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Assessing Resiliency in the Face of Sea-Level Rise

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ABSTRACT

The ocean is inextricably linked to human societies. Climate change and its associated impacts to the aquatic environment pose problems for human communities as well. It is important for students and citizens to understand the changes they can expect to see on a local level, and prepare to respond to those impacts due to climate change. In this lesson, high school earth science students participate in a mock "stakeholder meeting" activity, where they role-play as land planners, emergency responders, and watermen, using climate change projections and county elevation information to create resilience plans for their communities in the year 2050.

Students working in small groups to complete the stakeholder activity. Courtesy of Kristen Sharpe

INTRODUCTION

Climate change is the name given to a series of observable environmental phenomena over time that will continue to impact the Earth's ecosystems and human societies into the foreseeable future. The impact of climate change on coastal areas will be observed across a diverse suite of physical and chemical variables including changes in air, water and soil temperatures, water chemistry, the timing and intensity of precipitation and major storm events, and sea level.

As a result of eustatic (i.e., global) sea-level rise, coupled with localized issues, such as glacial isostatic adjustment and land subsidence, the southern Chesapeake Bay region is experiencing some of the highest relative rates of sea-level rise and its associated impacts along the Atlantic coast of the United States (Reay and Erdle 2011). Therefore, understanding changes in sea level and inundation, as well as associated responses of critical habitats and coastal communities, are key to the Chesapeake Bay region. These low-lying coastal communities are disproportionately affected by environmental and anthropogenic impacts of climate change—including habitat loss, changes in agricultural and marine ecosystems, infrastructure loss, property loss, and changes in industries critical to the regional economy such as commercial harvesting of marine resources, tourism, and recreation. Therefore, it is critical that these communities act now to plan for future impacts by adopting resilience strategies to ensure quick recovery from, and possible adaptation to, anticipated changes. Climate change is not an issue that solely concerns scientists—local citizens and professionals, such as land planners, emergency responders, and watermen, all need to be involved in cooperative and collaborative discussions while planning for the future of their communities.

While scientists' understanding of climate change has continued to evolve and solidify with the accumulation of data and the development of theories and models, public understanding and opinion regarding the issue has historically not followed suit (Weber and Stern 2011). A survey administered in 2016 by the Yale Program on Climate Change Communication found that just 52% of surveyed American adults agreed that the Earth was warming as a result of human activity (i.e. burning fossil fuels), while an abundance of peer-reviewed publications suggest that the percentage of scientists who hold a favorable opinion of the same statement range from 91-97% (Verheggen et al. 2014; Carlton et al. 2015). This emphasizes the importance of climate literacy within members of the general public. One avenue for encouraging the development of this essential skill is through K-12 education. Both national and state standards of learning for earth science align with many aspects of climate change research, and thus represent a great opportunity for incorporating climate science into classroom curricula (Next Generation Science Standards 2013; VA Dept of Education 2003). In addition, high school students are able to recognize that they are the future citizens and professionals whose livelihoods will be influenced by climate change impacts.

The Chesapeake Bay National Estuarine Research Reserve in Virginia (CBNERR) has developed and implemented a series of climate-science related activities for use in their Climate Education for a Changing Bay (CECB) program. The CECB program works with high schools within the Chesapeake Bay region, with the goal of nurturing climate literacy in ninth grade earth science students, teachers, and administrators. One of the activities developed for the CECB program, "Assessing the County's Readiness for a Climate Related Event," will be discussed. Students are engaged in a role-playing activity in which they represent one of three different stakeholder groups within their community (land planners, emergency responders, and watermen). Using a variety of resources, the groups must develop plans for their county for the year 2050.

