Investigating Coastal Acidification, Hypoxia, and Harmful Algal Blooms (HABs)

Prepared by: Pacific Shellfish Institute

Introduction

Since the Industrial Revolution, atmospheric levels of carbon dioxide have increased by 30% due to deforestation and the burning of fossil fuels. The absorption of excess CO2 into the oceans has resulted in a decrease in pH from 8.2 to 8.1 and is expected to fall by another 0.3-0.4 pH units by the end of the century. Because the pH scale is logarithmic, small changes can have significant impacts on aquatic organisms. The term for this shift in pH is called **ocean acidification**.

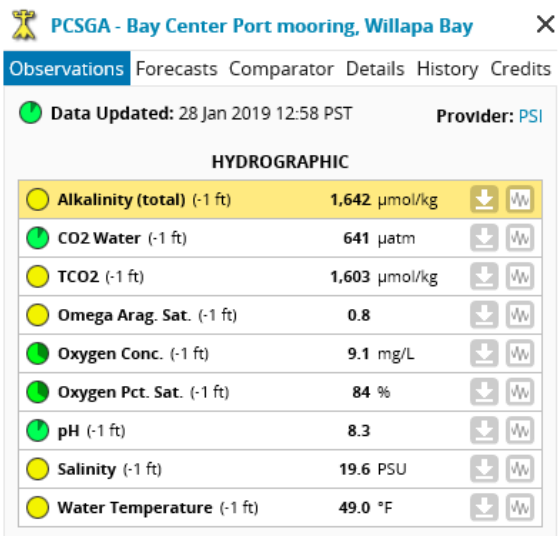
In this lesson, we will focus on changes in pH that are observed on a *more local level* – off the Washington coast and within Puget Sound. These local changes in pH are observed daily and seasonally and are caused by forces that are both natural (coastal upwelling, rivers, and phytoplankton) and human induced (nutrient inputs). The term for these changes in pH is called **coastal acidification**. Coastal estuaries are particularly sensitive to climate change because they experience the combination of both ocean and coastal acidification. Finally, we will learn about harmful algal blooms, or HABs, and how they may be influenced by warming temperatures.

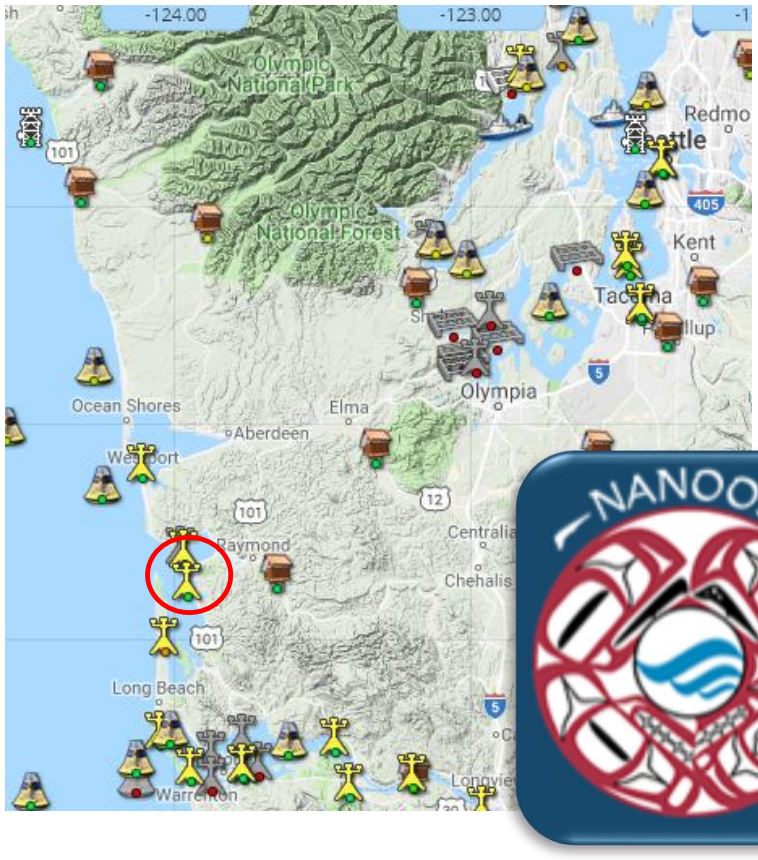
SECTION 1: Coastal Acidification – Rivers, Tides & Phytoplankton

Starting in 2005, shellfish growers began sounding the alarm that wild oysters on the coast were failing to reproduce successfully. Between 2006 and 2008, hatchery managers on the coast and in Puget Sound began experiencing high mortality rates among their juvenile oysters. The smoking gun in both cases was a decreased pH in the seawater.

Shellfish growers have learned to adapt to changing ocean conditions. One way they do this is by monitoring water quality to understand how it changes both daily and seasonally at their particular location. Moorings and buoys collect this data which is stored on a site called NANOOS, (www.nanoos.org) or Northwest Association of Networked Ocean Observing Systems. This data is available to growers (and you!) 24 hours a day!

