Activity 1: Explore NVS apps: find all the different features (part free exploration, part scavenger hunt, part "what could you do with this?")

Outline:

1. Go to nvs.nanoos.org
2. Click on the App "Shellfish Growers"
3. Explore the App. If you're having a hard time deciding what to do, try to following:
    a. Click on "Layers": What do you notice? What options do you have? What information can you find this way?
    b. Click on "Platforms": how does this change the map?
    c. Click on "Plots": what choices does this give you? What information can you find this way?
    d. Click on one of the "Platforms" on the map (the "Platforms" button on the left must be turned on).
    e. Find the "Settings" button. What choices do you have? You will need to be able to find this tab in case you want to switch back and forth between "Common" and "Scientific" units.
4. Use this link to navigate to a pre-set screen in the App: http://nvs.nanoos.org/ShellfishGrowers?snapshot=bc60042aba07392ad4e4d708b3103
    a. Which platform is being highlighted? Take a screenshot (or 2!) to support your answer.
    b. Scroll through the right-hand panel, titled "Observations". What information is shown in these plots? Can you find the following information?
        i. Current CO_2 concentration in the water.
        ii. Current pH
        iii. Chlorophyll concentration at a depth of 20ft
        iv. At what depth(s) is the water the warmest?
        v. At what depth(s) is the water the saltiest?
    c. Click on "Air Temperature" in the right hand panel. A graph should pop up at the bottom. Answer the following questions:
        i. What time period is shown on the graph?
        ii. What do you notice about the data? Why do you think it has this pattern?
    d. Click on "Chlorophyll" (the data should pop up on graph at the bottom). Note: chlorophyll is contained within phytoplankton, the tiny plants that live in the ocean. This is the same pigment that makes leaves green. Frequently, oceanographers measure chlorophyll as a way of figuring out where the phytoplankton are living.
        i. Is this data a point measurement (i.e. a measurement at a single depth) or a full-depth measurement? How do you know?
        ii. If you hover your cursor over the graph at the bottom, you will see a for the amount of chlorophyll at that time/depth. What is the maximum chlorophyll value on August 1 at 12:19am?
        iii. At approximately what depth is there the most chlorophyll (i.e. phytoplankton)? How does this change over time? Does this surprise you?
        iv. In late July and early August, the maximum chlorophyll values are frequently over 30 μg/L (micro-grams per liter)
        v. If Oysters eat phytoplankton (indicated by chlorophyll), what is the maximum depth at which you think oysters could successfully live?
    e. Click on "Details" and record the latitude and longitude of this Platform. Who collects this data?
    f. If you have extra time, identify a question you have about Puget Sound and see if you can find the answer.
5. Finally, navigate to this link:

