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Deepwater Coral Expedition: Reefs, Rigs and Wrecks

What's the Difference?
(adapted from the 2003 Mountains in the Sea Expedition)

Focus
Identification of biological communities from survey areas

Grade Level
9-12 (Life Science)

Focus Question
How can biological survey data be analyzed to identify groups based on similarities among sites being surveyed?

Learning Objectives
Students will be able to calculate a simple similarity coefficient based upon data from biological surveys of different areas.

Students will be able to describe similarities between groups of organisms using a dendrogram.

Students will be able to infer conditions that may influence biological communities given information about the groupings of organisms that are found in these communities.

Materials
- ☐ Copies of "Biological Survey Data from Eight Deep-Water Sites," "Similarity Analysis Tally Sheet (Table 1 and Table 2)," and "Dendrogram Construction Sheet," one for each student group
- ☐ Overhead transparencies or files for digital projection of "Jaccard Coefficient Calculation Example," "Similarity of Food Preferences," and "Dendrogram Construction Example"

Audio/Visual Materials
Overhead or digital projector

Teaching Time
Two 45-minute class periods

Seating Arrangement
Groups of 3-4 students

Maximum Number of Students
32

Key Words
Gulf of Mexico
Deepwater coral
Biodiversity
Endemic
Cluster analysis
Similarity matrix
Dendrogram
Similarity coefficient

Background Information
In recent years, rising costs of energy and a growing desire to reduce the United States' dependence upon foreign petroleum fuels have led to intensified efforts to find more crude oil and drill more wells in the Gulf of Mexico. This region produces more petroleum than any other area of the United States, even though its proven reserves are less than those in Alaska and Texas. Managing exploration and development of mineral resources on the nation's outer continental shelf is the responsibility of the U.S. Department of the Interior's Minerals Management Service

(MMS). Besides managing the revenues from mineral resources, an integral part of the Deepwater Coral Expedition: Reefs, Rigs, and Wrecks mission is to protect unique and sensitive environments where these resources are found.

To locate new sources of hydrocarbon fuels, MMS has conducted a series of seismic surveys to map areas between the edge of the continental shelf and the deepest portions of the Gulf of Mexico. These maps provide information about the depth of the water as well as the type of material that is found on the seafloor. Hard surfaces are often found where hydrocarbons are present. Carbonate rocks (such as limestone), in particular, are a part of nearly every site where fluids and gases containing hydrocarbons have been located. This is because when microorganisms consume hydrocarbons under anaerobic conditions, they produce bicarbonate which reacts with calcium and magnesium ions in the water and precipitates as carbonate rock. This rock, in turn, provides a substrate where the larvae of many other deep sea bottom-dwelling organisms may attach, particularly corals. In addition to carbonate rocks associated with hydrocarbon seeps, deepwater corals in the Gulf of Mexico are also found on anthropogenic (human-made) structures, particularly ship wrecks and oil platforms.

Deepwater coral reefs were discovered in the Gulf of Mexico nearly 50 years ago, but very little is known about the ecology of these communities or the basic biology of the corals that produce them. Recent studies suggest that deepwater reef ecosystems may have a diversity of species comparable to that of coral reefs in shallow waters, and have found deepwater coral species on continental margins worldwide. One of the most conspicuous differences between shallow- and deepwater corals is that most shallow-water species have symbiotic algae (zooxanthellae) living inside the coral tissue, and these algae play an important part in reef-building and biological productivity. Deepwater corals do not contain symbiotic algae (so these corals are termed "azooxanthellate"). Yet, there are just as many species of deepwater corals (slightly more, in fact) as there are species of shallow-water corals. Deepwater reefs provide habitats for a variety of plant, animal, and microbial species, some of which have not been found anywhere else. Branching corals and other sessile (non-motile) benthic (bottom-dwelling) species with complex shapes provide essential habitat for other organisms including commercially-important fishes such as longfin hake, wreckfish, blackbelly rosefish, and grenadiers. In addition, recent research has shown that less obvious, obscure benthic species may contain powerful drugs that directly benefit humans.

The major structure-building corals in the deep sea belong to the genus *Lophelia*, but other organisms contribute to the framework as well, including antipatharians (black corals), gorgonians (sea fans and sea whips), alcyonaceans (soft corals), anemones, and sponges. While these organisms are capable of building substantial reefs, they are also quite fragile, and there is increasing concern that deepwater reefs and their associated resources may be in serious danger. Many investigations have reported large-scale damage due to commercial fishing trawlers, and there is also concern about impacts that might result from exploration and extraction of fossil fuels. These impacts are especially likely in the Gulf of Mexico, since the carbonate foundation for many deepwater reefs is strongly associated with the presence of hydrocarbons. Potential impacts include directly toxic effects of hydrocarbons on reef organisms, as well as effects from particulate materials produced by drilling operations. Since many deepwater reef organisms are filter feeders, increased particulates could clog their filter apparatus and possibly smother bottom-dwelling organisms.

