The purpose of this lesson is to increase student understanding of Sea Level Rise impacts on our coastline and to increase student contributions to community-citizen science efforts that help municipal planners and climate change scientists.

**Introduction**

Two of the most important environmental issues of our time are how to address the rate of climate change and how to protect and sustain the health of coastal ecosystems. Coastal systems are especially vulnerable to climate change impacts such as ocean acidification, changes in ocean temperatures and sea level rise. The coast attracts people because of its beauty, environmental richness and economic values. It supports those near and far from the shores by providing food and other resources, trade and transportation, nurtures our souls and our need for outdoor recreation.

Global sea level rise is primarily attributed to changes in ocean volume due to two factors: melting of land-based ice and thermal expansion of seawater. The changes in air temperature have increased the melting of glaciers, land ice and continental ice masses contribute significant amounts of freshwater to the Earth's oceans. In addition, the increase of global air temperature creates an expansion of saltwater molecules, thereby increasing ocean volume. Planning for both the present and the future health and safety of our coastlines requires understanding long term trends in sea level and the relationship between global and local sea level changes.

**Goals**

1. Students will demonstrate increased knowledge about the impacts of climate change on sea level rise and an understanding of the science understanding and predicting sea level rise.
2. Students will engage in citizen/community science as volunteers by collecting and contributing photographic evidence of tidal heights during tidal extremes.
3. Students will effectively communicate their observations to the global King Tides Project community, and to members of their own community.
4. Students will be able to explain the impacts of climate change caused sea level rise on environmental, biological and social systems and give examples of strategies used in adaptation efforts.

**Background**

The rate of sea level rise continues to increase over the past two centuries, impacting coastal communities economically, environmentally, ecologically or culturally placing coastal communities on the front lines of climate change. While coastal areas only represent 17% of the continental land in the United States, over half of the population resides and works in coastal areas. These communities are on the front line and will directly experience the impacts of sea level rise in addition to other climate change impacts.
The impacts of climate change induced sea level rise include but are not limited to:

- More frequent (and more extensive flooding, which puts lives, homes, and businesses at risk)
- Erosion, which causes damage to man made structures
- Loss of natural habitats, that impact jobs such as fisheries and tourism,
- Damage to structures such as roads, and residences and
- Saltwater intrusion into drinking water supplies and agriculture areas.

What is sea level rise and why does it matter? Sea level is the measure of height of the Earth’s ocean. There are both global and local or regional sea level measurements, which may differ as there are many factors that effect these measurements including tides, currents, seasonal and decadal changes. Ice melt and thermal expansion of the ocean are the two main contributors to sea level rise over the last century. While there was very little change in sea level over the two thousand years prior to near the end of the 19th century, the height has risen on average 1.7 mm per year (.07 inches) according to the IPCC report. This trend has increased over the last two decades where sea level has risen at a rate of more than 3 mm/year (.12 inches). Both coastal tidal gauges and satellite telemetry demonstrate these findings.

Local sea level is a measure of the height of the ocean relative to a vertical point on land, typically a tide station measures local sea level. The land-water interface changes with subsidence and in other cases land being pushed slowly upward, thus time must also be defined.

Daily sea level heights change with tides, storms, wind and melting or flooding. Long term variations can include seasonal and decadal changes such as El Nino/La Nina conditions and Pacific Decadal Oscillation. Sea Level trends are measured over multiple decades to reduce errors and to account for these influences.

The IPCC report indicates with very high confidence that coastal systems and low-lying areas will increasingly experience adverse impacts such as submergence, coastal flooding and
coastal erosion due to relative sea level rise over the next century. The report also indicates with high confidence that beaches, sand dunes and cliffs currently eroding will continue to do so under increasing sea level.

Additional explanation can be found at: http://climate.nasa.gov/key_indicators/

Thermal expansion explained http://ed.ted.com/featured/3KsJMLba

Materials:
Chart paper and pens
Shrinking Ice, Rising Seas video animation http://climate.nasa.gov/climate_reel/MeltingIceRisingSeas640360/
Internet access or copies of tide charts
Method to photograph tides

**Prior knowledge: basic understanding of tides. NOAA’s tides tutorial can be found at http://oceanservice.noaa.gov/education/kits/tides/tides01_intro.html

Procedures

Engage: What do we know about climate change and sea level rise?

1. Ask the students what do they already know about sea level rise?

2. Create list of what they know, what they want to know, and what information they question or they would list as a misconception they’ve heard. These lists will be modified throughout this lesson.

3. Explain that sea level rise is one impact of climate change. Ask students why is the issue climate change so prevalent in the news?

