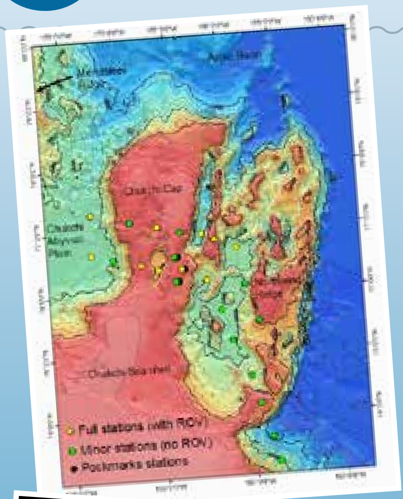
Ocean Exploration and Research



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lesson plan

Hidden Ocean Expedition 2016: Chukchi Borderlands

Three Cold Realms

(adapted from the 2005 Hidden Ocean Expedition)

Focus

Pelagic, benthic and sea ice realms of the Chukchi Borderlands

Grade Level

6-8 (Life Science)

Focus Question

What organisms are typical of the pelagic, benthic and sea ice realms in the Chukchi Borderlands environment, and how do these organisms interact?

Learning Objectives

- Students will compare and contrast the pelagic, benthic and sea ice realms of the Chukchi Borderlands environment.

- Students will predict and explain patterns of interactions among organisms across these three realms.

Materials

None

Audio-Visual Materials

None

Teaching Time

One or two 45-minute class periods, plus time for student research and preparation

Seating Arrangement

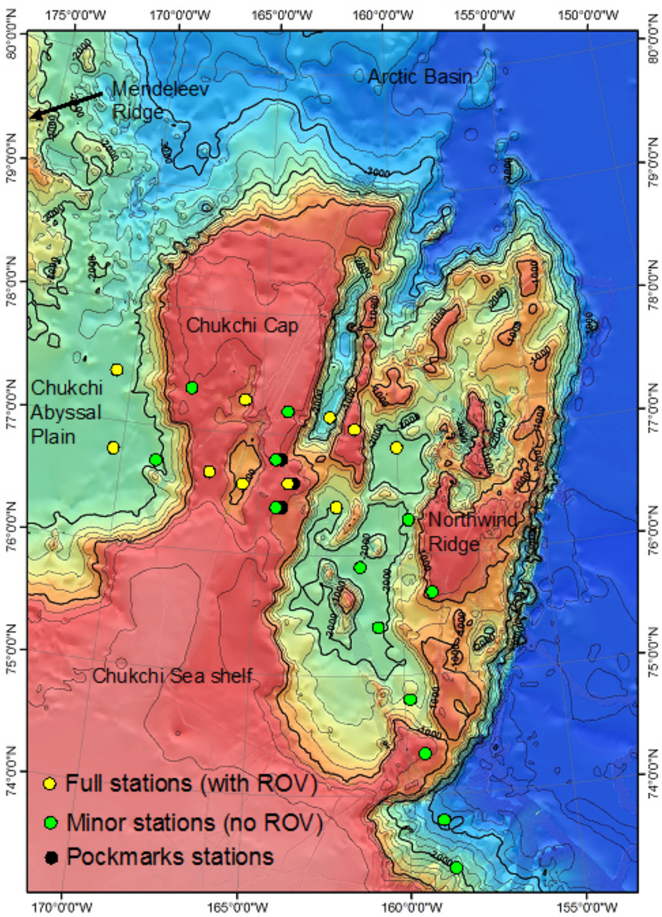
Three groups of students

Maximum Number of Students

30

Key Words

Pelagic realm
Benthic realm
Sea ice realm
Sympagic
Brine channel
Arctic Ocean
Chukchi Sea



Bathymetry of Chukchi Borderlands with tentative stations positions. Image courtesy M. Edwards, University of Hawaii.

Background Information

NOTE: Explanations and procedures in this lesson are written at a level appropriate to professional educators. In presenting and discussing this material with students, educators may need to adapt the language and instructional approach to styles that are best suited to specific student groups.

