Bermuda: Search for Deep Water Caves 2009

Distant Relatives




Image captions/credits on Page 2.

lesson plan

Focus
Biogeography of anchialine cave fauna

Grade Level
7-8 (Life Science)

Focus Question
What processes may explain the occurrence of anchialine cave fauna in widely separated locations?

Learning Objectives
- Students will be able to describe observations that suggest connections between widely separated populations of anchialine cave fauna.
- Students will be able to discuss at least three theories that could explain these observations.

Materials
- Copies of *Biogeography of Anchialine Cave Fauna 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
Stygobite
Lava tube
Lanzarote
Biogeography

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 processes that may explain the occurrence of stygobite species in widely separated locations.

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 *Biogeography of Anchialine Cave Fauna 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 analyzing and making inferences from the technical reading.

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. Say 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 *Biogeography of Anchialine Cave Fauna Inquiry Guide*. If students are not familiar with invertebrate phyla, you may want to briefly introduce the taxonomic groups listed in Table 1. Tell students that the hint in the last question should help them identify one theory that may help explain the distribution of cave animals, but that they should also try to think of other possible explanations as well.

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

- A species is said to be endemic to a particular location when that species is not found anywhere else.

- 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.

- Crustacea had the largest number of total species in all three sections, as well as the largest number of endemic species. This is typical of anchialine caves worldwide. There are many different types of crustaceans which may offer more possibilities for adapting to marine cave conditions, and it is also possible that crustaceans adapt to such conditions more readily than other groups.

- The Túnel de la Atlántida had the largest number of different animal groups (eight out of nine), the largest number of endemic species, as well as the largest number of species. Conditions in this section are more similar to the open sea than in other sections, so it should be easier for organisms from the open sea to inhabit this section.

- If students research Pangaea they will probably find an illustration of a supercontinent that is believed to have existed during the Paleozoic and Mesozoic eras about 250 million years ago, before the present-day continents were separated. As that separation occurred, the continents were separated by narrow seas that grew progressively larger. Early in this process, continental land masses were much closer than they are today, so one possible explanation for the distribution of modern stygobites is that their ancestors inhabited the sea between the neighboring continents or even marine caves that were close together at that time.

Another possibility is that deep-sea relatives of some stygobites reached marine caves via cracks in seafloor rock called "crevicular habitats." These habitats might provide a connection to caves in widely separate locations.

Yet another hypothesis is that the ancestors of some present-day cave-dwelling species lived in shallow bottom habitats, and colonized cave systems as well as deep sea habitats.

Students may suggest other explanations, and as long as these are based on solid reasoning they should be considered possibilities as well. At this point, none of the theories proposed to explain the distribution of stygobiotic groups has been completely proven or disproven. It is likely that several different processes account for the the distribution of stygobiotic animals, and much more needs to be known about anchialine ecology, especially in deep sea caves before the question can be settled.

The BRIDGE Connection

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

The "Me" Connection

Have students write a brief essay discussing reasons why someone might want to explore an underwater cave.

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 Relevant Lesson Plans from NOAA's Ocean Exploration Program

(The following Lesson Plan is targeted toward grades 7-8.)

Biological Communities of Alaska Seamounts
(5 pages, 108k) (from the Exploring Alaska's Seamounts 2002 Expedition)
http://oceanexplorer.noaa.gov/explorations/02alaska/background/edu/media/biocomm7_8.pdf

Focus: Biological communities of Alaska seamounts (Life Science)

In this activity, students will be able to infer why biological communities on seamounts are likely to contain unique or endemic species, calculate an index of similarity between two biological communities given species occurrence data, make inferences about reproductive strategies in species that are endemic to seamounts, and explain the implications of endemic species on seamounts to conservation and extinction of these species.

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 – Web site for the for the 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

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.