Our lesson specifically addresses the following Virginia-specific and National Education Standards:

- Virginia Standards of Learning (SOLs): ES. 1, ES. 8, ES. 10, ES. 11
- Next Generation Science Standards (NGSS): HS-ESS2-2, HS-ESS3-1, HS-ESS3-5
- National Oceanic and Atmospheric Administration (NOAA) Ocean Literacy Principles: 3, 5, 6
- U.S Climate Change Science Program Climate Literacy Principles: 3, 4, 5, 6, 7
- NERRS Estuary Principles and Concepts: 1, 2, 3, 4, 5, 6

The complete lesson plan, along with all resources used in the development and implementation of the activity, can be found online within the following two links: https://tinyurl.com/stakeholderpart1 and https://tinyurl.com/stakeholderpart2.

BACKGROUND

A variety of different stakeholders are concerned with localized climate change impacts. Land planners must establish a framework for future residential and commercial development, while maximizing the ecosystem services provided by natural habitats such as tidal wetlands. Emergency responders must highlight evacuation routes while identifying potential shelters and emergency response stations

within their county. Watermen must use information regarding projected changes in water temperature, salinity, and availability of habitat within the Chesapeake Bay to determine ideal target locations for the future of the blue crab fishery.

Through the "Assessing the County's Readiness for a Climate Related Event" activity, students use provided informational resources as research tools in order to develop plans for their community in the year 2050 from their assigned perspective. Students outline their plans on laminated county maps, and are then asked to participate in the mock "stakeholder meeting" by presenting their research and conclusions to the class. Through this activity, students are able to learn how to interpret local maps, compile resources to develop a plan, and make informed decisions regarding resilience to the impacts of climate change. They are also exposed to a variety of tools and resources, including the NOAA Digital Coast Sea-Level Rise Viewer.

LESSON PROCEDURES

Begin by providing an overview of the task at hand, in addition to why it is important. At this point, students have received preliminary lectures and lessons regarding climate change and associated impacts in their region through other aspects of the CECB program. You may want to include an introductory lesson on climate change first. Tell students that they will be using worksheets and the provided materials to take a closer look at how these impacts will affect their local community in the future. Students may need a refresher on their county map, and where landmarks are located.

Start a conversation with your students by asking questions about what they already know about some of the concepts they'll be investigating, and how they relate to their community. For example:

- What do you know about where development is in our county?
- Where do we have the most development?
- Where do we have the most agricultural land in our county?
- How can we benefit from some of the rural areas in the county?
- What are emergency responders?
- How do they provide aid during an extreme weather event?
- Do you know of any emergency shelters in our county?
- How do waterman know where blue crabs are located within the Bay?
- How could watermen be affected by water quality?
- How do watermen impact the local economy?

Separate students into three groups, and tell them they will be representing one of three "stakeholder" groups: land planners, emergency responders, or watermen. Talk about what these three groups do, and that they are all concerned with how climate change will impact the county. Distribute a folder with a worksheet and the necessary supplemental materials that the students will need to complete the lesson to each group. Each group's resources will be different. Also provide the land planner and emergency responder groups with a laminated map of the local county, and the watermen group with a laminated map of the Chesapeake Bay.

Tell students that they will be working together in their small group, following the instructions on the worksheet, and answering all of the questions using the materials that were provided in their folders. Tell them that after they have finished with the content questions, they will follow the instructions on their worksheet to map certain areas, buildings, land uses, and/or crabbing target spots on their laminated maps using the vis-a-vis markers. Tell students that they will be responsible for presenting their maps to the class in a mock "stakeholder meeting" at the end of class, and will need to be able to explain what they did and why.

This activity can be completed within a 60-minute class session. This gives students 45 minutes to complete the activity, and provides each group with a 5-minute window to present their map to the class.

After the groups present, review the positive items they mentioned. Add any additional comments or clarifications as needed. Conclude the lesson by explaining to your students that there are many people concerned about climate change—not just scientists—but also the groups they represented. As they get older, climate change is a topic that will continue to be discussed and they may eventually be in these roles as land planners, emergency responders, watermen, or other stakeholders making informed decisions regarding climate change impacts.

