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lesson plan

Bermuda: Search for Deep Water Caves 2009

Cave Critters

Focus
Anchialine cave species

Grade Level
5-6 (Life Science)

Focus Question
What kinds of habitats are found in anchialine caves, and what adaptations are seen in organisms that live in these habitats?

Learning Objectives
- Students will be able to describe anchialine cave habitats
- Students will be able to discuss at least three ways in which some organisms have adapted to the unusual or unique features of these habitats

Materials
- ❑ Copies of *Cave Critters Inquiry Guide,* one for each student

Audio-Visual Materials
- ❑ (Optional) Computer projector or other equipment for showing images of underwater caves

Teaching Time
One or two 45-minute class periods

Seating Arrangement
Groups of 3-4 students

Maximum Number of Students
32

Key Words
Anchialine cave
Habitat
Adaptation
Stygoxene
Stygophile
Stygobite

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.

Anchialine caves are partially or totally submerged caves in coastal areas. Anchialine (pronounced "AN-key-ah-lin") is a Greek term meaning "near the sea," and anchialine caves often contain freshwater and/or brackish water in addition to seawater. These caves may be formed in karst landscapes as well as in rock tubes produced by volcanic activity. Karst landscapes are areas where limestone is the major rock underlying the land surface, and often contain caves and sinkholes formed when acidic rainwater dissolves portions of the limestone rock. Volcanic caves are formed when the surface of flowing volcanic lava cools and hardens, while molten lava continue to flow underneath. If the molten lava continues to flow away from the hardened surface, a hollow tube will be formed that becomes a lava tube cave.

Water in anchialine caves tends to stratify according to salinity, with the heavier seawater below the level of fresh and brackish water. This stratification produces distinctive habitats occupied by a variety of species that are endemic to these locations. (Endemic means that these species are not found anywhere else). Some of these species are "living fossils" known as relict species, which means that they have survived while other related species have become extinct.

Animals that live only in anchialine habitats are called stygofauna or stygobites. Investigations of these species have revealed some puzzling relationships, including:

- Some stygobite species appear to have been in existence longer than the caves they inhabit, which implies that these species must have arrived in the caves from somewhere else; but how could this happen if these species are only found in caves?
- Some stygobite species are found in caves that are widely separated, such as crustacean species found in caves on opposite sides of the Atlantic Ocean and species in Australian anchialine caves that are also found Atlantic and Caribbean caves.
- Geographic distribution of some species suggests a possible connection with mid-ocean ridges. For example, shrimps belonging to the genus *Procaris* are only known from anchialine habitats in the Hawaiian Islands, Ascension Island in the South Atlantic, and Bermuda in the North Atlantic.
- Some anchialine species are most closely related to organisms that live in the very deep ocean.
- Some anchialine species are most closely related to organisms that live in deep sea hydrothermal vent habitats.

Images from Page 1 top to bottom:
Water in inland tidal cave pools in Bermuda is brackish at the surface, but reaches fully marine salinity by a depth of several meters. Image credit: NOAA, Bermuda: Search for Deep Water Caves 2009.
http://oceanexplorer.noaa.gov/explorations/09bermuda/background/bermudaorigin/media/bermudaorigin_5.html

Divers swim between massive submerged stalagmites in Crystal Cave, Bermuda. Such stalactites and stalagmites were formed during glacial periods of lowered sea level when the caves were dry and air-filled. Image credit: NOAA, Bermuda: Search for Deep Water Caves 2009.
http://oceanexplorer.noaa.gov/explorations/09bermuda/background/bermudaorigin/media/bermudaorigin_3.html

Ostracods are small, bivalve crustaceans that can inhabit underwater caves. The ostracod genus *Spelaeoecia* is know only from marine caves and occurs in Bermuda, the Bahamas, Cuba, Jamaica and Yucatan (Mexico). Image credit: Tom Iliffe, NOAA, Bermuda: Search for Deep Water Caves 2009.
http://oceanexplorer.noaa.gov/explorations/09bermuda/background/plan/media/spelaeoecia.html

