Ocean Currents, Zooplankton, & HAB's

A Data Story

Timeframe

3-4 Fifty minute class periods

Target Audience

Middle and High School

Materials

- HAB Scenerio card
- Datasets
- Matrix
- Foodweb cards
- Marine Pyramid sheet
- HABs issue cards
- Poster paper
- Red & blue markers

Contact:

SMILE Program

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Description

In this lesson, students will use generalized data loosely based on an actual study of harmful algal bloom (HAB) events off the Oregon coast to understand how interpreting patterns from several types data over many years can help us better understand ocean

Assumptions

For students to be successful in doing this activity they should:

- Have the ability to read a time-series graph, where the x-axis represents the passage of time, and the y-axis displays data
- Be familiar with the basics of the scientific method
- Know what phytoplankton and zooplankton are – and that they cannot swim against currents
- Have some knowledge of ocean currents

Objectives

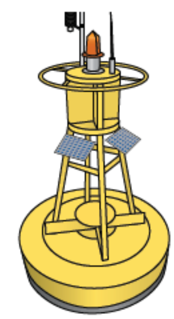
Students will:

- Learn that correlation does not equal causation
- Collaborate in a group and create a hypothesis about the origin of toxins in oceans
- Decide as a group what additional data would support or refute their hypothesis
- Analyze and interpret time-series graphs representing natural systems which vary over time
- Understand how harmful algal blooms (HAB's) may affect a food web, including larger organisms such as marine birds and mammals

Background Information

Collecting Data

Research vessels (R/Vs) play a crucial role in obtaining the data needed to learn more about important ocean topics including ocean acidification, tsunami prediction, declining fisheries, and harmful algal blooms (HABs), among many others. R/Vs provide a mobile platform where scientists can travel to locations worldwide to directly obtain in situ (on-site) data with a variety of sampling and survey equipment. These data types may include sampling water to study its chemistry, counting different types of algal or animal species present, mapping of the ocean floor, or obtaining basic information such as temperature of the ocean at different depths, among many, many others. With these data scientists work to answer difficult questions about how systems in the ocean work and how humans are affecting (or affected by) those systems.



In-water, unmanned data stations are also used by ocean scientists. These platforms may be stationary or mobile and are programmed to automatically take specific data and measurements such as temperature, salinity, wave height, wind and current speed, etc. Some may periodically send the data directly back to scientists by satellite while others have to be retrieved to get the data. Either way, scientists need R/Vs to deploy, service, and/or retrieve these platforms from the ocean. Moorings, for example, are typically stationary platforms that are attached to or suspended from an anchored, floating buoy. These are assembled on land and taken to sea with R/Vs. Scientists also need R/Vs to collect in-water data near the platforms to validate the accuracy of the instruments' readings.

In this activity, generalized data collected by R/Vs are used to describe the number and type of zooplankton present in an area over a certain time. Temperature data from a stationary mooring in the Pacific and toxin levels measured in razor clams collected at the shore are also included. This activity uses a type of data called "indexes." Rather than provide a direct measurement of condition at a time/place, indexes condition at a time/place compared to normal, or average, observations. So, instead of telling us the average water temperature in January, an index will tell us whether water temperature was "warmer" or "cooler" than usual by comparing THIS January to an average of ALL January measurements over many years.

Harmful Algae Blooms (HABs)

Microalgae, or phytoplankton, are typically benign to beneficial to an ecosystem. Harmful algal blooms (HABs), however, occur when algae cause harm to an ecosystem. Some HABs produce toxic substances that enter the marine food web and can make animals sick. **Pseudo-nitzschia** is group of algae with some species capable of producing the neurotoxin domoic acid (DA). DA can have harmful effects on marine mammals, seabirds, and humans that range from mild gastrointestinal sickness to memory loss, seizures, or death.