A primary goal of the Deepwater Coral Expedition: Reefs, Rigs, and Wrecks is to develop the ability to recognize areas where deepwater corals are likely to occur in the Gulf of Mexico, and to obtain information about the biology and ecology of deepwater coral communities needed to develop effective strategies for protecting these communities. When scientists study biological communities found at different deep-water sites, they need a way to measure how similar these communities are in terms of the species present. This information gives clues about how deepwater coral communities develop. For example, if similar biological communities are found on two sites that are far apart, this would suggest that the species have a mechanism for dispersing themselves over long distances (such as the ability to migrate, or a long larval stage that could allow their offspring to be carried by ocean currents). On the other hand, if sites have very different biological communities, it could suggest that these communities have not been populated from a common source, and that they may be influenced by different biological and/or physical processes.

Cluster analysis is a group of methods used to identify how similar different groups are based on a number of different characteristics. In this activity, students will use simple cluster analysis to determine which deep-water sites are most alike based on the number of biological species that they have in common.

Learning Procedure

1. To prepare for this lesson, review introductory essays for the Deepwater Coral Expedition: Reefs, Rigs, and Wrecks at http://oceanexplorer.noaa.gov/explorations/08lophelia/welcome.html.

   You may also want to visit http://www.bio.psu.edu/cold_seeps for a virtual tour of a cold seep community in the Gulf of Mexico, and http://oceanexplorer.noaa.gov/gallery/livingocean/livingocean_coral.html for images of deep-sea corals and seamount communities.

2. Briefly introduce the Deepwater Coral Expedition: Reefs, Rigs, and Wrecks and describe deepwater coral communities. You may want to show images from http://oceanexplorer.noaa.gov/gallery/livingocean/livingocean_coral.html. Point out the variety of organisms found in these communities, and briefly discuss their importance. Explain that deepwater coral reefs are often highly productive, and while they have not been extensively explored, expeditions to study them often report many species that are new to science. Discuss the potential importance of these communities (e.g., habitat for important food species; potential sources of new drugs), their relationship to hydrocarbon seep areas, and that this makes them vulnerable to damage from petroleum exploration and extraction activities. Be sure students understand why it is important to know the degree of similarity between communities in different locations.

3. Tell students that cluster analysis is a technique for identifying how similar groups are based upon certain characteristics. In this case, we will use biological species as a characteristic to identify sites that have similar biological communities. Our assumption is that communities that have many species in common are more similar than communities that have fewer species in common. Show students an overhead of "Similarity Analysis Tally Sheet Table 1." Explain that this is a convenient way to organize information comparing each individual in a group with every other individual in the group. The hypothetical matrix consists of a group of ten individuals (A through J). The individuals could be students, islands, seamounts, oranges, or anything else that we want to compare. The cells in the matrix show the similarity between each possible pair of individuals based on certain characteristics that interest us.

   Work through the following example of cluster analysis with your students. Say that we are going to examine data comparing food preferences among a group of ten students given a list of many foods. Students that chose exactly the same foods would be 100% similar. Show students the "Similarity of Food Preferences" table. The first column in the table shows how many foods Student A had in common with each of the other students in the group. The second column compares Student B's preferences to the other students, and so forth. We notice that all students had at least 25 food preferences in common with all other students in the group. Only half the table is filled in, because the other half would contain the same information. Cells in which the row and column represent the same student are marked with an X.

Once the similarity matrix is complete, we can construct a diagram called a dendrogram to show similarities among the entire group. We start by identifying cells in the matrix with the highest similarity, then those next highest, and so on. We find that Students A and C had 99 foods in common, followed closely by students E and H who had 98 foods in common. We list these pairs vertically on the left side of the "Dendrogram Construction Sheet", and join each pair with a right bracket so that the vertical portion of the bracket corresponds to the number of foods that pair had in common as indicated on the "Index of Similarity" scale. Be sure to leave some space between these groups so we have the option of adding more members to each group (see "Dendrogram Construction Example" Step 1).

