The Great Whales

A Curriculum for Grades 6–9

Vicki Osis
and Susan Leach Snyder, Rachel Gross, Bill Hastie, Beth Broadhurst
Oregon State University Marine Mammal Program

The Great Whales

This curriculum was produced for the Oregon State University Marine Mammal Institute

Dr. Bruce Mate, Project Director

Acknowledgments

Contributions and assistance from the following people and organizations made production of this curriculum possible.

Funded by a grant from the
National Oceanic and Atmospheric Administration Ocean Explorer Program

Artists
Pieter Folkens
Laura Hauck
Tai Kreimeyer
Craig Toll

Photography/illustrations
International fund for Animal Welfare
San Diego Natural History Museum

Cover photo
Pieter Folkens

Reviewers
Barbara Lagerquist
David Mellinger
Sharon Nieukirk

Reviewers/writers
Beth Broadhurst
Bill Hastie
Susan Leach Snyder
Rachel Gross

Design, layout, and editing
Cooper Publishing

Assistance with scientific data
Dr. Douglas Biggs
Dr. John Chapman
Dr. William Kessler
Dr. Bruce Mate

Field testers/reviewers
Jesica Haxel
John King
Tracie Sempier
Christian Tigges
Eugene Williamson
Theda Hastie

Contents

1. Purpose of the Curriculum

The protection of whales has moved well beyond ending commercial whaling. Current whale conservation issues are complex and directly related to human activities that impact ocean habitats on which the whales depend.

The aim of this curriculum is to focus on research efforts to expand human knowledge about marine mammals. We can't save whales unless we understand what whales need to live—their life habits and habitat needs. Through a variety of activities, this curriculum explores whale biology and ecology topics and discusses methods being used to study whales. Also covered are current conservation issues and concerns, as well as other topics such as exploitation and general information about whales. Charts matching curricula contents to National Science Content Standards and science process and essential learning skills are also included.

Whales are the largest mammals on Earth, yet we know very little about them. They are totally aquatic and therefore difficult to observe and study. The most accessible are those that come close to land, such as gray whales. For most whales, we do not have basic biological information, such as where they go to birth their calves or where their favorite feeding areas are located. We know that many whales make long migrations from summer feeding ground to winter calving areas, but for most whales, we do not know the routes traveled. Accurate counts to determine whether whale populations are recovering or shrinking are difficult to gather. These questions and many others are the focus of whale studies today.

Curriculum Design

This curriculum is intended for teachers interested in a whale unit for their 6th- to 9th-grade classes. Teachers can select individual activities and materials for instruction or work through them sequentially from beginning to end.

The content of the material provides an introduction to marine mammals with a focus only on the great whales. It is divided into eight main sections:

- Introduction and Purpose of Curriculum
- Introduction to Whales
- Whale Habitats
- Exploitation of Whales
- Current Threats and Hazards
- Whale Investigations
- Current Whale Research
- National Standards, Science Process, and Learning Skills

Concepts, understandings, and skills

This curriculum utilizes science process skills including recalling, observing, comparing, classifying, and estimating. Most of the activities develop thinking skills such as inferring, predicting, analyzing, and applying information to other issues. Basic science concepts are included throughout the curriculum. These include:

- Ocean habitats (how they are different from land habitats)

We know very little about most species of the great whales.

- Taxonomic structure and divisions for whales
- Adaptations of whales, both anatomical and behavioral
- Exploitation of natural resources
- Human impact on marine habitats
- Challenges for marine conservation
- Energy flow through ecosystems
- Bioaccumulation of toxic chemicals in marine animals
- How scientific studies are conducted
- Technology used to study whales

Interdisciplinary

To understand the world around them, students need a wide range of skills and knowledge. Understanding organisms and natural systems is not a single-discipline effort. The lessons in this curriculum are delivered through the use of biology, geography, geology, math, and physics.

The lessons in this curriculum are delivered through the use of biology, geography, geology, math, and physics.

2. Introduction to Whales

Whales! They are the largest mammals on Earth—even larger than the largest dinosaur. Whales live their entire lives in water. Their weight would crush them without the water to support their bodies. They have a fishlike shape, but their tail fins—called flukes—are horizontal rather than vertical, and they have paddle-like front limbs, called flippers. Their skin is smooth and glossy and, depending on the species, may be black, white, gray, and bluish. Some are marked with a variety of colors, from cream to yellow. Beneath the skin is a thick layer of fat, called blubber, which serves as a source of stored energy and insulation. Despite their enormous size, they feed on some of the smallest organisms in the sea. Favored foods include copepods and euphausiids (also called krill), or schools of small fish.

Whales are found in all oceans of the world. They are widely distributed, and a single species may be broken into several different stocks. A stock is a group of whales that are geographically isolated from other members of their species. For example, the Alaskan stock of humpback whales travel to Hawaii for the winter months and they do not mix with the Antarctic stock of humpbacks that migrate to Tonga for winter and calving.

Activity 1: Whale Facts

Concepts

Each whale species has distinctive characteristics and behavior patterns.

Materials

- ☐ Paper and pencil
- ☐ Computers
- ☐ Reference books
- ☐ Bulletin board with craft paper or large notebook

Subjects

- ■ Biology
- ■ Communications

Time

Homework assignment: allow three days

Teacher information

Bulletin board, class Whale book, or class Web site

This activity allows students to choose their favorite whale and gather information into a fact sheet format. As they are preparing the fact sheet, suggest that they gather "fun" facts about whales that can be used in the project, such as: bowhead baleen is twice as long as a six-foot-tall human.

The great whales are always of interest to students. Great whales are those of great size, including the gray, humpback, right, blue, sperm, bowhead, fin, sei, Minke, pygmy right, and Bryde's whales. Within this group, the size varies greatly from species to species. The smallest, the pygmy right whale, grows up to 8 meters, while blue whales reach 30 meters in length. The last four are not well studied; less information about these is available to students.

There are close relatives of the great whales identified as dwarf and pygmy

Despite their enormous size, whales feed on some of the smallest organisms in the sea.

species. Examples include the dwarf and pygmy sperm whale, dwarf Minke, and pygmy blue whales. From the selection of the dwarf and pygmy species, only the pygmy right whale is reviewed in this curriculum.

The Internet is a good source of information. Before students begin a Web search for whale information, provide a brief introduction to search engines and to selecting reliable Web sites. Good sources include NOAA (National Oceanic and Atmospheric Administration) or state and federal fisheries agencies, the American Cetacean Society, and the International Whaling Commission. Also, Web sites approved by NSTA (National Science Teachers Association) and the BRIDGE links to Web sites that have been screened by experts have good information. "Debbie's Favorite Whales" or "Mrs. Smith's fourth grade class" whale Web sites will likely have less reliable information. Ask students to list the Web sites or books they used to gather information.

How to reference a Web site

Citation styles vary, but they should list author (if available), title, date they retrieved the site, and URL. Example:

Nature's Humpback Whales: Retrieved January 13, 2004, from http://www.pbs.org/wnet/nature/humpback/

Fact sheets should include all or most of this data on the each of the whale species selected for study.

- Size and weight
- Color
- Food
- Reproduction
- Distribution and migration

The fact sheets can be organized in any number of ways that suit the class needs:

- Display fact sheets on a bulletin board. Frame the bulletin board with strips of butcher paper. Attach to the border interesting facts about whales.
- Develop a bulletin board on each whale and rotate the display at set intervals. Teams of students may pick their whale and use fact sheet information to build the display.
- Develop a class whale Web site, using fact sheet information.
- Place the sheets into a "Class Whale Book." Whale "fun facts" can become section dividers for the book.

While progressing through the whale study, students will be referring back to the sheets for various information or use them in other activities, such as Activity 3: Whale Families.

Classification of whales

Whales are mammals and share certain features with mammals, such as being warmblooded and giving birth to live young. Because whales are aquatic mammals, they are classified in the specific order of Cetacea, making them a cetacean. Suborders are used to make the major division between toothed whales (*odonticeti*) and baleen whales (*mysticeti*). Odonticetes have jaws lined with pointed teeth that are used in hunting fish, squid, and other prey. Mysticetes (baleen whales) lack teeth. These whales use giant, flexible combs of material called baleen to filter small fish and tiny crustaceans from the water.

Work through the following activities to learn how whales are classified into various divisions.

Whales share certain features with mammals, such as being warmblooded and giving birth to live young.

ACTIVITY 2: Are Whales Mammals?

Concepts
Scientists use anatomical characteristics to sort and classify organisms.

Materials
- ☐ Chalkboard

Subjects
- Biology

Time
15 minutes

Teacher-led discussion
Make a list of the characteristics of mammals and discuss with students whether they think these characteristics also apply to whales.

All mammals have these characteristics:

- Hair
- Breathe air with lungs
- Warmblooded
- Give birth to young
- Mammary glands, with which they suckle their young
- Four-chambered heart

Note: All species of whales have several hairs, either as embryos or as adults, with a few sparse hairs located on the snout, jaws, or chin. Whale mothers produce 100–130 gallons of milk per day that is 55 percent fat (like whipping cream!).

Where do whales fit in the animal kingdom?
All organisms are divided into groups by features they have in common. From large divisions to very small divisions, Earth's organisms are divided into *Kingdom, Phylum, Class, Order, Family, Genus,* and *Species.*

It is difficult to remember the proper sequence of classification. Help students commit facts to memory with learning aids. They can use this memory booster: ***K**ings **P**lay **C**hess **O**n **F**lat **G**reen **S**paces.* Or they can make up their own rhyme or sentence to remember the proper sequence of kingdom, phyla, class, order, etc.

Division	Division name	Common features
Kingdom	*Animalia*	Animals
Phylum	*Chordata*	With a spinal cord
Class	*Mammalia*	Warmblooded, nourish young with milk
Order	*Cetacea*	Entirely aquatic
Suborder	*Mysticeti*	Have baleen
Family	*Baleanopteridae*	Have throats with deep grooves
Genus	*Balaenoptera*	Six of the seven rorqual whales are this genus, including blue whales
Species	*Musculus*	True blue whale

Order Cetaceans
This grouping includes whales, dolphins, and porpoises. The cetaceans are divided into two suborders: *Odontocetes* (with teeth) and *Mysticetes* (with baleen).

Memorization of facts is necessary for learning science. Memorization can be made easier and fun with rhymes and songs.

Features of a mammal, to a rap beat:

It's got a hard backbone,
Hair on its skin,
Nurses from its mama,
And it's warm within.

A whale is a mammal,
But a snake is not,
You can tell a mammal by the kind of things it's got.

A four-chambered heart
And lungs to breathe
A whale is a mammal
It's all there to see.

Have students make up their own rhymes or songs to remember science information.

Memorization by association

Long lists are difficult to remember, but association of facts with some feature will make recall much easier.

For example, for characteristics of baleen whales:

Baleen whales have three stomachs. Associate with three e's in the words "baleen whales."

Hair is always present on adults. Baleen whales are *mysticetes*, which means mustache. Remember, baleen whales have hair on their bodies as adults.

Encourage students to develop their own lists of associations.

Odontocetes have various numbers of identical conical or spade-shaped teeth that are used to grasp food, primarily fish or squid.

Mysticetes use giant, flexible combs of a material called baleen to filter small fish and tiny crustaceans from the water. Stiff plates of baleen grow down from the gums of the upper jaw. The baleen plates are arranged in rows that extend down each side of the mouth.

The chart below lists a few of the many characteristics that divide the two suborders.

Differences between Odontocetes and Mysticetes

Anatomical features	Toothed whales	Baleen whales
Symmetry of skull	Asymmetrical	Symmetrical (both halves are same)
Feeding structures	Teeth	Baleen
Stomach divisions	Three to 13	Always three
External blow holes	One	Two
Digits in hand	Five	Four (five in right whales)
Wax ear plug	Not present	Present
Hair	Present in fetus	Always present on adults
Larger sex	Males largest	Females largest
Food	Squid, fish	Plankton, small fish

Activity 3: Whale Families and Scientific Names

Concepts

- Animals are divided into groups with common characteristics.
- Scientific names are assigned, using Latin and Greek words that describe the organism.