Food Webs and HABs

There are three major categories of living organisms in an ecosystem, and each has a special role. Together, producers (plants that produce energy from sunlight), consumers (animals, both herbivorous and carnivorous), and decomposers (and detritus feeders) are the building blocks of a food pyramid. Food energy produced by producers via photosynthesis is cycled through the ecosystem through food chains and more complex food webs by way of a series of energy/feeding levels called trophic levels.

Producers make up the first trophic level, or base of the pyramid. Primary/herbivorous consumers rely on producers for food energy and make up the second trophic level. Secondary/carnivorous consumers make up the third trophic level, and so on. Each trophic level depends on the levels below it for food energy.

When an animal consumes food having toxic residues the toxins accumulate in the tissue of the animal by a process called **bioaccumulation**, the accumulation of toxins in the tissue of a particular organism. The higher the animal is in the food web, the greater the concentration of toxins in their bodies, resulting in a process called **bio-magnification**, the increased concentration of a toxin that depends on what level the animal is on the food web. Some organisms are not affected by the toxins themselves, but act as vectors and transport the toxins up the food web into higher level organisms, like fish, seabirds, manatees, sea lions, turtles and dolphins.

Activity Part 1: Analyzing and Interpreting Data

1. Break students into 4 groups and give them the **"Harmful Algal Bloom Scenario Card"**. Have students take turns reading and give them time to discuss.
2. Tell students that their first task is to compare two time-series plots of data that was collected over a 20-year period. Handout **"Dataset 1: Domoic Acid & Ocean Index Time Series"** and go over it. This first time-series **(Graph 1)** includes data on when there were "outbreaks" on the Oregon coast of domoic acid in shellfish. The second time-series plot **(Graph 2)** shows the Ocean Index (OI) over the same period of time.
3. Explain that the OI describes patterns of ocean currents and water temperatures over very large areas, such as the entire Pacific Ocean, and usually have 2 patterns called "warm" and "cool" phases. The graphs at the bottom of Dataset 1 show what the ocean currents and water temperatures will look like along the U.S. West Coast as the OI moves through warm and cool phases over time (Graph 2).
4. Give students time to look at the plots and ask them to **discuss**:
   - What is happening to the ocean currents during periods when high levels of DA are detected in Oregon shellfish?
   - What similarities/differences do you see in the plots? What can we take away from these? *Students should see that high levels of DA in shellfish events occur around the same time as when there are warm phases in the OI, which means ocean currents are bringing big parcels of warm water up towards the Oregon coast.*

Next Generation Science Standards

DISCIPLINARY CORE IDEAS:

Ecosystems: Interactions, Energy, and Dynamics

PERFORMANCE EXPECTATIONS:

HS-LS2-2. Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.

HS-LS2-6. Evaluate claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.

MS-LS2.2. Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems.

MS-LS2.4. Construct an argument supported by empirical evidence that changes to physical and biological components of an ecosystem affect populations.

SCIENCE AND ENGINEERING PRACTICES:

Constructing Explanations and Designing Solutions

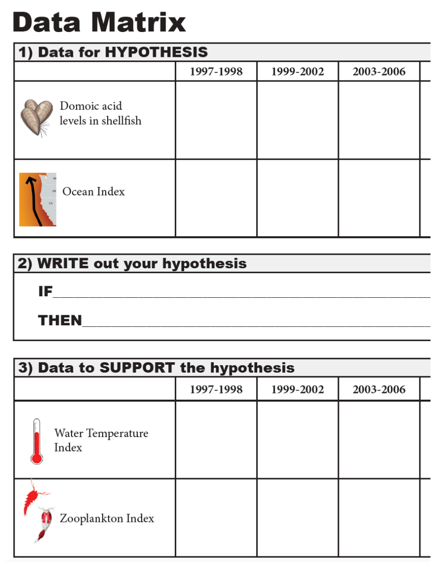
Engaging in Argument from evidence

CROSS CUTTING CONCEPTS:

