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Mountains in the Sea Exploration

No Escape

Focus
Fate of benthic invertebrate larvae in the vicinity of seamounts

Grade Level
9-12 (Earth Science)

Focus Question
Are floating larvae retained in the vicinity of seamounts by patterns of water circulation?

Learning Objectives
Students will be able to field data to evaluate an hypothesis about the influence of a water circulation cell on the retention of benthic invertebrate larvae in the vicinity of a seamount.

Students will be able to describe some potential advantages and disadvantages to species whose larvae are retained in the vicinity of seamounts where the larvae are produced.

Students will be able to describe the consequences of partial or total larval retention on the biological evolution of species producing these larvae.

Materials
- ❐ "Three-dimensional Diagram of Mean Flows in the Fieberling Guyot Circulation Cell" and "Topographic Map of Fieberling Guyot," copied onto an overhead transparency
- ❐ "Abundance of Hydroids Colonizing Settlement Plates Around Fieberling Guyot" and "Settlement Plate Data Summary Sheets," one copy for each student group

Audio/Visual Materials
Overhead projector

Teaching Time
One 45-minute class periods

Seating Arrangement
Groups of approximately four students

Maximum Number of Students
30

Key Words
Seamount
Biodiversity
Endemic
Circulation cell
Hydroid
Settlement plate
Plankton tow

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.

Unfortunately, seamount habitats are easily damaged by commercial trawl fishing. At the First International Symposium on Deep Sea Corals (August, 2000), scientists warned that more than half of the world's deep-sea coral reefs have been destroyed, and some believe that destruction of deep-sea corals by bottom trawlers is responsible for the decline of major fisheries, such as cod. Seamounts are important for other reasons in addition to commercial fisheries. Because the biological communities of seamounts have not been well-studied, these communities are likely to contain significant numbers of species that are not yet known to science. Some of these species may provide drugs that can directly benefit human beings.

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 a high degree of endemism (endemic species are species that are only found around seamounts). A key factor that affects biodiversity and endemism is the reproductive strategy used by benthic seamount species. Most benthic marine invertebrates produce free-swimming or floating planktonic larvae that can be carried for many miles by ocean currents until the larvae settle to the bottom and change (metamorphose) into juvenile animals that usually resemble adults of the species. A longer larval phase allows for greater dispersal, and gives the species a wider geographic range.

On the other hand, species with shorter larval stages do not have the advantage of broad dispersal, but are able to remain in favorable local environments. Some species do not have a free larval stage, but brood their larvae inside the adult animal or in egg cases until metamorphosis takes place. Other forces may tend to keep larvae from drifting away. Seamounts are often exposed to strong, steady ocean currents. When these currents impinge on a seamount, they cause an upwelling of deep cold water. This cold water has a higher density than surrounding water and tends to sink. This combination of water movements can cause an eddy to form that is known as a Taylor column. Taylor columns may remain over seamounts for several weeks, and can effectively trap larvae that would otherwise be carried away.

A key factor in protecting seamount communities is to understand the reproductive strategies used by benthic seamount species. If these species are able to keep their offspring nearby, protecting selected seamounts could be an effective way to improve populations of corals and other species on those seamounts that may have been damaged by human activities or natural events. But if the larvae produced on a protected seamount were actually carried far away from the protected area, protecting only a few seamounts might not produce major improvements to benthic communities on these seamounts.

The question of reproductive strategy is fundamental to protecting and managing seamount resources, and is one of the focal points of the Ocean Exploration 2003 Mountains in the Sea Expedition. This lesson builds on results of studies described in the "Round and Round" lesson plan. These studies showed that currents in the vicinity of one seamount formed a circulation cell that might tend to keep free-floating larvae in the vicinity of the seamount. This lesson is based on studies that were undertaken to test this hypothesis of larval retention by seamount-generated water flows.

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. Briefly describe larval reproduction used by many benthic invertebrates.

2. If students have completed the "Round and Round" lesson, remind them of the circulation cell diagrammed in "Three-dimensional Diagram of Mean Flows in the Fieberling Guyot Circulation Cell." Students should understand that this model suggests that larvae might be retained in a pancake-shaped region centered directly over the seamount center, extending vertically several hundred meters, and horizontally at least 7 km (possibly as far as 40 km). Proceed to Step #3.