Prof. Tom Iliffe, diving with a Megalodon closed-circuit rebreather, tows a plankton net through an underwater cave to collect small animals. Image credit: Jill Heinerth, NOAA, Bermuda: Search for Deep Water Caves 2009.
http://oceanexplorer.noaa.gov/explorations/09bermuda/background/plan/media/plankton.html

- An unusually large proportion of anchialine cave species in Bermuda are endemic to these caves, suggesting that these habitats have been stable for a long period of time.

Most investigations of anchialine caves have been confined to relatively shallow depths; yet, the observations described above suggest that connections with deeper habitats may also be important to understanding the distribution of stygobite species. Bermuda is a group of mid-ocean islands composed of limestone lying on top of a volcanic seamount. Because they are karst landscapes, the islands of Bermuda have one of the highest concentrations of cave systems in the world. Typical Bermuda caves have inland entrances, interior cave pools, underwater passages, and tidal spring outlets to the ocean. Bermuda's underwater caves contain an exceptional variety of endemic species, most of which are crustaceans. Most of these organisms are relict species with distinctive morphological, physiological, and behavioral adaptations to the cave environment that suggest these species have been living in caves for many millions of years. Yet, all known anchialine caves in Bermuda were completely dry only 18,000 years ago when sea levels were at least 100 m lower than present because of water contained in glaciers. Such observations suggest the possibility of additional caves in deeper water that would have provided habitat for anchialine species when presently-known caves were dry.

In this activity, students will investigate anchialine habitats and adaptations of organisms that live in these habitats.

Learning Procedure

1. To prepare for this lesson:
   (a) Review introductory essays for the Bermuda: Search for Deep Water Caves 2009 expedition at http://oceanexplorer.noaa.gov/explorations/09bermuda/welcome.html. You may also want to visit http://oceanexplorer.noaa.gov/technology/subs/rov/rov.html for images and discussions of various types of ROVs used in ocean exploration. If you want to explain multibeam sonar, you may also want to review information and images at http://oceanexplorer.noaa.gov/technology/tools/sonar/sonar.html.
   (b) Download a few images of anchialine caves from http://www.tamug.edu/cavebiology/index2.html.
   (c) Review the *Cave Critters Inquiry Guide*.
   (d) Decide whether you want to have students work individually or in groups. Groups are preferred, since students may help each other with nalyses and developing inferences.

2. Briefly introduce the Bermuda: Search for Deep Water Caves 2009 expedition, and show some images of marine caves. Tell students that Bermuda has an unusually large number of species living in marine caves that are not found anywhere else, and that some are called

living fossils because they have survived while other related species have become extinct. Explain that very little is known about deep water marine caves, and discuss why scientists might want to find and explore these caves. Briefly describe how anchialine caves may be formed.

3. Provide each student with a copy of the *Cave Critters Inquiry Guide*. Be sure students understand that while tides move seawater inside the lava tube, only portions of the tube that are near an opening to the sea actually have a significant exchange of water with the surrounding ocean. Water in the rest of the tube simply sloshes back and forth, and seawater exchange depends upon diffusion which in most underwater caves is very slow. This is important because inflowing seawater provides a source of food (plankton and suspended organic material), but this resource diminishes as distance from openings to the sea increases.

4. Lead a discussion of students' results. The following points should be included:

- An anchialine cave is a partially or totally submerged cave near the sea, and often contains freshwater and/or brackish water in addition to seawater.

- Anchialine caves may be solutional or volcanic. Solutional caves are formed in areas where limestone is the major rock underlying the land surface. Caves are formed when acidic rainwater dissolves portions of the limestone rock. Volcanic caves are formed when the surface of flowing volcanic lava cools and hardens, while molten lava continue to flow underneath. If the molten lava continues to flow away from the hardened surface, a hollow tube will be formed that becomes a lava tube cave.