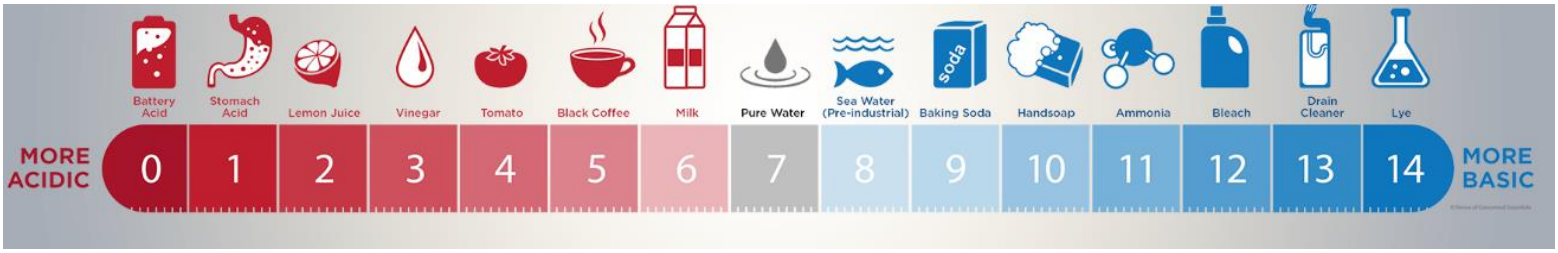
Shellfish growers have learned that carbon dioxide, oxygen, and pH levels fluctuate significantly throughout the day and seasonally. These changes are due in large part to natural local factors such as coastal upwelling, the interaction between tides and rivers, and phytoplankton.





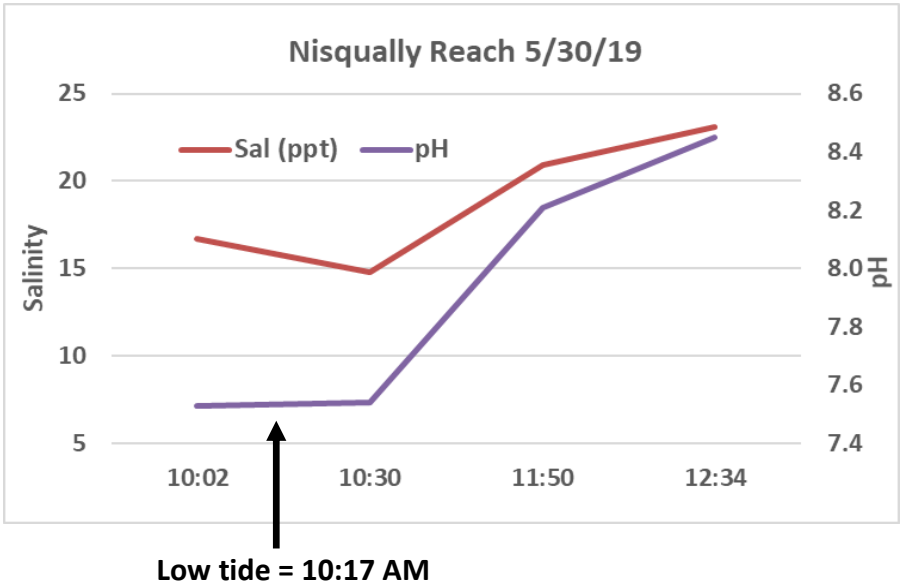
Tides & Rivers

Puget Sound is an estuary – a rich biological environment where rivers meet the sea. As fresh water rivers empty into Puget Sound, they influence the water's pH.