The Arctic Ocean is the most inaccessible and poorly studied of all the Earth's major oceans, and is the area that may experience the greatest impact from climate change. The Chukchi Borderlands (CBL) to the north of Alaska is one of the Arctic's least-explored and most rapidly changing regions. The topographic complexity of this region, which includes ridges, canyon, abyssal trenches, and shallow plateaus, suggests that there may be a similar variety of biological communities; but very little exploration has taken place to confirm this suggestion. The need for such exploration is urgent, because the rapid rate of environmental change within the CBL makes it likely that the region's biological communities will change as well. Exploring CBL biological communities is the purpose of the Hidden Ocean Expedition 2016: Chukchi Borderlands Expedition (*http://oceanexplorer.noaa.gov/explorations/16arctic/welcome.html*).

CBL biological communities are tightly linked to each other and occur in three distinct environments:

- The Benthic Realm, which is composed of organisms that live on the bottom, including sponges, bivalves, crustaceans, polychaete worms, sea anemones, bryozoans and tunicates;
- The Pelagic Realm, which includes organisms that live in the water column between the ocean surface and the bottom; and
- The Sea Ice Realm, which includes plants and animals the live on, in, and just under the ice that floats on the ocean's surface.

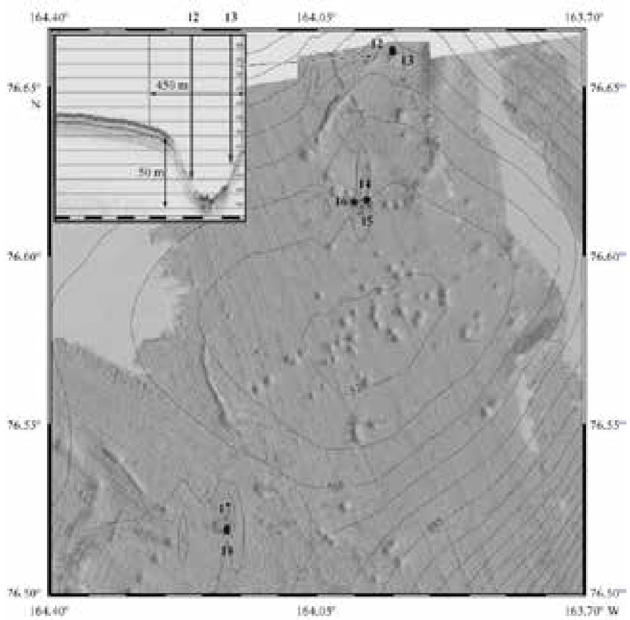
The Chukchi Borderlands Expedition uses an integrated ecosystem strategy that includes three components, each of which is focused on one of these realms.

Images from Page 1 top to bottom:
Bathymetry of Chukchi Borderlands with tentative stations positions. Image courtesy M. Edwards, University of Hawaii.

Sea ice extent in the Arctic in April 2014. Image courtesy of the National Snow and Ice Data Center.
http://oceanexplorer.noaa.gov/explorations/15arctic-microbes/background/seaice/seaice.html

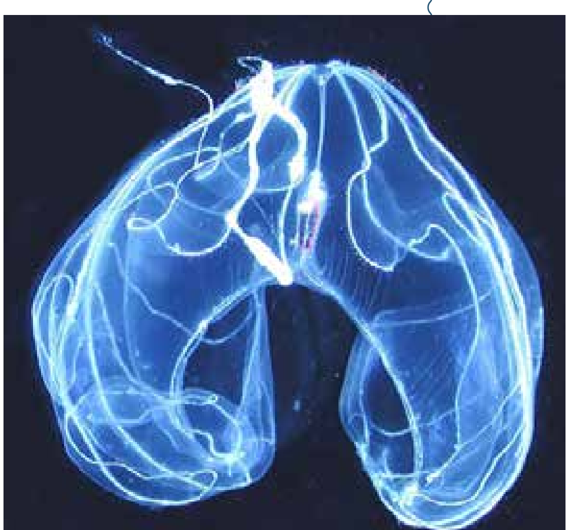
Single-celled (unicellular) algae, which develop in the lowermost sections of sea ice, often form chains and filaments. Ice algae are an important component of the Arctic marine food web. Image courtesy of the NOAA Arctic Research Program.
http://oceanexplorer.noaa.gov/explorations/15arctic-microbes/background/missionplan/media/arctic-algae.html

