Lesson Name:	Raising Awareness About Rising Sea Levels
Name of Sanctuary:	Endicott Wildlife Sanctuary: Salt Marsh Science Project
Grade Level:	6-12
Location Options:	On the Coast:
Time:	At least 1 hour
For more info:	lduff@massaudubon.org 781-392-6507

Lesson Description

How will rising sea levels impact coastal areas? What are current sea level rise projections, and how will they impact the high tides on local beaches? Students will use a spotting level to investigate and raise awareness about this impact of a changing climate. Students will discuss ways of reducing future sea level rise through individual and collective actions.

Massachusetts Curriculum Frameworks

Framework:	Science and Technology
Strand:	Earth and Space Science
Topic:	

Learning Standards Grades 6-8

6. Describe and give examples of ways in which the earth's surface is built up and torn down by natural processes, including deposition of sediments, rock formation, erosion, and weathering

Learning Standards Grades, High School

1. **Matter and Energy in the Earth System**
   1.6 Describe the various conditions associated with frontal boundaries and cyclonic storms (e.g., thunderstorms, winter storms [nor'easters], hurricanes, tornadoes) and their impact on human affairs, including storm preparations.
   1.8 Read, interpret, and analyze a combination of ground-based observations, satellite data, and computer models to demonstrate Earth systems and their interconnections.

3. Earth Processes and Cycles

3.1 Explain how physical and chemical weathering leads to erosion and the formation of soils and sediments, and creates various types of landscapes. Give examples that show the effects of physical and chemical weathering on the environment.

SIS1. Make observations, raise questions, and formulate hypotheses.
SIS2. Design and conduct scientific investigations.
SIS3. Analyze and interpret results of scientific investigations.
SIS4. Communicate and apply the results of scientific investigations.

Massachusetts Curriculum Frameworks

Framework: Science and Technology
Strand: Life Science

Learning Standards Grades 6-8

Evolution and biodiversity

13. Give examples of ways in which organisms interact and have different functions within an ecosystem that enable the ecosystem to survive.

Changes in Ecosystems Over Time

17. Identify ways in which ecosystems have changed throughout geologic time in response to physical conditions, interactions among organisms, and the actions of humans. Describe how changes may be catastrophes such as volcanic eruptions or ice storms.

Learning Standards Biology, High School

6 Ecology

6.2 Analyze changes in population size and biodiversity (speciation and extinction) that result from the following: natural causes, changes in climate, human activity, and the introduction of invasive, non-native species.

SIS1. Make observations, raise questions, and formulate hypotheses.
SIS2. Design and conduct scientific investigations.
SIS3. Analyze and interpret results of scientific investigations.
SIS4. Communicate and apply the results of scientific investigations.

***The New Draft Generation Science Standards By Topic (2013) that apply to this lesson are in the appendix. Go to** The draft NGSS and the survey to submit input can be found at www.nextgenscience.org. Deadline for Comments: January 29th 2013!

Direct Link to the Next Generation Science Standards pdf (2013) by topic:

http://www.nextgenscience.org/sites/ngss/files/Topic%20Arranged%20Standards-%20Public%20Release_0.pdf

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Lesson Objectives

What will students know and be able to do? These objectives must be observable and measurable.

Students will know and be able to:

- Participants will learn about current rates of sea level rise.
- Participants will use a spotting level to visualize projected sea level rise.
- Participants will discuss how physical changes in the ecosystem caused by rising sea level will impact populations in the ecosystem.
- Participants will discuss actions they can take to help improve the situation.

Materials

1 meter stick (Suggestion: If possible group participants in 3s and have one meter stick, one flag, and one sighting level for each team.)

Pocket Sighting level (about $15-$20)

5"x8" Flags on 3' wires

"Sea Level Rise in 2100" (Pink Flags)*

"Storm Surge Line in 2100" Yellow

Optional:

Tide Chart, Signs that say "50 cm""1 Meter" "2 Meter" "3 Meter" "4 meter"

Digital camera , GPS Unit.

*For pink flags email Liz Duff at lduff@massaudubon.org or call 781-392-6507.

Vocabulary

Sea Level	Carbon emissions	Projection
Wrack Line	Storm Surge	Climate Change

Mass Audubon Educator Background

Mass Audubon Educator should:

- Review current sea level rise history and projections.
- Be able to share suggestions for reducing carbon emissions.

