

Welcome to My Community!



Image captions/credits on Page 2.

lesson plan

Focus

Change detection in biological communities

Grade Level

9-12 (Life Science/Mathematics)

Focus Question

How can data from biological surveys be used to identify biological communities and to detect change in these communities?

Learning Objectives

- Students will define the concept of a biological community.
- Students will perform calculations to identify communities from biological surveys.
- Students will describe how biological surveys may be used to detect changes in deep-sea communities.

Materials

- Copies of *Biological Survey Data from Eight Deepwater Areas in the Gulf of Mexico*, *Similarity Analysis Tally Sheet Table 1*, *Similarity Analysis Tally Sheet Table 2*, and *Dendrogram Construction Sheet*; one copy for each student group
- (Optional) Copies of *Community Comparison Inquiry Guide*, one copy for each student group; see Learning Procedure, Step 1b

Audio-Visual Materials

- (Optional) Video projection or other equipment to show images

Teaching Time

One or two 45-minute class periods, plus time for student research

Seating Arrangement

Groups of 2-4 students

Maximum Number of Students

32

Key Words

Gulf of Mexico

Cold seep
Deepwater coral
Lophelia

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.

For the past four years, NOAA's Office of Ocean Exploration and Research (OER) has sponsored expeditions to locate and explore deep-sea chemosynthetic communities in the Gulf of Mexico. On April 20, 2010, a gas explosion occurred on the mobile offshore drilling unit Deepwater Horizon about 40 miles southeast of the Louisiana coast. The explosion killed 11 workers, injured 17 others, ignited an intense fire that burned until the Deepwater Horizon sunk 36 hours later, and resulted in a massive release of crude oil that is now considered the greatest environmental disaster in U.S. history. The total volume of oil released into the Gulf of Mexico is estimated to have been 205 million gallons (4.9 million barrels), dwarfing the 11-million gallon *Exxon Valdez* spill of 1989. Efforts to prevent the released oil from making landfall included the use of dispersants, some of which were injected at the wellhead to reduce the amount of oil that reached the surface. Extensive media attention has been directed toward the ecological impacts of released oil on beaches, marshes, birds, turtles, and marine mammals. Many scientists, however, are also concerned about how oil and dispersants may affect the unusual and biologically-rich communities of the Gulf of Mexico seafloor.

Deepwater ecosystems in the Gulf of Mexico are often associated with rocky substrates or "hardgrounds." Most of these hard bottom areas are found in locations called cold seeps where hydrocarbons are seeping through the seafloor. Two types of ecosystems are typically associated with deepwater hardgrounds in the Gulf of Mexico: chemosynthetic communities and deep-sea coral communities. Hydrocarbon seeps may indicate the presence of undiscovered petroleum deposits, so the presence of these ecosystems may indicate potential sites for exploratory drilling and possible development of offshore oil wells. At the same time, these are unique ecosystems whose importance is presently unknown.

The Deepwater Horizon blowout highlights the vulnerability of deep-sea ecosystems to impacts from human activity. Increasingly, the biological communities associated with deepwater corals, cold seeps, and hydrothermal vents are the focus of efforts to protect these resources that may have enormous value to human well-being. One of the ways that scientists may assess possible impacts from the blowout is to

Images from Page 1 top to bottom:

Lophelia pertusa on the seafloor. Note extended polyp on the right. Image courtesy of Ian MacDonald, NOAA.

http://oceanexplorer.noaa.gov/explorations/09lophelia/logs/sept1/media/lophelia_insitu_close.html

Video monitors inside Jason control van allow scientists and Jason crew to see all seafloor operations. Tim Shank (right) records observations using the "Virtual Van" software. Image courtesy Troy Kitch, NOAA.

<http://oceanexplorer.noaa.gov/explorations/09lophelia/logs/aug31/media/controlvan.html>

Preserved specimens collected during *Lophelia* II 2009. Image courtesy Troy Kitch, NOAA.

http://oceanexplorer.noaa.gov/explorations/09lophelia/logs/aug23/media/species_jar.html

Viosca Knoll Wreck: The stempost of the wreck is covered in *Lophelia*, Stalk Barnacles, *Acesta* clams and Anemones. A little *Eumunida picta* is also evident in the lower corner. Image courtesy Stephanie Lessa, NOAA.

http://oceanexplorer.noaa.gov/explorations/09lophelia/logs/sept6/media/7_biostem.html



NOAA Ship *Ronald H. Brown* at sunrise in the Gulf of Mexico. Image courtesy of Dana Mancinelli, NOAA, *Lophelia II* 2009.

<http://oceanexplorer.noaa.gov/explorations/09lophelia/logs/aug27/media/ronbrownship.html>



Jason II on the deck of the NOAA Ship *Ronald H. Brown*. Image courtesy of Sheli Smith, NOAA, *Lophelia II* 2009.

http://oceanexplorer.noaa.gov/explorations/09lophelia/logs/sept6/media/1_jason_ii.html



CTD rosette on deck ready for deployment. Image courtesy of NOAA, *Lophelia II* 2009.

http://oceanexplorer.noaa.gov/explorations/09lophelia/logs/sept1/media/ctd_on_deck.html

compare photographic surveys that were done before the blowout in some areas with follow-up surveys of the same areas after the blowout.

When scientists study deep-sea biological communities in different locations, they need a way to measure how similar these communities are from one place to another. Cluster analysis is a group of methods used to quantify the similarity of different groups based on a number of characteristics. In this activity, students will use simple cluster analysis to identify biological communities in different areas based on the number of species that they have in common.

