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2005 North Atlantic Stepping Stones Expedition

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Focus

Impacts of climate change on biological communities of the deep ocean

Grade Level

9-12 (Earth Science/Life Science)

Focus Question

How might changing climate affect biological communities of the deep ocean?

Learning Objectives

Students will be able to describe thermohaline circulation.

Students will be able to explain how climate change might affect thermohaline circulation, and identify the time scale over which such effects might take place.

Students will be able to explain how warmer temperatures might affect wind-driven surface currents, and how these effects might impact biological communities of the deep ocean.

Students will be able to discuss at least three potential impacts on biological communities that might result from carbon dioxide sequestration in the deep ocean.

Materials

- ❒ Copies of "Guidelines for Reports on the Impacts of Climate Change in the Deep Ocean," one copy for each student group

Audio/Visual Materials

- ❒ (Optional) Equipment for viewing downloaded images showing the location of the New England and Corner Rise Seamount chains

Teaching Time

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

Seating Arrangement

Groups of two to four students

Maximum Number of Students

30

Key Words

Seamount
Biogeography
Climate change
Thermohaline circulation
ENSO

Background Information

Seamounts are undersea mountains formed by volcanic activity. These volcanoes may rise as much as 4,000 m (13,000 ft) from the ocean floor, either as isolated peaks or more often as chains that may be thousands of miles long. One of the best-known seamount chains is the Hawaiian Islands – Emperor Seamount Chain that stretches more than 6,000 km across the Pacific Ocean from Hawaii to near the Aleutian Islands west of Alaska. In the North Atlantic Ocean, the New England and Corner Rise Seamounts are part of a volcanic chain that extends from Canada to the African tectonic plate.

Seamounts interrupt ocean currents and cause nutrient-rich deep ocean water to flow up and across the seamount surface. As a result, biological productivity is higher around seamounts than in adjacent deep ocean habitats. Seamounts also have many hard surfaces that can serve as attachment points for a variety of bottom-dwelling animals. By providing chains of favorable habitats that extend long distances across ocean basins, seamounts may serve as "stepping stones" that have a major role in dispersing deep-sea organisms. These dispersal processes have a fundamental impact on the biogeography (biological diversity and species composition) of all regions of the ocean environment. While the geology of seamounts has been studied to some extent, investigations of the role of seamounts in the ecology and evolution of deep-sea species are just beginning. The ultimate goal of the 2005 North Atlantic Stepping Stones Expedition is to determine whether seamounts function as "stepping stones" that allow organisms living on hard substrates to disperse among adjacent seamounts and extend their ranges across ocean basins. To achieve this goal, expedition scientists plan to collect video images and samples of living and fossil corals, as well as other animals living on and near the corals, from three sets of seamount peaks in the Corner Rise area and five seamounts in the New England Seamount Chain.

One of the major objectives of the North Atlantic Stepping Stones Expedition is to determine how climate change has shaped the evolutionary history of faunal populations that inhabit the New England and Corner Rise Seamounts. In this lesson, students will examine how climate change may affect biological communities of the deep ocean.

Learning Procedure

1. To prepare for this lesson, read the introductory essays for the 2005 North Atlantic Stepping Stones Expedition at http://oceanexplorer.noaa.gov/explorations/05stepstones/welcome.html. You may also want to review information on climate change at http://www.noaa.gov/climate.html.

   Download a map or other visual image that shows the location of the New England and Corner Rise Seamount chains. [http://oceanexplorer.noaa.gov/explorations/05stepstones/background/plan/plan.html]

2. Show students a map or other visual image that shows the location of the New England and Corner Rise Seamount chains. Explain that seamounts are the remains of underwater volcanoes, and that they are islands of productivity compared to the surrounding environment. Briefly describe the 2005 North Atlantic Stepping Stones Expedition, emphasizing that the overall goal is to determine whether these seamounts actually serve as biological stepping stones," and a major activity to answer this question involves collecting living and fossil specimens from various seamounts in the chain. Tell students that one of the Expedition's major objectives is to to determine how climate change has shaped the evolutionary history of faunal populations that inhabit the New England and Corner Rise Seamounts.

3. Tell students that their assignment is to prepare a written report that examines how climate change may affect biological communities of the deep ocean. Provide each student group with a copy of "Guidelines for Reports on the Impacts of Climate Change in the Deep Ocean."