   If students have not completed the "Round and Round" lesson, show them "Topographic Map of Fieberling Guyot" and tell them that a year-long study of currents on and around the seamount used current meters that were located at the center of the seamount (C), two on the rim of the seamount (R1 and R2), two on the slope (or "flank") of the seamount (F1 and F2), and two on the seabottom plain roughly 25 km from the base of the seamount (B1 and B2). The study found that water near the surface of the seamount moves outward from its center. Near the rim and flank of the seamount, water begins to move upward (toward the surface) and inward (back toward the center of the seamount). Over the center of the seamount and about 50 m above the seamount surface, water circulation is strongly downward, and is carried back toward the seamount surface. As the object moves through this vertical circulation cycle, it also moves in a generally clockwise direction. At stations B1 and B2, currents are weak with no definite circulation pattern. Show students "Three-dimensional Diagram of Mean Flows in the Fieberling Guyot Circulation Cell," and briefly discuss how this circulation pattern might affect free-floating larvae. Students should understand that this model suggests that larvae might be retained in a pancake-shaped region centered directly over the seamount center, extending vertically several hundred meters, and horizontally at least 7 km (possibly as far as 40 km).

3. Show students "Topographic Map of Fieberling Guyot." Tell students that the purpose of this study was to test the hypothesis that larvae from benthic invertebrates on the seamount will accumulate in a region that corresponds to the extent of the circulation cell. Two techniques were used to sample larvae around Fieberling Guyot to test this hypothesis. The first technique was to sample larvae with plankton nets towed from a research vessel at various depths. This technique allows scientists to identify the locations in which larvae are most likely to be found. A disadvantage is that samples are taken over a very short time span, so if larvae of some benthic animals may not be found if those animals produce their larvae at times other than those sampled.

   The second technique was to sample larvae by providing artificial surfaces onto which larvae might settle and grow. After the artificial surfaces have been in place for the desired period of time (usually several months or more), they are retrieved and the attached animals are identified and counted. The advantage of this method is that larvae are sampled over a long period of time. A disadvantage is that larvae of some species may prefer other substrates and fail to attach to the artificial surfaces. In this study, plastic plates were attached to mooring lines located at the seamount center (C and RF), rim (R1, R2, and SPR), flank (F1 and F2), and seabottom (B1 and B2). The plates were attached so that they could rotate freely around the mooring line and orient themselves parallel to the current flow. Four plates, each 23 cm x 28 cm, were attached at depths of about 500 m and 1500 m. At the RF and SPR sites, plates were attached 1 m, 5 m, 10 m, 20 m, and 40 m above the bottom to obtain additional information on larval abundances near the seamount surface. Three moorings were used at each of the RF and SPR sites, and the plates were retrieved after six months. Plates at the other sites were retrieved after one year.

4. Tell students that results from plankton tows showed that the most abundant larvae belonged to the same taxonomic groups that are abundant on the seamount surface: cnidarians, polychaetes, and gastropods. The plankton tows did not, however, contain larvae from taxonomic groups that are abundant in deepsea sediments (other types of polychaetes, tanaids, bivalves, and isopods). The scientists concluded from these data that larvae in the plankton tows came from benthic animals living on the seamount.

5. Provide each student group with a copy of "Abundance of Hydroids Colonizing Settlement Plates Around Fieberling Guyot" and "Settlement Plate Data Summary Sheet." Tell students that rough weather during recovery of the plates damaged, and may have dislodged, some of the attached organisms. One species of hydroid, however, had very strong attachments and investigators were able to count and identify this species.

   Have each student group fill in the Data Summary Sheet using information from "Abundance of Hydroids Colonizing Settlement Plates Around Fieberling Guyot."

   Each rectangle on the Data Summary Sheet corresponds to a particular depth and sampling station. Students should shade each rectangle to indicate the number of hydroids recovered from that location. Point out that the scale for stations RF and SPR is different from that used for other stations because settlement plates at stations RF and SPR were intended to sample larvae close to the bottom, while plates at the other stations were intended to reveal differences in larval abundance at deep (about 1500 m) and shallower (300 m -750 m locations).