1. What is the pH of Pure Water? A) 0 B) 3 C) 7 D) 14
2. What is the pH of Sea Water? A) 0 B) 4 C) 8 D) 12

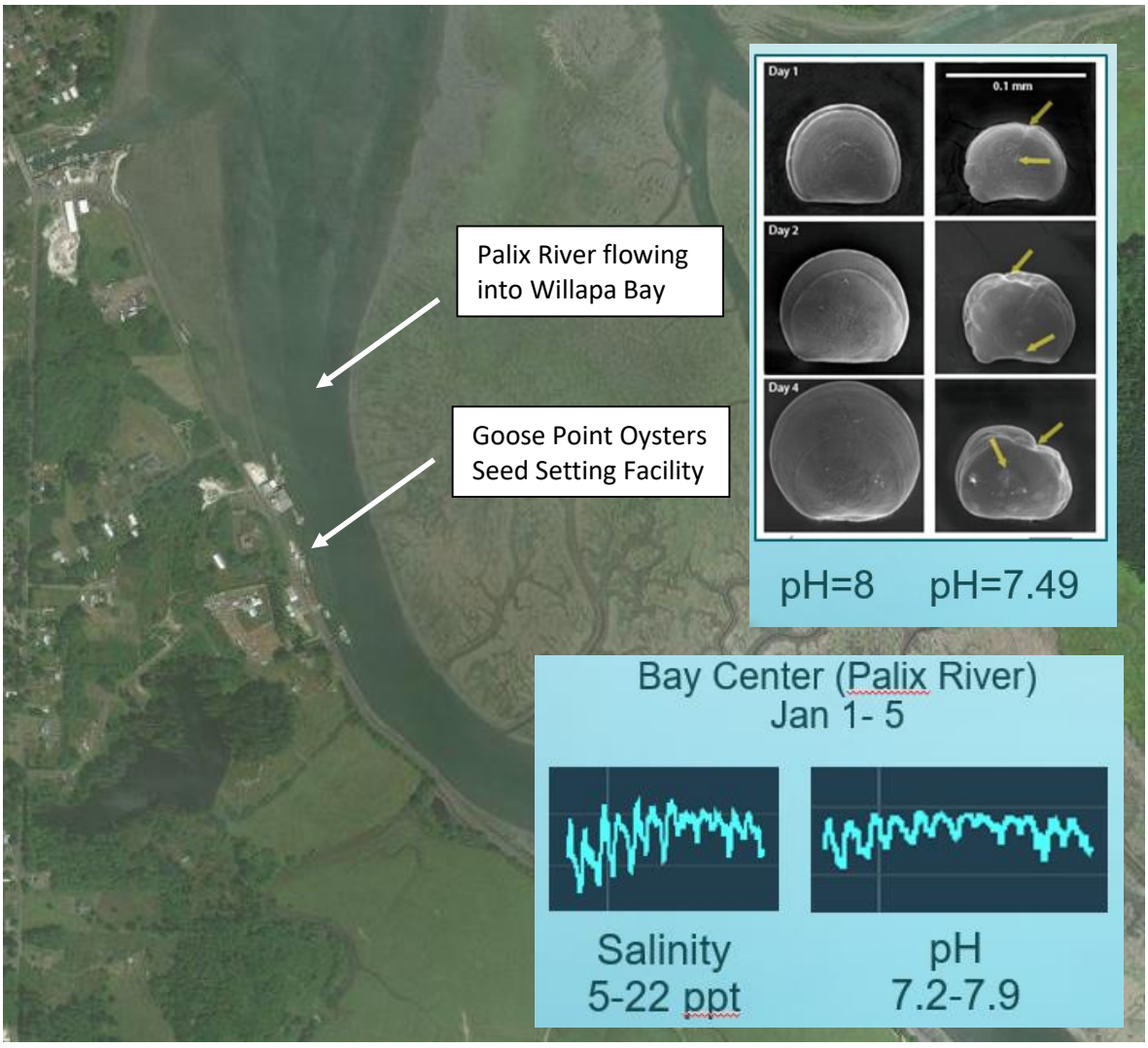
During Spring and Fall of 2019, local students collected water quality data at the Nisqually Reach Nature Center using a handheld YSI instrument. The Nisqually Reach Nature Center is located at the mouth of the Nisqually River and McAllister Creek. The following chart depicts data collected by 4 different groups of students throughout the day. Low tide was at 10:17 AM. At this time, the mudflats were exposed and great blue herons were actively feeding along the narrow tidal channels. But soon, the tide started surging back in carrying with it salty, plankton-rich ocean water. Salinity, or the concentration of salts, is measured in parts per thousand. Freshwater has a salinity of 0 and seawater averages 35 ppt.



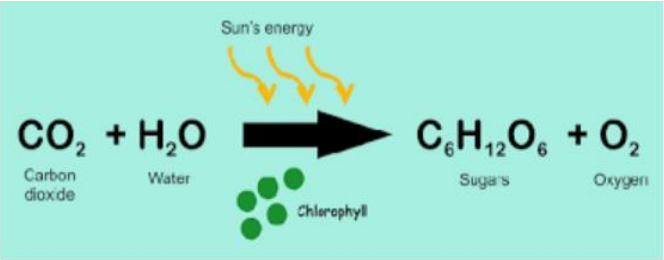
3. Does salinity increase or decrease between 10:30 and 12:34? A) increase B) decrease
4. Does pH increase or decrease between 10:30 and 12:34? A) increase B) decrease
5. What is the difference in pH between 10:30 and 12:34? A) 1.3 B) 0.4 C) 2.0 D) 0.9

6. If you are a shellfish hatchery manager located right at the mouth of the Nisqually River, would you draw seawater into your tanks on the incoming or outgoing tide to avoid lower pH water? A) Incoming tide B) Outgoing tide

7. Goose Point Oysters has an oyster seed rearing facility that is located at the mouth of the Palix River which flows into Willapa Bay on the Washington coast. The following NANOOS data illustrates how salinity and pH values fluctuate with the incoming/outgoing tide. Hatchery studies elsewhere have observed poor shell development in oyster larvae at a pH of 7.49. Given this data, do you think this is a good location to rear oyster larvae? A) Yes B) No