Learning Procedure

1. To prepare for this lesson:

- Review introductory essays for the *Lophelia II* 2010: Cold Seeps and Deep Reefs Expedition at <http://oceanexplorer.noaa.gov/explorations/10lophelia/welcome.html>. You may also want to consider showing students some images of deep-sea ecosystems from <http://oceanexplorer.noaa.gov/explorations/09lophelia/logs/photolog/photolog.html>. You can find a virtual tour of a cold-seep community at http://www.bio.psu.edu/cold_seeps.
- Review procedures and questions on the *Community Comparison Inquiry Guide*, and decide whether you will do this analysis as a class activity or have students work through the process in separate groups. If you decide to have student groups work independently, make a copy of the *Inquiry Guide* for each student group.
- Review the essay on The Ecology of Gulf of Mexico Deep-sea Hardground Communities (<http://oceanexplorer.noaa.gov/explorations/06mexico/background/hardgrounds/hardgrounds.html>), and decide whether to want to provide this to students as a reading assignment.
- Download an image of a photomosaic from http://oceanexplorer.noaa.gov/explorations/09lophelia/logs/hires/madrepورا_mosaic_hires.jpg.
- If you do not have computer projection equipment, copy Figure 1, Figure 2, and the *Dendrogram Construction Sheet* onto overhead transparencies for working through the example in Step 3, below.
- Download the PDF file for Master Appendix E of the Viosca Knoll survey report upon which this lesson is based (Sulak *et al.*, 2008; http://fl.biology.usgs.gov/coastaleco/OFR_2008-1148_MMS_2008-015/index.html; scroll to the bottom of the Web page to link to specific sections of the report). Master Appendix E contains images of the biotopes that the survey identified. You may also want to download Master Appendix D, which contains images of many of the organisms found in the survey.

2. If desired, provide students with the essay (or its URL) referenced in Step 1c to read prior to beginning this lesson.

3. Briefly introduce the *Lophelia* II 2010: Cold Seeps and Deep Reefs Expedition, and discuss, in general terms, cold-seep and deepwater coral communities. If desired, show images from the Web page referenced in Step 1a. Lead a brief discussion about the Deepwater Horizon blowout. Tell students that many scientists are concerned about possible impacts from the blowout on deep-sea ecosystems, and ask why these systems might be important enough to justify such concern.

Tell students that one way scientists may be able to find out whether deep-sea ecosystems have been affected is to compare photographic surveys that were done before the blowout with follow-up surveys. Show students the photomosaic image downloaded in Step 1d, and say that this image is made up of about 70 separate photographs that cover a total area of about 25 square meters (that is, the area is a square measuring roughly five meters on each side).

Explain 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 areas 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 Figure 1, A Hypothetical Similarity Matrix. Explain that this is a convenient way to organize information by 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, schools, 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 in which we are interested.

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 (at least in terms of food preferences). Show students Figure 2, Similarity of Food Preferences. 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 (see Figure 3, Step 1). Be sure to leave some space between these groups so we have the option of adding more members to each group.

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 Figure 3, 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 other 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 Figure 3, 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 obtain additional information from each group to decide whether this is a reasonable explanation.

4. Explain that we will next examine data from photographic surveys of eight areas in the Gulf of Mexico, and perform a cluster analysis to determine which of these 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 areas. 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 different species present in both groups.

If you have decided to do this analysis as a class activity, provide each student group with copies of:

- *Biological Survey Data from Eight Deepwater Areas in the Gulf of Mexico*
- *Similarity Analysis Tally Sheet Table 1*
- *Similarity Analysis Tally Sheet Table 2*
- *Dendrogram Construction Sheet*

Follow instructions on the *Community Comparison Inquiry Guide* through Step 4, then have students construct dendrograms on the *Dendrogram Construction Sheet*.

If student groups are to work independently, provide each group with a copy of:

- *Community Comparison Inquiry Guide*
- *Biological Survey Data from Eight Deepwater Areas in the Gulf of Mexico*
- *Similarity Analysis Tally Sheet Table 1*
- *Similarity Analysis Tally Sheet Table 2*
- *Dendrogram Construction Sheet*

If students have difficulty with the process, you may need to walk them through the first few steps. If necessary, refer to Figure 4. Step 1 of the Example shows how students' *Tally Sheets* should appear when they have completed Step 1 of the *Inquiry Guide*. Step 2 of the Example shows the results of Step 2 of the *Inquiry Guide*, and so forth through Step 4.

5. Have each group present their dendrograms and interpret the results. You may want to refer to Figure 5, *Dendrogram of Biological Similarity Between Eight Deepwater Areas in the Gulf of Mexico* when students have completed their presentations.

Lead a discussion of these results. Three pairs of areas (C-H, B-G, and A-F) were very similar with Jaccard Coefficients of 0.73 or higher. Areas A and B, B and F, and F and G were somewhat similar with Jaccard Coefficients of 0.5 or higher. Areas C, D and H were very different from the other areas with Jaccard Coefficients below 0.15.

Show students plates 1, 2, 3, 4, and 6 from Master Appendix E of the Viosca Knoll survey report. These plates correspond to areas B-G, C-H, A-F, D, and E respectively. Areas C and H are chemosynthetic biotopes while the other areas are inhabited by various corals and other cnidarians, which explains the low degree of similarity between areas C-H and the other areas. You may also want to show images of some of the animals in these areas from Master Appendix D.

Notice that most species in areas A, B, D, F, and G are carnivores, and none are primary producers. Ask students how this result might be explained. Students should realize that the primary producers might be microscopic organisms not visible in photomosaics. It is also possible that animals at these sites are dependent upon primary production that takes place elsewhere and is carried into the sites by currents.

Species present in areas C and H include Vestimentifera and *Beggiatoa* bacterial mats, both of which are organisms that obtain their nutrition from chemosynthesis, and are among the primary producers in food webs at this site. The sea urchin *Echinus*, also present in areas C and H, is often described as an algal grazer. Since there are no algae present at this site, it is reasonable to hypothesize that this species of *Echinus* may be grazing on the *Beggiatoa* mats. These bacterial mats are also abundant in area E, along with carnivorous cnidarians. It is not clear that the organisms in area E are part of the same food web, but even if they are, other organisms are probably more directly involved with the nutrition of the cnidarians.

The BRIDGE Connection

www.vims.edu/bridge/ - Click on "Gulf of Mexico" in the "Search" box on the left for resources and links about the Gulf.

