Ocean Exploration and Research

Deep-water Exploration of Glacier Bay National Park 2016

Ecosystem Engineers

Image captions/credits on Page 2.

lesson plan

Focus
Interdependent relationships in Glacier Bay National Park marine ecosystems

Grade Level
9-12 (Life Science)

Focus Question
What are ecosystem engineers, and what evidence exists of ecosystem engineers and complex interactions in Glacier Bay National Park marine ecosystems?

Learning Objectives
- Students will explain the concept of ecosystem engineers.
- Students will cite evidence of complex interactions in Glacier Bay National Park marine ecosystems.
- Students will cite evidence to support claims about the importance of deepwater coral ecosystems in Glacier Bay National Park.

Materials
❑ Copies of *Bald Eagles and Sea Otters in the Aleutian Archipelago: Indirect Effect of Trophic Cascades* and *Deep Sea Corals: Out of sight but no longer out of mind* see Learning Procedure, Step 1

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
Ecosystem engineer
Deepwater coral
Fjord
Trophic cascade
Keystone species

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.

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. Cold-water corals are one example of organisms that alter the physical environment in ways that modify and create habitats. Such organisms have been called "ecosystem engineers" (Jones, Lawton, and Shachak, 1994), and are often involved in complex interdependent relationships that involve many species, and in some cases, multiple ecosystems.

An interesting example of the latter is the connection between bald eagles, sea otters, kelp, fish, and sea urchins in Alaska's

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

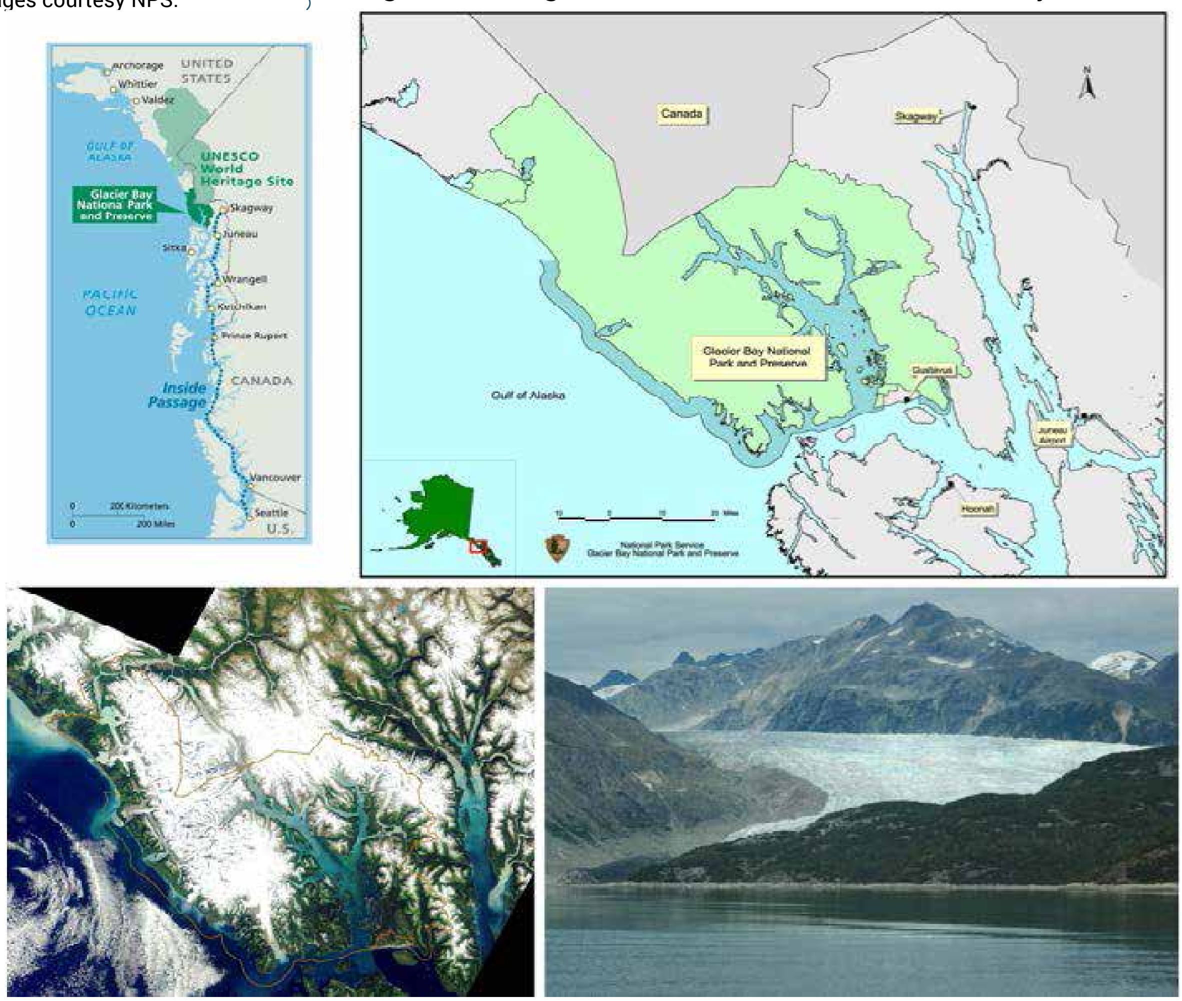
Aerial view of one of the glaciers in the Glacier Bay National Park. Image courtesy: National Park Service (NPS).

