



Mountains in the Sea Exploration

What's the Difference?

FOCUS

Identification of biological communities from survey data

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 Seamounts," "Similarity Analysis Tally Sheet (Table 1 and Table 2)," and "Dendrogram Construction Sheet," one for each student group
- Overhead transparencies of "A Hypothetical Similarity Matrix," "Similarity of Food Preferences," and "Dendrogram Construction Example"

AUDIO/VISUAL MATERIALS

Overhead projector

TEACHING TIME

Two 45-minute class periods

SEATING ARRANGEMENT

Groups of four

MAXIMUM NUMBER OF STUDENTS

32

KEY WORDS

Seamount
Biodiversity
Endemic
Cluster analysis
Similarity matrix
Dendrogram
Similarity coefficient

BACKGROUND INFORMATION

Seamounts (also called "guyots") are undersea mountains that rise from the ocean floor, often with heights of 3,000 m (10,000 ft) or more. Compared to the surrounding ocean waters, seamounts have high biological productivity, and provide habitats for a variety of plant, animal, and microbial species. Seamounts are formed by volcanic processes, either as isolated peaks or as chains that may be thousands of miles long. In the Atlantic Ocean, the New England Seamounts form a chain of more than 30 peaks that begins near the coast of New England and extends 1,600 km to the southeast. Some of the peaks are more than 4,000 m above

the deep-sea floor, similar to the heights of major peaks in the Alps.

Bear Seamount is the closest of the New England Seamounts to the coast of the United States, and rises from a depth of 2,000 - 3,000 m to a summit that is 1,100 m below the sea surface. Previous investigations have found numerous invertebrates, including cephalopods, crustaceans, and more than a hundred other species in 10 different phyla. These investigations also found more than 100 species of fishes, some of which are commercially important. Several species discovered at Bear Seamount were previously unknown to science.

Seamounts are good places to look for new species because they are relatively isolated from each other and from other marine habitats. This means that seamounts can vary greatly in their biodiversity (the number of different species present) and can also have an unusually large number of endemic species (species that are not found anywhere else). Some seamounts may act as “stepping stones” that allow coastal species to extend their range into areas of the ocean far from land. When scientists study biological communities found at different seamounts, they need a way to measure how similar these communities are in terms of the species present. This information gives clues about how living communities develop on seamounts. For example, if similar biological communities are found on seamounts that are far apart from each other, it 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 a group of seamounts have very different biological communities, it could suggest that these seamounts have not been populated from a common source, and that the seamounts 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 seamounts are most alike based on the number of biological species that they have in common.

LEARNING PROCEDURE

1. Explain that seamounts are the remains of underwater volcanoes, and that they are islands of productivity compared to the surrounding environment. Although seamounts have not been extensively explored, expeditions to seamounts often report many species that are new to science and many that appear to be endemic to a particular group of seamounts.
2. 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 seamounts 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 “A Hypothetical Similarity Matrix.” 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 we are interested in.

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.

3. Explain that we will next examine data from biological surveys of eight seamounts, and perform a cluster analysis to determine which seamounts 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 seamounts. 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 Seamounts,” “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 seamounts where the group was found, and also in the “Total Species” box for each individual seamount. 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 seamounts 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 seamounts 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 seamounts where species matches occurred. Use Table 2 on the tally sheet to summarize these calculations. Since seamounts 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 seamount A had a total of 6 species, 4 of these were not found

on seamount B. Similarly, since seamount B had a total of 5 species, 3 of these were not found on seamount A. So the denominator in the box of Table 2 for pair A + B is 2 (the number of species found on both seamounts) + 4 (the number of species found only on seamount A) + 3 (the number of species found only on seamount B). Solving this equation:

$$\frac{2}{2 + 4 + 3} = \frac{2}{9} = 0.22$$

Continue this process until all pairs of seamounts 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 seamounts included in the survey.

