Ocean Acidification

The Salmon Race

WOAC

WASHINGTON OCEAN ACIDIFICATION CENTER

Brainstorm

Take a look at your worksheet

Out of all of the data variables, which one do you think tells us the most about ocean acidification?

A. pH

B. Temperature

C. Chlorophyll

D. Salinity

Collaborate

Now out of all the data variables, which one tells us the most about ocean acidification?

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What is Ocean Acidification?

Ocean Acidification (OA) is:

"…the ongoing change in the chemistry of the ocean caused primarily by the ocean's absorption of carbon dioxide from the atmosphere."

– NANOOS

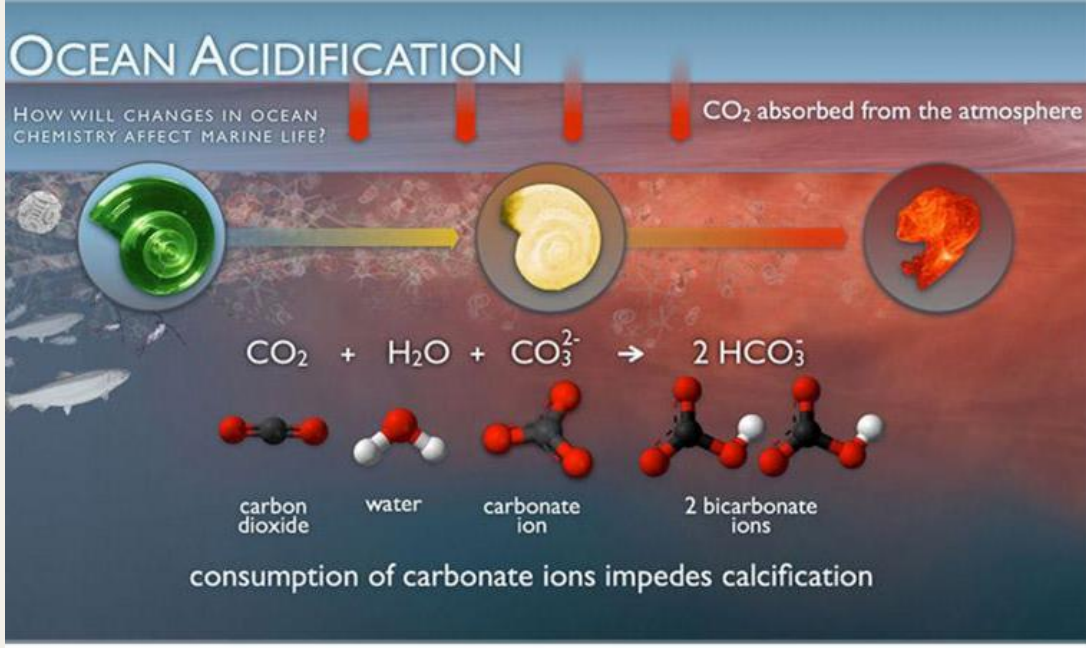
"…the term given to the chemical changes in the ocean as a result of carbon dioxide emissions."
- PMEL/NOAA

"Carbon emissions from the combustion of fossil fuels are causing changes to our atmosphere and our planet, including acidifying our oceans…Once absorbed by the ocean, this carbon dioxide undergoes a series of reactions that change seawater chemistry."
- WOAC

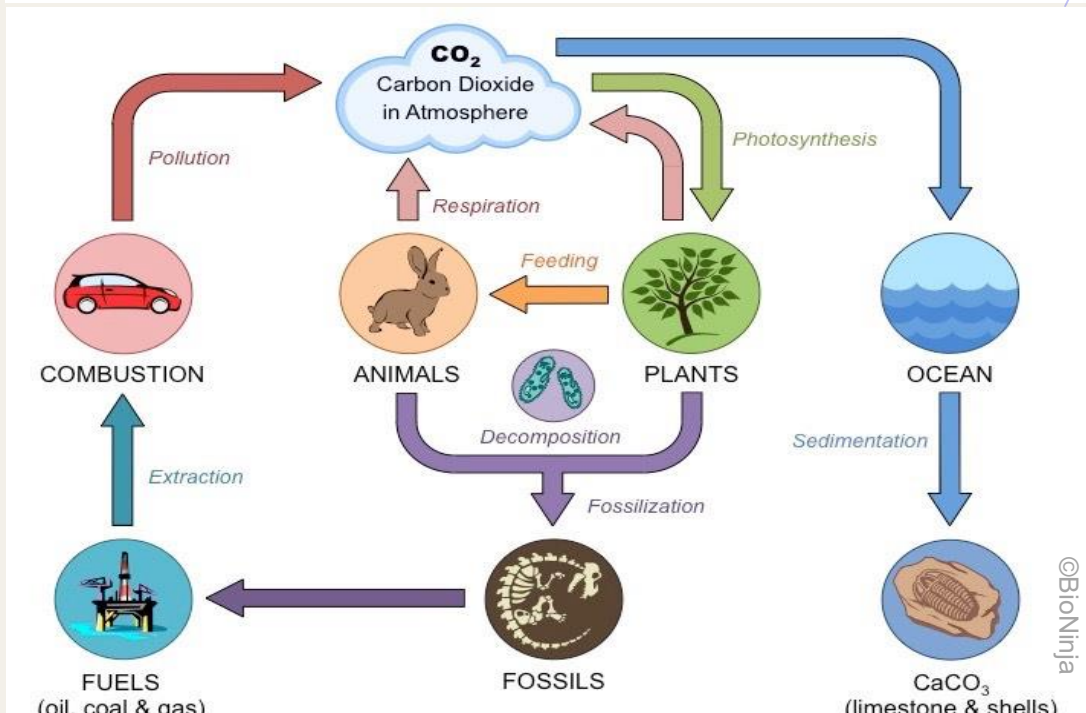
What are some key terms in these definitions provided by leading researchers and programs around ocean acidification? What is similar about these definitions? Different?

What causes OA?

1. In short, **we** are increasing atmospheric CO_2 by:
   + Burning fossil fuels, coal, oil, natural gas for transportation and energy
   + Deforestation, which takes away trees and plants that remove CO_2.
2. The ocean absorbs about 25-30% of the CO_2 released into the atmosphere every year.
   + The carbon cycle is a natural cycle- there is just more CO_2 because of the anthropogenic (human-based) causes.
   + The addition of CO_2 changes the chemistry of seawater by increasing the acidity and lowering the seawater's naturally occurring carbonate ion.
3. When CO_2 is combined with seawater it forms a weak acid (carbonic acid), which then increases the hydrogen ion concentration in the ocean.
4. This lowers the pH, making the oceans less alkaline/more acidified.



Schematic diagram of ocean acidification processes in the sea (image provided by the NOAA Pacific Marine Environmental Laboratory Carbon Group in collaboration with the University of Washington Center for Environmental Visualization).