The "Me" Connection

Have students write a brief essay about how deep-sea ecosystems, such as those used in this lesson, might be of personal importance.

Connections to Other Subjects

English/Language Arts, Earth Science, Mathematics

Assessment

Students' cluster analyses and class discussions offer opportunities for assessment.

Extensions

See http://www.education.noaa.gov/Ocean_and_Coasts/Oil_Spill.html for links to multimedia resources, lessons & activities, data, and background information from NOAA's Office of Education.

Multimedia Discovery Missions

<http://oceanexplorer.noaa.gov/edu/learning/welcome.html> - Click on the links to Lessons 3, 5, 6, and 12 for interactive multimedia presentations and Learning Activities on Deep-Sea Corals, Chemosynthesis and Hydrothermal Vent Life, Deep-Sea Benthos, and Medicine from the Sea.

Other Relevant Lesson Plans from NOAA's Office of Ocean Exploration and Research

Off Base

(from the *Lophelia* II 2009 Expedition)

<http://oceanexplorer.noaa.gov/explorations/09lophelia/background/edu/media/09offbase.pdf>

Focus: pH, buffers, and ocean acidification (Life Science/Chemistry)

Students will define pH and buffer, and explain in general terms the carbonate buffer system of seawater; explain Le Chatelier's Principle, predict how the carbonate buffer system of seawater will respond to a change in concentration of hydrogen ions; identify how an increase in atmospheric carbon dioxide might affect the pH of the ocean; and discuss how this alteration in pH might affect biological organisms.

A Tale of Deep Corals

(from the *Lophelia* II 2009 Expedition)

<http://oceanexplorer.noaa.gov/explorations/09lophelia/background/edu/media/09tale.pdf>

Focus: Deep-sea corals and hydrocarbon seeps (Life Science/Earth Science)

In this activity, students will analyze data on deep-sea corals and evaluate hypotheses to explain why these corals are often found in the vicinity of hydrocarbon seeps.

Cool Corals

(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.

The Benthic Drugstore

(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)

Students will 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!

(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)

Students will 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.

Living in Extreme Environments

(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; students will understand how to gather, record, and analyze data from a scientific investigation; students will begin to think about what organisms need in order to survive; students will understand the concept of interdependence of organisms.

Chemosynthesis for the Classroom

(from the 2006 Expedition to the Deep Slope)

http://oceanexplorer.noaa.gov/explorations/06mexico/background/edu/gom_06_chemo.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.

This Life Stinks

(from the 2006 Expedition to the Deep Slope)

http://oceanexplorer.noaa.gov/explorations/06mexico/background/edu/gom_06_stinks.pdf

Focus: Methane-based chemosynthetic processes (Physical Science)

Students will 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://oceanexplorer.noaa.gov/explorations/10lophelia/welcome.html> – Web site for the *Lophelia* II 2010: Cold Seeps and Deep Reefs Expedition

http://oceanexplorer.noaa.gov/edu/guide/gomdse_edguide.pdf – *Gulf of Mexico Deep-Sea Ecosystems Education Materials Collection Educators' Guide*

http://oceanexplorer.noaa.gov/edu/development/online_development.html – Online professional development opportunities, including *Lessons from the Deep: Exploring the Gulf of Mexico's Deep-Sea Ecosystems*

<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

<http://www.restorethegulf.gov/> – The official federal portal for public information about the Deepwater BP oil spill response and recovery

<http://response.restoration.noaa.gov/deepwaterhorizon> – NOAA Web site on Deepwater Horizon Oil Spill Response

http://docs.lib.noaa.gov/noaa_documents/NESDIS/NODC/LISD/Central_Library/current_references/current_references_2010_2.pdf – Resources on Oil Spills, Response, and Restoration: a Selected Bibliography; document from NOAA Central Library to aid those seeking information concerning the Deepwater Horizon oil spill in the Gulf of Mexico and information on previous spills and associated remedial actions; includes media products (Web, video, printed and online documents) selected from resources available via the online NOAA Library and Information Network Catalog (NOAALINC)

<http://www.gulfallianceeducation.org/> – Extensive list of publications and other resources from the Gulf of Mexico Alliance; click “Gulf States Information & Contacts for BP Oil Spill” to download the Word document

http://www.darrp.noaa.gov/southeast/deepwater_horizon/index.html – Information about damage assessments being conducted by NOAA’s Damage Assessment Remediation and Restoration Program

<http://www.noaa.gov/sciencemissions/bpoilspill.html> – Web page with links to NOAA Science Missions & Data relevant to the Deepwater Horizon/BP Oil Spill

<http://www.geoplatform.gov/gulfresponse/> – An online tool developed by NOAA, EPA, U.S. Coast Guard, and the Department of Interior that provides a “one-stop shop” for spill response information

http://www.education.noaa.gov/Ocean_and_Coasts/Oil_Spill.html – “Gulf Oil Spill” Web page from NOAA Office of Education with links to multimedia resources, lessons & activities, data, and background information

Coastal Response Research Center. 2010. Deepwater Horizon Dispersant Use Meeting Report May 26-27, 2010. Coastal Response Research Center, University of New Hampshire. June 4, 2010; available online at www.crrc.unh.edu/dwg/dwh_dispersants_use_meeting_report.pdf

Fisher, C., H. Roberts, E. Cordes, and B. Bernard. 2007. Cold seeps and associated communities of the Gulf of Mexico. *Oceanography* 20:118-129; available online at http://www.tos.org/oceanography/issues/issue_archive/20_4.html

Kellogg, C. A., 2009, Gulf of Mexico deep-sea coral ecosystem studies, 2008–2011: U.S. Geological Survey Fact Sheet 2009–3094, 4 pp. available at <http://pubs.usgs.gov/fs/2009/3094/>

Sulak, K. J., M. T. Randall, K. E. Luke, A. D. Norem, and J. M. Miller (Eds.). 2008. Characterization of Northern Gulf of Mexico Deepwater Hard Bottom Communities with Emphasis on *Lophelia* Coral - *Lophelia* Reef Megafaunal Community Structure, Biotopes, Genetics, Microbial Ecology, and Geology. USGS Open-File Report 2008-1148; http://fl.biology.usgs.gov/coastaleco/OFR_2008-1148_MMS_2008-015/index.html

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 b. An ocean basin's size, shape and features (such as islands, trenches, mid-ocean ridges, rift valleys) vary due to the movement of Earth's lithospheric plates. Earth's highest peaks, deepest valleys and flattest vast plains are all in the ocean.

