Lophelia II 2010:
Cold Seeps and Deep Reefs

Life on the Hardbottom

Image captions/credits on Page 2.

lesson plan

Focus
Hardbottom biotopes in the Gulf of Mexico

Grade Level
5-6 (Life Science)

Focus Question
What are biotopes and how can they be studied from photographs?

Learning Objectives
- Students will define and contrast the terms “biotope,” “habitat,” and “ecosystem.”
- Students will describe “hardgrounds.”
- Students will describe three major biotopes associated with hardgrounds in the Gulf of Mexico.
- Students will give examples of at least three species associated with each biotope.

Materials
- Copies of *Hardbottom Biotopes Inquiry Guide* (see Learning Procedure, Step 1b)
- Pencils and rulers for drawing grid lines, one for each student group

Audio-Visual Materials
- (Optional) Video projection or other equipment to show images (see Learning Procedure Steps 1a, 1c, 1e, and 4)

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
Biotope
Habitat
Ecosystem
Hardground
Photomosaic

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.

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

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 will assess possible impacts from the blowout is to compare photographic surveys that were done before the blowout in some areas, with follow-up surveys after the blowout. In this lesson, students will analyze diagrams based on a photographic survey of Viosca Knoll in the Gulf of Mexico, about 60 km from the Deepwater Horizon wellhead.

Learning Procedure

1. To prepare for this lesson:
   a) 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.
   b) Review procedures on the *Hardbottom Biotopes Inquiry Guide*. Decide how many diagrams you want each student group to analyze, and make the appropriate number of copies of the student version (without grid lines) for each group. This is largely a matter of how much time is available for student analyses.
   c) Download an image of a photomosaic from http://oceanexplorer.noaa.gov/explorations/09lophelia/logs/hires/madrepora_mosaic_hires.jpg.
   d) Review the essays on The Ecology of Gulf of Mexico Deep-sea Hardground Communities (http://oceanexplorer.noaa.gov/explorations/06mexico/background/hardgrounds/hardgrounds.html) and Photomosaics (http://oceanexplorer.noaa.gov/explorations/09lophelia/logs/aug30/aug30.html), and decide whether to want to provide one or both of these to students as a reading assignment.
   e) You may also want to download PDF files containing images from the Viosca Knoll survey 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 D contains images of many of the organisms found in the survey, and Master Appendix E contains images of the biotopes that the survey identified.

2. Introduce the *Lophelia* II 2010: Cold Seeps and Deep Reefs Expedition, and describe, in general terms, cold-seep and deepwater coral communities. If desired, show images from the Web pages

referenced in Step 1. 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.

3. 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 1c, 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 when scientists analyze and compare photomosaics, they often use some type of grid that is placed on top of the photograph. Then, they identify each animal that touches an intersection on the grid.

4. Tell students that their assignment is to analyze diagrams that are based on a photographic survey of Viosca Knoll in the Gulf of Mexico. You may want to show Figure 1, which includes the location of Viosca Knoll (sites beginning with VK) as well as the approximate location of the Deepwater Horizon wellhead. You may also want to show an image of the *Johnson Sea Link* submersible that was used

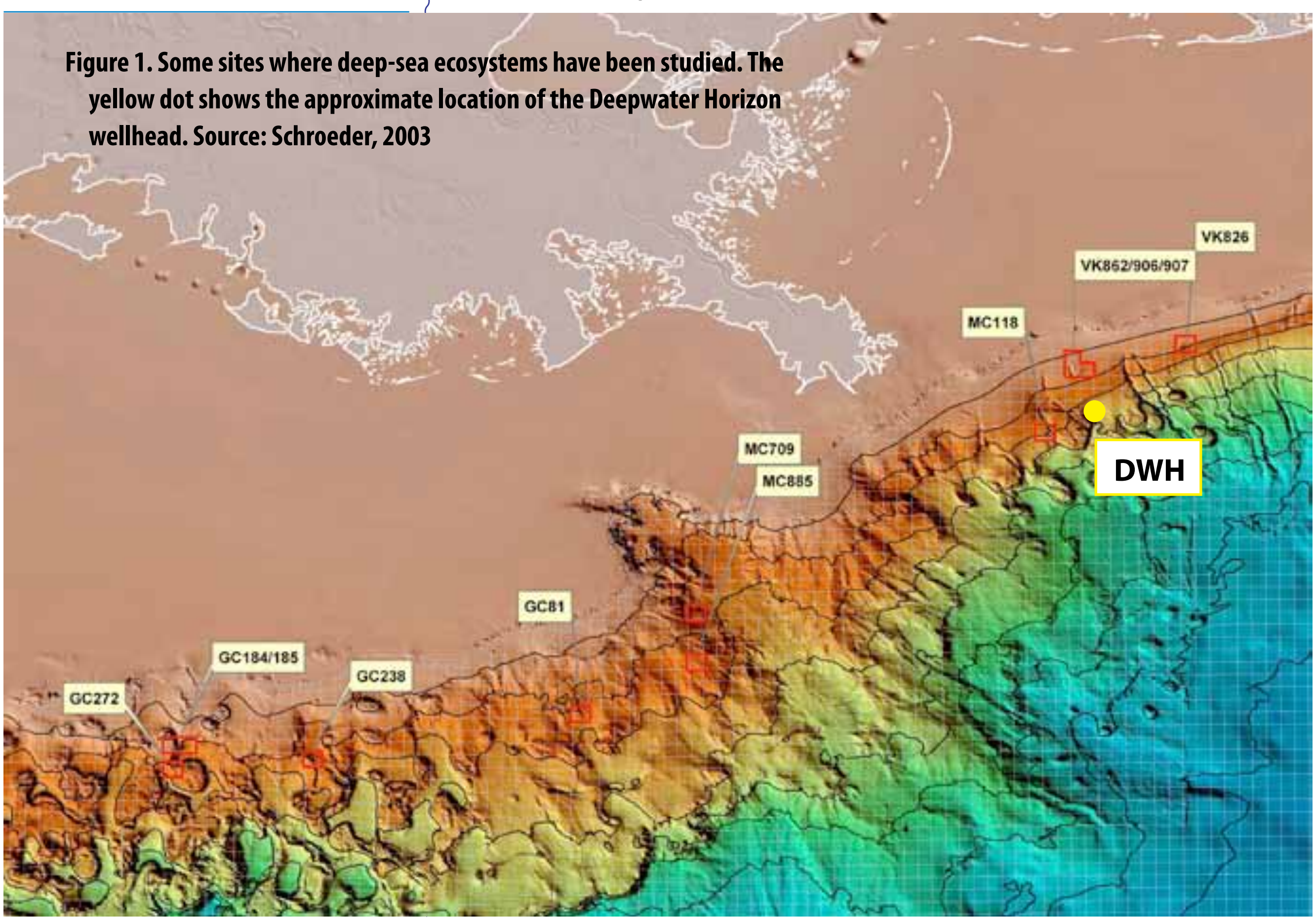


Figure 1. Some sites where deep-sea ecosystems have been studied. The yellow dot shows the approximate location of the Deepwater Horizon wellhead. Source: Schroeder, 2003

to obtain these photographs [http://oceanexplorer.noaa.gov/explorations/03edge/logs/aug22/media/sub_600.jpg]

Provide each student group with one or more of the photomosaic diagrams, and assign one or more of the organisms in the *Inquiry Guide* table to each group. Be sure students understand that they should draw LIGHT lines across the diagrams to create their grids. Provide each student group with a copy of the *Hardbottom Biotopes Inquiry Guide*, one or more of the photomosaic diagrams, and assign one or more of the organisms in Table 1 to each group.