4. 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 seamounts (B-C and F-G) were very similar with 80% or more of the same species. Three other seamounts (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 Seamounts” considering these three groups. Students should notice that major invertebrate groups (isopods, decapoda, cirrepoda, etc.) found on the B-C seamounts were also found on the F-G seamounts, 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 seamounts F and G favor greater biological diversity, and that species found on one group of seamounts 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 seamounts, 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 seamounts 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 seamounts.

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 click on "Ecology" in the "Ocean Science Topics" menu, then click on "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

EVALUATION

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 #4 before discussing the results as a group.

EXTENSIONS

1. Have students visit <http://oceanexplorer.noaa.gov> to find out more about exploration on Bear Seamount and opportunities for real-time interaction with scientists on current Ocean Exploration expeditions.
2. Have student groups research one or more of the invertebrate groups listed in "Biological Survey Data from Eight Seamounts" 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 #4.

RESOURCES

<http://seamounts.edsc.edu> - Seamounts website sponsored by the National Science Foundation

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.

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

FOR MORE INFORMATION

Paula Keener-Chavis, National Education
Coordinator/Marine Biologist
NOAA Office of Exploration
2234 South Hobson Avenue
Charleston, SC 29405-2413
843.740.1338
843.740.1329 (fax)
paula.keener-chavis@noaa.gov

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 Seamounts

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

Student Handout

Similarity Analysis Tally Sheet

Table 1

SEAMOUNT	A								
	B								
	C								
	D								
	E								
	F								
	G								
	H								
Total Species									
	A	B	C	D	E	F	G	H	