http://nvs.nanoos.org/Climatology?snapshot=2eac8e27ba08c632c037e42df5750

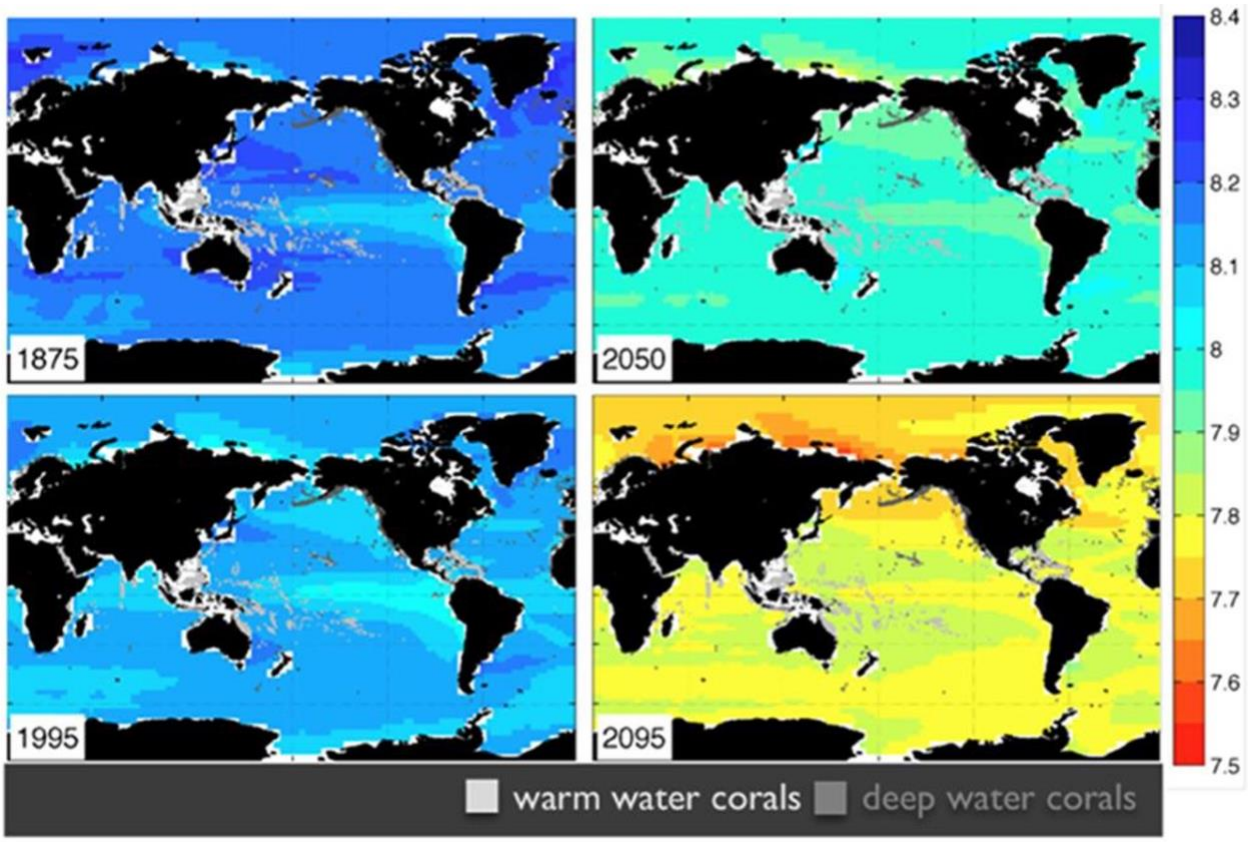
a. This is part of a different App called "Climatology". A climatology is a long-term description of a particular measurement, like Temperature. This App allows you to explore patterns in Temperature, Salinity, and Dissolved Oxygen at different stations.
b. The graph on your screen is for water temperature at 4m below the surface (~13ft). The dark blue line in the middle describes the annual pattern, the gray squiggles show all of the individual measurements, and the light blue line shows the measurements from this year.
    i. How would you describe the average annual pattern (blue line)?
    ii. How would you describe the variation from year to year (light gray lines)?
    iii. What do you notice about the data from August of this year (light blue line)?
    iv. Answer questions (i)-(iii) for water temperature at 25m below the surface. Why do you think this pattern looks different from the 4m pattern?
    v. How could you use this graph to decide where a good location for a shellfish hatchery?
c. Explore the patterns for salinity and dissolved oxygen. Pay attention to changes in the y-axis as you switch between 4m and 25m (sometimes the range is really different which can make interpreting the differences confusing).
    i. What do you notice about the data for dissolved oxygen at 25m for this year compared to the average? If you were a shellfish or fin fish farmer, do you think this would be a problem?

6. Based on your exploration thus far, how do you think you might be able to use these apps to help you make a decision about where to have your business?

Activity 2: Figure analysis from recent study about the effect of OA on different calcifying organisms (just the bivalve part)--what does this tell us about selecting a site for our hatchery?

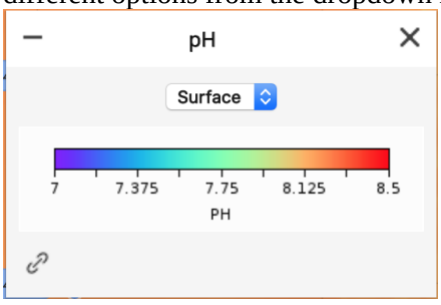
A. Look at the figure below of predicted ocean acidification. Use it to answer the following questions.

1. What would you estimate is the global average pH in 1875?
2. Where do you observe the lowest pH values? Is this true for all years?
3. What is the highest pH you see in the map for the year 2095? What is the lowest pH?



B. Navigate to this link:
http://nvs.nanoos.org/ShellfishGrowers?snapshot=ad42dbe1ba08baeaa7e5b76456101
(If you want to find this again for Activity 3, you can go to nvs.nanoos.org→Shellfish Growers, select "Layers", scroll down to "Forecasts" and select pH, and then zoom in).