5. Lead a discussion of students' results. You may want to show images of organisms in the *Inquiry Guide* using Master Appendix D from Sulak *et al.* (2008) as these are discussed. Table 2 provides specific plate references for the organisms listed. Table 3 shows the intersection count for organisms in each diagram. The *Educator's Version* of the photomosaic diagrams show the grids on which Table 2 is based.

Table 2
Plates from Master Appendix D (Sulak *et al.*, 2008) Illustrating Some Organisms Identified from Hardbottom Biotopes on Viosca Knoll

Organism	Code	Plate
Brown Lophelia Coral	BLC	no photo
White Lophelia Coral	WLC	1A
Bamboo Coral	BAM	3C
Red Black Coral	RBC	2C
White Black Coral	WBC	2D
Black Cerianthid	BCYR	7C
Pink Cerianthid	PCYR	7A
Venus Fly Trap Anemone	VFT	6D
White Anemone	WA	6C
Glass Sponge	GS	9C
Squat Lobster	SL	22A, 23C, 24B
Crinoid	CRI	16C
Bacterial Mat	BAC	11C, 12A
Unknown Alcyonarian	UAL	4A

Table 3
Number of Intersections for Organisms Shown in Photomosaic Diagrams 1 through 6

Organism	Number of Intersections					
	Diagram 1	Diagram 2	Diagram 3	Diagram 4	Diagram 5	Diagram 6
BLC	-	4	-	-	4	-
WLC	3	5	1	3	5	1
BAM	5	-	1	5	-	1
RBC	-	1	-	-	1	-
WBC	4	-	-	4	-	-
BCYR	-	-	4	-	-	4
PCYR	-	-	1	-	-	1
VFT	2	-	-	2	-	-
WA	6	-	2	6	-	2
GS	1	-	-	1	-	-
SL	-	2	-	-	2	-
CRI	-	1	-	-	1	-
BAC	-	-	3	-	-	3
UAL	-	3	-	-	3	-

The following points should be included:

- An **ecosystem** is the combination of living organisms and non-living features that interact in a single location.
- A **habitat** is an area where similar organisms live. Numerous habitats may exist in a single ecosystem.
- A **biotope** is an area that is uniform in terms of living organisms and non-living features.
- **Hardgrounds** are rocky bottom areas usually composed of limestone rock.
- Hardgrounds are usually found in association with cold seeps because limestone rocks are formed as a by-product of the breakdown of oil and gas by microbes.
- Brown *Lophelia* coral, white *Lophelia* coral, bamboo coral, red and white black corals, cerianthids, anemones, and the unknown Alcyonarian all belong to the phylum Cnidaria. All are carnivores, and feed on small plankton or larger organisms (including fishes) depending upon the size of the animal's mouth. Cnidarians are eaten by some fishes and a variety of invertebrates that includes

echinoderms, molluscs, and crustaceans. All live attached to hard surfaces, but many anemones are able to detach themselves and move to different locations.

- Glass sponges belong to the phylum Porifera. These animals consume small bacteria and plankton that they filter from the surrounding water. Their tissues contain glass-like structural particles that, together with various chemicals, provide defense against many predators. Some starfish, however, are known to feed on glass sponges. Glass sponges live attached to hard surfaces.

- Squat lobsters belong to the phylum Arthropoda. They are generally believed to be scavengers, but the 2003 Ocean Explorer Life on the Edge Expedition observed squat lobsters perched on top of *Lophelia* coral catching fish from the water column (http://oceanexplorer.noaa.gov/explorations/03edge/background/invertebrates/invertebrates.html). Most squat lobster predators are fishes. Squat lobsters move freely over bottom surfaces, and often are found hiding beneath ledges or other bottom structures.

- Crinoids belong to the phylum Echinodermata. They feed on floating particles that they catch with their feather-like arms. Predators include fishes, starfish, and crabs. Most crinoids are free-swimming but some are permanently attached to hard surfaces. Free-swimming crinoids may attach themselves temporarily to hard surfaces.

- Bacteria are a highly diverse group of organisms, and are usually considered to be a kingdom of their own. Some scientists think that the diversity of bacteria is so large that there should be many bacterial kingdoms. The bacterial mats often seen in the vicinity of cold seeps frequently belong to the genus *Beggiatoa*. This genus is classified in a variety of ways, and phylum names include Proteobacteria and Cyanobacteria. *Beggiatoa* oxidize sulfur to obtain energy, and require a supply of reduced sulfur such as hydrogen sulfide. They may provide an important food source for bottom-grazing animals. For more information, see http://oceanexplorer.noaa.gov/explorations/06mexico/background/microbiology/microbiology.html.

- Point out that none of these organisms are plants or herbivores. Be sure students realize that primary producers for food webs that include these species may be chemosynthetic organisms (such as *Beggiatoa*), but that many of these species may also receive food brought by currents from other ecosystems including photosynthetic systems in shallower water.

- Comparing Photomosaic Diagrams 1 through 6, students should identify three distinct biotopes represented by Diagrams 1 and 4, 2 and 5, and 3 and 6, respectively. These correspond to the Rock, Thicket, and Open biotopes pictured in Master Appendix E, plates 3, 4, and 6, respectively, which you may want to show to your students. You may also wish to point out that the study identified two other biotopes named Plate and Plate/Chemo, which are shown in Master Appendix E, Plates 1 and 2, respectively.

The BRIDGE Connection

www.vims.edu/bridge/ - Type "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 in which they discuss why scientists should or should not study deep-sea ecosystems in the Gulf of Mexico for possible impacts from the Deepwater Horizon blowout.

Connections to Other Subjects

Social Studies, English/Language Arts, Fine Arts

Assessment

Students' answers to inquiry guide questions and class discussions provide 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

Entering the Twilight Zone
(from the Expedition to the Deep Slope 2007)
http://oceanexplorer.noaa.gov/explorations/07mexico/background/edu/media/zone.pdf

Focus: Deep-sea habitats (Life Science)

Students will describe major features of cold-seep communities, list at least five organisms typical of these communities and infer probable trophic relationships within and between major deep-sea habitats. Students will also be able to describe the process of chemosynthesis in general terms, contrast chemosynthesis and photosynthesis, and describe major deep-sea habitats and list at least three organisms typical of each habitat.

Animals of the Fire Ice
(from the Expedition to the Deep Slope 2007)
http://oceanexplorer.noaa.gov/explorations/07mexico/background/edu/media/animals.pdf

Focus: Methane hydrate ice worms and hydrate shrimp (Life Science)

Students will define and describe methane hydrate ice worms and hydrate shrimp, infer how methane hydrate ice worms and hydrate shrimp obtain their food, and infer how methane hydrate ice worms and hydrate shrimp may interact with other species in the biological communities of which they are part.