Assessments

How will you know that the students have met the standards?

- Mass Audubon Educator will observe students .
- Students participate in discussions with Mass Audubon Educator-prompted questions.

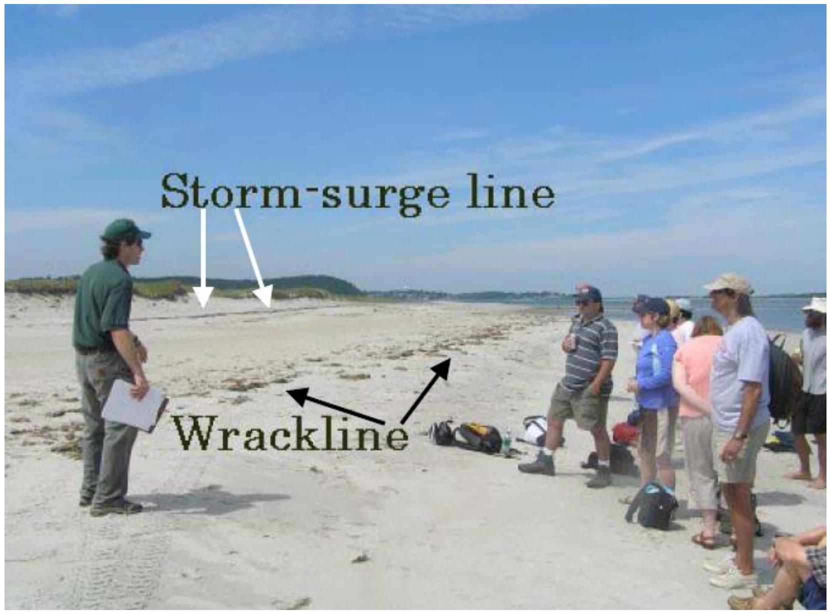
Procedure

1. Preparation: Mass Audubon Educator will prepare for the lesson by taking participants to a coastal environment that is special to you. Allow participants to bond with its beauty in advance of all this. (Or take students somewhere you know is already special to them.)

Please note: If you want to leave the flags in place as a way of raising public awareness, please contact landowners in advance to get their permission. Some dune areas are off limits to visitors, in order to minimize erosion. Do not go in areas that are off-limits unless you are given specific permission to do so.

Procedure:

1. Introduce your students to the topic of Climate Change and sea level rise. Since the industrial revolution, in the 1800's we have been burning more fossil fuels which act like extra blankets, warming our atmosphere. As you probably know, heat expands, so as the ocean expands, and land ice melts, sea level is rising. Scientists are now learning that pumping up water from under the ground is contributing to sea level rise. The rate, before industrialization was less than a millimeter per year. In your lifetime it has increased to more than 3 millimeters per year, and this rate, if we continue to emit so many heat trapping gasses, is expected to increase. Current (2012) projections range as high as 1-2 meters by the end of this century. When they say 1-2 meters, they mean vertically, not horizontally. We are going to investigate where one meter 2 meter sea level rise will place the high tide line on the landscape. (You can also do two meters). We will also discuss changes we can make individually and collectively to help reduce the emissions we are releasing.
2. Optional: Read and discuss "SEA LEVEL" background information with students.
3. Discuss coastal places that are important to them. Optional: Look on Massachusetts Coastal Zone Management (CZM) web-site to see how beaches have changed since the mid 1800's. Discuss a local beach or local salt marsh and ask students to imagine what 1 meter sea level rise might look like.
4. Introduce the idea that occasional storm surges would also impact shorelines dramatically.
5. Choose a site to visit as a class. Follow normal field trip procedures. (Permission slips, first aid kits, cell phones, appropriate apparel, insect repellent, etc.)
6. Check a tide chart and see if you can plan a trip to be at the beach when the tide is high. Note whether it is a spring tide, which is the highest tide of the month when the force of the sun and the moon's gravitational power is working together and result in our highest tides.
7. If it is not high tide when you are there, look for the wrack line along the beach, in an area that may still have wet sand. This is where the highest point of the tide has left behind sea-weed and debris. This is your starting elevation: this year's high tide line. You may notice further up the beach another line of wrack. This is typically high and dry sand. It is usually where our biggest storms left the wrack. That is the starting point for the storm surge line.



