Ocean Exploration and Research

Image captions/credits on Page 2.

lesson plan

Deep-water Exploration of Glacier Bay National Park 2016

Glaciers to Corals

Focus

Biodiversity in Glacier Bay National Park benthic ecosystems

Grade Level

6-8 (Life Science)

Focus Question

What factors contribute to biodiversity in Glacier Bay National Park benthic ecosystems, and how can biodiversity and ecosystem services be maintained within these systems?

Learning Objectives

- Students will identify and explain factors that contribute to biodiversity in Glacier Bay National Park benthic ecosystems.
- Students will evaluate design solutions for maintaining biodiversity and ecosystem services in Glacier Bay National Park benthic ecosystems.

Materials

- ❑ Copies of *Student Resource: The Ocean - Glacier Bay National Park and Preserve*; *Deep Sea Corals: Out of sight but no longer out of mind*; and *Glacier Bay Wilderness Character Narrative*; see Learning Procedure, Step 1
- ❑ Optional: Paper, rulers, pencils or markers for constructing Sierpinski triangles (see Learning Procedure, Step 1b)
- ❑ Optional: Materials for demonstrating branching corals' effects on currents—Stream table or large pan or tray (at least 30 cm wide x 60 cm long x 8 cm deep); modeling clay; 20 short dowels or pencils, about 10 cm long x 6 mm diameter; (see Learning Procedure, Step 1b)

Audio-Visual Materials

- ❑ (Optional) Interactive whiteboard

Teaching Time

One or two 45-minute class periods, plus time for students to prepare and present presentations

Seating Arrangement

Groups of two to four students

Maximum Number of Students

30

Key Words

Glacier Bay National Park
Biodiversity
Deepwater coral
Fjord

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.

Glacier Bay National Park (GBNP) on the Gulf of Alaska coast includes over 3 million acres of mountains, glaciers, rainforest, coastlines, and fjords. Two hundred years ago, this area was covered by a huge glacier that has now receded 60 miles from the coast, leaving a region of long, narrow, deep inlets between high cliffs of the Fairweather Mountains. These inlets are known as fjords, and the Southeastern Alaskan fjord region provides a wide variety of marine habitats that support highly diverse communities of living organisms. Because of this unusually high biodiversity, GBNP is one of the largest internationally protected Biosphere Reserves in the world, and is part of the much larger (24.3 million acres) Kluane/Wrangell-St. Elias/Glacier Bay/Tatshenshini-Alsek World Heritage site.

Biosphere reserves are areas that include terrestrial, marine and coastal ecosystems, and are established to conserve biodiversity and provide for its sustainable use by humans. In addition to including biologically diverse ecosystems that are representative of major biogeographic regions, Biosphere Reserves are expected to provide opportunities to explore and demonstrate approaches to sustainable development on a regional scale. Typically, Biosphere Reserves include three zones:

- Core areas in which ecosystems are strictly protected to conserve landscapes, species and biodiversity;
- Buffer zones that surround the core areas that may be used for activities compatible with sound ecological practices; and
- Transition areas where a variety of activities are allowed to foster economic and human development that is socio-culturally and ecologically sustainable.

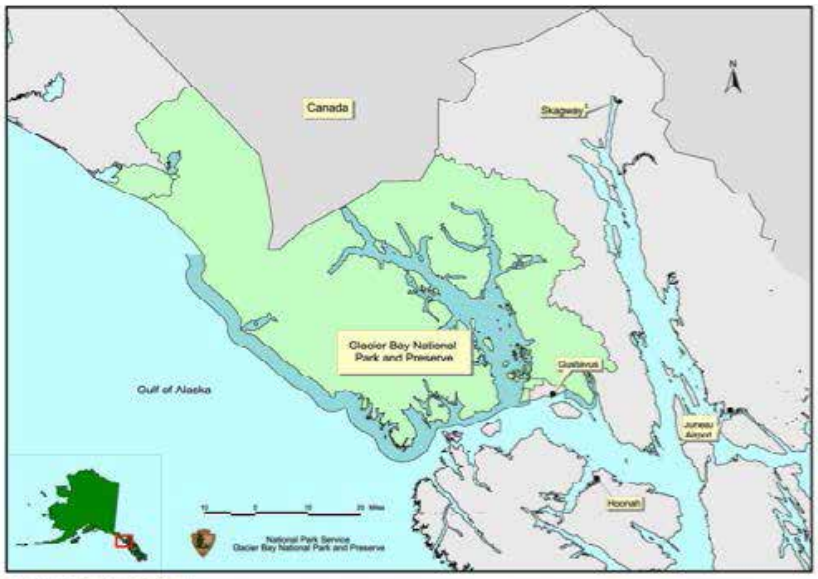
Images from Page 1 top to bottom:
Map of the Glacier Bay National Park. Image courtesy: National Park Service (NPS).