Next we find that Student F had 85 foods in common with Student A, so we add F to the first group with a right bracket whose vertical portion is aligned with "85" on the "Index of Similarity" scale. Similarly, we notice that Student J had 80 foods in common with Student E, so we add J to the second group with a right bracket whose vertical portion is aligned with "80" on the "Index of Similarity" scale (see "Dendrogram Construction Example" Step 2).

[Note: In this method for constructing dendrograms, Student F is joined to the group containing A and C at the 85% similarity level, even though its similarity to Student C is lower. This is called the "single linkage method." There are other methods; for example the "complete linkage method" would require a new group member to share a certain threshold similarity level with every member of the existing group.]

We continue this process by adding Students G, D, and I to the first group with indices of similarity of 60, 50, and 40 respectively; and Student B to the second group with an index of similarity of 65. Finally, we link both groups together with a bracket corresponding to an index of similarity of 25 (see "Dendrogram Construction Example" Step 3).

Now we have to interpret our dendrogram. We clearly have two groups (ACFGDI and HEJB) that are quite different. Perhaps the HEJB group is vegetarian, and Students H and E are strictly vegan so they have more preferences in common than with Students J and B, and very few preferences in common with the carnivorous students in the ACFGDI group. Of course, this is just an hypothesis; we would have to examine the specific preferences of each group to decide whether this is a reasonable explanation.

4. Explain that we will next examine data from biological surveys of eight deep-water sites, and perform a cluster analysis to determine which sites are most similar, and how many different types of communities may be represented. For this analysis, we will calculate an index of similarity called Jaccard's Coefficient for each pair of sites. This coefficient is the ratio of the number of species (or genera, or other taxonomic group) found in both groups compared to the total number of species present in both groups.

Provide each student group with copies of "Biological Survey Data from Eight Deep-Water Sites," "Similarity Analysis Tally Sheet," and "Dendrogram Construction Sheet." Tell students that for larger data sets this analysis would be done by computer, but this approach gives a better feel for how the analysis actually works.

Walk students through the following procedure: For each invertebrate group listed in the biological survey data, make a tally mark in the appropriate box in Table 1 of the tally sheet for each pair of sites where the group was found, and also in the "Total Species" box for each individual site. So, for the coral group *Cirripathes*, students should make tally marks in the boxes corresponding to the pairs A + E, A + H, and E + H, and additional tally marks in the "Total Species" boxes for sites A, E, and H (see "Jaccard Coefficient Calculation Example", Step 1). Next, for the polychaete group *Eunice*, students should make tally marks in the boxes corresponding to the pairs F + G, F + H, and G + H, and additional tally marks in the "Total Species" boxes for sites F, G, and H (see "Jaccard Coefficient Calculation Example", Step 2). Continue this process until all invertebrate groups in the survey data have been included. Your tally sheet should now look like "Jaccard Coefficient Calculation Example," Step 3.

Next, use the tally data sheet to calculate Jaccard's Coefficient for each pair of sites where species matches occurred. Use Table 2 on the tally sheet to summarize these calculations. Since sites A and B had two species in common, we write 2 as the numerator in the box in Table 2 corresponding to pair A + B. Since site A had a total of 6 species, 4 of these were not found on site B. Similarly, since site B had a total of 5 species, 3 of these were not found on site A. So the denominator in the box of Table 2 for pair A + B is 2 (the number of species found on both sites) + 4 (the number of species found only on site A) + 3 (the number of species found only on site B). Solving this equation:

$$2 \div (2 + 4 + 3) = 2 \div 9 = 0.22$$

Continue this process until all pairs of sites where species matches occurred have been included. Your tally sheet should now look like "Jaccard Coefficient Calculation Example," Step 4.

Have students construct a dendrogram as directed in Step #2, using their calculations of Jaccard's Coefficient for the eight sites included in the survey.

5. Have each group present their dendrograms and interpret the results. You may want to refer to "Dendrogram of Biological Similarity Between Eight Seamounts" when students have completed their presentations.

   Lead a discussion of these results. Two groups of sites (B-C and F-G) were very similar with 80% or more of the same species. Three other sites (A-E-D) have at least 50% of their species in common with each other. Each of these three groups is distinctly different from the others, with only 25% or less of their species in common.

   Ask the students to examine "Biological Survey Data from Eight Deep-Water Sites" considering these three groups. Students should notice that major invertebrate groups (isopods, decapoda, cirrepeda, etc.) found on the B-C sites were also found on the F-G sites, but the species were different. Also, the F-G group had twice as many total species as the B-C group. These observations suggest that conditions on sites F and G favor greater biological diversity, and that species found on one group of sites may be adapted to different conditions than species found on the other group. Students may also notice that corals, barnacles, and decapod crustaceans accounted for most of the species found on the A-E-D group of sites, and that molluscs were only found on the F-G group. Ask students what factors could account for these differences. They should identify current patterns, physical topography, depth, latitude, and distance between sites as important potential influences. Discuss what additional information scientists could use to decide which of these factors are most likely to account for the differences observed between these sites.

