U.S. Department of Commerce
National Oceanic & Atmospheric Administration
National Marine Fisheries Service

Lesson 21: Marine Ecosystems

Overview

This lesson provides a primer on marine ecosystems. The lecture describes the different ocean zones and some common organisms that live in each zone. In the activity, students analyze abundance data for Chesapeake Bay blue crabs. They apply their knowledge of ecosystem interactions to hypothesize what trends in blue crab abundance might indicate about the Bay as an ecosystem.

Lesson Objectives

Students will:

1. Identify vertical and horizontal ocean zones
2. Define an ecosystem, biotic and abiotic factors
3. Explain how changes in the abundance of a single species can have impacts throughout an ecosystem

Lesson Contents

1. Teaching Lesson 15
    a. Introduction
    b. Lecture Notes
    c. Additional Resources
2. Teacher's Edition: State of the Bay
3. Student Activity: State of the Bay
4. Student Handout
5. Mock Bowl Quiz

Standards Addressed

National Science Education Standards, Grades 9-12
Life science
Science in personal and social perspectives

Ocean Literacy Principles
The ocean supports a great diversity of life and ecosystems

DCPS, High School
Environmental Science
E.2.1 Understand and explain that human beings are part of Earth's ecosystems, and that human activities can, deliberately or inadvertently, alter ecosystems
E.6.7 Collect, record, and interpret data from physical, chemical, and biological sources to evaluate the health of the Chesapeake Bay watershed and wetlands, and describe how the Bay supports a wide variety of plant and animal life that interact with other living and nonliving things

Lesson Outline[1]

I. Introduction

Your students probably have some ideas about what constitutes an ecosystem. Begin the class by asking students to define ecosystems and their components. Guide students to think about an ecosystem as a community of different species interacting with one another and their surroundings in a physically distinct space. You may want to ask students the following questions to provoke discussion:

1. Does an ecosystem have to be a certain size?
There is no specific size that defines an ecosystem. Ecosystems can range in size from a small puddle to the entire ocean.

2. What are some ways in which organisms in an ecosystem interact?
Some examples include predator-prey relationships, parasitic interactions and mutually beneficial (symbiotic) interactions.

3. Are ecosystems themselves completely isolated or can they be connected to one another?
In many cases, ecosystems are connected by a common resource (e.g., a river flowing through a forest into the ocean) or by common species.

After a brief discussion of ecosystems, ask for a few volunteers to come to the front of the room. Each volunteer represents some aspect of an ecosystem. Ask the rest of the students in the class to choose two abiotic (nonliving) factors of an ecosystem (e.g., temperature, sun, oxygen, carbon dioxide) and four biotic (living) factors (e.g., different types of plants, animals or bacteria).

Hand a ball of yarn to one key abiotic factor. Have the student then toss the ball to any of the other factors that it interacts with – for example the student representing a plant may toss the yarn to the sun or to an herbivore. Have that student hold on to a piece of the yarn. While still holding on, toss the ball to another interacting factor and so forth. Students may toss the ball back to the same factor or to a new factor. After every student has had at least one chance, point out to the class how tightly the ecosystem is held together by each interaction. To demonstrate what happens when there is a disturbance in one aspect of the ecosystem, have one factor give a tug on his or her string. Notice how this tug rebounds throughout the ecosystem.

[1] Unless otherwise indicated, all websites provided or referenced in this guide were last accessed in November 2010.