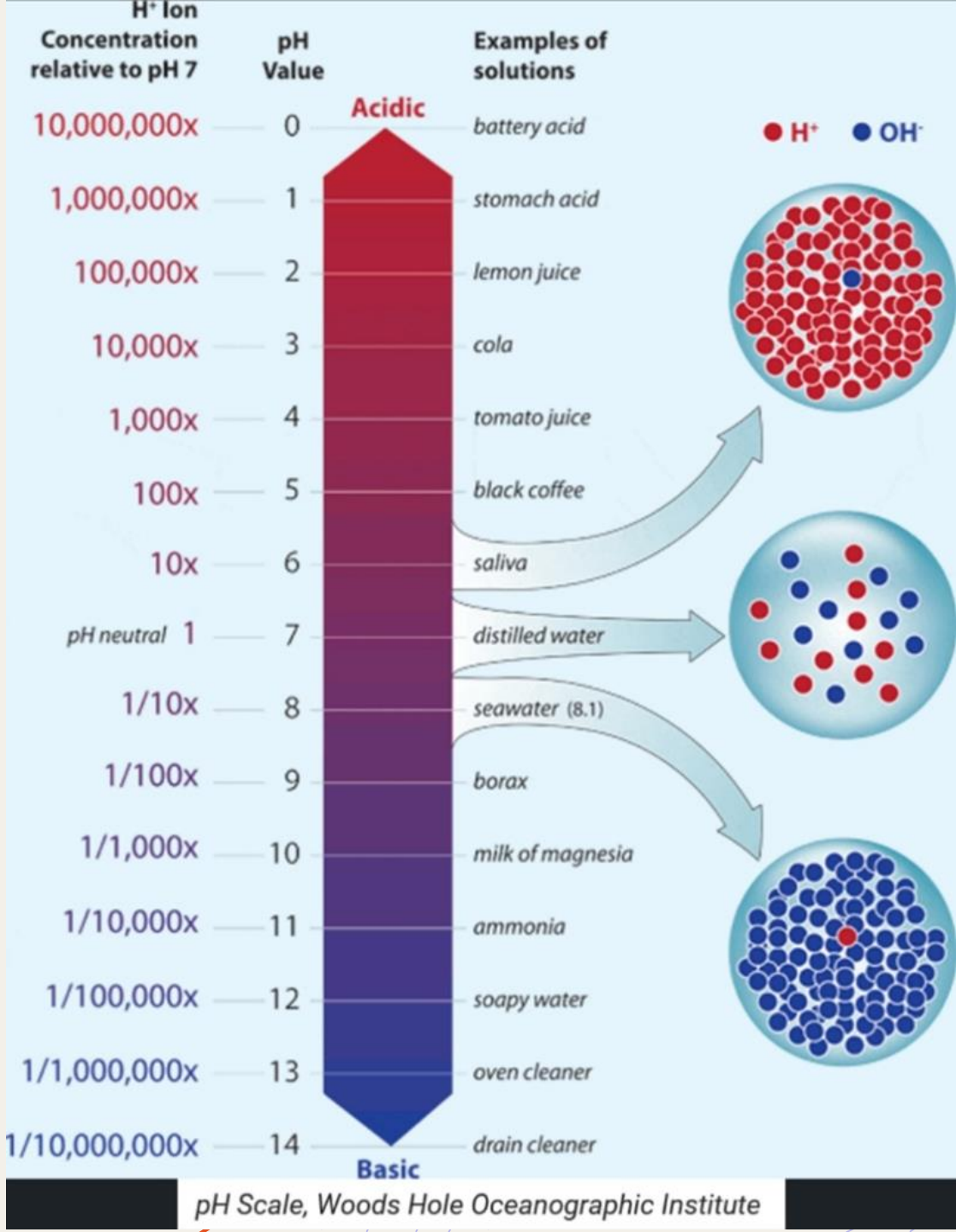


How do we measure for OA?- pH

- OA is indicated by the value of **pH**
  - The pH scale runs from 0-14
- pH measures the concentration of Hydrogen ions
  - pH tells us whether seawater is more **alkaline/basic** or **acidic**
- Pure water has a pH of 7 which is considered neutral
  - Depending on depth, season, and geographic location, seawater pH can range from 7.5 to 8.5.
  - *The ocean's average pH is 8.2 , which is basic (or alkaline), but as the ocean continues to absorb more* CO_2*, pH decreases, and the ocean becomes more acidified. Already, the pH has dropped 0.1, which is 30% because pH is on a logarithmic scale.*

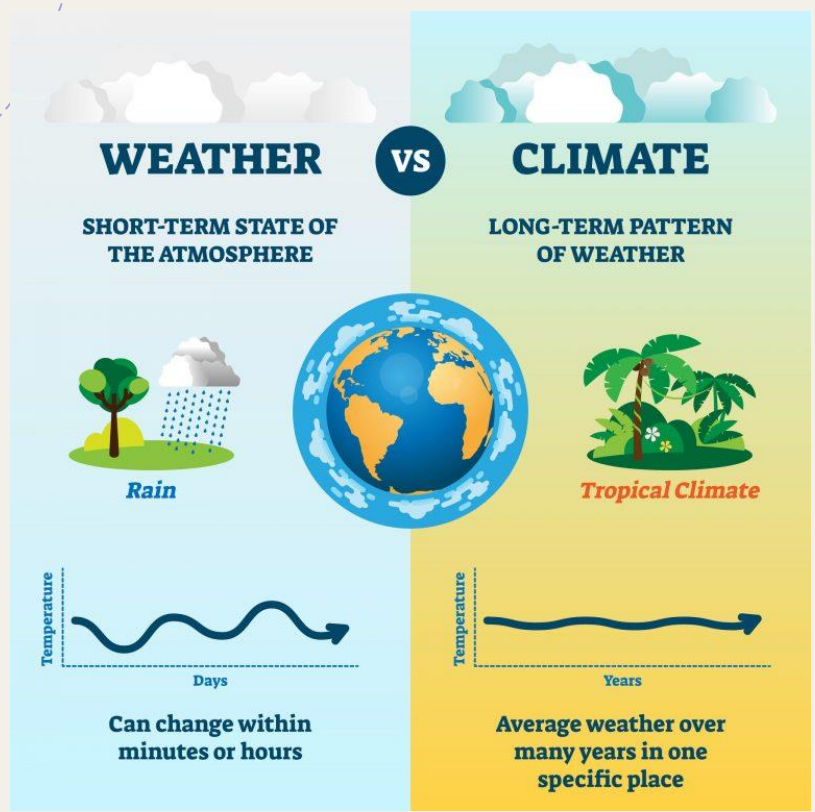
<7 is considered acidic, so *the lower the pH of the water, the more acidic the water is.*

>7 is considered **alkaline/basic** so, *the higher the pH of the water, the less acidic the water is.*



pH Scale, Woods Hole Oceanographic Institute

How does Temperature contribute to OA?



Australian Environmental Education, © normaals.

- **Rising CO_2 in the atmosphere also drives up ocean surface temperatures**
  - Although ocean acidification and ocean warming are different phenomena, they interact, causing negative effects to marine ecosystems.
  - These effects are felt differently depending on geography, depth, and latitude.
  - *How much seawater can absorb CO_2 decreases as temperature of water increases.*
    - Colder waters in the poles absorb more CO_2 than warmer waters by the equator
      - Polar surface waters acidify faster than equatorial ones
      - Equatorial regions of the ocean are *releasing* CO_2 into the atmosphere more than absorbing it. (https://sos.noaa.gov/catalog/datasets/ocean-atmosphere-co2-exchange/)
  - Temperature is the instantaneous measure of the kinetic energy of the molecules of a given substance, like air or water.
    - It is the most measured quantity in the atmosphere. (CIMSS and NOAA)
  - Climate is the long-term average condition in a particular place. (NASA)
    - atmospheric variables - temperature, precipitation, humidity, sunshine, wind velocity
    - ocean variables - temperature, pH, salinity, oxygen

How does Salinity contribute to OA?

Salinity tells us how fresh or salty the seawater is:

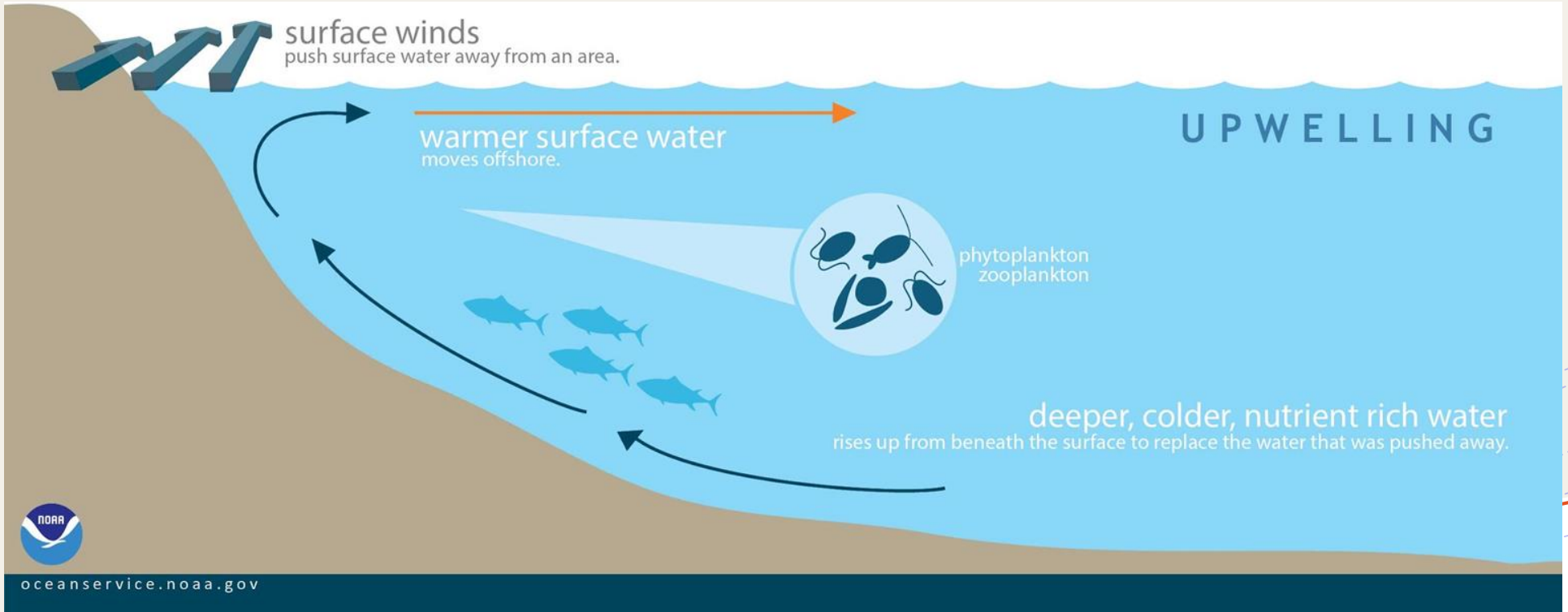
- Rivers contribute freshwater, and river input can affect the pH
- This can be seen in estuaries, river outlets/deltas

In polar regions, elevated sea water temperatures cause glacier and sea ice melting

+ When icebergs melt, they release freshwater into the saltwater of the ocean, therefore reducing salinity

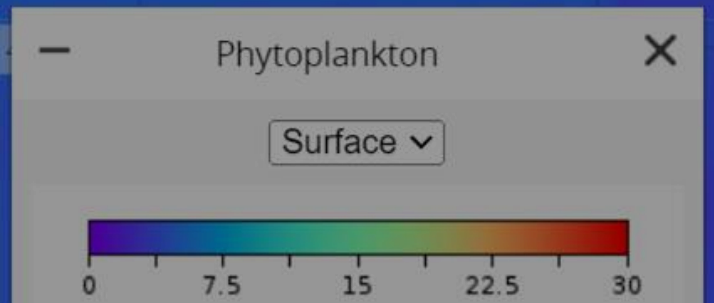
The balance of salinity is important for fish

- When salinity either becomes too high or too low, fish habitat can shift
- Imbalanced transitioning from freshwater to saltwater can affect osmoregulation in salmon (https://www.frontiersin.org/articles/10.3389/fevo.2021.689233/full)



How does Chlorophyll contribute to OA?