Cause and Effect

Stability and Change

5. Tell students that each one of their groups is going to fill in a data matrix using "datasets" that represent specific periods of the time series in Dataset 1. Handout and review the **"Data Matrix"** with students.
6. Handout and have students review **"Dataset 2: Domoic Acid in Shellfish & Ocean Index"** give each group 2-3 sets of time periods to look at (ex. group 1: 1999- 2002 & 2003-2006; etc.). Dataset 2 graphically simulates the time series on Dataset 1. It provides data on domoic acid in shellfish and an ocean index map in a format students can enter into their matrix.
7. Ask: As scientists, can we assume that because we see a similar pattern and trend for DA in shellfish and the OI that they are related? No, correlation does not equal causation! We have to develop a hypothesis and find evidence to support it.
8. Tell students that they are going to create a hypothesis about the origin of the toxin DA in ocean. As a class ask students what hypothesis they might develop based on the information they have from the graphs in the form of an **IF** ____ **THEN** ____ statement. Lead them to the common hypothesis: IF the Ocean Index is in a warm phase THEN domoic acid outbreaks in Oregon shellfish are likely to occur.
9. Tell students that their next step is to figure out an explanation as to WHY this hypothesis could possibly be true— what type of data could connect the warm OI periods to the elevated domoic acid in shellfish?
10. Remind students that the OI is measured far away from Oregon and describes a pattern for the entire Pacific Ocean (on handout), this means local conditions in Oregon don't always match the OI. In order to test our hypothesis that the ocean currents along Oregon have changed in response to the warm OI phases we need to examine data from Oregon that describes the ocean currents and water temperature.
11. Ask students what data might support the hypothesis that a warm OI phase has caused a shift in ocean currents that has brought warmer than normal waters to the Oregon coast?
Possible answers: ocean current measurements and water temperature measurements.


Data Matrix

1) Data for HYPOTHESIS

	1997-1998	1999-2002	2003-2006
Domoic acid levels in shellfish			
Ocean Index			

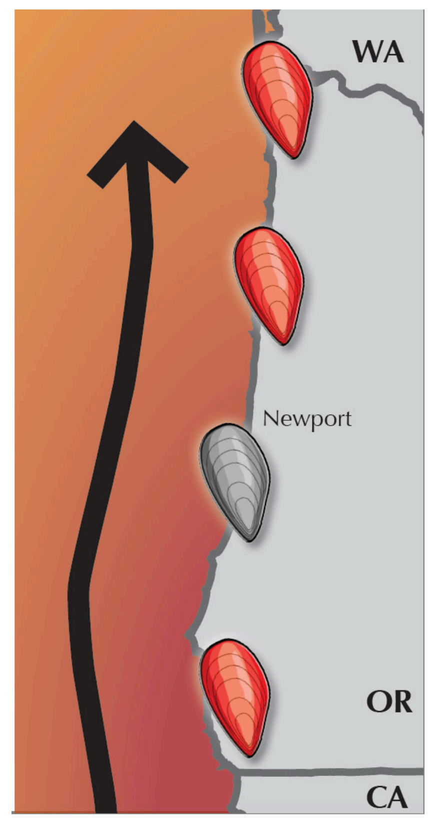
2) WRITE out your hypothesis

IF____________________

THEN____________________

3) Data to SUPPORT the hypothesis

	1997-1998	1999-2002	2003-2006
Water Temperature Index			
Zooplankton Index			

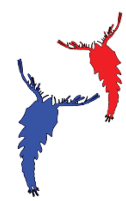


12. Next handout **"Dataset 3: Temperature Index"**. Talk to students about how researchers collect water quality data onboard vessels and with buoys. Have students fill in their data matrix for water temperature an discuss why they still do not have enough information to support their hypothesis. There are many things which ca impact water temperature. The Temperature Index tells us when waters are warmer or cooler than usual, but unusually warm waters can happen for reasons other than big changes in the ocean currents.

TEMPERATURE DATA

Changes in winds and river outflow can bring unusually warm river water to the area of the coast where the buoy measures temperature. The temperature index alone is helpful, but to solidify a hypothesis students would need to look at more data!