The high tide leaves behind seaweed and debris, forming the wrack line. The wet wrack line shows the elevation of the last high tide. The storm-surge line is typically drier wrack placed higher on the beach and is evidence of the height of recent storm surges.

8. Demonstrate how to use the spotting level.*
    a. Remind participants that scientists predict sea level may rise as high as 1to 2 meters in the next 100 years.
    b. Stand on the wrack line, with your back to the ocean, facing perpendicular to the shore.
    c. Place the spotting level on the top of a meter stick, and place one end of the meter stick on the wrack line.
    d. Look through the pocket sighting level (the end with a small hole) and line up the bubble of the level in the center. Do not cover the top with your fingers- you need light to see!
    e. Look through the clear glass area of the level to see where the black cross line intersects on the beach.
    f. Ask a participant to take a flag and go to that point to mark it.
    g. Communicate with each other until that person is in the correct spot, and has flagged it.
    h. Use the same protocol with the storm surge line, starting at the storm surge elevation.

With your back to the ocean, spot from the top of the meter stick, looking perpendicular to the shore. A partner can make sure the meter stick is perpendicular to the ground.

*Depending on how many spotting levels you have, you may do this as a whole group, or divide into multiple groups after demonstrating the procedure.

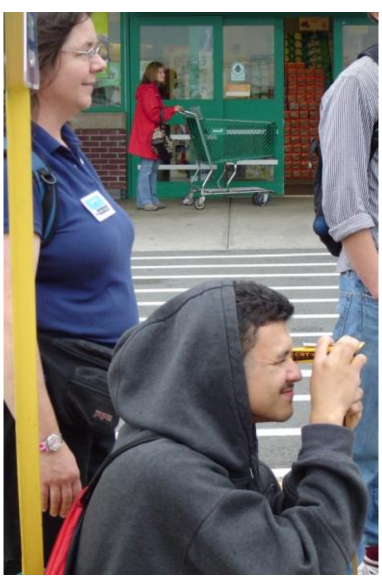
Mark the 1 meter rise spot on the beach with a "Sea Level Rise in 2100?" flag. (Not actual size!)

Place the "Storm Surge Line in 2100" flag one meter up from the storm surge line. Make sure you have permission if you are going in fragile areas. (Not to actual size.)

Optional: Predictions for sea-level rise vary. We may be able to slow the rate of sea level rise down if we change our behavior. You can see where 50 cm and 2 meters are. You can write messages on the backs of the flag sin permanent marker to encourage behaviors that support less sea level rise.

Optional: Have participants stand holding cards that say "50 CM", "1 Meter" "2 Meters" "3 Meters" and "4 Meters" stand at the locations that your projections are made. Take photos to illustrate the high water marks. Also GPS their locations, and add these to a map in GOOGLE Earth.

Optional: From a salt marsh: Find the upper edge of the marsh, and spot for one meter up from there.



Optional: Do this in a coastal place that is developed by humans, and predict sea level rise

9. **Discuss:**

How do people feel about the prediction? Share your own feelings, and listen to group members. Discuss what are things that people can do to slow down the rate of sea level rise? (See some suggestions in the background information.)
The web-site listed on our flags is one web-site that has suggestions for what people can do. There are lots of others. Suggest participants check it out and have participants do a web-search to find more.

Follow-up activities:
Explore sea level rise in other places: +1 to +10 feet:
http://sealevel.climatecentral.org/surgingseas/place/states/MA#show=cities&center=15/42.6182/-70.6515&surge=9

From +0 to +60 meters at http://flood.firetree.net/ .

Have participants investigate their own ecological footprint and discuss actions that they may choose to take to slow down the rate of sea-level rise. Visit www.myfootprint.org, or www.redefiningprogress.org.
Have participants research the best ways of slowing down sea-level rise, and plan a public outreach day where you share this information, and also show the sea-level predictions.
Make posters to go in public viewing areas such as your local library or city hall.

Summarizer

How will the Mass Audubon Educator close the lesson to see if students met the objectives?

