Case Study: Coastal Virginia Ecosystem Health

Background for instructors:

The goals of this lesson are for students to be able to:

- Look for patterns in environmental drivers, environmental indicators, and human interactions to describe ecosystem health across VA's coastline
  - Accomplished by evaluating multiple drivers
- Use the scientific process and data they collected to form conclusions about ecosystem health, and use those conclusions to discuss how/why ecosystem health differs between VCR and Chesapeake Bay
  - Accomplished by using established methods and data analysis techniques to form conclusions and using debates to communicate with peers
- Get exposed to different scientific methods, go through the scientific process from start to finish, and feel empowered to do science
  - Accomplished by treating the students as scientists throughout the case study
  - Importance: When asked to draw a scientist, most middle-schoolers drew the caricature of a “mad scientist” – white male, frizzy hair, glasses, very old, wearing a lab coat. Students rarely drew themselves or considered themselves as scientists. I tried to emphasize pictures that included younger women (and men, but the VCR undergraduate and graduate student populations are primarily female right now).
  - All people pictured on all slides are scientists who work in the VCR or the bay: undergraduate students, graduate students, professors, VCR staff, and staff from The Nature Conservancy (TNC)
- Other necessary background? (scientific or otherwise?)
CLASSROOM COMPONENT 1 LESSON PLAN

Investigative Question: How are the VCR and the Chesapeake Bay ecosystems similar and different? Based on your field measurements, would you consider these areas to be healthy? Why or why not? What measurable variables are the best indicators of ecosystem health? Why?

Materials: For the instructor: corresponding PowerPoint presentation, instructor notes, white board. For students: hard copy handouts of the field notebook

Total allotted time: 1 hr 30 min (my estimates provided throughout, but they are just suggestions)

Instructor notes/PowerPoint notes:
Use the PowerPoint for the lesson, and the whiteboard to keep a list of drivers

5 minutes – Brief lesson overview (this section should be broad, general, and quick – all topics will be touched on in more detail later. The goal of this section is to make sure all students are starting off on the same page)

1. VA has two main coastal ecosystems: the Chesapeake Bay and the Volgenau Virginia Coast Reserve (VCR)
   a. Slide gives students context for the lesson plan
2. Why are we curious about similarities and differences?
   a. Point out where both estuaries are on the map
   b. To get the conversation started, ask students the questions on the slides and encourage them to keep them in mind as we move forward
3. How will we figure this out? By thinking like scientists!
   a. Curiosity, teamwork, and organization – all foreshadow the field component
      i. Curiosity → how we go from interest in a topic to a full-scale research project
      ii. Teamwork → real science doesn’t get done alone in a windowless lab. Scientists rely on each other. Also, scientists can use each other’s data, like we will do with the long-term VCR-LTER data
         1. Stop to point out the picture: these are VCR scientists, including college students and full-time staff scientists (Cora, who they will meet, is in the back in the green shirt), on their way to collect data in a seagrass meadow. The black mesh box is a trap which is used to catch fish, clams, crabs, and more in the meadow
      iii. Organization → this is important because it’s true, and also because students should understand that the field notebooks are a real thing, and that’s why we’re asking them to keep one
iv. **Hand out field notebooks**

b. Throughout the case study, we want students to feel like they are scientists working on a team. Students CAN do meaningful science.

c. **Explain that to model the scientific process, they will take notes today and in the field in their field notebook**

d. **Instructor note: Many students do not have a solid or accurate idea of who can be scientists and what scientists do. This slide highlights pieces of science that are critical for success, but lie outside the standard understanding of data collection and lab work.**

20 minutes - **Introduction to ecosystem health and drivers**

4. What is ecosystem health?
   a. Ecosystem health definition: A healthy ecosystem is intact in its physical, chemical, and biological components/drivers and their relationships; it is resilient to change and stressors
      i. Examples of stressors: increased temperatures from climate change, pollution from nearby human areas, invasive species

   ii. **Encourage them to write definition in field notebook to look back on after they have data**

b. Resilience definition: ability of an ecosystem to recover/return to normal after experiencing stressors

5. Why do we care about ecosystem health on the coast?

6. Watch the video that introduces ecosystem health, ecosystem services, and the Chesapeake Bay.
   a. They mention some of the ecosystem services on the previous slide (nursery habitat) – point them out

7. **EXERCISE: ~3 minute free write then ~3 minute class discussion: try to guide students towards measurable variables (our drivers) and encourage debate/multiple ideas**
   a. Examples should come up after the conversation
   b. **One way to do this is to encourage them to think like a scientist or think of other variables they’ve explored in class so far**
   c. Write down drivers that are said on the board. (Be generous with what you include – can refine later)

   **d. People don’t always agree on how to determine ecosystem health, which students hopefully demonstrated during the discussion**

8. Connect the dots – what are drivers?
   a. Ask someone to re-read the definition of ecosystem health. Does it sound measurable? Not really!
      i. To draw meaningful conclusions, we need to break ecosystem health down into something measurable, aka drivers
b. Car analogy: Like the person driving a car is in charge of the car, these variables are in charge of or drive ecosystem health

9. EXERCISE: Identify classes of variables/drivers (do not flip to the next slide until done with the exercise)
   a. On the board while this slide is up, write out driver categories: physical, biogeochemical, biodiversity, human impacts
      i. Categories = umbrellas for variables
   b. Prompt students to sort the drivers you already have from the class prompt into the appropriate categories
   c. Prompt them to add more (from previous experiences). Be generous with what you include. We will refine later
   d. If conversation is slow, use this example to prompt more conversation:
      i. If it looks like there is a lot of algae in the water, we can predict that the ecosystem is not healthy, but how do we use data to evaluate that prediction?
      ii. First, we can measure the amount of algae in the water. Put “algae” under the biotic/biodiversity category
      iii. Then, ask how algal blooms would affect the environment? Decreases O2 and light availability which other organisms need. Put “O2” in the biogeochemical category and “light” under the physical category
      iv. Next, think about the possible causes of increased algae? Maybe there was an increase in runoff from polluted areas. We can measure the amount of nitrate in the water column. Put “nitrate” in the human impacts category

