Working with Deep-Sea Data: Animal Distribution in the Lau Back-arc Basin

Hydrothermal vent environments are known for their extreme conditions (e.g., super hot temperatures, near-freezing seawater, toxic vent fluid, absence of light, crushing pressure). Still, lush communities thrive here - tubeworms, mussels, snails, crabs, fish, and more. *What makes these environments habitable for so much life? Why are the animals found here on the seafloor?* These are the kinds of questions deep-sea biologists investigate.

Aggregation of mussels, *Bathymodiolus brevior*, in Lau

Unlike surface water and terrestrial ecosystems, there are no plants in these deep-sea environments. Sunlight cannot penetrate to these depths so plants do not exist here. Instead, microbes (bacteria and Archaea) provide the energy base for these deep-sea food webs. Microbes harness chemical energy from vent fluids to convert CO_2 to sugars. The process, analogous to photosynthesis, is called chemosynthesis. Microbes inhabit nearly every possible space in the deep-sea hydrothermal vent environment –in seafloor cracks and crevices, in thick mats stretching over rocks and sessile animals, and even inside animals.

Some animals, like tubeworms and mussels, live in a symbiotic relationship with bacteria. These animals obtain or take up hydrogen sulfide, oxygen, and carbon dioxide from the environment and provide these to the bacteria living inside them. The bacteria, in exchange, use these raw materials to create sugars that are shared with the tubeworm or mussel.

The Lau vent snail, *Alviniconcha hessleri*

Two important types of animals found at hydrothermal vent fields in the Lau back-arc basin are mussels and snails. The deep-sea mussel, *Bathymodiolus brevior*, grows in clumps around cracks in the seafloor. It has symbiotic bacteria living in its gill tissue and lives off of the sugars produced by the bacteria. Scientists hypothesize that the mussel can also filter feed, allowing it to survive for short periods when hydrothermal fluids stop flowing. Two species of snail are also very common at Lau vents: *Alviniconcha hessleri* (white snail) and *Ifremeria nautilei* (black snail). These snails, just like the mussels, live in a symbiotic relationship with bacteria. The bacteria live inside the snails' gills and produce sugars that are an integral part of the snails' diet.

Visit the Lamont-Doherty Earth Observatory Marine Geoscience Data System Media Bank for more images of hydrothermal vent life forms (http://media.marine-geo.org/category/5/66).

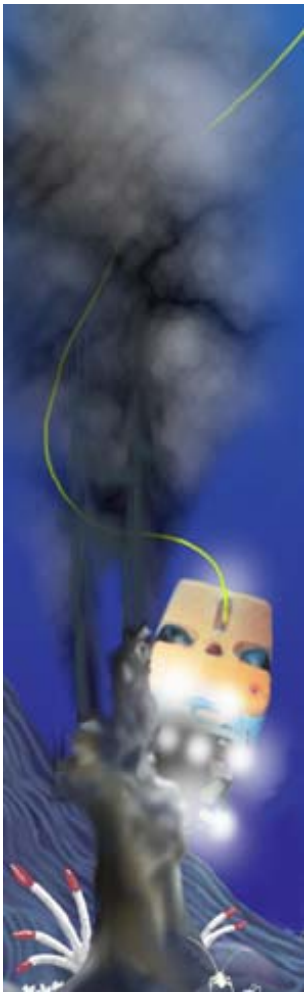
The Dive and Discover Web site also has information on vent biology (http://www.divediscover.whoi.edu/vents/biology.html).

The Lau vent snail, *Ifremeria nautilei*

Data Collection

Investigating remote areas such as the vent environment is expensive and requires careful planning and coordination between scientists, submersible crew members, and ship crew. Because of the vents' inaccessibility, seafloor scientists are only able to visit their study sites once year or so. With such limited time, scientists must work quickly and efficiently to learn as much about the vent environment as possible. One very useful tool, particularly for biologists studying living organisms, is photography. Photographic images allow the scientist to capture 2D snapshots or 'samples' of the animals living around a vent, and quantify the number of organisms in particular areas (roughly since you can't really see how many are piled on top of each other), as well as study their distribution (i.e., where are the animals found, what other animals are present, how many can inhabit an area). By piecing individual images together into a mosaic, scientists can also get a landscape view of the area. Finally, combining photomosaics with other data, such as temperature measurements at specific locations, can greatly enhance our understanding of where vent organisms live and why.