- The Canary Islands are located off the northwest coast of Africa, about 100 km west of the border between Morocco and the Western Sahara. They were formed by a series of volcanic eruptions that began about 22 million years ago.

- A habitat is the place where an organism lives and the conditions that are normally found in that place.

- Saying that an animal is adapted to its habitat means that the animal has certain abilities or physical features that make it well-suited to live in that habitat.

- Typical adaptations seen among animals that live exclusively in caves include:
  - Lack of pigmentation

- Reduction in the size of eyes (or absence of eyes altogether)
- Development of sensory mechanisms that do not depend on light for detecting food or predators
- Adaptations that reduce the need for oxygen, since anchialine caves habitats tend to be oxygen-depleted because there is no photosynthesis and very limited water circulation (the Túnel de la Atlántida, however, is not oxygen depleted because there is sufficient tidal flow to bring in oxygenated water from the open sea). These adaptations may be behavioral, morphological, or physiological. Behavioral adaptations include swimming slowly or intermittently while searching for food, and reduced territorial or antagonistic behavior. Morphological adaptations include increasing the size of sensory body parts that do not require light, and may also include reducing energy requirements by eliminating unused body parts (e.g., eyes and pigments), and reducing the overall physical size of the organism. Physiological adaptations include lower metabolic rates and accumulation of lipids which contain about twice as much energy per gram as proteins or carbohydrates. Lipids also increase buoyancy and can reduce the energy required for swimming.

  Be sure students understand that adaptations do not happen because an animal "wants to adapt" or "needs to adapt." Adaptations happen as random events, and if they provide an advantage the organism is more likely to survive and reproduce than other organisms that do not have these adaptations.

• Habitats found in the Corona Lava Tube include pelagic habitats in the water column, as well as benthic habitats on the floor of the tube. Pelagic habitats are somewhat different in each of the three sections. The Cuevo de Lagos is farthest from the sea, and consequently receives the lowest input of suspended food material and oxygen from the open ocean. The Jameos del Agua pelagic habitat is influenced by primary production that is possible because of light that enters this section, and has greater availability of food and oxygen, as well as enough light to allow visual organs to function. Because the Túnel de la Atlántida is closest to the open sea, this section also has better food and oxygen resources than Cuevo de Lagos.

  There is a variety of benthic habitats, including rock surfaces, patches of volcanic gravel along the cave floor, the sand of the Montana de Arena area, and carpets of benthic diatoms in the Jameos del Agua. Some of the animals that inhabit the cave create additional habitats for other organisms. For example, echiuran worms feed on the organic material in sediments. When the organic material is digested, the worms produce fecal pellets of compacted sediment which they deposit on the cave floor. These pellets are

used as a habitat by other worms. Students are not expected to know these details, but may infer generally that activities of some animals may create habitats for others.

- Animals found in the Corona Lava Tube habitats may exhibit any of the adaptations discussed above. Be sure students realize that conditions in some of these habitats, particularly the Jameos del Agua, do not require special adaptations. Students should also realize that not all of the organisms found in cave habitats are confined to those specific habitats. In general, cave dwellers can be classified as
  - Stygoxenes, which spend some of their time in caves but also leave periodically for some purpose, usually to find food (many fish and crayfish are stygoxenes);
  - Stygophiles, which live permanently in the dark zone, but can also live in other habitats (e.g., salamanders); or
  - Stygobites, which are highly adapted to the cave environment and cannot live anywhere else.

The BRIDGE Connection

www.vims.edu/bridge/ – Type "adaptation" in the Search box for links to resources and activities involving evolution in marine organisms.

The "Me" Connection

Have students write a brief essay describing ways in which they are adapted to their own habitat, and what adaptations they would like to have to make them better suited to the habitat in which they would most like to live.

Connections to Other Subjects

English/Language Arts, Earth Science

Assessment

Written reports and class discussions provide opportunities for assessment.