10. Brainstorm important drivers!
   a. Is there anything students missed that should be added to our list on the board?
   b. DON’T erase the board
   c. We’ll use these categories to understand local ecosystems

11. Estuaries: the middle child of aquatic ecosystems
   a. Examples of ways drivers are related
      i. Changes in temperature and nutrients can stress out species diversity, decreasing it
      ii. River pollution transported into estuaries can increase nutrients
   b. Because they are all connected, it’s hard to know what the most important drivers are without collecting data

12. Now we need to shift from something we are curious about to a real question we can answer
   a. Our question is a good question, but it’s hard to say what our answer would look like
   b. A scientific question is different from a regular question in 2 ways:
      i. 1-the point is to explain something about the natural world
ii. 2-questions can be tested/answered using evidence (data)

13. These are the questions for this case study
   a. Point out that Q1 requires an explanation from field measurements to describe something in the natural world (ecosystem health in two systems)

14. An environmental scientist’s plan for investigation
   a. Reminds students to stay in the scientist mindset, and also gives you a chance to let them know how this exercise will continue
   b. Other scientists: They will share their findings with each other through debates
   c. The public: important because environmental science is affected by human impacts, so we really try to update the public on what we’re doing. 2 headlines are some of many examples
      i. VIMs oyster article: Chesapeake Bay
      ii. Seagrass article: VCR

30 minutes – Background Research:

15. How are the VCR and Chesapeake Bay ecosystems similar and different?
   a. We will come back to this Venn diagram, keep it in mind

16. Chesapeake Bay Fact Sheet
   a. Scientists would want to know these things before going into the field, so students may want some of this information in their field notebooks
   b. Map shows entire Chesapeake Bay watershed, which drains parts of NY, PA, MD, DE, VA, D.C.

17. Chesapeake Bay salinity graphs
   a. Salinity gradient is because of river input in north and ocean inlet at south

18. Pictures of common ecosystems and human impacts in the bay

19. Virginia Coast Reserve (VCR) Fact Sheet
   a. Point out some of the barrier islands on the map

20. VCR-LTER
   a. There are other groups that do research in the VCR, but we are going to be modeling our case study after VCR-LTER techniques
   b. Map shows all 28 LTER sites

21. Main ecosystems in the Chesapeake Bay and VCR
   a. These ecosystems are in order of upland areas to the ocean
   b. Chesapeake Bay and VCR have some ecosystems in common, but these estuaries are slightly different
   c. Biggest differences are the locations of the beaches and water depth
   d. Beach location: Virginia Beach is extremely impacted by humans because it is easily accessible. Not true for barrier islands at VCR

22. Ecosystem Spotlight: Seagrasses
   a. This slide underscores relationships between drivers in estuaries
      i. Seagrasses decline when other drivers change
23. Seagrass Restoration Efforts in VA
   a. Talk about Chesapeake Bay map - decline is dramatic
   b. Play Karen's video - point out drivers she mentions. How do seagrasses and other drivers interact?
      i. She mentions the long-term seagrass synoptic effort, which is a yearly sampling blitz where a bunch of scientists go into the seagrass meadow and record a ton of data
      ii. NOTE: numbers in this video are old (from 2016) updated on next slide

24. Seagrass restoration outcomes
   a. Chesapeake Bay graph shows that seagrass abundance is NOT increasing overall. Year to year, it can seem like it is increasing, but when you look at long term data there is no increase
   b. VCR graph shows that seagrass abundance has increased a lot
      i. Why might VCR support seagrass restoration better than the Chesapeake Bay?
   c. **Yes there is more seagrass in the Chesapeake Bay, but the Bay also started out with more seagrass AND has a larger area**

25. Food webs in the Chesapeake Bay and VCR
   a. Step through chart from primary producers to top predators — important for field component!

26. Organism spotlight: Oysters, a keystone species
   a. Oysters can influence ecosystem health by filtering nutrients out of the water
   b. Oyster REEFs also influence ecosystem health, by providing habitat, food, hiding places for other organisms
   c. Food web → go through organisms on the diagram
      i. Fish: left one is a goby and right is a blenny. fish are small enough to fit in shells and camouflaged
   d. Protection ⛔ organisms can hide in oyster shells (like the goby) or mud

27. Oyster Reef Restoration
   a. Play Bo’s video first

28. EXERCISE: fill out the Venn diagram
   a. Short class discussion while students fill in their Venn diagram
   b. Fine to have different things than peers, everyone’s can be different

**Five minutes - Predictions and prior knowledge** (individual):
29. Based off of what we learned, what are your predictions?
   a. Frame this as something a scientist would do – they will look back on this after the field to see if their knowledge changed
b. *They will look back on this after the field to see how their knowledge changed*

**30 minutes – Study Sites and Methods** *(tone shift back to thinking like a scientist)*

30. Study site selection: inside the brain of an environmental scientist
   a. Walks through process of selecting the best site
   b. The reality of environmental science is that you’re limited by nature, hazards, and weather

31. Chesapeake Bay Study Site: Savage Neck Dunes Natural Area Preserve
   a. Point out location on map

32. Savage Neck Dunes Ecosystems
   a. Some ecosystems are present and some are absent. This is okay because it would be hard for us to access the others

33. Virginia Coast Reserve Site: VCR-LTER Dock
   a. Point out location on map

34. Study Plan
   a. Since we are using the VCR lab’s methods, equipment, and long-term data, we are contributing to science happening at the LTER