4. Assign students to review and share with the class an article or video on climate change; specifically sea level rise if possible. (Help students to define what is a trusted or credible source.)

Note to teacher: guide students to think about whether Sea Level Rise will impact them individually.

5. Look at and update the established lists from the previous session based upon the student shared articles.

6. Have students view Shrinking Ice, Rising Seas NASA video http://climate.nasa.gov/climate_reel/MeltingIceRisingSeas640360/

7. Discuss what do we know and what is still challenging for scientists studying sea level rise. Have students discuss how they think that these questions might be answered.
Sea Level Rise – from Classroom to Citizen Science

Explore: What evidence can we use to see potential and current changes in sea level rise?

King tides are the very highest tides that occur at each place. They:
• occur naturally and regularly,
• are predictable and expected, and
• are not an every day occurrence.

During extreme high tide events, we can get an idea of what a permanent rise in sea level might look like in our communities in the future. That is because these king tides – the highest tides of the year – will be the average daily tides of the future. In the San Francisco Bay Area, the king tide of today is what the average daily high tide will be by about 2050 (i.e., within the lifetime of the students).

Have students in small groups review the previously captured images of king tides from the attached list or from other sources, and discuss the following questions in preparation to share their observations with the rest of the group. You may wish to have students find images that can be grouped before they look at the questions below.

Student questions:
1. What risks do you see from increased tidal levels?
2. How would you categorize the impact of the tide shown? (it may effect more than one area)
   a. effects public recreation and access
   b. effects coastal habitats
   c. effects coastal agriculture
   d. effects cultural resources
   e. effects coastal development
   f. effects groundwater aquifers - freshwater sources

3. Identify where and when the photo was taken and what the tide height was on that date.
4. Why did you group your photo with others, what characteristics do the photos share?

Have students report out to the group their findings.
• Why would people want to take photos and contribute them to the project?

As a class discuss how scientists and community leaders might use this array of photos including:
1. Document current flood risk in coastal areas
2. Visualize the impacts of future sea level rise in their community
3. Ground-truth and validate climate change models by comparing model predictions with the high-tide reality
4. Serve as a living record of change over time for future generations
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See King Tides Initiative http://california.kingtides.net/how-are-king-tides-photos-used/

**Explain:** How can we forecast sea level rise for the future?

The steady rise in sea levels has been attributed to both a warming expansion of the oceans and contributions from melting glaciers and land-based ice sheets. Climate modeling combined with direct observations from tidal gauges and satellites suggest sea level rise will continue well into the future with significant implications for California's coastal communities.

Satellites provide a measure of the sea surface height. To gain an understanding of how satellites have built our knowledge by watching the Sea Level Viewer Overview at http://climate.nasa.gov/interactives/sea_level_viewer

Some environments will be squeezed out or eroded with sea level rise; other terrestrial environments and populations will need to retreat from the coast to survive both economically and ecologically. Ascertaining how far to retreat to better ensure long-term success is difficult to determine without modeling.

Scientists use models to understand the universe. A model is a physical or mathematical object, idea, mechanism or system that helps to explain a phenomena that cannot be seen due to scale, time or inability to experience it directly. Models are critical to scientists being able to communicate their work. They serve as a simplified representation and enable predictions. Scientists use known current and past data in testing their model to see if the model fits the data. They are then able to predict what is likely to happen. There may be several models for the same question. Inaccuracy in a model can be from not having enough data. Climate models are often computerized and need to be continually tested and revised as we gain new data, thus continuing to refine our knowledge about climate.

Together with the class look at sea level predictions http://www.csc.noaa.gov/digitalcoast/tools/slrviewer and discuss the following questions.

- What is expected to happen in your larger community?
- Which areas or surrounding areas are especially vulnerable?
- How will sea level rise effect recreation, infrastructure and residences?
- How will sea level rise effect you?
- If you plan to photograph for the King Tides Initiative, where would be the best location near you to photograph and why?

More information on models can be found at:
Elaborate: Contributing to Community Science

Join the King Tides Project by selecting areas in your region to take photos not only during the highest high tides of the year but also when there are extremely high waves or storm surge. Plan your photo shoot in advance. Where can you collect data to support a project or fill in a data gap (where there are few king tide photos). Check your local tide chart for the tidal prediction. First of all be safe. Don’t go into areas where there is dangerous surf. Take extra precautions before you step on slippery surfaces and watch sets of waves to ensure where you are photographing will not put you in harm’s way. Take photos from a distance to show relationships with structures.