13. Tell students that researchers often look at organisms in the water called plankton to better understand changes in the marine environment. Talk to students about what plankton is and make sure that students understand that plankton are weak swimmers and are transported by currents. Because they drift with currents we can learn a lot by looking at the specific organisms which are present. Handout **"Dataset 4: Zooplankton Index".**
14. Once groups have put all of their data into their individual matrices, have them add their data to a larger class data matrix that includes all of the years and all of the data sets (you can do this on an overhead or using a piece of poster paper). **Have students use a red marker for warm years and blue for cool years.** As a class discuss:
    - What patterns can we see?
    - What information have we gained?
    - Is there anything that connects warm water to the domoic acid events?



15. Students should see that IF there are warm currents off the coast THEN there are domoic acid outbreaks in shellfish. This data supports our hypothesis! But WHY?

Discuss with students: The Zooplankton Index provides evidence of changes in ocean currents because, as drifting animals that can't swim, the groups of zooplankton observed off the Oregon coast can be considered **indicators of where the water came from.** This is because the types of zooplankton in the warmer waters that originate south and far offshore of Oregon are very different from the types of zooplankton in the cooler waters that originate far north of Oregon. So if scientists see warmer water temperatures than usual AND lots of warm water species of zooplankton, that is **strong evidence in favor of a major change in ocean currents.** Therefore, the data supports that warmer currents are likely WHY we are seeing these DA outbreaks!

FUN FACT

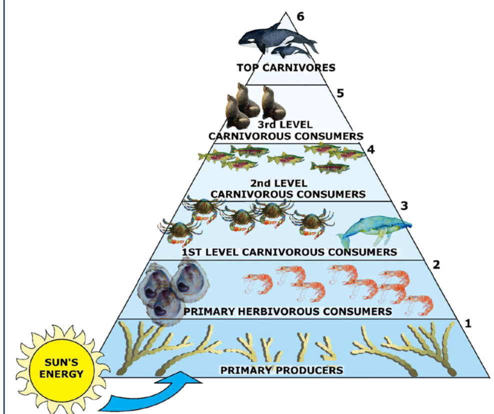
In the real world, direct measurements of ocean currents would have been ideal to support the hypothesis that OI related changes in currents were related to domoic acid events, however these measurements were not available. In the actual study the scientists used the zooplankton index as it was the only data available over that time long frame, other than temperature, in the region that provided evidence of changes in the ocean currents.

16. Tell students that they now have the WHY for their hypothesis and

can report back to those who hired them as to why they believe the HAB's are happening, but they also need to determine what impact HAB's may be having on the larger marine food web. This information will help them determine other important organisms to study on future research expeditions and to propose future research that their team will do.

Activity Part 2: Building a Marine Pyramid

17. Tell students that they are now going to examine a marine food web off of the Oregon coast. This activity can be done indoors on a large sheet of butcher paper or outdoors on an asphalt surface using chalk. Discuss what the students know about food chains and food webs.
18. Hand out **"Tropic pyramid"** sheets and make sure that students understand the energy flow within a pyramid. Discuss primary and secondary producers and consumers. Hand out "**Food Pyramid Cards"** and have students build their marine pyramids. Let them know that their assignment is to explore how and where these organisms get the energy they need to survive in the ocean.
19. Have students read the descriptions of the organisms and predict which belongs on each trophic level. Ask students to consider why each organism belongs at a particular trophic level.
20. Ask students to think about other ways that organisms are connected. Do organisms only eat those below them in the pyramid? Have students connect organisms that they believe depend on each other with arrows. Arrows should go in the direction that the energy flows. **Ask:** do organisms always stay withn the same trophic levels?
21. Remind students that in learning about HABs they saw that shellfish were negatively impacted by domoic acid in plankton, however, sometimes organisms are not affected by the toxins themselves, but act as vectors and transport the toxins up the food web into higher level organisms—like fish, seabirds, and sea lions. Tell students that they are going to examine how similar changes to the ocean might impact their food web.
22. Have students look at their **"HAB Event Cards"** and read them one at a time. Have them make changes accordingly by either removing affected organisms or covering them with small post-it