In 2005, NOAA explorers discovered the reproductive mode for the deep-water copepod *Euaugaptilus hyperboreus*. Image courtesy of the The Hidden Ocean Arctic 2005 Expedition.



Bottom topography of a pockmark field in the Chukchi Borderlands.. The insert shows a distinct depression in the bottom profile of pockmark crater #12. Image courtesy Astakhov *et al.* 2014.

The **Unexplored Seafloor Community** component focuses on the benthic realm. Benthic invertebrate and fish fauna will be collected with a combination of corer, trawl, and remotely operated vehicle (ROV) techniques. Collected specimens will be identified with standard morphological techniques, as well as DNA sequencing. These techniques will allow explorers to look for relationships between CBL fauna and organisms found on the Chukchi shelf and adjacent deep-sea environments. An important part of this component is to improve understanding of trophic relationships between benthic organisms, bottom-feeding fishes, and higher trophic levels such as marine mammals. This component also includes investigations of unusual bottom features called "pockmarks," which are craters ranging in size from less than one meter to over 100 meters in diameter. Pockmarks are typically formed by seeping sulfur or carbon compounds, which provide specialized habitats for organisms that are able to tolerate and utilize seep fluids that are toxic to many other species.



This is an example of a ctenophore, *Bathocyroe fosteri*, which is a mesopelagic species. Image courtesy of Arctic Exploration 2002, Marsh Youngbluth, NOAA/OER.
http://oceanexplorer.noaa.gov/explorations/02arctic/background/fauna/media/cteno.html

The **Exploration of Pelagic Life in a Complex Polar Environment** component focuses on the pelagic realm. Many pelagic species are floating organisms collectively known as zooplankton, including floating crustaceans, jellyfishes, and larvae of many species. Studies of zooplankton are traditionally biased to organisms that can be captured by plankton nets, usually in waters shallower than 200 m. This bias excludes many fragile species as well as those that are able to avoid plankton nets. Very little is known about the ecology and distribution of gelatinous zooplankton such as ctenophores, siphonophores, hydromedusae, and scyphomedusae. Deepwater gelatinous zooplankton are an important part of the global carbon cycle, because they are constantly grazing and re-processing carbon produced by photosynthesis in shallower water. The primary objective of this component is to inventory pelagic species including deepwater and gelatinous zooplankton, including DNA libraries of these species. To include species usually excluded by traditional sampling methods, explorers will use photographic and video documentation of living animals accompanied by collection of representative specimens. Specialized collection devices and

ROV Global Explorer will be used for both pelagic and benthic work. Equipped with new 4K cameras, this ROV will yield ultra-high-definition quality imaging of in situ habitats and communities, plus specimen collection capabilities essential for the discovery of delicate pelagic and benthic species. Image courtesy Deep Sea Systems.

photographic equipment will be included on the Expedition's ROV *Global Explorer*.

The **Navigating the Hidden Microbial Network in Sea Ice** component focuses on the sea ice realm. Sea ice provides a complex habitat for many species that are called sympagic, which means "ice-associated." The ice is riddled with a network of tunnels called brine channels that range in size from microscopic (a few thousandths of a millimeter) to more than an inch in diameter. Some areas of Arctic sea ice persist throughout the year, and endemic species (species that are not found anywhere else) have developed in the multi-year sea ice of the deep ocean basins. Diatoms and algae inhabit these channels and obtain energy from sunlight to produce biological material through photosynthesis (a process called "primary production"). Bacteria, viruses, and fungi also inhabit the channels, and together with diatoms and algae provide an energy source (food) for flatworms, crustaceans, and other animals.