- Chlorophyll is an indicator for the biological primary producers that are in the surface of our oceans
- The more chlorophyll that is present=the more abundant algae and phytoplankton are
  - However, some species can have toxins and are known as harmful algal blooms (HABs)

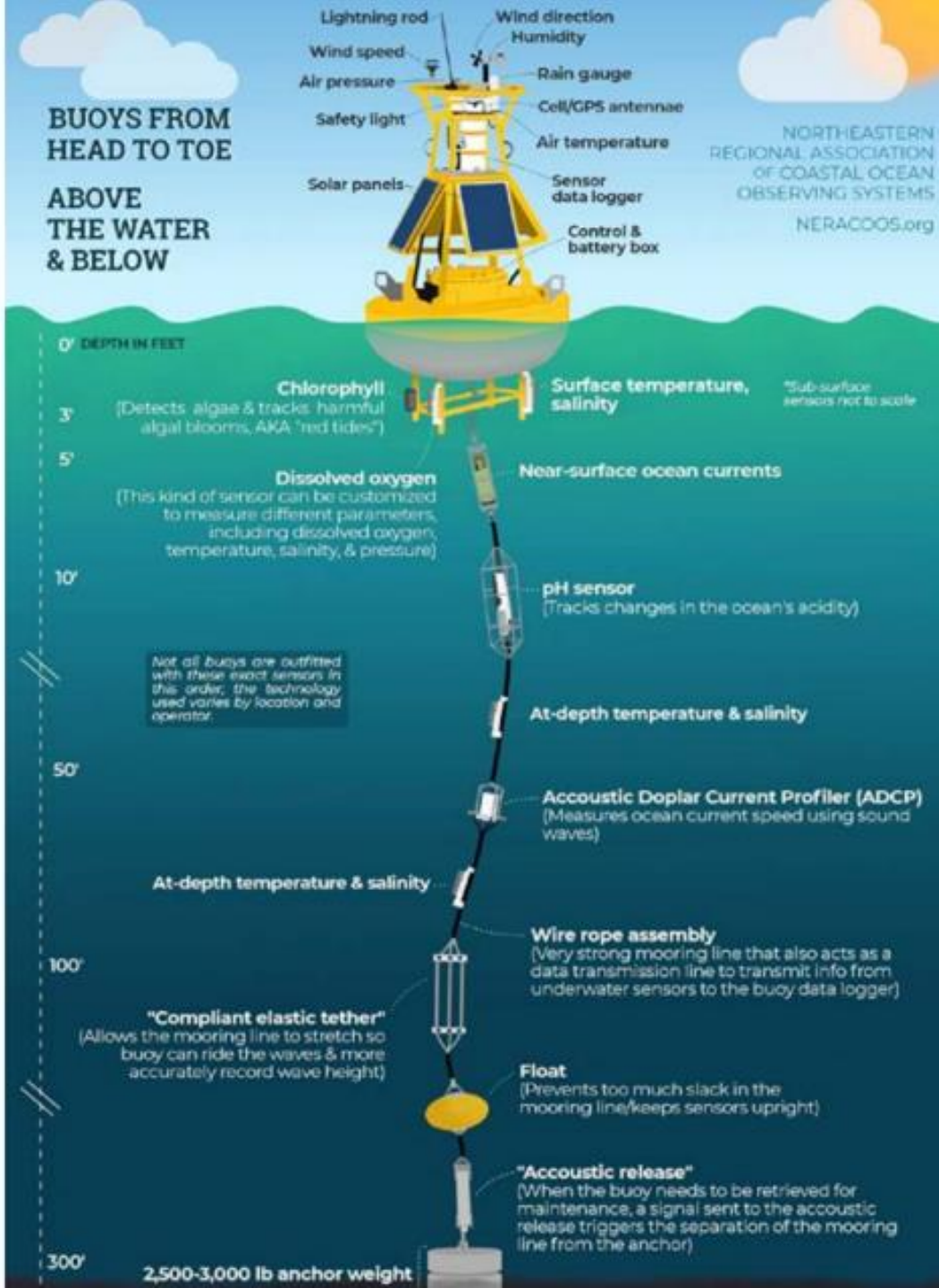


Utilizing Networked Ocean Data for Ocean Observation

-Live Ocean and NVS

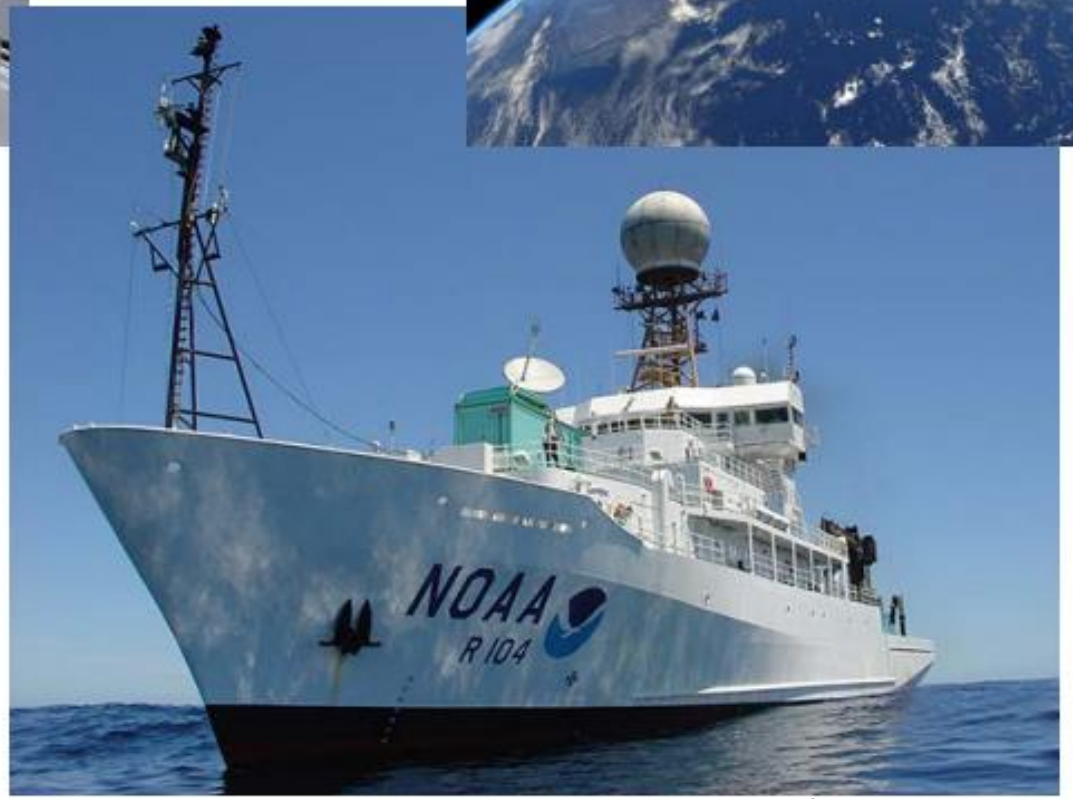
How do we measure the ocean & Puget Sound to see a temperature anomaly?

- Moored buoy system
  - At the surface
  - At the bottom
  - In between



lide from Marine Heatwaves Slide Deck, NANOOS

Other ways to collect measurements?



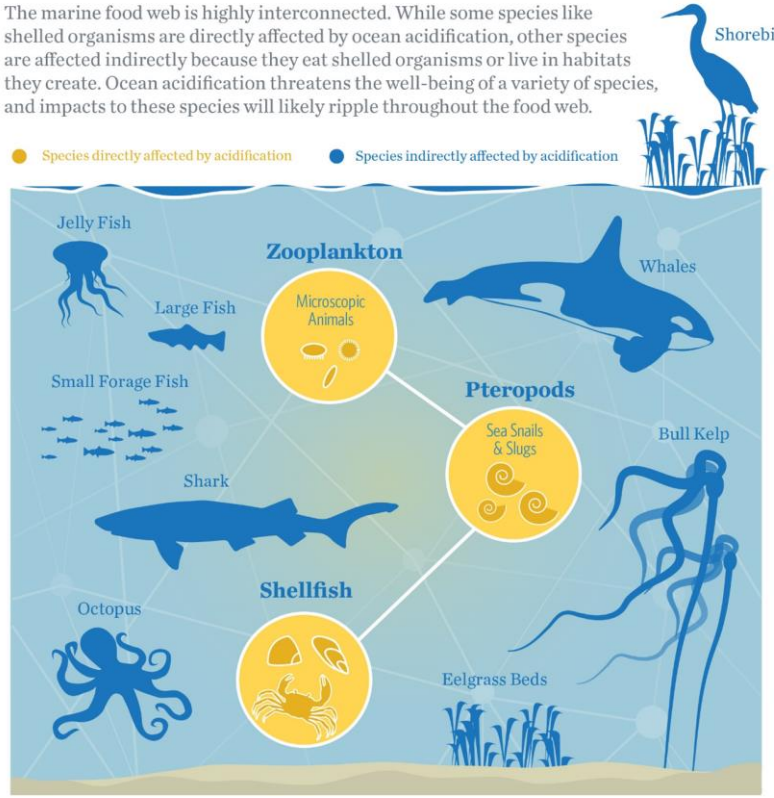
- Buoy
- Cruise
- Float Plane
- HF Radar
- Land Station
- Model
- Moored Array
- River Gauge
- Satellite
- Seabed Sensor
- Seaglider
- Shellfish Raft
- Shore Station