Marine Pyramid Key

Top Carnivores
Killer whale, White shark
3rd Level Carnivorous Consumers
Sea lion, Dogfish shark, Science teacher
2nd Level Carnivorous Consumers
Salmon, Halibut, Lingcod, Murre
1st Level Carnivorous Consumers
Jellyfish, Dungeness crab, Herring, Sardine
Primary Herbivorous Consumers
Oyster, Geoduck clam, Pacific krill, Humpback whale, Copepod
Primary Producers
Pseudo nitzchia, Alexandrium, Asterionellopsis, Chaetoceros, Noctilucales

notes. Once students have made changes to their food pyramids ask:

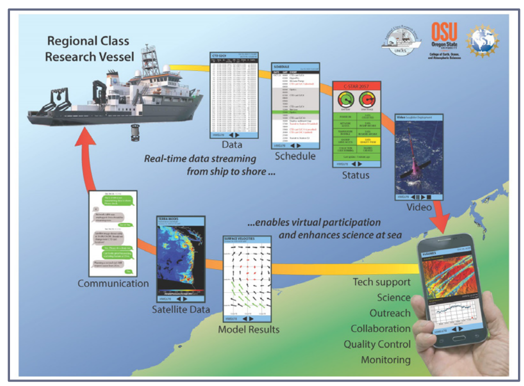
- What impact did the warm current have on the organisms?
- Why do these changes matter?
- Are some organisms impacted more than others?
- Which organism does your group think would be an important/interesting species to study further? Why?

Activity Part 2: Presenting Your Findings

23. Tell students that they are now going to put together everything that they learned into a presentation that they will give to shellfish managers. In addition to their learnings, they must propose a plan for a future research cruise off the Oregon Coast. Give students a piece of poster paper and outline what their presentations should include:
    - Team hypothesis
    - Interpretation of the datasets
    - Whether the data supported their hypothesis- their conclusion
    - What questions do they still want to find the answers to?
    - A proposal for a research cruise that would help their group learn more about HAB's *(i.e.* **WHAT** *you will study,* **WHY** *you are studying it, and* **HOW** *you will study it).*

Wrap Up:

24. Discuss how those data were used to support and explain that hypothesis in the real world.
25. Discuss how research vessels play an important role in finding the answers to real world problems.
26. Talk about the **Regional Class Research Vessel** project and datapresence. What is datapresence and how will it help researchers with better understanding and forecasting environmental issues such as HABs? *Data presence would give scientists everywhere access to quality real-time data and to shore-based expertise and participation in sea-going operations. It would also allow scientists to more readily engage in educational activities and that engage local communities and the general public.*



Resources:

Vector images on handouts are courtesy of the Integration and Application Network, University of Maryland Center for Environmental Science (**ian.umces.edu/symbols/**)

An unprecedented coastwide toxic algal bloom linked to anomalous ocean conditions, Geophysical Research Letters

(**http://onlinelibrary.wiley.com/doi/10.1002/2016GL070023/epdf**)

It's a plankton eat plankton world **(https://askabiologist.asu.edu/experiments/plankton)**

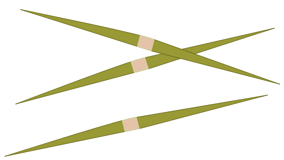
This project is supported by the **Regional Class Research Vessel Program** in the College of Earth, Ocean, and Atmospheric Sciences at Oregon State University.

Thanks to Morgaine McKibbens for contributing her expertise on harmful algal blooms and creating generalized data loosely based on an actual study.

