REEF RESTORATION RECONNAISSANCE

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Grade Level
9th – 12th Grade

Subject Area
Life Science

VA SEA is a collaborative project between the Chesapeake Bay National Estuarine Research Reserve, the Virginia Institute of Marine Science's Marine Advisory Program, and Virginia Sea Grant. The VA SEA project is made possible through funding from the National Estuarine Research Reserve System Science Collaborative, which supports collaborative research that addresses coastal management problems important to the reserves. The Science Collaborative is funded by the National Oceanic and Atmospheric Administration and managed by the University of Michigan Water Center.

Title: Reef Restoration Reconnaissance

Focus: Gauge the success or failure of restored oyster reefs by collecting and interpreting ecological data from oyster samples and aerial images.

Grade Level: High school life science (grades 9-12)

Florida Science Standards

SC.912.L.17.1: Discuss the characteristics of populations, such as number of individuals, age structure, density, and pattern of distribution.

SC.912.L.17.4: Describe changes in ecosystems resulting from seasonal variations, climate change and succession.

SC.912.L.17.6: Compare and contrast the relationships among organisms, including predation, parasitism, competition, commensalism, and mutualism.

SC.912.L.17.8: Recognize the consequences of the losses of biodiversity due to catastrophic events, climate changes, human activity, and the introduction of invasive, non-native species.

SC.912.L.17.13: Discuss the need for adequate monitoring of environmental parameters when making policy decisions.

Learning Objectives

- Students will collect data from oyster reef samples and aerial images of co-occurring marsh and oyster habitats.
- Students will record data and transform it as needed (i.e., scale up abundance from a sample to a larger area).
- Students will evaluate their data and determine whether the restoration effort was successful, and will back up their conclusion based on the data they collected.

Total Length of Time Required

60-75 mins, 15 mins prep time

Vocabulary

Abundance: The number of individuals (for example, total number of oysters)

Climate change: Long-term changes in global temperatures weather patterns which can occur naturally or as a result of human activity

Erosion: Gradual wearing away of soil or rock by water.

Ecological restoration: Assisting in or managing the recovery of an ecosystem which has been destroyed or degraded.

Ecosystem: A community of interacting organisms and the specific physical environment in which they exist

Market oyster: Market oysters are those which can be legally collected by oyster harvesters and sold to restaurants or consumers. Market oysters are those which are greater than 75 mm in length (7.5 cm).

Mutualism: A form of symbiosis which benefits both organisms involved.

Oyster larva: The free-swimming immature form of an oyster which develops into an adult, sessile oyster.

Oyster reef: Dense aggregation of oysters which results from juvenile oysters settling and growing on other individuals, both living and dead (empty shells).

Substrate: The raw material from which an oyster reef is constructed, including materials like oyster shells or cement blocks.

Background Information

Coastal ecosystems like salt marshes, seagrass beds, and oyster reefs benefit humans by serving as locations for recreation, storing carbon, and protecting coastal communities. However, coastal ecosystems are being degraded or lost entirely due to both direct (e.g., coastal development) and indirect human action (e.g., increased sea-surface temperatures caused by climate change). In the last several decades, there has been a dramatic increase in efforts to restore these lost ecosystems. The goal of restoration is to facilitate the recovery of destroyed or damaged ecosystems, ideally producing an ecosystem which has the same structure and function as the original system.

Oyster reefs are a common focus of restoration efforts. Oyster reefs provide a wide range of services to human and animal communities alike, and are also an important commercial and recreational fishery. Oyster reefs form much like coral reefs, meaning larval, free-swimming oysters select and settle onto live oysters or the shells left behind after death. Over time oyster reefs accumulate multiple generations of oysters, with the oldest individuals buried and the youngest, living oysters on the outside. Therefore, a common method of oyster restoration is to put out materials onto which larval oysters can settle, mimicking the structure of a dead reef. Many researchers are looking into ways to optimize reef restoration, including by comparing potential materials (anything from recycled oyster shell to cement).