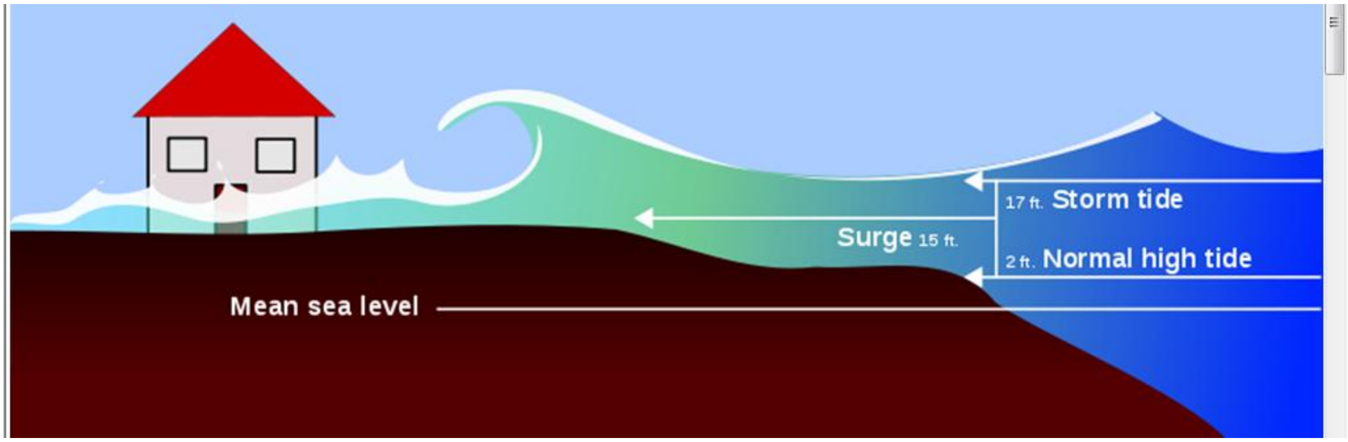
- Students will accurately place flags one meter up on the coastline.
- Students will discuss possible ways of adapting to and mitigating sea level rise.

Mass Audubon Teacher Naturalist Reflections

This activity is dedicated to one of my favorite places. As you can see, the high tide leaves very little beach. Rising sea level will dramatically change this place I love. It's one of the places that got me thinking about the big picture, and caring about my actions, and the actions of other people. I hope you have special places that you love deeply enough to influence the choices you make, and that you have the awareness that our individual and collective choices make a difference. Please share this lesson with other educators. It is not limited to Mass Audubon staff.
Liz Duff 2005

Photos by Elizabeth B. Duff

Background Information



http://en.wikipedia.org/wiki/Storm_Surge

A storm surge is an offshore rise of water associated with a low pressure weather system, typically tropical cyclones and strong extratropical cyclones. Storm surges are caused primarily by high winds pushing on the ocean's surface. The wind causes the water to pile up higher than the ordinary sea level.

Surging Sea Sea Level Rise Maps: http://sealevel.climatecentral.org/ http://sealevel.climatecentral.org/ (2012)

Free Climate Education for High School Students: http://www.acespace.org/ (2012) Alliance for Climate Education –ACE- is the national leader in high school climate science education. They are an award-winning national nonprofit dedicated to educating America's high school students about the science behind climate change and inspiring them to do something about it—while having fun along the way.

Mass Audubon Climate Change Websites (2012)

http://www.massaudubon.org/renewableenergy/index.php

For Mass Audubon Staff:

http://www.massaudubon.org/Staff/forms.php?type=25

http://www.massaudubon.org/Staff/forms.php?type=14\

Recommended Reading

"Don't Panic, But the Shoreline Is Moving Inland" Submitted by John Englander on Fri, 11/30/2012 - 13:06
http://www.disinfo.com/2012/11/dont-panic-but-the-shoreline-is-moving-inland/

Be a part of the Global Warming Solution:

Low Carbon Diet by David Gershon

http://www.empowermentinstitute.net/lcd/

Journey For the Planet by David Gershon

http://www.empowermentinstitute.net/journey/index.htm

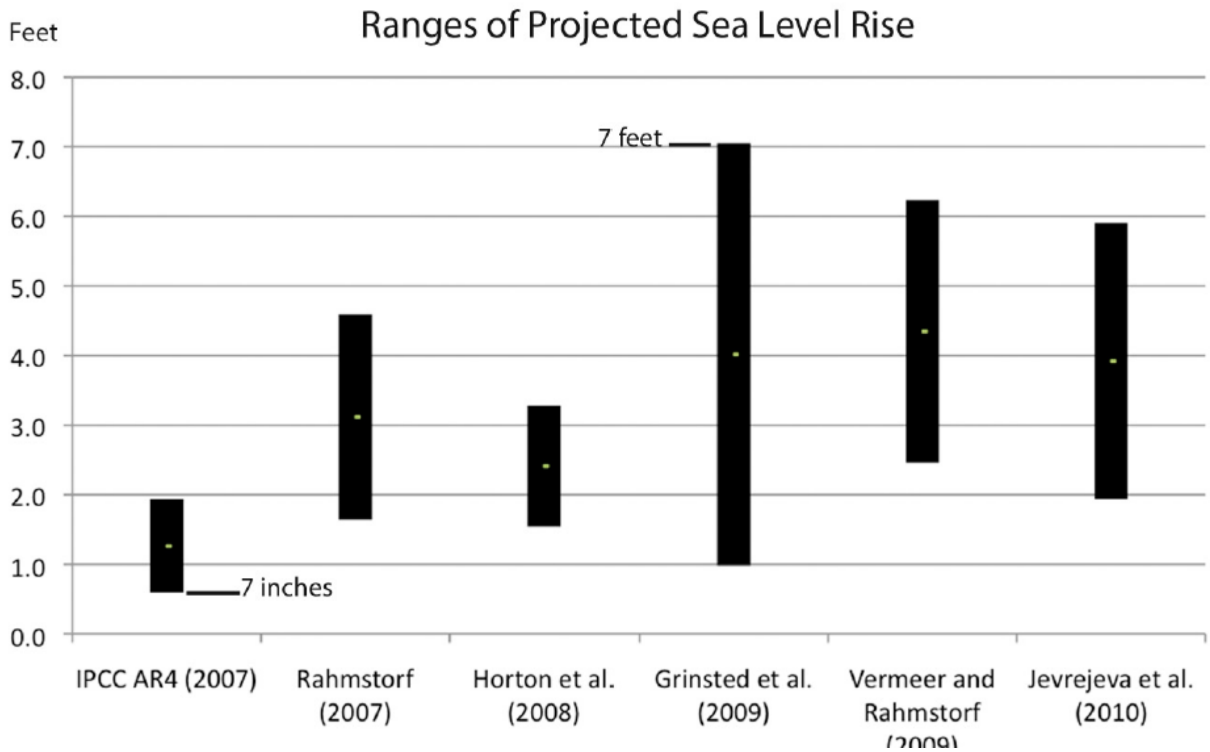


Figure 6-3. Six different projections for sea level rise by year 2100 range from seven inches (18 cm) to seven feet (two meters). Large variation results from varied assumptions about the rate of greenhouse gas emissions and sources of energy over the course of this century. IPCC figures did not include accelerating melt rates in Greenland or Antarctica. Projections do not reflect possibility of catastrophic melting. (Data from Rahmstorf, 2010 .)

http://www.hightideonmainstreet.com/

from: *High Tide on Main Street* by John Englander

Sea Level Rise Accelerating Faster than Initial Projections

http://www.climatecentral.org/news/sea-level-rising-faster-than-ipcc-projections-says-new-study-15293

Comparing climate projections to observations up to 2011

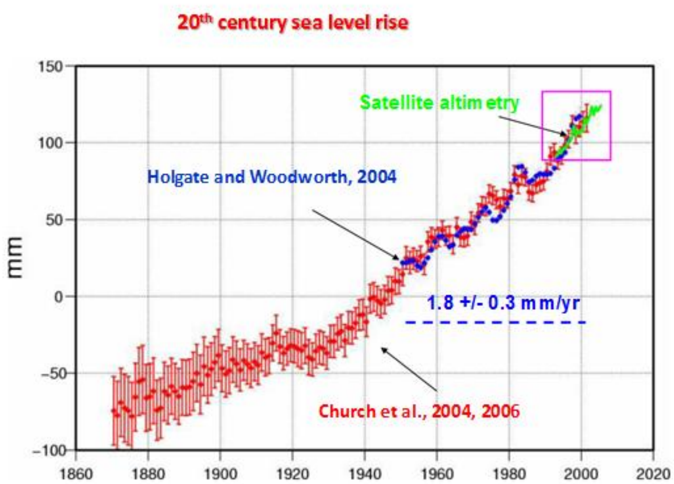
http://iopscience.iop.org/1748-9326/7/4/044035/article

Stefan Rahmstorf[1], Grant Foster[2] and Anny Cazenave[3]