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

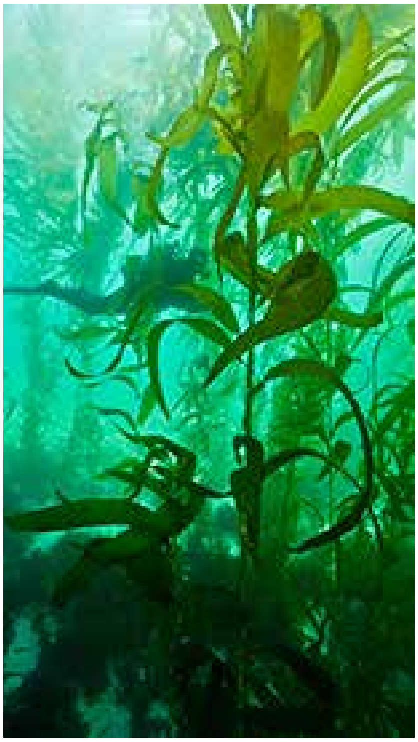
Glacier Bay National Park is home to a wide variety of animals, such as this otter. Image courtesy: National Park Service (NPS).

Sea urchins. Image courtesy NPS.

Aleutian Islands (Anthony, *et al.*, 2008). Surveys of bald eagles in 1993-1994 when sea otter populations were high were compared to surveys conducted in 2000-2002, when otter populations were extremely low. Researchers found that sea otter pups and fishes were an important part of eagles' diets in 1993-1994, but these species were much less significant in 2000-2002 and had been replaced by several species of birds. The explanation for this dietary shift is that sea otters are a "keystone species" in near-shore coastal environments (a keystone species is a species whose removal results in massive changes to species composition and other ecosystem attributes). Sea otters eat sea urchins, which can consume large quantities of kelp. Kelp forests provide habitat, shelter, and a buffer from waves and currents for numerous aquatic species. When sea otter populations were high, the otters controlled sea urchin numbers and ensured that the kelp could thrive. When sea otter populations declined (probably due to increased predation from orcas), the kelp-forest ecosystem began to collapse. Eventually, a deforested underwater landscape and lack of sea otter pups for food forced the bald eagles to change their diets. Similar interactions may occur in



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.



Kelp. Image courtesy NPS.

GBNP, whose ecosystems include many of the same species found in the Aleutians.

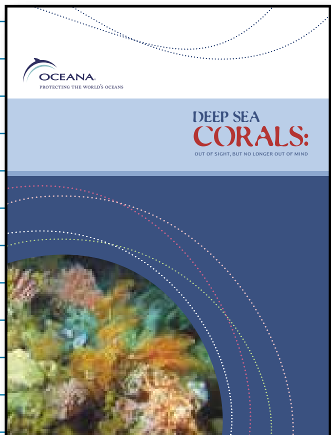
At present, it is not known whether analogous interdependencies occur in GBNP's deepwater coral ecosystems, because their location, extent, species composition, and interaction with other ecosystems are unknown. The need to improve our knowledge of these ecosystems in GBNP is more than a matter of scientific curiosity. In many other areas of Earth's ocean, 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.

In this lesson, students will investigate interdependent relationships in GBNP marine ecosystems, and evaluate the potential role of deepwater corals as ecosystem engineers.

Learning Procedure

1. To explore the topic of interdependent relationships in GBNP marine ecosystems, students first investigate relationships associated with kelp forest ecosystems, then create inferences about analogous relationships in deepwater coral ecosystems. This strategy may be implemented in a variety of ways, depending upon available time, instructional objectives, and student learning styles. Key information for student investigations is provided in two documents:
   - Anthony *et. al.* (2008) *http://soundwaves.usgs.gov/2008/11/research.html*.
   - Roberts and Hirshfield (2003) *http://oceana.org/reports/deep-sea-corals-out-sight-no-longer-out-mind#*

   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. Alternatively, you may choose to provide some information to the entire class as background, then have student groups work independently on Steps 3 and 4.