Materials

- ☐ Paper and pencil
- ☐ Framework for families
- ☐ Description of whale families

Subjects

- Biology

Time

20–30 minutes

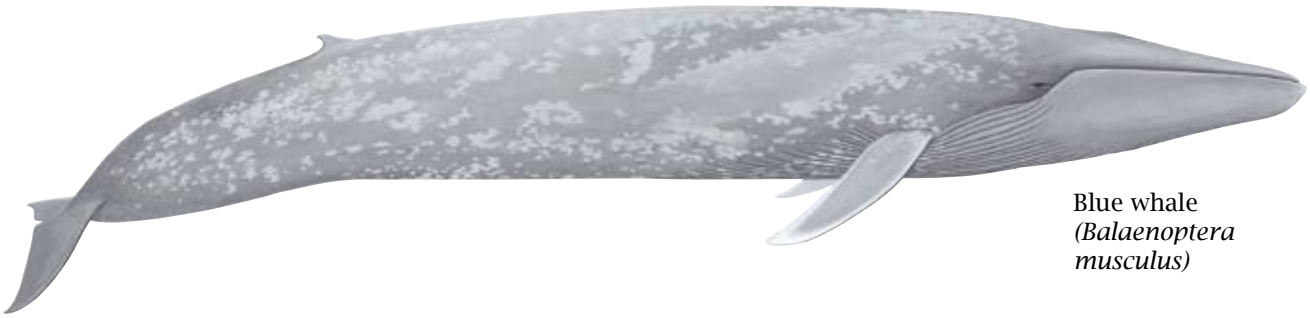
Procedure

Whales are divided into smaller and smaller groups until they are sorted into groups that all have the same characteristics (species level). Families of whales have similar features. Check over the chart below to see how they are divided into families.

Have students refer back to their fact sheet and assign their whale to the proper family. Use the description of family characteristics to match to their whale.

Teacher key to student worksheet #3

Suborder Mysticeti	Genus	Family Characteristics
Rorqual Family		These whales have throat grooves that extend from the mouth to the flipper area or further. The folds of skin and blubber expand the capacity of the mouth during feeding.
Blue whales	*Balaenoptera*	
Fin whales	*Balaenoptera*	
Humpbacks	*Megaptera*	
Sei	*Balaenoptera*	
Bryde's whale	*Balaenoptera*	
Minke	*Balaenoptera*	
Pygmy right whale	*Caperea*	
Gray Whale Family		Members of this family have no dorsal fin or throat grooves. They have two to seven short, deep creases on their throat.
Gray whales	*Estrichtius*	
Right Whale Family		Members of this family lack throat grooves. They have very large heads that make up 1/3 of their total body. They also have very long baleen.
Right whales three species	*Eubalaena*	
Suborder Odontoceti		
Sperm Whale Family		This group of whales has a huge, squared head that makes up over 35 percent of the total body. It has a skull depression filled with a fine oil called spermaceti. This is the only great whale family that has teeth.
Sperm whale	*Physeter*	
Pygmy sperm	*Kogia*	



Blue whale *(Balaenoptera musculus)*

Gray whale *(Eschrictius robustus)*

Northern right whale *(Balaena glacialis)*

Sperm whale *(Physeter macrocephalus)*

Name **Date**

Student Worksheet #3

Whale family chart instructions

1. Compare the family characteristics below with the pictures of the whales on page 10. Select the family that best matches the whale's features. Complete the sheet by putting the whale into the correct family.
2. Place the whale from your whale report into the proper family.
3. Match the following whales to family characteristics and complete the chart: humpback, bowhead, fin, sei, pygmy right, minke, and Bryde's whale. Use the Web to gather information about each species of whale.

Suborder Mysticeti

Common Name	Genus	Family Characteristics
Rorqual Family		
_____	_____	These whales have throat grooves that extend from the mouth to the flipper area or further. The folds of skin and blubber expand the capacity of the mouth during feeding.
_____	_____	
_____	_____	
_____	_____	
_____	_____	
_____	_____	
_____	_____	
Gray Whale Family		
_____	_____	Members of this family have no dorsal fin or throat grooves. They have two to seven short deep creases on their throats.
Right Whale Family		
_____	_____	Members of this family lack throat grooves. They have very large heads that make up 1/3 of their total body. They also have very long baleen.

Suborder Odontoceti

Sperm Whale Family		
_____	_____	This group of whales has a huge, square head that makes up over 35 percent of the total body. It has a skull depression that is filled with a fine oil called spermaceti. This is the only great whale family that has teeth.

Activity 3 Continued: Scientific Names

Concepts
Latin and Greek root words are used for scientific names and often describe the organism.

Materials
- ☐ Student worksheet

Subjects
- Biology

Time
30 minutes

Scientific names
Every different type of plant or animal is assigned a unique scientific name. The use of scientific names establishes a uniform system of identification of organisms that scientists can use to communicate with one another. Common names are easier to remember, spell, and understand, but there is no accepted system for assigning common names.

Scientific names consist of a genus and a species name. Carolus Linnaeus invented the system, and it is referred to as the *binomial nomenclature* or the two-name system (bi = 2; nomial = name). Genus places the animal or plant with a small group of organisms with similar characteristics, but the species applies to one unique type of organism. There may be many individual members of the species but they have unique features that apply only to them.

Common names are easier to remember, spell, and understand, but there is no accepted system for assigning common names.

Scientific names are derived from Latin or Greek and often use root words to describe the organism. For example, the name may describe the animal's appearance, behavior, or locality where they are found. Sometimes names are used to honor the person who discovered the organisms or an important person in science.

Procedure
- Instruct students to read through "The Discovery of a New Species."
- Analyze how scientific names are used to describe species.
- Select a name for the new species from the list of Latin and Greek roots.

Teacher key to student worksheet #3
1. *Balaen* = baleen
   Mysticetus = mustache
   Mustachioed baleen whale
2. *Mega* = big
   Optera = wings
   Nova = new
   Angliae = England
   Big-winged New Englander
3. *Balaen* = baleen
   Optera = wings
   Musculus = muscular
   Muscular baleen whale with wings
4. Family: right whales, because of the size of its head and length of baleen.
5. Possible scientific names for the new species:
   Melanomusulus mysticetus
   Balaenomusculus albanoptera
   Megacephalus acutoptera
   Novabalaena robustus

Name **Date**

Student Worksheet #3

Scientific name examples

- Sperm whale: *Physeter macrocephalus. Physeter* = spouter; *macro* = large; *cephalus* = head. The name literally means "big-headed spouter."
- Northern right whale: *Eubalaena glacialis. Eu* = true; *baleaena* = baleen or whales; *glacialis* = icy. The name means "true whale that lives in icy waters."

Below are three whales and their scientific names. Analyze the scientific names. Use the list of Latin roots to figure out the meaning of both the genus and the species names. Write what the name means in the blank next to the scientific name. Use the example above as a guide.

1. Bowhead whale: *Balaena mysticetus* _____
2. Humpback whale: *Megaptera novaeangliae* _____
3. Blue whale: *Balaenoptera musculus* _____

From the description below, place this new species of whale into one of the whale families and explain why you selected that family. Make up a genus and species name for the whale using the list of Latin roots given below. There will be several choices that may be used to describe this whale.

Discovery of a new species:

4. Family _____ Why this family?
5. Scientific name you have designated for this whale:

   Genus _____ Species _____

Discovery of a new species

The following is NOT a true story. It is an exercise to illustrate how animals are categorized.

A new whale has just been discovered! Scientists have gathered information about this whale, but it has not been classified or named as yet. It was discovered in the far northern waters in the icy Bering Sea off Alaska. The description they have gathered is as follows.

A. Very large, muscular whale—as large as a blue whale (specimen found was 100 feet long)
B. Black in color with long, white flippers
C. Lives near the ice floes in the Bering Sea
D. Has a high, arched mouth
E. Very large head, making up 1/3 of its body
F. Has extremely long baleen, up to 14 feet long
G. Its flukes have unusually long, sharp points
H. No throat grooves
I. Its back dorsal fin is 1/2 meter tall

Latin roots and their meaning:

mysticetus = mustache	*melanus* = black
musculus = muscular	*curvus* = arched or bent
optera = wing or fin	*balaena* = baleen
macros = large	*mysticetus* = mustache
physeter = blower	*cephalus* = head
dens = tooth	*acutus* = sharp
eu = true	*mega* (Latin) = big
glacialis = icy	*nova* = new
pteron = wing	*robustus* = strong
albus = white	*anglaie* = England

Greek roots and their meaning:

physa = bellows	*gigas* = big

ACTIVITY 4: Whale Adaptations

Concepts

Whales have various adaptations for life in the oceans.

Materials

- ☐ Reading assignment
- ☐ Markers
- ☐ Enlarged illustration of a whale

Subjects

- Biology

Procedure

- Instruct students to read through the adaptations below and list them on the whale illustration.
- Put a large line drawing of a whale outline on the bulletin board or the wall of the classroom. Assign each student a part of the whale. They are to go to the large drawing, indicate the part they are assigned, and explain how that part helps a whale live in ocean waters.

  Example: Fluke—large, flat tail of the whale. It is used for swimming and helps to whales to dive.
- Compare the whale to the dolphin. What is similar and what is different about their adaptations?

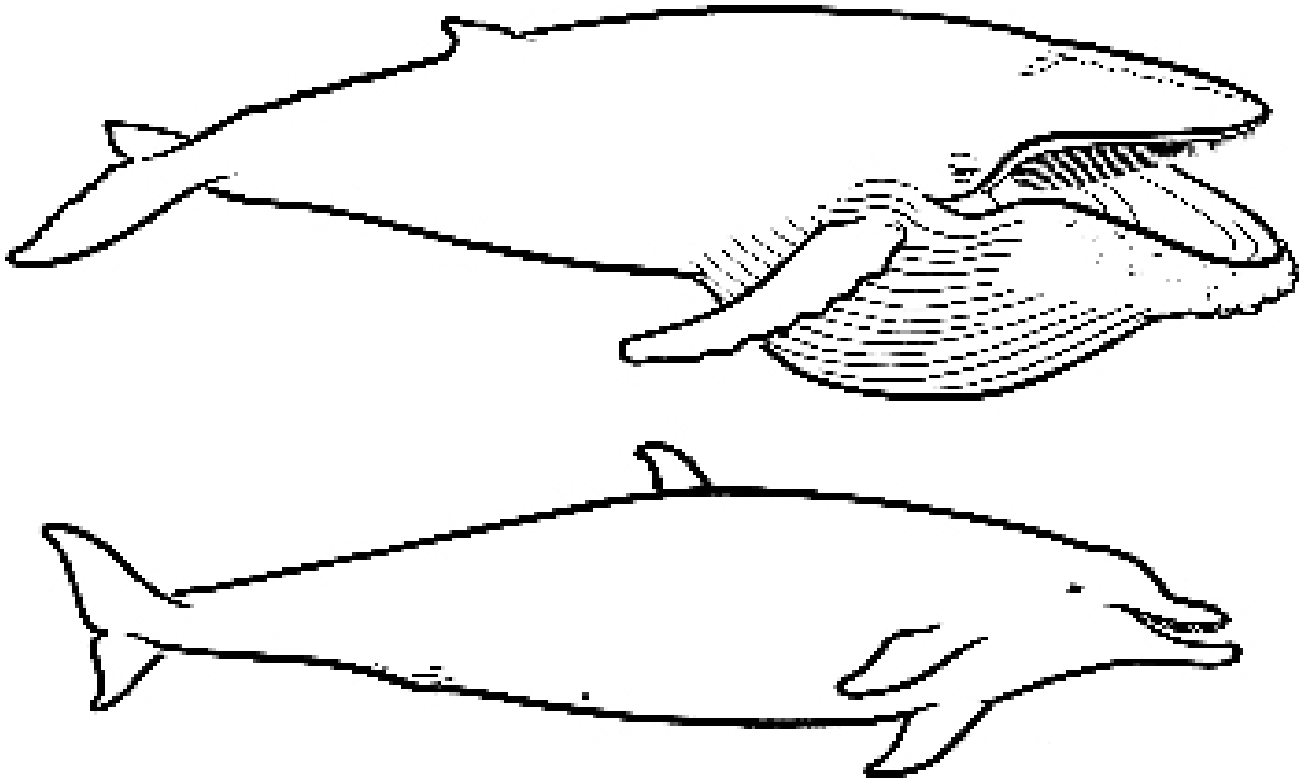
  Answer: Dolphins are smaller and sleeker. They do not carry the big store of blubber that the great whales do. Most great whales have baleen. The dolphin has teeth. Notice the large mouth for the whale, which strains huge gulps of water, while the dolphin is a fish eater and has a smaller mouth.

Dolphins are smaller and sleeker, and do not carry the big store of blubber that the great whales do.