Pumping groundwater raises sea level- Two new studies flag an underreported factor in global ocean change. "In recent years, sea level has been rising around 3.1 millimeters each year. Besides groundwater depletion, other major contributors include the melting of glaciers and polar ice fields, and the expansion of ocean water as it heats up. By 2003, groundwater removal was responsible for about 34 percent of that sea-level rise,"

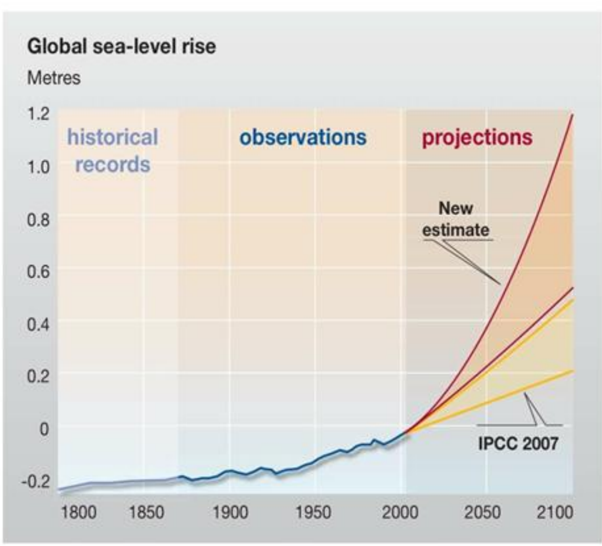
http://www.sciencenews.org/view/generic/id/340873/title/Pumping_groundwater_raises_sea_level (2012)

The next four graphs were taken from a talk by Anne Giblin, lead scientist of Plum Island Ecosystems Long Term Ecological Research 2012.



In the time period from 1850-2009, global average sea level has risen 17 cm, or an average of 1.7 mm per year. In the period from 1950-2009, the rate has increased to an average of 3.3 mm per year (http://en.wikipedia.org/wiki/Current_sea_level_rise).

Sea level is rising, and the rate of sea level rise has been increasing, and is expected to continue increasing at a more rapid rate.



"Sea level rose by 6 cm during the 19th century and 19 cm in the 20th century"
http://adsabs.harvard.edu/abs/2008GeoRL..3508715J

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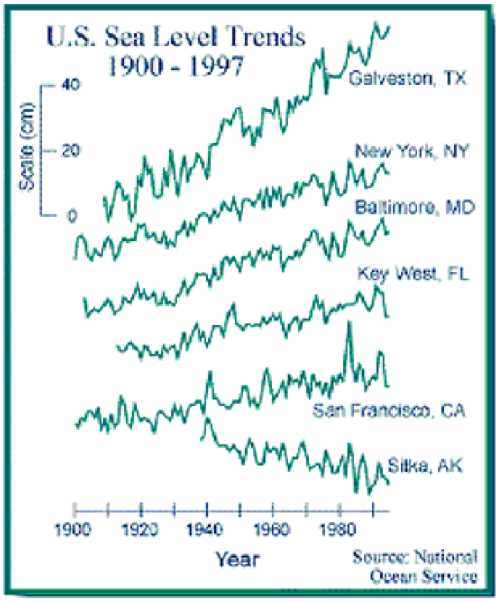
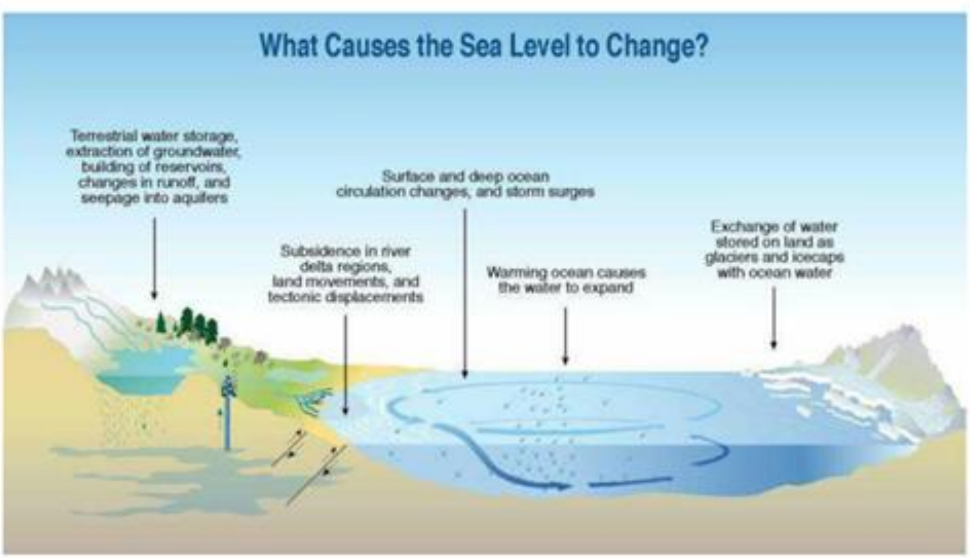


