sum p_i^2$

D = the index
p_i = the relative abundance of species *i*

Reference:
http://biology.kenyon.edu/courses/biol229/diversity.pdf

Additional resources:

The Maryland Sea Grant has some helpful background information on diversity measures that can provide context for class discussion.
http://ww2.mdsg.umd.edu/interactive_lessons/biofilm/diverse.htm#2

This worksheet has another good explanation of the calculation procedures.
http://entnemdept.ifas.ufl.edu/hodges/ProtectUs/lp_webfolder/9_12_grade/Student_Handout_1A.pdf

This document presents the equations in a slightly different format and provides some basic pros/cons of each index.
http://www.webpages.uidaho.edu/range357/notes/Diversity.pdf

Potential project extensions

Based on available resources, the following projects could be completed as an extension of the field study.

Poster presentations

Poster presentations are a regular event a scientific conferences. Posters generally are 4x3 ft, and contain a short introduction, methods description, graphs, and their conclusions. Bulleted items are prefered over blocks of text, and posters should emphasize visuals (like the graphs). Have each student group create a poster about their project and present it in a poster session.

Poster session info - there are two major ways to run a poster session:

- Option 1: Posters are all hung at once, and students stand near their poster. Guests (the public, parents, or other students outside of the class) wander through the exhibition and listen to students providing an overview and ask questions.
- Option 2: Half of the class hangs posters at once. The "guests" are the other half of the class, and, since students worked in groups of 3-4, 1-2 of the group members can check out other posters during their presentation slot (just make sure everyone has time in front of their own poster). After a designated amount of time, switch the hanging posters.

Art show

Students will have created artistic works for their field notebooks. Host an art exhibition where students show their works to their parents, other students, etc. For a more-involved show, students can also create additional works to showcase, like a podcast, sculpture, interpretive dance, etc - as long as it reflects their experience/response to the field study.

Zines

Zines traditionally are hand-made, self-published, mini-magazines, which tell some kind of narrative. In this case, students could extend their impressions from the field notebook into a zine project, where they must tell - and illustrate - a narrative about their experience with the field study. Traditionally, zines are often created by cutting out pictures from other magazines and pasting them onto card-stock, but students can feel free to add text and draw, too.

More information about what a zine is: https://zines.barnard.edu/definition

A zine can be constructed from a single piece of paper. Directions can be found at: http://www.rookiemag.com/2012/05/how-to-make-a-zine/

More about zines, including a reference library of them, can be found at the Papercut Zine Library.

http://www.papercutzinelibrary.org/wordpress/

Journal of Emerging Investigators
For sufficiently rigorous studies, the student projects can be written up in a scientific-journal-like format and submitted to JEI for review/publication. See http://www.emerginginvestigators.org/

Project SPLASSH
Share your class project on Project SPLASSH! This is a website where you can share your research project with other students and researchers working on water projects around the US.

Create a project blog on a free platform like Wordpress.
Students can create blog entries about their studies, results, the class discussion, management issues/ideas, etc. Blog entries can be written, a video-blog format, or a podcast, depending on student interest.

To be fair, you may need students to all turn in their material at the same time, and then you post it over the semester/year.

Here's an example of a blog that we kept in an invertebrate embryology class for undergraduates and graduate students. At the beginning of the semester, students signed up for a week where they would be responsible for writing a blog post. Posts were edited by the class TF and then the blog was shared with friends and family.

Participate in citizen science projects
If students really enjoyed the activities, encourage them to continue participating through citizen science.

Zooniverse.org has a bunch of fun projects. A particularly relevant one is the Plankton Portal (http://www.planktonportal.org/), where participants ID critters in the pictures (a pictoral guide is provided). Students may have observed similar critters in their plankton tows.

Guest speakers
Invite an ecology graduate student from GradWagon (or reach out to family and friends to see if anyone knows a scientist involved in ecology or conservation biology research)- to visit your classroom talk about their research

Develop management plans

Taking into account the data collected from their field research project, have students work in groups to develop a management plan for their ecosystem. If applicable, encourage students to draft letters to local legislators.

Other resources

While these materials are not directly related to this lesson, they may provide inspiration for modifications to the lesson or discussion topics.