6. Lead a discussion about the summarized data. Students should recognize that hydroid colonization occurred at all but one of the sampling stations, and that colonization was limited to a depth range of 450 - 500 m. These observations are consistent with the hypothesis that larvae from benthic invertebrates on the seamount accumulate in a pancake-shaped region that corresponds to the extent of the circulation cell.

   Students should also recognize that data from stations RF and SPR indicate that hydroid colonization decreases with increasing distance from the bottom. Ask students to speculate on why this might be the case. Some suggestions are that larvae may be attracted to areas that are close to adult populations of the same species, since these areas would have suitable conditions for the species. Another possibility is that differences in water flow conditions close to the surface (such as drag from bottom features that would decrease current flow) cause larvae to accumulate. The vertical distribution of hydroids found at these sites is consistent with the primary hypothesis, but is not predicted by the hypothesis. The investigators are not sure why this distribution occurred.

Ask students to speculate on the implications of larval retention to seamount ecosystems and species. Students should recognize that if the larvae of benthic seamount species tend to be retained on one or a few specific seamounts, then those species will have reduced exchange of genetic material with other populations of their species. If populations are completely isolated, then they may evolve into new species. This is probably fairly rare, since most seamounts occur in chains and water circulation around these chains is primarily influenced by the topography of the entire chain.

Students may wonder whether data from only one species are sufficient to draw general conclusions about the behavior of the larvae of many species. This is a legitimate concern, and is a good opportunity to point out that it is usually impossible to absolutely prove a hypothesis, since it only takes one exception to show that a hypothesis is not always valid. In fact, many other species were also recovered from the settlement plates at stations RF and SPR, including ciliates, anemones, other hydroids, serpulid polychaetes, and ascidians. These species were not included in the analyses, however, to maintain consistency with analyses of data from other stations.

The BRIDGE Connection

www.vims.edu/bridge/ - In the Navigation toolbar, click on "Ocean Science Topics." In the "Ocean Science Topics" menu, click on "Physics."

The "Me" Connection

Ask students whether they think additional investigations are needed of the hypothesis presented in Step #3, and if so, what measurements or experiments should be undertaken.

Connections to Other Subjects

Earth Science; Physics

Evaluation

Develop a rubric for grading students, performance in completing Step #5. This could include accuracy, attention to instructions, and appearance of the final summary sheet. Have students prepare individual written interpretations of their data summaries (Step #6) prior to the group discussion.

Extensions

Have students visit http://oceanexplorer.noaa.gov to find out more about exploration on the Bear Seamount and opportunities for real-time interaction with scientists on current Ocean Exploration expeditions. Remind students that the data used in this lesson are from a single seamount and that other seamounts may have very different patterns of larval dispersal and retention. Suggest that students ask scientists if they have found indications of similar or different circulation patterns on other seamounts.

Resources

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

Brink, K. H. 1995. *Tidal and lower frequency currents above Fieberling Guyot.* J. of Geophysical Research, 100:10,817-10,832; and Mullineaux, L. S. and S. W. Mills. 1997. A test of the larval retention hypothesis in seamount-generated flows. Deep-Sea Research 44:745-770. The journal articles 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 B: Physical Science

- Motion and forces

Content Standard C: Life Science
- Biological evolution
- Matter, energy and organization in living systems
- Behavior

Content Standard D: Earth and Space Science
- Energy in the Earth system

Content Standard G: History and Nature of Science
- Nature of scientific knowledge