Essential Principle 4.

The ocean makes Earth habitable.

Fundamental Concept a. Most of the oxygen in the atmosphere originally came from the activities of photosynthetic organisms in the ocean.

Fundamental Concept b. The first life is thought to have started in the ocean. The earliest evidence of life is found in the ocean.

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

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 f. Coastal regions are susceptible to natural hazards (such as tsunamis, hurricanes, cyclones, sea level change, and storm surges).

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:

oceaneducation@noaa.gov

For More Information

Paula Keener, Director, Education Programs

NOAA's Office of Ocean Exploration and Research

Hollings Marine Laboratory

331 Fort Johnson Road, Charleston SC 29412

843.762.8818 843.762.8737 (fax)

paula.keener-chavis@noaa.gov

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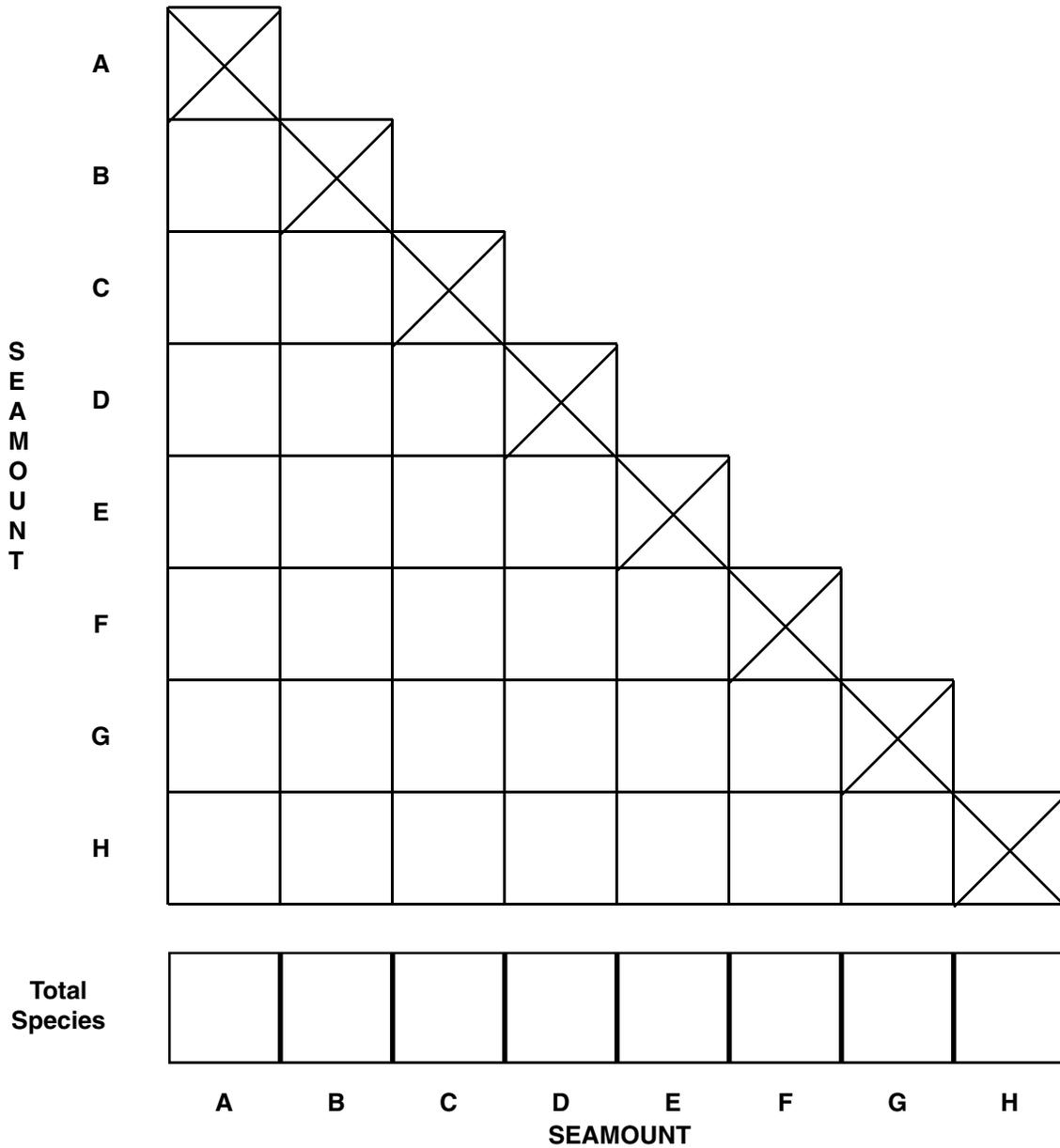
Biological Survey Data from Eight Deepwater Areas in the Gulf of Mexico

(adapted from Sulak *et al.*, 2008)

Species	Areas Where Found								
Brown <i>Lophelia</i>	A			D			F		
White <i>Lophelia</i>	A	B		D	E	F	G		
Bamboo Coral	A	B			E	F	G		
Pink Black Coral		B			E		G		
Red Black Coral	A	B			E				
White Black Coral	A	B				F	G		
Black Cerianthid					E				
Pink Cerianthid					E				
Unknown Anemone		B			E		G		
Venus Fly Trap Anemone	A	B				F	G		
White Anemone	A	B			E	F	G		
Demo Sponge	A					F			
Glass Sponge	A	B				F	G		
Squat Lobster			C	D					
<i>Echinus</i>			C	D				H	
Brisingid				D					
Crinoid				D					
<i>Vestimentifera</i>			C					H	
<i>Beggiatoa</i> Bacterial Mat			C		E			H	
Hydroid	A					F			
Unknown Alcyonarian				D					

