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Expedition to the Deep Slope 2007

Cool Corals

[adapted from the 2003 Life on the Edge Expedition]

Focus
Biology and ecology of *Lophelia* corals

Grade Level
9-12 (Life Science)

Focus Question
What do scientists know about the basic biology and ecology of *Lophelia* corals?

Learning Objectives
Students will be able describe the basic morphology of *Lophelia* corals and explain the significance of these organisms.

Students will be able to interpret preliminary observations on behavior of *Lophelia* polyps, and infer possible explanations for these observations.

Students will be able to explain why biological communities associated with *Lophelia* corals are the focus of major worldwide conservation efforts.

Materials
- ❒ Copies of "Preliminary Studies of *Lophelia pertusa* Polyp Behavior," one for each student group

Audio/Visual Materials
- ❒ Chalk board, marker board, or overhead projector with transparencies and markers for group discussion

Teaching Time
One to one-and-a-half 45-minute class periods, plus time for research

Seating Arrangement
Groups of 4-6 students

Maximum Number of Students
30

Key Words
Continental shelf
Continental slope
Hard bottom
Lophelia pertusa
Deep-water coral
Trawling

Background Information
The Gulf of Mexico produces more petroleum than any other region in the United States, even though its proven reserves are less than those in Alaska and Texas. Since the 2005 disruption in Gulf of Mexico oil production caused by Hurricane Katrina, efforts have intensified to find more crude oil and drill more wells. Responsibility for managing exploration and development of mineral resources on the nation's outer continental shelf is a central mission of the U.S. Department of the Interior's Minerals Management Service (MMS). In addition to managing the revenues from mineral resources, an integral part of this mission is to protect unique and sensitive environments where these resources are found.

Cold seeps are areas of the ocean floor where gases (such as methane and hydrogen sulfide) and oil seep out of sediments. These areas are commonly found along continental margins, and are home to many species of organisms that have not been found anywhere else on Earth. Unlike biological communities in shallow-water ocean habitats, cold-seep communities do not depend upon sunlight as their primary source of energy. Instead, these communities derive their energy from chemicals through a process called chemosynthesis (in contrast to photosynthesis in which sunlight is the basic energy source). MMS scientists are particularly interested in finding deep-sea chemosynthetic communities in the Gulf of Mexico, because these are unique communities that often include species that are new to science and whose potential importance is presently unknown. In addition, the presence of these communities often indicates the presence of hydrocarbons at the surface of the seafloor.

The 2006 Expedition to the Deep Slope was focused on discovering and studying the sea floor communities found near seeping hydrocarbons on hard bottom in the deep Gulf of Mexico. The sites visited by the Expedition were in areas where energy companies will soon begin to drill for oil and gas. A key objective was to provide information on the ecology and biodiversity of these communities to regulatory agencies and energy companies. Expedition to the Deep Slope 2007 is focused on detailed sampling and mapping of four key sites visited in 2006, as well as exploring new sites identified from seismic survey data.

While locating and exploring chemosynthetic communities is a primary objective of the Deep Slope expeditions, another objective is to explore and describe all other hard bottom biological communities in the central and western Gulf of Mexico, regardless of whether or not they are associated with active hydrocarbon seepage or chemosynthetic communities. Protecting these communities is an essential component of the overall MMS mission.

Hard or "live" bottom habitats support diverse biological communities that include valuable fish and invertebrate resources. In many areas, the deep-sea coral *Lophelia pertusa* forms another almost-unexplored habitat. Branches of living coral grow on mounds of dead coral branches that can be several meters deep and hundreds of meters tall. Unlike corals that produce reefs in shallower waters, *Lophelia* does not have symbiotic algae and receives nutrition from plankton and particulate material captured by its polyps from the surrounding water. *Lophelia* mounds alter the flow of currents and provide habitats for a variety of filter feeders. Scientists suspect that many other organisms may also inhabit deep-sea coral reefs, including commercially important fishes and crustaceans. But they don't know for sure, because most of the hard bottom and deep-sea coral habitats on the edge and slope of the continental shelf are still unexplored.