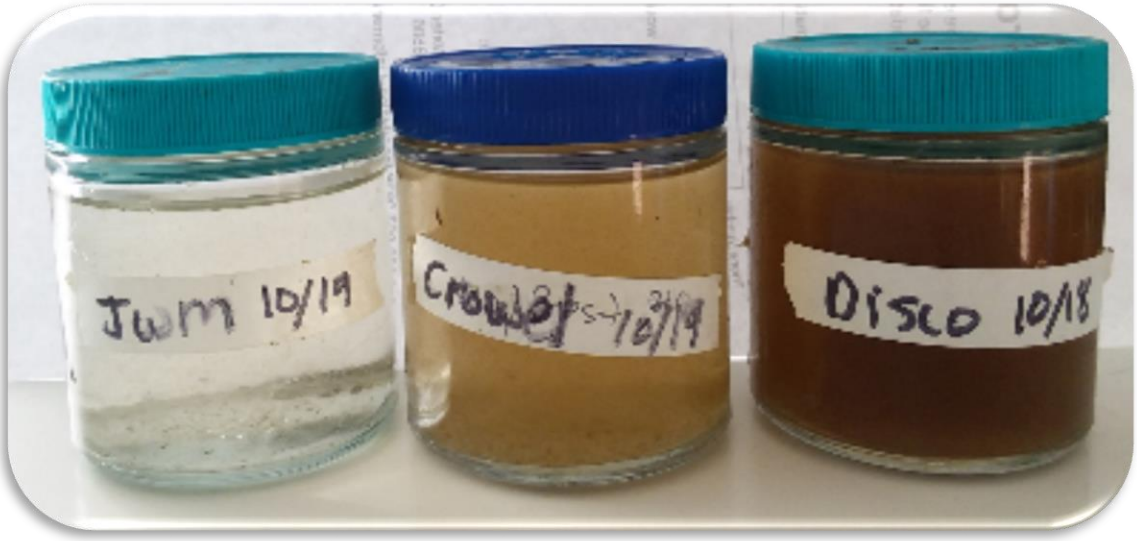
Phytoplankton – Photosynthesis



www.quora.com

Phytoplankton are microscopic plant-like organisms (they are actually protists!) that are the base of the marine food chain. While small in size, they are large in number. In fact, phytoplankton are responsible for producing up to 50% of the oxygen that we breath. During photosynthesis, phytoplankton use carbon dioxide and water (in the presence of sunlight) to produce simple sugars and oxygen. At night (in the absence of sunlight) phytoplankton respire – using oxygen and releasing carbon dioxide back into the water.

PSI is currently involved in a research project evaluating biotoxin levels found in commercially raised rock scallops. During each site visit, staff collect plankton and water quality data. The following images illustrate the powerful impact that phytoplankton can have on pH and oxygen. All 3 plankton samples were collected from different sections of Sequim and Discovery Bays within 1 hour of each other. Each site had significantly different plankton concentrations.



Oxygen:	**5.5 mg/L**	**8.0 mg/L**	**13.7 mg/L**
pH:	**7.9**	**8.1**	**8.7**

Observe how the amount of plankton impacts oxygen and pH. Use the image and collected data to answer the following questions.

1. An **increase** in phytoplankton causes a(n) A) Increase B) Decrease in dissolved oxygen?
2. An **increase** in phytoplankton causes a(n) A) Increase B) Decrease in carbon dioxide?
3. An **increase** in phytoplankton causes a(n) A) Increase B) Decrease in pH?

4. If you are a shellfish hatchery manager, when would you draw water into your tanks to avoid low pH water? In other words, what time of the day would you expect oxygen levels and pH to be the highest?
   A) During the night B) During early morning C) During the afternoon

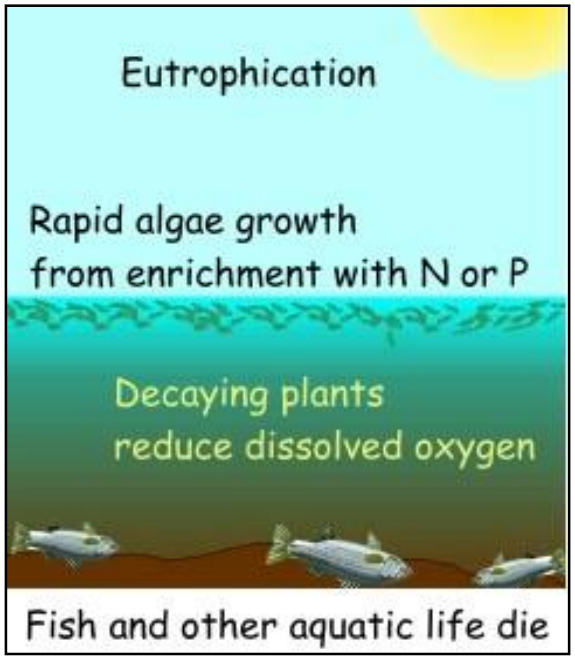
SECTION 2: Coastal Acidification – Influence of Nutrient Pollution

Phytoplankton are incredibly important for many reasons. They produce oxygen and are the base of the food web. And as you just observed, an increase in phytoplankton is typically associated with an increase in both pH and oxygen. *Do you think it is possible for high concentrations of phytoplankton to result in dangerously LOW levels of oxygen and pH?* Do you ever think you can have too much phytoplankton? Unfortunately, the answer is yes.

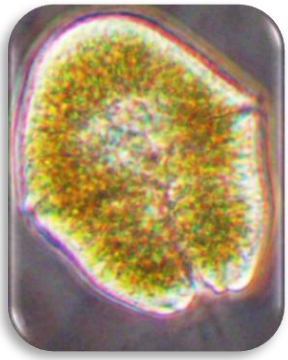
Watch this short, interactive animation about Coastal Acidification found at:
https://oceanacidification.noaa.gov/sites/oap-redesign/Classroom/story_html5.html

Budd Inlet provides a great example of coastal acidification right here in your own backyard. For the past decade, Budd Inlet has experienced low dissolved oxygen levels during late summer, particularly in East Bay (by the Hands On Children's Museum). Excess nutrients from multiple sources fuel the growth of rich phytoplankton blooms throughout early spring and summer. These blooms elevate oxygen levels and pH while they are blooming, but as they dissipate and sink to the bottom of the Inlet, they are decomposed by bacteria. Bacteria respire (like us!), so

as they break down the phytoplankton, they use oxygen and release carbon dioxide. This results in dangerously low oxygen levels and pH for marine life. Hypoxia is the term for oxygen deficiency in a marine environment.