Similarity Analysis Tally Sheet

Table 1



Similarity Analysis Tally Sheet

Table 2

S E A M O U N T	A	X						
	B		X					
	C			X				
	D				X			
	E					X		
	F						X	
	G							X
	H							
Total Species								
	A	B	C	D	E	F	G	H

SEAMOUNT

Dendrogram Construction Sheet

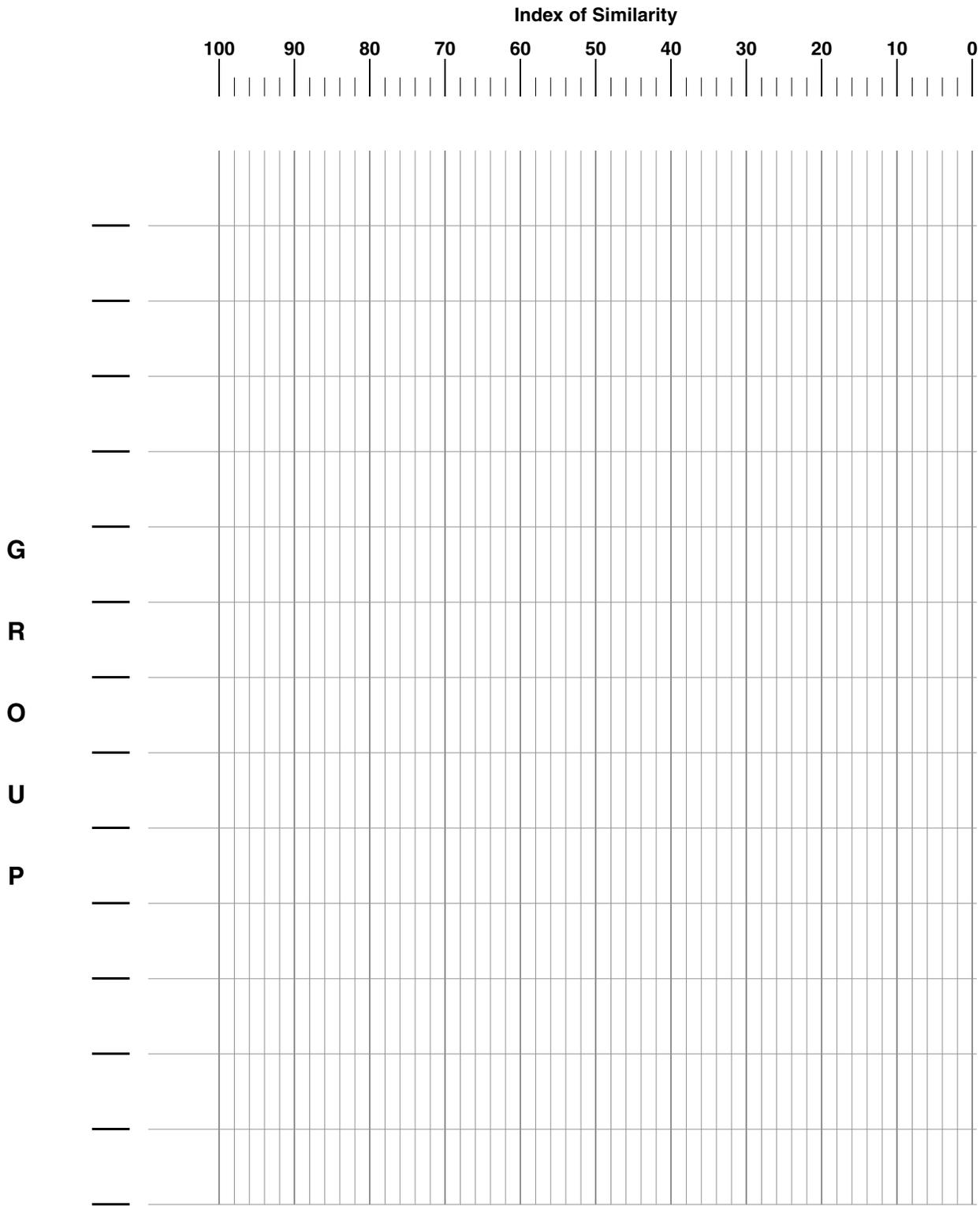


Figure 1: A Hypothetical Similarity Matrix