In this activity, students will research basic information on *Lophelia pertusa* and interpret results of a preliminary study of polyp behavior in this species.

Learning Procedure

1. To prepare for this lesson, visit http://oceanexplorer.noaa.gov/explorations/07mexico/welcome.html for information about Expedition to the Deep Slope 2007. You may want to visit http://www.bio.psu.edu/cold_seeps for a virtual tour of a cold-seep community, and http://oceanexplorer.noaa.gov/explorations/islands01/background/islands/sup10_lophelia.html for more background on *Lophelia* reefs.

2. Introduce Expedition to the Deep Slope 2007, and briefly discuss the importance of deep-sea bottom communities and the fact that these communities are largely unexplored. Be sure students understand that cold-seep communities are one type of deep-sea community, but that there are others that are also important and require protection from potential damage by human activities.

3. Tell students that their assignment is to prepare a written report on *Lophelia pertusa* that should include:
   - A brief summary of the biology of this species (what kind of animal is it and what are its general characteristics)
   - Preferred habitat (where is it found, what are the general physical conditions in this habitat)
   - Associations with other species
   - Significance to humans
   - Interactions with humans

4. Provide each student group with a copy of "Preliminary Studies of *Lophelia pertusa* Polyp Behavior." Each group should graph the data and answer the following questions
   a. Why did scientists want to avoid exposing the corals to visible light?
   [To avoid exposing the corals to an unnatural physical factor (light) that might affect their behavior, since these corals normally live in very deep waters where there is virtually no light.]

   b. How did the scientists control their experiment for possible effects of infrared light?
   [They didn't.]

   c. In the second experiment, why did the scientists have one colony that was not exposed to sand?
   [To provide a control for the experimental treatment.]

   d. Other researchers have suggested that *L. pertusa* polyps are permanently expanded. Do data from this study support this idea?
   [No.]

   e. Do *L. pertusa* polyps extend and retract at the same rate?
   [No; the rate of extension is slower than the rate of retraction.]

   f. Why might *L. pertusa* polyps suddenly retract?
   [Because they are disturbed by some external factor; or because a rapid retraction could produce a more vigorous water movement (possibly useful for exchanging water in the coelenteron cavity or for expelling waste products of metabolism); or …]

   g. Why might *L. pertusa* periodically extend and contract?
   [To exchange water in the coelenteron cavity or expel waste products of metabolism; or …]

   h. Does sand appear to have an effect on *L. pertusa* polyps? If so, what is the effect?
   [Yes, it appears to reduce extension of the polyps.]

5. Lead a group discussion about *Lophelia pertusa* and the results of preliminary experiments on the behavior of *L. pertusa* polyps. Student reports should address the questions listed above, and should include most of the following points:
   - *L. pertusa* is a scleractinian (stony) coral with a branched growth form; live corals are often found growing on mounds of dead branches that form deep-water reefs.
   - About 20 of 703 known species of deep-sea scleractinians build reef structures.
   - *L. pertusa* is distributed throughout the Earth's oceans except in polar regions, usually in depths ranging from 200 m to 1,000 m at temperatures between 6° C and 8° C; live *L. pertusa* reefs have been reported from depths greater than 3,000 m.
   - Growth rates of *L. pertusa* have been estimated at 4 – 5 mm per year, which is slower than that of reef-building corals in shallow water.
   - Deep-sea corals often are long-lived and may be hundreds of years old.
   - The branching growth form of *L. pertusa* pro-

vides a variety of habitats for other species.

- Complex biological communities are associated with *L. pertusa* reefs on continental shelves, slopes, and seamounts.
- Biological diversity on *L. pertusa* reefs has been reported to be about three times greater than on surrounding soft bottom habitats.
- About 800 species have been reported to be associated with these reefs in the North Atlantic.
- Very little is known about reproduction in *L. pertusa*, but colonies of the coral have been found on oil rigs that are far away from known locations of natural reefs, suggesting that this species may have long-lived planktonic larvae (this would be advantageous for the potential recolonization of damaged areas).
- *L. pertusa* reefs have been known to fishermen for centuries and are considered good fishing areas, especially for gillnets and longlines.
- Scientists paid little attention to reports of *L. pertusa* reefs until the 1990's, at least partially because the deep-sea environment was very difficult to explore prior to that time.
- Use of heavy bottom trawls in recent years has greatly increased damage to *L. pertusa* reefs from fishing activities.
- Trawling causes mechanical damage to *L. pertusa* reefs, and stirs up large quantities of silt; siltation is believed to be a major cause of *L. pertusa* reef degradation on a global scale.
- Silt has been reported to suppress growth rates of adult *L. pertusa* polyps and to reduce the diversity of associated species.
- Oil exploration and extraction activities can also damage *L. pertusa* reefs by increasing sedimentation and discharging toxic chemicals.