Slide from Marine Heatwaves Slide Deck, NANOOS

Here's why OA is an issue:

Nina Bednaršek, SeaDoc Society (2018)

- **People have various relationships with the ocean**
  - Food source
  - Natural resources
  - Sense of place/culture
- **Effects on Daily Life/Ecosystems**
  - Reduces the amount of carbonate in water
    - Less building blocks for organisms requiring calcium carbonate like the shellfish people like to eat and coral reefs, which provide habitat and tourism
  - Loss of food
    - Pteropods, or sea butterflies, are a vital food source for salmon and other commercially important fish like mackerel, herring, cod, and even whales
  - Loss of olfactory senses in some fish
    - This is important as some of the salmon species with this behavior are endangered

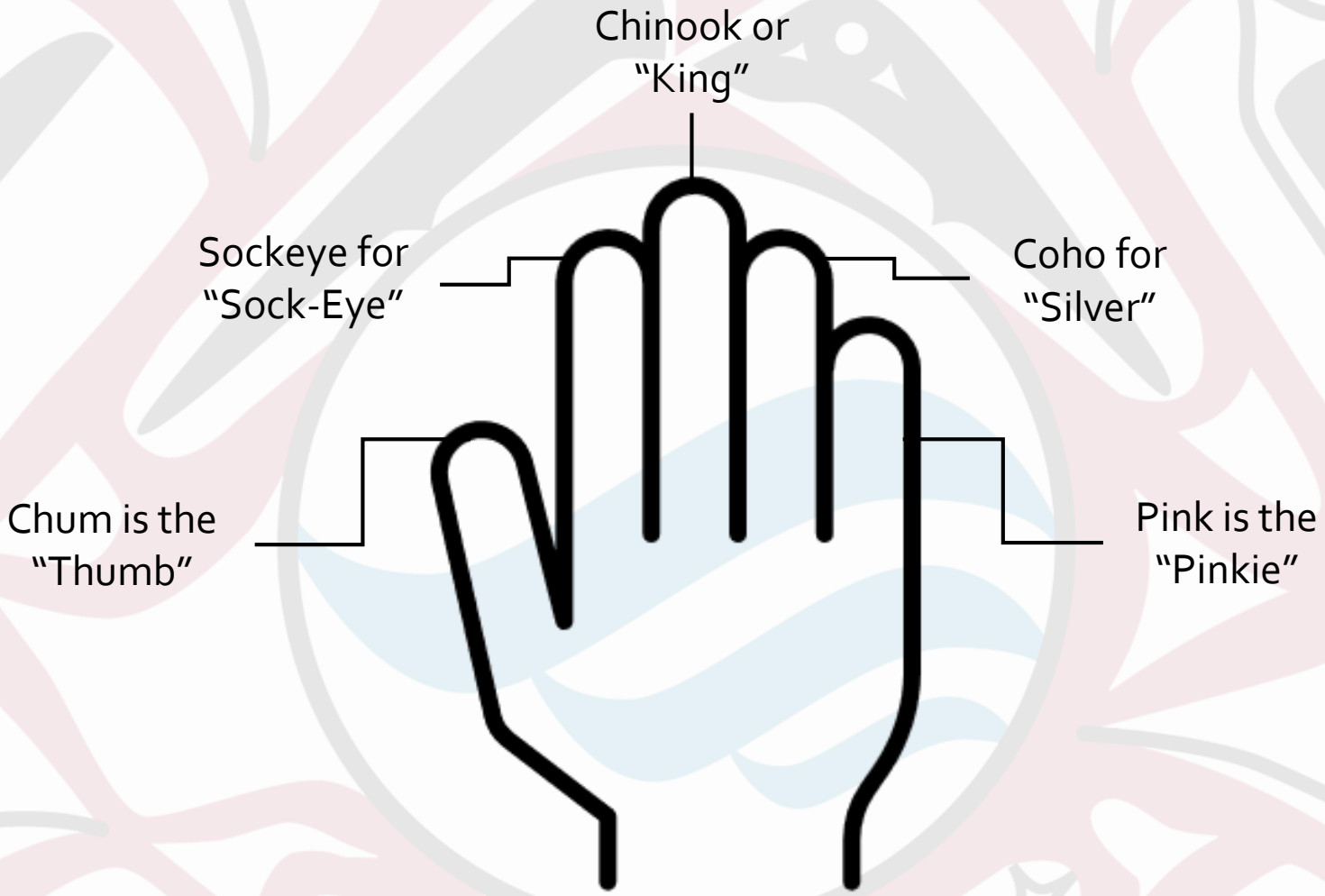


Washington State Blue Ribbon Panel on Ocean Acidification (2012)

Brainstorm

Take a look at your worksheet

What do you already know about salmon, and what makes them important in the Pacific Northwest? (You can include examples of culture, diet, other animal species, and natural resources).


Chinook or
"King"
Sockeye for
"Sock-Eye"
Coho for
"Silver"
Chum is the
"Thumb"
Pink is the
"Pinkie"

Salmon ID

Salmon Facts- Coloration

Pink Salmon
Oncorhynchus gorbusha

Chinook Salmon
Oncorhynchus tshawytscha

Sockeye Salmon
Oncorhynchus nerka

Chum Salmon
Oncorhynchus keta

Coho Salmon
Oncorhynchus kisutch

Salmon Facts- Size and Abundance

Ranked from most abundant to least abundant*

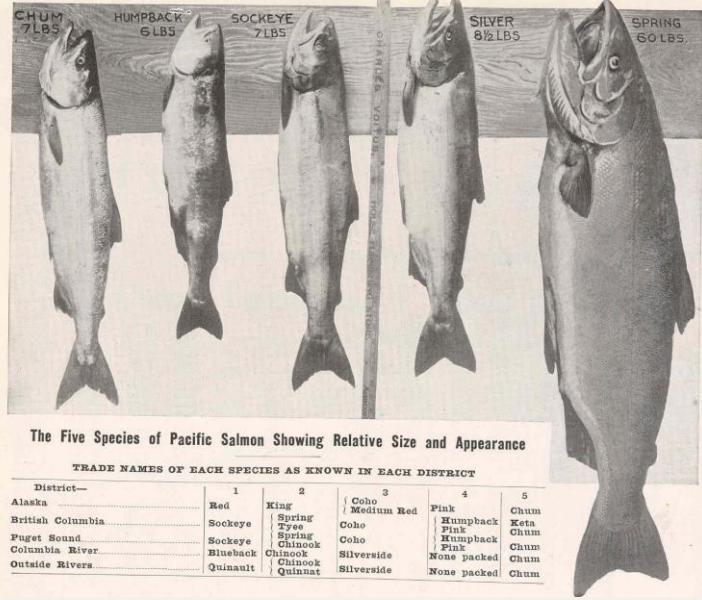
1. Pink- status unknown, more populous in odd years
2. Chum- 2 populations Threatened under ESA
3. Sockeye- 1 population listed as Endangered; 1 population listed as Threatened under ESA
4. Coho- Many individual stocks are not overfished, but 1 is listed as Endangered, and 3 are considered Threatened under ESA
5. Chinook- 2 populations Endangered, and 7 Threatened under ESA

Ancient Chinook Sizes

The n → Now

© Salmon for All, orig. photo in 1936

©East Fork Outfitters and Columbian News, 2021



The Five Species of Pacific Salmon Showing Relative Size and Appearance

TRADE NAMES OF EACH SPECIES AS KNOWN IN EACH DISTRICT

District—	1	2	3	4	5
Alaska	Red	King	Coho / Medium Red	Pink	Chum
British Columbia	Sockeye	Spring / Tyee / Spring	Coho	Humpback / Pink	Keta / Chum
Puget Sound	Sockeye	Chinook	Coho	Humpback / Pink	Chum
Columbia River	Blueback	Chinook	Silverside	None packed	Chum
Outside Rivers	Quinault	Quinnat	Silverside	None packed	Chum