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

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*.

b. Download and review:

- "Bald Eagles and Sea Otters in the Aleutian Archipelago: Indirect Effect of Trophic Cascades" [*http://pubag.nal.usda.gov/pubag/downloadPDF.xhtml?id=30861&content=PDF*], or "Alaska's Sea-Otter Decline Affects Health of Kelp Forests and Diet of Eagles" [*http://soundwaves.usgs.gov/2008/11/research.html*] and
- "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#*]

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

c. You may also want to review the GBNP slide show about kelp forests [*http://www.nps.gov/glba/forteachers/loader.cfm?csModule=security/getfile&PageID=1102071*]

2. Briefly introduce major features of GBNP and its marine environment. Describe the overall objectives of the Deep-water 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. Introduce the concept of "ecosystem engineers," but do not discuss deepwater corals or the example provided in the Background section at this point.

3. Provide student groups with copies of Anthony *et. al.* (2008) or the abstract of this paper, or the summary of this paper by Lausten (2008). Students should read and discuss the provided document in preparation for a discussion in which each group describes one aspect of the interdependencies reported in the paper (*e.g.*, one group could discuss the role of sea otters and changes in their populations, another could describe the role of kelp forests, etc.). Lead this discussion, then ask students which species could be considered "ecosystem engineers" and what evidence they are able to cite to support their answers.

4. Provide student groups with copies of Roberts and Hirshfield (2003). You may want to assign specific aspects of the document to different student groups (*e.g.*, importance of deepwater corals, threats, management options, etc.) or assign the entire document in preparation for a class discussion on these topics, as well as to gather evidence to support claims that these corals should or should not be considered ecosystem engineers. Lead a discussion in which students cite evidence to support the latter claim, as well as to explain why further exploration of deepwater coral ecosystems is or is not justified.

The BRIDGE Connection

www.vims.edu/bridge/ – In the menu on the left, scroll over “Ocean Science Topics,” then “Habitats,” then “Deep Sea” for links to information and activities about deepwater ocean ecosystems.

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.

Anthony, R., J. Estes, M. Ricca, A. Miles, E. Forsman. 2008. Bald eagles and sea otters in the Aleutian Archipelago: Indirect effects of trophic cascades. Ecology, 89(10):2725–2735. Available online at*: http://pubag.nal.usda.gov/pubag/downloadPDF.xhtml?id=30861&content=PDF*

Lausten, P. 2008. "Alaska's Sea-Otter Decline Affects Health of Kelp Forests and Diet of Eagles." Available online at*: http://soundwaves.usgs.gov/2008/11/research.html*

Roberts, S. and M. Hirshfield. 2003. "Deep Sea Corals: Out of sight but no longer out of mind." Available online at: *http://oceana.org/reports/deep-sea-corals-out-sight-no-longer-out-mind#*

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.

HS-LS2 Ecosystems: Interactions, Energy, and Dynamics

Performance Expectation

HS-LS2-6. Evaluate the 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.

[Clarification Statement: Examples of changes in ecosystem conditions could include modest biological or physical changes, such as moderate hunting or a seasonal flood; and extreme changes, such as volcanic eruption or sea level rise.]

Science and Engineering Practices

Engaging in Argument from Evidence

- Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments.

Disciplinary Core Ideas

LS2.C: Ecosystem Dynamics, Functioning, and Resilience

- A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability.

Crosscutting Concepts

Stability and Change

- Much of science deals with constructing explanations of how things change and how they remain stable.

Connections to Nature of Science

Scientific Knowledge is Open to Revision in Light of New Evidence

- Scientific argumentation is a mode of logical discourse used to clarify the strength of relationships between ideas and evidence that may result in revision of an explanation.

Common Core State Standards Connections:

ELA/Literacy –

RST.9-10.8 Assess the extent to which the reasoning and evidence in a text support the author's claim or a recommendation for solving a scientific or technical problem.

RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.

RST.11-12.7 Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.

RST.11-12.8 Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information.

Mathematics –

MP.2 Reason abstractly and quantitatively.

HSS-ID.A.1 Represent data with plots on the real number line.

HSS-IC.A.1 Understand statistics as a process for making inferences about population parameters based on a random sample from that population.

HSS-IC.B.6 Evaluate reports based on data.

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 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 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