35. Drivers we will measure in the field using VCR methods
   a. We will explain methods in the field, but go through the drivers we will measure and have students copy into field
   b. You can show them the methods if you want

36. Hypotheses:
   a. Investigative questions are up to jog people’s memory
   b. Students should develop 2 hypotheses and write them in their notebooks
FIELD COMPONENT LESSON PLAN

Daily Materials: For instructors: lesson plan, 2 hard copies of the data sheets on Rite-in-the-Rain paper (1 for each team), 3-5 extra copies of station 3 datasheets (regular paper), 2 copies of the methods (1 per team), equipment necessary for methods

For students: field notebooks, pencils, close-toed shoes, water, snacks, mask (for VCR day), warm clothing, rain/sun protection (depending on weather)

**DAY 1: VCR-LTER Dock**

8:00-9:00: Kayleigh prep stations

9:00-9:15: Students arrive at VCR-LTER, brief tour of deck and dock

9:15-9:30: Collect data and qualitative observations on the dock (full group)

9:30-10:00: Students break into 2 teams of 12. **Team 1 at Station 1, Team 2 at Station 2**

10:00-10:30: Teams switch stations

10:30-10:40: Break/buffer time

10:40-11:20: **Everyone at Station 3**

11:20-11:30: Break/buffer time to walk back to the building, wash hands. Students can start filling out data analysis if they are ready early

11:30-12:00: Long term data, data analysis, wrap-up

***Students should carry their WATER BOTTLES with them all day***

9:00-9:15: Tour lab, meet Kayleigh & anyone else who's around. Start on middle deck, walk through lab (covid permitting), front/back deck, sheds

- On deck: Explain what a field station is: VCR scientists from all over use this lab space to prepare for fieldwork, be close to their lab sites, borrow equipment, do lab work, and collaborate.
  - **Today they are visiting scientists at this field station**

- On deck: Common types of scientists who use the field station
  - Staff scientists: people whose full-time job it is to conduct research, help visitors conduct research, coordinate long-term sampling, run the lab
    - Likely doing lots of different research, they have to know about many aspects of the VCR
    - Live local, not at the station
    - **Site director** is in charge of the field station!
  - University/research scientists: professors, graduate students, and undergraduate students who are usually working on 1 specific project
They have to know a lot about 1 ecosystem or research topic!
- They live elsewhere and come to the field station when they need to
- Research is a job (it's work and you're paid for it, even students!)
  - We also collaborate with other science groups (like the students)
- Work with VCR Nature Conservancy on seagrass & oyster restoration, use each other's equipment and boats
  - Point out the dorms (on the right): Most field stations have housing. About 30 people can be in the dorms at once. Mostly bunk beds!
- In lab & decks: The lab has to accommodate all sorts of research going on in the different VCR ecosystems. Point out different lab and field equipment.
- Walk down to the dock: Point out the dive shed, tool shed, boats (we have 4)

9:15-9:30: Collect environmental data and qualitative observations. Students sit on the dock with their field notebooks

1. Review case study (class discussion)
   - What are our investigative questions?
   - What is the definition of ecosystem health?
   - What are drivers and what are some of the drivers we're interested in?
   - Students should reread their own hypotheses
2. What do you already know about the VCR-LTER dock? (class discussion)
   - Share information from field notebooks
3. Before we collect data, we need to familiarize ourselves with the field site
   - Students should jot down their qualitative observations individually
   - Then, share out
4. When we do science, it's important to collect standard environmental data so that you have an idea of the conditions that may affect your results
   - Ex: on a sunny day, water temperatures may be warmer. On a rainy day, salinity may be lower
5. Collect environmental data
   - Tidal stage: want to track over time
6. Class will be split into 2 teams. Both teams will conduct the same analyses, and after we are done, we will compare our results and analyze data
   - Explain why: We want lots of replicates of our data because a natural environment can be so variable
   - This is "data blitz" style, where everyone has specific job they are responsible for completing, BUT because you are a team, you always check and see who needs help if you finish first
7. Explain data sheets. We will write everything down on our data sheets so it is in the same place. One important job at each station is being the data recorder – you have to keep track of everyone!
a. When someone takes a measurement, they should call it to the data recorder. The recorder should repeat it back to make sure they heard correctly, then write down the value and the person’s initials.
   i. Initials so that if someone has a question about the result, they know who to ask. Can fill in initials later if too much work
b. Data sheets are printed on Rite in the Rain paper so they can get wet!
8. Explain field notebooks: it’s important to keep notes about what you do in the field and what you thought. It can help with your analysis later.
   a. Information isn’t the same as what goes on the datasheet
   b. You can reference your notes from class
   c. In environmental science, fieldwork is hands on and it’s normal to have to carve out a few minutes to fill out your field notebook. To decrease the work on-site, lots of scientists write prompts for themselves to remember what to record
9. Explain some of the more complex methods for station 1:
   a. Secchi disc, DO probe, TDS probe
10. Field safety: NO running, be careful around the edges of the dock, be careful with the instruments
11. Split class into 2 teams and send to first station
   a. Team names?

9:30-10:30: Stations 1 and 2

Station 1:

Materials: The equipment will be set up on the dock. You should give the full RIR datasheet and a clipboard to the recorder, an extra copy of the first page of the datasheet and a clipboard to the observation people

1. We are:
   a. Qualitatively and quantitatively assessing human use/impacts by tallying and taking notes about boats, people, plastic, and organisms
   b. Beginning a long-term experiment called Biochemical Oxygen Demand (BOD), which will tell us about how much oxygen the system uses over time
   c. Using the VCR-LTER water quality protocol to collect physical, chemical, and light measurements in the water column
2. Demonstrate how to use the DO probe
3. Assign jobs and give data sheet to person recording
   a. Jobs: 1 recording data, 2 boats, 2 physical, 3 chemical, 2 light, 2 BOD
   b. The recorder should take down the start and end times
   c. They are the expert in the analysis they are conducting
4. Pass out individual sheets of the methods to the students
   a. Groups should gather their equipment and find a spot - they can spread out
b. If students are waiting for equipment, encourage them to watch/help other groups do their measurements
   i. Physical group and BOD bottle group will need to share DO probe. Make sure the metal cage is ON the probe for harbor measurements and OFF for BOD bottle measurements

c. After they’re done recording data, they should fill out station 1 in their field notebooks and then calculate their averages. We can share calculators or students can use their phones
   i. Group members are responsible for making sure their averages get calculated, but others can help if they aren’t doing anything.

