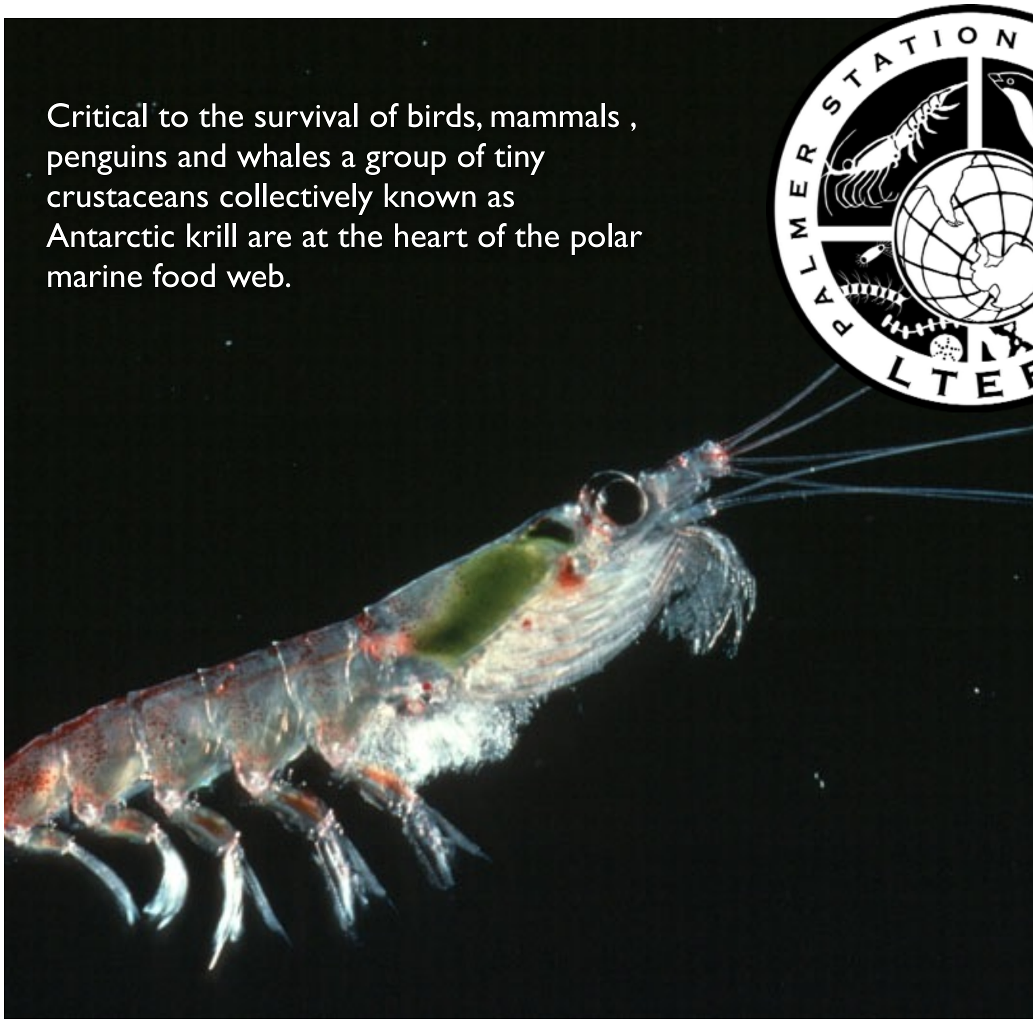
Investigating behavior of krill



Antarctica harbors one of the most extreme yet productive ecosystems on Earth.

The Antarctic marine ecosystem supports vast populations of penguins, seals, albatross, petrels, whales and fish that flourish in its cold waters. These and dozens of other organisms are sustained by a keystone species called Antarctic krill (*Euphausia superba*). Euphausiids are abundant and encompass over 25% of zooplankton biomass in the world's oceans. They are shrimp-like crustaceans that play a critical role in the polar marine food web acting as both grazers and prey (Quetin el al 2007).