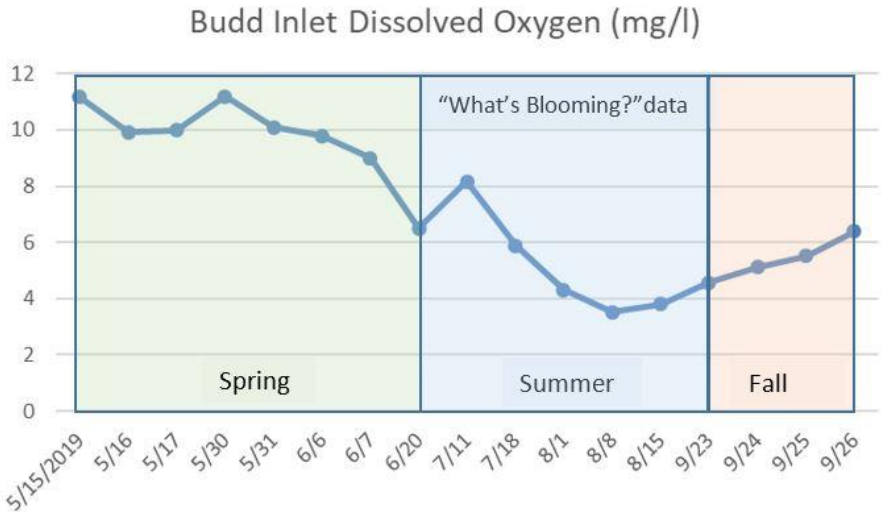


Credit: www.nyc.gov



Caption: Water visibility drops below 1-meter as a bloom of Akashiwo sanguinea takes hold. As the phytoplankton eventually settle to the bottom of the inlet, they are decomposed by bacteria resulting in low oxygen levels and pH.

During Spring and Fall of 2019, students collected plankton and water quality data at the Nisqually Reach Nature Center to compare to Budd Inlet – located 2 inlets to the west. During the Summer, citizen scientists collected similar data through the "What's Blooming in Budd?" program. When pieced together, the data sets illustrate how dissolved oxygen levels changed over the course of the year.



1. When were oxygen levels the highest? A) May, B) June, C) July, D) August, E) September

2. When were oxygen levels the lowest? A) May, B) June, C) July, D) August, E) September

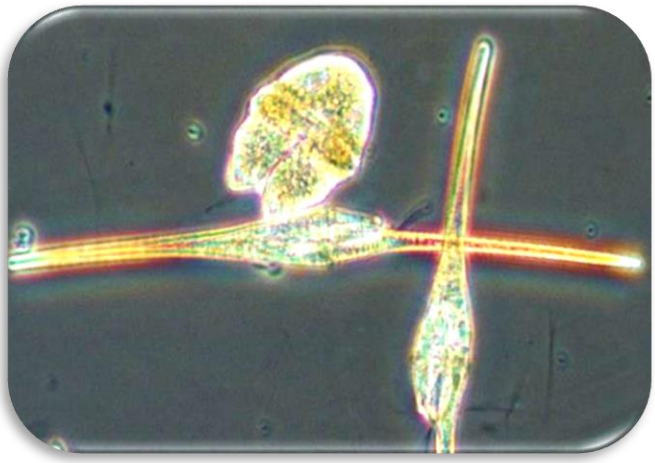
3. Your friend says that pH follows the same trend as oxygen in Budd Inlet - increasing during the spring phytoplankton bloom and decreasing in late summer when phytoplankton are decomposing. Would you A) Agree or B) Disagree?

4. What actions help decrease the amount of nutrients that enter into Puget Sound? A) Wash car on the lawn or at a commercial car wash, B) Maintain septic systems, C) Decrease the use of synthetic lawn fertilizers, D) Scoop, Bag, and Trash pet waste, E) All of the above

SECTION 3: Phytoplankton ID & Harmful Algal Blooms (HABs)

Marine **plankton** include all of the organisms that live in the ocean that are unable to swim against a current – the drifters! These include **phytoplankton** (the microscopic plant-like protists) and **zooplankton** (the microscopic animals).

Phytoplankton are hugely important because they are the base of the aquatic food web and produce approximately 50% of the oxygen in our atmosphere through photosynthesis. Phytoplankton are single celled and are comprised of two main classes: diatoms and dinoflagellates.