5. When everyone is finished, gather together
   a. Measure tidal height again! Let recorder do it if possible
   b. Group members should share how they measured their variable and what their results were
   c. If there is time, discuss why we measured these drivers and what results might mean. Are results expected?

<table>
<thead>
<tr>
<th>Driver</th>
<th>Method</th>
<th>Driver category?</th>
<th>Why measure? Instructor notes for conversation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light availability and turbidity</td>
<td>Secchi depth, TDS probe</td>
<td>Physical</td>
<td>Lower turbidity and more light = better water quality; seagrasses need good water quality</td>
</tr>
<tr>
<td>Dissolved oxygen (DO)</td>
<td>DO probe</td>
<td>BGC</td>
<td>Organisms need DO to survive. Low DO can indicate high nutrients, eutrophication</td>
</tr>
<tr>
<td>Water temperature</td>
<td>DO probe</td>
<td>Physical</td>
<td>High water temperatures (from climate change) can stress organisms. Important that temperature swings are ok - it’s morning, so likely colder</td>
</tr>
<tr>
<td>Salinity</td>
<td>Refractometer</td>
<td>Physical</td>
<td>Lower salinity = more freshwater input (high potential for polluted runoff)</td>
</tr>
<tr>
<td>Nitrate-nitrite concentrations</td>
<td>Test strip</td>
<td>BGC</td>
<td>Can run off from agricultural and industrial areas, can increase eutrophication &amp; turbidity</td>
</tr>
<tr>
<td>pH</td>
<td>Test strip</td>
<td>BGC</td>
<td>Ocean pH is ~8.1. Small changes in pH can stress organisms because pH is on a logarithmic scale, so pH=7 ten times more acidic than pH=8</td>
</tr>
<tr>
<td>Number of people using the system and why</td>
<td>Count and describe</td>
<td>Human impacts</td>
<td>Potential sources of pollution, point and nonpoint. Also, is it mostly recreation/tourism, or work (aquaculture)</td>
</tr>
<tr>
<td>O2 demand</td>
<td>BOD bottles</td>
<td>Human imp.</td>
<td>Higher BOD in eutrophic ecosystems</td>
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**Station 2:**

*Materials: clipboard, lesson plan, data sheets, towel to dry hands, quadrat for demonstration*

6. What can primary producers (PP’s) tell us about ecosystem health?
   a. PP’s photosynthesize, so they take up CO2 from the water column and add O2, which consumers need to be able to breathe
   b. PP’s need nutrients to grow (mostly nitrate and phosphate)

7. What are the main primary producers at the VCR?
   a. Algae (micro & macro, phytoplankton), seagrass, salt marsh grass
   b. By assessing these we get a bit of a gradient of land-sea PP’s

8. We are assessing primary producers using modifications of VCR protocols:
   a. Amount of algae in the water column (VCR water quality protocol)
   b. Seagrass health (subset of an old VCR seagrass synoptic protocol)
   c. Percent cover of salt marsh grasses (modified from VCR end of year biomass)

9. Split students into 3 groups of 4

**ACTIVITY 1: Chlorophyll A (algae)**

10. Algae are hard to see or count, so we use Chlorophyll A to estimate amounts
    a. Chlorophyll A is the green pigment that gives algae their color and is critical for photosynthesis
    b. Chlorophyll A is commonly measured in the Chesapeake Bay to indicate the abundance of phytoplankton
    c. In a balanced ecosystem, phytoplankton provide food for fish, crabs, oysters, and worms
    d. When too many nutrients are available, phytoplankton may grow out of control and form blooms that harm fish, shellfish, mammals, birds, people

11. Each group performs 1 Chlorophyll A test. Pass at least 200 mL of water through the syringe. Syringe is 60 mL so each student should get at least 1 turn. Discussion points while filtering:
    a. How do you think chlorophyll A would change seasonally? Probably increases during growing season, when algae increases due to temps
    b. How does chlorophyll A change with nutrient input? Increases because primary producers use nutrients to grow
    c. What are the problems with too much algae? Blocks like for other PP’s, decomposition removes DO which creates hypoxia or anoxia

12. When groups are finished, they should agree on an observation about the filter color and write it on the datasheet
    a. Do observations agree between groups?

13. Explain the rest of the method that we aren’t doing (see methods)

**ACTIVITY 2: Seagrass**
14. What do students know about seagrass? Is seagrass sensitive to changes in the environment?
   a. It is sensitive to increases in water temperature, suspended solids, and nutrients, and to decreases in light availability
   b. It provides ecosystem services and supports the food web
   c. We expect seagrass health to reflect ecosystem health

15. Seagrass biology - demonstrate with shoot
   a. Seagrasses can survive mild periods of stress because they store nutrients in roots and rhizomes
   b. Seagrasses grow in shoots from the rhizomes, so there is an underground network that connects them to each other
   c. On each shoot, new leaves grow up in between old leaves, where they are protected
   d. Oldest leaves are on the outside, and newest leaves are on the inside (they grow up on alternating sides). Some organisms eat outer leaves

16. Pass out shoots (1 per 4 students)
17. In the groups of 4, have them pull apart their seagrass shoot and measure each leaf length. Instructor records data or pass around datasheet
18. In field notebooks assess the seagrass shoot using the field notebook questions
   a. Dry hands on towel
   b. Discuss as a group