University of Washington, Freshwater and Marine Image Bank, 1921

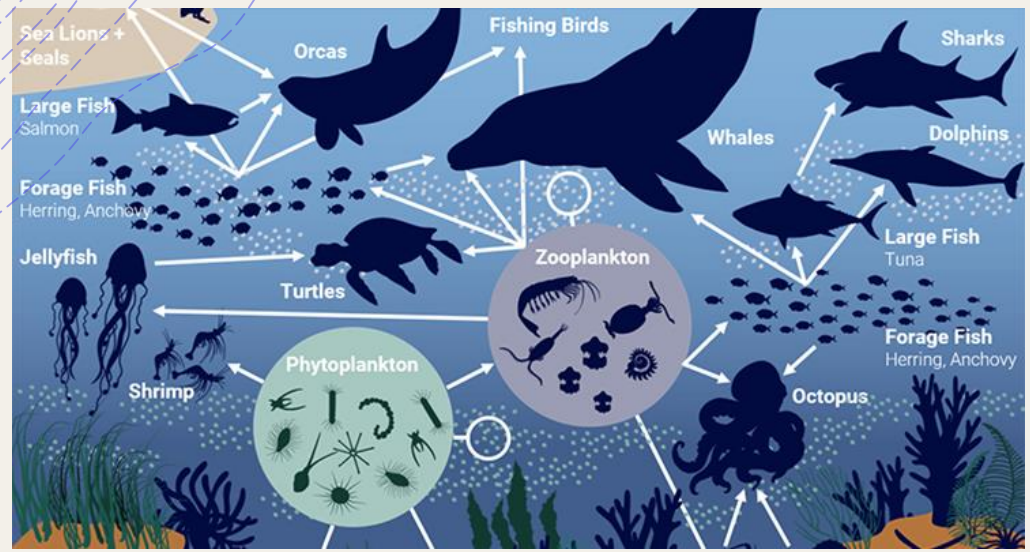
Ranked from largest to smallest*

- Chinook <4.9 ft.
- Chum <3.6 ft.
- Coho 2-2.5 ft.
- Sockeye 1.5-2.5 ft.
- Pink 1.6-2 feet

*Data used from NOAA and Endangered Species Act (ESA) listings,

*This does not include fat %, or width-- only length and weight

Salmon need Phytoplankton!



©Kathryn Wilson, Seattle Aquarium

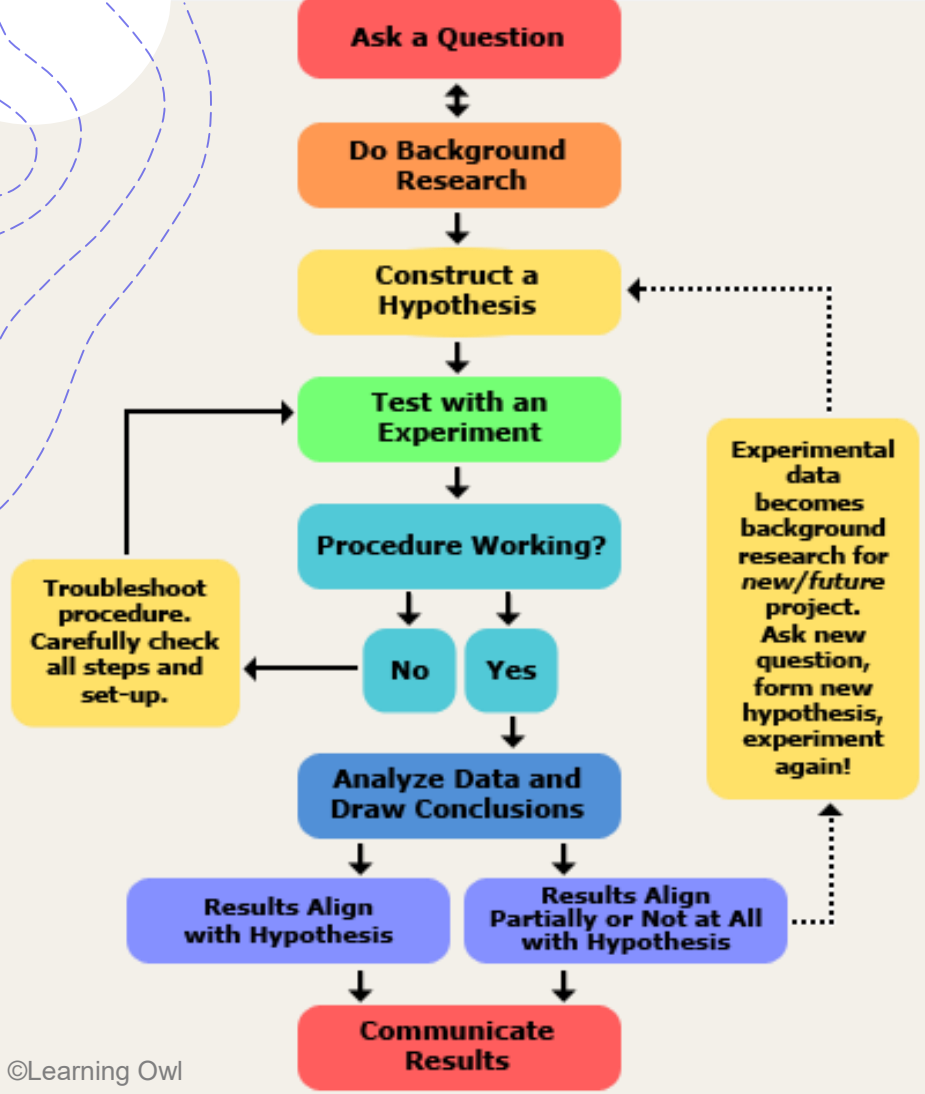
The Ecosystem Food Web

The marine food web relies primarily on phytoplankton as they are *primary producers* and foundational species of the food web

Zooplankton, example being pteropods, are shelled organisms that use carbonate to build their shells

Other organisms are indirectly affected because they eat these organisms or live in habitats that these organisms create

When phytoplankton homeostasis is threatened, their lack of existence will negatively ripple through the food web



Scientific Method: *the process of objectively establishing facts through testing and experimentation*

Vocab to Know

Homeostasis	pH	Chlorophyll
Phytoplankton	Temperature	Salinity
Endangered	Threatened	Ocean acidification

Creating Hypotheses:

If____then____because

Example: If the pH value of the ocean is too low, then the coho salmon will not make it back to its home river, because their olfactory senses will be weaker.

Computer Lab Time!

Salmon Race

Leading Research Question: Based on what you may/may not know about salmon already, make a hypothesis as to which salmon species from which river you think will win based on what you know about OA variables.

(Remember to use the format: If___then___because)

Instructions

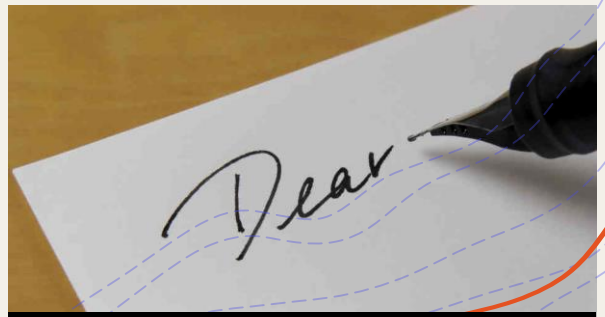
1. Choose your salmon group
2. Go to www.nanoos.org
3. Navigate to the NANOOS Visualization System (NVS).
4. The homepage of NVS will take you to a variety of Apps. Click on the *Data Explorer* app for this exercise.
5. Assign yourself as a moderator, note taker, reporter, or navigator
6. Follow further instructions provided on your worksheet.

Share Out

What can we do to protect salmon and mitigate OA?

Everyone has the capability to slow down climate change effects in our ocean:

1. Dispose of your trash properly and wash your car at a car wash!
   + Protects our waterways
2. Utilize reusable and compostable materials
   + Offer to others a swap that is better for the planet
   + Use what you have
3. Carpool and take public transportation!
   + Use less gas emissions, take the bus, and bike
4. Contact policy makers and government officials
   + Advocate for conservation of species and habitats
5. Understand Tribal Treaty Rights
   + Tribes as stewards of the land and sea have treaties that guarantee the right to protect and use natural resources



Learn More!

Information Page for OA at NANOOS

Participate in Long Live the Kings with your class

Understand the history of treaty rights for tribal communities from the Northwest Indian Fisheries Commission (NWIFC)

What lands do you reside on?

More things you can do to protect salmon and our ocean

Acknowledgements

- **Jan Newton** – NANOOS Executive Director, WOAC Co-Director
- **Rachel Wold** - NANOOS Education and Outreach Lead
- **Ava Hays** – WOAC/NANOOS Intern with UW Earthlab

NAME:_____ DATE:_____

Ocean Acidification Worksheet

Brainstorming and the Scientific Method

Brainstorming

1. Out of all of the data variables, which one do you think would be the most important regarding ocean acidification?
    A. pH
    B. Temperature
    C. Chlorophyll
    D. Salinity

2. Jot what you already know about salmon, and what makes them important in the Pacific Northwest. (You can include examples of culture, diet, other animal species, and natural resources).

During Lecture

3. Circle the appropriate **word**:

    <7 is considered acidic, so the lower the pH of the water, the **more/less** acidic the water is.

    >7 is considered alkaline/basic so, the higher the pH of the water, the **more/less** acidic the water is.

    The rate at which water absorbs CO_2 increases as the temperature of water **increases/decreases**.