Aerial view of one of the glaciers in the Glacier Bay National Park. Image courtesy: National Park Service (NPS).

Primnoa Coral (*Primnoa pacifica*)
Image credit: NOAA/Olympic Coast National Marine Sanctuary.

Glacier Bay National Park is home to a wide variety of animals, such as this otter. Image courtesy: National Park Service (NPS).

While there has been substantial scientific research in the GBNP on marine mammals, birds and fishery species, benthic ecosystems are not well known. In many parts of Earth's ocean, cold-water corals are a critical part of deepwater ecosystems because they provide habitats for many other species. Dense colonies of red-tree corals (*Primnoa pacifica*) have been found in shallow depths within GBNP, suggesting that there may be other important deepwater coral ecosystems within the Southeastern Alaska fjord region. In many areas, deepwater coral populations have been severely damaged or destroyed by deepwater fishing activities; but benthic ecosystems within the GBNP have been protected from such destruction since 1925. If deepwater coral ecosystems do exist within the GBNP, they will provide important ecological baseline data about undisturbed ecosystems. The purpose of the Deep-water Exploration of Glacier Bay National Park 2016 is to thoroughly map and classify habitat-forming organisms within GBNP, and to collect samples for genetic studies of cold-water coral populations within the fjord region and the outer Gulf of Alaska.



Glacier Bay National Park in Context. Clockwise from Top Left: The Southeastern Alaska coastline; GBNP and surrounding towns; Riggs Glacier within GBNP (Waller); and a satellite image of the park. All images courtesy NPS.

The Ocean — Glacier Bay National Park and Preserve

Directions: Read about Glacier Bay's ocean environments.

Glacier Bay's Ocean Environments

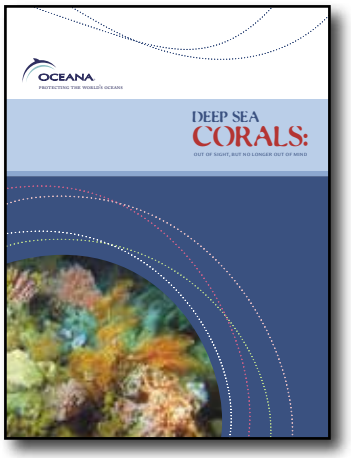
Recent studies show that Glacier Bay contains a very complicated **oceanographic** system within a relatively small area. This complexity is one of the reasons why such an unusual variety of marine life is found here. The ocean's invasion, as the glaciers retreated, created a wide array of underwater environments with biological communities that often overlap.

Oceanographers classify Glacier Bay as a "*recently* ***deglaciated***, *tidally mixed,* ***fjord estuarine*** *system with [many] underwater sills.*" This means that the bay is a network of large, U-shaped valleys that were filled, once, by glaciers but now are flooded by the ocean and fed by streams and rivers.

Upper Bay — Tidewater Glaciers Characterized by Estuarine Circulation

At the glaciated faces of the system there is a more or less continual supply of fresh water. Fresh water floats on salt water because it is less dense. This fresh water forms an upper layer of water a few meters thick that flows toward the sea, picking up some salt water from below and carrying it along on its current. A layer of salt water from the ocean balances the outward flow. This salt water is denser, very cold, and it sinks below the less dense fresh water. This current flows into the bay and the exchange of fresh water and salt water is known as an **estuarine circulation**. Estuarine circulation typifies the ocean waters of the Upper Bay, near the glaciers.

Student Resource: The Ocean - Glacier Bay National Park and Preserve



Deep Sea Corals: Out of sight but no longer out of mind

Glacier Bay Wilderness Character Narrative

In this lesson, students will investigate factors that contribute to biodiversity in GBNP benthic ecosystems, and will evaluate design solutions for maintaining biodiversity and ecosystem services (conditions that benefit multiple species within an ecosystem, such as providing habitat, removing contaminants, or nutrient recycling) within these systems.

Learning Procedure

1. This lesson may be implemented in a variety of ways, depending upon available time and instructional objectives, and student learning styles. At a minimum, the lesson should include:
   - Background on natural processes that contribute to biodiversity in GBNP;
   - Basic information on deep-sea coral ecosystems; and
   - Threats to wilderness preservation and strategies to manage these threats.