4. Lead a discussion of students' reports. The following points should be included:
   - An increase in global sea surface temperature does not imply that every area on Earth will also become warmer; some areas may experience an overall cooling (such as northern Europe) because of changes in global heat transport.
   - Thermohaline circulation is circulation in the oceans that results when cold, high salinity

water sinks (because lower temperature and high salinity result in increased density) in polar regions and moves toward the equator along the ocean floor.

- Sinking water oxygenates deep ocean waters. Thermohaline circulation distributes heat from equatorial regions to higher latitudes.

- High salinity waters are formed in the North Atlantic and around Antarctica. The two mechanisms involved are surface evaporation in stormy regions and freezing of sea water (which removes water, but leaves salt in solution).

- Surface waters of the Indian Ocean are too warm to sink. Waters of the northern Pacific Ocean are diluted by surface runoff from mountains of western Canada and the United States.

- Warmer ocean temperatures could increase melting of sea ice, which would lower the salinity of surface waters in polar regions. Lower salinity and warmer ocean temperature would tend to lower the density of surface waters in polar regions, leading to a weakening of thermohaline circulation. Evidence from Greenland ice cores suggests that changes of this sort may have taken place in the past in only five to ten years. These abrupt changes are most likely the result of melting icebergs from continental glaciers, which release large volumes of freshwater that reduce salinity of polar waters.

- Weakening of thermohaline circulation could reduce oxygenation of deep-sea environments, as well as affect primary production (see below). Weaker thermohaline circulation could also reduce heat transport from equatorial regions (e.g., the Gulf Stream), causing the climate to become significantly colder in regions currently warmed by such transport (e.g, northern Europe).

- Heat from surface waters is transferred to air masses near the sea surface. When air masses are warmed, they rise, resulting in a low pressure area. When sea surface temperatures are above 27°C, this process results in tropical storms, as air from high pressure areas flows into low pressure areas accompanied by absorption of large amounts of moisture, heavy rainfall, and high winds.

- Wind-driven surface currents drive upwelling processes in which deep ocean waters rise toward the surface to replace surface waters pulled away by wind-driven surface currents. Because these deep waters are rich in nutrients, they are important to primary production at the ocean surface. Since the nutrition of many deep-sea organisms depends upon the "rain" of organic material from the surface, disruption of primary production at the surface could have direct impacts on biological communities in deeper waters.

- Ocean stratification results when surface waters are warmed, reducing their density and tendency to mix with deeper waters. This occurs in temperate areas during the summer, but ceases when surface waters are cooled during fall and winter. Mixing is essential to supply nutrients from deep waters to primary producers near the surface. So increased stratification could interfere with primary production, and reduce food resources to shallow-water food webs as well as deep-sea communities.

- The solubility of carbon dioxide and oxygen in seawater decreases with increasing temperature. On the other hand, solubility increases as salinity is reduced, so reduced solubility due to warmer temperatures might be balanced to some extent in polar regions by reduced salinity due to melting sea ice. Oxygen and carbon dioxide are essential to respiration and photosynthesis respectively. Dissolved carbon dioxide (in the form of carbonate ions) is also essential to the formation of shells and skeletons in many organisms. It is difficult to predict the direct effects of solubility changes on deep ocean organisms, but the same processes that might cause the changes also tend to reduce oxygenation of deep ocean waters, which could have severe impacts on organisms that depend upon aerobic respiration.

- ENSO and NAO stand for El Niño Southern Oscillation and North Atlantic Oscillation respectively. These are variations in ocean temperatures called "oscillations" because they seem to occur in repeating cycles over periods on the order of approximately ten years. These oscillations disrupt normal ocean circulation patterns, and change the ways in which heat is distributed to global air masses. During an ENSO event, for example, surface waters in the Pacific Ocean are unusually warm and may block the upwelling of cold deep-ocean water that normally occurs, particularly along the equator in the eastern half of the Pacific basin. During the 1982-83 El Niño event, interference with upwelling had enormous economic impact on the fishing industries in Ecuador and Peru due to the failed anchovy harvest that occurred when the fish unexpectedly migrated south into Chilean waters. In addition, unusually severe weather hit Hawaii and Tahiti; monsoon rains fell over the central Pacific instead of the western Pacific, leading to droughts and disastrous forest fires in Indonesia and Australia; and winter storms battered southern California, causing widespread flooding across the southern United States. Warmer temperatures could make such events more frequent.
- When attempting to evaluate the potential impacts of proposals such as carbon dioxide sequestration in the deep ocean, it is critical to remember that most of the deep ocean is totally unexplored. The regular discovery of new species and new types of deep-sea communities by ocean exploration expeditions underscores how much remains to be discovered. With this in mind, it is impossible to predict the impacts of radical changes in carbon dioxide concentration on deep-sea organisms. It is well-known, however, that high concentrations of carbon dioxide are toxic to most animal life, and that increasing concentrations of dissolved carbon dioxide produce highly acidic conditions that are unfavorable to most organisms. Dropping "torpedoes" of solid carbon dioxide would obviously cause severe physical disruption at the points of impact, and such points would require intensive study in advance to reduce the likelihood of destroying new species and unique habitats before they have even been discovered.