II. Lecture Notes

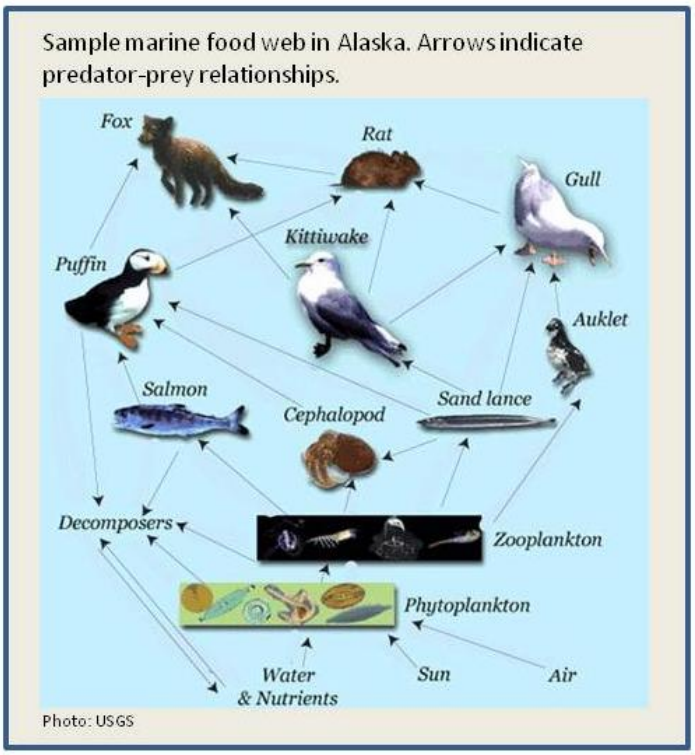
Use the PowerPoint for Lesson 21 (File: Lesson 21 – Marine Ecosystems.ppt) to present the following information. Distribute the Student Handout before you begin for students to take notes on key information.

Pelagic and benthic zones (slide 5)

1. A simple ocean zone designation is between the open water (pelagic zone) and the ocean floor (benthic zone).

2. Organisms that can actively swim independent of currents in pelagic environments are referred to as nekton, while those that live on the ocean floor are referred to as benthos.

3. Plankton are different from nekton: plankton are "drifters" that passively float at the surface or have weak swimming ability, while nekton are those organisms that can actively swim through the water column.



Energy is transferred through ecosystems (slide 10)

1. Primary producers are those that convert solar or chemical energy into energy that is usable (carbohydrates) by most members of an ecosystem.

2. Energy is transferred to different levels of the food web (sometimes referred to as trophic levels) as organisms consume each other. Primary consumers eat primary producers and secondary consumers eat primary consumers[2].

Important interactions (slide 12)

1. All the life within an ecosystem is connected. It is effective to manage natural resources with this in mind. Ecosystem-based management (EBM) is one such approach to natural resource management.

2. NOAA applies EBM in its fisheries management.

[2] Photo: http://alaska.usgs.gov/science/biology/seabirds_foragefish/marinehabitat/index.php

III. Additional Resources

1. Background
   http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/O/Oceans.html
   http://www.nhptv.org/natureworks/nwep6c.htm

2. Estuary activities and resources
   http://estuaries.gov/estuaries101/Teachers/Default.aspx?ID=79

The State of the Bay

Overview
This activity provides students with real blue crab abundance data from the Chesapeake Bay. First, students research the blue crab and its food web connections to the greater ecosystem. A link is provided to help the students research the crab: http://archive.chesapeakebay.net/fish1.htm. If possible, it is best for the students to use the link for their research because the website links to other useful information. If this is not possible, a separate file is include in the lesson 21 folder with information about the crab (File:Blue Crab Information Sheet.pdf). Second, students graph the data and make inferences about the health of the Bay based on the status of blue crab populations. Note that the data and information in this activity are from 2008; more current information and new understanding about the crab populations may now be available.

Background
The Chesapeake Bay is a very important ecosystem on a local and national level. It provides habitat to plant and animal species like oysters, crabs, seagrasses and fish. It provides recreational opportunities for residents and visitors. It is also a vital part of our economy: millions of pounds of seafood are caught here including blue crabs.

As you may know, there has been growing concern over the state of the Chesapeake Bay ecosystem. Runoff from farms, roads and water treatment plants contains nutrients like nitrogen and phosphorus, which lead to algal blooms and low-oxygen conditions as excess algae decay. In 2009, President Obama issued an Executive Order to protect and restore the Chesapeake Bay. As top NOAA scientists, you have been asked to serve on an advisory board to the President regarding the Chesapeake Bay. You won't have time to conduct a detailed analysis on every aspect of this complex ecosystem. The panel's response has been requested within a short time period.