In the course of the discussion, ask why so much attention is suddenly being directed toward *L. pertusa* reefs. Students should recognize that the extent and diversity of these reefs (like many other biological communities in the deep ocean) simply wasn't known until recently, and the potential benefits of other species associated with these reefs are still unknown. The availability of deep-sea exploration technology has been critical to gaining a better understanding of these systems and the extent to which they are threatened. The relationship of these reefs to productive fisheries has been known to fishermen for many years, and the recent introduction of heavy "rock hopping" trawl gear poses a new threat of major destruction. Apart from ethical or moral considerations, it is simply in our best interest to protect potentially useful resources.

The Bridge Connection

www.vims.edu/bridge/ – Click on "Ocean Science" in the navigation menu to the left, then "Ecology," then "Coral" for resources on corals and coral reefs.

The "Me" Connection

Have students write a short essay on how *L. pertusa* reefs might be potentially important to their own lives.

Connections to Other Subjects

English/Language Arts, Earth Science

Assemssment

Reports prepared in Steps 3 and 4 provide opportunities for assessment.

Extensions

Visit http://oceanexplorer.noaa.gov/explorations/07mexico/welcome.html to keep up to date with the latest Expedition to the Deep Slope 2007 discoveries.

Multimedia Learning Objects

http://www.learningdemo.com/noaa/ Click on the links to Lessons 3, 5, 6, 11, and 12 for interactive multimedia presentations and Learning Activities on Deep-Sea Corals, Chemosynthesis and Hydrothermal Vent Life, Deep-Sea Benthos, Energy from the Oceans, and Food, Water, and Medicine from the Sea.

Other Relevant Lessons from the Ocean Exploration Program

What's Down There? (8 pages; 278kb PDF) (from the Cayman Islands Twilight Zone 2007 Expedition) http://oceanexplorer.noaa.gov/explorations/07twilightzone/background/edu/media/whatsdown.pdf

Focus: Mapping Coral Reef Habitats
In this activity, students will be able to access data on selected coral reefs and manipulate these data to characterize these reefs, and explain the need for baseline data in coral reef monitoring programs. Students also will be able to identify and explain five ways that coral reefs benefit human beings, and identify and explain three major threats to coral reefs.

The Benthic Drugstore (8 pages; 278kb PDF) (from the Cayman Islands Twilight Zone 2007 Expedition) http://oceanexplorer.noaa.gov/explorations/07twilightzone/background/edu/media/drugstore.pdf

Focus: Pharmacologically-active chemicals derived from marine invertebrates (Life Science/Chemistry)

In this activity, students will be able to identify at least three pharmacologically-active chemicals derived from marine invertebrates, describe the disease-fighting action of at least three pharmacologically-active chemicals derived from marine invertebrates, and infer why sessile marine invertebrates appear to be promising sources of new drugs.

Watch the Screen! (8 pages; 278kb PDF) (from the Cayman Islands Twilight Zone 2007 Expedition) http://oceanexplorer.noaa.gov/explorations/07twilightzone/background/edu/media/watchscreen.pdf

Focus: Screening natural products for biological activity (Life Science/Chemistry)

In this activity, students will be able to explain and carry out a simple process for screening natural products for biological activity, and will be able to infer why organisms such as sessile marine invertebrates appear to be promising sources of new drugs.