The developmental life cycle for krill involves hatching from a free-floating egg up through larval and juvenile stages which include a series of molts (casting off their external skeleton). This outer skeleton remains soft so the individual can increase in size, grow new segments and gradually add appendages. Throughout most of their life Antarctic krill occur in the upper 250 m of the ocean, swimming horizontally within densely packed schools which some say may serve as a defense mechanism. Krill will leave the safety of the school to molt, mate, release eggs and forage on patches of algae under sea ice.

Adult Antarctic krill grow approximately 2.5 inches long, making them the largest of the 85 known krill species. The Antarctic krill can live for an average of 7 years or more with a recognizable shape that consists of an elongated head-trunk region. A muscular segmented tail (abdomen) and 5 pairs of paddle-like swimming legs form its main body. The head has thirteen modified limbs gathered together to form a feeding basket which functions to collect their food which consists of phytoplankton (diatoms and dinoflagellates).

Palmer Long Tern Ecological Research

2014

Palmer station LTER was established in 1990 by the National Science Foundation Office of Polar Programs (OPP) as the first polar biome and Long Term Ecological Research (LTER) site in the Southern Hemisphere. The objective of this program is to understand the ecosystem's natural seasonal changes from nearshore habitats including the continental shelf to offshore open ocean.

Behavior of Antarctic Krill

Krill make an abrupt transition after the last larval molt from living a planktonic lifestyle into a highly social juvenile and then as an adult into highly organized schools (Hamner, 2000). The behavior of krill can be connected to a combination of biological factors such as increased feeding opportunities or increased reproductive success. Although, the advantages of certain behaviors must outweigh the associated costs of being eaten. At the mercy of their physical environment, krill are **planktonic,** transported by tides or ocean currents and this lifestyle also contributes to certain behaviors (Hoffmann and Murphy 2004).

To study krill, scientists use a variety of collection mechanisms from sampling nets to scuba diving. Krill schools can also be surveyed using **acoustic eco sounders** which are particularly helpful in the Antarctic due to the patchy distribution of krill (Bernard et. al. 2012).

The Antarctic austral summer (November - March), provides longer daylight hours when sea ice melts quickly, and it is easier to document year-to-year changes in the distribution of krill. Scientists most commonly measure krill growth, distribution, **abundance** and **recruitment** (the successful passage of a 'year class' of krill into their second year of growth). Typically a good krill recruitment year is correlated with an early, seasonal release of eggs during the Antarctic summer (Loeb et al. 1997). The success and growth of a population of krill depends greatly on the success of the class from the previous season.

Another important aspect in understanding krill is knowing their life cycle which is heavily dependent on two important factors; the duration and extent of the sea ice cover and the amount of food available in a given area. Scientists from the Palmer Long Term Ecological (LTER) research program have been studying the region along the Western Antarctic Peninsula (WAP) since 1990 documenting ecosystem changes and identifying the strategies that krill use to survive the harsh conditions.

The western Antarctic Peninsula region is experiencing the world's most rapid regional warming with winter atmosphere temperatures increasing by ~1 degree C per decade over the last 60 years (Vaughan et. al., 2003). The area is changing from a dry polar marine climate regime into one that is sub-polar-warmer and moister, with more precipitation. This warming causes declines in sea ice extent and duration (Stammerjohn 2008a) and the sea ice loss in turn causes changes in the ecosystem. Since krill are particularly sensitive to environmental change and tightly linked to sea ice, scientists are studying how these environmental changes are impacting krill populations and their **biological responses** (behaviors) as well as the impacts throughout the marine food web.