Name **Date**

Student Worksheet #4

Read through each adaptation of the whale. Label each on the illustration. Draw the blow holes on the whale and the dolphin in the correct locations. Compare the whale and dolphin. Do all adaptations apply to both?



Adaptations

Body size—The large size of the whales provides the following advantages:

- Protects them from predators such as sharks and killer whales.
- Helps them retain body heat. This is due to a large volume (body core) in relation to a smaller surface area where heat is lost.
- Blubber stores energy, adds to the size, and helps with heat retention. Many whales feed for only 4 to 5 months and rely mostly on blubber reserves the rest of the year.

Blowholes (Nostrils)—Openings to the respiratory system (nostrils) are located on top of the head, which is the first part of the animal to break the surface of the water.

Body shape—Streamlined body shape to reduce drag as it moves through the water makes it more energy efficient.

Front flippers—The forelimbs of baleen whales are called flippers. They are used for swimming and turning and may be used by some species to herd food items for feeding.

Flukes—Each lobe of the tail is called a fluke. The flukes have no bones, just muscle and connective tissue. Whales sweep their tails up and down to swim through the water.

Baleen—Baleen is made of the same material as fingernails and hair. It is an adaptation for filter feeding. Baleen grows throughout the whale's lifetime; the terminal end continually wears off.

Blubber—Thick layer of fat that stores energy and helps retain body heat in cold waters.

Feeding adaptations

Baleen whales are skimmers, gulpers (also called lunge feeders), and suckers. Toothed whales are chompers.

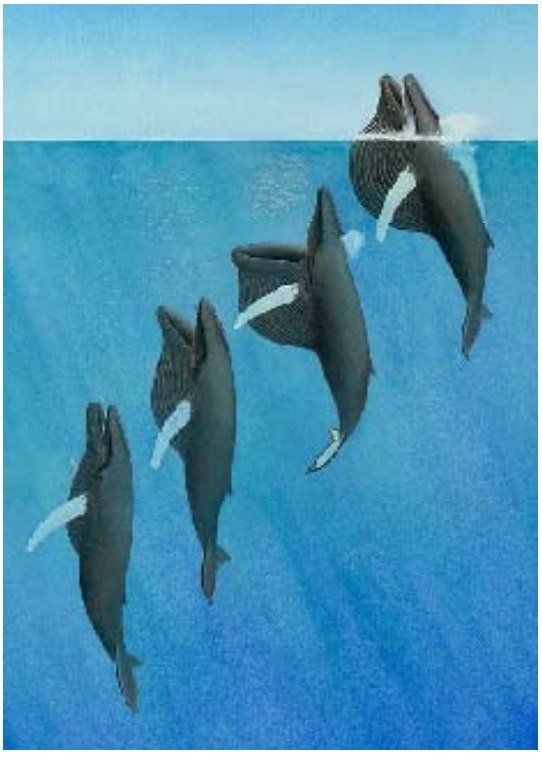
Skimmers include the right whale family, whose members are the right and bowhead whales. These whales often feed near the surface, with their mouths open to filter out small organisms called copepods and euphausiid (krill) for food. Skimmer baleen will be fine and feathery, as these whales are only filtering krill or copepods from the water.

Suckers include the gray whale family. When feeding, gray whales roll on their sides with their mouths parallel to the ocean floor. They pull their huge tongues into the back of their mouths, sucking huge amounts of mud, and everything in the mud, into their mouths. The mouthful of mud and water is pushed through the baleen to filter out the amphipods. Baleen for this method of feeding will be tough, thick, and durable, as these whales must filter mud and sand.

Gulpers are the rorqual whales. These whales have throat grooves that expand when they are feeding and their mouths are filled with water. Their feeding behavior is also referred to as lunging, as they propel through the water to gather food. The water is gulped then forced through the baleen, filtering out krill and small fish. This baleen will be tougher than skimmers but not as thick and tough as sucking baleen.

Chompers are toothed whales that catch squid and fish. Killer whales are the only toothed whales that hunt seals and sea lions—and even other whales—for food. All their teeth are sharp and pointed; they have no flat teeth for grinding, like the molar teeth of cows.

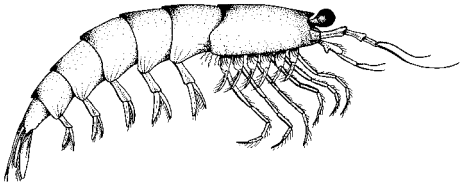
Dr. Bruce Mate holding gray whale baleen.



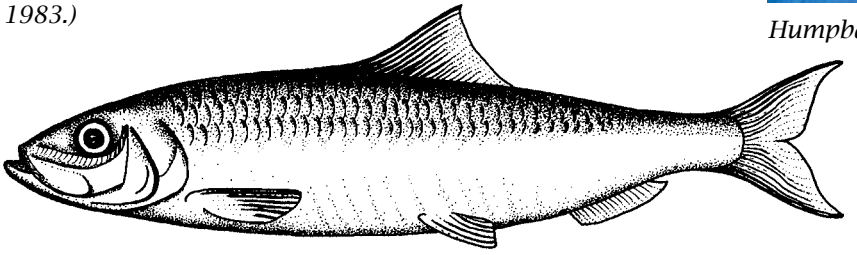
Humpback feeding (gulping or lunge method)

Favorite whale foods

Amphipod (Amphelisca macrocephala). Actual size: 2.2 cm. *(After Dickinsen 1983.)*



Krill (Euphasia superba). *Actual size: 6.2 cm. (Illustration by Laura Hauck.)*



Herring (Clupea harengus). *Actual size: up to 33 cm. (Illustration by Laura Hauck.)*

Activity 5: Suckers, Skimmers, and Gulpers

Concepts
Whales use several methods for feeding.

Materials
- ☐ Small kitchen sieve with handle
- ☐ Turkey baster
- ☐ Large flat paintbrush
- ☐ Comb
- ☐ Plastic ants or small plastic beads
- ☐ Rice grains, pepper
- ☐ Large bowls of water with sand sprinkled over the bottom

Time
15 minutes

Procedure
Sprinkle plastic ants and pepper to float in the bowls of water and add rice grains to sink to the bottom.

- Divide students into groups.
- Have them review the kitchen gear available and ask them to make predictions: which utensil will be the most efficient at collecting the ants or the rice, pepper?
- Direct students to collect the ants and rice using the different utensils and record which worked the best on which food type. Refer back to their predictions to see how accurate they were.
- Have each group report (either in writing or orally) on their method of feeding, suckers, skimmers, gulpers, the food collected, and the utensil they used.
- Identify which whale would use this method of feeding.

Activity 6: Baleen Types

Concept
Baleen is adapted to various methods of feeding.

Materials
- ☐ Illustrations of whale baleen
- ☐ Pencils

Subjects
- Biology

Time
20 minutes

Procedure
- Review again the types of baleen from the discussion above.
- Look closely at the drawings of the three types of baleen whales and the food they eat.
- Read again the explanation of how whales feed.
- Write under the whale baleen illustration the type of feeding that it is best suited for: skimming, sucking, or gulping.
- Note which food each whale eats.

Name **Date**

Student Worksheet #5-1

Baleen shows interesting adaptations for the various types of feeding used by different species of whales. The illustrations below show a comparison of baleen from bowhead, fin, and gray whales. (Illustration by Laura Hauck.)

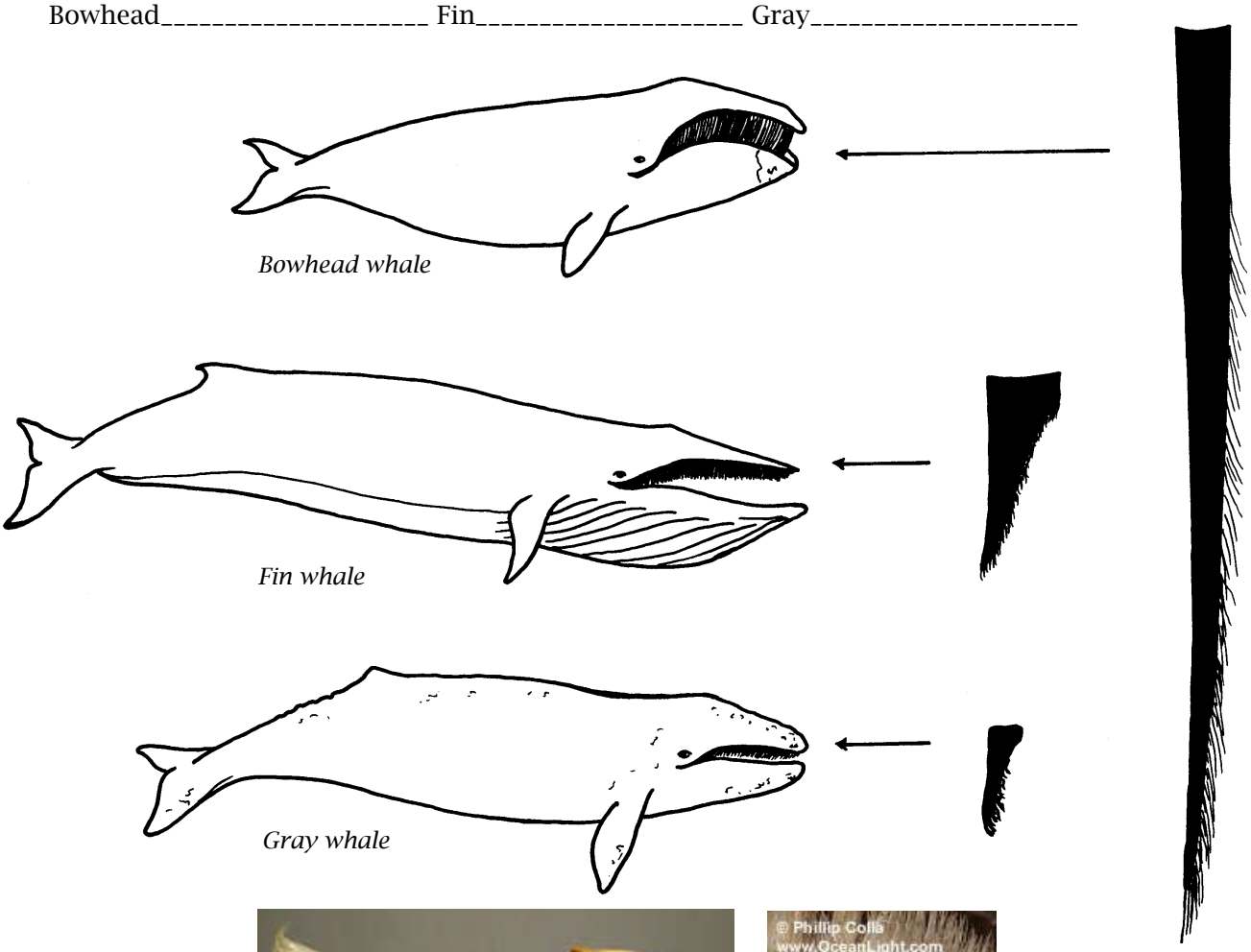
Questions

1. What are the most striking differences between the types of baleen?_____

   _____

2. What type of feeding behavior does each whale use?

   Bowhead_____ Fin_____ Gray_____



Bowhead whale

Fin whale

Gray whale

Gray whale baleen.

Close up view of gray whale baleen.