   These topics are addressed in resource documents listed in Step 1a. These documents may be reviewed by all students; or, if time is limited, by different student groups who subsequently share their information with the entire class.

To prepare for this lesson:

a. Review background information about the Deep-water Exploration of Glacier Bay National Park 2016 *http://oceanexplorer.noaa.gov/explorations/16glacierbay/welcome.html*.

Download and review:

- "Student Resource: The Ocean - Glacier Bay National Park and Preserve" [*http://www.nps.gov/glba/forteachers/loader.cfm?csModule=security/getfile&PageID=1104574*]
- "Deep Sea Corals: Out of sight but no longer out of mind" [*http://oceana.org/reports/deep-sea-corals-out-sight-no-longer-out-mind#*]
- "Glacier Bay Wilderness Character Narrative" [*http://www.nps.gov/glba/parkmgmt/upload/GLBA-Wilderness-Character-Narrative.pdf*]

Duplicate these documents as needed, depending upon your overall strategy for this lesson.

b. You may also want to consider using some or all of the following:

- GBNP's Marine Environment Curriculum [*http://www.nps.*

gov/glba/learn/education/the-marine-environment.htm]
-- This curriculum consists of four activities focused on the interactions between physical, chemical, geological, and biological components of GBNP marine ecosystems and their effects on biodiversity within these systems. These activities are supported with a variety of reference materials and worksheets, but do not deal extensively with deepwater corals or their ecosystems as these are still largely unexplored.

- Demonstration of the moderating effect of branching corals on ocean currents (Learning Procedure Step 3 in "Forests of the Deep Ocean;" *http://oceanexplorer.noaa.gov/explorations/08lophelia/background/edu/media/forests.pdf*)

- Demonstration of the contribution of corals' branching growth form to creating habitats for other species (also Learning Procedure Step 3 in "Forests of the Deep Ocean" referenced above)

2. Briefly introduce major features of GBNP and its marine environment. Describe the overall objectives of the Deepwater Exploration of Glacier Bay National Park 2016, highlighting the global importance of corals in deepwater ecosystems and the fact that very little is known about deepwater ecosystems in GBNP.

3. The following topics may be assigned to the entire class, or to separate student groups as discussed above. If different groups will be assigned different topics, tell students that their task is to create a presentation to introduce and describe their topic to students in their grade level at another school. This presentation must include answers to all of the questions listed for their assigned topic. If all groups will be assigned all three activities, tell students that they must create a presentation that answers all of the questions for all three topics. Presentations may be in the form of a PowerPoint® or Keynote® slide show, musical or dramatic performance, or written reports.

Topic A:
Processes that contribute to biodiversity in GBNP

Resource document: *Student Resource: The Ocean—Glacier Bay National Park and Preserve*

(1) How is biodiversity in GBNP influenced by physical, chemical, geological, and biological processes?

- Physical processes include tides, currents, salinity,

temperature, light, and precipitation.
- Chemical processes include nutrients, density, and pH.
- Geological processes included glaciation, depth, sedimentation rates, and marine substrates.
- Biological processes include phytoplankton, zooplankton, fish, invertebrates, marine mammals, and humans.

Topic B: Deepwater coral ecosystems

Resource document: *Deep Sea Corals: Out of sight but no longer out of mind*

(1) What do deepwater corals look like (appearance and type of skeletal structure)?
(2) Where are deepwater corals found?
(3) How old are the oldest known deepwater coral reefs?
(4) What ecosystem services (conditions that benefit multiple species within an ecosystem, such as providing habitat, removing contaminants, or nutrient recycling) are provided to other species by deepwater corals?
(5) How does the physical form of deepwater corals contribute to the ecosystem services they provide?
(6) What are some ways in which deepwater corals or associated species may be important to humans?

Topic C: Maintaining biodiversity and ecosystem services of deepwater coral ecosystems

(Ecosystem services are conditions that benefit multiple species within an ecosystem, such as providing habitat, removing contaminants, or nutrient recycling)

Resource Documents: *Deep Sea Corals: Out of sight but no longer out of mind*; *Glacier Bay Wilderness Character Narrative*

(1) What are some threats to biodiversity and ecosystem services of deepwater coral ecosystems?
(2) What needs to be done to manage and protect deepwater coral ecosystems?