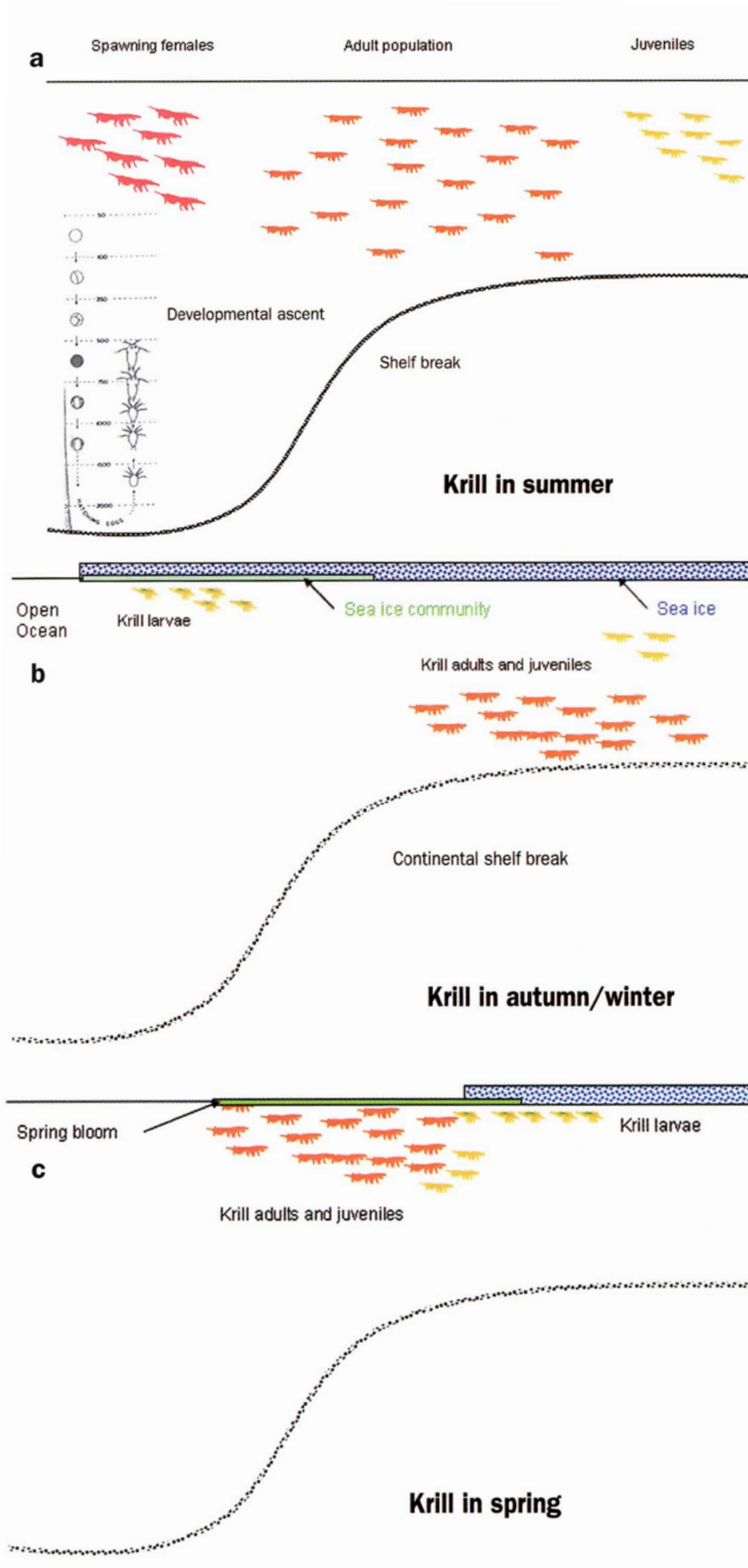


Figure 1: Simplified seasonal representation of the vertical and horizontal distribution of krill from offshore(left) to onshore (right): (a) summer, (b) autumn-winter, and (c) spring. © BioScience (2006) Vol. 56 No. 2 pg.17 (permission granted for educational use).

LESSON

Investigating Krill Behavior: Reactions To Physical Stimuli?

Any organism must respond to changes in its environment in order to get food, avoid predators, and successfully breed and survive. In this exercise, students simulate aspects of the Antarctic ecosystem and see how simple life forms respond. Although brine shrimp are different from krill, students will draw inferences about Antarctic krill behavioral responses in a changing environment.

Grade Levels: 6 - 9 (ages 12 - 15)

Time: 1 - 2, 50 minute lab periods

Ocean Literacy Principles:

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

5d. Ocean biology provides many unique examples of life cycles, adaptations and important relationships among organisms…

5f. Ocean habitats are defined by environmental factors…

5h. Tides, waves and predation cause vertical zonation patterns along the shore, influencing the distribution and diversity of organisms.

Climate Literacy Principles:

Life on Earth depends on, is shaped by and affects climate.