Deep Gardens
(from the Cayman Islands Twilight Zone 2007 Expedition)
http://oceanexplorer.noaa.gov/explorations/07twilightzone/background/edu/media/deepgardens.pdf

Focus: Comparison of deep-sea and shallow-water tropical coral communities (Life Science)

Students will compare and contrast deep-sea coral communities with their shallow-water counterparts, describe three types of coral associated with deep-sea coral communities, and explain three benefits associated with deep-sea coral communities. Students will explain why many scientists are concerned about the future of deep-sea coral communities.

Let's Make a Tubeworm!
(from the 2002 Gulf of Mexico Expedition)
http://oceanexplorer.noaa.gov/explorations/02mexico/background/edu/media/gom_tube_gr56.pdf

Focus: Symbiotic relationships in cold-seep communities (Life Science)

Students will describe the process of chemosynthesis in general terms, contrast chemosynthesis and photosynthesis, describe major features of cold seep communities, and list at least five organisms typical of these communities. Students will also be able to define symbiosis, describe two examples of symbiosis in cold seep communities, describe the anatomy of vestimentiferans, and explain how these organisms obtain their food.

Chemists with No Backbones
(from the 2003 Deep Sea Medicines Expedition)
http://oceanexplorer.noaa.gov/explorations/03bio/background/edu/media/meds_chemnobackbones.pdf

Focus: Benthic invertebrates that produce pharmacologically-active substances (Life Science)

Students will identify at least three groups of benthic invertebrates that are known to produce pharmacologically-active compounds and will describe why pharmacologically-active compounds derived from benthic invertebrates may be important in treating human diseases. Students will also be able to infer why sessile marine invertebrates appear to be promising sources of new drugs.

Keep Away
(from the 2006 Expedition to the Deep Slope)
http://oceanexplorer.noaa.gov/explorations/06mexico/background/edu/gom_06_keepaway.pdf

Focus: Effects of pollution on diversity in benthic communities (Life Science)

In this activity, students will discuss the meaning of biological diversity and compare and contrast the concepts of variety and relative abundance as they relate to biological diversity. Given information on the number of individuals, number of species, and biological diversity at a series of sites, students will make inferences about the possible effects of oil drilling operations on benthic communities.

What's In That Cake?
(from the 2006 Expedition to the Deep Slope)
http://oceanexplorer.noaa.gov/explorations/06mexico/background/edu/gom_06_cake.pdf

Focus: Exploration of deep-sea habitats (Life Science)

Students will explain what a habitat is, describe at least three functions or benefits that habitats provide, and describe some habitats that are typical of the Gulf of Mexico. Students will also be able to describe and discuss at least three difficulties involved in studying deep-sea habitats and describe and explain at least three techniques scientists use to sample habitats, such as those found on the Gulf of Mexico.

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*

Schroeder, W. 2003. NOAA Office of Ocean Exploration: Quick Look Report project number OE_2003_011: The occurrence and ecology of deep-water corals and associated communities; http://docs.lib.noaa.gov/OEDV/GOM_Deep_habitats_2003/docs/Schroeder/QLReport_Lophelia.doc

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.piersystem.com/go/site/2931/ – Main Unified Command Deepwater Horizon response site

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

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

- Populations and ecosystems
- Diversity and adaptations of organisms

Content Standard E: Science and Technology

- Understandings about science and technology

Content Standard F: Science in Personal and Social Perspectives

- Populations, resources, and environments
- Risks and benefits
- Science and technology in society

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 2.
The ocean and life in the ocean shape the features of the Earth.
Fundamental Concept a. Many earth materials and geochemical cycles originate in the ocean. Many of the sedimentary rocks now exposed on land were formed in the ocean. Ocean life laid down the vast volume of siliceous and carbonate rocks.

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 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 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 a. The ocean affects every human life. It supplies freshwater (most rain comes from the ocean) and nearly all Earth's oxygen. It moderates the Earth's climate, influences our weather, and affects human health.
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

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

Acknowledgements

This lesson was developed by Mel Goodwin, PhD, Marine Biologist and Science Writer. Design/layout by Coastal Images Graphic Design, Mt. Pleasant, SC. If reproducing this lesson, please cite NOAA as the source, and provide the following URL: http://oceanexplorer.noaa.gov/

Hardbottom Biotopes Inquiry Guide

Part A – Background Research

1. Define the following terms:

   Ecosystem:

   Habitat:

   Biotope:

2. What are hardgrounds?

3. Why are hardgrounds usually associated with cold seeps?

4. The following table is a list of some of the animals that live in hardbottom biotopes in the Gulf of Mexico. Your teacher will assign one or more of these animals for you to research. For each of your assigned animals, answer the following questions:
   a. What phylum does the animal belong to?

   ____

   b. What does the animal eat?

   ____

   ____

   c. What eats the animal?

   ____

   ____

   d. Where does the animal live?

   ____

   ____

   Note: Most of these animals have not been well-studied. If you have trouble finding out exactly what your animal eats and what eats your animal, it's acceptable to make inferences about your animal based on what you learn about similar animals.

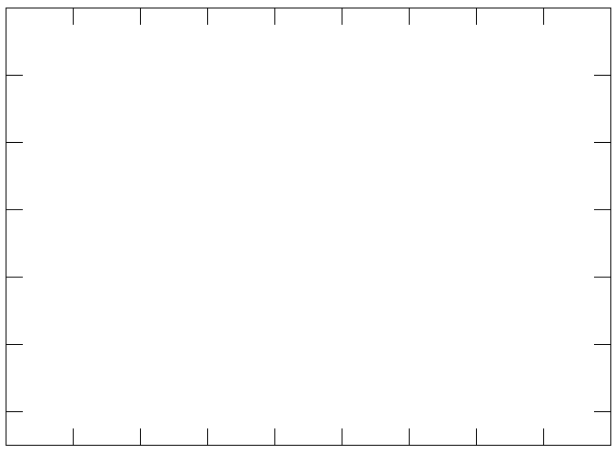
Table 1.
Some Organisms Identified from Hardbottom Biotopes on Viosca Knoll

Organism	Code
Brown Lophelia Coral	BLC
White Lophelia Coral	WLC
Bamboo Coral	BAM
Red Black Coral	RBC
White Black Coral	WBC
Black Cerianthid	BCYR
Pink Cerianthid	PCYR
Venus Fly Trap Anemone	VFT
White Anemone	WA
Glass Sponge	GS
Squat Lobster	SL
Crinoid	CRI
Bacterial Mat	BAC
Unknown Alcyonarian	UAL

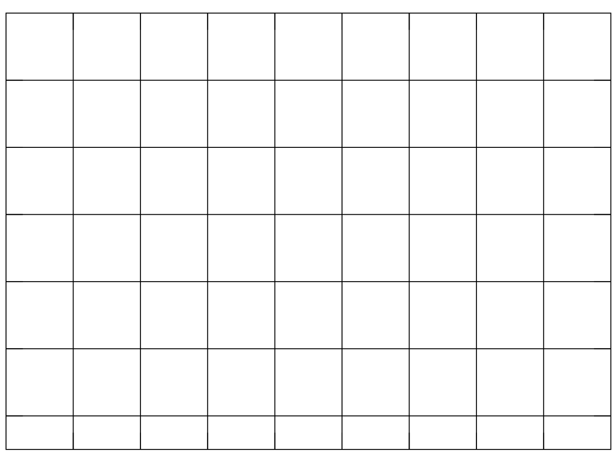
Part B – Analyze and Interpret

Your teacher has given you one or more diagrams that illustrate some the animals seen in a series of six photomosaics of biotopes on Viosca Knoll in the Gulf of Mexico. A photomosaic is a series of overlapping photographs that are connected to form one continuous image or landscape view of an area. Your assignment is to analyze these diagrams to find out how many different biotopes can be identified.