Send Us Your Feedback

We value your feedback on this lesson.
Please send your comments to:
oceanexeducation@noaa.gov

For More Information

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

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Distant Relatives
Biogeography of Anchialine Cave Fauna Inquiry Guide

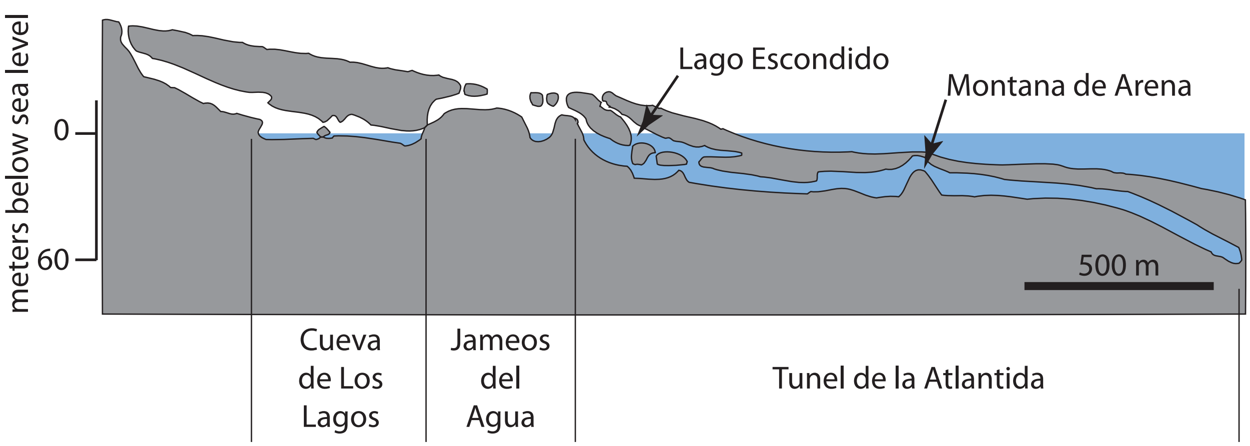
A. Background

The Canary Islands consist of seven major islands and several smaller ones formed by a series of volcanic eruptions that began about 22 million years ago. The island of Lanzarote is one of the older islands, formed about 15.5 million years ago.

The volcanoes that formed Lanzarote have erupted many times. One of these eruptions produced the Corona Lava Tube, which is more than 6,000 m long and extends from the base of the volcano to an enclosed tunnel into the Atlantic Ocean that reaches a dead-end 64 m below sea level. 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 areas that provide entry points for explorers.

About one-third of the tube closest to the coast is flooded with seawater, and 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).

The Túnel de la Atlántida (Tunnel of Atlantis) is the longest portion of the flooded cave. About 400 m 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.

Distant Relatives

Biogeography of Anchialine Cave Fauna Inquiry Guide – 2

B. Research

1. What does endemic mean?

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2. What is an anchialine cave?

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C. Analyze

In 2008, a team of scientists explored the underwater portions of the Lanzarote lava tube to investigate the types of animals that live in cave. Table 1 summarizes some of these investigations. Use these data to calculate the percentage of endemic species for each group in each section of the cave. Fill in the blanks with your answers. Then using the information on Table 1, answer the questions on the following page.

Table 1

Distribution of Animals in Three Sections of the Corona Lava Tube

	Cueva de los Lagos			Jameos del Agua			Tunel de la Atlantida		
Group	Species	Endemic Species	% Endemic	Species	Endemic Species	% Endemic	Species	Endemic Species	% Endemic
Annelida	3	3	________	17	4	________	13	8	________
Cnidaria	0	0	-	0	0	-	2	0	0
Crustacea	11	11	________	10	8	________	26	24	________
Ctenophora	0	0	-	1	0	0	0	0	-
Echinodermata	0	0	-	0	0	-	1	0	0
Echiura	0	0	-	1	0	0	1	0	0
Mollusca	2	0	0	10	0	0	3	1	________
Nematoda	0	0	-	0	0	-	2	0	0
Priapulida	0	0	-	0	0	-	1	0	0
TOTALS	**16**	**14**	________	**39**	**12**	________	**49**	**25**	________