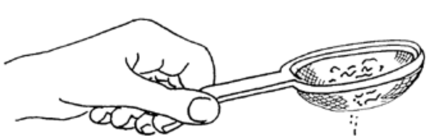
3a. Climate's role in habitats ranges and adaptation of species of climate changes.

Objectives: Students conduct controlled experiments using brine shrimp...

✓ to draw inferences about Antarctic krill behavioral responses in a changing environment.
✓ to generate discussions on the life history of Antarctic krill in the Southern ocean.
✓ to understand the impacts of climate change in a rapidly changing region along the Antarctic peninsula.

Materials:

✓ bar magnets
✓ Live large brine shrimp (*Artemia*) in *Ball* glass jar
✓ ice cubes (in plastic ziplock bags)
✓ light source
✓ small plastic cup with tight fitting lid
✓ tall / transparent beaker or glass
✓ microscope/hand lens
✓ small fine sieve/strainer
✓ ziplock plastic sandwich bags
✓ aluminum foil
✓ stop watch/timer



Procedure:

Effect of Light

1. Fill two small plastic cups with lids 3/4 full of water and collect a few brine shrimp using a sieve..
2. Wrap aluminum foil around <u>one</u> cup to prevent light from entering. Leave 5mm (a small window) at the top free of foil for viewing purposes.
3. Hold or prop up both cups with side nearest a light bulb for at least ten minutes (set timer). Try to keep the cups stationary. Observe the brine shrimp in each cup. (Be careful not to let the cups get hot). Record your observations below and replace the brine shrimp into designated container.

____

____

____

SCIENTIFIC CLASSIFICATION

Kingdom: Animalia

Phylum: Arthropoda

Subphylum: Crustacea

Class: Malacostraca

Order: Euphausiacea

Family: Euphausiidae

Genus: *Euphausia*

Species: *superba*

Type: Zooplankton, crustacean

Habitat: Southern Ocean, along continental shelf break and slope

Diet: Phytoplankton and microzooplankton

Lifespan: 5 - 7 years

Size: Adult length 1.3 - 2.5 inches (33 - 65 mm)

Breed: in their second and third year, releasing eggs during the Antarctic summer.

Eggs: Female krill can lay up to 3,600 eggs in a single spawning (December - March). Eggs laid at the surface, embryos sink, then hatch, & larvae swim upward.

Known Predators: Crabeater seals *(Lobodon carcinophagus*), Fish, Blue whale (*Balaenoptera musculus*),

Humpback whale (*Megaptera novaeangliae*), Penguins, *Pygoscelis adeliae, Pygoscelis antarctica, and*

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Investigating Krill Behavior: Reactions To Physical Stimuli?

Procedure Continued:

Effect of Temperature

4. Fill two small plastic cups with lids with a few brine shrimp.
5. Set one cup on a large ice bag/block of ice and prop the other on your lab table for at least 5 minutes. Set timer. What response do you observe? Record your answer then pour the brine shrimp back into the designated container. Response:____

Effect of Currents

6. Fill two small cups with a few brine shrimp. (Note: make sure you have tight fitting lids)
7. Leave one cup on the table top for at least 5 minutes and observe the swimming behavior of the shrimp without disturbing the water. With the other cup, turn it by a 1/4 turn clockwise every three seconds. Observe and record the swimming behavior of the brine shrimp. Then write your answer below. Replace the shrimp back into the designated container.

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Habitat / Distribution Patterns

8. Fill a tall beaker / glass with several , at least ten (10) brine shrimp.
9. Set the beaker on a steady surface and lay the other cup on the table top for five minutes. Do you observe a preference in brine shrimp movement or distribution? Do they swim near the top? Do they move vertically , horizontally? Record your answer then replace the brine shrimp back into the designated container.

____

____

____

Further Connections: Answer the following questions on the back of this sheet.

a. Which stimuli appeared to have the greatest effect on the behavior of your brine shrimp?

b. From your reading, list some environmental factors that influence krill?

c. Describe how your observations on brine shrimp may be applied to the movements/habits and behaviors of krill in the Southern Ocean near the Western Antarctic Peninsula?

d. Describe how climate is changing along the Western Antarctic Peninsula.

e. How are krill affected by climate change near Palmer Station?