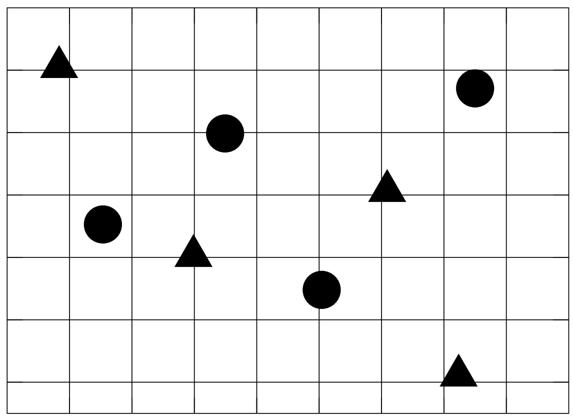
1. Notice that each diagram has short lines at the top, bottom, left and right:



2. Make a grid by using a ruler to lightly draw thin lines to connect the short lines on opposite sides, so that the diagram now looks like this:



3. To analyze your diagrams, you will count how many animals of each type are touching an intersection on the grid where a horizontal line crosses a vertical line (if the box with the code letters touches an intersection, it is the same as if the animal drawing touches the intersection). Do not count animals that are between the lines, or that only touch a horizontal line or only touch a vertical line. For example in the drawing below, only the triangles would be counted:



4. Count how many animals of each type are touching an intersection on the grid where a horizontal line crosses a vertical line. Record the code for each animal, and how many are touching an intersection on the grid in the data chart.

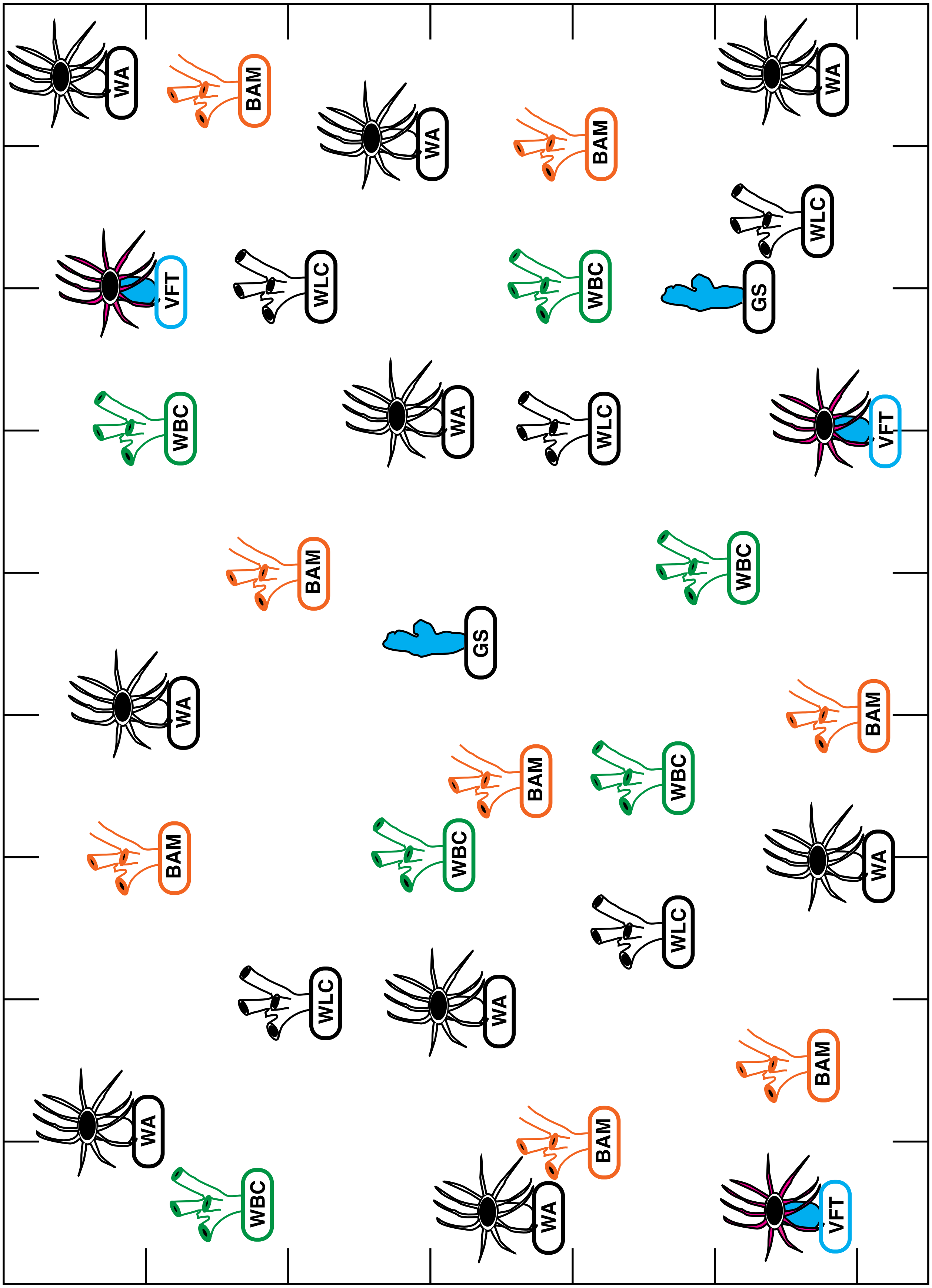
5. If you only have been given one diagram to analyze, follow your teacher's instructions for combining data from your analysis with data from other groups.

   If you have analyzed more than one diagram, compare the information from each diagram summarized in your data chart. Do you think these diagrams represent different biotopes?