Distant Relatives

Biogeography of Anchialine Cave Fauna Inquiry Guide – 3

1. Which group of animals had the largest number of species?

2. Which section of the cave had the largest number of different animal groups?

3. Which section of the cave had the largest number of species?

4. Which group of animals had the most endemic species?

5. Which section of the cave had the most endemic species?

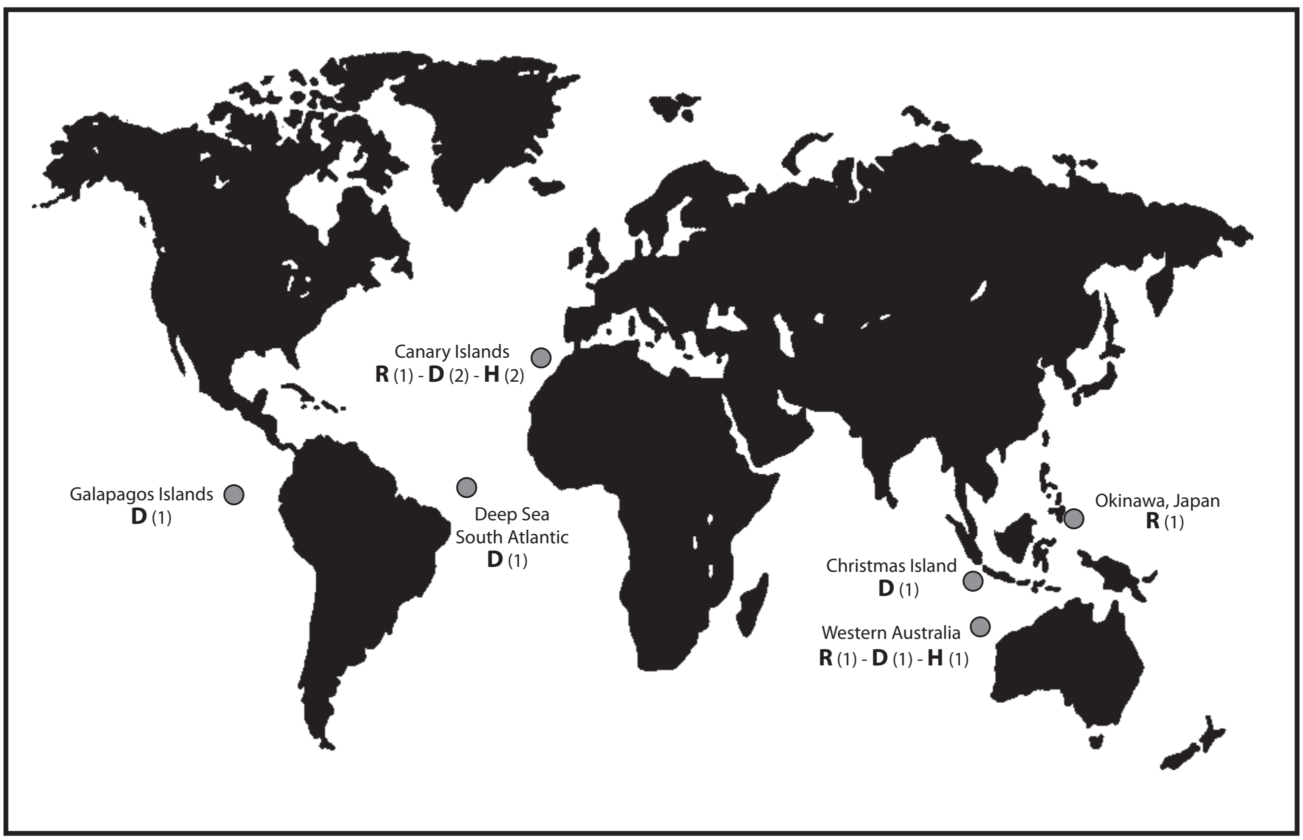
6. How are these results related to conditions in the three sections of the cave?

Distant Relatives
Biogeography of Anchialine Cave Fauna Inquiry Guide – 4

D. Infer

A stygobiotic animal is an animal that can only live in caves. Figure 2 shows locations where three groups of stygobiotic animal groups have been found. If stygobiotic animals can only live in caves, how could very similar stygobiotic groups be in such widely separated locations? Hint: What is Pangaea?

Figure 2



Distribution of three groups of stygobiotic crustaceans; number of species in parentheses; D = *Danielopolina* (an ostracod); H = *Halosbaena* (a thermosbaenacean); R = Remipedia (adapted from Wilkins, et al., 2009).