Answer Key
Part I

1. Are adult blue crabs classified as benthic or pelagic organisms? Why?
   Adult crabs are benthic organisms, which means they primarily live on the ocean floor.

2. Are blue crab larvae classified as benthic or pelagic organisms? Why?
   Blue crab larvae are free-floating planktonic organisms that drift through the water. Organisms that drift through the water column are classified as pelagic.

3. Crabs live in the coastal intertidal zone. What is a broad name for the zone that includes the intertidal, sub-littoral and super-littoral zones?
   Neritic zone.

4. What types of food sources do blue crabs rely upon?
   They feed on bivalves, crustaceans, fish, annelids (including marine worms), plants, detritus and nearly anything else they can find, including dead fish and plants.

5. Some fish, including striped bass, eat some of the same types of food as the blue crab. These fish are often found in the well-lit layer of the ocean around 200m deep and above. What is this zone called?
   Epipelagic.

6. Aside from some species of fish, which other marine organisms eat similar food as the blue crab?
   Sea stars and other filter feeders eat bivalves; shrimp also eat marine worms, detritus and crustaceans; immature fish like the striped bass feed on small crustaceans and other fish.

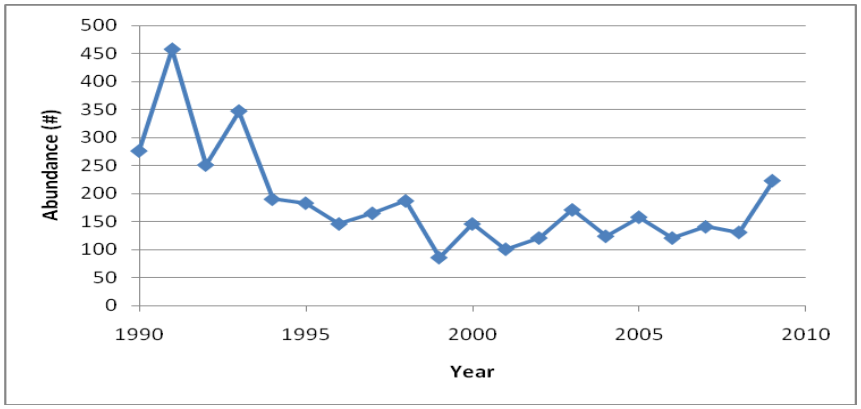
7. If blue crabs dropped out of the food chain, would you expect to see a decline in any other organisms in the Bay? Which organisms?
   Crabs are an important food source for eel, drum, spot, Atlantic croaker, striped bass, sea trout and catfish. Some sharks, cownose rays and Kemp's riddley and loggerhead sea turtles also feed on blue crabs at different life stages. If blue crabs dropped out of the food chain, it is possible that population declines in any of these species in the Bay could occur.

8. Where do blue crabs typically live? What type of habitat do they need to grow and forage?
   Adult crabs are primarily benthic creatures and live on the bottom of the Bay. Bay grass beds are very important for crabs because the young crabs use them for nursery areas and crabs of all sizes forage for food there.

9. Are there other organisms that share this environment?
   Underwater bay grasses provide crucial habitat for a host of aquatic organisms, including fish, shellfish, invertebrates and waterfowl. Zooplankton feed on decaying bay grass particles and provide food for larger organisms.

10. Are there any known threats to the blue crab? What are they?
    Loss of seagrass habitat and overharvesting by humans are major problems. Nutrient pollution facilitates growth of algal blooms. Low-oxygen conditions that result as bacteria break down dead algae have been known to kill crabs.

Part II
After having students read up on and answer questions about the Chesapeake Bay ecosystem, have students conduct a graphing exercise to assess the health of Bay. They will use blue crab abundance data that NOAA scientists have collected since 1990. Students should graph the raw data on the grid provided on Page 13. Make sure students label the axes of the graph, write a title above the graph and answer the questions that follow.



1. What trend do you notice in blue crab abundance from 1990 to 2008?
Blue crab numbers decline sharply from 1990 to around 2000. Between 2000 and 2008 they increase slightly, then sharply increase between 2008-2009.