Sterilely sectioning a sea ice core in Franklin Bay, Canada. Image courtesy of Eric Collins.
http://oceanexplorer.noaa.gov/explorations/15arctic-microbes/background/seaice/media/core.html

The basic method is as follows:
1) collect sea ice cores using a specialized ice auger;
2) cut the ice into 6 in (10 cm) sections;
3) melt the ice;
4) pump the melted ice through a filter to collect the microbes;
5) extract DNA from the filters; and
6) sequence the DNA to determine the diversity of genes and organisms in the ice.

In the spring, melting ice releases organisms and nutrients that interact with the ocean water below the ice. Large masses of algae form at the ice-seawater interface and may form filaments several meters long. On average, more than 50% of the primary production in the Arctic Ocean comes from single-celled algae that live near the ice-seawater junction. This interface is critical to the polar marine ecosystem, providing an energy source (food) for many organisms, as well as protection from predators. Arctic cod use the interface area as nursery grounds, and in turn provide an important food source for many marine mammals and birds, as well as migration routes for polar bears. In the spring, the solid ice cover breaks into floes of pack ice that can transport organisms, nutrients, and pollutants over thousands of kilometers. Partial melting of sea ice during the summer months produces ponds on the ice surface called polynyas that contain their own communities of organisms.

Fishing for microbes in the Chukchi Sea. Image courtesy of the Mapping the Uncharted Diversity of Arctic Marine Microbes expedition.
http://oceanexplorer.noaa.gov/explorations/15arctic-microbes/logs/january11/media/fig2.html

Vacuum pump apparatus for cleaning up and isolating genetic material. Image courtesy of the Mapping the Uncharted Diversity of Arctic Marine Microbes expedition.
http://oceanexplorer.noaa.gov/explorations/15arctic-microbes/logs/january11/media/fig4-hires.jpg

When sea ice melts, more sunlight enters the sea, and algae grow rapidly since the sun shines for 24 hours a day during the summer. These algae provide energy for a variety of pelagic organisms, including floating crustaceans and jellyfishes called zooplankton, which are the energy source for larger pelagic animals including fishes, squids, seals, and whales. When pelagic organisms die, they settle to the ocean bottom, and become the energy source for inhabitants of the benthic realm. These animals, in turn, provide energy for bottom-feeding fishes, whales, and seals.

Since 2007, the extent of Arctic sea ice has declined sharply. Further declines may have serious consequences for pelagic and benthic Arctic realms if these declines reduce the amount of sea ice-produced organic matter available to these realms. In particular, the loss of organic detritus from sea ice algae may have major nutritional impacts on primary and secondary consumers.

This lesson is intended to introduce students to the three realms of marine life in the Chukchi Borderlands, and to the diversity of organisms that inhabit these realms.

Learning Procedure

1. To prepare for this lesson:
   a. Review background information about the Hidden Ocean Expedition 2016: Chukchi Borderlands [*http://oceanexplorer.noaa.gov/explorations/16arctic/welcome.html*]
   b. You may also want to review the following essays from the Hidden Ocean, Arctic 2005 Expedition:
   "Arctic Sea Ice" by Rolf Gradinger [*http://oceanexplorer.noaa.gov/explorations/05arctic/background/sea_ice/sea_ice.html*]
   "Spineless Wonders II: The Pelagic Fauna" by Russ Hopcroft [*http://oceanexplorer.noaa.gov/explorations/05arctic/background/fauna/fauna.html*]
   "Arctic Biodiversity" by Bodil Bluhm and Russ Hopcroft [*http://oceanexplorer.noaa.gov/explorations/05arctic/background/biodiversity/biodiversity.html*]
   c. Review information on the Arctic Ocean Biodiversity Web site (*http://www.arcodiv.org/#*), which, in addition to the Ocean Explorer Web site, has much of the information needed for students to complete this lesson.