Name **Date**

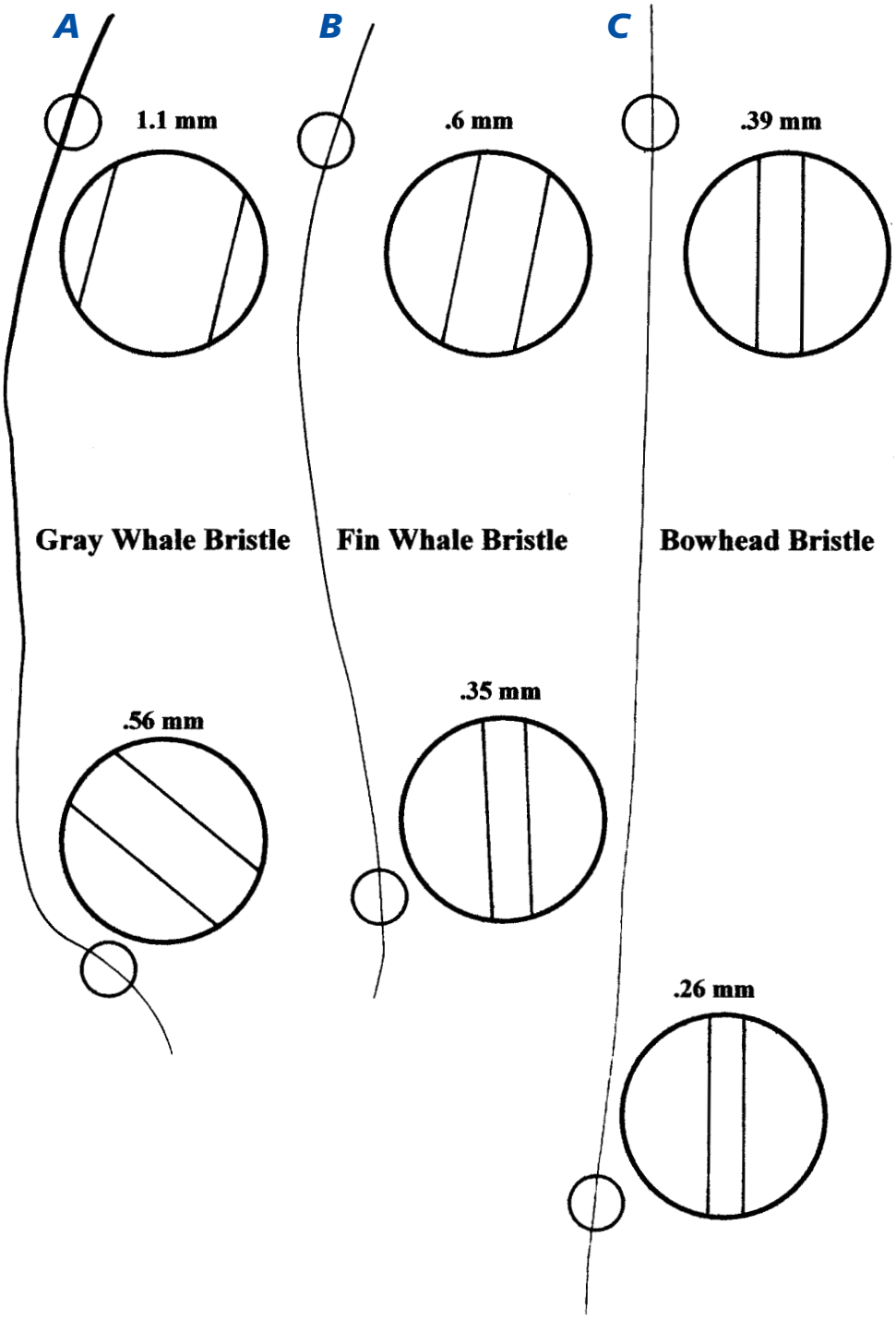
Student Worksheet #5-2

Bristles show adaptations for the various feeding methods of whales. Compare the bristles of each type of whale. Note the thickness of the bristles. (Illustration by Laura Hauck.)

Which is best for sucking and sorting food from sands and mud?_____

Which is best for skimming fine krill from the water?_____

Which is best for filtering gulped mouthfuls of water forced out through the baleen to capture small fish and krill?_____



Activity 7: How Much Food Do Whales Eat?

Concept
Whales eat an enormous quantity of food.

Materials
- ☐ Paper
- ☐ Pencil
- ☐ Copy of math problem

Subjects
- ■ Math
- ■ Biology

Time
15 minutes

Teacher information
Right and bowhead whales are examples of skimmer feeders. Right whales eat tiny copepods that live on the ocean's surface and make feeding dives for deeper swarms of prey. These whales skim the surface and dive through the waters with their mouths partially open. There is a gap at the front of the mouth between the two rows of baleen. Seawater streams through this gap and passes out through the fringes of baleen, leaving behind the small organisms trapped against the screen of baleen. Small crustaceans, principally copepods and euphausiids, form the diet of right whales. There is no evidence they eat fish.

Some baleen whales feed for only 4 or 5 months a year when they are in cold polar or upwelling regions that are particularly rich in food. A large whale swallows an estimated 2 tons of food a day and builds up a store of energy in the form of a thick layer of blubber. The blubber is believed to store energy that may last through the rest of the year, when food supplies are scare during their long migrations.

Toothed whales, on the other hand, feed on squid or fish. Sperm whales feed on squid, including the giant squid, and have very large, cone-shaped teeth. They are believed to feed year-round, although long, unpredictable periods of no food supply are likely to occur. All toothed whales have cone- or spade-shaped teeth. This tooth shape allows the animal to capture and hold prey. A large sperm whale eats an estimated $1^1/_2$ tons of food per day (International Whaling Commission Estimate).

Teacher key to student worksheet #7
1. 15,291 liters filtered per minute
2. 229.4 liters in one bathtub
3. 66.7 per minute
4. 4,002 per hour
5. $2^1/_2$ pickup loads
6. 5 pickup loads

Help students visualize measurements of quantity
A liter compared to a quart:
Fill an empty 1-liter soft-drink container with water. Pour it into a 1-quart jar. Add the remaining water to a measuring cup. How much more is a liter than a quart?

Visualizing a ton:
One ton = 2,000 pounds. A large, heavy-duty pickup truck will carry $^3/_4$ ton. Imagine: It would take two loaded pickup trucks to feed one sperm whale per day.

Name **Date**

Student Worksheet #7

Right and bowhead whales filter 15,291 liters of water per minute. A bathtub holds 229.4 liters of water.

1. How many bathtubs full of water equal the amount of water filtered by a right whale each minute?

   _____ liters filtered per minute

2. How many bathtubs full would equal the amount of water a right whale can filter in 1 hour?

   _____ liters in one bathtub

3. How many full bathtubs need to be filtered each minute? _____ per minute

4. How many tubs are filtered per hour? _____ per hour

Having difficulty visualizing a liter? Fill a 1-quart jar with water. Empty it into an empty 1-liter soft-drink container. Add the remaining water to a measuring cup. How much more is a quart than a liter?

How many tons of food are consumed by filtering all that water?
Bowheads eat up to 2 tons per day.

A large pickup carries $^{3}/_{4}$ ton of weight. One ton = 2,000 pounds.

5. How many pickup loads of food will the bowhead whale eat? _____ pickup loads

6. How many pickup loads of food will the blue whale eat? _____ pickup loads

3. Whale Habitats

To discover where whales live and what areas of the oceans are used for feeding or giving birth, we first must be able to find them. During the early whaling days, the word got out when whalers were successful. Since most of the whales had regular seasonal migrations or were plentiful at a certain place at a certain time, their locations were predictable. As places where whales hung out were discovered, the whaling fleets followed. When whaling vessels met at sea, they shared the stories, successes, and failures of the voyage. This was called "gamming." Also, the accuracy of maps and charts was improving, and locations where whales had been seen could be easily passed along. As you have learned, the whales that were the easiest to find and the slowest were the ones the whaling fleets went after first.

But the whalers' knowledge about the whales consisted only of where they could be found and how much whale oil they were likely to produce. That was all that was important to them to have a successful whaling voyage. Today, we are trying to bring them back from near extinction. And that means we must know not only where the whales are found, but also where they are going, what hazards they encounter in today's busy oceans, what they are eating and what is eating them, and where they mate and give birth. We must know what kind of habitat they need to answer many of these questions.

The early whalers knew little about habitat. After all, they could only guess what it was like under the surface of the ocean, and most of a whale's life is spent under the surface. The whalers knew only a little piece of the lives of whales, and we need to know the entire life cycle if we are to help whales recover. For instance, if we don't know what they eat, we can't protect that part of the ocean that produces their food source.

Oceans have many different habitats, and, like land habitats, they must provide food, water, oxygen, shelter, and living space. There are shallow water areas surrounding continents, habitats on continental slopes that drop to the ocean basin floor, and habitats on underwater mountain ranges and flat sandy plains. There are even habitats in deep ocean canyons, called trenches, that are nearly seven miles deep. There are undersea mountains and volcanoes, rocky reefs and coral reefs. Each of these areas can be called a habitat. Warm water zones, cold water areas, and areas where winds mix the waters in a process called upwelling, all contribute to the factors that make each habitat unique. Whales depend on different habitats just as land animals are associated with different habitats. Destroy or damage the habitat and the whales will decline in numbers.

As you learned in Activity 1, "Whale Fact Sheets," most references gave broad areas of the oceans as the habitats for whales. But scientists who are interested in whale biology must locate the specific areas of the oceans where these whales live and learn what makes the area important to the whales. Land animals can't survive when their habitats are destroyed. The same is true of whales. Using radio tags, oceanographic instruments, and satellite technology, scientists are tracking whales to find their feeding areas, calving grounds, and migration patterns. Once these areas are identified, scientists collect ocean data such as temperature, salinity, plankton abundance, and ocean bottom types (for example, mud sand, seamounts, etc.).

We know that whales seek out habitats that are very productive, areas that produce abundant food. Various regions of oceans are known to be very productive. These include cold polar waters, continental shelf areas that are shallower than areas of the open oceans, and areas of upwelling.

Cold polar areas can be very productive because these areas have long summer days with sunlight needed for plant growth. These same areas have winter storms that stir the waters, bringing deep water to the surface. This water carries nutrients that fertilize the phytoplankton, which in turn feeds the zooplankton. Cold water dissolves gases better than warm waters, and that also encourages plant growth.

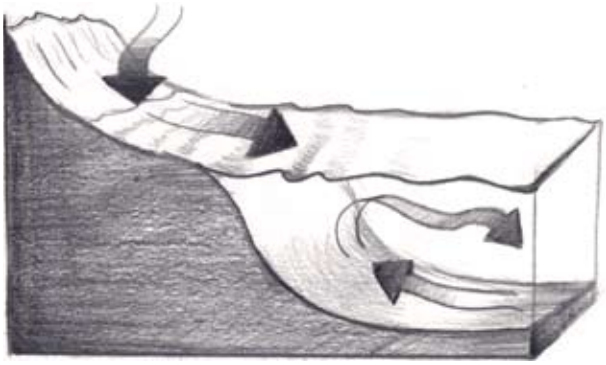
Continents' shelves are also productive, as nutrients can be stirred to the surface more

easily than in deep waters. Sunlight penetrates shallow waters to encourage plant growth.

Upwelling

Of all the places in the oceans, upwelling areas are the most productive. Cold deep water is drawn to the surface, carrying nutrients that fertilize the phytoplankton that forms the base of the food chain. Upwelling areas can be found along coasts, where winds push surface waters away front continents, or where ocean currents meet and stir the waters. Upwelling can also occur where surface currents create circular eddies that pull cold water to the surface, such as eddies in the Gulf of Mexico. Upwelling areas are most often found on the western margins of continents, such as the waters off British Columbia to California or off the west coasts of South America and Africa.

Whales, with their enormous need for food, are attracted to these most productive areas of the oceans. Summer feeding grounds are always found in food-rich waters. Winter regions where whales prefer to give birth usually offer shallow, warm, protected waters, but may not necessarily offer very good food supplies. These areas are often found around tropical islands or continental landmasses near the equator. The fact that gray, right, and humpback whales swim to winter calving areas and return to summer



Upwelling. (Illustration by Tai Kreimeyer, adapted from Ocean Oasis Teacher's Guide, San Diego Natural History Museum.)

feeding grounds with little feeding is one of the truly amazing events in the animal kingdom. The mothers must migrate to warm waters, give birth, then make the return trip with a nursing calf, on the energy stored in their blubber during the previous summer.

Seasons are opposite in the northern and southern hemispheres. Whale stocks of some species are found living both north and south of the equator. These stocks seldom interact because their migration patterns follow the seasons. Both northern and southern stocks winter in tropical waters but never meet, as winter occurs in different months north and south of the equator.

ACTIVITY 8: Identifying Whale Habitats

Concepts

Ocean habitats are different from land habitats and are shaped by ocean depths, ocean currents, ocean floor topography, and phenomena such as upwelling.

Materials

- ☐ Copies of Pacific habitat map
- ☐ Pencils
- ☐ Copies of the reading assignment "Habitats: Where whales live"

Time

15 minutes

Procedure

Distribute worksheets and follow the instructions.

Teacher notes

Students should select areas of upwelling, the shallow-water areas (continental shelves), and cold polar waters for the summer feeding-ground areas. These will have high plankton production. The winter calving areas can be warmer regions of the oceans near islands or land masses near the equator. Since scientists don't know where the breeding and birthing areas are actually located for each stock of whales, there will be no right or wrong answers. The idea is to encourage students to think about the need for rich summer feeding grounds and warm, protected waters for birthing.

Since the seasons are opposite in the northern and southern hemispheres, the stocks of whales, even if they are of the same species, probably do not mix, though they may both be using tropical waters close to the equator.