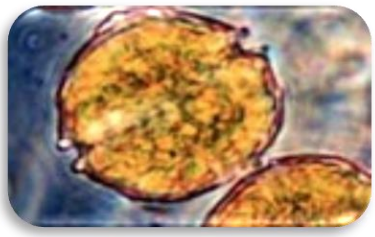


Common Budd Inlet dinoflagellates: Akashiwo sanguinea & Ceratium fusus (bottom)

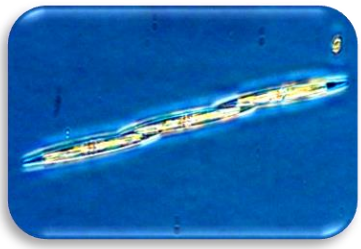
Diatoms tend to be circular or pen shaped, have walls made of silica, are solitary or form chains, and may have spines or hairs to increase buoyancy and prevent sinking out of sunlit surface waters. Diatoms bloom in the spring and to a lesser degree in the fall. **Dinoflagellates** have walls made of cellulose and two whip-like flagellas that are used for limited mobility. Dinoflagellate concentrations tend to increase during the summer and early fall when waters are warm and stratified and they are able to swim to deeper waters to access nutrients.

Zooplankton are microscopic animals. Some remain as zooplankton their entire lives (i.e. copepods), whereas others develop into invertebrates that we recognize in the intertidal zone (i.e. crabs, barnacles, sea stars, worms, etc.)

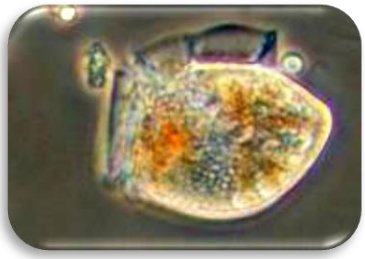
Harmful Algal Blooms, or HABs, occur when phytoplankton multiply and produce toxic or harmful effects on people, fish, shellfish, marine mammals and birds. Some types of phytoplankton can produce powerful biotoxins. These biotoxins can accumulate in the guts and tissues of shellfish during filter feeding making them toxic to people and animals. Washington Department of Health tests shellfish tissue throughout the state on a regular basis to ensure that shellfish are safe to eat. A few phytoplankton species that produce powerful biotoxins include the following:



Alexandrium – responsible for Paralytic Shellfish Poisoning (PSP). Symptoms include tingling lips, fingers, toes, paralysis, suffocation and possible death.



Pseudo-nitzschia – responsible for Amnesic Shellfish Poisoning (ASP). Symptoms include vomiting, diarrhea, loss of short-term memory, seizures, coma, and possible death.



Dinophysis – responsible for Diarrhetic Shellfish Poisoning (DSP). Symptoms include diarrhea, nausea, vomiting, cramps, and chills.

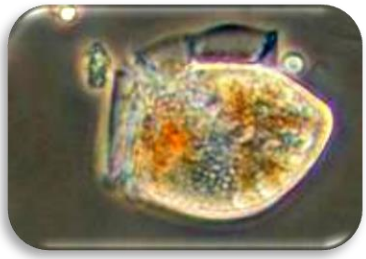
SoundToxins is a phytoplankton monitoring program designed to provide early warning of harmful algal bloom events to minimize human health risk and economic losses to Puget Sound fisheries. Pacific Shellfish Institute is one of many partners in the program, sampling in Budd Inlet year-round. YOU can help collect data for the program during the summer by participating in Stream Team's "What's Blooming in Budd?" program. Watch this video to learn more!

https://youtu.be/FtSw32ucBUs

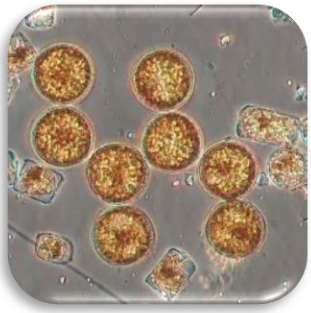
Learn more about HAB monitoring by visiting the following links:

Washington Department of Health's Marine Biotoxins Program: www.doh.wa.gov/CommunityandEnvironment/Shellfish/RecreationalShellfish/Illnesses/Biotoxins
SoundToxins: www.soundtoxins.org/
What's Blooming in Budd?: www.pacshell.org/whats-blooming-in-budd.asp

The following are common plankton species in Budd Inlet. Refer to the Identification Keys to answer the following questions.



A



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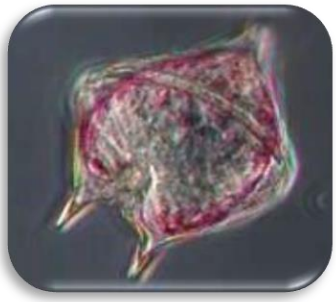

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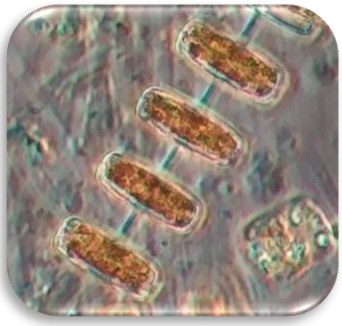