Extensions

1. Visit http://oceanexplorer.noaa.gov/explorations/09bermuda/welcome.html for more about the Bermuda: Search for Deep Water Caves 2009 expedition.

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/09bermuda/welcome.html – Bermuda: Search for Deep Water Caves 2009 expedition

http://celebrating200years.noaa.gov/edufun/book/welcome.html#book – A free printable book for home and school use introduced in 2004 to celebrate the 200th anniversary of NOAA; nearly 200 pages of lessons focusing on the exploration, understanding, and protection of Earth as a whole system

Koenemann, S. and T. M. Iliffe. 2009. The Atlántida 2008 Cave Diving Expedition. Mar Biodiv 39:153.

Wilkens, H., T. M. Iliffe, P. Oromí, A. Martínez, T. N. Tysall, and S. Koenemann. 2009. The Corona lava tube, Lanzarote: geology, habitat diversity and biogeography. Mar Biodiv 39:155–167.

http://www.tamug.edu/cavebiology/index2.html – Web site, Anchialine Caves and Cave Fauna of the World

http://www.goodearthgraphics.com/virtcave/index.html – Virtual Cave Web site

Iliffe, T. M. and R. E. Bishop. 2007. Adaptations to Life in Marine Caves. In Fisheries and Aquaculture. Patrick Safran, ed., in Encyclopedia of Life Support Systems. UNESCO. EOLSS Publishers. Oxford, UK; available online at http://www.tamug.edu/cavebiology/reprints/reprint-176.pdf

National Science Education Standards

Content Standard A: Science As Inquiry

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Content Standard C: Life Science

- Populations and ecosystems
- Diversity and adaptations of organisms

Content Standard D: Earth and Space Science

- Earth's history

Ocean Literacy Essential Principles and Fundamental Concepts

Essential Principle 2.

The ocean and life in the ocean shape the features of the Earth.

Fundamental Concept c. Erosion—the wearing away of rock, soil and other biotic and abiotic earth materials—occurs in coastal areas as wind, waves, and currents in rivers and the ocean move sediments.

Fundamental Concept e. Tectonic activity, sea level changes, and force of waves influence the physical structure and landforms of the coast.

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

Fundamental Concept e. The ocean is three-dimensional, offering vast living space and diverse habitats from the surface through the water column to the seafloor. Most of the living space on Earth is in the ocean.

Fundamental Concept f. Ocean habitats are defined by environmental factors. Due to interactions of abiotic factors such as salinity, temperature, oxygen, pH, light, nutrients, pressure, substrate and circulation, ocean life is not evenly distributed temporally or spatially, i.e., it is "patchy". Some regions of the ocean support more diverse and abundant life than anywhere on Earth, while much of the ocean is considered a desert.

Fundamental Concept h. Tides, waves and predation cause vertical zonation patterns along the shore, influencing the distribution and diversity of organisms.

Essential Principle 7.
The ocean is largely unexplored.

Fundamental Concept a. The ocean is the last and largest unexplored place on Earth—less than 5% of it has been explored. This is the great frontier for the next generation's explorers and researchers, where they will find great opportunities for inquiry and investigation.

Fundamental Concept f. Ocean exploration is truly interdisciplinary. It requires close collaboration among biologists, chemists, climatologists, computer programmers, engineers, geologists, meteorologists, and physicists, and new ways of thinking.