Sea level rise varies in different locations because in some areas the land is sinking or rising relative to sea level. Also not that the rate of changes is not constant but varies from year to year. These annual variations can be fairly large.

Locally other factors matter Subsidence, glacial rebound, changes in currents



Appendix

New Draft Generation Science Standards (2014)

Middle School Next Generation Standards:

MS.Matter and Energy in Organisms and Ecosystems

MS.Matter and Energy in Organisms and Ecosystems

MS-LS2-4. Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations. [Clarification Statement: Emphasis is on recognizing patterns in data and making warranted inferences about changes in populations, and on evaluating empirical evidence supporting arguments about changes to ecosystems.]

MS.Human Impacts

MS.Human Impacts

Students who demonstrate understanding can:

MS-ESS3-2. Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects. [Clarification Statement: Emphasis is on how some natural hazards, such as volcanic eruptions and severe weather, are preceded by phenomena that allow for reliable predictions, but others, such as earthquakes, occur suddenly and with no notice, and thus are not yet predictable. Examples of natural hazards can be taken from interior processes (such as earthquakes and volcanic eruptions), surface processes (such as mass wasting and tsunamis), or severe weather events (such as hurricanes, tornadoes, and floods). Examples of data can include the locations, magnitudes, and frequencies of the natural hazards. Examples of technologies can be global (such as satellite systems to monitor hurricanes or forest fires) or local (such as building basements in tornado-prone regions or reservoirs to mitigate droughts).]

MS-ESS3-3. Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment. [Clarification Statement: Examples of the design process include examining human environmental impacts, assessing the kinds of solutions that are feasible, and designing and evaluating solutions that could reduce that impact. Examples of human impacts can include water usage (such as the withdrawal of water from streams and aquifers or the construction of dams and levees), land usage (such as urban development, agriculture, or the removal of wetlands), and pollution (such as of the air, water, or land).]

HS-ESS2-2. Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems. [Clarification Statement: Examples should include climate feedbacks, such as how an increase in greenhouse gases causes a rise in global temperatures that melts glacial ice, which reduces the amount of sunlight reflected from Earth's surface, increasing surface temperatures and further reducing the amount of ice. Examples could also be taken from other system interactions, such as how the loss of ground vegetation causes an increase in water runoff and soil erosion; how dammed rivers increase groundwater recharge, decrease sediment transport, and increase coastal erosion; or how the loss of wetlands causes a decrease in local humidity that further reduces the wetland extent.]

High School Next Generation Standards

HS.Human Impacts

HS.Human Impacts

Students who demonstrate understanding can:

HS-ESS3-1. Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity. [Clarification Statement: Examples of key natural resources include access to fresh water (such as rivers, lakes, and groundwater), regions of fertile soils such as river deltas, and high concentrations of minerals and fossil fuels. Examples of natural hazards can be from interior processes (such as volcanic eruptions and earthquakes), surface processes (such as tsunamis, mass wasting and soil erosion), and severe weather (such as hurricanes, floods, and droughts). Examples of the results of changes in climate that can affect populations or drive mass migrations include changes to sea level, regional patterns of temperature and precipitation, and the types of crops and livestock that can be raised.]

HS-ESS3-5. Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems. [Clarification Statement: Examples of evidence, for both data and climate model outputs, are for climate changes (such as precipitation and temperature) and their associated impacts (such as on sea level, glacial ice volumes, or atmosphere and ocean composition).] [Assessment Boundary: Assessment is limited to one example of a climate change and its associated impacts.]