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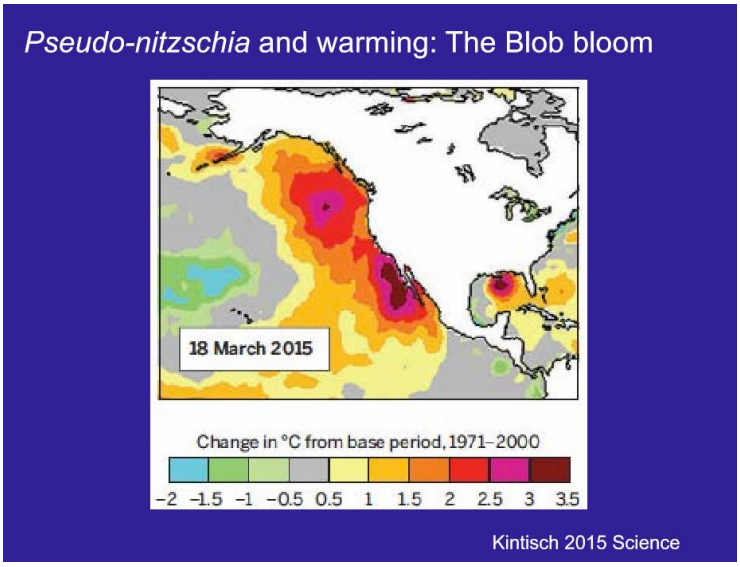
H

1. Which 2 images are of diatoms? _____
2. Which 4 are of dinoflagellates? _____
3. Which 2 are zooplankton? _____
4. Which is a HAB species that produces a harmful biotoxin? _____

HABs & Climate Change

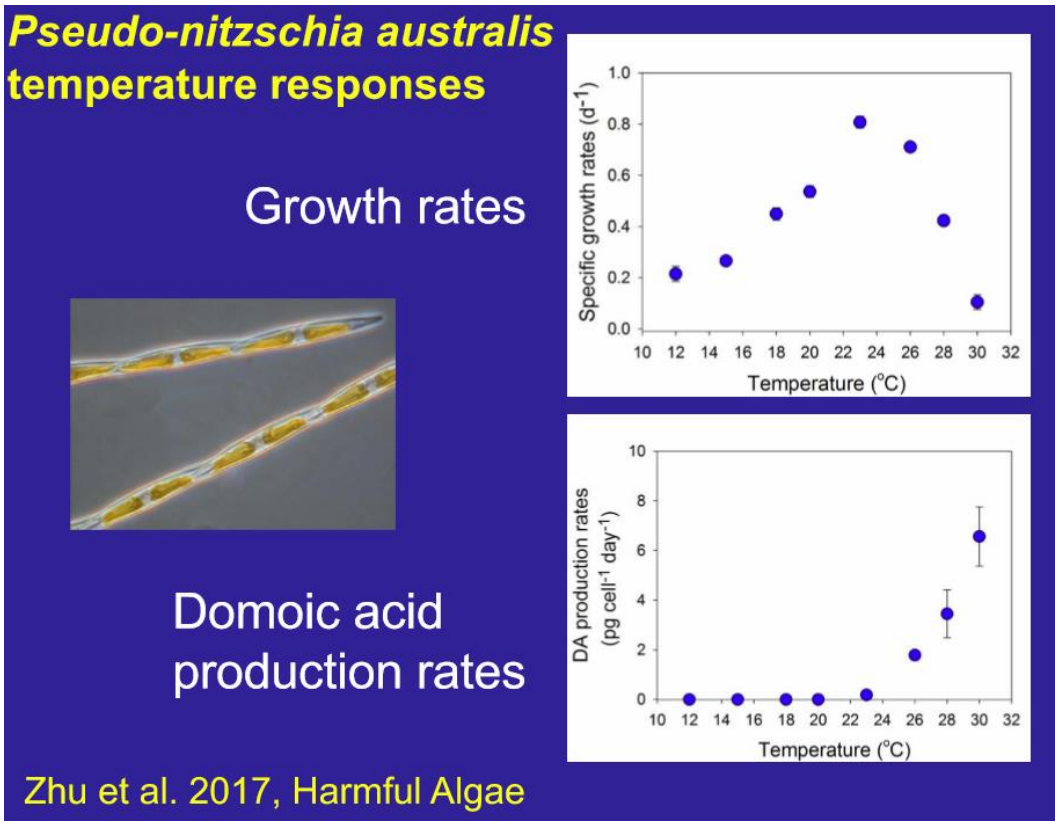


Researchers worldwide are discovering that changing ocean conditions are having an impact on phytoplankton communities, particularly HAB species.

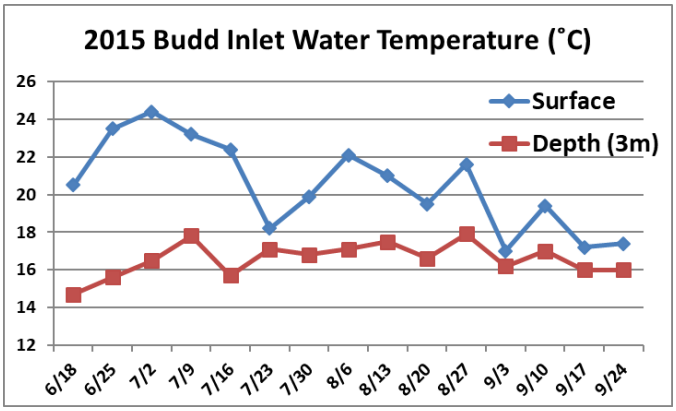
Between 2015-2016, a warm water mass, nicknamed the Blob, formed along the west coast providing clues as to what the impacts of warming ocean conditions might look like in the future. During this time, the coast experienced a significant bloom of *Pseudo-nitzschia,* the species responsible for Amnesic Shellfish Poisoning. Reports of marine mammal illnesses and mortalities were substantial. Economic losses to the west coast Dungeness crab fishery due to harvesting closures were estimated at $50-100 million.