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Cave Critters
Cave Critters Inquiry Guide

A. Research Questions

1. What is an anchialine cave?

2. How are anchialine caves formed?

3. Where are the Canary Islands? How were they formed?

4. What is a habitat?

5. What does it mean when someone says that an animal is adapted to its habitat?

6. What kind of adaptations may be seen in animals that live all of their lives in caves?

Cave Critters
Cave Critters Inquiry Guide – 2

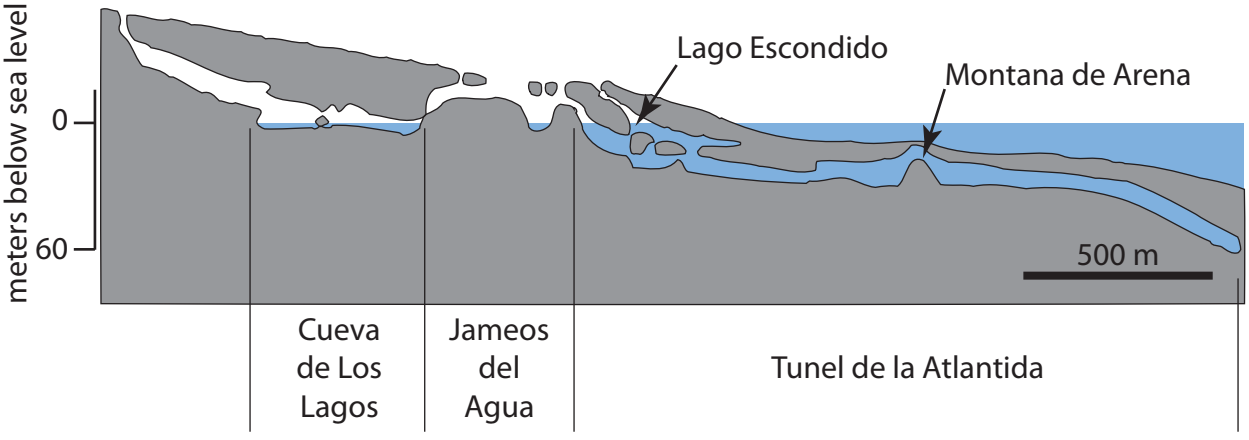
B. Read About a Lava Tube Cave

Lanzarote is one of the Canary Islands, and has several volcanoes which have erupted many times. One of these eruptions produced the Corona Lava Tube, which is more than 6,000 m long. Part of the Corona Lava Tube is flooded by seawater, and the underwater portion of the cave is the world's longest known undersea lava tube. The roof of the lava tube has collapsed in several places, and these places provide a way for explorers to get inside. Coarse volcanic gravel is spread over the floor throughout most of the tube.

Sea water moves inside the lava tube as the tides rise and fall, but most of the water stays in the tube and only moves back and forth. Only parts of the lava tube that are close to openings to the sea exchange significant amounts of water with the surrounding ocean.

The flooded part of the Corona Lava Tube is divided into three sections (see Figure 1). The Cueva de Lagos (Cave of Lakes) is the most inland portion of the lava tube, and is completely dark.

Figure 1



adapted from Wilkins, *et al.* 2009

The Jameos del Agua is the next section, and receives indirect daylight from areas where the roof of the lava tube has collapsed (the word "jameo" refers to a volcanic cave with a collapsed roof, and del Agua is Spanish for "of the water"). This light allows microscopic plants (diatoms) to grow on the floor of the cave, and these provide a source of food for animals in this section.

Cave Critters

Cave Critters Inquiry Guide – 3

The Túnel de la Atlántida (Tunnel of Atlantis) is the longest portion of the flooded cave. About 400m from the entrance to the Jameos del Agua, a smaller air-filled cave extends above the main lava tube and forms the Lago Escondido (Hidden Lake). Further along, about 700 m from the entrance, a large mound of white sand called the Montana de Arena (Sand Mountain) rises 11 m from the tunnel floor. The sand enters the tunnel through a small hole in the ceiling from the the overlying sea floor. The end of the Túnel de la Atlántida is a dead-end about 1,618 m from the entrance to the Jameos del Agua. At this point, the cave is 64 m below sea level.

C. Infer

1. Describe the habitats that you think explorers would find in the underwater part of the Corona Lava Tube.

2. What kind of adaptations do you think animals might have in each of the habitats you described for Question 1?