   If students will not have access to the internet, you may want to make copies of selected essays, as well as the Web pages for "Water Column," "Sea Ice," and Sea Bottom" on the Arctic Ocean Biodiversity Web site. You may also want to prepare a background sheet for the collage that students will create using the schematic diagram of the three realms on the Arctic Ocean Biodiversity introduction page as a guide.

2. Briefly review the geography of the Arctic Ocean, highlighting the location of the Chukchi Borderlands and its relationship to the Arctic and Pacific Oceans. Introduce the three realms of marine life in the Chukchi Borderlands. You may also want to briefly discuss Arctic climate change and why it is so important to gather information on species that presently inhabit the three realms as soon as possible.

3. Divide students into three groups. Tell students that their assignment is to:
   - Research one of the three realms;
   - Find out what kinds of organisms inhabit their assigned realm
   - Obtain a picture of each organism
   - Work with other groups to assemble a collage that illustrates the inhabitants of the three realms; and
   - Prepare a brief report in which they predict and explain patterns of interactions among organisms across these three realms. Predictions should focus on consistent patterns of interactions in different realms including relationships among and between organisms and abiotic components of these realms.

   You may also want to have students include a label on their images giving the classification of the organism (phylum and class) as well as its common name.

4. Direct students to the Arctic Ocean Biodiversity Web site and to the Hidden Ocean Expedition pages on the Ocean Explorer Web site. Call students' attention to the "Photo and Video Log" section of the Ocean Explorer Web site which contains images that they may want to use for their collage.

5. Have each group present an oral summary of their written report, then lead a discussion of students' collage of the three realms. These reports and discussions should include the following points:
   - Many inhabitants of the sea ice realm are endemic to this ecosystem.
   - Sea ice inhabitants include protozoa, turbellaria,

nematodes, rotifers, and amphipods; in the spring larvae and juveniles of benthic animals are also found in the ice.

- In addition to providing a feeding ground for larvae and juveniles of benthic animals, the sea ice realm is linked to the pelagic realm by Arctic cod which feed on the amphipods that inhabit the underside of ice floes; the cod, in turn, are an important food source for seals, birds, whales, and predatory fishes.
- Fauna of the pelagic realm (water column) are dominated by small crustaceans and gelatinous animals; the latter are not well-known because they are usually destroyed in sampling nets.
- Pelagic realm inhabitants include protists, cnidaria, ctenophores, polychaetes, pteropods, cephalopods, heteropods, cladocerans, ostracods, copepods, mysids, amphipods, euphausiids, decapods, chaetognaths, tunicates, and fishes.
- Inhabitants of the benthic realm are constrained by food supplies, because they depend primarily on food particles that settle from higher in the water column or that are transported from the continental slopes. This means that many other organisms have had access to the food particles before they reach the bottom, so benthic organisms are left with what has been missed or rejected by inhabitants of the pelagic realm.
- Benthic realm inhabitants include polychaetes, crustaceans, bivalves, fishes, anemones, and tunicates. Shells of scaphopods and gastropods have also been recovered from deep areas, but these may have been deposited from the continental shelves. Be sure students understand that the Sea Bottom page on the Arctic Ocean Biodiversity Web site includes images of organisms found in shallow waters as well as those of the deep benthos.

The BRIDGE Connection

www.vims.edu/bridge/ – Mouse over "Ocean Science Topics," then "Habitats," then "Polar" to find links to information and activities concerning the Arctic region.

The "Me" Connection

Have students write a brief essay explaining why they think it is important (or not important) to explore areas such as the Chukchi Borderlands. If some students believe these activities are unimportant, point out that many of the most promising drugs for serious human diseases (such as cancer) are being found in organisms that live in the deep sea.

Connections to Other Subjects

English/Language Arts, Geography

Assessment

Student reports prepared in Learning Procedure Step 3, the group collage and discussions in Step 5 provide opportunities for assessment.