Now Take a Deep Breath (8 pages; 278kb PDF) (from the Cayman Islands Twilight Zone 2007 Expedition) http://oceanexplorer.noaa.gov/explorations/07twilightzone/background/edu/media/breath.pdf

Focus: Physics and physiology of SCUBA diving (Physical Science/Life Science)

In this activity, students will be able to define Henry's Law, Boyle's Law, and Dalton's Law of Partial Pressures, and explain their relevance to SCUBA diving; discuss the causes of air embolism, decompression sickness, nitrogen narcosis, and oxygen toxicity in SCUBA divers; and explain the advantages of gas mixtures such as Nitrox and Trimix and closed-circuit rebreather systems.

Biochemistry Detectives (8 pages, 480k) (from the 2002 Gulf of Mexico Expedition) http://oceanexplorer.noaa.gov/explorations/02mexico/background/edu/media/gom_biochem.pdf

Focus: Biochemical clues to energy-obtaining strategies (Chemistry)

In this activity, students will be able to explain the process of chemosynthesis, explain the relevance of chemosynthesis to biological communities in the vicinity of cold seeps, and describe three energy-obtaining strategies used by organisms in cold-seep communities. Students will also be able to interpret analyses of enzyme activity and ^{13}C isotope values to draw inferences about energy-obtaining strategies used by organisms in cold-seep communities.

Hot Food (4 pages, 372k) (from the 2003 Gulf of Mexico Deep Sea Habitats Expedition) http://oceanexplorer.noaa.gov/explorations/03mex/background/edu/media/mexdh_hotfood.pdf

Focus: Energy content of hydrocarbon substrates in chemosynthesis (Chemistry)
In this activity, students will compare and contrast photosynthesis and chemosynthesis as processes that provide energy to biological communities, and given information on the molecular structure of two or more substances, will make inferences about the relative amount of energy that could be provided by the substances. Students will also be able to make inferences about the potential of light hydrocarbons as an energy source for deep-water coral reef communities.

Cool Corals (7 pages, 476k) (from the 2003 Life on the Edge Expedition) http://oceanexplorer.noaa.gov/explorations/03edge/background/edu/media/cool.pdf

Focus: Biology and ecology of *Lophelia* corals (Life Science)

In this activity, students will describe the basic morphology of *Lophelia* corals and explain the significance of these organisms, interpret preliminary observations on the behavior of *Lophelia* polyps, and infer possible explanations for these observations. Students will also discuss why biological communities associated with *Lophelia* corals are the focus of major worldwide conservation efforts.

Submersible Designer (4 pages, 452k) (from the 2002 Galapagos Rift Expedition) http://oceanexplorer.noaa.gov/explorations/02galapagos/background/education/media/gal_gr9-12_l4.pdf

Focus: Deep Sea Submersibles

In this activity, students will understand that the physical features of water can be restrictive to movement; students will understand the importance of design in underwater vehicles by designing their own submersible; Students will understand how submersibles such as ALVIN, use energy, buoyancy, and gravity to enable them to move through the water.

What's the Difference? (15 pages, 1Mb) (from the 2003 Mountains in the Sea Expedition) http://oceanexplorer.noaa.gov/explorations/03mountains/background/education/media/mts_difference.pdf

Focus: Identification of biological communities from survey data (Life Science)

Students will be able to calculate a simple similarity coefficient based upon data from biological surveys of different areas, describe similarities between groups of organisms using a dendrogram, and infer conditions that may influence biological communities given information about the groupings of organisms that are found in these communities.

Living in Extreme Environments (12 pages, 1Mb) (from the 2003 Mountains in the Sea Expedition) http://oceanexplorer.noaa.gov/explorations/03mountains/background/education/media/mts_extremeenv.pdf

Focus: Biological Sampling Methods (Biological Science)

In this activity, students will understand the use of four methods commonly used by scientists to sample populations; will understand how to gather, record, and analyze data from a scientific investigation; will begin to think about what organisms need in order to survive; and will understand the concept of interdependence of organisms.

Cut-off Genes (12 pages, 648k) (from the 2004 Mountains in the Sea Expedition) http://oceanexplorer.noaa.gov/explorations/04mountains/background/edu/media/MTS04.genes.pdf

Focus: Gene sequencing and phylogenetic expressions (Life Science)

In this activity, students will be able to explain the concept of gene-sequence analysis; and, given gene sequence data, will be able to draw inferences about phylogenetic similarities of different organisms.