THE BRIDGE CONNECTION

www.vims.edu/bridge/ – In the Navigation toolbar, click on "Ocean Science Topics." In the "Ocean Science Topics" menu, click on "Biology," then on "Invertebrates;" or "Biodiversity."

THE "ME" CONNECTION

Have students write a short report on how cluster analysis could be used to study similarities within another type of group, and what characteristics might be used to identify similarities.

CONNECTIONS TO OTHER SUBJECTS

Mathematics, Geography, Earth Science

ASSESSMENT

Evaluate the "Similarity Analysis Tally Sheets" and "Dendrogram Construction Sheets" completed by each student group. You may also want to have students prepare individual written analyses as described in Step #5 before discussing the results as a group.

EXTENSIONS

1. Have students visit http://oceanexplorer.noaa.gov/explorations/08lophelia/welcome.html to find out more about the Deepwater Coral Expedition: Reefs, Rigs, and Wrecks and to learn about opportunities for real-time interaction with scientists on the current expedition.

2. Have student groups research one or more of the invertebrate groups listed in "Biological Survey Data from Eight Deep-Water Sites" to learn how these groups obtain their food, what habitats they prefer, and how they may interact with other members of the biological communities on seamounts. Have students use this information to infer some of the relationships that may exist between members of the groups identified in Step #5.

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 LESSON PLANS FROM NOAA'S OCEAN EXPLORATION PROGRAM

The Robot Archaeologist

(17 pages, 518k) (from AUVfest 2008)
http://oceanexplorer.noaa.gov/explorations/08auvfest/background/edu/media/robot.pdf

Focus: Marine Archaeology/Marine Navigation (Earth Science/Mathematics)

In this activity, students will design an archaeological survey strategy for an autonomous underwater vehicle (AUV); calculate expected position of the AUV based on speed and direction of travel; and calculate course correction required to compensate for the set and drift of currents.

My Wet Robot

(300kb) (from the Bonaire 2008: Exploring Coral Reef Sustainability with New Technologies Expedition)
http://oceanexplorer.noaa.gov/explorations/08bonaire/background/edu/media/wetrobot.pdf

Focus: Underwater Robotic Vehicles

In this activity, students will be able to discuss the advantages and disadvantages of using underwater robots in scientific explorations, identify key design requirements for a robotic vehicle that is capable of carrying out specific exploration tasks, describe practical approaches to meet identified design requirements, and (optionally) construct a robotic vehicle capable of carrying out an assigned task.

Where Am I?

(PDF, 4 pages, 344k) (from the 2003 Steamship *Portland* Expedition)
http://oceanexplorer.noaa.gov/explorations/03portland/background/edu/media/portlandwhereami.pdf

Focus: Marine navigation and position finding (Earth Science)

In this activity, students identify and explain at least seven different techniques used for marine navigation and position finding, explain the purpose of a marine sextant, and use an astrolabe to solve practical trigonometric problems.

Do You Have a Sinking Feeling?

(9 pages, 764k) (from the 2003 Steamship *Portland* Expedition)
http://oceanexplorer.noaa.gov/explorations/03portland/background/edu/media/portlandsinking.pdf

Focus: Marine archaeology (Earth Science/ Mathematics)

In this activity, students plot the position of a vessel given two bearings on appropriate landmarks, draw inferences about a shipwreck given information on the location and characteristics of artifacts from the wreck, and explain how the debris field associated with a shipwreck gives clues about the circumstances of the sinking ship.

Where's My 'Bot?

(492kb) (from the Bonaire 2008: Exploring Coral Reef Sustainability with New Technologies Expedition)
http://oceanexplorer.noaa.gov/explorations/08bonaire/background/edu/media/wheresbot.pdf

Focus: Marine Navigation (Earth Science/ Mathematics)

In this activity, students will estimate geographic position based on speed and direction of travel, and integrate these calculations with GPS data to estimate the set and drift of currents.

The Big Burp: Where's the Proof?

(5 pages, 364k) (from the Expedition to the Deep Slope 2007)
http://oceanexplorer.noaa.gov/explorations/07mexico/background/edu/media/burp.pdf

Focus: Potential role of methane hydrates in global warming (Earth Science)

In this activity, students will be able to describe the overall events that occurred during the Cambrian explosion and Paleocene extinction events and will be able to define methane hydrates and hypothesize how these substances could contribute to global warming. Students will also be able to describe and explain evidence to support the hypothesis that methane hydrates contributed to the Cambrian explosion and Paleocene extinction events.