Tampons used to spot pollution in sewage water
Tampons were used as passive samplers to test water in sewage pipes for optical brighteners, indicators of the presence of sewer misconnection discharge. Using this low cost method, researchers were able to pinpoint areas where sewer systems are polluted.
Smithsonian magazine:
http://www.smithsonianmag.com/innovation/how-scientists-monitoring-water-with-tampons-180955008/
https://www.sheffield.ac.uk/news/nr/tampon-sewage-pollution-river-sheffield-university-1.453262
http://www.popsci.com/tampons-can-staunch-flow-wastewater-streams
http://onlinelibrary.wiley.com/doi/10.1111/wej.12112/abstract

Link between man-made structures and jellyfish blooms
http://www.smithsonianmag.com/science-nature/big-moon-jelly-blooms-tied-new-dock-construction-180953251/
http://link.springer.com/article/10.1007/s10872-014-0249-1
summary:
Jellyfish ephyrae increased after a floating pier was installed in a bay in Japan. Sampling before and after the pier installation revealed a 2.5x increase in ephyrae. Ephyrae abundance did not increase in a nearby port which was sampled as a control site.

Increased oceanic microplastic debris enhances oviposition in an endemic pelagic insect
*project by a high school student
http://rsbl.royalsocietypublishing.org/content/8/5/817
http://blogs.discovermagazine.com/notrocketscience/2012/05/08/insects-that-skate-on-the-ocean-benefit-from-plastic-junk/#.VZwf5BNViko
summary:
The exponential increase in oceanic microplastic in ocean gyres in the past 40 years has created a new oceanic hard substrate, available for colonization. In particular, microplastics in the NPSG were found to be colonized by the eggs of the pelagic insect *Halobates sericeus.*

Introduction for students

A note for teachers: what's here

This section contains materials for specifically for students. The contents of this section were designed as a preliminary homework assignment due on the first day of the lesson activity.

In the next several pages, you will find three short readings and two assignments for deliverables.

- Field notebooks
    - This includes reading to introduce the idea of a field notebook to students, as well as a short assignment where students will explore examples of field notebooks.
- Human impacts on aquatic ecosystems
    - Background reading for students about a recent scientific research study which investigated California's Elkhorn Slough wetlands ecosystem and how the communities found in the ecosystem can be drastically altered by human influences.
    - This reading also provides some context for the students' upcoming project.
- Designing an experiment
    - This includes two parts. First, there is a short bit of background reading which introduces the idea of testable hypotheses and controls. Second, there is a "Check-in Questions" worksheet, where the students will apply what they learned from the reading to write some testable hypotheses and design some controls.
    - This section will help students think about how to frame their own experiments.

Field notebooks

For centuries scientists have recorded their observations of the natural world in field notebooks, in the form of labeled sketches, detailed scientific illustrations and written descriptions. Following in the footsteps of the members of the Hassler, Wilkes, and Albatross expeditions, we will be keeping our own field notebooks as we explore and investigate human impacts on a local ecosystem. Remember, no detail is too small or too insignificant to record in your field notebook! Details such as the weather condition, time of day, description of the noises you can hear, the water level of the stream or pond, any noticeable scents at the field site, or anything else that you observe could be crucial contributions to your research project. If you think that a detail *could* be important, write it down! You might not realize the value of these observations until you are back in the classroom analyzing your data, so it is best to record anything at all that you think could be relevant to your project.

Take some time to look at some examples of lab notebooks from famous biologists. Answer each of the following questions in a few sentences, and be ready to discuss your responses in class.

Why does a scientist keep a field notebook?
What kind of information is included?
What is or isn't effective about storing information and data in this way?
What value do they hold for the researcher?
What value do these documents hold for us today?

Field notebook e-resources:

Tips:
-select "show in thumbnails" so that you can better navigate through the many pages
-many of these links lead to notebooks of handwriting that can be difficult to read. Below are highlighted some expedition notebooks with drawings that would be good examples to use for this activity:

Harvard University Library Open Collections Program

1. Alexander Agassiz, Pacific Expeditions of the US Fish Commission Steamer *Albatross*, 1891, 1899-1900, 1904-1905
   Expedition background
   Navigate to "Selected manuscripts and records in *Expeditions and discoveries*" to find examples of Agassiz's notebooks
   Drawings of Agassiz's assistant, Henry Bryant Bigelow:
   Drawings of Medusae Made on Board the "Albatross," 1904-1905
   Drawings of Siphonophores Made on Board the "Albatross," 190401905
2. Louis Agassiz, Hassler Expedition to South America, 1871-1872

Expedition background

Drawings of expedition artist, James Henry Blake:

Hassler Expedition Watercolors and Pencil Drawings, Chiefly of Fish with Several Mollusks and Invertebrates, 1871-1872

Original zoological drawings and plates, 1830-1880

3. Wilkes Expedition, United States South Seas Exploring Expedition, 1838-1842

Expedition background

William Starling Sullivant, Drawings of the bryophytes of the US Exploring Expedition under the command of Captain WIlkes

Pickering, Charles. Coleoptera of the US exploring expedition, 1844-1847.