Some extraordinary images taken in coastal areas are in those areas subject to flooding and erosion, including places where high water levels can be gauged against familiar landmarks (such as buildings, breakwaters, roads, bridge supports, sea walls, staircases, dikes, and piers). A listing of recommended places to take pictures that contribute to specific projects can be found at http://california.kingtides.net/when/

Once you have taken pictures submit your photos. Recommendations are found at: http://california.kingtides.net/share-pictures/

The pictures you take may help scientists better understand which areas are most at risk of flooding and future sea level rise. Researchers will compare your photos of the high tide against computer simulations of flooding to see how well these simulations match reality. This is a fun, easy way for you to provide important information that will help future sea level rise adaptation planning efforts.

Regional and local governments planning for the future rely upon scientific data to select the best solution for their constituents to better prepare under the conditions of a higher sea level. This approach is to use adaptation planning where designs and plans take into account shifting environments and incorporate strategies to reduce economic and social risks. These strategies may include planned retreat, moving back from the coast, alternative building materials, installing more permeable surfaces, protective structures, increased flood proofing, identifying and protecting vulnerable populations, and much more.

More on the need for adaptation planning http://www.ted.com/talks/vicki_arroyo_let_s_prepare_for_our_new_climate

Evaluate: How do you share what you’ve learned?

1. Have students serve as stewards as they create and outreach to others sharing a presentation about sea level rise for their chosen audience. This could include other classes at the school, a school newspaper article, students in another school, community panels or organizations.

2. Include in the presentation an overview of what is Sea Level Rise, how it is caused and what is the evidence we have for this, what are some of the risks to your community and what can be done to reduce risks.
Sea Level Rise – from Classroom to Citizen Science

Common Core Standards

Listening and Speaking

Comprehension and Collaboration:
CCSS.ELA-Literacy.SL.6-8.1
Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade level topics, texts, and issues, building on others' ideas and expressing their own clearly.

Presentation of Knowledge and Ideas:
CCSS.ELA-Literacy.SL.6.4
Present claims and findings, sequencing ideas logically and using pertinent descriptions, facts, and details to accentuate main ideas or themes; use appropriate eye contact, adequate volume, and clear pronunciation.

CCSS.ELA-Literacy.SL.6.5
Include multimedia components (e.g., graphics, images, music, sound) and visual displays in presentations to clarify information, emphasize salient points and add evidence.

CCSS.ELA-Literacy.SL.6.6
Adapt speech to a variety of contexts and tasks, demonstrating command of formal English when indicated or appropriate. (See grade level Language standards 1 and 3)

Comprehension and Collaboration:
CCSS.ELA-Literacy.SL.9-12.1
Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grades 9-12 topics, texts, and issues, building on others' ideas and expressing their own clearly and persuasively.

Presentation of Knowledge and Ideas:
CCSS.ELA-Literacy.SL.9-12.4
Present information, findings, and supporting evidence, conveying a clear and distinct perspective, such that listeners can follow the line of reasoning, alternative or opposing perspectives are addressed, and the organization, development, substance, and style are appropriate to purpose, audience, and a range of formal and informal tasks.

CCSS.ELA-Literacy.SL.9-12.5
Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest.

CCSS.ELA-Literacy.SL.9-12.6
Adapt speech to a variety of contexts and tasks, demonstrating a command of formal English when indicated or appropriate. (See grades 11-12 Language standards 1 and 3 here for specific expectations.)

CA Science Standards

6th grade
2. d. Students know earthquakes, volcanic eruptions, landslides, and floods change human and wildlife habitats.
4. d Students know convection currents distribute heat in the atmosphere and oceans.
7. e. Recognize whether evidence is consistent with a proposed explanation.
f. Read a topographic map and a geologic map for evidence provided on the maps and construct and interpret a simple scale map.
g. Interpret events by sequence and time from natural phenomena (e.g., the relative ages of rocks and intrusions).

7th grade
4. a. Students know Earth processes today are similar to those that occurred in the past and slow geologic processes have large cumulative effects over long periods of time.
Sea Level Rise – from Classroom to Citizen Science

7. d. Construct scale models, maps, and appropriately labeled diagrams to communicate scientific knowledge (e.g., motion of Earth’s plates and cell structure).

e. Communicate the steps and results from an investigation in written reports and oral presentations.

9th – 12th grades

Ecology
6. Stability in an ecosystem is a balance between competing effects. As a basis for understanding this concept: a. Students know biodiversity is the sum total of different kinds of organisms and is affected by alterations of habitats. b. Students know how to analyze changes in an ecosystem resulting from changes in climate, human activity, introduction of nonnative species, or changes in population size.