The dataset for this activity consists of two parts: (1) a series of high-resolution, overlapping photographs that you will use to generate a mini-mosaic of a large section of the seafloor (see accompanying Seafloor-Mini-Mosaic.pdf); (2) a set of temperature measurements (see table below) made within the mosaicked area. These data are part of a much larger dataset collected by Dr. Chuck Fisher and colleagues as part of their study of the ecology of vent animals.



The high-resolution photographs that you will use to create a mosaic were taken with a high-definition camera attached to the remotely operated vehicle (ROV) JASON II. The images were taken in a vent field named "ABE" over a section of seafloor venting warm (5-30˚C), chemical-rich fluid. This type of venting is called "diffuse flow" rather than the "focused flow" characteristic of black smoker chimneys. With a camera mounted on the ROV and pointing straight downward, the scientist takes pictures at regular intervals as the JASON pilot maneuvers the ROV three meters above the seafloor. Keep in mind that the seafloor is not entirely flat so keeping the ROV at precisely three meters above seafloor is not an easy task.

The ROV is tethered to the ship with a fiber optic cable. Seafloor images are uploaded to the ship's computer instantly. Shortly after a section of seafloor is imaged, a mosaic of the section is constructed onboard allowing the scientists to see the animal distributions on the seafloor and to determine where to focus their studies. The ROV is then returned to that section and the scientist uses a specialized temperature probe attached to the ROV to record temperature measurements at specific locations within the mosaicked space. Note: the vent environment is extremely variable and temperatures can fluctuate substantially in a very short period of time or vary within a short distance. Temperatures are recorded for 1 minute at each location. Maximum and minimum temperatures are recorded however you will use maximum temperature for this activity.

Deep-sea biologists collect seafloor images and temperature measurements because they want to understand if temperature is an important variable in determining where animals live. Here is a subset of their data– what patterns can you identify?

Question 1 – Making Observations – What IS that?

a. Look closely at the mini-mosaic and try to identify the 3 dominant types of aggregated organisms: mussels and 2 different types of snail. Describe these 3 organisms (e.g., what color are they? how big are they? do they have any distinguishing characteristics?)

b. Focusing on these three species, make a few observations about their distribution (e.g., how many are there of each species? where are they located? are they randomly distributed? how are the animals distributed in relation to one another?)

c. What other organisms can you find? Where are these located? What is different about these animals?

d. How could we find out more about each of the organisms?

Question 2 – Plotting temperature measurements and looking for patterns

Temperature measurements were taken at 23 locations in this area and are listed in the table below. The table also includes notes about what was found at each location. Using a mylar overlay, or marking directly on the mini-mosaic, record the temperature readings on the image where the temperature was taken. For example, mark 6.5˚C over the number “1” on the image.

a. Using these temperature measurements, which area appears to be the warmest? Describe what is living there.

b. Which area appears to be the coldest? Describe what is living there.

c. What general patterns can you identify with respect to the mussels and two species of snails?

Number on Mosaic	Max. Temp. (ºC)	Measurement taken on:
1	6.5	bare rock
2	6.5	*I. nautilei* & mussels
3	5.0	bare rock
4	7.5	*I. nautilei*
5	5.0	*I. nautilei* & mussels
6	7.0	*I. nautilei*
7	5.0	bare rock
8	5.0	mussels
9	4.0	bare rock
10	27.0	*I. nautilei* & *A. hessleri*
11	12.5	*A. hessleri*
12	9.0	*I. nautilei*
13	9.5	mussels
14	8.0	*I. nautilei* & mussels
15	22.5	*A. hessleri*
16	14.0	*A. hessleri*
17	6.0	*I. nautilei*
18	6.0	mussels
19	10.0	bare rock
20	6.0	*I. nautilei*
21	6.5	bare rock
22	14.0	*A. hessleri*
23	35.0	*A. hessleri*

Question 3 – Thinking critically – Formulating an hypothesis

a. Given the patterns you described, hypothesize why the animals are distributed the way they are. What are possible reasons for these patterns?

b. How would you test your hypothesis?

c. Do you think any of these 3 animals are ecosystem engineers?