What's the Big Deal?

(5 pages, 364k) (from the Expedition to the Deep Slope 2007)
http://oceanexplorer.noaa.gov/explorations/07mexico/background/edu/media/deal.pdf

Focus: Significance of methane hydrates (Life Science)

In this activity, students will be able to define methane hydrates and describe where these substances are typically found and how they are believed to be formed. Students will also describe at least three ways in which methane hydrates could have a direct impact on their own lives, and describe how additional knowledge of methane hydrates expected from the Blake Ridge expedition could provide human benefits.

Cool Corals

(7 pages, 476k) (from the Expedition to the Deep Slope 2007)
http://oceanexplorer.noaa.gov/explorations/07mexico/background/edu/media/corals.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.

This Old Tubeworm

(10 pages, 484k) (from the Expedition to the Deep Slope 2007)
http://oceanexplorer.noaa.gov/explorations/07mexico/background/edu/media/old_worm.pdf

Focus: Growth rate and age of species in cold-seep communities

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 construct a graphic interpretation of age-specific growth, given data on incremental growth rates of different-sized individuals of the same species. Students will also be able to estimate the age of an individual of a specific size, given information on age-specific growth in individuals of the same species.

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.

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, understand the importance of design in underwater vehicles by designing their own submersible, and understand how submersibles such as ALVIN and ABE, use energy, buoyancy, and gravity to enable them to move through the water.

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; understand how to gather, record, and analyze data from a scientific investigation; begin to think about what organisms need in order to survive; and understand the concept of interdependence of 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 $\delta^{15}N$, $\delta^{13}C$, and $\delta^{34}S$ 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)

In this activity, 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 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://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 focussing on the exploration, understanding, and protection of Earth as a whole system

Parin, N. V., A. N. Mironov, and K. N. Nesis. 1997. Biology of the Mazca and Sala y Gómez Submarine Ridges. Adv. Mar. Biol. 13:47-69. The journal article on which this activity is based.

http://www.gomr.mms.gov/index_common.html – Minerals Management Service Web site

http://www.gomr.mms.gov/homepg/lagniapp/chemcomp.pdf – "Chemosynthetic Communities in the Gulf of Mexico" teaching guide to accompany a poster with the same title, introducing the topic of chemosynthetic communities and other ecological concepts to middle and high school students.

http://www.gomr.mms.gov/homepg/lagniapp/lagniapp.html – Kids Page on the Minerals Management Service Web site, with posters, teaching guides and other resources on various marine science topics

http://www.coast-nopp.org/ – Resource Guide from the Consortium for Oceanographic Activities for Students and Teachers, containing modules, guides, and lesson plans covering topics related to oceanography and coastal processes

http://cosee-central-gom.org/ – Web site for The Center for Ocean Sciences Education Excellence: Central Gulf of Mexico (COSEE-CGOM)

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

- Interdependence of organisms

Content Standard E: Science and Technology

- Understandings about science and technology

Content Standard F: Science in Personal and Social Perspectives

- Natural resources
- Environmental quality
- Natural and human-induced hazards
- Science and technology in local, national, and global challenges

Ocean Literacy Essential Principles and Fundamental Concepts

Essential Principle 1.
The Earth has one big ocean with many features.

Fundamental Concept g. The ocean is connected to major lakes, watersheds and waterways because all major watersheds on Earth drain to the ocean. Rivers and streams transport nutrients, salts, sediments and pollutants from watersheds to estuaries and to the ocean.

Fundamental Concept h. Although the ocean is large, it is finite and resources are limited.

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

Fundamental Concept b. Most life in the ocean exists as microbes. Microbes are the most important primary producers in the ocean. Not only are they the most abundant life form in the ocean, they have extremely fast growth rates and life cycles.

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 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 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 e. 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 (such as point source, non-point source, and noise pollution) and physical modifications (such as changes to beaches, shores and rivers). In addition, humans have removed most of the large vertebrates from the ocean.

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 c. Over the last 40 years, use of ocean resources has increased significantly, therefore the future sustainability of ocean resources depends on our understanding of those resources and their potential and limitations.