Teacher Key to map

Winter habitats: E, F, G

Summer habitats: A, B, C, D, E

Extension

Have students become whale scientists and tackle the question of the mixing of stocks at the equator. Challenge them to come up with a plan they could use to determine whether southern hemisphere whale species mix with northern hemisphere stocks. Have them identify:

- what months of the year they would need to set up observations
- what methods they would use to conduct the study
- what equipment they would use (ships, satellites, tags, planes, cameras, etc.)
- how they would identify individual whales to distinguish between northern and southern whales

Related activity

Whale Investigations, Activity 17

Ocean habitats are shaped by ocean depths, ocean currents, ocean floor topography, and phenomena such as upwelling.

Name **Date**

Student Handout #8

Instructions

Part 1

1. Read through the reading assignment, "Whale Habitats."
2. Draw a line across the Pacific habitat map to represent the equator.
   - Identify on the map the equatorial (warm) areas. Tropical areas of the oceans lie between the Tropic of Cancer and the Tropic of Capricorn (latitudes 23.5 degrees north and south of the equator).
   - Identify on the map the cold polar regions. Locate the Arctic and Antarctic circles.
3. Write the months of winter and summer for the northern hemisphere in the margins of the map next to the northern hemisphere. Then repeat for the southern hemisphere.
4. Draw arrows showing the migration direction for the southern and northern hemisphere whales from their summer feeding habitats to their winter calving areas. Will northern and southern hemisphere whales be using the warm tropical waters at the same time of year? Is there ever a chance that southern hemisphere right whales will meet and mix with northern hemisphere right whales, or will their stocks remain isolated from each other?

Part 2

5. On the Pacific habitat map, write the letter (A, B, C, etc.) from the list provided for characteristics of winter or summer habitats.
6. Locate and circle favorable summer and winter habitat areas for northern and southern hemisphere whales on the habitat map. Remember: they favor waters where they will find abundant food supplies for summer feeding grounds, but food supplies are not a critical factor for the winter calving areas.
7. Draw a line from the list of summer and winter habitats to the areas you have circled.

List of habitat traits for summer and winter whale habitats

A. Cold water

B. Well-mixed waters—includes shallow water areas near continents where storms or upwelling enrich the waters

C. High levels of dissolved gasses

D. Large number of plankton

E. Sunshine

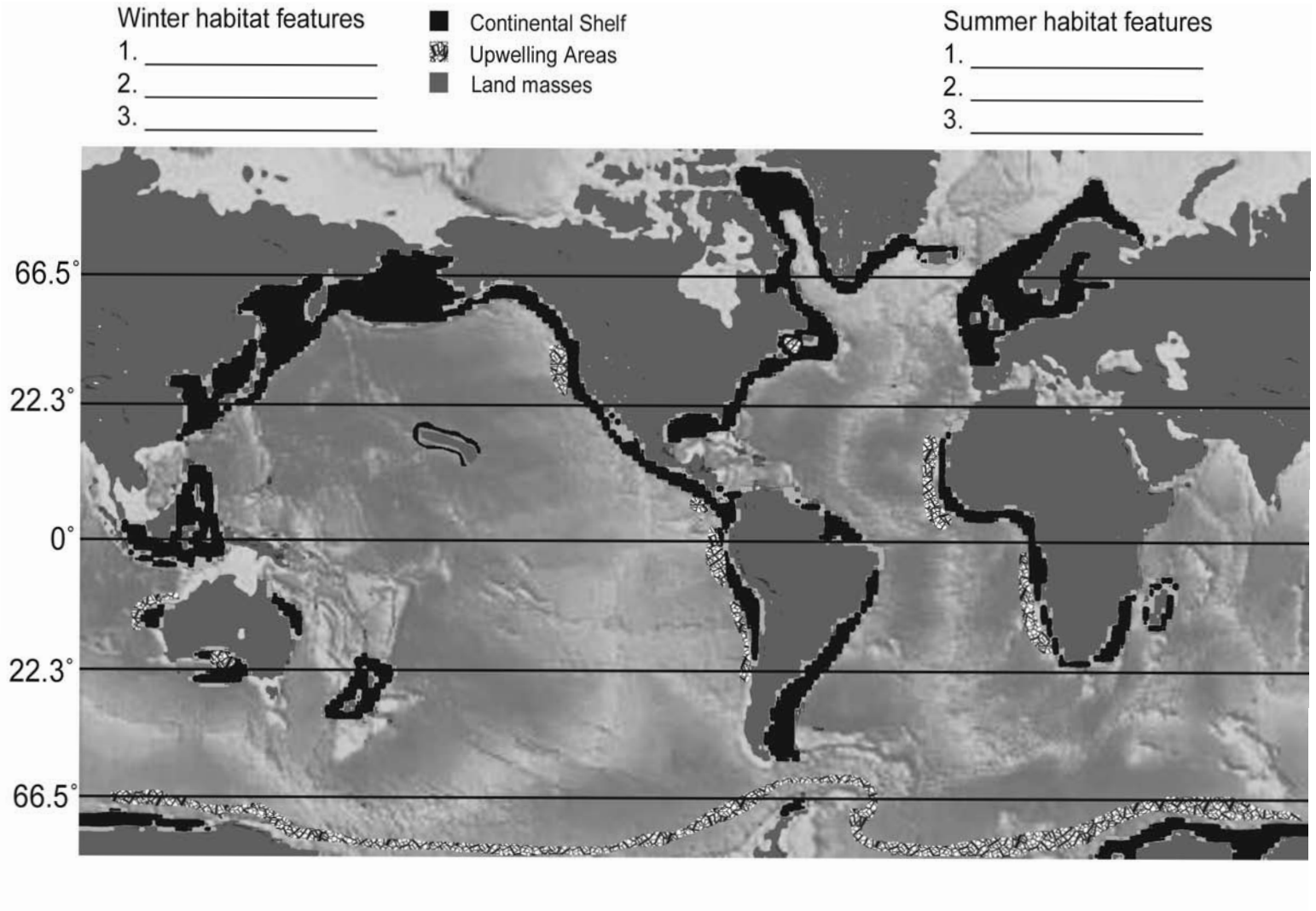
F. Shallow, warm waters

G. Little plankton production

Name **Date**

Student Worksheet #8

Whale habitat map



4. Exploitation of Whales

Whales have been hunted for centuries for subsistence purposes by coastal aboriginal (native) people all over the world. Subsistence hunting means that these early human hunters used the whales for food, clothing, and housing materials. Whales played such an important role in their lives that for many aboriginal peoples subsistence hunting was incorporated into their cultural traditions as well. Historical evidence indicates that right whales and gray whales were hunted in the North Sea and the English Channel from at least the 9th century.

Native people in many countries still hunt marine mammals for subsistence and cultural purposes today. For example, U.S. law permits Native Americans in Alaska (the Inuits) to hunt a limited number of bowhead whales for aboriginal subsistence purposes. However, the impact of such limited hunting pressure on marine mammal populations has been localized and small in comparison to industrialized whaling.

Industrialized whaling is the practice of hunting whales for commercial purposes. It began in earnest in the late 1800s. Whaling became an important industry because of the demand for clean-burning whale oil (from the whale blubber), which was used to light lanterns and gas lamps before electricity was invented. Other products from whales were also collected and sold at a high price, including baleen (a popular material used by women's garment makers in dresses and corsets in the 1800s). Whaling became a very rich industry that supported not only the whalers but shipbuilders, businesses that sold whale oil, and dress makers who used the baleen for dress stays.

Industrialized whaling used larger ships and specialized equipment for harvesting large numbers of whales. It soon severely reduced the numbers of many species of great whales, to the point they are now considered endangered. Endangered means that animals in a population are so few that without protection they may continue to dwindle to extinction.

Two of the most endangered whale populations are the Western North Pacific gray whale, found in waters near Japan (around 100 animals), and the North Atlantic right whales, near Maine and Nova Scotia (around 300 animals). In recent decades, whale hunting has dropped off dramatically across the globe, due to increased whale protection through national and international regulation. The new rules and international agreements have given whales a break, and fortunately some populations are beginning to recover.

The story of commercial exploitation is long and detailed. It begins in the 12th century with the Basques, a group of people who inhabited the coast of France and Spain. They used simple rowboats and handmade harpoons to hunt and kill whales. The Basques killed North Atlantic right whales because they were slow moving, had extremely long baleen, were located close to shore, and had an abundance of blubber. By the 1500s, the Basques had killed off the European North Atlantic right whales and began to make their way across the Atlantic and down the North American coast in search of more whales. This pattern of decimating one stock of whales then moving on to the next species or stock continued until not a species or stock remained untouched. (Stock is a geographically isolated population of whales that does not intermix with whales of the same species living in other parts of the oceans.)

Colonists in the New World were whaling during the 1700s. By 1750, right and bowhead whales were endangered and close to extinction. The gray whale was already extinct on the Atlantic Coast. In the early 19th century, American whalers (known as the Yankee whalers) expanded their hunting range into the Pacific and Indian oceans, searching for slow-swimming sperm, right, bowhead, and gray whales.

In the 1860s, the Pacific bowhead whale was specifically hunted by whalers for its long baleen (up to 14 feet). By 1900, bowheads were nearly extinct. When a substitute for baleen was invented (spring steel), the price and demand for baleen dropped and whalers stopped coming to Alaska for bowheads—just in the nick of time for the depleted bowheads.

Until 1880, blue and fin whales were virtually untouched by commercial whaling. They were too large, too fast, and they sank when they were killed. In the 1860s, the more powerful and efficient cannon-fired, explosive-head harpoon was invented. At the same time, faster steam-powered boats were being developed. These two mechanical developments allowed whalers to take large numbers of the faster-swimming blue and fin whales.

In 1900, Antarctica was discovered to be the greatest whaling grounds in the world. Antarctic waters were abundant with blue, fin, and humpback whales that had never been hunted. Humpback whales formed 95 percent of the total catch in the 1910–1911 whaling season, but their numbers quickly began to decline. By 1918, they comprised only 2 percent of the total catch.

Another development that accelerated the whaling industry was the discovery that liquid animal fats could be converted to solid fats by the process of hydrogenation. This gave rise to a thriving industry for the manufacture of soap, margarine, and nitroglycerine, all of which could be derived from whale fat.

At first, the processing of blue and fin whales was conducted from land-based stations. But then, the invention of the stern slipway in 1925 allowed seagoing ships to haul harpooned whales aboard for processing while at sea. The whalers no longer needed to come to shore to process their kills, which saved them time and money and allowed them to stay at sea longer, increasing the kill of whales dramatically from 176 blue whales in 1910 to 37,000 in 1931. In the Antarctic, from 1925 to 1935, there was the greatest slaughter of whales that had ever occurred. Afterward, blue whales became increasingly scarce and catches declined until they became commercially insignificant by the mid-1950s.

Whaling operations basically stopped during World War II as the whaling nations concentrated all of their resources into fighting the war. But the war caused a shortage of whale oil, and the end of the conflict encouraged several nations to begin whaling again. Without large populations of blue whales to exploit, whalers switched to the smaller, more numerous fin whales. By 1960, the fin whale population had plummeted and whalers began taking even smaller sei (pronounced “say”) whales. By the late 1960s, sei whales became commercially extinct and the whaling effort switched to the even smaller but more numerous Minke (pronounced “minky”) whales. Minke whales continued to be the target species until an international moratorium was enacted in 1986.

The massive take of whales eventually led to a surplus of whale oil on the market. Too much oil meant that the price would come down (they couldn’t charge as much) and the whalers would lose money. When the whalers took the hit in their pocketbook, they tried to self regulate and reduce the amount of oil being harvested, in hopes that the “shortage” they created would drive up prices.

The whalers didn’t know the long-term consequences of their whaling activities. Essentially, there was no management plan for whales…no rules or regulations for them to follow. As it turned out, commercial whaling demonstrated one bad example after another of how NOT to manage a wild animal population. Whalers were not motivated to care about dwindling whale numbers, because there was always another species to move on to.

Gray whale breaching. (Photo by Pieter Folken.)

At this point, stop and conduct Activity 10, "What's your Opinion?" Repeat the activity at the end of the lesson and ask students whether their opinions changed as they gained more information.

The first significant attempt at regulating international whaling activities came in 1946 through the establishment of the International Whaling Commission (the IWC). The IWC attempted to balance conservation with the economics of whaling. The mission of the IWC was "to provide for the proper conservation of whale stocks and thus make possible the orderly development of the whaling industry."