What Was for Dinner? (5 pages, 400k) (from the 2003 Life on the Edge Expedition) http://oceanexplorer.noaa.gov/explorations/03edge/background/edu/media/dinner.pdf

Focus: Use of isotopes to help define trophic relationships (Life Science)

In this activity, students will describe at least three energy-obtaining strategies used by organisms in deep-reef communities and interpret analyses of ^{15}N, ^{13}C, and ^{34}S isotope values.

Chemosynthesis for the Classroom (9 pages, 276k) (from the 2006 Expedition to the Deep Slope) http://oceanexplorer.noaa.gov/explorations/06mexico/background/edu/GOM%2006%20Chemo.pdf

Focus: Chemosynthetic bacteria and succession in chemosynthetic communities (Chemistry/Biology)

In this activity, students will observe the development of chemosynthetic bacterial communities and will recognize that organisms modify their environment in ways that create opportunities for other organisms to thrive. Students will also be able to explain the process of chemosynthesis and the relevance of chemosynthesis to biological communities in the vicinity of cold seeps.

How Diverse is That? (12 pages, 296k) (from the 2006 Expedition to the Deep Slope) http://oceanexplorer.noaa.gov/explorations/06mexico/background/edu/GOM%2006%20Diverse.pdf

Focus: Quantifying biological diversity (Life Science)

Students will be able to discuss the meaning of biological diversity and will be able to compare and contrast the concepts of variety and relative abundance as they relate to biological diversity. Given abundance and distribution data of species in two communities, students will be able to calculate an appropriate numeric indicator that describes the biological diversity of these communities.

C.S.I. on the Deep Reef (Chemotrophic Species Investigations, That Is) (11 pages, 280k) (from the 2006 Expedition to the Deep Slope) http://oceanexplorer.noaa.gov/explorations/06mexico/background/edu/GOM%2006%20CSI.pdf

Focus: Chemotrophic organisms (Life Science/Chemistry)

In this activity, students will describe at least three chemotrophic symbioses known from deep-sea habitats and will identify and explain at least three indicators of chemotrophic nutrition.

This Life Stinks (9 pages, 280k) (from the 2006 Expedition to the Deep Slope) http://oceanexplorer.noaa.gov/explorations/06mexico/background/edu/GOM%2006%20Stinks.pdf

Focus: Methane-based chemosynthetic processes (Physical Science)

In this activity, students will be able to define the process of chemosynthesis, and contrast this process with photosynthesis. Students will also explain the process of methane-based chemosynthesis and explain the relevance of chemosynthesis to biological communities in the vicinity of cold seeps.

Other Links and 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/07mexico/welcome.html – Follow Expedition to the Deep Slope 2007 daily as documentaries and discoveries are posted each day for your classroom use.

http://www.bio.psu.edu/People/Faculty/Fisher/fhome.htm – Web site for the senior biologist on Expedition to the Deep Slope 2007

Fosså, J. H., P. B. Mortensen, and D. M. Furevik 2002. The deep-water coral *Lophelia pertusa* in Norwegian waters: distribution and fishery impacts. http://www.imr.no/Dokumenter/fossa.pdf

Roberts, S. and M. Hirshfield. Deep Sea Corals: Out of sight but no longer out of mind. http://northamerica.oceana.org/uploads/oceana_coral_report_final.pdf

National Science Education Standards

Content Standard A: Science As Inquiry
- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

Content Standard C: Life Science
- Interdependence of organisms
- Behavior of organisms

Content Standard D: Earth and Space Science
- Geochemical cycles

Content Standard E: Science and Technology
- Abilities of technological design
- Understandings about science and technology

Content Standard F: Science in Personal and Social Perspectives
- Natural resources
- Environmental quality

Ocean Literacy Essential Principles and Fundamental Concepts

Essential Principle 1.
The Earth has one big ocean with many features.
Fundamental Concept h. Although the ocean is large, it is finite and resources are limited.