Extensions

1. Have students visit [*http://oceanexplorer.noaa.gov/explorations/16arctic/welcome.html*] to keep up to date with the latest Hidden Ocean Expedition 2016: Chukchi Borderlands discoveries.

2. Visit *http://oceanexplorer.noaa.gov/explorations/02arctic/background/education/education.html* and *http://oceanexplorer.noaa.gov/explorations/05arctic/background/edu/edu.html* for more lesson plans and activities related to the 2002 and 2005 Hidden Ocean expeditions.

Other Relevant Lessons from NOAA's Ocean Exploration Program

Life in the Crystal Palace (grades 5-6)
from the 2002 Arctic Exploration Expedition
[*http://oceanexplorer.noaa.gov/explorations/02arctic/background/education/media/arctic_crystal.pdf*]

Focus: Sea ice communities in the Arctic Ocean (Life Science)

Students identify major groups of organisms found in Arctic sea ice communities, describe major physical features of sea ice communities and how these features change during summer and winter, and explain how these changes affect biological activity within these communities. Students also describe interactions that take place between sea ice communities, and explain the importance of sea ice communities to Arctic ecosystems.

Would You Like a Sample? (grades 7-8)
from the 2003 Charleston Bump Expedition
[*http://oceanexplorer.noaa.gov/explorations/03bump/background/education/media/03cb_complex.pdf]*

Focus: Sampling strategies for biological communities (Life Science)

Students identify the three realms of the Arctic Ocean, and describe the relationships between these realms and discuss the advantages and limitations of sampling techniques to study biological communities.

Meet the Arctic Benthos (grades 7-8)
from the 2002 Arctic Exploration Expedition
[*http://oceanexplorer.noaa.gov/explorations/02arctic/background/education/media/arctic_benthos.pdf]*

Focus: Benthic invertebrate groups in the Arctic Ocean (Life Science)

Students recognize and identify major groups found in the Arctic benthos, describe common feeding strategies used by benthic animals in the Arctic Ocean, and discuss relationships between groups of animals in Arctic benthic communities. Students also discuss the importance of diversity in benthic communities

Where Have All the Glaciers Gone? (grades 7-8)
from *Okeanos Explorer Education Materials Collection, Volume 1: Why Do We Explore?*
[*http://oceanexplorer.noaa.gov/okeanos/edu/collection/media/wdwe_glaciers.pdf]*

Focus: Arctic Climate Change (Earth Science)

Students describe how climate change is affecting sea ice, vegetation, and glaciers in the Arctic region, explain how changes in the Arctic climate can produce global impacts, and provide three examples of such impacts. Students also explain how a given impact resulting from climate change may be considered 'positive' as well as 'negative', and provide at least one example of each.

Other Resources

The Web links below are provided for informational purposes only. Links outside of Ocean Explorer have been checked at the time of this page's publication, but the linking sites may become outdated or non-operational over time.

[*http://oceanexplorer.noaa.gov/explorations/16arctic/welcome.html*] – Follow the Hidden Ocean Expedition 2016: Chukchi Borderlands as documentaries and discoveries are posted each day for your classroom use.

http://www.coml.org/arctic-ocean-dicersity-arcod – The Arctic Ocean biodiversity section of the Census of Marine Life Web site *http://www.arctic.noaa.gov/* – NOAA's Arctic theme page with numerous links to other relevant sites

http://maps.grida.no/arctic/ – Thematic maps of the Arctic region showing populations, ecoregions, and more

http://www.thearctic.is/ – A Web resource on human environment relationships in the Arctic

http://www.dfo-mpo.gc.ca/regions/central/index-eng.htm — Web site produced by Fisheries and Oceans Canada on the Arctic.

Next Generation Science Standards

The primary purpose of this lesson is to assist educators with incorporating information about pelagic, benthic and sea ice realms of the Chukchi Borderlands of the Arctic into their instructional program. While they are not intended to target specific Next Generation Science Standards, activities in this lesson may be used to address specific NGSS elements as described below.