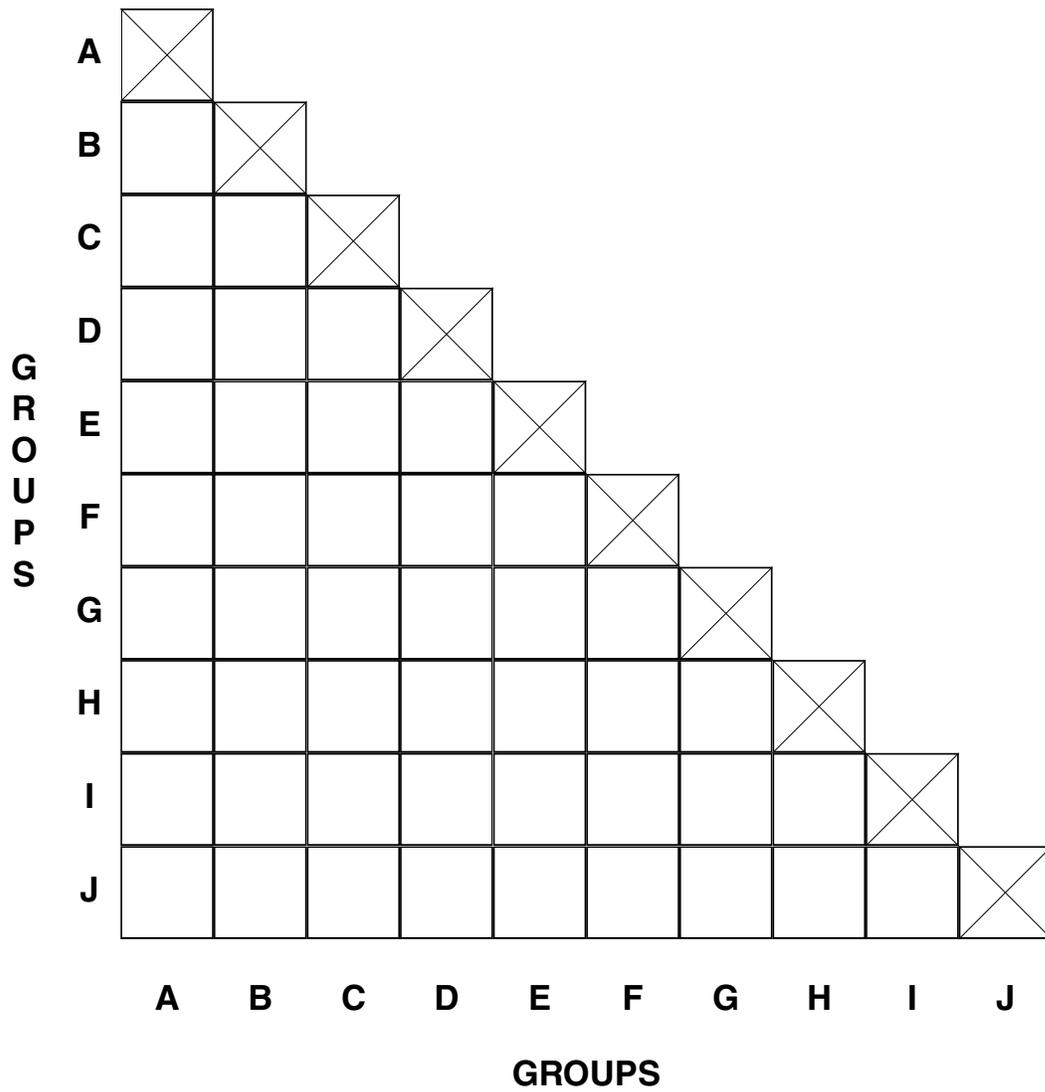


Figure 2: Similarity of Food Preferences

S T U D E N T S	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	
		A	B	C	D	E	F	G	H	I	J
		STUDENTS									

Figure 3: Dendrogram Construction Example

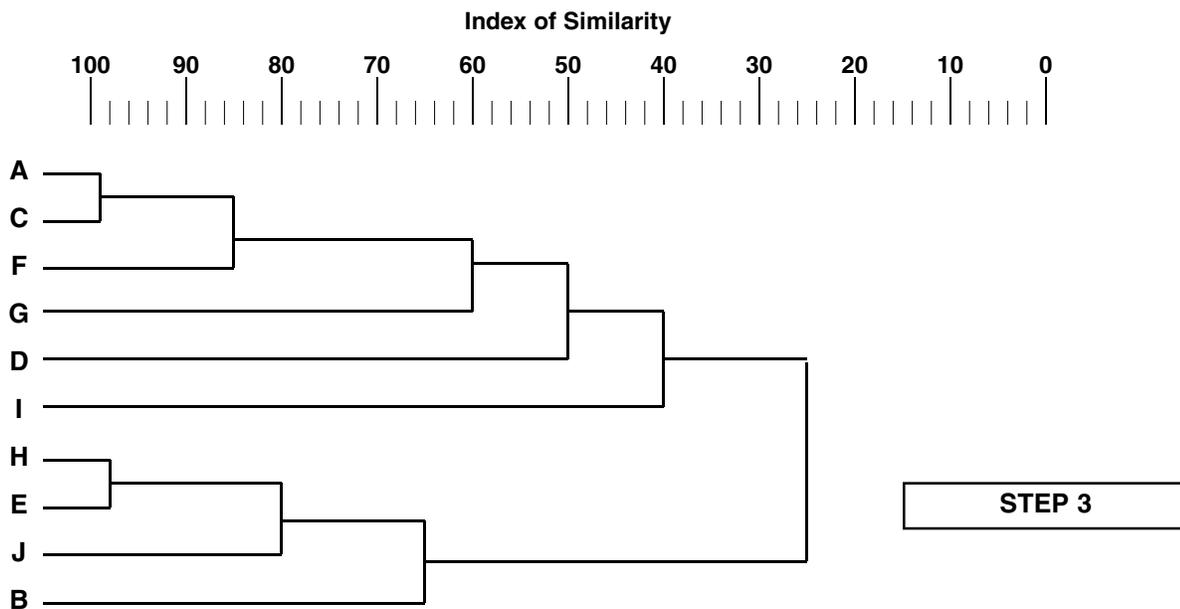
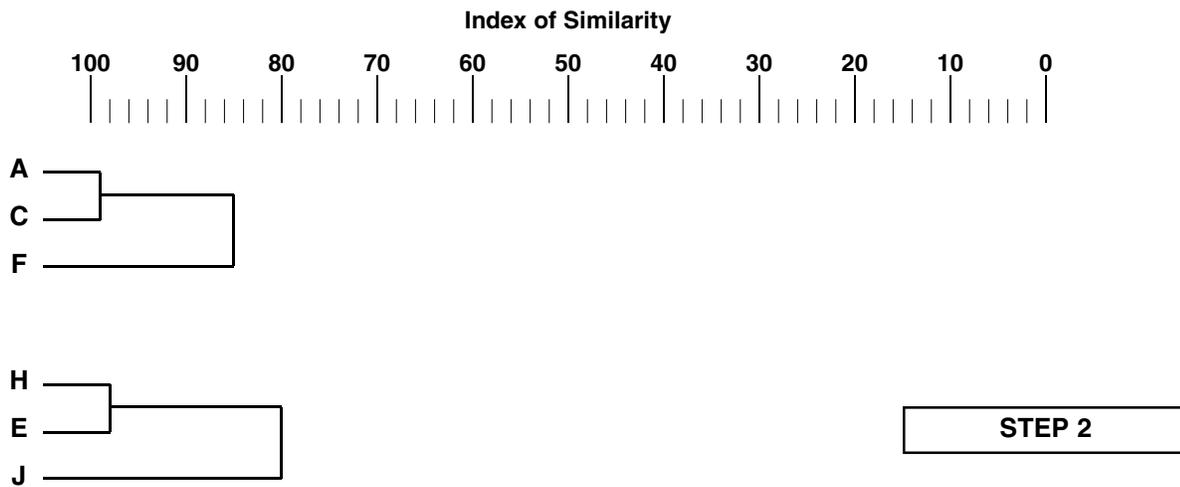
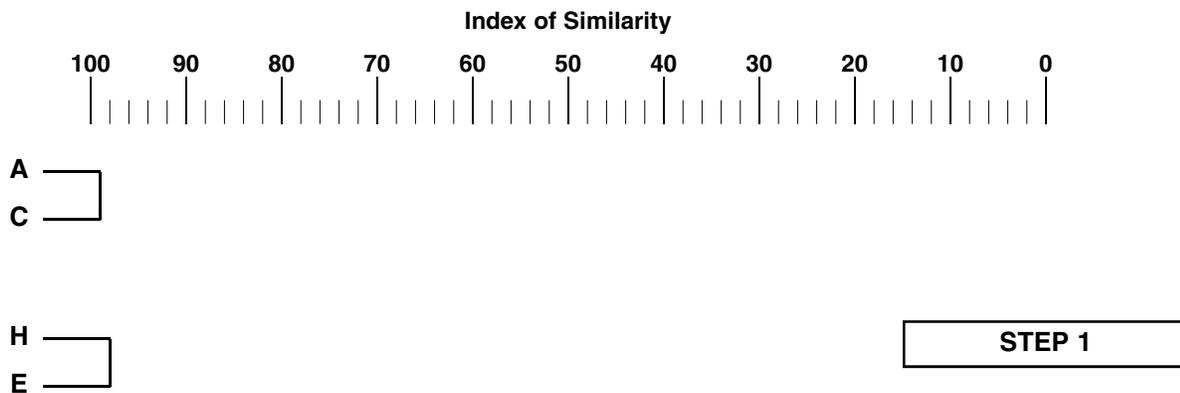