VOCABULARY

abundance: the number of a particular organism within a specific area.

biomass: total mass of a living species in a specific area.

biological response: living response

bioacoustic transects: detection of krill and other schooling organisms like small fish by echoes from a sound source on a ship (echosounder).

chlorophyll: green pigment found in plants.

diatom: type of single celled algae.

dinoflagellate: a large group of unicellualr protists found in marine environments.

distribution: geographic or depth range of a particular species.

echosounder: scientific device using sound to find the depth of water or schools of fish.

larval stage: juvenile form of an animal that often looks different from the adult.

molt: cast off their outside skeleton to enable growth in size

phytoplankton: diatoms, dinoflagellates

recruitment: successful survival of a year class of krill and passage from their first to second year.

zoooplankton: freely drifting marine

Teacher Notes:

✓**This exercise and the extended challenge provide opportunities to generate discussions on the life history of Antarctic krill in the Southern ocean based on the observations students make using brine shrimp**. Brine shrimp are being used as a proxy given the lack of availability of Antarctic krill.

✓If time allows, and/or students have never worked with brine shrimp before it may be helpful to have students make some initial observations on the organism using a dissecting microscope or a magnifying glass prior to running experiments.

✓If time is a factor, this lesson can be jigsawed where groups of two or three students are assigned one specific variable to observe and document Then, the results are shared in a class discussion format.

✓The extended challenge can be expanded to include groups of students observing the commuting behaviors of brine shrimp in response to environmental factors like schooling, light and dark (day versus night), sea ice, or predation to reinforce experimental design skills.

✓ Live brine shrimp may be purchased from http://www.brineshrimpdirect.com/ or from a local pet store. Growing your own as a class project adds another creative dimension to the investigation. Typically store bought brine shrimp are larger and easier for students to observe under these conditions.

✓ If brine shrimp are purchased, it is recommended to have each class of students draw shrimp from a fresh new batch throughout the day, placing used shrimp in a separate container. Otherwise the results become less obvious.

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Teachers Making Broader Connections to Antarctic krill

1. Effect of Light on brine shrimp / Antarctic krill

Seasonal changes in Antarctica contribute to changing light conditions. Due to the Earth's tilt and orbit around the sun, the poles receive less light and heat from the sun. In summer at the poles, the sun does not set, and in winter the sun does not rise. Organisms like krill living in Antarctica must deal with these seasonal shifts in light and challenging conditions. The community of microorganisms growing on the underside of the ice (phytoplankton) seeds the surface waters with algae in spring when the sea ice retreats and the days are filled with more light. As summer approaches and sea ice cover is reduced, the water column becomes more stratified (mixed) due to light availability which in turn promotes diatom blooms (Smith el al., 2008). The large blooms of algae provide higher grazing opportunities by larger organisms like krill near the surface.

2. Effect of Temperature on brine shrimp / Antarctic krill

The extreme seasonal changes in Antarctica require krill to use a variety of strategies to survive. Observing krill in laboratory situations is often very difficult although one study has demonstrated that the rate at which krill molt seems to be directly proportional to temperatures (between 0° and 5°C) in *E. superba* (Poleck et. Al. 1982). Since molting is necessary for growth it may be that increased temperature might correlate with a faster growth rate but more studies have to be conducted.

3. Effect of Currents on brine shrimp /Antarctic krill

Along most of the Antarctic coastline, the ocean currents are complicated. The adult krill are distributed near the continental shelf break where currents are especially complex. Whereas juveniles can be found near inshore waters, krill eggs and larvae are found in offshore waters. Some observations suggest that smaller scale circulation patterns like gyres or eddies on the shelf and slope influence krill vertical and horizontal migration patterns. Students should understand that since the life history of krill includes stages of development, their distribution patterns are a direct product of multiple factors that take into account vertical migration, water currents, and sea ice extent and is not just a product of currents alone.

4. Habitat / Distribution patterns / Antarctic krill

The distribution and abundance of krill can be explained by the interaction between the animal's evolved life cycle and it's physical environment. The developmental life cycle for krill involves hatching from a free-floating egg up through larval and juvenile stages which include a series of molts (casting off their external skeleton). Throughout most of their life Antarctic krill occur in the upper 250 m of the ocean, swimming horizontally within densely packed schools which some say may serve as a defense mechanism. Krill will leave the safety of the school to molt, mate, release eggs and forage on patches of algae under sea ice. Sea ice communities are essential for larval krill in winter, and their movement is linked to that of the ice.