The IWC covers all commercial pelagic whaling activities of member nations. However, the IWC is limited in its ability to inspect and enforce its own rules and regulations. Any nation can "object" to any decision it doesn't agree with and excuse itself from the limitations of that decision. Member nations can also issue their own permits to take whales for scientific purposes. Although the IWC was established as early as 1946, the reduction in whale populations continued.

The IWC's system of self-regulation is a bit like "the fox guarding the hen house." In other words, the IWC was imposing regulations on itself that many of its members weren't inclined to follow. In fact, in recent years a few nations have issued themselves permits for "scientific purposes," but not without great skepticism and criticism from other IWC members. Much of that criticism has been generated by the public's changing attitudes and intolerance of whale harvesting and the resulting outcry and pressure put on the IWC by constituents of member nations.

Early IWC management procedures were based on the Blue Whale Unit (BWU) as a means of setting quotas. It was considered that one blue whale was equal to two fin whales, two and-a-half humpbacks, and six sei whales (based on their relative oil yields). In 1963, the total quota was 10,000 BWU. Whale experts and resource managers began to realize that a new management scheme was needed. The Blue Whale Units could be filled with only one species, which resulted in that species being decimated. The BWU management plan was not a successful program. In 1979, a proposal to end all commercial whaling except for Minke whales was adopted. In 1986 a moratorium was placed on all commercial whaling, with plans for conducting a comprehensive assessment of large whale stocks by 1990.

Enforcement measures still allowed members of the IWC to object to and reject any decision they didn't agree with. Norway objected to the moratorium and resumed commercial exploitation of Minke whales in the North Atlantic in 1994, even though the moratorium had not (and still has not) been lifted. Products from commercial whaling of Minkes in Norway are used for food, and admittedly, whaling has boosted the economies of coastal Norwegian communities. Finally, it is unlikely that a *limited* Norwegian harvest would harm the now-healthy Minke population. However, the IWC seeks to avoid the total unabated slaughter that brought the Minkes to endangered levels in the first place, and this is why Norway has received such criticism.

In 1994, the IWC accepted a revised procedure for estimating the number of whales that could be taken without causing the affected population to be reduced in numbers. Because some whale populations have recovered, it is possible that the IWC will allow the resumption of commercial whaling of some species (Minke whales, for example). The limited and sustainable harvest of some whale species should not have a negative impact on healthy populations. Some countries are still interested in harvesting whales because whale meat is considered a delicacy in their culture and whalers can charge a premium price for the meat.

United States has been active in whaling and in whale protection. Besides participating in several international marine mammal treaties and being a supporting member of the IWC, the U.S has also enacted legislation to protect Marine Mammals in U.S. territories. The Marine Mammal Protection Act (MMPA) of 1972 established a moratorium on the taking of marine mammals in U.S. waters and on importing marine mammals and marine mammal products into the U.S. This was the first full protection extended to all species of marine mammals.

Reductions in the number of whales available, new national and international regulations, changing market demands, and changing atti-

tudes about killing large whales for profit have all contributed to the collapse of large-scale, pelagic whaling. People have caused serious damage to marine mammals, and in some cases that damage is irreparable and irreversible. However, as we go into the 21st century, we can celebrate some successes in our attempts to protect marine mammals from extinction. For example, populations of most large baleen whales are increasing. These increases can be attributed, in large part, to the international and national regulations and management plans.

We must protect whales using a more comprehensive approach than just setting limits on whaling. Like terrestrial habitats and land animals, humans also impact ocean habitats and their inhabitants. In order to save the whales, our efforts must also entail protecting the places where they give birth and their feeding areas. If we lose these valuable habitats, we also lose the whales.

History of commercial whaling, at a glance

1100s	Basques hunt right whales in Bay of Biscay
1500s	Basques hunt in Newfoundland/ Labrador, Spitzbergen, etc.
1600s	Bowheads killed at Spitzbergen, Greenland; Atlantic gray became extinct
1700s	Sperm and humpback whaling in N. Atlantic; right whales, bowheads overexploited
1800s	Rights, bowheads, sperms, humpbacks, grays all heavily overexploited
1868	Svend Foyn develops explosive harpoon, harpoon gun, and steam-powered catcher, begins exploitation of blue and fin whales, etc.
1905–1920	Antarctic whaling begins
1925–1939	Heavy blue whaling in Antarctic
1939–1945	World War II—whaling efforts ceased
1946	International Whaling Commission formed to regulate harvest of whales
1935–1965	Heavy fin whaling in Antarctic
1965	Blues and humpbacks given complete protection
1950–1975	Heavy sperm whaling worldwide (highest-quality lubricating oil in the world)
1960–1975	Heavy sei whaling in Antarctic
1972	U.S. passes marine mammal protection act to ban taking marine mammals in U.S. waters.
1979	Proposal to end all commercial whaling except for Minke whales
1970–2003	Limited Minke whaling in Antarctic by Norway and Japan

List of products from whales

Early whaling days

Whale part	Use
Blubber	Oil for lamps Leather tanning Cooking Soap Oil base for paints
Baleen	Buggy whips Thin, flat pieces were used to stiffen men's shirt collars and ladies' corsets Fishing rods Umbrella ribs

Present-day uses

Blubber	Hydrogenated into margarine Soap Nitroglycerine
Muscles	Canned and sold in supermarkets Liver is sold in meat markets Pet food Fertilizers
Sperm whale teeth	Scrimshaw—the ivory is etched and blackened for art pieces

ACTIVITY 9: Exploitation: Whale Populations Then and Now

Concept

Overharvest has depleted whale populations.

Materials

- ☐ Whale population chart
- ☐ Pencils

Subjects

- ■ Math
- ■ Biology

Time

1/2 hour

Teacher key

Whale population chart answers

Whale	% of whales left	% increase or decrease
Gray	85%	15% decrease
Humpback	13%	87% decrease
Northern right	3%	97% decrease
Antarctic blue	1%	99% decrease
Bowhead	26%	74% decrease
Sperm	81%	19% decrease

Name **Date**

Student Worksheet #9

Whale population chart

Species	Pre-whaling Estimate	Present Population	% left	% Change more + or less -
Baleen whales				
Gray	26,000	22,000		
Humpback	115,000	21,500		
Northern right	10,000	300		
Antarctic blue	150,000	1,400		
Bowhead	30,000	8,000		
Toothed whales				
Sperm	2,400,000	1,950,000		

Divide present population by pre-whaling population to find the percent population left. Subtract from 100 percent to find percent loss or gain in population.

Northern right whales have the most reliable population numbers. The numbers for the other whales represent best estimates. Reliable data is difficult to obtain.

Sources

Original population estimates

Congressional Records Service 1997, in "A Universal Metaphor: Australia's Opposition to Commercial Whaling," Report of the National Task Force on Whaling, Environment Australia, May 1997.

Antarctic blue whales: Seiji Ohsumi, http://luna.pos.to/whale/jwa_v10_oh.html. Retrieved 1/05.

Present population estimates

Sperm whale: International Whaling Commission, Whale Population Estimates, http://members.aol.com/cmwwrc/marmamnews/93051003.html

Antarctic blue whale: International Whaling Commission, http://22.iwcoffice.org/Estimate.htm. Retrieved 1/05.

Northern right whale: NOAA National Marine Fisheries Service, "Facts about Northern Right Whales," http://www.nmfs.noaa.gov/prot_res/species/Cetaceans/rightwhalefacts.html. Retrieved 1/05.

Humpback whale: http://nmml01.afsc.noaa.gov/education/cetaceans/humpback2.htm. Retrieved 1/05.

Gray whale: "Pacific gray whale population estimate released," http://www.fakr.noaa.gov/newsreleases/2002/gwhalepop_0502.htm. Retrieved 1/05.

ACTIVITY 10: What's Your Opinion?

Concept
Drawing conclusions and forming personal opinions on an issue.

Materials
None

Subjects
- Communication

Time
10–30 minutes

Procedure
Conduct this activity after the first part of the reading assignment and again at the end of the reading, to see whether students' attitudes change as they learn more about the issue.

Teacher asks students to:

- Review the meaning of subsistence hunting.
- Share their thoughts, feelings, and opinions about subsistence hunting.

  —Teacher may choose to use an "opinion continuum" (see example below) to demonstrate the diversity of opinions about this subject.

  —Teacher draws the continuum on the board or on an overhead and asks students to come to the front of the class and make a mark on the continuum indicating their feelings about whale hunting. Have students stand in a line according to their opinion on the continuum—those against whaling on one end and those for whaling on the other, just as it appears on the black board. Divide students into groups of three, representing each level on the continuum. Have them take turns explaining their opinion to one another and have them back up their arguments with as much information as possible.

  Have each group list one or two of their best reasons on the black board or present it to the whole group at the end of the activity.

  —It's important to remind the students that everyone is entitled to his/her own opinion. There isn't necessarily a right or wrong answer in this exercise.

Discussion questions
- Ask students to define sustainable whaling.
- Ask students to recall the first "opinion continuum" activity. Now that the students have more information, have their opinions about whaling changed? Construct another opinion continuum and compare these results to results from the first round.

Related activity
Activity 23, "Whaling debate"

Whale hunting opinion continuum

No whale hunting EVER!!! | Some whale hunting is OK. | I have no problem with whaling!

ACTIVITY 11: Early Whale Management

Concepts

- Politics and greed played an important role in whale management in the early days.
- Animal populations must be protected from overexploitation.

Materials

- ☐ Paper
- ☐ Pencil

Subjects

- Sociology
- Biology

Time

15 minutes

Procedure

Direct students to complete whale exploitation reading, and complete the worksheet.

Teacher key to student worksheet

Calculate the total oil collection or BWUs for the following whale takes.

1. 10,000 fin whales = 5,000 BWU

   5,000 BWU X 20 tons oil/BWU = 100,000 tons of oil
2. 1 BWU= 20 tons of oil

   Answer: 9,750/20 = 487.5, or 488 whales
3. That species would be depleted.
4. Yes
5. Why or why not? NO. It does not consider individual whale stocks but establishes one set of rules to govern all stocks.

Marine Mammal Protection Act answers

1. It was the first legislation that took into consideration all stocks of whales.

   It was the first legislation passed by a governmental agency rather than representatives of whaling interests.
2. The IWC did not look at individual stocks of whales. Entire species of whales could be wiped out under this system.
3. Most marine mammal species are increasing in numbers under this protection, although recovery is very slow for some species.

Extension

Set up a bulletin board showing the past and present use of whale products.

Name **Date**

Student Worksheet #11

Blue Whale Units (BWU)

1 BWU = one blue whale = 20 tons oil

1 BWU = one blue whale, or two fin whales, or two and-a-half humpback whales, or six sei whales

Calculate the total oil collection, or BWUs, for the following whale takes:

1. From 1950 to 1955, the crew of the *Revolution* harvested 10,000 fin whales. How much oil did they collect?

   _____BWU _____amount of oil

2. In 1850, the crew of the *Margaret* collected 9,750 tons of oil from blue whales. Approximately how many whales did they harvest?

   _____whales

3. What would happen if the entire BWU quota had been met by taking only one species of whale, like the fin whale, for example?

4. Could whalers wipe out a species even while following regulations? Explain.

5. Does the BWU system seem like a sustainable management plan? Why or why not? Explain.

Marine Mammal Protection Act

6. Why was the MMPA a significant piece of legislation?

7. How is this different from the International Whaling Commission's (IWC's) blue whale quota system?

8. Is there evidence that the MMPA has indeed protected marine mammals in U.S. waters? Give examples.

ACTIVITY 12: Lessons Learned from the Whaling Experience?

Concepts

- The demand for whale products led to depletion of whale stocks.
- Whale depletion experiences are similar to other natural resource problems.
- It is difficult to regulate natural resources that have high commercial value.

Subjects

- Biology
- Economics

Materials

- ☐ Paper
- ☐ Pencils

Procedure

Read through the boxes discussing commercial fish harvest on both the east and west coasts of the U.S.