4. Circle the appropriate answer:

The pH of a healthy ocean can range between 7.5 to 8.5	True	False
Colder water absorbs less CO2 than warmer water	True	False
Salinity tells us how fresh or salty the water is	True	False
Chlorophyll is a bad indicator of phytoplankton abundance	True	False

NAME:_____ DATE:_____

Ocean Acidification Worksheet

The Salmon Race Computer Lab

Vocabulary Review

ocean acidification	The ongoing decrease of pH value of the Earth's oceans, caused by the uptake of CO_2 from the atmosphere.[1]
pH	A figure expressing the acidity or alkalinity of a solution.[2]
salinity	The salt concentration in seawater. Measured in PSU (Practical Salinity Unit) based on the properties of seawater conductivity. Equivalent to per thousand (o/00) or to g/kg.[3]
temperature	The degree or intensity of heat present in a substance (in this case water). Usually measured as sea surface temperature in the ocean.[4]
chlorophyll	A green pigment (the same one that makes tree leaves green) that phytoplankton use to absorb sunlight.[5]
phytoplankton	Microscopic organisms that live in water environments. Can be bacteria, protists, or single-celled plants. Derived from the Greek words phyto (plant) and plankton (made to wander/drift).[6]
homeostasis	The state of steady internal, physical, and chemical conditions maintained by living organisms. This is a condition of optimal functioning for the organism.[7]
threatened	A species is likely to become endangered within the foreseeable future.[8]
endangered	When a population of a species has declined at least 70% and the cause of decline is known, or when a species has declined at least 50% and the cause is not known.[9]

The Scientific Method- Hypotheses

Leading Research Question: Based on what you may/may not know about salmon already, make a hypothesis as to which salmon species from which river you think will win based on what you know about OA variables. (Remember to use the format: If___then___because).

Hypothesis:

_____ Salmon Group

	Saturn 07	**Seattle Aquarium**	**LiveOcean**
pH			
Temperature **(°F or °C)**			
Chlorophyll (µg/L) **(Phytoplankton is µmol/L)**			
Salinity **(PSU or ppt)**			

NAME:_____ DATE:_____

Computer Lab Instructions utilizing NVS and LiveOcean

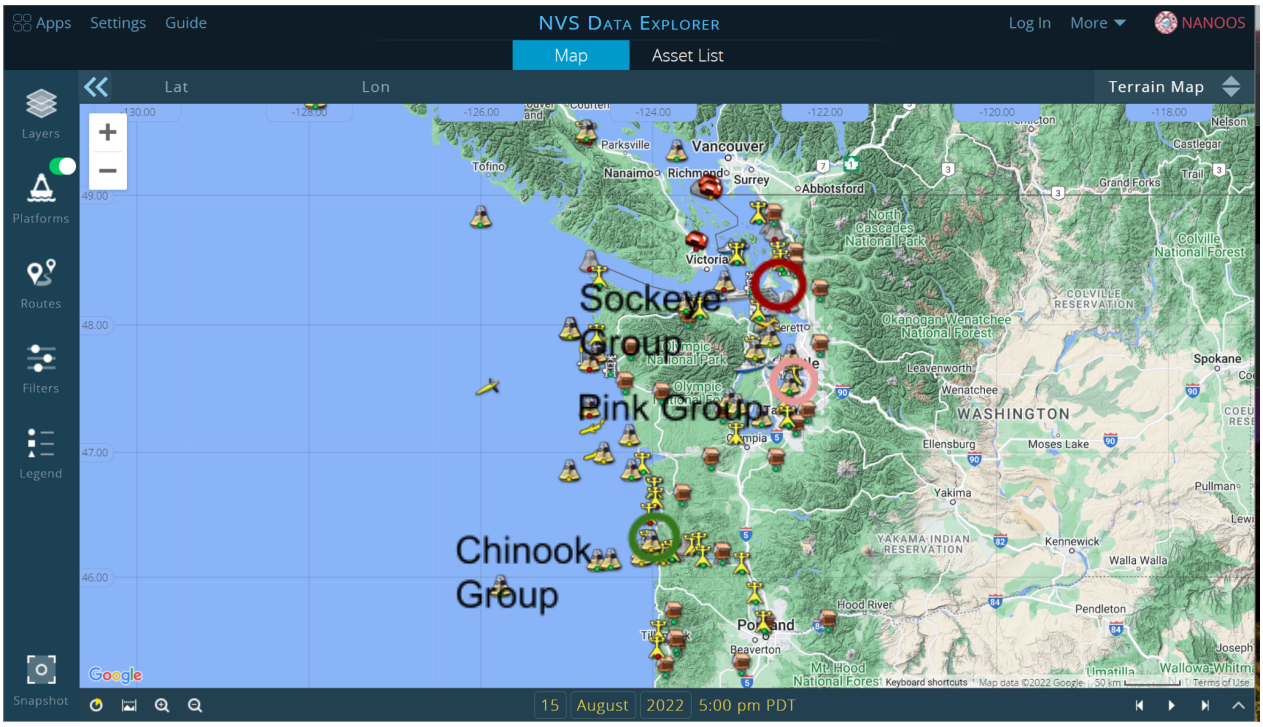
Imagine you are a salmon in your salmon group and are trying to get back to your home river before the rest of your friends. You are going to use the NANOOS Visualization System (NVS) to see if you are likely to beat them home and stay alive in the big open ocean.

1. Choose your salmon group (around 4 people per group, but multiple salmon groups are fine!)

   Chinook Salmon Group- Look for the buoy **Saturn 07** near the mouth of the **Columbia River** (Hint: The river borders Washington and Oregon)

   Pink Salmon Group- Search for the **Seattle Aquarium** Shore Station near the mouth of the **Duwamish River/Green River** (Hint: The shore station is near the central part of Washington near Seattle!)

   Sockeye Salmon Group- Zoom in near the **Skagit River** (Hint: Near the uppermost part of the state feeding into the Skagit Bay.)



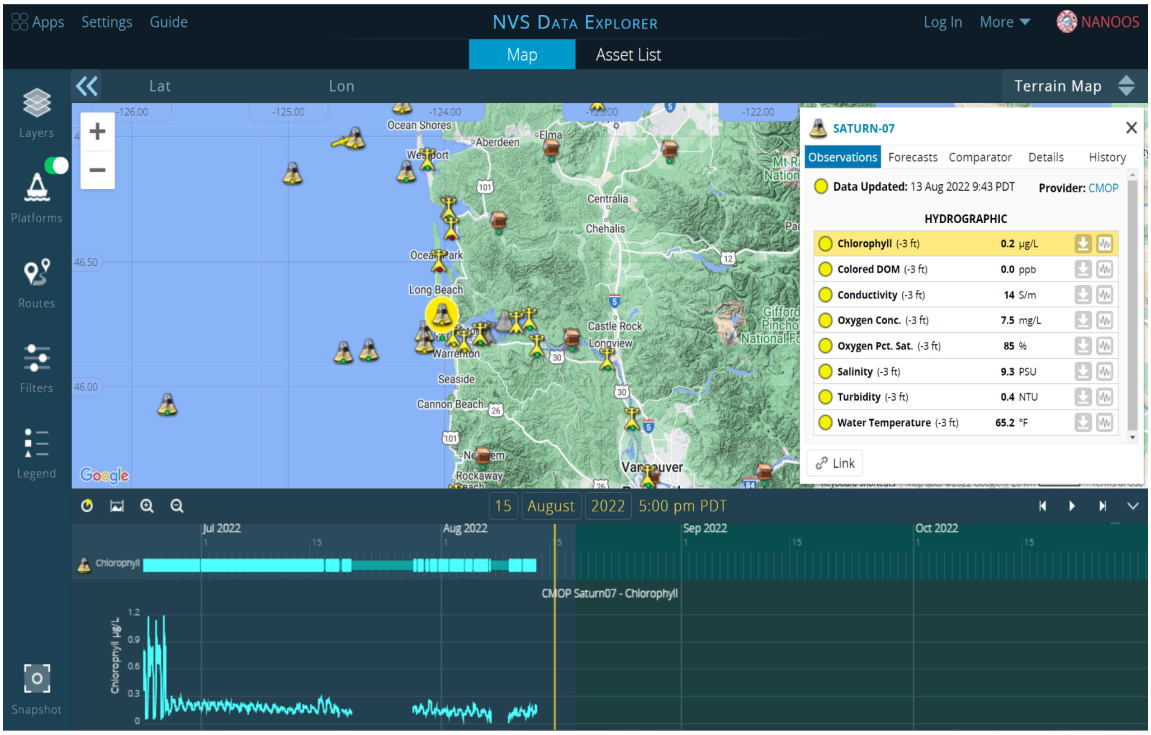
NAME:_____ DATE:_____

2. Assign yourself as a moderator, note taker, reporter, or navigator
    a. *Moderator*- keeps track of time within the group and makes sure your group is staying on track.
    b. *Note Taker*- In this exercise, this will be the person who is filling out the table on this worksheet to use later.
    c. *Reporter*- this person will share out the data variables for their salmon group once the computer lab is over.
    d. *Navigator*- this person will be the one leading through navigating NVS, and making sure the Note Taker writes down variables.