ACTIVITY 3: Marsh grass

19. Walk up the boardwalk
20. Field notebooks: Pass around grass samples (these are the 4 dominant grass species for Oyster Harbor and for most of the east coast).
   a. Fill out field notebooks
21. Pass out binoculars (optional) and have students look around the harbor. Where do they see the different species? Record in notebook. If they have trouble seeing different species, record that too.
22. Discuss: Ask then where they see species and explain where each species lives
   a. S. alterniflora likes low elevation, salty areas. They can survive underwater at low tide. They are threatened by sea level rise and may be declining
      i. Look down over the boardwalk. Is the S. alterniflora underwater?
      ii. If the tide is low enough, what organisms can you see in the grass?
   b. S. patens & D. spicata are mid-elevation species that survive in areas that only go under water during some very high tides
      i. Are they underwater right now? Can you differentiate them?
   c. P. australis is right at the edge of the maritime forest and prefers brackish conditions. It is invasive and taking over multiple areas, may be increasing
      i. Walk up the boardwalk so they can see where it turns to forest
23. How do we measure what species is dominant, and how species composition may change due to invasives and sea level rise?
   a. Percent cover is a method that typically involves throwing a quadrat and estimating the percentages that each species covers in the quadrat.
   b. Throwing the quadrat is random and is much smaller than the actual marsh, so we need a lot of data over many years to fully understand how grass percent cover changes
   c. Look at 1 or 2 graphs from previous year percent cover and ask students what they see. Increase in P. australis and decrease in S. alterniflora
24. Next, students should individually (or in pairs) estimate the percent cover of the 4 species around the harbor
   a. Have them draw their own bar graphs but also make sure to write % out
25. Compare student responses
   a. Does your percent cover match previous years?
   b. Do people think the same thing?
   c. What does percent cover say about invasive vs. native species?
   d. Don't compute averages. We will compute one average later

10:30-10:40: Break/Buffer Time

10:40-11:20: Station 3

1. Collect field notebooks and put them away until we go to the classroom.
2. Pull up cubes. Use pliers to cut the zip ties, and then gently dump the cube contents into the bins. Let the cages dry on the dock during this station.
3. Make sure there is enough space around the bins (and enough bins) so that all students can participate in the activity
4. Oyster cubes are a form of artificial reef
   a. Not a restoration project, but they do provide habitat
   b. Formed with oyster shells and live oysters that settle to create habitat
   c. You can find the same organisms in a cube that you'd find out on a reef
   d. In a healthy ecosystem we would expect high species diversity and a balanced food web. Ask students to name some possible organisms
5. Explain how to use the dichotomous key: follow the steps for each organism
   a. Pass out copies
   b. Go through an example
6. Students will use the dichotomous keys to identify organisms and tally what they find. Then, they should measure the length of it. If they keep finding the same organisms, they don't have to measure them all. 5 is a good maximum unless lengths are wildly different
7. Once a student has tallied and measured something, they shouldn't put it back in the same bin to avoid counting something twice
8. Pass out the extra data sheets (not RIR paper) so that students can all record at once
9. Let students sort. They can go until time runs out, or until space on the datasheets runs out. They should also look at the organisms attached to the cage itself.
10. If they start to slow down before time runs out, then stop early to get the data together.
11. Leave at least 5 minutes to move everything from the bins back into the oyster cubes and lower back into the harbor.

11:20-11:30: Short break/buffer time (walk back to the building, wash hands, start filling out the data analysis in the conference room)

Set-up (Kayleigh & Charlie):

1. Write ecosystem health definition on the board
2. Open PowerPoint and open slide with data table for students to write on
3. On the board or on a piece of paper, write: Seagrass health: how did the seagrass look?
   a. Make a table for inner leaves. Make 8 columns: brown, green, transparent, opaque, long, short, broken, other. Students should put a tally in the column of every word they circled. We will make a word cloud and/or a bar graph out of their answers
   b. Repeat for outer leaves
   c. Make another 2 columns, healthy and unhealthy. Students should put a tally in the column corresponding to the answer in their field notebook
4. Optional- probably skip this. On the board or on a piece of paper, do the same thing for salt marsh grasses. Table words for each species: flat, round, hollow, flexible, brittle, sharp, other
5. On the board, write: what were your estimated percent covers for the marsh grasses? Based on your percent cover and observations, does the marsh seem healthy?
   a. Draw 5 columns (each grass and "other")
      i. Students should write their percent for each category
   b. Write a short answer using field observations
6. On a giant sticky note, draw a blank graph. On the side (not in the graph), make columns "Organism" and "Number counted"
   a. Students can start filling things out as soon as they are ready
   b. Won’t do lengths until classroom component 2
7. Staple student field notebooks together

11:30-12:00: Data analysis

Team data reporting:

1. Explain: need to synthesize data and compare team data so we can draw conclusions.
2. Return field notebooks. Help make sure students have all datasheets
3. Students should rotate through sections
   a. Students finish any individual averaging for station 1
   b. Ask a representative from each team to fill in their tables on the PowerPoint slide
   c. Everyone should copy Table 1 and Table 2a into their results page (field notebooks)
   d. Everyone should report their data on the pieces of paper or on the board
   e. Ask for volunteers to finish tallying the oyster cube counts and oyster lengths. Next to the graph, they should list all organisms found and the total counts

Class data analysis - DISCUSSION

1. The purpose of this section is to:
   a. (1) make sense of all of their data and how it might relate to ecosystem health so they can eventually answer their investigative question
   b. (2) gradually introduce the concepts of claim, evidence, and reasoning
   c. (3) help students make a claim about ecosystem health at the VCR

2. Discuss field notebook responses for Station 1 - how did their field experience go?
   Did everyone have a similar experience?
   a. What did you find most interesting while collecting data?
   b. What went well?
   c. What was unexpected or tricky?
   d. Did anyone experience instrument issues or something that might cause an outlier?
   e. Unexpected things can happen during fieldwork!