Harmful Algal Bloom Scenario Card

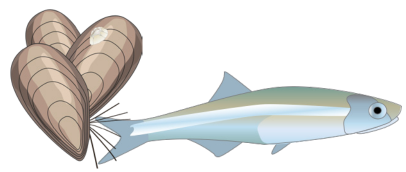
High concentrations (blooms) of toxin-producing phytoplankton

EXAMPLE: ***PSEUDO-NITZSCHIA***



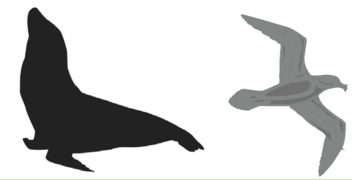
Toxic phytoplankton are ingested by filter-feeders

EXAMPLES: *ANCHOVIES (FISH) AND MUSSELS (SHELLFISH)*



Ingestion of toxic filter-feeders can lead to sickness or death

EXAMPLES: ***MARINE MAMMALS, SEABIRDS, HUMANS***

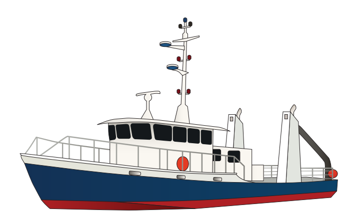


There has been a major shellfish closure off of the Oregon coast because of a "Harmful Algal Bloom" (HAB) that led to high levels of the toxin domoic acid in crabs, clams, and mussels, making them unsafe to eat. While most blooms of phytoplankton (microscopic, single-celled algae) are beneficial, HABs have toxic or otherwise harmful effects on the ecosystem and organisms that live in it. The diagram above explains how toxic HABs can enter the foodweb and sicken animals and humans.

Over the past few years there have been many closures costing the shellfish industry millions of dollars. The State of Oregon has decided to invest in this issue and hire scientists to find out WHY these events are happening so they can better forecast them. You are part of the research team who has been hired to take on this important environmental problem.

Your task:

- Analyze and interpret existing data that has been collected by research vessels and buoys
- Determine what impact HAB's may be having on the larger marine food web
- Propose future research that your team would like to do to on a vessel
- Share all of your findings with the shellfish managers



Data Matrix

1) Data for HYPOTHESIS

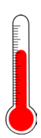
	1997-1998	1999-2002	2003-2006	2007-2009	2010	2011-2013	2014-2015
 Domoic acid levels in shellfish							
 Ocean Index							

2) WRITE out your hypothesis

IF____

THEN______________________________________

3) Data to SUPPORT the hypothesis

	1997-1998	1999-2002	2003-2006	2007-2009	2010	2011-2013	2014-2015
 Water Temperature Index							
 Zooplankton Index							

Data Matrix - completed example

1) Data for HYPOTHESIS

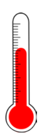
	1997-1998	1999-2002	2003-2006	2007-2009	2010	2011-2013	2014-2015
 Domoic acid levels in shellfish	very high	none	high	none	high	none	very high
 Ocean Index	warm phase	cool phase	warm phase	cool phase	warm phase	cool phase	warm phase

2) WRITE out your hypothesis

IF the ocean index is in a warm phase

THEN domoic acid outbreaks in Oregon shellfish are likely to occur.

3) Data to SUPPORT the hypothesis

	1997-1998	1999-2002	2003-2006	2007-2009	2010	2011-2013	2014-2015
 Water Temperature Index	much warmer than usual	much cooler than usual	warmer than usual	cooler than usual	warmer than usual	much cooler than usual	much warmer than usual
 Zooplankton Index	many more “warm water” zooplankton than usual	more “cool-water” zooplankton than usual	more “warm water” zoo-plankton than usual	many more “cool-water” zooplankton than usual	more “warm water” zoo-plankton than usual	many more “cool-water” zooplankton than usual	more “warm water” zoo-plankton than usual