SEAMOUNT

Student Handout

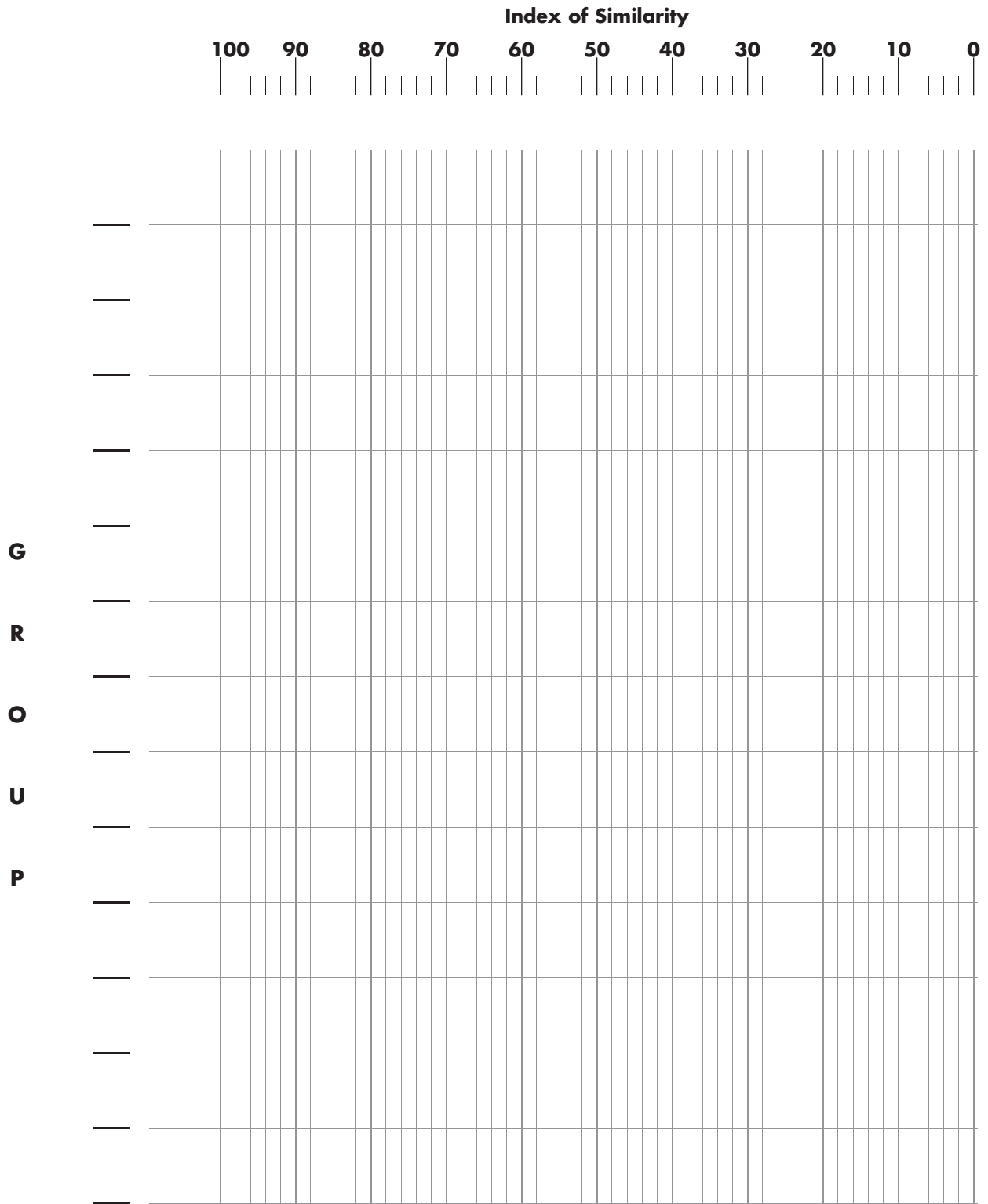
Similarity Analysis Tally Sheet

Table 2

A	X								
B		X							
C			X						
D				X					
E					X				
F						X			
G							X		
H								X	
Total Species									
	A	B	C	D	E	F	G	H	