This is the same app we used previously, but now we are looking at the predicted pH levels for Puget Sound and the Washington Coast. Note that you can select different depths to look at pH by selecting different options from the dropdown menu:



Use this map (and different dropdown menu options) to answer the following questions:

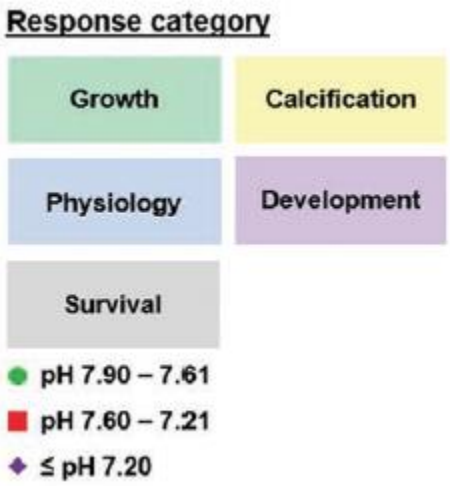
1. What is the highest pH you see on the map?
2. What is the lowest pH you see on the map? (be sure to specify which depth you are talking about)
3. What would you estimate is a typical surface pH for Puget Sound? A typical bottom pH?
4. Where are the highest pHs located? Where are the lowest pHs located?

Compare this map to the global maps you observed above. Which year in the global map has pHs most

similar to those you observed for Puget Sound?

What does this tell you about conditions in Puget Sound right now compared with global ocean conditions?

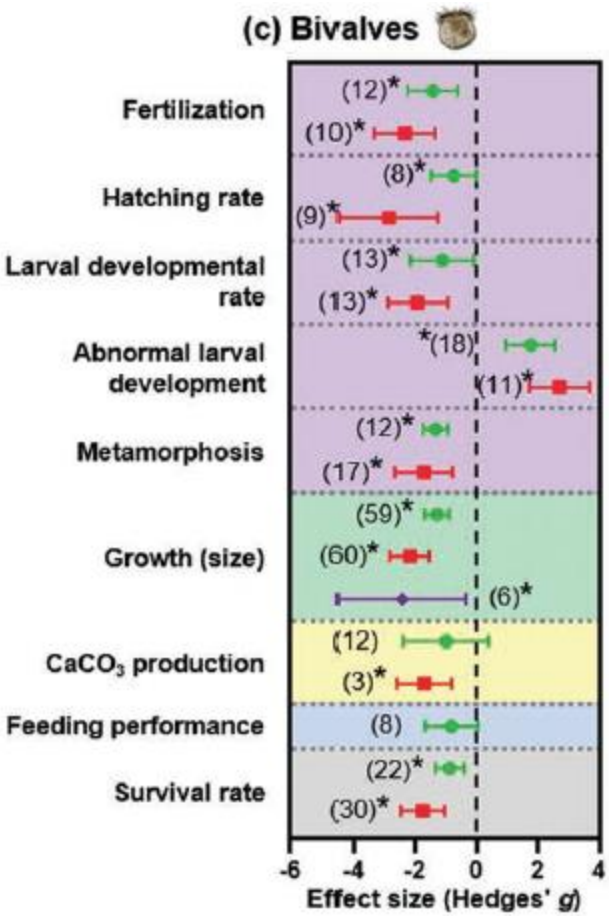
Below is a figure from a scientific paper that was published this summer about the effects of ocean acidification and future climate change conditions on various calcifying organisms (i.e. marine animals that build shells). To make this figure, the scientists looked at lots of research about bivalves (clams, oysters, geoducks, etc) and the pH conditions under which the experiments were done. They then looked at how big an effect different pH conditions had on each aspect of bivalve development, in this case for the larvae. First, let's look at the key that helps us interpret the figure:



–The shading tells us which aspect of animal development the results relate to.
–The color symbols tell us whether the research was about "near-future climate change" (green symbols: pH 7.90-7.61), "far future climate change" (red symbols, pH 7.60-7.21) or "extreme" and possibly unrealistic (purple symbols).

How do these ranges relate to the pH values we currently observe in Puget Sound?

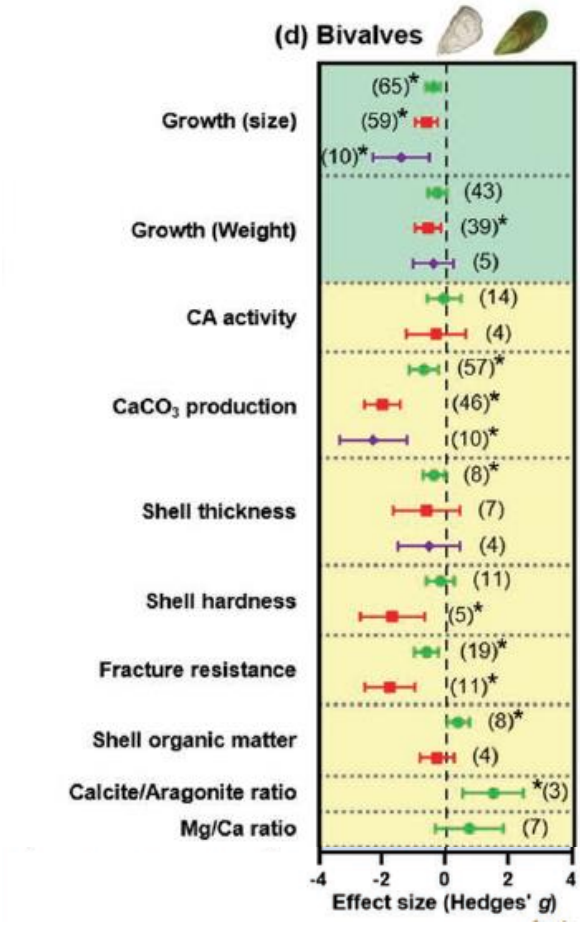
In the figure, a negative number means that the lower pH conditions had a bad/negative/adverse effect on the animals for that category. We'll talk about one example, Fertilization, as a group: what effect do lower pH (ocean acidification) conditions have on Fertilization? In which case is the effect bigger/more extreme/worse? Do we see conditions like this in Puget Sound now?