Unsurprisingly, ecological restoration is extremely money- and labor-intensive. Another hot research topic therefore is co-restoration, or assessing the feasibility of restoring several ecosystems at the same time and using natural ecological relationships to improve success. In nature, oyster reefs can facilitate salt marshes by protecting them from wave energy and stabilizing the sediment into which the plants grow. Salt marshes are another extremely valuable coastal ecosystem, and are threatened many places in the U.S. by erosion. Erosion is the gradual wearing away of marsh sediment and plants by wave energy, eventually causing collapse of the marsh shoreline and habitat loss. A valuable case of co-restoration could therefore be restoration of oyster reefs adjacent to salt marshes, with the reefs ultimately shielding marsh vegetation from wave impact.

In this activity, your class will monitor the outcome of a reef restoration project and determine whether a reef restoration project was successful and consider other complexities in the restoration process, including the efficacy of different restoration materials and the benefit of co-restoration.

Materials & Supplies

- Rulers
- Non-scientific calculators (preferable to doing math by hand, as some calculations might be time-consuming)
- Pencils
- Projector set up (inc. screen or other white backdrop onto which introductory presentation can be displayed)

Teacher Preparation

The activity works best with students split into pairs or groups of three. Each pair or trio will be given a worksheet “set”. For a two-person team, a “set” would include: 2 printed student worksheets, 1 oyster quadrat worksheet (5-yr timepoint), and 2 aerial imagery worksheets (0 and 5-yr timepoint). Important: The reef type and number on the aerial imagery and oyster worksheets must all match. In addition to a worksheet set, students should be provided with pencils, a calculator, and a ruler. Rulers should include imperial (inches) and metric (mm) scales.

Procedure

Introduction

Instructors will load the introductory Powerpoint (Appendix A) and explain the background information (slides 1-27). Talking points for each slide are provided in the Notes field of the Powerpoint. Instructors will then explain the activity and monitoring tasks (slides 28-29).

Activity

The goal of the activity is to collect monitoring data from two aerial images (Appendix B) and an oyster sample (Appendix C), both of which were “collected” at a given restored oyster reef. Students will then use their data to infer whether the restoration was successful.

Data Collection

Students will be grouped into pairs (trios if necessary), and each pair given:

- 2 sets of printed student worksheets (each student will receive a copy of Worksheets 1A, 1B, and 2);
- 2 aerial imagery sheets (Appendix B);
- 1 oyster “quadrat” sample sheet (Appendix C);

- A ruler; and
- A calculator.

The aerial images and oyster sample should all have matching codes, meaning the same reef number and reef material (e.g., Shell Bag – Reef 1, Cement – Reef 2). One aerial image should be the baseline timepoint (T_0), and the second should be the 5 year timepoint (T_5). The oyster sample will be only from the 5-year timepoint (T_5). The students will work through the printed student worksheet, collecting measurements from the aerial images and oyster sample using their rulers. They will also complete the specified calculations (e.g, converting from image scale to real-world scale, converting abundance to density). After completing the worksheet, the students will obtain 4 metrics: reef area, erosion, oyster abundance, and oyster size class structure. These metrics will be numeric, categorical (erosion did or did not happen), categorical (total reef oyster abundance did or did not exceed 1,500), and categorical (oyster community had a balanced or unbalanced size class structure) respectively.

Data Sharing

Instructor will load slide 31, either onto a whiteboard or with the Powerpoint open and editable. The instructor will go around the room and ask each student group to report on the four metrics for their reefs (reef area, oyster density, oyster community size class structure, and erosion). Instructor can record these outcomes with a plus sign or a check mark either with a marker on the board or by typing the symbol directly into the box.

Conclusion

After all students have reported, the class will then discuss the results shown in the table. Specifically, students should discuss whether one reef material was more successful than the other, why this might be, and what they would recommend to the group who built the reefs.

Assessment

Students will be assessed based on their performance collecting and interpreting data and the final worksheet questions relating to their samples. Instructors will be provided with Answer Keys to grade student worksheets.

Student Worksheets

- Worksheet 1A: Aerial Image Analysis, Part 1
- Worksheet 1B: Aerial Image Analysis, Part 2
- Worksheet 2: Oyster Sample Analysis

Appendices

- Appendix A: Lesson plan Powerpoint presentation for instructor.
- Appendix B: Reef “aerial images”
- Appendix C: Oyster quadrat “samples”

Worksheet 1A

Aerial Image Analysis, Part 1

Using the aerial image marked "T_0", complete the following tasks describing the baseline state of the restored oyster reef and salt marsh.