Figure 4: Jaccard Coefficient Calculation Example

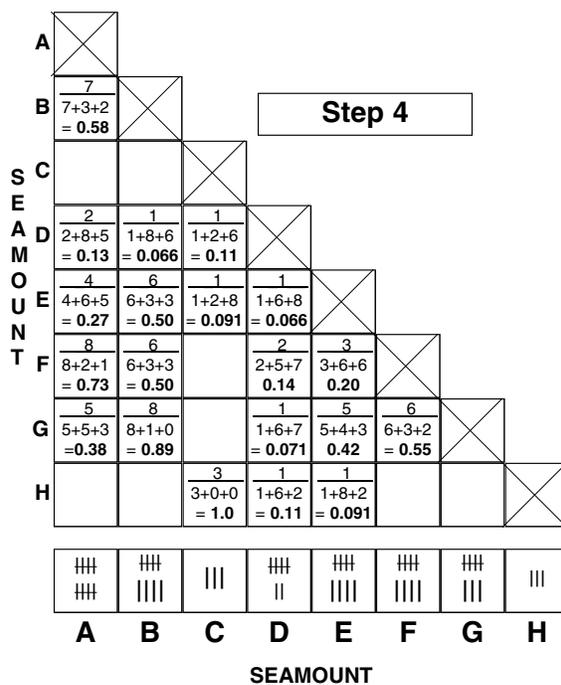
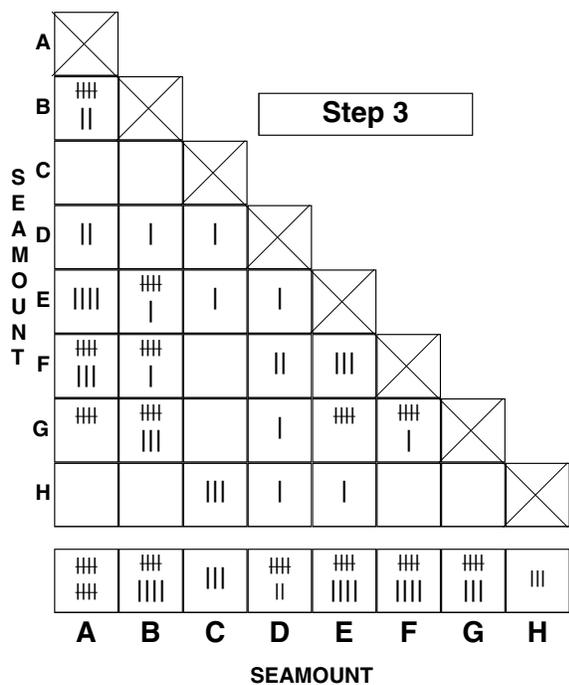
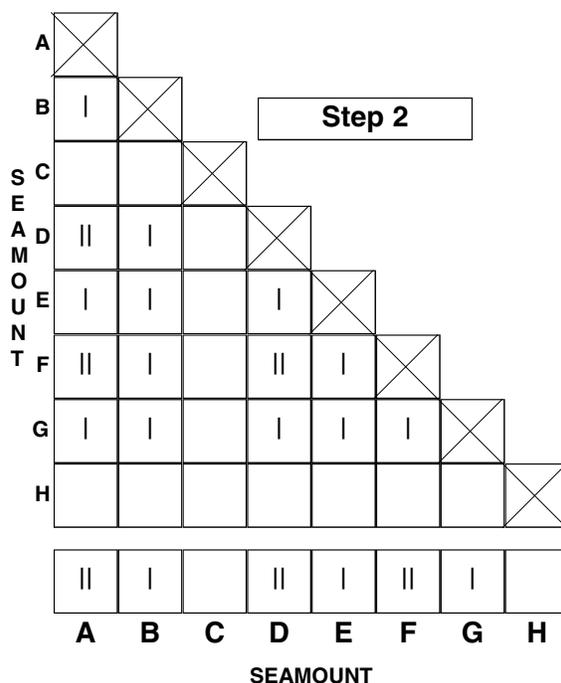
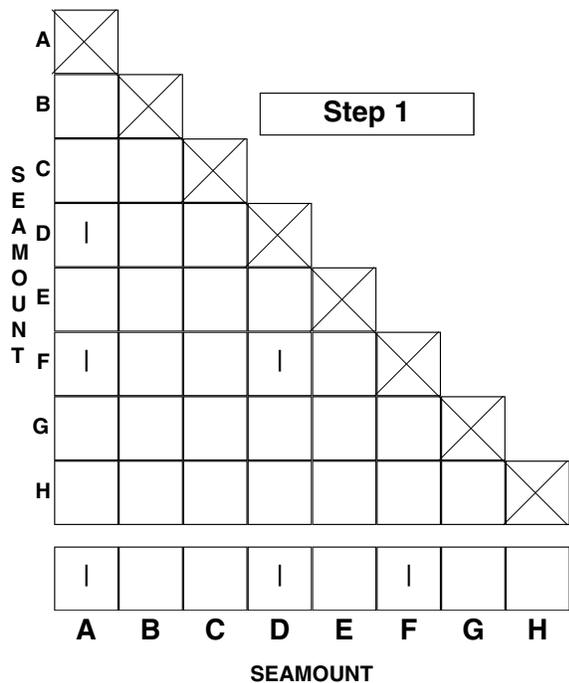
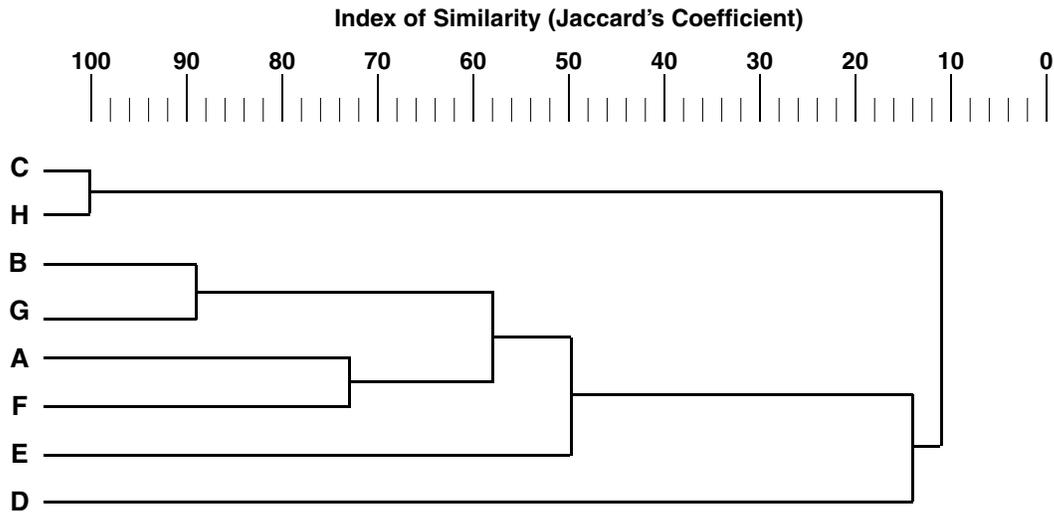