3. Station 1 field experience - how did water quality results vary between teams?
   a. Looking for patterns in our data
   b. If things are different, they are not wrong. Estuaries are HIGHLY DYNAMIC and conditions can change quickly
   c. Point out any glaring differences. If something looks weird, we can go back to the data sheets later and check for outliers

4. How is the water quality at Oyster Harbor?
   a. Try not to spend too much time on this part
   b. This is the first step towards thinking about ecosystem health
   c. Students should be able to give a reason why (water quality is high because there were not many boats, because DO is high, because Chlorophyll A is low, etc)

5. Long-term trends can track ecosystem change
   a. Kayleigh draws new bar graph on giant sticky note by this point that has their data on it
   b. In 2001, there was no phragmites and there was more of the other species. S. alterniflora was super dominant, near 80%
   c. How does this graph compare to our data from today?
d. Why did this change happen?
  i. Ask for their ideas then show next slide

6. Threats to native species
   a. Native species are all generally declining. Why?
      i. S. alterniflora is so low in the marsh that when sea levels increase, it can go underwater (Drown)

7. P. australis is the only species increasing
   a. Does our data support this?
   b. What do we learn from our data?

8. Seagrass health
   a. Show word clouds of inner and outer leaves
   b. What qualitative evidence do we have to determine whether or not the seagrass looks healthy?
      i. The number of times each word was circled in field notebook
   c. What previous knowledge helped make that decision? Look back in field notebook
      i. Restoration project
   d. What kind of graph would be best to describe the percent of class who thought seagrass looked healthy or not?
      i. Pie chart: ask for student volunteers to draw on giant sticky note

9. What does our data tell us about primary producers?
   a. Introduce reasoning

10. Oyster cube survey
    a. Relative abundance: what kind of graph would be best for species abundance?
       i. Bar graph - ask for student volunteers to draw
    b. Everyone fill out table 3 in their field notebook!!

4. Finally, we will make a claim about ecosystem health at the VCR (field notebooks)
   a. Introduce reasoning

11. Fill out final observations for the field site:
    a. How were you surprised by our results?
    b. What result are you most interested in, and why?
    c. What would you do differently next time?
    d. Final notes, thoughts, or reminders about the VCR site:

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**DAY 2: Savage Neck Dunes**

**Schedule:**

9:00-9:40: Arrive, walk from the parking lot to the dunes, orient students to the area, make qualitative observations of forest and dunes, environmental data
9:40-10:10: Students break into 2 teams of 12. **Team 1 at Station 1, Team 2 at Station 2**

*Station 1 = physical/BGC/humans (student-led) Station 2 = primary producers (Charlie)*

10:10-10:40: Teams switch stations

10:40-10:55: Break / buffer time

10:55-11:40: **Everyone at Station 3** (Food webs) Charlie leaves at 11:30

11:40-12:00: Students pack up and walk to bus

***Students should carry their WATER BOTTLES with them all day***

**9:00-9:30**

In parking lot:

- **BEACH SAFETY:** technically Savage Neck Dunes is a beach and people swim there, but you should establish in the beginning what students are allowed to do. Up to you!
  - Do they need waders to go into the water? **Be clear about whether or not they need waders or if they’re optional.**
    - If they don't need them, do they need waterproof shoes? Bathing suit so they're not uncomfortable? No restrictions?
    - If they wear waders, they need to remain standing while in them
  - Who do they have to stay in sight of (the chaperone, the rest of the team, a partner?)
  - Do not go off without a partner
- **RESERVE SAFETY:** Savage Neck Dunes is a reservation. Please treat the area with respect
- **FOREST SAFETY:** Stay on the trail when possible. Off trail are native and/or endangered plants we don't want to disturb, and also poison ivy
  - Poison ivy has 3 leaves, a red dot in the center, and is usually shiny. It can be low to the ground and be hidden under plants.
  - If someone gets poison ivy on them, wash the spot with cool water and technu. If it touches other areas it will spread
  - Watch your step when going off trail
  - Try to walk around things and not through them
  - **STAY TOGETHER**
- They will have to help carry equipment. Pass it out
  - One person should carry the stack of field notebooks

Walk through forest to beach

- On the way, chat about what they see on the way to the beach
- Ask person holding field notebooks to read out the qualitative questions
- Encourage them to think about how it looks different from the VCR
- Check in with people holding equipment - do they need to pass it off to someone else or take a water break??
- At the beach, decide on a spot for equipment. Put it down and weigh down anything light
- Pass out field notebooks (Savage Neck Dunes pages only)

**IMPORTANT DISCUSSION** (for sensemaking): Explain and compare dunes. This section will orient them so they know what to look for during qualitative observations

- Estuarine dunes form when the wind blows sand from the beach and the sand gets trapped under wrack
  - Wrack: debris from the ocean, mostly dead vegetation
  - Do they see any wrack?
- Dunes usually form at the high water (normal high tide) line
  - Do they see the high water line?
  - If not, guesses about where it is?
  - It’s likely where there is a buildup of wrack
- Then, dune-building grasses start to colonize and grow, holding it in place
  - Do they see grasses?
  - Do the grasses look like the salt marsh grasses? (No - they are never submerged)
  - They can check them out more during qualitative
- Recall: Where are the beaches and dunes at the VCR?
  - Back-barrier islands
- **ACTIVITY:** hand raise poll
  - How many people have been to a beach on the Chesapeake Bay?
  - How many people have been to a beach on a VCR barrier island?
  - **Jot down results in field notebook margins**
  - Do they think the results would be the same for someone who lives in mainland VA?
  - Can chat about how often they’ve been to each as well
- Which estuary has more accessible dunes & beaches?
  - Chesapeake Bay
  - Need a boat to get to VCR beaches