Reef Number:______ Material:__________ Timepoint (T_0 or T_5):_______

Step 1: Use your ruler to measure the short and long sides of your reef in inches, and record the measurements. Measure to the nearest quarter inch. Convert the measurements based on the scale bar in the image. In this case, "1 inch = 0.4 meters." Multiply your measurements (in inches) by 0.4 to calculate the length in meters.

Short side: ________ in x ____ m = ________ m

Long side: ________ in x ____ m = ________ m

Step 2: Multiply the short and long sides of the reef, yielding reef area in m^2.

Reef area: ________ x ________ = ________ m^2

Step 3: Measure three transects (or, lines) between the reef and the marsh using your ruler. Use your ruler to measure each of the three lines drawn on the image and round their length to the nearest quarter inch. Write the lengths in the spots below and convert the measurements based on the scale bar in the image.

Transect 1: ________ in x ____ m = ________ m

Transect 2: ________ in x ____ m = ________ m

Transect 3: ________ in x ____ m = ________ m

Step 4: Average the length of the three transects using this formula: $\frac{length1+length2+length3}{3}$

Average transect length = ________ m

Worksheet 1A
Answer Key

Important: All T_0 aerial images are the same within reef type. For example, Shell Bag reefs 1-4 will all produce the same answers, and Cement reefs 1-4 will all produce the same answers.

Step 1:

- Shell bag: Short side = 1 m (2.5 inches), Long side = 2 m (5 inches)
- Cement: Short side = 1 m (2.5 inches), Long side = 2 m (5 inches)

Step 2:

- Shell bag reef area = 2 m^2
- Cement reef area = 2 m^2

Step 3:

- Shell bag:
  - Transect 1 = 0.9 m (2.25 in)
  - Transect 2 = 1 m (2.5, rounded up from 2.4 in)
  - Transect 3 = 1 m (2.5 in)
- Cement:
  - Transect 1 = 1 m (2.5, rounded up from 2.4 in)
  - Transect 2 = 1 m (2.5, rounded up from 2.4 in)
  - Transect 3 = 1 m (2.5 in)

Step 4:

- Shell bag average transect length: 0.967 m
- Cement average transect length: 1 m

Worksheet 1B

Aerial Image Analysis, Part 2

Using the aerial image marked "T_5", complete the following tasks describing the baseline state of the restored oyster reef and salt marsh.

Reef Number:______ Material:___________ Timepoint (T_0 or T_5):________

Step 5: Use your ruler to measure the short and long sides of your reef in inches, and record the measurements. Measure to the nearest quarter inch. Convert the measurements based on the scale bar in the image. In this case, "1 inch = 0.4 meters." Multiply your measurements (in inches) by 0.4 to calculate the length in meters.

Short side: _________ in x _____ m = _________ m

Long side: _________ in x _____ m = _________ m

Step 6: Multiply the short and long sides of the reef, yielding reef area in m^2. You will need this number for the calculations on the next worksheet!

Reef area: _________ x _________ = _________ m^2 ★

Step 7: Measure three transects (or, lines) between the reef and the marsh using your ruler. Use your ruler to measure each of the three lines drawn on the image and round their length to the nearest quarter inch. Write the lengths in the spots below and convert the measurements based on the scale bar in the image.

Transect 1: _________ in x _____ m = _________ m

Transect 2: _________ in x _____ m = _________ m

Transect 3: _________ in x _____ m = _________ m

Step 8: Average the length of the three transects using this formula: $\frac{\boldsymbol{length1+length2+length3}}{\boldsymbol{3}}$

Average transect length = _________ m

Step 9: Determine whether your site experienced erosion by comparing the average transect length at each timepoint. If the transect length <u>increased</u> between the first and second timepoint, erosion occurred.