3. Go to the NANOOS Visualization System (NVS) Data Explorer: http://nvs.nanoos.org/Explorer
4. Use the zoom buttons to adjust your view to only the WA coast, from the tip of the Olympic Peninsula to the Columbia River.
5. On the uppermost right side of the screen, click on **Settings** and change the **Plot Y-Axis** by selecting **Local** instead of **Global** for more accurate readings.
6. Go to your designated buoy or system for your salmon group and fill out the column for your affiliated buoy. *Then work on filling out the other two columns on the table provided above for the other groups when you're done.*

Group Chinook Salmon Instructions

1. Once you have found the **Saturn 07 Buoy** (Coordinates: 46.2860, -124.0151) make sure the bottom text in yellow displays the current date and time, and the tab on the top right by the name of the buoy is on **Observations**. Your screen should look like this:

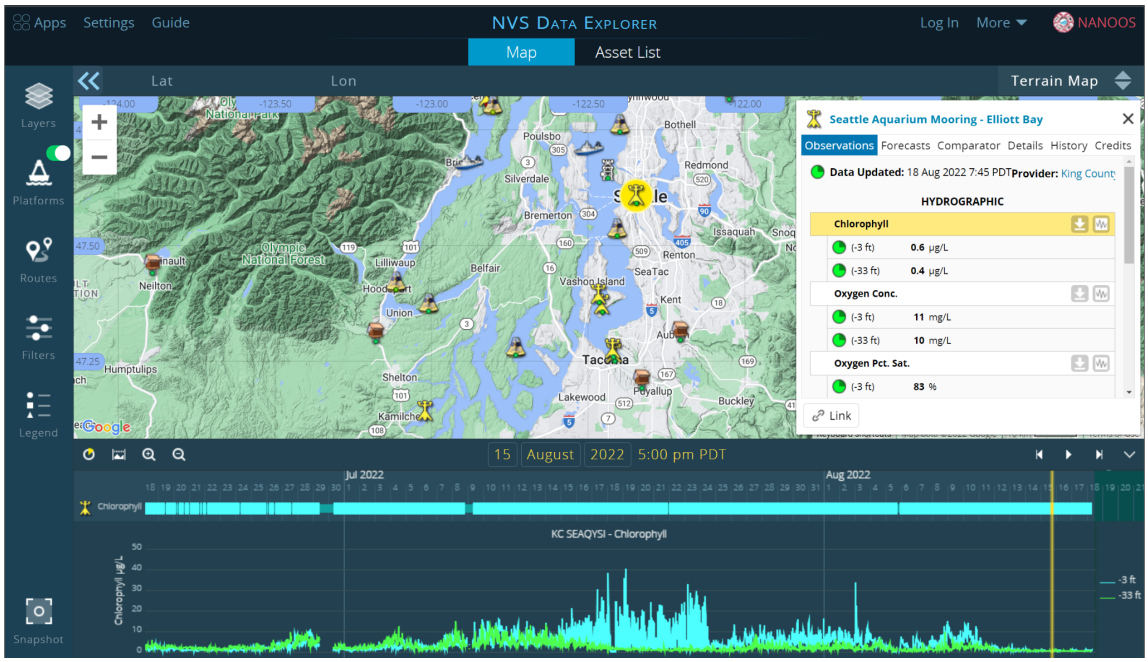


NAME:_____ DATE:_____

2. Scroll through the **Hydrographic** data, and fill in the blanks on your table for **Temperature** (in degrees Fahrenheit), **Chlorophyll**, and **Salinity** until your table column for your group is completely filled. **Make sure to put decimals and circle the right units on the table if shown**
3. You will look at pH with **LiveOcean**, as this variable is not measured on this buoy.
4. Navigate to the **Live Ocean Model** by clicking on **Layers** on the top left of the side menu and expand **Models** until you see the section labeled **LiveOcean.**
5. Select the box labeled **pH**. Get an estimate for the **Surface pH level** and then uncheck that box when you are done filling in the table.
6. You are now ready to move on to the next group assignment.

Group Pink Salmon Instructions

1. Once you have found the Seattle Aquarium Shore Station (Coordinates: 47.6080, -122.3438) make sure the bottom text in yellow displays the current date and time, and the tab on the top right by the name of the station is on **Observations.** Your screen should look like this:



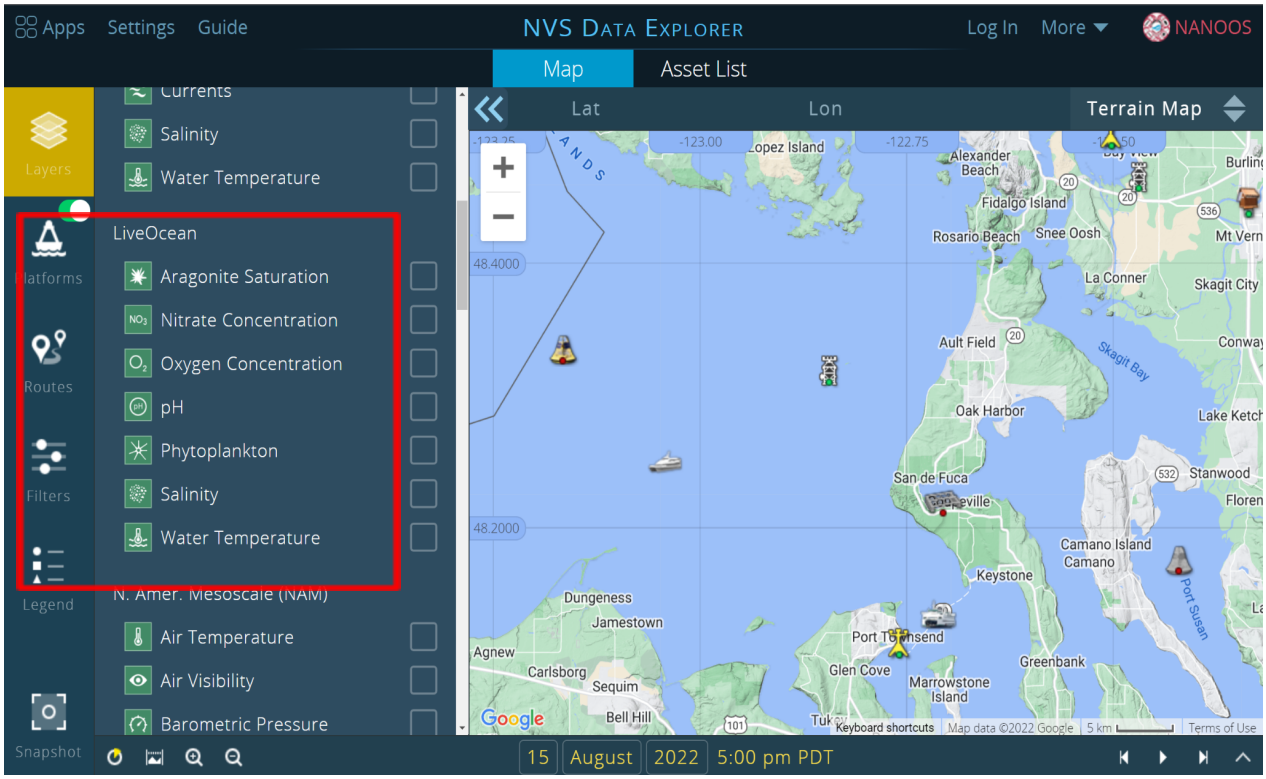
2. Scroll through the **Hydrographic** data, and fill in the blanks on your table for **pH**, **Temperature**, **Chlorophyll** concentration, and **Salinity** until your table column for your group is completely filled. **Make sure to put decimals if shown.**

NAME:_____ DATE:_____

3. For all measurements, be aware that there are most likely two different depths shown in parentheses under the variable listed. Choose the number after **(-3)** to put on your table for surface level measurements. **NOT (-33)**.
    a. *(Salmon tend to swim on the surface to catch prey and get bigger, and zooplankton do not prefer darker areas since they move less and photosynthesize less (light decreases with depth), so the shallower the measurement the better.)*
4. You are now ready to move on to the next group assignment.

Group Sockeye Salmon Instructions

1. Once you are near Skagit Bay where the Skagit River feeds into the Puget Sound, navigate to the **Live Ocean Model** by clicking **Layers** on the top left of the side menu, and expand **Models** until you see the section labeled **LiveOcean.** Your screen should now look like this:



2. Your group will be gaining all of your data completely through the LiveOcean layer. Follow the order of the table on this worksheet by first clicking on the **pH** box under **LiveOcean**. Get an estimate for the **Surface pH level** and then uncheck that box.
3. Next select the box labeled **Water Temperature**. *Make sure to circle on the table whether this measurement is in degrees Fahrenheit or Celsius.* Once you have found the temperature estimate near the mouth of the Skagit River, uncheck this box.

NAME:_____ DATE:_____

4. The table asks you to find the **Chlorophyll** amount. In the lecture, we learned that **Phytoplankton** is a great indicator of chlorophyll concentration, so we will select that box. *Make sure that units are in **µmol/L** for the LiveOcean unit.*
5. Finally, the last variable to check is **Salinity**. Uncheck Phytoplankton if you haven't already done so, and then select the box labeled salinity. Fill in that last part of your table with the measurement that you found and uncheck that box.
6. You are now ready to move on to the next group's assignment.

Wrap-Up Questions

1. Looking at the table you created, out of the three salmon from each river, which one do you think will win the race and make it back home safely? (Hint: which conditions seem to be the best for the salmon to survive from the variables you noticed?) Make sure to explain all of the variables and why you think certain variables improve the homeostasis of salmon compared to others.

2. Salmon are important to native cultures and the seafood industry, but can you think of why phytoplankton are just as important? Use an example of why from the lecture.

3. How does ocean acidification affect oxygen levels? Why is this important for salmon? (Bring it back to effects of ocean acidification).