Further Connections:

a. **Which stimuli appeared to have the greatest effect on the behavior of your brine shrimp?** A variety of answers may exist here for students.

b. **From your reading, list some environmental factors that influence krill?** Tides, currents, daylight hours, sea ice, concentrations of algae, atmosphere temperature, sea water temperature, precipitation.

c. **How might your observations be applied to the movements,habits and behaviors of krill in the Southern Ocean near the Western Antarctic Peninsula?** Processes underlying krill distribution, growth and abundance in the Antarctic are not totally understood and vary with season and from year to year. Scientists are still investigating if what they are documenting is a part of krill's natural life cycle or a response to changing conditions.

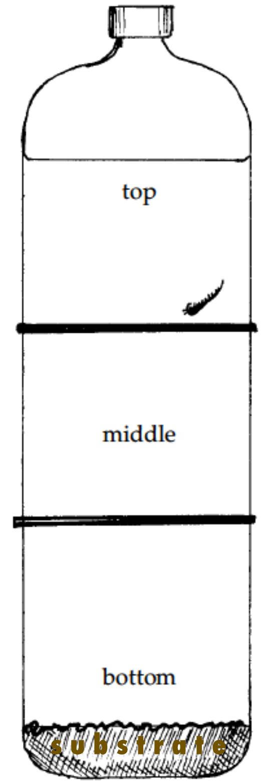
d. **Describe how climate is changing along the Western Antarctic Peninsula.** The western Antarctic Peninsula region is experiencing the world's most rapid regional warming with winter atmosphere temperatures increasing by ~1 degree C per decade over the last 60 years (Vaughan et. al., 2003). The area is changing from a dry polar marine climate regime into one that is sub-polar-warmer and moister, with more precipitation. This warming causes declines in sea ice extent and duration(Stammerjohn 2008a) and the sea ice loss in turn causes changes in the ecosystem.

e. **How are krill affected by climate change near Palmer Station?** The behavior of krill is intimately connected to climate change since they are at the mercy of their physical environment. Their behavioral response is related to the rapid regional warming of winter atmosphere temperatures along the western Antarctic peninsula. The ecosystem is changing from a dry polar marine climate regime into one that is sub-polar-warmer and moister, with more precipitation. This warming causes declines in sea ice extent and duration (Stammerjohn 2008a) and krill are particularly sensitive to sea ice for their feeding opportunities and reproductive success.These conditions impact their recruitment year after year. Climate change is affecting krill populations and their biological responses (behaviors) and many of the impacts can be documented throughout the marine food web.

Extended Challenge: Are Brine Shrimp Vertical Commuters?

(Adapted from Brine Shrimp Ecology by Michael Dockery and Stephen Tomkins, British Ecological Society)
Reference: Nicol, Stephen (2006) Krill, Currents and Sea Ice: *Euphausia superba and its Changing Environment.* BioScience Vol. 56 (2) 111- 120.

Review : Krill make abrupt transitions after the last larval molt from living a planktonic lifestyle into a highly social juvenile and then again as an adult into highly organized school (Hamner, 2000). The behavior of krill can be connected to this life history however the advantages of certain behaviors must outweigh the associated costs during these migrations. Brine shrimp are being used as a proxy in this exercise given the lack of availability of Antarctic krill so students can simulate these phenomenon.



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Ocean Literacy Principles:

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

5d. Ocean biology provides many unique examples of life cycles, adaptations and important relationships among organisms…

Climate Literacy Principles:

Life on Earth depends on, is shaped by and affects climate.

3a. Climate's role in habitats ranges and adaptation of species of climate changes.

Objectives: Students conduct controlled experiments using brine shrimp...

Do brine shrimp commute vertically in a container?
What would be a suitable hypothesis to test in this experiment?

Materials:

rubber elastic bands
clear plastic bottle
small-50ml beaker
brine shrimp (*Artemia)*
ruler
sharpie pen
stop watch / timer

Optional Materials:

mineral substrate = sand + crushed limestone or sea-shells
Note: This challenge could also be set up as an additional experiment where students have several variations of this set up and compare their findings.