Define your field site

- Decide on the area where you will collect data
  - Want to make sure everyone is collecting data within the same ~50m area so results are consistent
  - Lay a transect tape parallel to the water
  - Size is up to the class!! Anywhere from 30-50m should be fine
Qualitative observations

- In pairs or small groups, let them roam/explore the beach area outside the field site and record qualitative data
  - Personally, this is probably the only time I’d let them go out of sight of you/chaperone (around the bends and stuff)
  - Tell them how long they have to do this
  - **They should focus on the beach since they already did qualitative in the forest**
    - Have fun but make sure they are also recording data
  - Remind them to record qualitative data about forest too (observations they remember from the walk)

Environmental data

- Call everyone back
- Sit on beach and fill out data in field notebooks
- For tidal height: use the parallel transect tape to decide where you will make all height measurements (ex: stand at the 2m point)
  - Agree on the distance into the water we want to measure at (ex: 5 m into water)
  - One person holds the end of the second transect tape at the point and someone else walks in with a meter stick to the pre-determined depth
  - Person in water measures depth
  - **Any distances are fine, but they must also be the same at Station 1 so we can track tide change over time**
- Then explain that station 1 is student led today. They are the experts, they are in charge. They should help each other and collect data within the field site
  - **You can include Chlorophyll A in station 1 if you want**
  - **I suggest sticking with the same teams as VCR**
- Water quality methods are the same today
  - Its important to remain consistent with methods so data are comparable
  - Discuss the secchi disc- do they think it will work the same?
  - Probably not but this is a standard method and science can be imperfect
- However, methods for primary producers and food webs are different
  - Different organisms here that we can evaluate
  - Also, ease of access
  - Easier to do salt marshes and seagrasses at vcr
  - Easier to do dunes and maritime forest here
  - Seine net possible here, no oyster cubes here. Seine net not possible at vcr dock

9:40-10:40: Stations 1 and 2

**Station 1: Student-led**
Materials: The students should have a bin full of equipment. You should give the full RIR datasheet and a clipboard to the recorder, an extra copy of the first page of the datasheet and a clipboard to the observation people.

26. Make sure everyone has a job and knows to stay within the field site
27. Students can do a different job than yesterday if you want, or they can keep the same job since they are now "experts" in it
28. **Secchi depth group will probably need help figuring out where to go

Station 2:

Materials: clipboard, lesson plan, data sheets, towel to dry hands, waders

1. Explain that we are not doing the same methods for primary producers here as we did at the VCR. We will repeat Chlorophyll A and then assess the dunes and maritime forest.
2. Remind them that the Chesapeake Bay DOES have seagrasses and salt marshes, and the VCR DOES have dunes (barrier islands) and maritime forests as well

ACTIVITY 1: Vegetation Transects for Percent Cover

1. The transect work is good for a big group but will require some organization
   a. Roles should change during this activity. Students should take turns being the data recorder, taking the measurements, and watching
   b. The method is written so that you will do one plot at a time, switching roles as you go. If things are going well you can add in more than one quadrat and have multiple plots gong at once
2. Team will do 6 plots on each transect. Split them into pairs and give each pair one plot per transect. For each plot:
   a. Identify a data recorder
   b. Identify the pair that will do the measurement
   c. Give someone the role of reading the method instructions out loud
   d. Encourage others to watch/help
   e. If things are going well, you can do multiple plots at once
   f. If there isn't enough to do, some students can do Chlorophyll A
3. % sand and % vegetation will be easy, but types of vegetation and their relative percentages may be harder. Make sure they record these on the datasheet
4. Start with the beach transect because it'll be easier.
   a. If they do a weird throw, that's okay. They can throw again
   b. Also, because it's for a class, if they get a throw that's just sand but there's other stuff nearby that's more interesting, you can let them throw again. Just try not to aim too much
5. For the forest transect, you'll have to decide on the spot what the best location is and how far into the forest you want to go. Try your best to lay your transect parallel to the water.
6. If you don't know what a species is, take a picture and we can identify it later. Or download the app iNaturalist to ID it on the spot.

**ACTIVITY 2: Chlorophyll A (algae)**

29. Split students into groups of 4. This activity is the same as yesterday.
30. Recap: Chlorophyll A is the green pigment that gives algae their color and is critical for photosynthesis, and is commonly measured in the Bay to indicate phytoplankton abundance.
   a. In a balanced ecosystem, phytoplankton provide food for fish, crabs, oysters, and worms.
   b. When too many nutrients are available, phytoplankton may grow out of control and form blooms that harm fish, shellfish, mammals, birds, people.
31. Each group performs 1 Chlorophyll A test. Pass at least 200 mL of water through the syringe. Ok if not everyone gets a turn since they did it at VCR. Discussion points while filtering:
   a. How representative do they think Savage Neck Dunes is of the Bay?
   b. What do they expect the differences to be between here and VCR?
32. When groups are finished, they should agree on an observation about the filter color and write it on the datasheet.
   a. Do observations agree between groups?

**10:40-10:55: Break**

1. **If you are leaving early, it'll be fine because students should be self-sufficient at counting after a few minutes of help at Station 3**
   a. **They probably need you for the seine so depending on when you need to go you could also move the break to partway through Station 3**
   b. Before you leave, make sure you explain that they need to pack and take back the equipment (if not done during the break).
   c. There is a packing list.
   d. May want to take DO probe with you since it should be separate anyways and you'll likely have to take a measurement without them. Just tell them if you do so they don't panic.