During this bloom, researchers collected samples of *Pseudo-nitzschia* cells to test the effect of increased water temperature on cell growth and toxicity in a controlled lab setting. Years prior, researchers at the University of Washington modeled how increased temperature might affect the timing and duration of another harmful algal bloom species, *Alexandrium catenella*.

Refer to the following data to answer the questions.

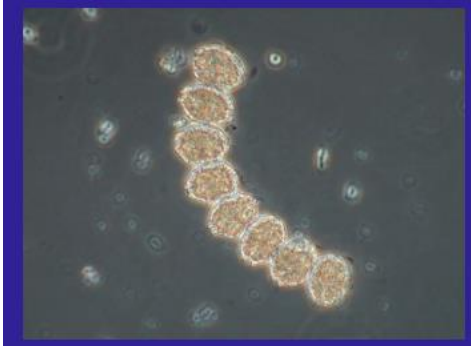


1. As water temperature increases from 10°C to 24°C, *Pseudo-nitzschia* cell growth:
   A) Increases or B) Decreases?
2. At what temperature do *Pseudo-nitzschia* cells experience the highest growth rates and start to increase their production of the biotoxin, Domoic acid?
   A) 15°C, B) 23°C, C) 30°C



Water temperatures collected at the surface and 3-meter depth in Budd Inlet during the "BLOB."

Effects of a warming-induced extended growing season on *Alexandrium catenella*



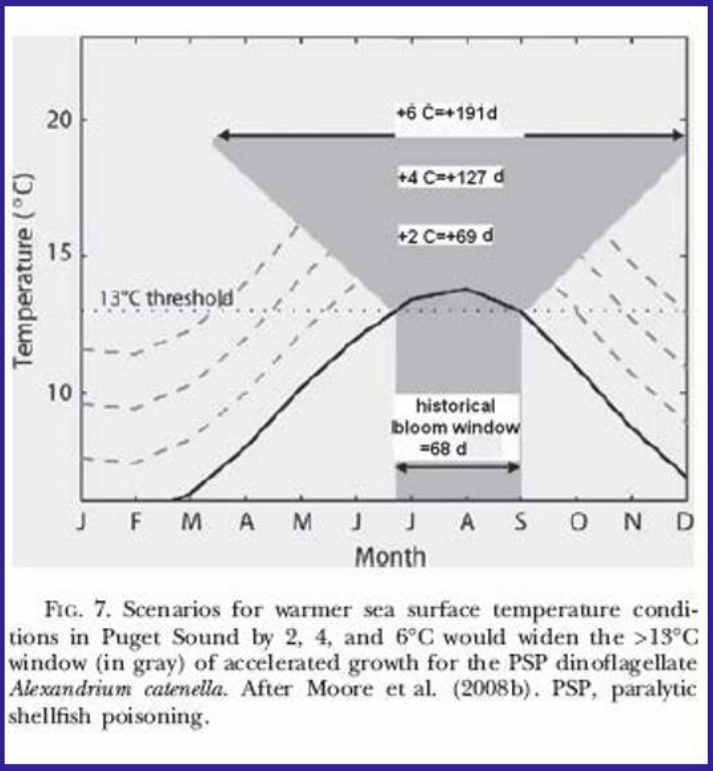


FIG. 7. Scenarios for warmer sea surface temperature conditions in Puget Sound by 2, 4, and 6°C would widen the >13°C window (in gray) of accelerated growth for the PSP dinoflagellate *Alexandrium catenella*. After Moore et al. (2008b). PSP, paralytic shellfish poisoning.

Moore et al. 2008, Environmental Health 7

3. *Alexandrium* is the species responsible for Paralytic Shellfish Poisoning. During historic conditions, when would one expect to see optimal conditions for accelerated cell growth? In other words, what is the typical growing season for this species?
   A) Late June to September, B) May to October, C) Mid March to December.
4. If the ocean temperature was to increase by 6°C, what months would we expect to see accelerated growth of *Alexandrium*?
   A) Late June to September, B) May to October, C) Mid March to December.

THE TAKE HOME…

Globally, the pH of the world's oceans has decreased by 0.1 pH units since the Industrial Revolution. Coastal estuaries like Puget Sound experience additional fluctuations in pH due to natural causes (upwelling, tides/rivers, phytoplankton) as well as human induced causes (nutrient pollution). The *combination* of global and local decreases in pH make coastal estuaries more sensitive to changing ocean conditions.

With climate warming, there will be "winners" and "losers." Certain plankton like jellyfish and *Noctiluca* (a bioluminescing dinoflagellate) appear to be thriving. In addition, evidence suggests that harmful algal blooms may increase in duration and intensity. Other species, however, like shellfish and invertebrates that form calcium carbonate shells, will have difficulty building and maintaining strong shells.

Individuals can take many positive actions to address climate change and its impacts. Reducing nutrient pollution into Puget Sound is one way to protect local water quality and the marine life that depend on it.

A smack of moon jellies, West Bay Marina, Budd Inlet.

"Jellyfish biomass reached record levels in Budd Inlet in fall of 2014 and summer of 2015, coinciding with 'the Blob' of unusually warm water."

(Michalek & Krembs et al. 2016)