MATERIALS

- Laminated maps of the students' county
- Laminated map of the Chesapeake Bay
- Supplemental information listed in the "Resources" section below
- Student worksheets
- Vis-a-vis markers
- Computer (optional, not necessary if you print out sea-level rise maps beforehand, but needed if you plan to include NOAA Digital Coast tools)

ASSESSMENT

- Each group presents their research and conclusions to the rest of the class.
- Worksheets are completed, which can then be graded to assess comprehension of material.

MODIFICATIONS

- Non-coastal communities can still benefit from this activity, by modifying the content to reflect the challenges that their local communities will face in the wake of climate change. Focus can be placed on flooding of non-coastal waterways, changes in temperatures, and increases in extreme weather events.
- In addition to altering content, it is also possible to change the three different stakeholder groups who are represented in the activity in order to accurately represent the interest groups of your local community.
- All of the materials used in developing this activity were assembled from local land planning, land use, and zoning agencies. Each locality should have its own version of these organizations, which may be contacted to provide the necessary information to modify the activity to be more local and relevant to your community. See Appendix 1 on page 14 for a list for a list of resources used for our region.
- If you are in a non-coastal area and want to include the watermen portion, you can talk to students about the resources (including food) that come from the Chesapeake Bay, and how changes in that region can impact the seafood industry.

EXTENSION

One school that was involved in the program had a few representative student groups present their completed resiliency maps to members of a local land planning commission. It was an additional opportunity for the students to be able to share their products with others, as well as to reinforce the concepts that they gleaned from the activity and understand the real-life implications of this type of planning exercise.

SUMMARY

CBNERR's Climate Education for a Changing Bay (CECB) program, of which the highlighted activity is a part of, had impressive results. In the first iteration of the program, in the years from 2013-2015, CBNERR educators worked with all earth science teachers in Gloucester and Mathews counties in Virginia. Educators provided two classroom visits to each class, in addition to a field-based educational experience on the Virginia Institute of Marine Science (VIMS) campus. Non-paired, pre- and post-assessments were given to each student who participated in the program, and assessments included both knowledge-based and attitude-based questions.

The results showed that the average score on the knowledge portion of the pre-assessment was 55.11%, while the average post-assessment score was 64.02%. This is equivalent to approximately 16% change in knowledge gain. Most notably, there was a 35% increase in the number of students who could correctly identify how rising sea level would impact salinity further upriver. On the attitude-based questions, students were asked to rank on a scale of 1-5 how strongly they felt about each of six statements: one meaning that they strongly disagreed with the statemen; and five being that they strongly agreed. There was a statistically significant difference between pre- and post-assessment answers on all six questions, including the statements, "Human impacts are playing an increasing role in climate change," and "I know how to access and use environmental data."

In subsequent years of the program (2015-2017), CBNERR educators continued to work with Gloucester and Mathews high schools, allowing the teachers to take the lead on implementing the program while they provided supplies and advisory support. In addition, they began working with the earth science teacher at Middlesex High School, another local county, to implement the two classroom visits and field experience. Students were given a slightly different pre- and post-assessment, which again included both knowledge-based and attitude-based questions.

The results of the pre- and post-assessments for the 2016-2017 implementation year are summarized below.

School Name	Pre-Test Score	Post-Test Score	% Change
Gloucester	61.11	61.61	0.82
Mathews	59.72	61.11	2.33
Middlesex	50.56	52.03	2.92
OVERALL	57.13	58.25	1.96

It is important to note that 310 students completed the pre-assessment, while only 273 completed the post-assessment. This is likely due to scheduling conflicts, since teachers were tasked with implementing the evaluations on their own and on their school grounds. In addition, identifiers were not collected along with the data, so there is no way to proof the data to be sure only those who completed both assessments, along with the three separate activities, were considered.

Review of the individual question responses highlighted the need for further reiteration of some of the program's key concepts, including water quality parameters and localized impacts of climate change. However, there was a significant increase in certain knowledge portions of the assessment, including a 21% increase in correct responses regarding the effects of ocean acidification on sea life, and a remarkable 78% increase in knowledge gain regarding the causes and concept of relative sea-level rise.