Student Handout

Dendrogram Construction Sheet



Student Handout

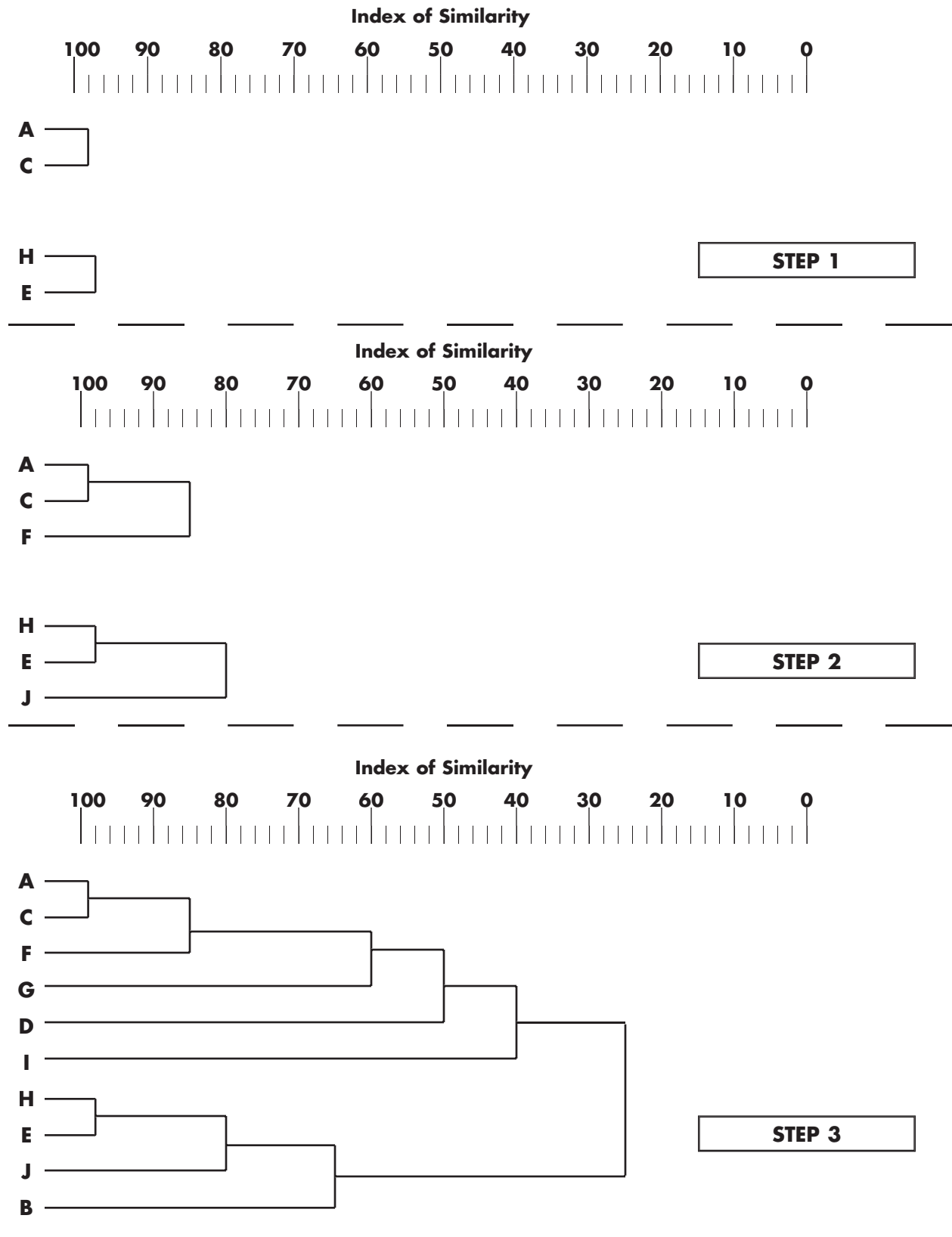
Similarity of Food Preferences

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

STUDENTS

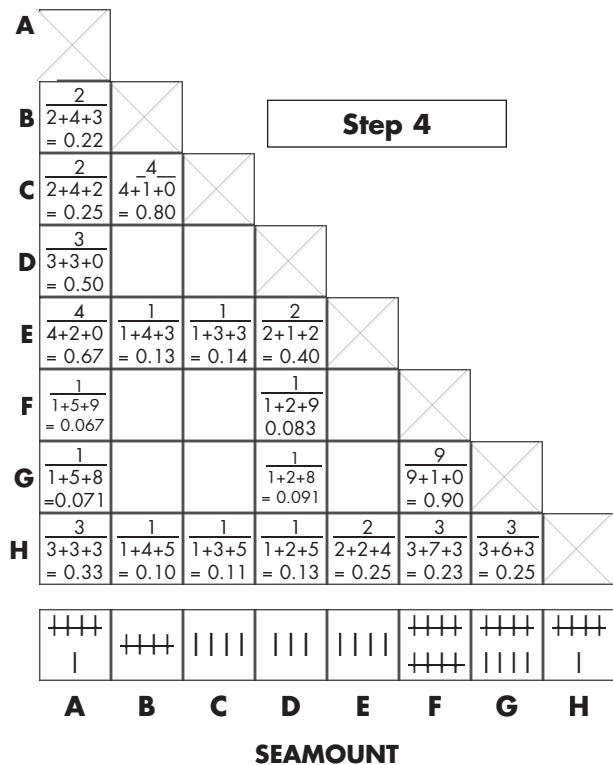
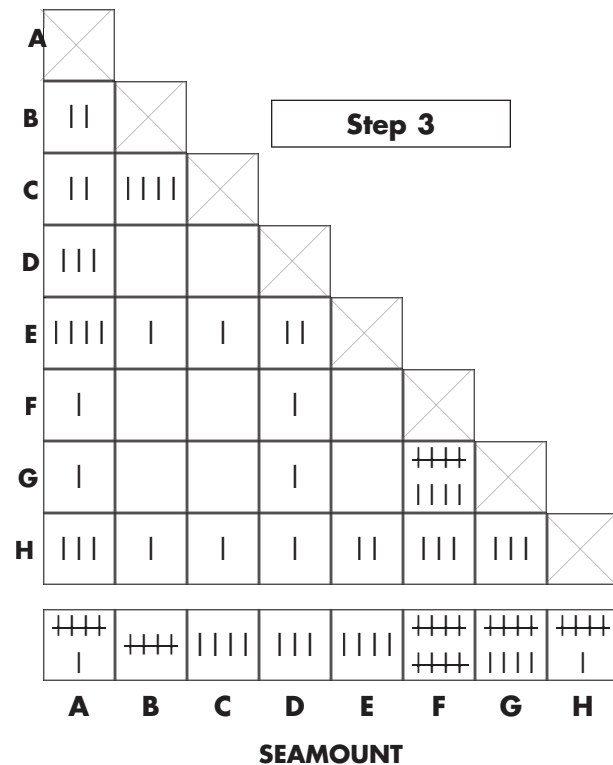