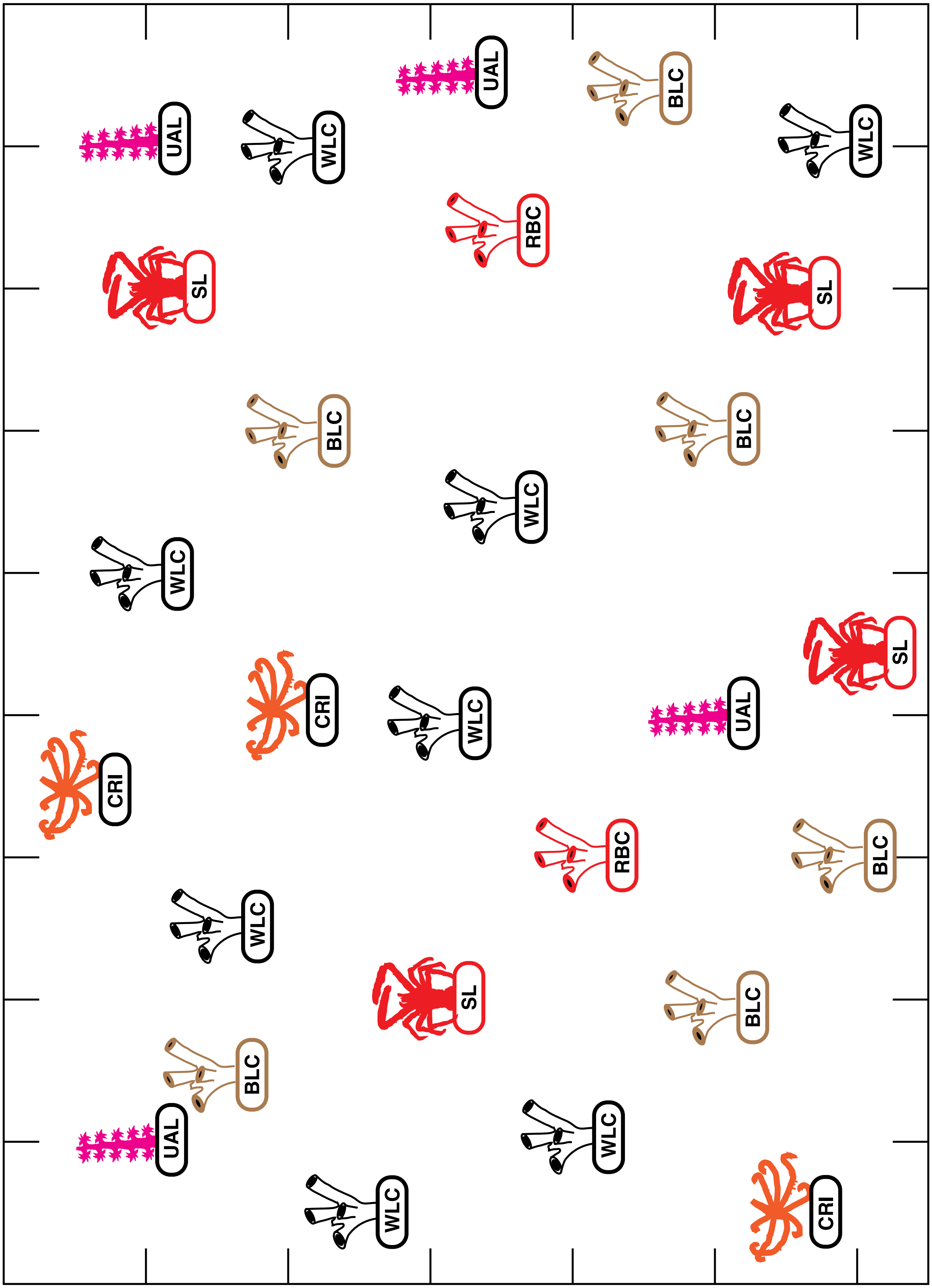
Data Chart

Photomosaic Diagram Number	Animal Code	Number of Intersections

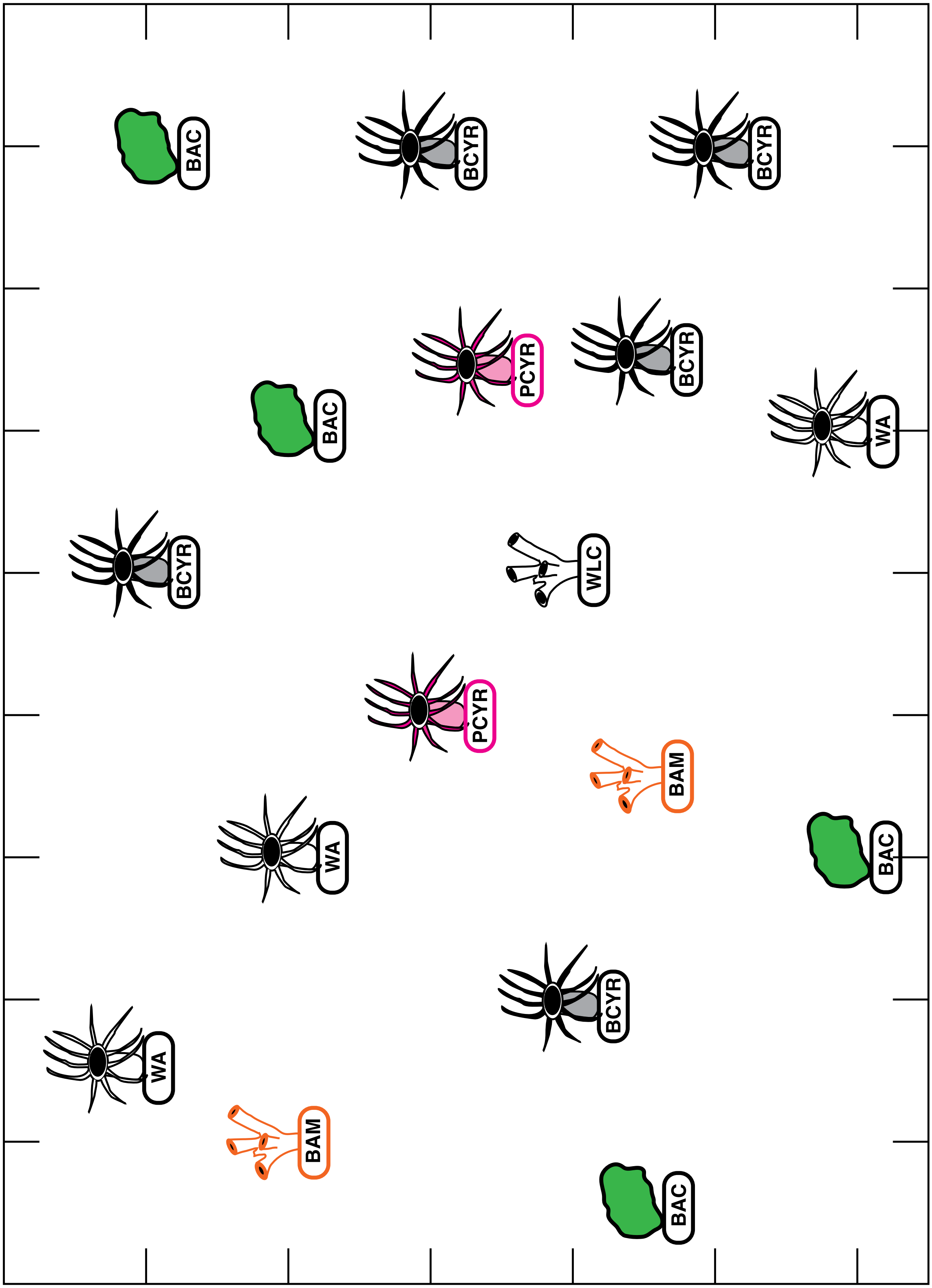
Photomosaic Diagram 1



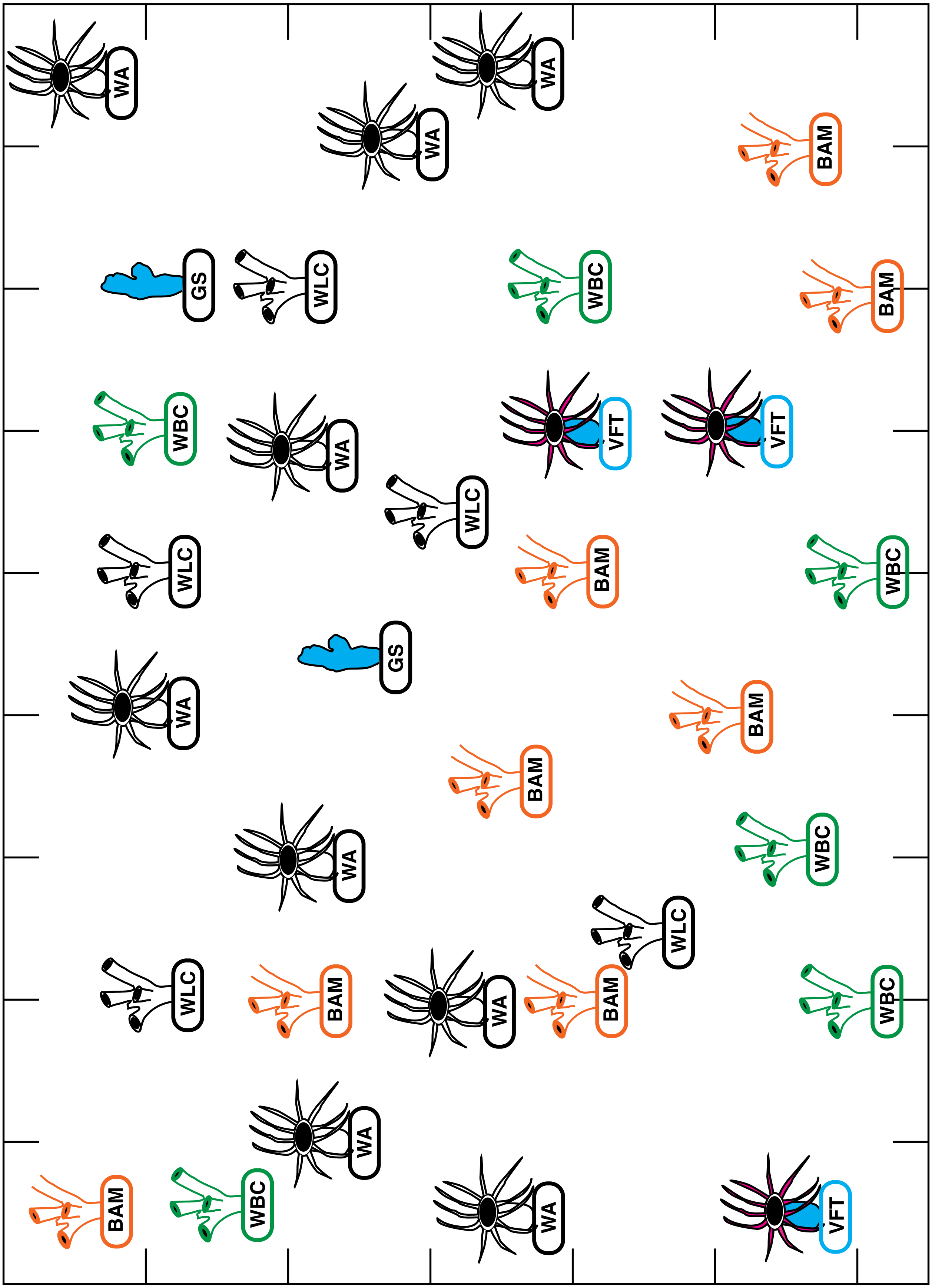