When asked on the pre- and post-assessments to name a way that students could work with their community to reduce the impacts from climate change and lower CO_2 levels, it was clear that students gleaned a better understanding of the causes of climate change, as more answers on the post-assessment focused on plausible solutions to carbon dioxide emissions mitigation (carpooling, no idling, conserving energy, investing in alternative energy sources), rather than the abundance of answers in the pre-assessment focusing on other viable yet unrelated environmental issues, including recycling trash and limiting marine debris pollution and litter.

As far as the attitude portion of the assessments, students demonstrated an increased understanding of zonation patterns in a salt marsh habitat, along with increased confidence in their ability to access and use environmental data, and to run a transect line to survey a marsh habitat. These results are important in showing the efficacy of the program with regards to allowing students to develop a new knowledge of important environmental concepts, while also allowing for the development of new skills and increased understanding of technical resources and tools.

FUTURE PROSPECTS

The most current iteration of the program involves CBNERR educators serving a mentorship role to the earth science teachers in Gloucester, Mathews, and Middlesex counties—and supporting their implementation of the activities through providing supplies, advice, and guidance. Through this mentorship, the partnership between CBNERR and local high school teachers has led to the development and maintenance of a sustainable educational program that can be used to supplement classroom curriculum and concepts. CBNERR educators have completed Institutional Review Board (IRB) training in order to be able to collect identifying information from students for the current iteration evaluations, which will help provide more comprehensive and revealing analysis of future student evaluation data.

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REFERENCES

Carlton, J. S., R. Perry-Hill, M. Huber, and L.S. Prokopy. (2015). The climate change consensus extends beyond climate scientists. *Environmental Research Letters*, 10(9). doi: 10.1088/1748-9326/10/9/094025

Next Generation Science Standards (NGSS). (2013). Retrieved from: https://www.nextgenscience.org/

Pew Research Center. (2009). *Public Praises Science; Scientists Fault Public, Media*. Washington, DC.

Reay, W. G., and S.Y. Erdle. (2011). *Sea Level Rise: Local Fact Sheet for the Middle Peninsula, Virginia* [Pamphlet]. Gloucester Point, VA: CBNERRVA.

Verheggen, B., B. Strengers, J. Cook, R. V. Dorland, K. Vringer, J. Peters, H. Visser, and L. Meyer. (2014). Scientists' views about attribution of global warming. *Environmental Science & Technology*, 48(16), 8963-8971. doi: 10.1021/es501998e

Virginia Dept of Education (VDOE). (2003). *Science Standards of Learning Curriculum Framework: Earth Science*. Retrieved from: http://www.doe.virginia.gov/testing/sol/frameworks/science_framewks/framework_science-earthsci.pdf

Weber, E. U., and P.C. Stern. (2011). Public understanding of climate change in the United States. *American Psychologist*, 66(4), 315-328. doi: 10.1037/a0023253

Yale Program on Climate Change Communication. (2016). *Yale Climate Opinion Maps: U.S.* Retrieved from: http://climatecommunication.yale.edu/visualizations-data/ycom-us-2016/?est=happening&type=value&geo=county

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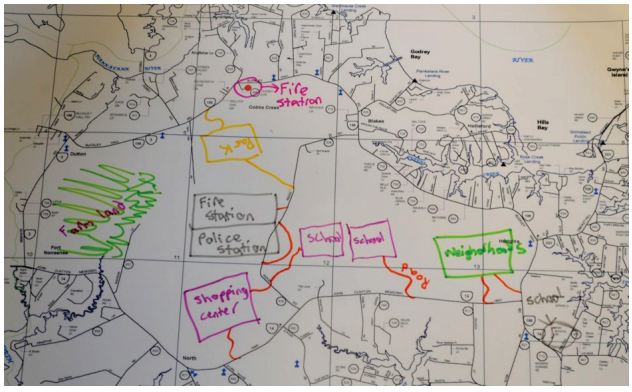
Students presenting their completed map to the class. Courtesy of Kristen Sharpe