Figure 5: Dendrogram of Biological Similarity Between Eight Deepwater Areas in the Gulf of Mexico



Community Comparison Inquiry Guide

Your assignment is to examine data from photographic surveys of eight deep-sea areas in the Gulf of Mexico, and perform a cluster analysis to determine which of these are most similar and how many different types of communities may be represented. For this analysis, you will calculate an index of similarity called Jaccard's Coefficient for each pair of survey areas. 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 different species present in both groups.

You should have copies of *Biological Survey Data from Eight Deepwater Areas in the Gulf of Mexico*, *Similarity Analysis Tally Sheet Table 1*, *Similarity Analysis Tally Sheet Table 2*, and *Dendrogram Construction Sheet*. For larger data sets this analysis would be done by computer, but this approach gives a better feel for how the analysis actually works.

1. For each species or group listed in the *Biological Survey Data*, make a tally mark in the appropriate box in the *Similarity Analysis Tally Sheet Table 1* for each pair of areas where the group was found, and also in the Total Species box for each individual area. So, for the Brown *Lophelia* Coral, you should make tally marks in the boxes corresponding to these pairs:

A + D
A + F
D + F

Make additional tally marks in the Total Species boxes for areas A, D, and F.

2. Next, for the White *Lophelia* Coral, you should make tally marks in the boxes corresponding to these pairs:

A + B
A + D
A + E
A + F
A + G
B + D
B + E
B + F
B + G
D + E
D + F
D + G
E + F
E + G
F + G

Make additional tally marks in the Total Species boxes for areas A, B, D, E, F, and G.

3. Continue this process until all species and groups in the survey data have been included.
4. Next, use *Similarity Analysis Tally Sheet Table 2* to summarize calculations for Jaccard's Coefficient for each pair of areas where species matches occurred. Since areas A and B had seven species in common, we write 7 as the numerator in the box in Table 2 corresponding to pair A + B. Since area A had a total of ten species, three of these were not found in area B. Similarly, since area B had a total of nine species, two of these were not found in area A. So the denominator in the box of Table 2 for pair A + B is 7 (the number of species found in both areas) + 3 (the number of species found only in area A) + 2 (the number of species found only in area B). Solving this equation:

$$7 \div (7 + 3 + 2) = 7 \div 12 = 0.58$$

Continue this process until all pairs of areas where species matches occurred have been included.

5. Now you can construct a dendrogram to show similarities among the eight areas. Start by identifying cells in *Similarity Analysis Tally Sheet Table 2* that have the highest similarity, then those next highest, and so on. 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 value of Jaccard's Coefficient for that pair as indicated on the "Index of Similarity" scale. Be sure to leave some space between these groups so you have the option of adding more members to each group.

Continue this process until all areas are included on the dendrogram.