2. Does it appear that efforts made in 2000 to restore the blue crab population to 1990 levels are working?
It appears that there is an upward trend. You should stress to your students that there is variation in population size every year, so data from 2010 and beyond will be necessary to confirm whether there is a significant trend toward 1990 levels.

3. What might the trends you noticed indicate about the health of the Bay? Are there any ecosystem-wide issues that could contribute to the trend?
There are many problems that could be associated with the decline that occurred from 1990-2000. If habitat loss continues to be a problem, other species that rely upon seagrass could also be declining. Loss of seagrass could have effects all the way up the food chain since zooplankton rely on this habitat for food. Low-oxygen conditions could also be killing crabs, which would impact other local species as well. It appears that restoration efforts have slowly led to a rising trend in crab abundance, which might mean that water quality and habitat quality have improved.

4. Aside from monitoring the blue crab, are there other factors you would recommend investigating to assess the status of the Bay? Remember that you will be working with limited time and resources.
Answers vary but may include monitoring seagrass habitat, sediment, salinity, oxygen levels, runoff levels into the Bay and/or the abundance of other species

Part III
Students should write a brief paragraph summarizing their answers to the questions in the worksheet. Answers will vary.

The State of the Bay

The Chesapeake Bay is a very important ecosystem on a local and national level. It provides habitat to over 2,700 plant and animal species like oysters, crabs, seagrasses and fish. It provides recreational opportunities for residents and visitors. It is also a vital part of our economy: millions of pounds of seafood are caught here including blue crabs.

As you may know, there has been growing concern over the state of the Chesapeake Bay ecosystem. Runoff from farms, roads and water treatment plants contains nutrients like nitrogen and phosphorus, which lead to algal blooms and low-oxygen conditions as excess algae decay. In 2009, President Obama issued an Executive Order to protect and restore the Chesapeake Bay. As top NOAA scientists, you have been asked to serve on an advisory board to the President regarding the Chesapeake Bay. You won't have time to conduct a detailed analysis on every aspect of this complex ecosystem. The panel's response has been requested within a short time period.

What will you do?

In today's activity you will use what you know about linkages in ecosystems to make recommendations for the Bay based on analysis of the abundance of the economically important blue crab.

Part I. Understanding the Bay ecosystem

Before you start analyzing trends in the Bay, it is important to get a basic picture of the Bay as an ecosystem. Visit the Chesapeake Bay Program link that contains information about the blue crab: http://archive.chesapeakebay.net/fish1.htm.

Draw a basic food web of the Bay that includes the crab, its prey, predators of the crab and consumers of crab predators. Feel free to click on other species linked in the crab article if you need more information. You may also refer to the Student Handout. After constructing your food web, answer the questions for Part I.

Questions – Part I

1. Are adult blue crabs classified as benthic or pelagic organisms? Why?

2. Are blue crab larvae classified as benthic or pelagic organisms? Why?

3. Crabs live in the coastal intertidal zone. What is a broad name for the zone that includes the intertidal, sub-littoral and super-littoral zones?

4. What types of food sources do blue crabs rely upon?

5. Some fish, including striped bass, eat the same types of food as the blue crab. These fish are often found in the well-lit layer of the ocean around 200m deep and above. What is this zone called?

6. Aside from some species of fish, which other marine organisms eat similar food as the blue crab?

7. If blue crabs dropped out of the food chain, would you expect to see a decline in any other organisms of the Bay? Which organisms?

8. Where do blue crabs typically live? What type of habitat do they need to grow and forage (search for food)?

9. Are there other organisms that share this environment?

10. Are there any known threats to the blue crab? What are they?

Part II. Abundance of the blue crab

After reading up on the Bay, your team decides now is the time to assess the health of this productive ecosystem. You decide to analyze blue crab abundance data, which NOAA scientists have collected since 1990.

Graph the raw data on the grid provided found on the next page. Don't forget to label the axes of the graph and write a title above the graph! When you are finished, answer the Part II questions below.