A map completed by one of the land planner stakeholder groups, showing the locations of the students' proposed future developments in Middlesex County, Virginia. Courtesy of Kristen Sharpe

APPENDIX 1. RESOURCES USED IN ACTIVITY

Land Planning Group:

- County map of land use gathered from local land use and zoning commissions
- Elevation profile for the county
- Supplemental NOAA "Coastal County Snapshot." Retrieved from: https://coast.noaa.gov/snapshots/

Emergency Responder Group:

- County maps of shelters, schools, emergency evacuation routes, emergency service stations, storm surge inundation zones, etc., gathered from local land use and zoning commissions, in addition to local emergency hazard plans
- Elevation profile for the county
- NOAA Sea Level Rise Viewer - can print out snapshots of different sea-level rise scenarios, or pull up on a laptop or tablet for students to interact with. Retrieved from: https://coast.noaa.gov/slr/

Waterman Group:

- Chesapeake Bay Program graphs of mean surface salinity in fall and spring. Retrieved from: http://www.chesapeakebay.net/maps
- Chesapeake Environmental Communications' Graph of Bay Dissolved Oxygen in August. Retrieved from: http://www.chesapeakedata.com/
- Chesapeake Bay Foundation's Crab Jubilee and Eelgrass articles, in addition to a map of current eelgrass bed distribution throughout the Bay. Retrieved from: www.conservationgateway.org/Documents/CBF-BadWatersReport.pdf
- Blue Crab life cycle graphic. Retrieved from: http://serc.si.edu/labs/fish_invert_ecology/bluecrab/migration.aspx
- Yearly water temperature fluctuation graphs can be created using: https://coast.noaa.gov/swmp/#/index

APPENDIX 2. EXAMPLE STUDENT WORKSHEET (LAND PLANNING GROUP)

You and your group members are acting as a group of land planners and are having a discussion about how climate change could impact your future plans for development in your community. You all live near the coast and have some prior knowledge about where development occurs and where there are areas for concern. Discuss with your group members what you already know about land planning.

You will be focusing on the long-term ecosystem impacts of climate change. In order to predict the long-term landward movement of marshes, you will need to take into consideration sea-level rise, land subsidence, and growth of marshes. Please use the provided materials to help you answer the following questions. Look through all of the materials first; some of the materials are general information about your county and local maps. Your discussion will then be reported to the class as a conclusion of the program in a discussion panel. Please feel free to ask your instructors questions.

QUESTIONS

1. What are some factors land planners may take into account when thinking about their community and climate change?

2. Where in your county do you find tidal wetlands? What is an example of a tidal wetland?

3. Knowing that the marsh can build up and will move landward as sea-level rises; draw on your map where the marsh could potentially reach using the provided materials? Do you have any developments too close to the marsh edge, how could this impact the marsh?

4. As a land planner, how could you maximize the natural services provided by these habitats?

5. Visit NOAA Sea Level Rise and Coastal viewer at http://csc.noaa.gov/slr/viewer/. Zoom in on the map to your county. Under Sea level, slide the bar up to 2 ft. SLR. And read the map overview on the left. What areas in your county are most likely to see impacts due to sea-level rise?

6. Now slide the Sea level bar to 3 ft. SLR, was there much change in the land that would be affected?

7. Using the provided materials and the blank map, draw out where you would like to see development in your county in the future. Label where each of the following will be built by the year 2050. (It may be helpful to draw where the water will be by 2050 when planning.) Keep in mind that existing infrastructure could still be used!
   a. Neighborhoods
   b. New schools
   c. Fire stations and police stations
   d. Shopping centers
   e. Farmland
   f. Parks
   g. Access to waterfront

8. How did you choose the areas that you decided to develop?