Which areas of bivalve development seem to be most affected by more acidic conditions? How do you know? How large are the effect sizes? (give an approximate number for fertilization, hatching rate, growth, and survival rate)

The next figure is about adult bivalves.

1. First, notice the scale on the bottom: for larvae, the scale went all the way to -6, whereas for adults it only reaches -4. What do you think this means about the typical size of negative effects in adults compared with larvae?
2. How big are the typical effect sizes? Give an approximate value for growth (size and weight), shell thickness, and shell hardness



If you were a shellfish farmer, which stage of the shellfish life cycle would you be the most concerned about?

What pH values would you try to target for your shellfish hatchery?

Thinking back to your observations of pH in Puget Sound and how pH effects shellfish growth, you should have some good information for one consideration to use in selecting a location for your hatchery.

Activity 3: Pick a sample species: look at their preferred habitat and use tools in NVS apps to select a good location (this will be practice for the project)

In the first two activities, we looked at a lot of information about: current conditions in Puget Sound, project ocean conditions under climate change/ocean acidification, and the effect of these acidifying conditions on shellfish success. For this activity, we're going to build on this and other data about Puget Sound to start thinking about good locations for a shellfish hatchery. You can use this as a foundation for your work later in the project when you are developing your business plan and need to justify your choice of location for the species you want to work with.

Here is what you need to do for this activity:

1. Select an organism from the list below and find its preferred habitat (ideally, temperature and salinity ranges).
2. Review your notes from the previous activity about how shellfish are affected by different pHs. If you need to find the pH map again, you can go to nvs.nanoos.org→Shellfish Growers, select "Layers", scroll down to "Forecasts" and select pH, and then zoom in.
3. Using both the "Shellfish Growers" app, which gives you "real-time" measurements of pH, temperature, and salinity, and the "Climatology" app, which gives you yearly variation, identify one location that would be really bad for a shellfish hatchery and one location that you think would be really good for a shellfish hatchery.
    a. For each location, provide the annual maximum and minimum temperatures, the current pH at the surface and bottom of the water column, and any other information you think is important.
    b. Use the information from (a) and your research about your organism to write a short paragraph justifying why each location is good or bad.
    c. You can use a very similar approach for your final project once you have selected an organism for your business.

Organism resources (temperature range, salinity range, temperature for spawning, etc):

1. Pacific Oyster: https://www.aquariumofpacific.org/onlinelearningcenter/species/pacific_oyster
2. Olympia Oyster: https://www.aquariumofpacific.org/onlinelearningcenter/species/olympia_oyster
3. https://www.fisheries.noaa.gov/find-species
4. Geoduck: https://web.archive.org/web/20111217220815/http://www.agf.gov.bc.ca/fisheries/cabinet/GeoduckFactsheet05_01.pdf
5. Razor clam: https://www.dfw.state.or.us/mrp/shellfish/docs/Life%20History%20of%20the%20Razor%20Clam.pdf

Other Oceanography of Puget Sound resources

1. Have students watch/read something to remind them of what the context is
    a. https://www.pmel.noaa.gov/co2/story/What+is+Ocean+Acidification%3F
    b. https://www.nrdc.org/stories/what-you-need-know-about-ocean-acidification
    c. https://www.youtube.com/watch?v=MgdlAt4CR-4
    d. https://www.youtube.com/watch?v=x7MpI9dZIjk
    e. https://www.youtube.com/watch?v=kxPwbhFeZSw
2. Answer some basic questions before diving into data exploration (including some project connection pieces! Esp what do you need to be thinking about for your shellfish business)
3. Connection to aquaculture piece: location of shellfish hatchery

For students who want to get more into the details on some concepts: could use PhET simulations for different topics (this can be independent work):

1. Greenhouse effect
2. pH basics
3. Chemical equations