Time

30 minutes

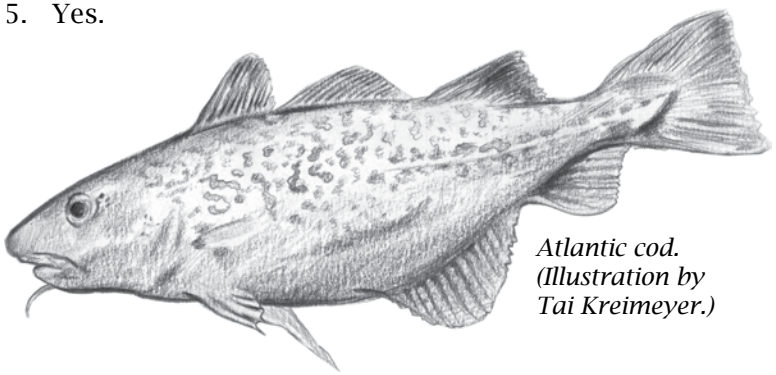
Teacher's note: These fish have been overharvested, much as the whales were. Unlike whales, however, the fish are not endangered, because they release millions of fish eggs and larval fish each year. Like whales, the age of the fish and the numbers of babies they can produce determines whether the populations recover quickly or slowly (see Activity 19, comparison of recovery of right whales with gray whales). Rockfish are very long-lived, and their older age of maturity when reproduction begins slows the recovery rate for their populations.

Before completing the study questions:

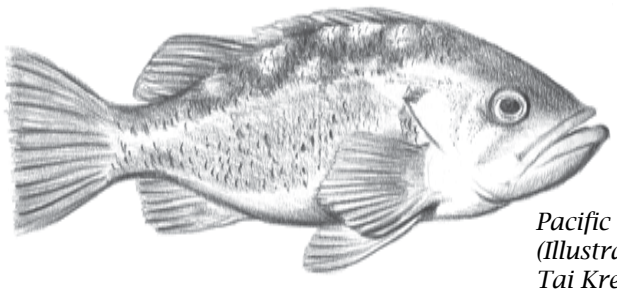
- Lead a discussion about the causes of overharvest. Introduce the idea of other valuable natural resources being in danger of depletion.
- Introduce the concepts of renewable and nonrenewable resources.
- Encourage students to come up with their own answers to the study questions. If they find this too difficult or the solutions inappropriate, have them use the list provided.

Teacher key to student worksheet

1. Cod/haddock. They begin reproducing at a younger age.
2. Financial hardship for fishermen, processors, and seafood markets.
3. Fishermen, seafood processors, truckers who deliver fish, seafood markets.
4. Any of the answers are acceptable. Encourage students to find their own before using the list.
5. Yes.



Atlantic cod. (Illustration by Tai Kreimeyer.)



Pacific rockfish. (Illustration by Tai Kreimeyer.)

6. Renewable resources:
   B, C, E, F, G, H

   Nonrenewable resources: A, D

A. Oil	E. Cod
B. Rainforests	F. Rockfish
C. Salmon	G. Solar power
D. Diamonds	H. Wind power

7. A renewable resource is one that can be replaced in nature at a rate close to its rate of use. Examples are oxygen in the air, trees in the forest, food grown in the soil, and solar energy form the sun.

   A nonrenewable resource is one that is used up faster than it can be replaced in nature. Many of Earth's resources are nonrenewable because of their very slow rate of replacement. These include metals, oil, coal, etc.

   Source: Namowitz and Spaulding, *Earth Science*, D.C. Heath and Company, Lexington, MA 1989.

8. Possible causes of overharvest. Rockfish and cod, like whales, have high values and many people can earn a living from the resources. Causes of over harvest may include:

   - High demand for the product
   - The pressure to harvest as many fish as possible for financial gains pushes the animal's populations beyond their ability to repopulate.
   - Regulations to protect the resource rather than reaping as much profit as possible are unpopular and met with great resistance.

Name **Date**

Student Worksheet #12

1. Which of these fish stocks are expected to recover more quickly?
   ☐ Rockfish ☐ Cod/haddock Why?

2. What financial impact do you think the fisheries closures caused?

3. Who would have been impacted by the closures?

4. Why is it so difficult to keep from overharvesting valuable natural resources?

5. Are the reasons for overharvest of fish about the same as for whales? ☐ Yes ☐ No

6. Nonrenewable resources are also being depleted. Decide which are renewable or nonrenewable resources and write the letter in the proper blank

   Renewable resources: _____ Nonrenewable resources: _____

   A. Oil B. Rainforests C. Salmon D. Diamonds
   E. Cod F. Rockfish G. Solar power H. Wind power

7. What makes a resource renewable or nonrenewable?

8. Explain why each resource you listed is renewable or nonrenewable.

East Coast—groundfish (cod and flatfish, such as haddock)
Traditional groundfish resources on the East Coast have been overfished and the numbers of fish have dropped to extremely low levels. Fishing was greatly reduced in the mid 1990s to allow the fish stocks to recover.

- Atlantic cod grow to be 10 to 15 years of age.
- Females begin reproducing at three years of age.
- Female cod and haddocks release up to two million eggs each.

West Coast—rockfish stocks
Rockfish stocks on the West Coast have been fished so heavily that drastic measures were enacted to save the fish. Large areas were closed to fishing on the West Coast in 2000–03 to allow these fish populations to recover.

- Rockfish species grow to be 50–80 years of age.
- Many species of rockfish do not begin to produce eggs until they are 10–15 years of age.
- Rockfish give birth to millions of babies (they are just barely past the egg stage).
- The older and larger the females, the more young they produce.

5. Current Threats to Whales

There are few environmental issues that do not directly relate to human impacts on the planet. These impacts are harmful to the great whales. Most conservation issues for whales are now tied directly to human impact on ocean habitats, on which these great creatures depend.

Human activities and the world's oceans

People, people! They are everywhere, and every year 81 million more are added to the Earth's population, according to 2001 statistics. The world's population is predicted to grow from the present 6 billion to 10 billion before leveling off. There is no doubt that people impact the Earth. Although the number of whales that are killed each year has been drastically reduced, human activities bring threats that have replaced whaling as the major concern for saving these unique animals.

Human population growth, both globally and in the U.S., adds more toxic chemical pollutants to the water, intensifies the need to explore for more oil and gas, and increases the number of ships on the seas for shipping products from country to country. More people create more demand for fish. Adding more humans to the planet also releases more carbon dioxide into the air, which in turn traps heat and changes climates.

We may be protecting whales from hunting, but there are many other issues that concern agencies working to protect whales in the 21st century.

Oil and gas exploration

Ever-growing demand for gas and oil creates pressure to find new sources as old fields are depleted and shut down. The ocean floors are now areas of oil exploration. Seismic exploration uses loud explosions to send sound waves to the ocean floor's rock and sediment layers. This information can be used to identify rock stratum that are likely to hold oil reserves. The explosions—as well as drilling and oilrig platform construction—in whale habitats is thought to disrupt and harm whales.

Mining and mineral extraction

Mining the ocean is accomplished by dredging (scooping or sucking up) sand, which is used to make cement and to replenish the sand that is vanishing from some beaches. Other items that we mine from the oceans include gravel, phosphates (an ingredient in fertilizers), petroleum, natural gas, and salt.

Chemical pollution

Chemicals from farming, industry, and home use wash into the sea. They accumulate through the food chain and contaminate animals that feed at the top of the food chain. Dead killer whale calves wash up on our beaches. When examined, they may contain high levels of toxic chemicals. Mother orcas give birth at age 11. West coast orcas, especially those in the Puget Sound, give birth to their first calf at age 15. Scientists speculate that these whales also have calves at age 11 but the newborn may die from PCBs and other contaminants and are never observed. The 11-year accumulation of pollutants is passed to the calf in the womb and through the mother's milk. Subsequent calves survive because they get a smaller dose of the toxins as the accumulation has been passed on to the first born. Industrial and toxic wastes placed into landfills, chemicals from farming, chemicals put on our lawns, and oil from cars all eventually wash into the ocean waters and into whale food supplies.

Fishing gear entanglements

We harvest millions of tons of fish from the oceans each year, and the demand continues to grow. Fish are the primary source of animal protein for one-half of the world's people, and fishmeal is added to food for livestock. Fishermen use various types of gear, from large nets, that are dragged through the water, to traps that are set on the bottom and marked with ropes and floats that extend to the surface. Nets accidentally tear loose and pots and traps get torn away by storms, and whales often become entangled in the nets or ropes.

Shipping

Automobiles, electronics, clothing, wheat, and petroleum are a few of the products transported

across oceans in ships. Without shipping, it would be very difficult to move products from some regions to others. Near large ports, shipping lanes can be quite congested. The big propellers on these ships can kill or seriously injure slow-moving whales.

Tourism

Whale watching and recreational boating are very popular along the East and West coasts, as well as in Hawaii. There is concern that boating activities may be stressful to whales. Regulations have been enacted to maintain boats at a set distance from whales.

Sounds

Military activities can produce loud sounds in the oceans. The use of sound for oil exploration and low-frequency sonar used to locate submarines also create intense sounds. Whales use sounds to navigate, find food, and communicate. How disruptive is a noisy ocean to whales? We know that loud sounds in some areas have harmed whales, and research is being conducted to assess the problem.

Climate change

People burn fossil fuels for energy and transportation. This adds massive amounts of $C0_2$ (carbon dioxide) to the atmosphere every year. $C0_2$ traps heat from the sun and warms the earth. We are adding so much $C0_2$ that scientists believe it is changing the climates of the world. Whales have survived for millions of years and lived through shifts from ice ages to warm periods. During past climate changes, whale populations were large and healthy. We have reduced numbers of whales to the point where they are endangered. We know that climate events such as El Niños can stress whales and increase whale mortalities (upwelling is depressed and productivity reduced). Can the great whales survive changes in ocean habitats that will result from climate change? We don't know.

Ocean acidification

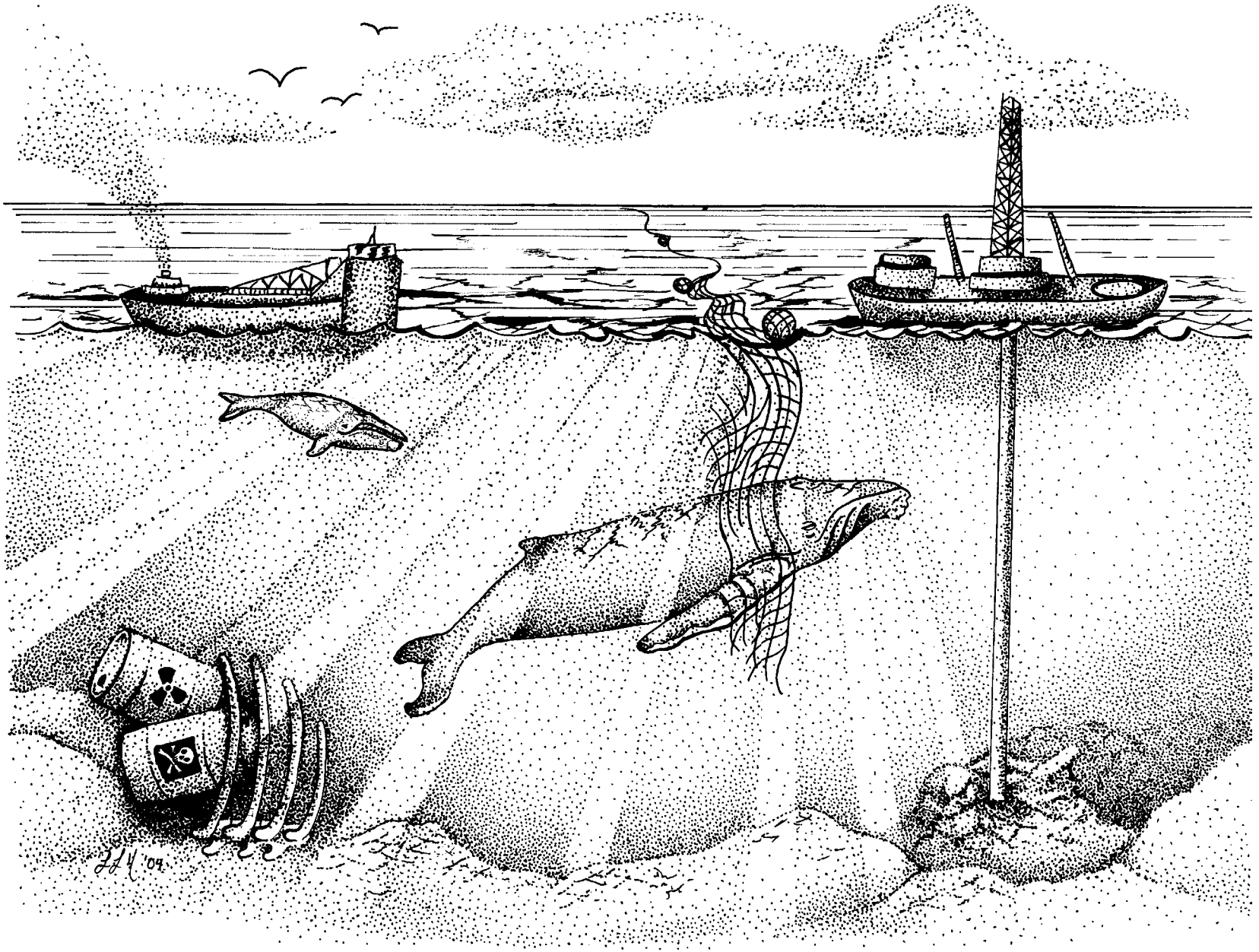
NOAA cruises in 2007–08 brought the discovery that the world's ocean waters are becoming acidic. Millions of tons of carbon dioxide are released into the atmosphere each year from the burning of fossil fuels. At the interface of the ocean and air, a mixing of $C0_2$ into the waters occurs and the chemical reaction produces carbonic acid. A number of studies have demonstrated that acid adversely affects marine organisms, especially animals with calcium shells such as corals. Negative impacts have also been observed on the tiny organisms that make up plankton, both plant and animal, as acid reduces the organisms' ability to maintain a protective shell. All whales depend on plankton either directly or indirectly, as it is the base of the ocean food chain. Acidification is expected to increase as $C0_2$ continues to be released and accumulates in the atmosphere.