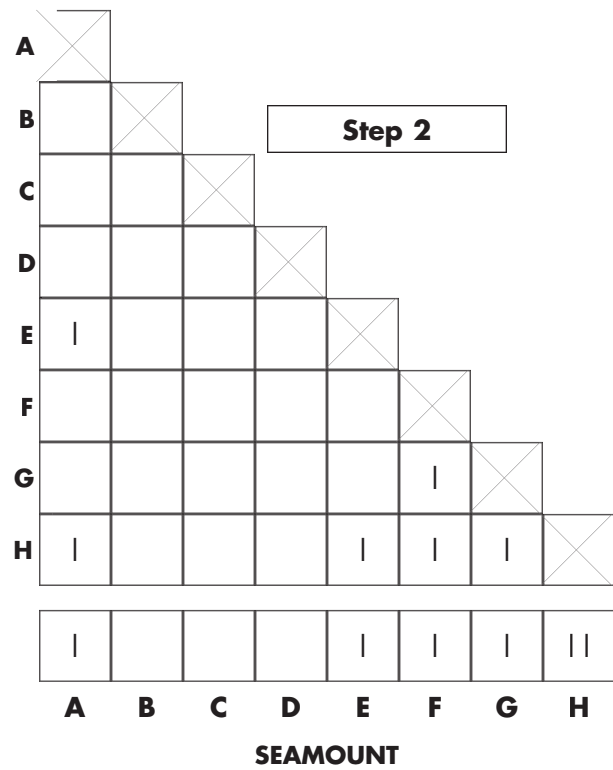
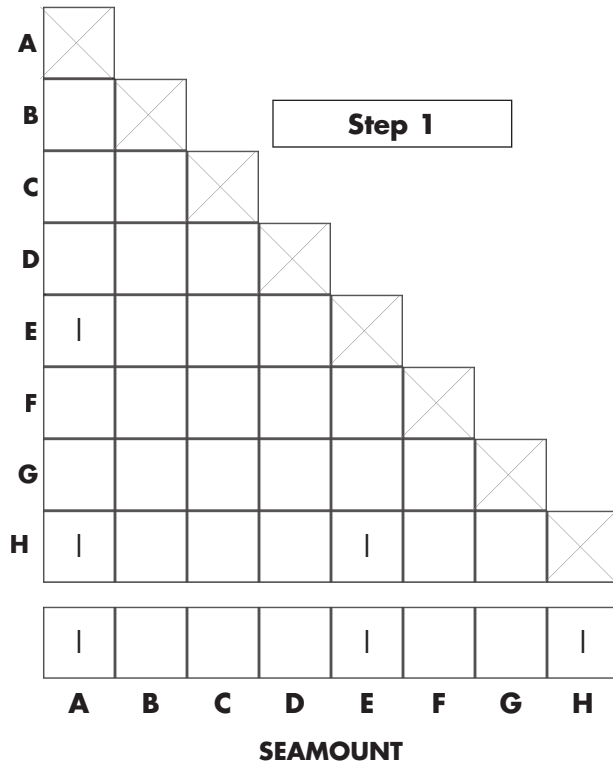
Student Handout

Dendrogram Construction Example



Student Handout

Jaccard Coefficient Calculation Example



Student Handout

Dendrogram of Biological Similarity Between Eight Seamounts