Photomosaic Diagram 2



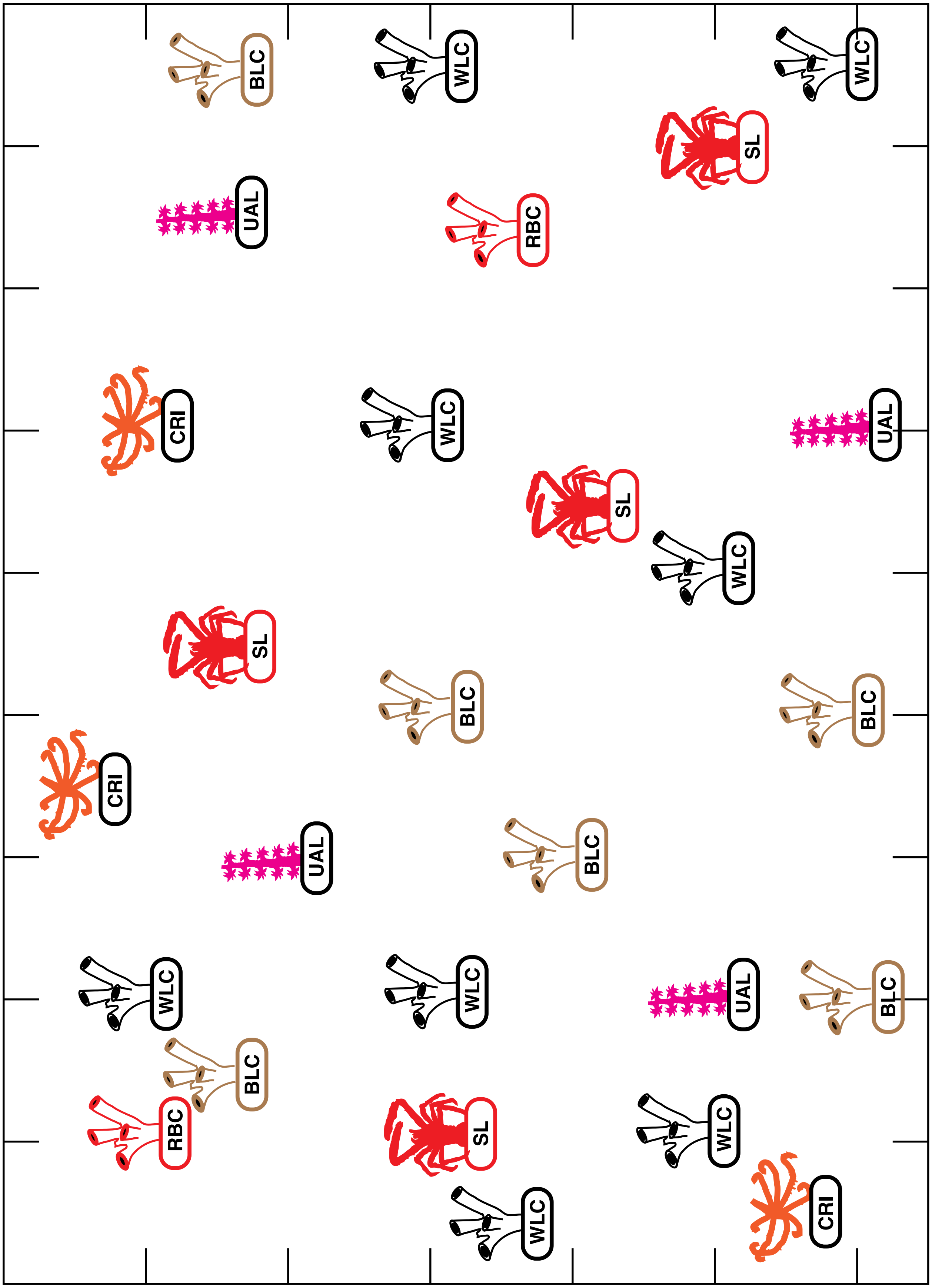
Photomosaic Diagram 3



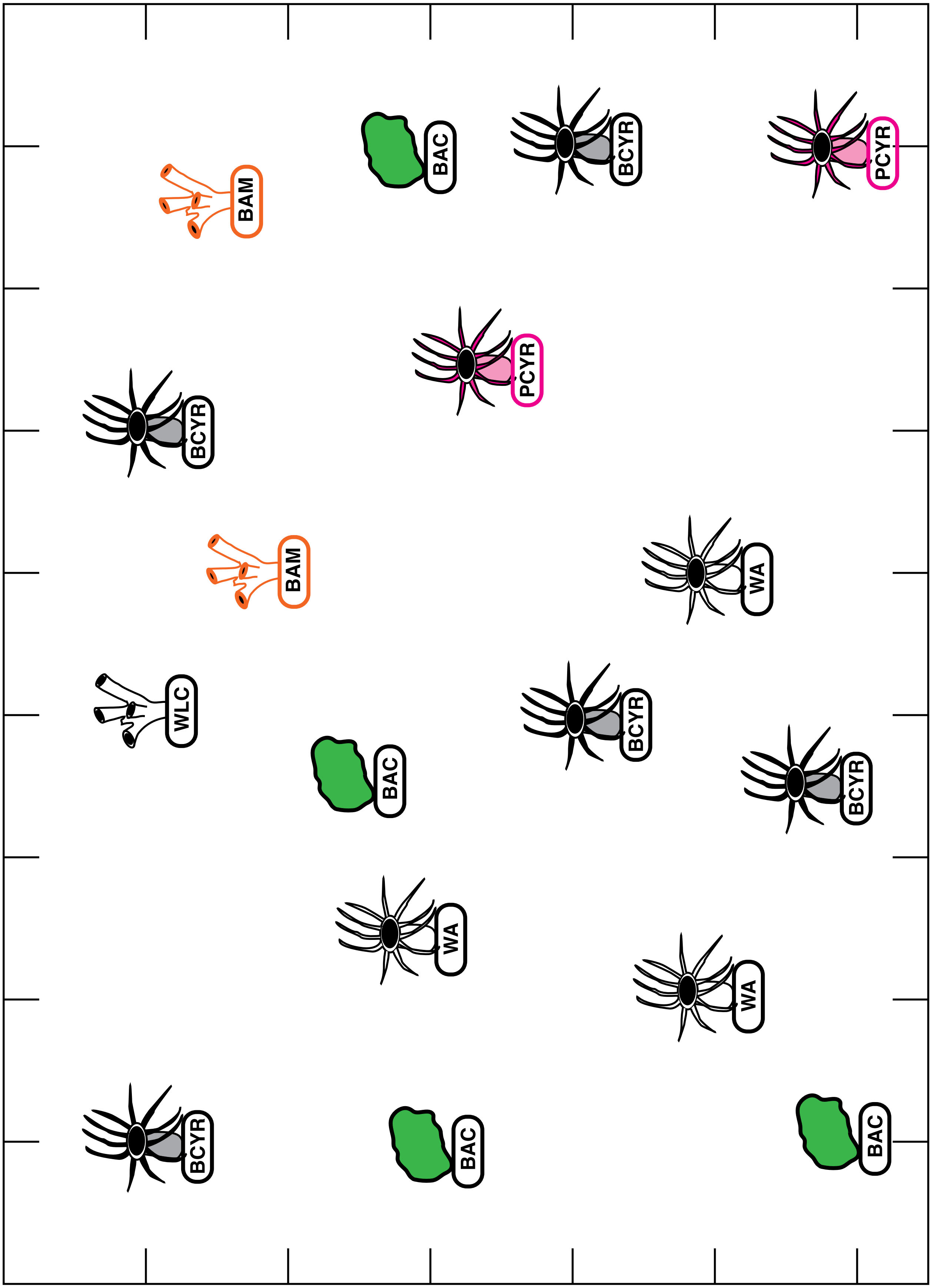
Photomosaic Diagram 4



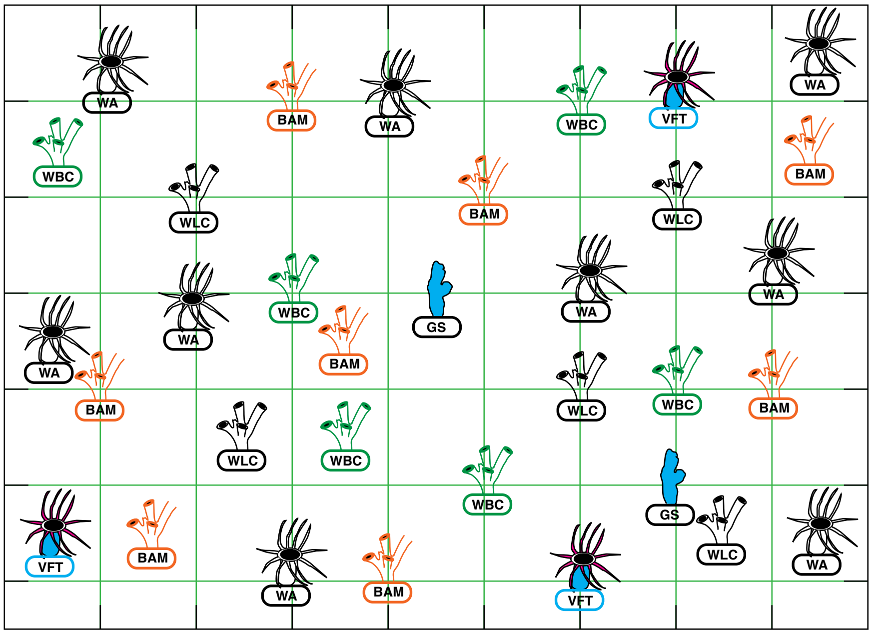
Photomosaic Diagram 5