Earth Science
5. Heating of Earth’s surface and atmosphere by the sun drives convection within the atmosphere and oceans, producing winds and ocean currents. As a basis for understanding this concept: a. Students know how differential heating of Earth results in circulation patterns in the atmosphere and oceans that globally distribute the heat.

6. Climate is the long-term average of a region’s weather and depends on many factors. c. Students know how Earth’s climate has changed over time, corresponding to changes in Earth’s geography, atmospheric composition, and other factors, such as solar radiation and plate movement. d.* Students know how computer models are used to predict the effects of the increase in greenhouse gases on climate for the planet as a whole and for specific regions.

7. b. Students know the global carbon cycle: the different physical and chemical forms of carbon in the atmosphere, oceans, biomass, fossil fuels, and the movement of carbon among these reservoirs.

8. b. Students know how the composition of Earth’s atmosphere has evolved over geologic time and know the effect of outgassing, the variations of carbon dioxide concentration, and the origin of atmospheric oxygen.

9. b. Students know the principal natural hazards in different California regions and the geologic basis of those hazards. c. Students know the importance of water to society, the origins of California’s fresh water, and the relationship between supply and need.

Investigation and Experimentation
1. d. Formulate explanations by using logic and evidence. g. Recognize the usefulness and limitations of models and theories as scientific representations of reality.

Climate Literacy Principles: found at http://www.cleanet.org/cln/climateliteracy.html
5 Our Understanding of the Climate System is Improved through Observations, Theoretical Studies and Modeling - C

6 Human Activities are impacting the climate system
B, C, D

7 Climate Change will Have Consequences for the Earth System and Human Lives
A and D

Ocean Literacy Principles: found at http://oceanliteracy.wp2.coexploration.org/

2 The ocean and life in the ocean shape the features of the Earth

6 The ocean and humans are inextricably interconnected

Education in the Environment Initiative found at http://www.californiaeei.org/

Next Generation Science Standards found at http://www.nextgenscience.org/next-generation-science-standards
Resources
oceans climate dance poster and associated activities http://sealevel.jpl.nasa.gov/education/posters/jason1poster/
tips and tricks for using NASA’s global climate change website http://climate.nasa.gov/education/TipsandTricks/
Windows to the Universe climate and sea level rise http://www.windows2universe.org/earth/climate/cli_sea_level.html
Common misconceptions about climate change http://cires.colorado.edu/education/outreach/climateCommunication/CC%20Misconceptions%20Handout.pdf
NOAA’s sea level trends http://tidesandcurrents.noaa.gov/sltrends/sltrends.shtml
NOAA’s frequently asked questions about sea level desandcurrents.noaa.gov/sltrends/faq.shtml#q1

Shrinking Ice, Rising Seas NASA video – includes scientist interviews http://climate.nasa.gov/climate_reel/MeltingIceRisingSeas640360/

NASA 2 minute video role of carbon in climate change - The Carbon Crisis in 90 seconds http://climate.nasa.gov/climate_reel/CarbonClimateChange

http://climate.nasa.gov/climate_reel/MeltingIceRisingSeas640360/

National Geographic article on sea level rise impacts from climate change http://ngm.nationalgeographic.com/2013/09/rising-seas/folger-text


Thank You Ocean King Tides Initiative video http://www.youtube.com/watch?v=y4Soho0Fd0E

US EPA intro to King Tides http://www2.epa.gov/cre/king-tides-and-climate-change
STUDENT WORKSHEET

As a group discuss the risks from increased tidal level that shown in the photo and prepare to share back with the group your observations.

How would you categorize the risk of increased sea level?

<table>
<thead>
<tr>
<th>IMPACTS</th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effects coastal habitats</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Effects coastal agriculture</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Effects coastal resources</td>
<td></td>
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<tr>
<td>Effects coastal development</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Effects groundwater aquifers – freshwater sources</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Effects public recreation and access</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other:</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Compare the when the photo was taken with the date and time of high/low tide that day. You may look up the tides for the date the photo was taken on line.

- Photo location: _____
- Date of photo: _____
- Time of high tide: _____
- Time of low tide: _____

Why do you think people would want to volunteer to take photos documenting extreme tidal heights?

Why do you think the photo(s) you viewed was selected as an example?