4. Lead a discussion of students' presentations. The following points should be included:
- Interactions between physical, chemical, geological, and biological factors described in the *Student Resource* produce a wide variety of habitats and environmental conditions, and this variety contributes to the high biodiversity found in GBNP (specific details about these factors are provided in the *Student Resource*).
- Deepwater corals are found globally, and off all U.S. coasts, including Alaska and Hawaii.
- Radiocarbon dating has established that some coral

colonies are 10,000 - 12,000 years old (around the end of the last Ice Age).

- Two-thirds of known coral species live in deep, cold water, and are suspension feeders.
- The majority of deep-sea corals have not been located; very few deep-sea coral reefs have been intensively studied.
- Deep-sea coral colonies may host hundreds of other organisms (*e.g.*, more than 2,000 individual animals and hundreds of species, including worms, crabs, shrimp and fishes were found in a small coral colony with a head the size of a basketball).
- Deep-sea corals provide multiple benefits to other species, including shelter, protection from predators, nursery areas, reduction of strong currents, and feeding areas.
- The branching growth form of deep-sea corals also increases the surface area available to other organisms (particularly microorganisms).
- The branching growth form of deep-sea corals reduces the force of strong currents that are often found in the vicinity of deep-water coral communities, making it possible for more delicate species to live in these communities.
- Deep-sea coral reefs provide essential habitat for many commercially important fish species, including red porgy, amberjack, snappers, groupers, and orange roughy.
- Besides supporting commercial fisheries, deep-sea coral communities may also contain other species that can provide new pharmaceuticals; recent research has discovered a variety of deep-sea bottom-dwelling invertebrates that produce powerful drugs that can be used to treat cancer, inflammatory diseases, and heart disease.
- Skeletons of deep-sea corals contain records of climate change over thousands of years.
- Destructive fishing gear, particularly bottom trawls, is one of the greatest threats to deep-sea coral ecosystems. Other threats include pollution and climate change.

5. Discuss students' ideas about options for maintaining biodiversity and ecosystem services in deepwater coral ecosystems. Two essential requirements are improving public awareness of the importance of these ecosystems, and improving our understanding of where they are located (note the comment in the Resource Document for Topic B, "The only practical way of protecting these reefs is to find

out where they are and then prevent boats from trawling over them.") This underscores the importance of the type of surveys being undertaken through the Deep-water Exploration of Glacier Bay National Park 2016. Encourage students to support their ideas with specific evidence from the Resource Documents or from other sources. Discuss the role of technology in threats to deepwater coral ecosystems (*e.g.*, sophisticated fishing and underwater mining technologies), as well as to potential solutions to maintain biodiversity and ecosystem services (*e.g.*, remotely operated vehicles, mapping, and imaging technologies that can help locate important deepwater ecosystems).

The BRIDGE Connection

www.vims.edu/bridge/ – In the menu on the left, scroll over "Ocean Science Topics," then "Biology," then "Biodiversity" for links to information and activities about ocean biodiversity.

The "Me" Connection

Have students write a brief essay discussing how preserving deepwater coral ecosystems in GBNP might be of personal importance.

Connections to Other Subjects

English/Language Arts, Social Studies

Assessment

Students' presentations and participation in class discussions provides opportunities for assessment.

Extensions

Visit [*http://oceanexplorer.noaa.gov/explorations/16glacierbay/welcome.html*] for daily logs and updates about discoveries being made by the Deep-water Exploration of Glacier Bay National Park 2016

Other Relevant Lessons from NOAA's Ocean Exploration Program

Forests of the Deep Ocean (grades 7-8)
from the Lophelia II 2008: Deepwater Coral Expedition: Reefs, Rigs, and Wrecks Expedition
[*http://oceanexplorer.noaa.gov/explorations/08lophelia/background/edu/media/forests.pdf*]

Focus: Morphology and ecological function in habitat-forming deep-sea corals (Life Science)

Students describe at least three ways in which habitat-forming deep-sea corals benefit other species in deep-sea ecosystems, explain at least three ways in which the physical form of habitat-forming deep-sea corals contributes to their ecological function, and explain how habitat-forming deep-sea corals and their associated ecosystems may be important to humans. Students also describe and discuss conservation issues related to habitat-forming deep-sea corals.

Keep it Complex! (grades 9-12)
from the 2003 Charleston Bump Expedition
[*http://oceanexplorer.noaa.gov/explorations/03bump/background/education/media/03cb_complex.pdf]*

Focus: Effects of habitat complexity on biological diversity (Life Science)

Students describe the significance of complexity in benthic habitats to organisms that live in these habitats and will describe at least three attributes of benthic habitats that can increase the physical complexity of these habitats. Students will also be able to give examples of organisms that increase the structural complexity of their communities and infer and explain relationships between species diversity and habitat complexity in benthic communities.