Connections to **MA Draft Revised Science and Technology/Engineering Standards (January 2014)**

http://www.doe.mass.edu/stem/review.html

Next Generation Science Standard	Corresponding Massachusetts Standard
MS-LS2-4	**MS-LS2-4. Analyze data to provide evidence that disruptions (natural or human-made) to any physical or biological component of an ecosystem can lead to shifts in all its populations.** [Clarification Statement: Focus should be on ecosystems characteristics varying over time, including disruptions such as hurricanes, floods, wildfires, oil spills, and construction.]
MS-ESS3-2	**MS-ESS3-2. Obtain and communicate information on how data from past geologic events are analyzed for patterns and used to forecast the location and likelihood of future catastrophic events.** [Clarification Statement: Geologic events include earthquakes, volcanic eruptions, floods, and landslides. Examples of data typically analyzed can include the locations, magnitudes, and frequencies of the natural hazards.] [Assessment Boundary: Assessment does not include analysis of data nor forecasting.]
MS-ESS3-3 (the state merged this standard with MS-ESS3-4)	**MS-ESS3-4. Construct an argument supported by evidence that human activities and technologies can be engineered to mitigate the negative impact of increases in human population and per capita consumption of natural resources on the environment.** [Clarification Statement: Arguments should be based on examining historical data such as population graphs, natural resource distribution maps, and water quality studies over time. Examples of negative impacts can include changes to the amount and quality of natural resources such as water, mineral, andenergy supplies.]
HS-ESS2-2, the state did not change this (originally HS-ESS2-b)	**HS-ESS2-2. Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth's systems.** [Clarification Statement: Examples should include climate feedbacks, such as how an increase in greenhouse gases causes a rise in global temperatures that melts glacial ice, which reduces the amount of sunlight reflected from Earth's surface, increasing surface temperatures and further reducing the amount of ice. Examples could also be taken from other system interactions, such as how the loss of ground vegetation causes an increase in water runoff and soil erosion; how dammed rivers increase groundwater recharge, decrease sediment transport, and increase coastal erosion; or how the loss of wetlands causes a decrease in local humidity that further reduces the wetland extent.]

HS-ESS3-1	**HS-ESS3-1. Construct an explanation basedon evidence for how the availability of key natural resources and changes due to variations in climate have influenced human activity**. [Clarification Statement: Examples of key natural resources include access to fresh water (such as rivers, lakes, and groundwater), regions of fertile soils (such as river deltas), high concentrations of minerals and fossil fuels, and biotic resources (such as fisheries and forests). Examples of changes due to variations in climateinclude changes to sea level and regional patterns of temperature and precipitation.]
HS-ESS3-5	**HS-ESS3-5. Analyze results from global climate models to describe how forecasts are made of the current rate of global or regional climate change and associated future impacts to Earth systems.** [Clarification Statement: Climate model outputs include both climate changes (such as precipitation and temperature) and associated impacts (such as on sea level, glacial ice volumes, or atmosphere and ocean composition).] [Assessment Boundary: Assessment is limited to one example of a climate change and its associated impacts.]

Mass Audubon School Programs

At Mass Audubon we strive to create learning experiences that are enriching, innovative, meaningful, and engaging. All our school programs are aligned with Massachusetts Curriculum Frameworks. Our network of wildlife sanctuaries and nature centers located in urban, suburban, and rural communities around the state enable us to have strong relationships with local schools.

Our Education Foundations

- Place-based education is an educational philosophy that connects learning to what is local for an individual. We help build conservation communities, working with students and teachers in cities and towns to develop place-based environmental education that is linked directly to their home community.
- Inquiry-based learning is focused on teamwork, being learner-centered, questioning ourselves and the world around us, providing a more focused, time-intensive exploration, promoting lifelong learning, communication, and learning as fun.
- We are fully committed to creating a positive and supportive environment for all learners.
- We strive to be culturally sensitive, recognizing and embracing cultural differences.

Differentiated Instruction

- We strive to create a positive learning environment that is inclusive, supportive to all learners, and sensitive to cultural diversity.
- Outdoor classroom experiences are structured to meet the needs of the particular learners.
- Students work in small groups using hands-on materials.
- A variety of educational media are used, including colorful illustrations.
- With advance notice, efforts will be made to accommodate all learning styles and physical needs.

Notes

- Nature exploration is dependent upon the weather and other conditions. A class might observe different wildlife than they expected to see. An outdoor lesson can sometimes provide unexpected, but enriching teachable moments on a natural history topic that was not planned.
- Mass Audubon nature centers each have a unique landscape and will customize programs to work best at their particular site.
- Our lessons can be adapted to incorporate a classroom teacher's needs.