Circle one: Did erosion occur? YES NO

Worksheet 1B
Answer Key

Step 5

- Shell bag reefs
  - Reef 1:
    - Short side = 1.3 m (3.25 in; rounded up from 3.2)
    - Long side = 2.8 m (7 in)
  - Reef 2:
    - Short side = 1.5 m (3.75 in)
    - Long side = 2.5 m (6.25 in)
  - Reef 3:
    - Short side = 1.3 m (3.25 in)
    - Long side = 3 m (7.5 in)
  - Reef 4:
    - Short side = 1.5 m (3.75 in)
    - Long side = 2.7 m (6.75 in)
- Cement reefs
  - Reef 1:
    - Short side = 1.3 m (3.25 in; rounded up from 3.2 in)
    - Long side = 2.3 m (5.75 in, rounded up from 5.7 in)
  - Reef 2:
    - Short side = 1.3 m (3.25 in)
    - Long side = 2.2 m (5.5 in; rounded down from 5.6 in)
  - Reef 3:
    - Short side = 1.3 m (3.25 in)
    - Long side = 2.3 m (5.75 in; rounded up from 5.7 in)
  - Reef 4:
    - Short side = 1 m (2.5 in)
    - Long side = 2.5 m (6.25 in)

Step 6

- Shell bag reefs
  - Reef 1 area: 3.64 m^2
  - Reef 2 area: 3.75 m^2
  - Reef 3 area: 3.9 m^2
  - Reef 4 area: 4.05 m^2
- Cement reefs
  - Reef 1 area: 2.99 m^2
  - Reef 2 area: 2.86 m^2
  - Reef 3 area: 2.99 m^2
  - Reef 4 area: 2.5 m^2

Step 7

- Shell bag reefs
    - Reef 1:
        - Transect 1: 0.7 m (1.75 in, rounded up from 1.74 in)
        - Transect 2: 0.7 m (1.75 in, rounded down from 1.81 in)
        - Transect 3: 0.8 m (2 in, rounded up from 1.92 in)
    - Reef 2:
        - Transect 1: 1 m (2.5 in)
        - Transect 2: 1.2 m (3 in, rounded up from 2.9 in)
        - Transect 3: 1.2 m (3 in)
    - Reef 3:
        - Transect 1: 1 m (2.5 in)
        - Transect 2: 1 m (2.5 in, rounded down from 2.58)
        - Transect 3: 1.1 m (2.75, rounded up from 2.7)
    - Reef 4:
        - Transect 1: 0.6 m (1.5 in)
        - Transect 2: 0.6 m (1.5, rounded down from 1.6 in)
        - Transect 3: 0.7 m (1.75, rounded down from 1.77 in)
- Cement reefs
    - Reef 1:
        - Transect 1: 0.7 m (1.75 in, rounded up from 1.7 in)
        - Transect 2: 0.7 m (1.75 in)
        - Transect 3: 0.7 m (1.75 in)
    - Reef 2:
        - Transect 1: 1.2 m (3 in, rounded up from 2.9 in)
        - Transect 2: 1.2 m (3 in, rounded up from 2.9 in)
        - Transect 3: 1.1 m (2.75 in, rounded up from 2.7)
    - Reef 3:
        - Transect 1: 0.7 m (1.75 in, rounded down from 1.8 in)
        - Transect 2: 0.6 m (1.5 in, rounded down from 1.6 in)
        - Transect 3: 0.8 m (2 in)
    - Reef 4:
        - Transect 1: 1.2 m (3 in)
        - Transect 2: 1.2 m (3 in)
        - Transect 3: 1.2 m (3 in, rounded down from 3.1 in)

Step 8

- Shell bag reefs
    - Reef 1 average transect length: 0.73 m
    - Reef 2 average transect length: 1.13 m
    - Reef 3 average transect length: 1.03 m
    - Reef 4 average transect length: 0.63 m
- Cement reefs
    - Reef 1 average transect length: 0.7 m
    - Reef 2 average transect length: 1.16 m

- Reef 3 average transect length: 0.7 m
- Reef 4 average transect length: 1.2 m

Step 9

- Shell bag reefs
  - Reef 1: No erosion
  - Reef 2: Erosion
  - Reef 3: Erosion
  - Reef 4: No erosion
- Cement reefs
  - Reef 1: No erosion
  - Reef 2: Erosion
  - Reef 3: No erosion
  - Reef 4: Erosion

Worksheet 2

Oyster Sample Analysis

Using the oyster sample marked "T_5", complete the following tasks monitoring the reef's oyster community.