Plan what you will report out to your group.
Sea Level Rise – from Classroom to Citizen Science

Photo links for San Francisco Bay area and beyond

Photos by Kelsey Ducklow,
Marine Stadium, Long Beach, CA, January 31, 2014, 3:45 pm,  
https://www.flickr.com/photos/92644156@N07/12295409536/in/pool-cakingtides

Marine Stadium, Long Beach, CA, January 31, 2014, 8:45 am
https://www.flickr.com/photos/92644156@N07/12294841175/in/pool-cakingtides/

Tiberon, CA, Elephant Rock, December 31, 2013, 5:30 pm
https://www.flickr.com/photos/92644156@N07/12241300585/in/pool-cakingtides/

Tiberon, CA, Elephant Rock, December 31, 2013, 11:58 am
https://www.flickr.com/photos/92644156@N07/12241300245/in/pool-cakingtides/

Embarcadero, San Francisco, January 2, 2014, 11:45 am, photo by Bimu Shrestha
https://www.flickr.com/photos/92644156@N07/12091681333/in/pool-cakingtides/

Photos by Claire Fackler, NOAA
Campus Point, Santa Barbara, CA, January 29, 2014, 8:48 am,
https://www.flickr.com/photos/clairefackler/12213513974/in/pool-cakingtides/

Campus Point, Santa Barbara, CA, January 29, 2014, 8:44 am
https://www.flickr.com/photos/clairefackler/12213114965/in/pool-cakingtides/

Campus Point, Santa Barbara, CA, January 29, 2014, 2:51 pm
https://www.flickr.com/photos/clairefackler/12213513314/in/pool-cakingtides/

Photos by Tom Mikkelson
Marina Bay- Richmond, CA, January 29, 2014, -1.26 tidal height
https://www.flickr.com/photos/tmikkphoto/12225141366/in/pool-cakingtides/

Marina Bay- Richmond, CA, January 29, 2014, +7.75 tidal height
https://www.flickr.com/photos/tmikkphoto/12225142546/in/pool-cakingtides/

Marina Bay- Richmond, CA, January 29, 2014, +7.75 tidal height
https://www.flickr.com/photos/tmikkphoto/12224962584/in/pool-cakingtides/

Marina Bay- Richmond, CA, January 29, 2014, -1.26 tidal height
https://www.flickr.com/photos/tmikkphoto/12224962464/in/pool-cakingtides/

Marina Bay- Richmond, CA, January 29, 2014,
https://www.flickr.com/photos/tmikkphoto/12225143436/in/pool-cakingtides/
https://www.flickr.com/photos/tmikkphoto/12225143586/in/pool-cakingtides/

Bay Trail Sausalito, CA, January 1, 2014,
https://www.flickr.com/photos/tmikkphoto/11700807984/in/pool-cakingtides/
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https://www.flickr.com/photos/tmikkphoto/11680113305/in/pool-cakingtides/

Buchanan Street Marsh, CA, December 30, 2013
https://www.flickr.com/photos/tmikkphoto/11680896956/in/pool-cakingtides/
https://www.flickr.com/photos/tmikkphoto/11680896836/in/pool-cakingtides/
https://www.flickr.com/photos/tmikkphoto/11680894606/in/pool-cakingtides/

Berkeley Pier, CA, December 30, 2013
https://www.flickr.com/photos/tmikkphoto/11680365373/in/pool-cakingtides/
https://www.flickr.com/photos/tmikkphoto/11680475174/in/pool-cakingtides/

Photo by Tom Hilton
Embarcadaro, Pier 14, San Francisco, CA, January 29, 2014, 7:40 am
https://www.flickr.com/photos/tomhilton/12225011886/in/pool-cakingtides/

Photos by Abe Doherty
Tomales Bay Resort, Inverness, CA, December 31, 2013, 11:30 am
https://www.flickr.com/photos/113781824@N04/113781824@N04/11830514475/in/pool-cakingtides/

Inverness Store Parking Lot, CA, 11:50 am, December 31, 2013
https://www.flickr.com/photos/113781824@N04/113781824@N04/11830951314/in/pool-cakingtides/

Inverness Yacht Club, Tomales Bay, CA, December 31, 2013, 11:55 am
https://www.flickr.com/photos/113781824@N04/113781824@N04/11830815193/in/pool-cakingtides/

Photo by Dave R
Pacifica Pier, Pacifica, CA, December 1, 2012
https://www.flickr.com/photos/tmikkphoto/11700807984/in/pool-cakingtides/

Agriculture Building, Embarcadaro, San Francisco, CA, February 14, 2011

Photos by Lindsay Kingston
Kirby Park Nature Trail, August 8, 2013,
https://www.flickr.com/photos/97276503@N02/97276503@N02/9465737901/in/pool-cakingtides/

South Marsh, Elkhorn Slough Reserve, August 8, 2013,
https://www.flickr.com/photos/97276503@N02/9465712967/in/pool-cakingtides/

Tijuana River Estuary, August 6, 2013
https://www.flickr.com/photos/97276503@N02/9457519342/in/pool-cakingtides/