Questions – Part II

1. What trend do you notice in blue crab abundance from 1990 to 2008?

2. Does it appear that efforts made in 2000 to restore the blue crab population to 1990 levels are working?

3. What might the trends you noticed indicate about the health of the Bay? Are there any ecosystem-wide issues that could contribute to the trend?

4. Aside from monitoring the blue crab, are there other factors you would recommend investigating to assess the status of the Bay? Remember that you will be working with limited time and resources.

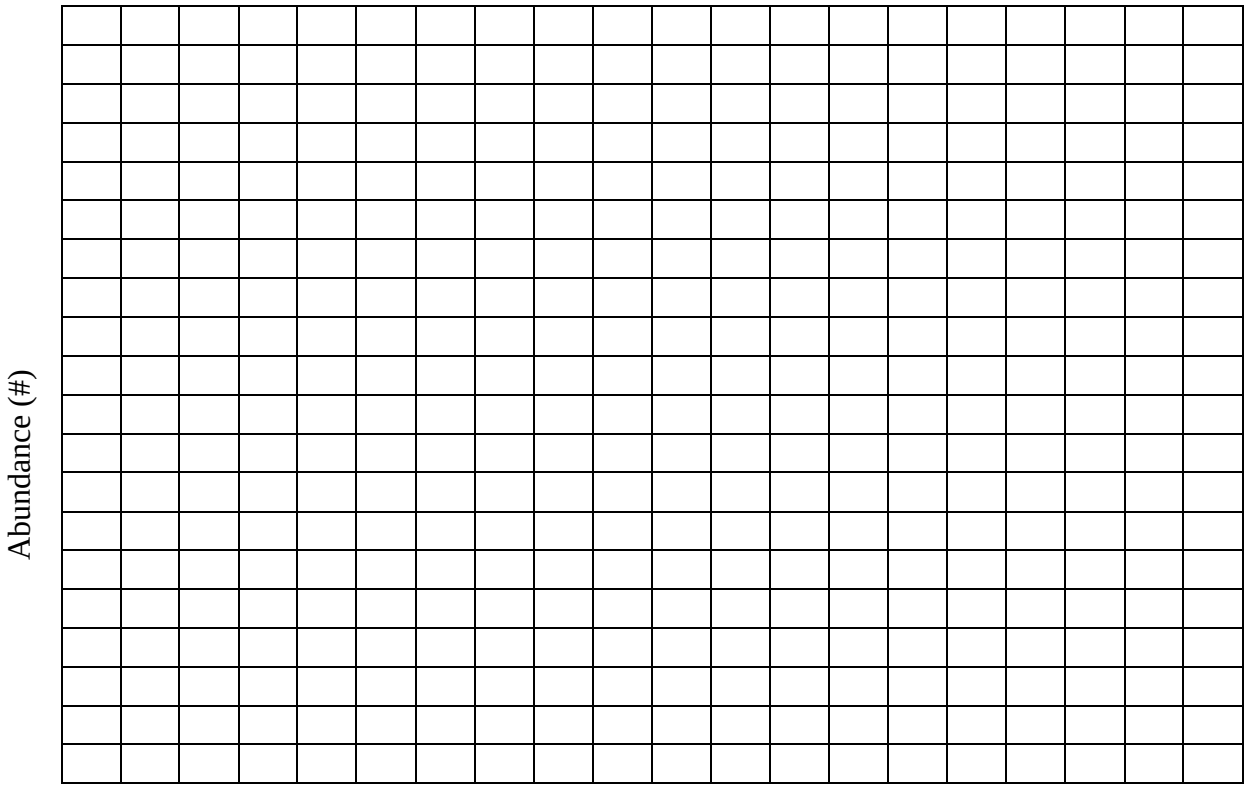
Part III. Report to the President

Prepare a brief paragraph (6-10 sentences) to advise the President on the state of the Bay. Explain whether or not you think the Bay is an ecosystem in need of restoration efforts and how you came to your conclusion. Suggest any additional monitoring efforts that you would recommend in the future to tell whether restoration efforts are working.