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:
oceanexeducation@noaa.gov

For More Information

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Acknowledgements

This lesson plan was produced by Mel Goodwin, PhD, The Harmony Project, Charleston, SC for the National Oceanic and Atmospheric Administration. If reproducing this lesson, please cite NOAA as the source, and provide the following URL: http://oceanexplorer.noaa.gov

Student Handout

Biological Survey Data from Eight Deep-Water Sites

Invertebrate Group	Sites Where Found
Hexacorallia	
Cirripathes	A, E, H
Polychaeta	
Eunice	F, G, H
Lanice	B, C
Cirripeda	
Altiverruca	F, G, H
Heteralepas	B, C
Poecilasma	A, D, E, H
Isopoda	
Austroniscus	F, G
Ilyarachna	B
Decapoda	
Glyphocrangon	F, G
Pandalina	A, D, F, G
Mursia	A, D, E
Projasus	A, B, C, E
Amphineura	
Leptochiton	F, G
Gastropoda	
Gymnobela	F, G, H
Bivalvia	
Cuspidaria	F, G
Echinoidea	
Coeloplelurus	F
Asteriodea	
Plinthaster	F, G
Ophiuroidea	
Ophiomyces	A, B, C, H

Student Handout

Similarity Analysis Tally Sheet

Table 1

S I T E	**A**	☒							
	B		☒						
	C			☒					
	D				☒				
	E					☒			
	F						☒		
	G							☒	
	H								☒
	Total Species								
		A	**B**	**C**	**D**	**E**	**F**	**G**	**H**
					SITE				

Student Handout

Similarity of Food Preferences

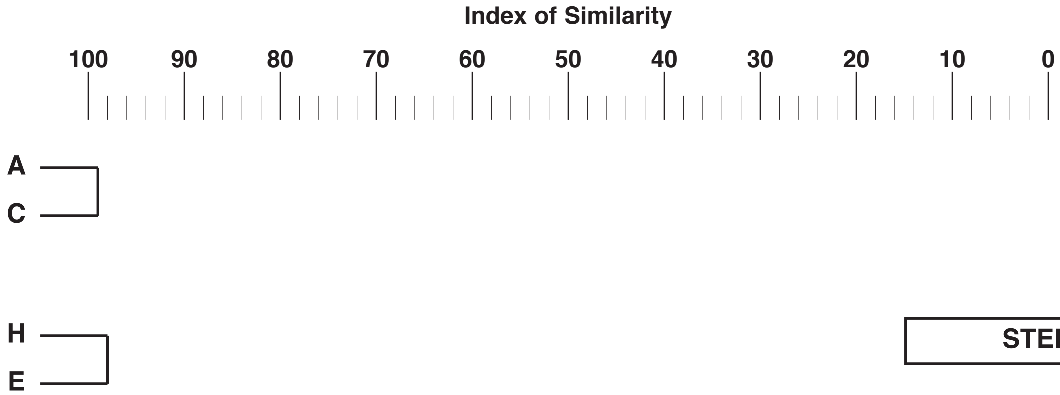
STUDENTS

	A	B	C	D	E	F	G	H	I	J
A	☒									
B	25	☒								
C	99	25	☒							
D	45	25	50	☒						
E	25	65	25	25	☒					
F	85	25	70	50	25	☒				
G	60	25	55	50	25	50	☒			
H	25	50	25	25	98	25	25	☒		
I	40	25	35	40	25	30	35	25	☒	
J	25	50	25	25	80	25	25	60	25	☒