For More Information

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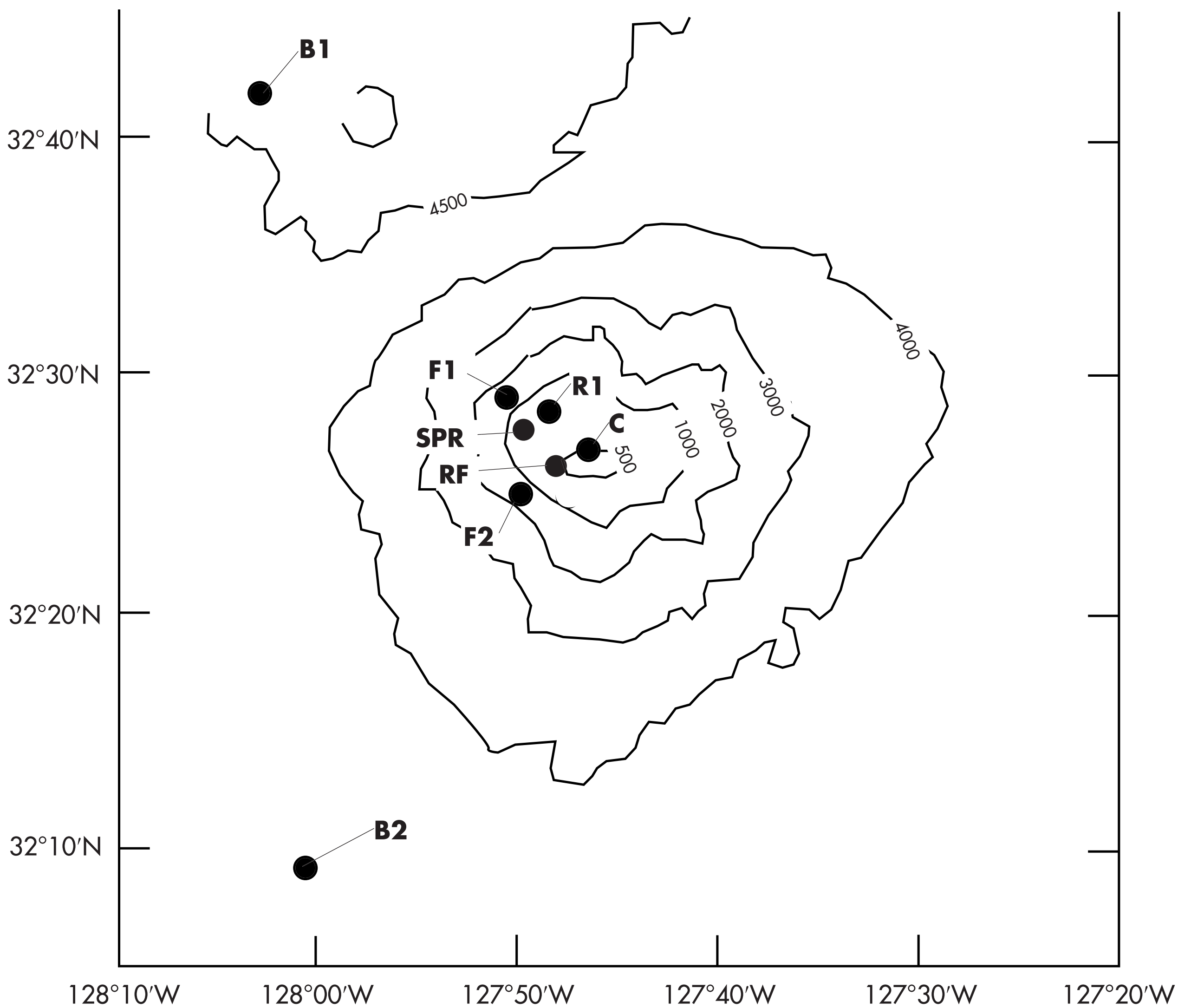
Student Handout