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://www.unesco.org/new/en/natural-sciences/environment/ecological-sciences/biosphere-reserves/ – Web page about Biosphere Reserves

http://www.fs.fed.us/rm/pubs_other/rmrs_2014_landres_p001.pdf -- "Keeping It Wild in the National Park Service: A user guide to integrating Wilderness character into park planning, management, and monitoring

Next Generation Science Standards

While they are not intended to target specific Next Generation Science Standards, activities in this lesson may be used to support specific NGSS elements as described below.

MS-LS2 Ecosystems: Interactions, Energy, and Dynamics

Performance Expectation

MS-LS2-5. Evaluate competing design solutions for maintaining biodiversity and ecosystem services. [Clarification Statement: Examples of ecosystem services could include water purification, nutrient recycling, and prevention of soil erosion. Examples of design solution constraints could include scientific, economic, and social considerations.]

Science and Engineering Practices

Engaging in Argument from Evidence

- Evaluate competing design solutions based on jointly developed and agreed-upon design criteria.

Disciplinary Core Ideas

LS2.C: Ecosystem Dynamics, Functioning, and Resilience

- Biodiversity describes the variety of species found in Earth's terrestrial and oceanic ecosystems. The completeness or integrity of an ecosystem's biodiversity is often used as a measure of its health.

Crosscutting Concepts

Stability and Change

- Small changes in one part of a system might cause large changes in another part.

Connections to Engineering, Technology, and Applications of Science

Influence of Science, Engineering, and Technology on Society and the Natural World

- The use of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Thus technology use varies from region to region and over time.

Connections to Nature of Science

Science Addresses Questions About the Natural and Material World

- Scientific knowledge can describe the consequences of actions but does not necessarily prescribe the decisions that society takes.

Common Core State Standards Connections:

ELA/Literacy –

RST.6-8.8 Distinguish among facts, reasoned judgment based on research findings, and speculation in a text.

RI.8.8 Trace and evaluate the argument and specific claims in a text, assessing whether the reasoning is sound and the evidence is relevant and sufficient to support the claims.

Mathematics –

MP.4 Model with mathematics.

6.RP.A.3 Use ratio and rate reasoning to solve real-world and mathematical problems.

Ocean Literacy Essential Principles and Fundamental Concepts

Essential Principle 5.

The ocean supports a great diversity of life and ecosystems.

Fundamental Concept e. The ocean provides a vast living space with diverse and unique ecosystems from the surface through the water column and down to, and below, the seafloor. Most of the living space on Earth is in the ocean.

Fundamental Concept f. Ocean ecosystems are defined by environmental factors and the community of organisms living there. Ocean life is not evenly distributed through time or space due to differences in abiotic factors such as oxygen, salinity, temperature, pH, light, nutrients, pressure, substrate, and circulation. A few regions of the ocean support the most abundant life on Earth, while most of the ocean does not support much life.

Essential Principle 6.

The ocean and humans are inextricably interconnected.

Fundamental Concept b. The ocean provides food, medicines, and mineral and energy resources. It supports jobs and national economies, serves as a highway for transportation of goods and people, and plays a role in national security.

Fundamental Concept c. The ocean is a source of inspiration, recreation, rejuvenation, and discovery. It is also an important element in the heritage of many cultures.

Fundamental Concept d. Humans affect the ocean in a variety of ways. Laws, regulations, and resource management affect what is taken out and put into the ocean. Human development and activity leads to pollution (point source, nonpoint source, and noise pollution), changes to ocean chemistry (ocean acidification), and physical modifications (changes to beaches, shores, and rivers). In addition, humans have removed most of the large vertebrates from the ocean.

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).

Fundamental Concept g. Everyone is responsible for caring for the ocean. The ocean sustains life on Earth and humans must live in ways that sustain the ocean. Individual and collective actions are needed to effectively manage ocean resources for all.

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 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 e. Use of mathematical models is an essential part of understanding the ocean system. Models help us understand the complexity of the ocean and its interactions with Earth's interior, atmosphere, climate, and land masses.

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

Paula Keener, Director, Education Programs
NOAA Office of Ocean Exploration and Research
Hollings Marine Laboratory
331 Fort Johnson Road, Charleston SC 29412
843.762.8818
843.762.8737 (fax)
paula.keener@noaa.gov

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Credit