Essential Principle 3.
The ocean is a major influence on weather and climate.
Fundamental Concept f. The ocean has had, and will continue to have, a significant influence on climate change by absorbing, storing, and moving heat, carbon and water.

Essential Principle 5.
The ocean supports a great diversity of life and ecosystems.
Fundamental Concept c. Some major groups are found exclusively in the ocean. The diversity of major groups of organisms is much greater in the ocean than on land.
Fundamental Concept d. Ocean biology provides many unique examples of life cycles, adaptations and important relationships among organisms (such as symbiosis, predator-prey dynamics and energy transfer) that do not occur on land.
Fundamental Concept g. There are deep ocean ecosystems that are independent of energy from sunlight and photosynthetic organisms. Hydrothermal vents, submarine hot springs, and methane cold seeps rely only on chemical energy and chemosynthetic organisms to support life.

Essential Principle 6.
The ocean and humans are inextricably interconnected.
Fundamental Concept b. From the ocean we get foods, medicines, and mineral and energy resources. In addition, it provides jobs, supports our nation's economy, serves as a highway for transportation of goods and people, and plays a role in national security.
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 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 b. Understanding the ocean is more than a matter of curiosity. Exploration, inquiry and study are required to better understand ocean systems and processes.

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 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:
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Student Handout

Preliminary Studies of *Lophelia pertusa* Polyp Behavior
(adapted from Roberts and Anderson, 2000)

Scientists who conducted this study used time-lapse video recording to study polyp behavior. The recordings were made using infrared light to avoid potential effects of exposing the corals to visible light. Light from an infrared-emitting diode was diffused through a translucent screen. A coral branch in an aquarium was placed between the video camera and the screen so that the branch produced a silhouette. This allowed the scientists to see when polyps were extended and when they were retracted into the calices (a calyx is the "cup" formed by the coral skeleton that shelters the individual coral polyps).

At the beginning of the first experiment, the corals were gently tapped to cause them to retract. An image of the coral branch was recorded at 20-minute intervals. When the experiment was completed, the scientists measured the diameter of each calyx recorded at the beginning of the experiment, and compared this measurement to the diameter of the same calyx at 20-minute intervals. If the polyps were extended or partially extended, the diameter would appear larger than if the polyps were retracted (and hence out of sight in the silhouette). To compensate for size differences among the polyps, a "corrected index of extension" was calculated by dividing the amount of extension by the calyx diameter:

Corrected Index of Extension = (Extended Diameter - Calyx Diameter) ÷ Calyx Diameter

A second experiment was conducted to investigate the effect of sand deposition on polyp behavior; the scientists used a pump to drop sand onto one colony while a second colony was left undisturbed. Time-lapse video recordings were made of both colonies at 20-minute intervals for 24 hours.

Table 1 contains data from a single polyp in the first experiment. Data from the second experiment are summarized in Table 2.

Table 1

Time	Corrected Index of Extension	Time	Corrected Index of Extension	Time	Corrected Index of Extension
1900	0.41	0020	0.43	0540	0.04
1920	0.44	0040	0.45	0600	0.07
1940	0.46	0100	0.47	0620	0.14
2000	0.47	0120	0.02	0640	0.16
2020	0.39	0140	0.00	0700	0.23
2040	0.42	0200	0.03	0720	0.29
2100	0.44	0220	0.06	0740	0.35
2120	0.47	0240	0.08	0800	0.28
2140	0.50	0300	0.11	0820	0.28
2200	0.48	0320	0.10	0840	0.32
2220	0.42	0340	0.00	0900	0.40
2240	0.43	0400	0.02	0920	0.43
2300	0.45	0420	0.04	0940	0.34
2320	0.47	0440	0.07	1000	0.35
2340	0.47	0500	0.10		
0000	0.48	0520	0.02		

Student Handout

Table 2

Polyp Number	Treatment	Mean Corrected Index of Extension Over 24 hours
1	sand	0.07
3	no sand	0.35
4	sand	0.08
6	sand	0.05
8	no sand	0.36
12	no sand	0.39
13	sand	0.03
15	no sand	0.40
19	sand	0.11