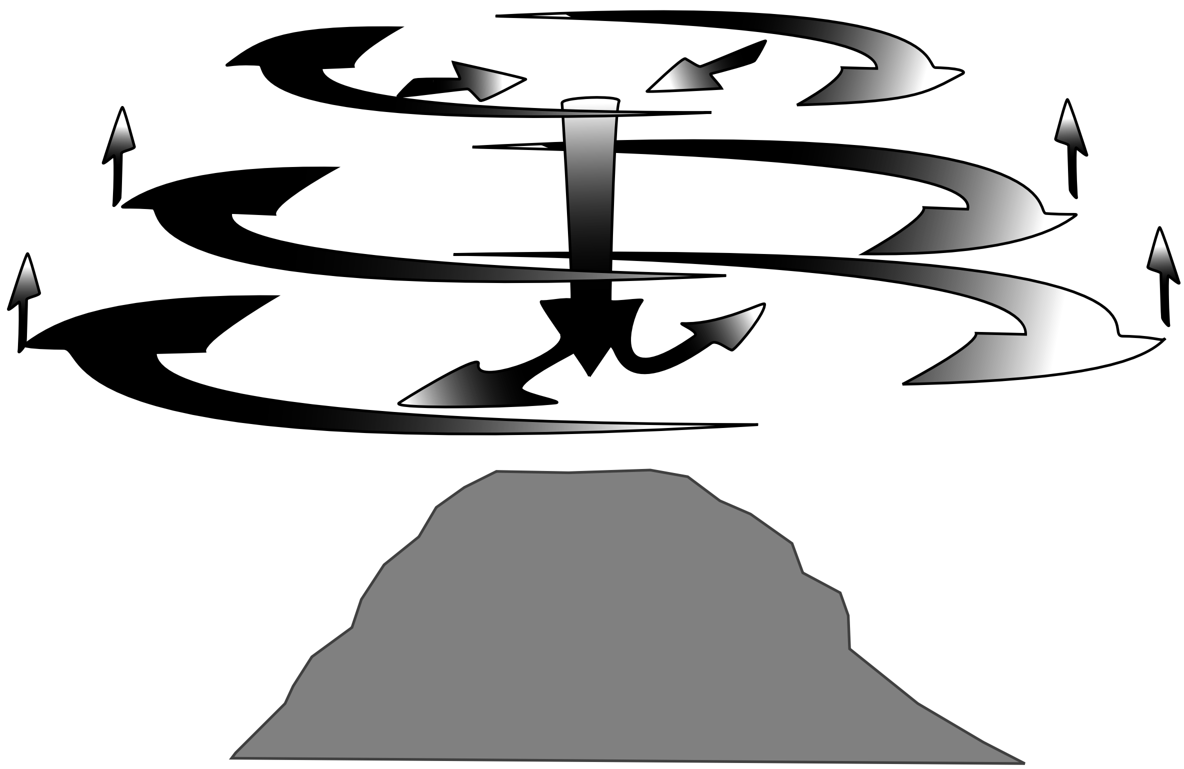
Topographic Map of Fieberling Guyot
Depths in meters
(redrawn from Mullineaux and Mills, 1997)



Student Handout

Three-dimensional Diagram of Mean Flows in the Fieberling Guyot Circulation Cell

(redrawn from Mullineaux and Mills, 1997)



Student Handout

Abundance of Hydroids Colonizing Settlement Plates Around Fieberling Guyot

Location	Depth (m)	Distance Above Bottom (m)	Hydroids (number of individuals)
C	300	215	0
C	400	115	0
C	500	15	4
RF1	450	40	2
RF1	470	20	0
RF1	480	10	2
RF1	485	5	6
RF1	489	1	12
RF2	450	40	0
RF2	470	20	0
RF2	480	10	0
RF2	485	5	4
RF2	489	1	14
RF3	450	40	0
RF3	470	20	0
RF3	480	10	0
RF3	485	5	2
RF3	489		
1 6			
R1	300	286	0
R1	450	136	2
R1	550	36	6
SPR1	598	40	0
SPR1	618	20	2
SPR1	628	10	2
SPR1	633	5	8
SPR1	637	1	10