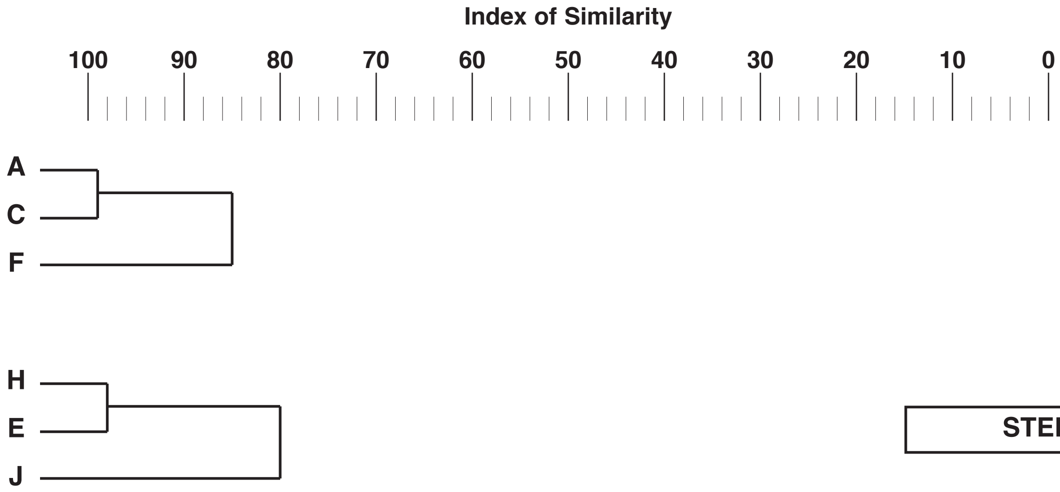
STUDENTS

Overhead

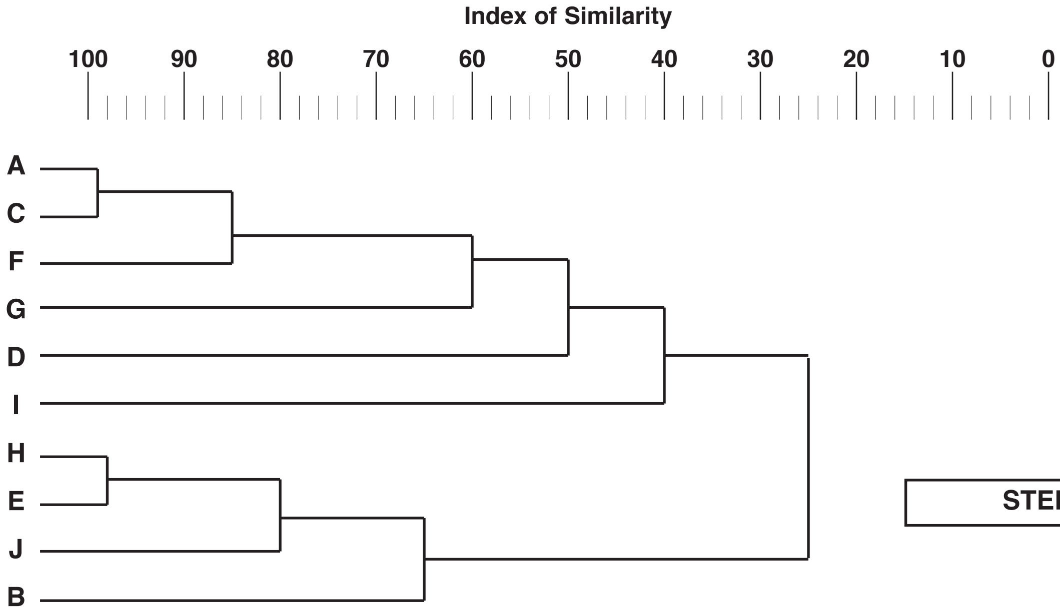
Dendrogram Construction Example



STEP 1



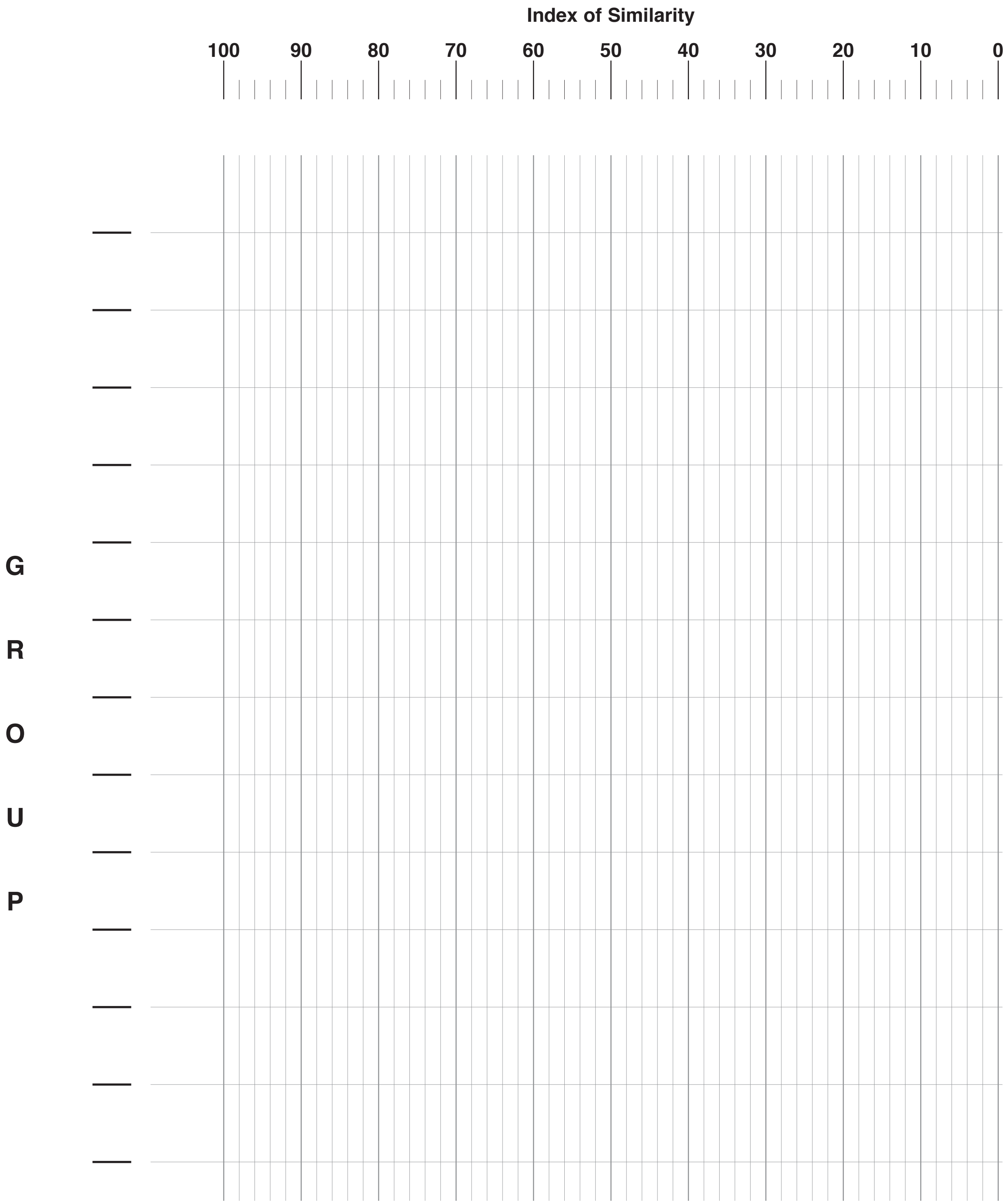
STEP 2



STEP 3

Overhead

Dendrogram Construction Sheet



Overhead

Jaccard Coefficient Example

Step 1

SITE								
A	☒							
B		☒						
C			☒					
D				☒				
E	I				☒			
F						☒		
G							☒	
H	I				I			☒
Total Species	I				I			I
	A	B	C	D	E	F	G	H

SITE

Step 2

SITE								
A	☒							
B		☒						
C			☒					
D				☒				
E	I				☒			
F						☒		
G						I	☒	
H	I				I	I	I	☒
Total Species	I				I	I	I	II
	A	B	C	D	E	F	G	H

SITE

Step 3

SITE								
A	☒							
B	II	☒						
C	II	IIII	☒					
D	III			☒				
E	IIII	I	I	II	☒			
F	I			I		☒		
G	I			I		卌 IIII	☒	
H	III	I	I	I	II	III	III	☒
Total Species	卌 I	卌	IIII	III	IIII	卌 卌	卌 IIII	卌 I
	A	B	C	D	E	F	G	H