4. Challenger Expedition: 1873-76 under the command of Captain George S. Nares and the late Captain Frank Tourle Thomson.
5. More resources are available:

additional expeditions

Smithsonian Institution Archives

The Field Book Project and the Field Book Registry

The Biodiversity Heritage Library

search: for “field notebook”

Human impacts on aquatic ecosystems

As humans, we value aquatic ecosystems as a source of water, food, and recreation. As with any ecosystem, aquatic systems feature a set of complex interactions between abiotic and biotic factors. Human activity can affect the balance of these interactions, potentially damaging the ecosystem.

Human impact on aquatic ecosystems can take a number of forms, including pollution, introduction of invasive species, habitat destruction, changing water flow (dams, etc), overfishing, and disruption of nesting sites. Each of these changes can have surprisingly large effects on the ecosystem – and can be passed on to others!

California's Elkhorn Slough, a coastal wetlands system, illustrates these concepts. The Elkhorn Slough is a critical nursery for several types of food fish, which hide in the sheltered wetlands until they are big enough to move into the ocean.

Water from the mainland drains to the ocean through the Elkhorn Slough. Because the area is surrounded by farms, a huge amount of fertilizer is constantly being swept into the Slough in run-off. This build-up of fertilizer increases the amount of nutrients like nitrogen and phosphorous available to algae. You can think of these algae as being plant-like: they use the nutrients and photosynthesis to make their energy. But, at night, when there is no sun, the algae stop photosynthesizing and use cellular respiration for energy, consuming oxygen in the water. When there is too much algae, it can consume nearly all the available oxygen in the water (making "hypoxic" or low-oxygen water), causing the growing fish to suffocate.

While the death of the fish changes the food web in the Elkhorn Slough itself, it also causes the ocean environment occupied by the adult fish to change: no new fish ever arrive! Slowly, this oceanic ecosystem changes as the top-predators are fished out without being replaced.

So, we can see that human activity can have drastic effects on an ecosystem's integrity.

While this example may seem remote, many of our local aquatic environments are also being shaped by human activity. Boston Harbor and the Charles River, for example, are seasonally hypoxic, and have been since the 1980s.

Over the next few classes, we will be investigating the effects of human activity on a local water system.

About the scientific study:
Title: Climate mediates hypoxic stress on fish diversity and nursery function at the land–sea interface
Journal: *Proceedings of the National Academy of Sciences*

Related resources:

- *http://www.chesapeakebay.net/discover/bayecosystem*
- *http://www.ramp-alberta.org/resources/tourism/wildlife.aspx*

- *http://www.wri.org/our-work/project/eutrophication-and-hypoxia/interactive-map-eutrophication-hypoxia*
- *http://sciencelearn.org.nz/Contexts/Toku-Awa-Koiora/Science-Ideas-and-Concepts/Human-impact-on-rivers*

Designing an experiment

Testable hypotheses

In our investigation, we will compare two sites, one where there is a lot of human impact, and one with less. With a small group of your classmates, you will choose one characteristic of the environment, predict how this characteristic will differ between the two sites, and go out into the field to test your prediction.

Your prediction is what scientists call a “hypothesis” – a proposed explanation for why something happens or how two things are related. But, not all hypotheses are useful.

For example, consider, “Temperature affects plant growth.”

While this statement is a hypothesis – it predicts that temperature is related to plant growth – it does not indicate how you might know that temperature is affecting plant growth. What we really need is a “testable” hypothesis. Testable hypotheses are a special type of prediction that tells you how you will know if two factors are related. These often take the form:

If [two variables are related], then [we will see this specific outcome].

For example, a testable version of the above hypothesis: “If temperature is related to plant growth, then plants raised at different temperatures will grow to different sizes.”

From this testable hypothesis, we can see what experiment we need to do: raise a bunch of plants at different temperatures, and measure how big they are.

Controls: accounting for other factors

In most experiments, there will be other factors that could affect the outcome. In our plant example, some additional factors might be sunlight, fertilizer use, and how often the plants are watered. In addition, maybe two people measuring the plants use a slightly different technique! To make sure that the differences we see are only due to temperature, we need to “control” the other factors.

For example, we could make sure all the plants are watered on the same schedule, and we could create a standard technique for measuring the plants.

When designing your field study, you will need to create a testable hypothesis and decide how to control other possible influences.

Check-In Questions

1. Which of the following statements are testable hypotheses? Circle all that apply.

    a. The month an apple is picked affects how sweet it is.
    b. Cell phones may cause cancer.
    c. If eelgrass shelters baby fish, then areas with more eelgrass will have more fish.
    d. If UV light causes skin cancer, then people who have been exposed to more UV will have higher skin cancer rates.

2. Rewrite this statement as a testable hypothesis.

    Bacterial colony size is affected by sugar availability.

3. In your own words, explain what is meant by “controlling other factors,” and why this is important.