Experimental Design:

1. Start by filling a clear bottle about three-quarters full with water and then add two spoonfuls 2 - 3 cm of substrate to the bottom of your bottle. You may already have it made from the main tank. Leave this to settle for a few minutes.

2. **Propose a hypothesis:**____

3. **Set up:** Take a small beaker and put some water from the main jar into it, about one third full. Then with the teat pipette, sieve or spoon, collect an adult male, an adult female and a young shrimp from the tank and put them carefully into the small beaker. (Note: if you have difficulty identifying the gender of your shrimp due to their size (see student data sheet), you may just choose three different size shrimp.

4. While the shrimp are acclimating use a ruler to measure the vertical height from the surface of the bottom substrate to the top of the water column. Divide this height into three sections and label the bottle with a sharpie pen. Put elastic bands around the bottle to show the three sections. Make sure the elastic bands are horizontal and level.

5. **Gather Evidence:** Put one adult female in the bottle and give her five minutes to get used to her new surroundings. Then, using the stop watch, record which zone of water she is in every 10 seconds for a period of ten minutes and how many times she changes zones in those ten minutes. This will mean that you will have 60 pieces of information for this animal.

6. Repeat step four (5) with a male shrimp and then with a very young shrimp, about one half the length of the adults.

7. **Results:** Consider the best way to share your results (compound graph, bar graph, line graph). Also, approximate the total time that each organism spent in each of the three sections of the bottle. Is there a difference between the three shrimps?

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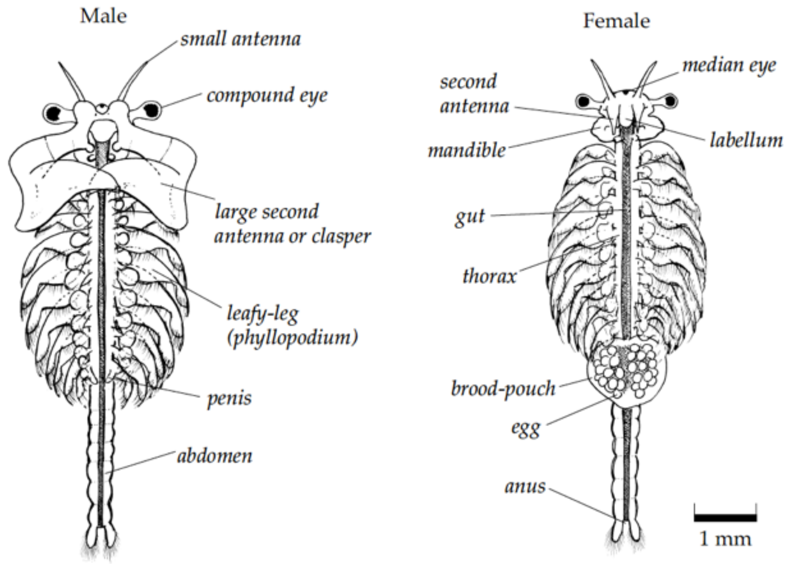
STUDENT DATA SHEET



Know your brine shrimp anatomy
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Position in the Water Column

Shrimp	Top Zone	Middle Zone	Bottom Zone	Changed zones
#1. Brine Shrimp (Female)				
#2. Brine Shrimp (Male)				
#3. Brine Shrimp (Young)				

Connections:

1. Did you have to make any changes to the experimental design? Explain.
2. Were you able to distinguish between male, female and larval brine shrimp in your experiment? If you used three shrimp similar in size and gender, then explain the commuting pattern that you observed. Then, consider how it might have been different using the different genders based on your background reading on page 2.
3. Correlate how your brine shrimp behaved in your water column to krill living in a challenging environment like Antarctica. Remember that even though krill appear to be planktonic (freely floating), their life cycle and their physical environment play a critical role.
4. Explain how you might test the commuting pattern of your shrimp over a twenty four hour period. What would you hypothesize might happen at night or in the dark?
5. Choose two environmental challenges in Antarctica and explain how they influence a biological response by krill. (Environmental: changing light conditions, ocean circulation patterns, sea ice extent, water column / Biological Response: reproduction, feeding, development, and survival).

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