Step 4

SITE								
A	☒							
B	$\frac{2}{2+4+3}$ = **0.22**	☒						
C	$\frac{2}{2+4+2}$ = **0.25**	$\frac{4}{4+1+0}$ = **0.80**	☒					
D	$\frac{3}{3+3+0}$ = **0.50**			☒				
E	$\frac{4}{4+2+0}$ = **0.67**	$\frac{1}{1+4+3}$ = **0.13**	$\frac{1}{1+3+3}$ = **0.14**	$\frac{2}{2+1+2}$ = **0.40**	☒			
F	$\frac{1}{1+5+9}$ = **0.067**			$\frac{1}{1+2+9}$ **0.083**		☒		
G	$\frac{1}{1+5+8}$ =**0.071**			$\frac{1}{1+2+8}$ = **0.091**		$\frac{9}{9+1+0}$ = **0.90**	☒	
H	$\frac{3}{3+3+3}$ = **0.33**	$\frac{1}{1+4+5}$ = **0.10**	$\frac{1}{1+3+5}$ = **0.11**	$\frac{1}{1+2+5}$ = **0.13**	$\frac{2}{2+2+4}$ = **0.25**	$\frac{3}{3+7+3}$ = **0.23**	$\frac{3}{3+6+3}$ = **0.25**	☒
Total Species	卌 I	卌	IIII	III	IIII	卌 卌	卌 IIII	卌 I
	A	B	C	D	E	F	G	H

Student Handout

Dendrogram of Biological Similarity Between Eight Deep-Water Sites