**10:55-11:40: Station 3**

Materials: Seine net, Fish ID key, waders

2. Collect and put away field notebooks until classroom component.
3. For this station, 3 people will need to go into the water. Make sure they have waders (if that's what you determined).
4. Demonstrate how to use the seine net before doing it by asking someone to read the method out loud and for two people to demonstrate
5. Send the seine net crew into the water
6. Make sure all organisms make it back in the water at the end!
7. Optional: if time permits, they can do 3 seine drags (and different people can do it each time). Just make it clear on the datasheets which trial is which

Wrap-Up
1. Use the provided pack list to make sure all equipment is accounted for
2. Try to dry things and shake sand off of them as much as possible, but we expect everything to come back salty and sandy
3. May want to keep DO probe separate since you still need it
4. Make sure students have picked up anything else they came with (snack wrappers, etc) and then walk back to parking lot

CLASSROOM COMPONENT 2 (OUTLINE)

Investigative Question: How are the VCR and the Chesapeake Bay ecosystems similar and different? Based on your field measurements, would you consider these areas to be healthy? Why or why not? What drivers are the best indicators of ecosystem health? Why?

Materials: Debate requirements sheet, debate rubric, completed field notebook worksheets

Total time:

Outline:

In this section, they should:
- Complete their field notebooks to gather all the data
- Make plots and discuss data as a class to make sense of their results
- Learn how to make a claim through assessing the VCR data
- Use long-term data to compare VCR and Dunes data

Fill out field notebooks - VCR and Savage Neck Dunes
1. Students should fill out anything they are missing (including qualitative information) in their field notebook and contribute to questions on the board
2. On the board, write: what were your estimated percent covers for the marsh grasses? Based on your percent cover and observations, does the marsh seem healthy?
   a. Draw 5 columns (each grass and "other")
      i. Students should write their percent for each category
   b. Write a short answer using field observations
3. On a giant sticky note, draw a blank graph. On the side (not in the graph), make columns "Organism" and "Number counted".
a. Ask for volunteers who have their notebooks filled in to tally information from the datasheets
b. Do this for the oyster cubes and seine net. Use the flip chart paper if there is room, if not, do one on the board
c. Wait until it’s mentioned in the PowerPoint to make the graph

4. REPORT and record all data, THEN analyze it as a class

Data analysis for each field site and practicing making claims- Use PowerPoint

Long-term data
12. Long-term data
   a. This is how we can start to make sense of our data and figure out what the patterns in drivers are
   b. Long-term data is important in environmental science, where variables that we are interested in (ie. nutrient load) may change over time due to changes in human impacts, climate change, etc
   c. VCR-LTER scientists have been collecting data for over 30 years. Some data sets are continuous, others measure a few years of data here and there, others are very old

13. Compare your data to the VCR-LTER data
   a. This is the data portal, where anyone can go online and download
   b. There are lots of data sets in the portal
   c. This is the water quality sampling record, which was started in 1992
      i. Annual data collection 4x a year, including April

14. How does your water temperature data compare to the full dataset?
   a. Students refer to the tables they copied into field notebooks
   b. Interpret graph: Y axis is temp in °C, X is time
      i. Why is data cyclical? Seasons
      ii. Do students see a temperature increase over time? Not really, but in the past few years (since ~2017) it looks like it hasn't been getting as cold
   c. What temperature did we measure? Where would it go on this graph?

15. Does your data follow an annual trend?
   a. Zooming in to a few years
   b. Find the April dates
   c. Plot our average temperature on the April dates. Are they similar? If not, why?
      i. Could be a different time of day, different location
      ii. Maybe it just rained

16. Understanding sampling, in order to understand data
   a. ?**

17. Does your data contain outliers?
a. This graph of phosphate has 2 huge spikes on it. Is it more likely that phosphate got really high, or that there may have been an error while sampling? What do students think? 
b. What seems to be the average phosphate concentration? 2-3 
c. Phosphate concentrations would have had to increase 10x, the drop 10x 
d. Most likely a sampling error! 
  i. We can't say for sure (downside of using historic data!)

18. Data has patterns, peaks, and precious points**

19. Data has trends 
  a. The average Secchi depth and maximum Secchi depths have DECREASED over time. Why? increase in water quality, maybe from increase in seagrass (their roots prevent sediment resuspension) 
  b. Minimum Secchi depths have decreased slightly over time, but not as much 
  c. What does it mean that max depth decreased the most? 
     i. Water quality probably improved

20. Data tells a specific story 
  a. What is the relationship between DO and water temperatures? 
  b. DO is also cyclical, but it is opposite of water temperature (when DO increases, water temperature decreases) 
  c. As temperatures increase at the end of the graph, DO starts to decrease. Is this what you would expect?

21. Data can show relationships 
  a. How does DO change with salinity? 
  b. Plot your DO and salinity - do they agree with this long-term relationship?Was our site representative of the entire VCR? 
     i. Our measurements agree with most of the recent data for Oyster Harbor 
     ii. Chlorophyll A has been fairly consistent in the harbor. Is this surprising? 
         1. Ask students - surprising due to aquaculture presence? 
     iii. Chlorophyll A at VCR slightly increasing. Surprising? Any reasons why?

Ecosystem Health Report Card as debate prep

1. The Chesapeake Bay has an ecosystem health report card
2.

70 minutes – Debates

3. Debate #1: Physical vs. biogeochemical drivers 
4. Debate #2: Biodiversity vs. human impact drivers
Additional resources for instructors:
Information on Savage Neck Dunes:
Ecosystems in the Chesapeake Bay:
https://www.nps.gov/chba/planyourvisit/ecosystems.htm
VCR research highlights:
http://www.vcrlter.virginia.edu/home2/?page_id=71&topicNum=10
Chesapeake Bay seagrass density mapper:
Chesapeake Bay seagrass restoration and coverage graphs:
https://www.vims.edu/research/units/programs/sav/
Chesapeake bay declining seagrass extent:
VCR seagrass restoration:
https://www.vims.edu/research/units/programs/sav1/restoration/index.php