Blue Crab Data Sheet – Data from NOAA Chesapeake Bay Office

Blue Crab Abundance

Year	Abundance
1990	276
1991	457
1992	251
1993	347
1994	190
1995	183
1996	146
1997	165
1998	187
1999	86
2000	146
2001	101
2002	121
2003	171
2004	124
2005	158
2006	121
2007	141
2008	131
2009	223

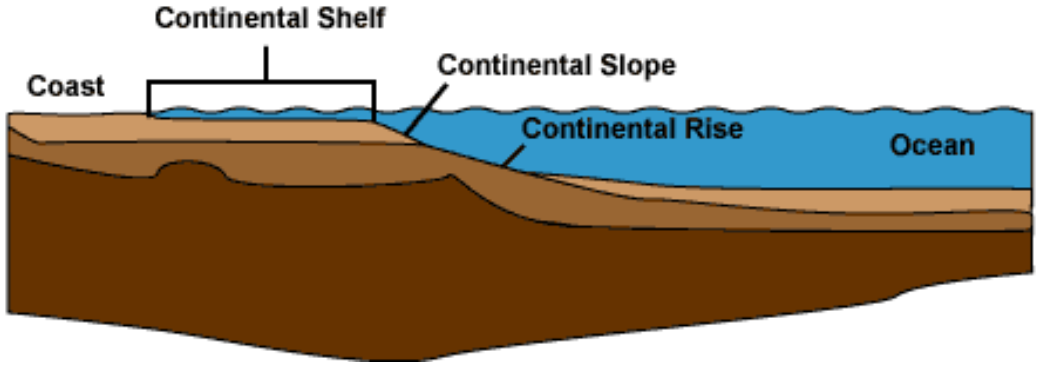


Tips for the Bowl - Marine Ecosystems

Know your zones!! You learned about the pelagic and benthic zones today, but both can be further divided horizontally or based on depth. You will be expected to know the subdivisions at the NOSB!

The Continental Margin & Continental Rise

The **continental margin** is the submerged extension of a continent and includes the **continental shelf, continental slope and continental rise.** The **continental shelf** is the gently sloping component that begins at the shoreline and typically goes to a depth of around 200 meters. This region contains a vast amount of benthic organisms (those that live on the ocean floor). The **continental slope** begins at the edge of the continental shelf, also know as the **shelf break** (usually around 200m), and drops very sharply in depth. Beyond the steep drop-off of the continental slope, sediments accumulate, forming a much more gradual slope known as the **continental rise**. [3]



Horizontal & Vertical Zonation of Pelagic Zones

The pelagic zone has two primary horizontal divisions:

1. The coastal zone is the area between low tide and the end of the continental shelf. Also called the **neritic zone.**

2. The open water beyond the coastal zone is the **oceanic zone**

The pelagic zone has three primary depth divisions based on the amount of light received:

1. The **euphotic zone** is the uppermost sunlit layer where photosynthesis can take place
2. The **dysphotic zone** beneath is dimly lit, but without enough light for photosynthesis
3. The **aphotic zone** receives no light and is typically below 1,000m deep

[3] Photo: http://www.onr.navy.mil/Focus/ocean/regions/oceanfloor2.htm

Other Vertical Pelagic Zones
The following pelagic zones are based on depth from the surface:

- Epipelagic (0-200m)
- Mesopelagic (200-1,000m)
- Bathyalpelagic (1,000-4000m)
- Abyssopelagic (4,000-6,000m)
- Hadalpelagic (6,000-10,000m)

Benthic province/Benthic zones are broken down as follows:

- Shallow
    - Supralittoral – the area above the high tide line that gets splashed, but not submerged by water
    - Littoral – the intertidal zone that is sometimes submerged and sometimes above water
    - Sublittoral – the seafloor from the low tide line to edge of the continental shelf
- Deep
    - Bathyal – the seafloor along the continental slope toward the deep ocean bottom
    - Abyssal – the deep ocean bottom below the slope and above 6,000m
    - Hadal – the deepest zone, below 6,000m

Know your ecosystem basics! You are expected to know some basic facts and terminology about ecosystems for NOSB questions. Below are some common terms to get you started.