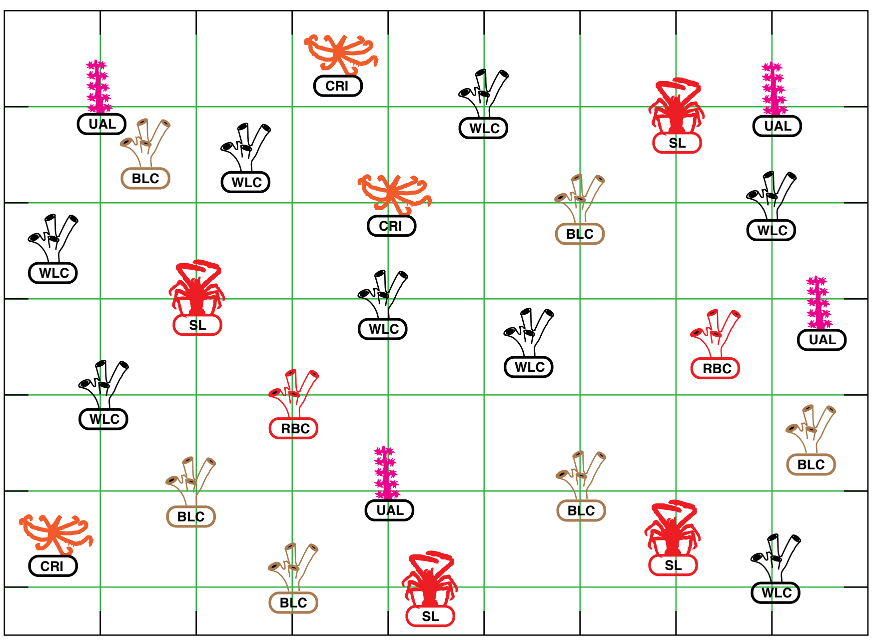
Photomosaic Diagram 6



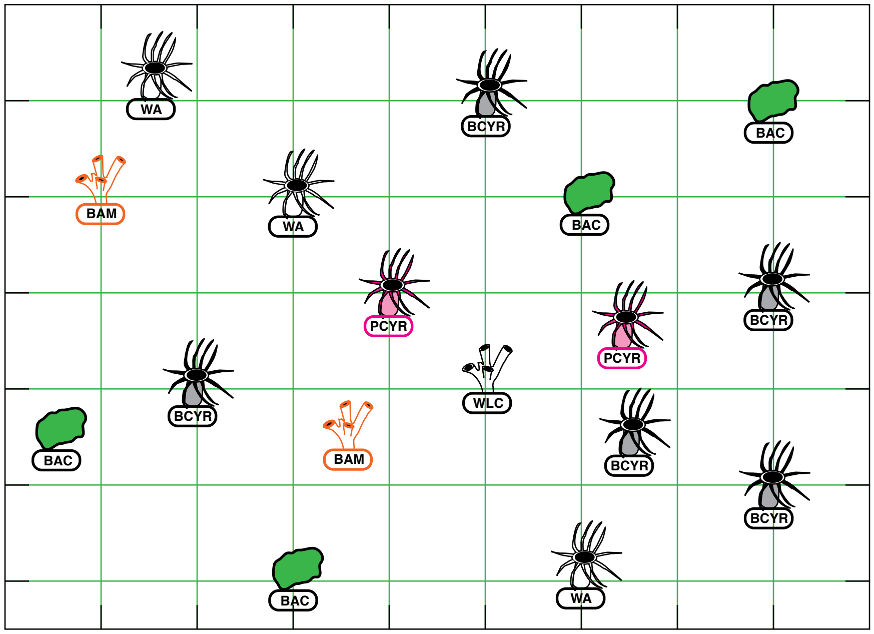
Photomosaic Diagram 1
Educator's Version



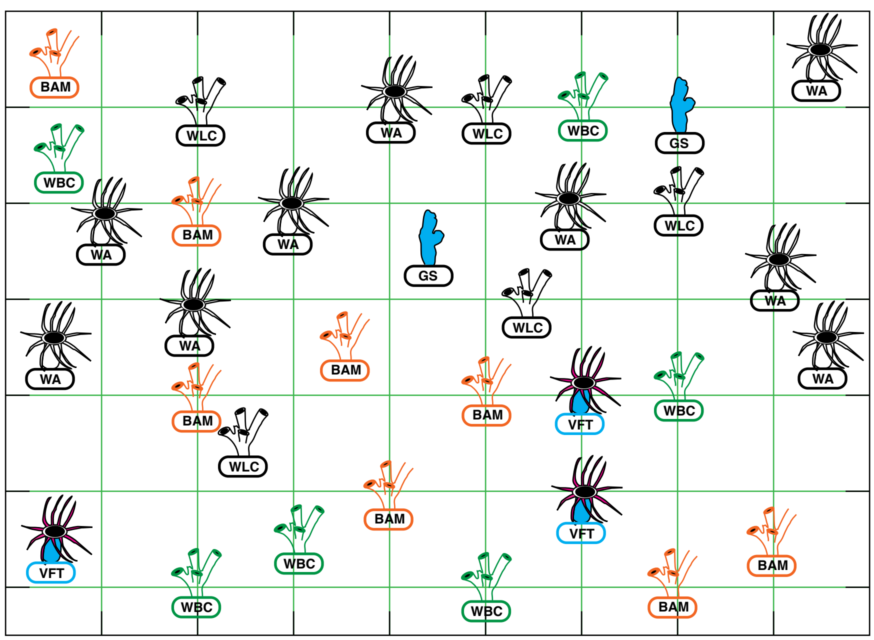
Photomosaic Diagram 2