The Bridge Connection

http://www.vims.edu/bridge/ – In the "Site Navigation" menu on the left, click on "Ocean Science Topics," then "Atmosphere," then "Global Climate Change" in the menu bar at the top of the page for links to resources about climate change.

The "Me" Connection

Have students write an essay describing how changes to deep ocean communities resulting from climate change might affect them personally, and what actions they might take as individuals to alter these effects.

Connections to Other Subjects

English/Language Arts, Geography, Life Science

Evaluation

Group reports and class discussions provide opportunities for assessment.

Extensions

1. Have students visit http://oceanexplorer.noaa.gov/explorations/05stepstones/welcome.html to keep up to date with the latest discoveries by the North Atlantic Stepping Stones Expedition.

2. Visit NOAA's Climate Timeline and Paleoclimatology Web sites (http://www.ngdc.noaa.gov/paleo/ctl/index.html and http://www.ncdc.noaa.gov/paleo/primer.html) for more information and activities related to paleoclimatology and climate change.

Resources

http://oceanexplorer.noaa.gov/explorations/05stepstones/welcome.html – The North Atlantic Stepping Stones Expedition Web site.

http://www.ngdc.noaa.gov/paleo/ctl/resource.html – The Climate TimeLine's Resource section provides links to sources of information and references, including ideas for further inquiry into climate processes and their human dimension.

http://www.noaa.gov/climate.html– NOAA's Paleoclimatology Web site

http://www.unep-wcmc.org/news/addressing-climate-change--why-biodiversity-matters – Addressing climate change: Why biodiversity matters. United Nations Environment Programme's World Conservation Monitoring Centre

Lippsett, L. 1997. Lamont's Broecker Warns Gases Could Alter Climate. Columbia University Record 23 (11). Available online at http://www.columbia.edu/cu/record/23/11/13.html.

National Science Education Standards

Content Standard A: Science as Inquiry
- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Content Standard B: Physical Science
- Motions and forces

Content Standard C: Life Science
- Interdependence of organisms

Content Standard D: Earth and Space Science
- Energy in the Earth system
- Geochemical cycles

Content Standard E: Science and Technology
- Understandings about science and technology

Content Standard F: Science in Personal and Social Perspectives
- Natural resources
- Environmental quality
- Natural and human-induced hazards
- Science and technology in local, national, and global challenges

Content Standard G: History and Nature of Science
- Nature of scientific knowledge

For More Information

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Guidelines for Reports on the Impacts of Climate Change in the Deep Ocean

1. Does an increase in global sea surface temperature mean that every area on Earth will also become warmer?

2. What is thermohaline circulation?

3. What is the impact of thermohaline circulation on deep oceans and heat distribution in the oceans?

4. There are two regions of the world where water of high salinity is formed. Where are they, and what mechanisms increase salinity?

5. Why is the thermohaline circulation of the Indian Ocean and northern Pacific Ocean weaker than that of the North Atlantic Ocean?.

6. How might warmer ocean temperatures affect thermohaline circulation? Is there any evidence that such effects have taken place in the past?

7. How might changes in thermohaline circulation affect deepsea environments and global heat transport?

8. How might warmer ocean temperatures affect global wind patterns?

9. How might changes in wind-driven surface currents affect deep-sea biological communities?

10. How might warmer ocean temperatures affect ocean stratification, and why is this important to biological communities in the ocean?

11. How might warmer ocean temperatures affect dissolved gases in ocean waters? How might these changes affect biological communities in the deep ocean?

12. What are ENSO and NAO? How do they affect climate? How might they be affected by warmer temperatures?

13. Increased concentrations of atmospheric carbon dioxide has been linked to a trend toward warmer sea surface temperatures. Some researchers have proposed that atmospheric carbon dioxide could be reduced by injecting liquid carbon dioxide into deep ocean areas where it would form a stable layer on the sea floor. An alternative technique would drop torpedo-shaped blocks of solid carbon dioxide through the water column to eventually penetrate deep into benthic sediments. What impacts might these procedures have on deep-sea biological communities?