MS-LS2 Interdependent Relationships in Ecosystems

Performance Expectation

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

[Clarification Statement: Emphasis is on predicting consistent patterns of interactions in different ecosystems in terms of the relationships among and between organisms and abiotic components of ecosystems. Examples of types of interactions could include competitive, predatory, and mutually beneficial.]

Science and Engineering Practices

Constructing Explanations and Designing Solutions

- Construct an explanation that includes qualitative or quantitative relationships between variables that predict phenomena.

Disciplinary Core Ideas

- ***LS2.A: Interdependent Relationships in Ecosystems***
  - Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. These limits result from such factors as the availability of living and nonliving resources and from such challenges such as predation, competition,

and disease. Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem.

Crosscutting Concepts

Patterns

- Patterns can be used to identify cause and effect relationships.

Common Core State Standards Connections:

ELA/Literacy –

RST.6-8.1 Cite specific textual evidence to support analysis of science and technical texts.

WHST.6-8.2 Write informative/explanatory texts to examine a topic and convey ideas, concepts, and information through the selection, organization, and analysis of relevant content.

WHST.6-8.9 Draw evidence from literary or informational texts to support analysis, reflection, and research.

SL.8.1 Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 8 topics, texts, and issues, building on others' ideas and expressing their own clearly.

SL.8.4 Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation.

Mathematics –

6.SP.B.5 Summarize numerical data sets in relation to their context.

Ocean Literacy Essential Principles and Fundamental Concepts

Essential Principle 1.
Earth has one big ocean with many features.
Fundamental Concept h. Although the ocean is large, it is finite, and resources are limited.

Essential Principle 3.
The ocean is a major influence on weather and climate.
Fundamental Concept g. Changes in the ocean-atmosphere

system can result in changes to the climate that in turn, cause further changes to the ocean and atmosphere. These interactions have dramatic physical, chemical, biological, economic, and social consequences.

Essential Principle 5.
The ocean supports a great diversity of life and ecosystems.

Fundamental Concept b. Most of the organisms and biomass in the ocean are microbes, which are the basis of all ocean food webs. Microbes are the most important primary producers in the ocean. They have extremely fast growth rates and life cycles, and produce a huge amount of the carbon and oxygen on Earth.

Fundamental Concept d. Ocean biology provides many unique examples of life cycles, adaptations, and important relationships among organisms (symbiosis, predator-prey dynamics, and energy transfer) that do not occur on land.

Essential Principle 6.
The ocean and humans are inextricably interconnected.

Fundamental Concept e. Changes in ocean temperature and pH due to human activities can affect the survival of some organisms and impact biological diversity (coral bleaching due to increased temperature and inhibition of shell formation due to ocean acidification).

Essential Principle 7.
The ocean is largely unexplored.

*Fundamental Concept a.*The ocean is the largest unexplored place on Earth—less than 5% of it has been explored. The next generation of explorers and researchers will find great opportunities for discovery, innovation, and investigation.

Fundamental Concept b. Understanding the ocean is more than a matter of curiosity. Exploration, experimentation, and discovery are required to better understand ocean systems and processes. Our very survival hinges upon it.

Fundamental Concept c. Over the last 50 years, use of ocean resources has increased significantly; the future sustainability of ocean resources depends on our understanding of those resources and their potential.

Fundamental Concept d. New technologies, sensors and tools are expanding our ability to explore the ocean. Ocean scientists are relying more and more on satellites, drifters, buoys, subsea observatories and unmanned submersibles.

Fundamental Concept f. Ocean exploration is truly interdisciplinary. It requires close collaboration among biologists, chemists, climatologists, computer programmers, engineers, geologists, meteorologists, physicists, animators, and illustrators. And these interactions foster new ideas and new perspectives for inquiries.

Send Us Your Feedback

In addition to consultation with expedition scientists, the development of lesson plans and other education products is guided by comments and suggestions from educators and others who use these materials. Please send questions and comments about these materials to: *oceanexeducation@noaa.gov*.

For More Information

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Credit