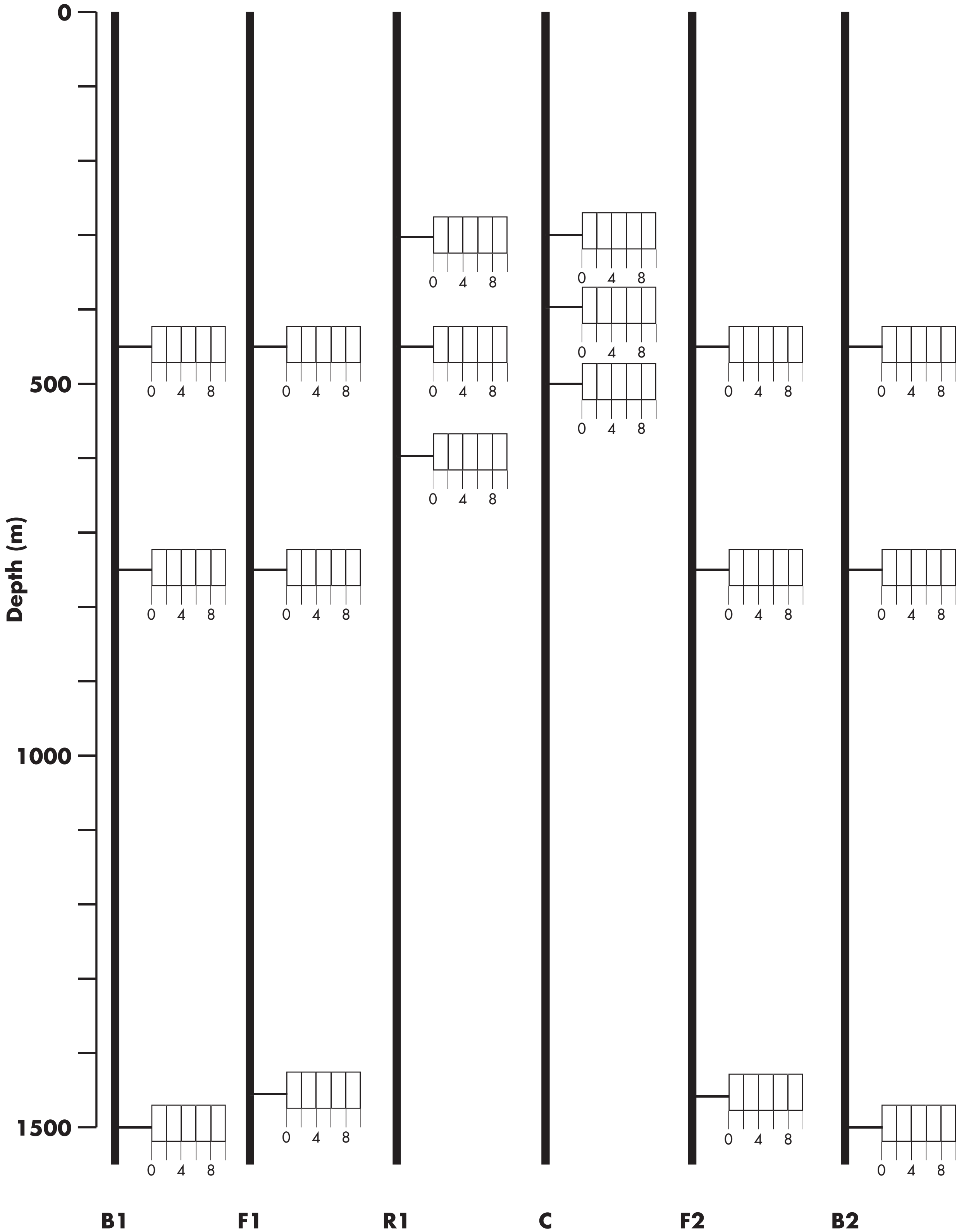
Student Handout

Abundance of Hydroids Colonizing Settlement Plates Around Fieberling Guyot (continued)

Location	Depth (m)	Distance Above Bottom (m)	Hydroids (number of individuals)
SPR2	599	40	0
SPR2	619	20	0
SPR2	629	10	2
SPR2	634	5	2
SPR2	638	1	4
SPR3	600	40	0
SPR3	620	20	0
SPR3	630	10	6
SPR3	635	5	12
SPR3	639	1	8
F1	450	1058	6
F1	750	758	0
F1	1450	58	0
F2	450	1005	2
F2	750	705	0
F2	1440	15	0
B1	450	4074	4
B1	750	3774	0
B1	1500	3024	0
B2	450	3830	4
B2	750	3530	0
B2	1500	2780	0

Student Handout

Settlement Plate Data Summary Sheet for Locations C, R1, F1, F2, B1, B2



Student Handout

Settlement Plate Data Summary Sheet for Locations RF1, RF2, RF3, SPR1, SPR2, SPR3