Reef Number:______ Material:__________ Timepoint: T_5

Step 1: Count the total number of oysters in the sample (abundance): _______ oysters

Step 2: Using your ruler, measure the length of every oyster (in mm) and record in the table below. Make sure to measure the oysters <u>on both sides of the page</u>. Measure the line to the left of each oyster to make it easier! Next to each length, write a small "M" (Market), "A" (Adult), or "J" (Juvenile) based on the size breakdown below. ***Note: a "market" oyster is one which is large enough to be legally harvested and sold! Any oysters below this length must be left in their habitat until they grow to "market" size.***

[Market: >75 mm, Adult: 25 – 75 mm, Juvenile: <25 mm]

\# of Market oysters: ______ # of Adult oysters: ______ # of Juvenile oysters: ______

Step 3: Calculate what percentage of the sample is made up by each size class by dividing the tallies for each size class by the total number of oysters in the sample (round to the first decimal if needed).

Market: _________% Adult: _________% Juvenile: _________%

Step 4: Determine whether the size class structure of your sample is balanced or unbalanced. In a balanced sample, each size class has minimum 25% representation.

Balanced or Unbalanced? ______________

Step 5: Calculate the number of oysters on the entire reef. The oyster sample was collected from a square area, with each side measuring 25 cm (0.25 m). The area of the sample is therefore 0.0625 m^2 (0.25 m x 0.25 m). To find the total number of oysters on the reef, solve for X using the oyster abundance in this sample and the reef area you calculated in Worksheet 1: Step 6 (make sure it's the correct timepoint!) Write your answer here: X = _________

$$X = \frac{(\text{ \# of oysters in sample }) \times (\text{ reef area in m}^2)}{(0.0625 \text{ m}^2)}$$

Step 6: Other researchers have argued that restored oyster reefs are successful only if they have 1,500 or more oysters after 5 years. Based on this standard and your result from Step 5, is your reef successful? Circle one: YES NO

Worksheet 2
Answer Key

Step 1

- All samples have 27 oysters.

Step 3

- Shell bag reefs
  - Reef 1
    - Market: 9/27 = 33%
    - Adult: 10/27 = 37%
    - Juvenile: 8/27 = 29%
  - Reef 2
    - Market: 10/27 = 37%
    - Adult: 9/27 = 33%
    - Juvenile: 8/27 = 29%
  - Reef 3
    - Market: 10/27 = 37%
    - Adult: 8/27 = 29%
    - Juvenile: 9/27 = 33%
  - Reef 4
    - Market: 8/27 = 29%
    - Adult: 10/27 = 37%
    - Juvenile: 9/27 = 33%
- Cement reefs
  - Reef 1
    - Market: 4/27 = 14%
    - Adult: 9/27 = 33%
    - Juvenile: 14/27 = 51%
  - Reef 2
    - Market: 3/27 = 11%
    - Adult: 9/27 = 33%
    - Juvenile: 15/27 = 55%
  - Reef 3
    - Market: 4/27 = 14%
    - Adult: 7/27 = 25%
    - Juvenile: 16/27 = 59%
  - Reef 4
    - Market: 4/27 = 14%
    - Adult: 8/27 = 29%
    - Juvenile: 15/27 = 55%

Step 4

- Shell bag reefs

    - Reef 1: Balanced
    - Reef 2: Balanced
    - Reef 3: Balanced
    - Reef 4: Balanced
- Cement reefs
    - Reef 1: Unbalanced
    - Reef 2: Unbalanced
    - Reef 3: Unbalanced
    - Reef 4: Unbalanced

Step 5

- Shell bag reefs
    - Reef 1: 1,572
    - Reef 2: 1,620
    - Reef 3: 1,684
    - Reef 4: 1,749
- Cement reefs
    - Reef 1: 1,291
    - Reef 2: 1,235
    - Reef 3: 1,291
    - Reef 4: 1,080

Step 6

- Shell bag reefs
    - Reef 1: Yes
    - Reef 2: Yes
    - Reef 3: Yes
    - Reef 4: Yes
- Cement reefs
    - Reef 1: No
    - Reef 2: No
    - Reef 3: No
    - Reef 4: No