Abiotic: nonliving

Biotic: living

Community: populations of organisms living and interacting in the same ecosystem

Ecosystem: a physically distinct area that contains a community of interacting organisms

Niche: an organism's role in its habitat

Population: a group of interacting members of the same species

Resources
For more information on ecosystems, check out the links below:
http://www.pbs.org/earthonedge/ecosystems/index.html
http://library.thinkquest.org/11353/ecosystems.htm
http://faculty.mccfl.edu/rizkf/OCE1001/OCEnotes/chap11.htm

Marine Ecosystems

1. If an animal is considered benthic, it is typically found:
    w. In the water column
    x. At or near the bottom of the ocean
    y. On the beach
    z. Breaching or jumping out of the water

2. If an animal is considered pelagic, it is found:
    w. Near the bottom of the ocean
    x. In the water column
    y. On the beach
    z. Within ocean sediment

3. The aphotic zone is a part of the water column where photosynthesis cannot occur because of the absence of:
    w. Carbon dioxide
    x. Oxygen
    y. Nutrients
    z. Sunlight

4. Reminder question: Which of the following is likely to be found at a subduction zone:
    w. A barrier island
    x. An ocean gyre
    y. A trench
    z. Elusive species of beaked whales

5. The deepest zone of the ocean, below 6,000 meters, is called:
    w. Epipelagic
    x. Mesopelagic
    y. Abyssopelagic
    z. **Hadalpelagic**

6. Animals like the great white shark and whale shark can be found in the epipelagic zone among other areas of the ocean. This means that they can be found:
    w. Near the surface
    x. At depth between 1,000-4,000 meters
    y. In ocean trenches (4,000-6,000 meters)
    z. Below 6,000 meters

7. Short answer: This term refers to a physical location with distinct abiotic conditions that supports a community of interacting species.
   Answer: Ecosystem

8. The euphotic zone is:
   w. In the deep sea below 1,000 meters
   x. In the well-lit surface layer where plants undergo photosynthesis
   y. In the uppermost sediment layer of the ocean bottom
   z. In the deepest sediment layer of the ocean bottom

9. Short answer: What term refers to the area of the shore between mean high water and mean low water?
   Answer: Littoral or intertidal

10. Team Challenge Question

    Consider the following ecosystem: A freshwater lake with a small crustacean species called Daphnia that feed on phytoplankton. Nutrients from a nearby farm occasionally run into the lake. The phytoplankton use the nutrients and sunlight to reproduce. Daphnia's only predator is a species of mosquito fish that lives in the lake.

    1. Name three abiotic factors and three biotic factors that comprise this ecosystem. (6pt)

    2. Collectively, the Daphnia, phytoplankton and mosquito fish form what group of interacting species? (2pt)

    3. A chemical from a nearby factory causes the mosquito fish population to die off. Assuming the chemical does not directly affect the Daphnia or phytoplankton directly, what would you expect to happen to each species following the die-off? Explain your reasoning. (2pt)

ANSWER

Consider the following ecosystem: A freshwater lake with a small crustacean species called Daphnia that feed on phytoplankton. Nutrients from a nearby farm occasionally run into the lake. The phytoplankton use the nutrients and sunlight to reproduce. Daphnia's only predator is a species of mosquito fish that lives in the lake.

1. Name three abiotic factors and three biotic factors that comprise this ecosystem. (6pt)
   Abiotic: Water, sunlight and nutrients (1pt each)
   Biotic: Daphnia, mosquito fish and phytoplankton (1pt each)

2. Collectively, the Daphnia, phytoplankton and mosquito fish form what group of interacting species? (2pt)
   A community (Food web or food chain also acceptable)

3. A chemical from a nearby factory causes the mosquito fish population to die off. Assuming the chemical does not directly affect the Daphnia or phytoplankton directly, what would you expect to happen to each species following the die-off? Explain your reasoning. (2pt)
   Because the mosquito fish feed on Daphnia, the Daphnia population would grow without the pressure from their only predator (1pt). The growing Daphnia population might reduce the phytoplankton population size (1pt).