Educator's Version



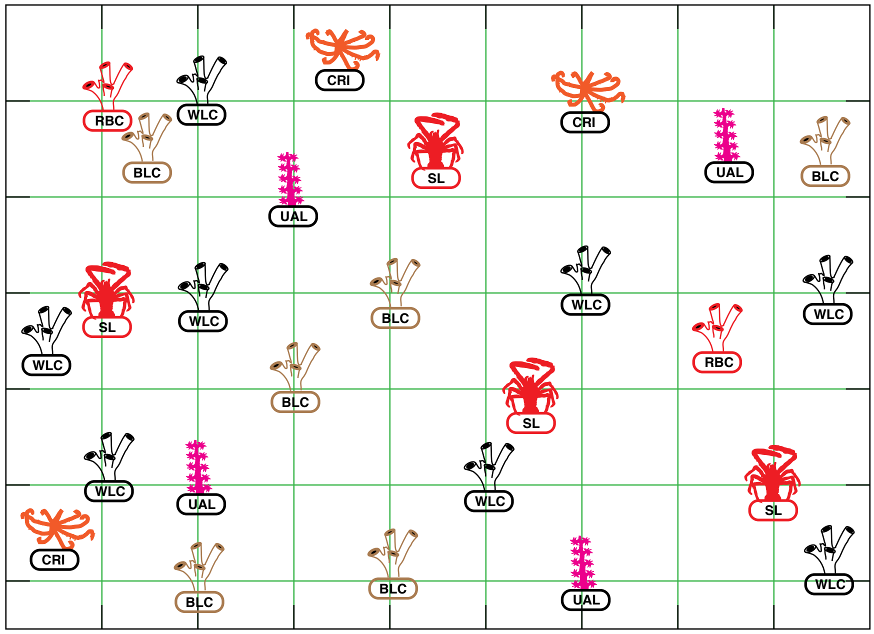
Photomosaic Diagram 3
Educator's Version



Photomosaic Diagram 4
Educator's Version



Photomosaic Diagram 5
Educator's Version



Photomosaic Diagram 6
Educator's Version