Marine Trophic Pyramid

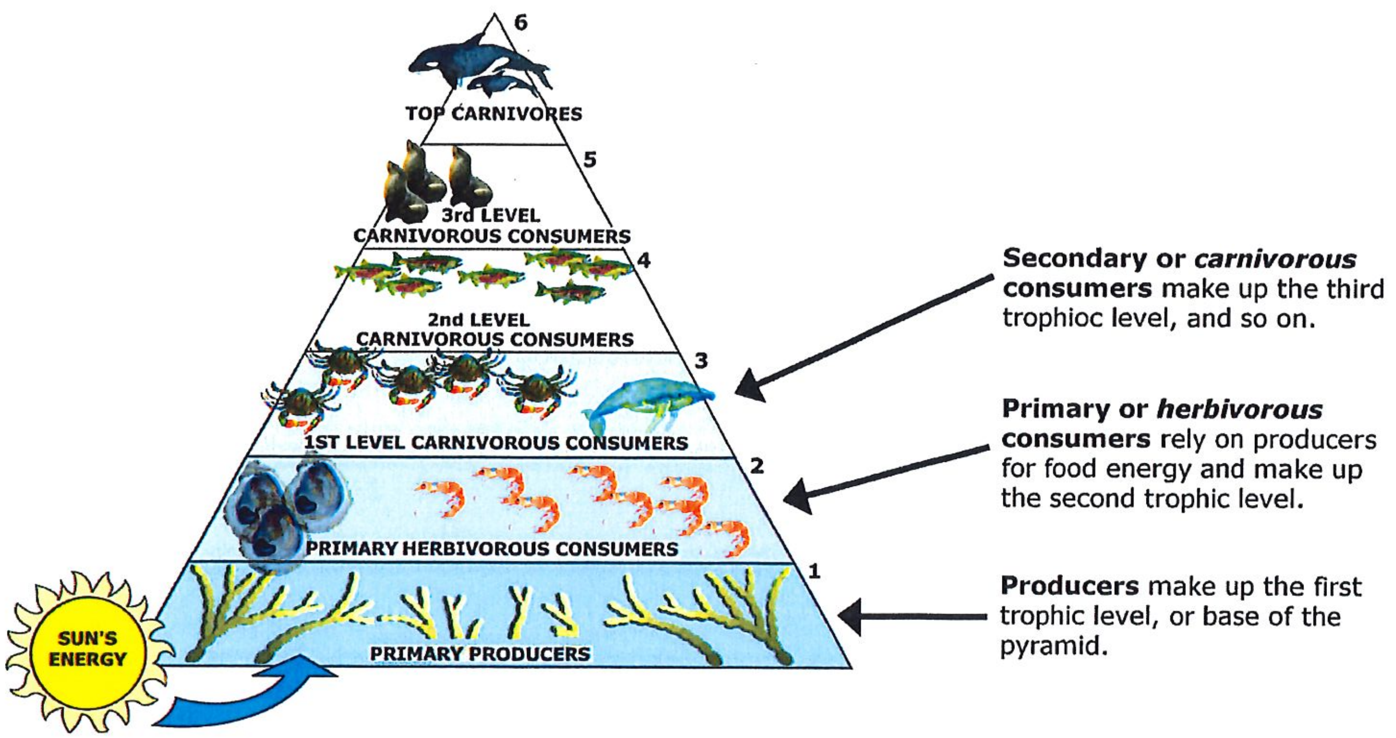
There are three major categories of living organisms in an ecosystem, and each has a special role and are the building blocks for a food pyramid!

- Producers are plants that produce energy from sunlight
- Consumers are animals that are both herbivorous and carnivorous
- Decomposers are organisms that break down dead and decaying material.

You are going to focus on producers and consumers while you build your own marine food pyramid!

Food energy produced by producers is cycled through the ecosystem through food chains and more complex food webs by way of energy/feeding levels called "trophic levels".

Each trophic level depends on the levels below it for food energy.



Build your own trophic pyramid!

1. Read the descriptions on the organism cards and predict which trophic level they belong in. Consider why each organism belongs at a particular trophic level.

2. Once you have placed all of your organisms in a group, connect organisms that you believe depend on each other with arrows. Arrows should go in the direction that the energy flows.

3. Use your "HAB Event Cards" to examine how changes to the ocean might impact your food web.