4. According to NOAA and the U.S. EPA, Chinook salmon (*Oncorhynchus tshawytscha)* is federally recognized as an *endangered* species. From what we talked about regarding *phytoplankton* and the *food cycle*, can you conclude that a cause of their dwindling numbers is direct <u>because of *ocean acidification*</u>? Why or why not?

5. What more information should be assessed to see if salmon are affected by ocean acidification?

Teacher Supplemental Notes

Corresponding to the Salmon Race Ocean Acidification Curriculum

Prep Work:

- Print a worksheet for each group, but have students use their own piece of paper to write out answers.
- Make sure all NANOOS buoy systems are working, and prepare for using alternative buoys provided if necessary. (http://nvs.nanoos.org/Explorer)

  Other ocean observation systems for each salmon group:

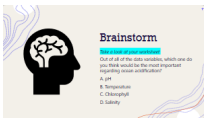
  Chinook Group: Saturn 07, Saturn 02, CDIP Clatsop Spit, and NOS Cape Disappointment. Any empty data for each buoy/shore station can be supplemented by using LiveOcean.
  Pink Group: Seattle Aquarium, NOS Seattle, KC Point Williams. Any empty data for each buoy/shore station can be supplemented by using LiveOcean.
  Sockeye Group: N/A for LiveOcean, just use the earlier date or last recorded date for accuracy. Make this known to students if that pop-up does occur.

- Create a 5x4 table on a dry-erase board or classroom easel paper pad.

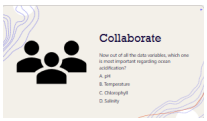
Land Acknowledgement

NANOOS, WOAC, and The University of Washington acknowledge that many others reside on different territories revoked from indigenous peoples, and we invite you to take a moment to reflect on the lands you occupy, and their original stewards and consider within this lecture the land and water rights of that region. This lecture was created on land that touches the shared waters of all tribes and bands within the Duwamish, Puyallup, Suquamish, Tulalip, and Muckleshoot nations. Salmon is a culturally intertwined species with the Coast Salish peoples, and we recognize this strong relationship within this lecture. We are consciously supportive of the rights to fish, acquire resources, and maintain relationships with the land through reciprocity shared between indigenous peoples and the Earth since time immemorial.

Slide 1: Title and introductions, land acknowledgment.

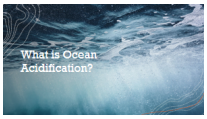


Slide 2: First, have students look at the corresponding worksheets to begin their brainstorming questions.



Slide 3: Same question as the previous slide meant to engage students to work together to figure out the answer.

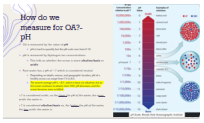
Slide 4: Reveals the right answer. Give students the opportunity to ask why, and have the opportunity for those who guessed it correctly to give their reasoning.



Slide 5: *Transitional Slide*- Redirect students to pay attention to questions provided *During the Presentation* part of the worksheet.

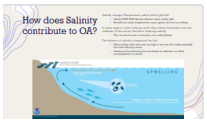
Slide 6: Various definitions of the same thing, why? Talk about highlights of similarities, and then a final full definition that makes the most sense for the class.

Slide 7: Focus on it being an anthropogenically caused issue, but is natural as well (carbon cycle). More **acidified**, not acidic (not actually lemonade, but used as a guide.)

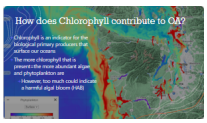


Slide 8: pH has no unit, is a scale, matched by a color gradient. Measured by hydrogen ions which change the chemistry of the water. *Fill in the blank for the worksheet on this slide.*

Slide 9: Although the graphic includes tropical environments the trend of rising CO_2 is found everywhere. The ocean is a carbon sequester and absorbs CO_2 from the atmosphere, but temperature determines *at what rate*. *Fill-in-the-blank opportunity on the worksheet.*

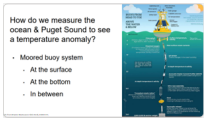


Slide 10: Salinity=Salt, saltwater vs. freshwater and salinity measures how salty or fresh, define olfactory senses and osmoregulation. *Make sure students are still actively looking during the lecture section of the worksheet to circle true or false.*



Slide 11: Chlorophyll is a biological oceanography measurement, of the relationship between phytoplankton, and balance though. Too much/little=negative consequences. *Last true or false question for the During the Lecture portion of the worksheet.*

Slide 12: *Transition Slide*- at this point direct the students to LiveOcean and NVS data provided by NANOOS.

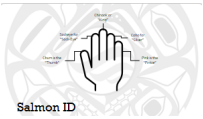


Slide 13: Ocean data is collected from a variety of instruments on fixed stations or moored buoys, like the one shown here.

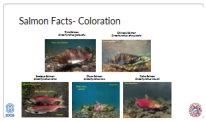
Slide 14: Satellite and modeling are important to fill in the spatial gaps between instrument locations and forecasting conditions.

Slide 15: Describe how we benefit from the ocean, but then how some of our benefits can particularly be at risk because of the ecosystem effects of OA. *Note: See Proxy Papers for further references on olfactory loss and pteropod research.*

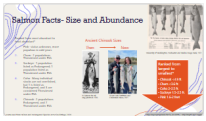
Slide 16: Transition Slide- Go over the worksheet again and guide students to the brainstorming section to answer the question to shift gears toward discussing salmon.



Slide 17: Go over the salmon finger trick, and see if anyone knows it! And as you go through coloration and facts bring it back to this finger activity so students can connect concepts.

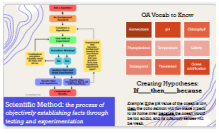


Slide 18: Pink- prominent hump, elongated snout, silvery to pale slate, brownish or even greenish gray, with a white underbelly. Chinook-vary by river origin, but don't have vibrate transition like sockeye and coho. Sockeye- Red body, olive-green head, small hump above dorsal, elongated snout. Chum- purple and green calico patterned vertical bars, canine-like teeth, and hooked noses. Coho- forms hooked snout, bright red streak on lateral line, bluish-green head.
Note: Only discusses males going through sexual dimorphism - greatest change in coloration. Females change color when sexually mature, but most of the time maintain body shape.



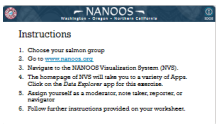
Slide 19: Connect abundance with the literal size of each salmon. Discuss the size decrease over time of Chinook salmon in response to climate change, making them leave the ocean earlier. *Photo Information:* Jalmer Wilson of Astoria with a Chinook salmon weighing 82.5 pounds, caught on May 26, 1936, in the ship channel opposite Flavel Dock. *Photo 2:* Clients with East Fork Outfitters with Spring Chinook salmon caught last year (2021).

Slide 20: Go through foodweb by having students imagine themselves as being the energy that transfers as if they are each organism. Emphasize that usually what people consider the most insignificant things, are indeed the most important! They help all of the flagship species (students can name cool sea creatures (from the picture or otherwise) survive!

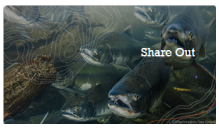


Slide 21: Introduce the scientific method. Foundational concept is used every day by scientists young and old! This will be the time to let students formulate their own hypotheses on the worksheet provided. Take the time to have students ask questions if there are any words on here they still need help defining.

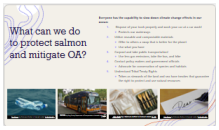
Slide 22: Give students time to form groups and finish formulating their own hypotheses before beginning this exercise. Answer any questions that arise before the activity begins so students know what is expected of them.



Slide 23: Make sure to have data ranges of what to expect from students handy depending on the day of data collection from the NANOOS website.



Slide 24: *Transition Slide*- Give time for each reporter to share out their variable results. Can be done by coming up and filling it out or the teacher fills it out as they share verbally. This will give you time to double-check if students did this correctly, and ensure a mitigated discussion for each group.



Slide 25: Run through examples shown on the slide, and give students a chance to share if they have other ideas on what they can do (either at home or school to narrow it down) on ways to be better for the planet. End on a positive note!

Slide 26: Give acknowledgments, and describe what each hyperlink represents.

Proxy Papers for reference from WOAC Publications and Resources:

Bednaršek, N., Feely, R.A., Tolimieri, N. et al. 2017. Exposure history determines pteropod vulnerability to ocean acidification along the US West Coast. Sci Rep, 7, 4526. https://doi.org/10.1038/s41598-017-03934-z

Williams, C.R., Dittman, A.H., McElhany, P., et al. 2018. Elevated CO2 impairs olfactory-mediated neural and behavioral responses and gene expression in ocean-phase coho salmon (Oncorhynchus kisutch). Glob Change Biol., 25: 963– 977. https://doi.org/10.1111/gcb.14532

Vocabulary Sources:

1. Ocean Acidification, Washington Ocean Acidification Center (WOAC)
2. pH, National Oceanic and Atmospheric Association (NOAA)
3. Salinity, Science Mission Directorate- National Aeronautic and Space Administration (NASA)
4. Temperature, NOAA's National Weather Service
5. Chlorophyll, NOAA's National Marine Ecosystem Status
6. Phytoplankton, NASA's Earth Observatory
7. Homeostasis, Google Definitions
8. Threatened, US Geological Survey (USGS), Department of the Interior
9. Endangered, National Geographic

Any questions? Contact us at: http://www.nanoos.org/contact_us/contact_us.php