Polluting coastal waters

Many people are attracted to the shore to live or vacation. In fact, 50 percent of the population of the United States now lives within 50 miles of a coast. By 2010, it's projected that the number will increase to 60 percent. People bring land development that removes forests and replaces them with houses, shopping centers, and industries to produce the products they use. Human activities produce toxic chemicals that are washed away by the rains into the rivers and streams and oceans.

There are very few environmental issues that cannot be directly related to people and human activities. People are the source of pollution, and their activities destroy animal habitats both on land and in the oceans. There are ever-increasing numbers of humans on the planet. Is there a correlation between the pressures of human populations and the health of whale populations?

Human threats to whales



Threats to whales by species

Threats to whales	Stocks	Gas and oil exploration	Fishing gear entanglements	Shipping collisions	Sound seismic	Tourism	Climate shifts (el Niño) disrupt food supply	Environmental pollutants
Sperm	Gulf of Mexico	√			√			
Right	New England		√	√		√		
Blues	Mexico/ S. California				√		√	
Gray	Alaska/Mexico	√	√			√	√	
Humpbacks	Alaska/CA Hawaii		√			√	√	
Orca	Eastern Pacific					√		√
Bowhead	Arctic areas	√				√	√	√

Source

Dr. Bruce Mate, Oregon State University. Personal communication, May 2004.

ACTIVITY 13: People and Whales

Concept

Human population growth creates threats to whales.

Materials

- ☐ Duplicates of graphs, grid of threats to whales, and "Threats to Whales" reading

Subjects

- Sociology
- Biology

Time

1 hour

Procedure

Student instructions

- Plot these numbers on the graph below and connect the dots.

  World population growth

1927	2 billion people
1960	3 billion
1974	4 billion
1987	5 billion
1999	6 billion

- Using the information you just plotted, estimate how many people will be on Earth in the years 2015 and 2025. Mark it on the chart and extend the line.

Teacher key to student worksheet #13-1

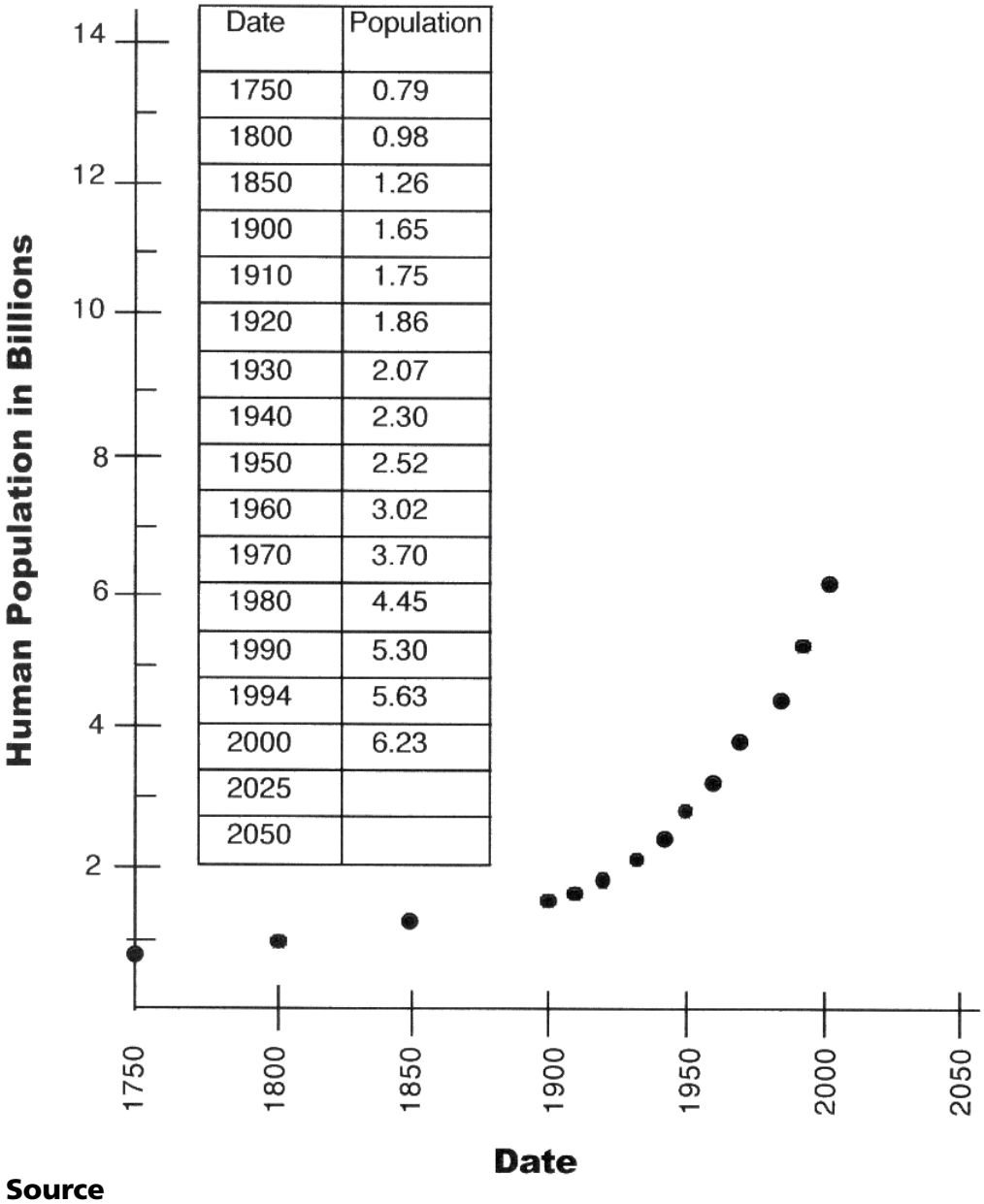
1 and 7: see the chart key.

2. a. 30,303.030
   b. 71,428,571
   c. 83,333,333
3. The population keeps increasing every year as there are more births than deaths, and there are more young people each year who enter their childbearing years.
4. Eight years.
5. a. More toxic chemical pollutants.
   b. Oceans will be warmer from global climate change that could reduce productivity. Ocean currents may change, which could greatly affect their habitats.
   c. More shipping, oil exploration, etc.

   Whale habitat: existing problems will likely worsen while some habitats could be greatly affected.
6. a. Better health care.
   b. Cultural beliefs that encourage large families.
   c. Little effort is being made to slow population growth.
7. a. War.
   b. Starvation.
   c. Disease.
   d. Easier access to birth control methods.
   e. Better medical care, and higher living standards for all nations.

World Population Growth 1750–2050

Date	Population
1750	0.79
1800	0.98
1850	1.26
1900	1.65
1910	1.75
1920	1.86
1930	2.07
1940	2.30
1950	2.52
1960	3.02
1970	3.70
1980	4.45
1990	5.30
1994	5.63
2000	6.23
2025	
2050	



Source

www.**world**bank.org/depweb/beyond/beyondco/beg_03.pdf. Accessed Jan. 2005.

Teacher key to student worksheet #13-2

1. a. 1970–1980: 35,000,000
   b. 1980–1990: 50,000,000
   c. 1990–2000: 75,000,000
2. a. Yes.
   b. Both growth rates are getting steeper.
3. a. 47 million
   b. 53 million
4. 1990–2000
5. 1930–40—This was the decade of the depression. Many people were out of work and could not sup-

port children. As a result, the birth rate dropped.

6. No, growth cannot continue indefinitely.

   Another depression would slow the growth.

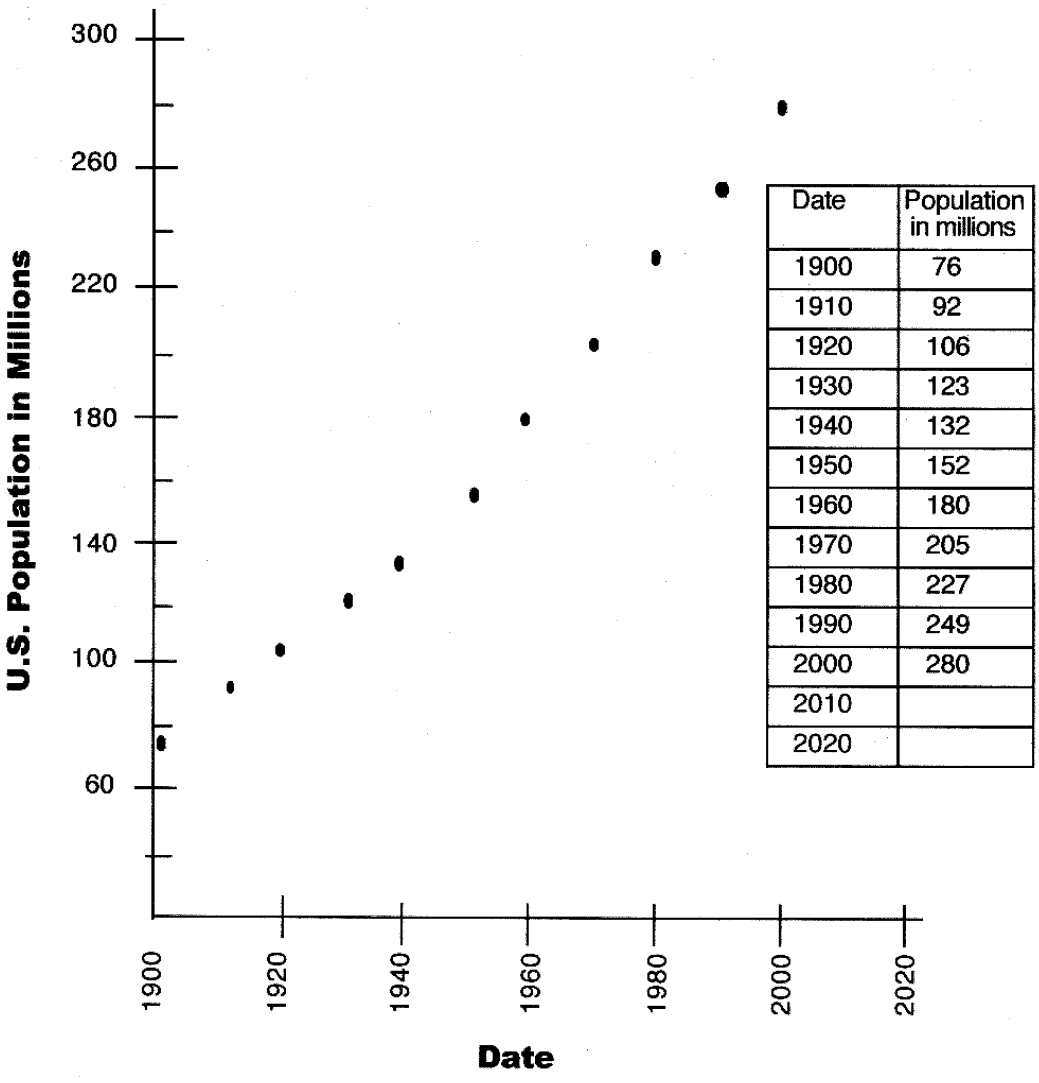
   War.

   Disease.

7. Both ocean and land habitats will likely continue to be degraded.
8. Faster rates of immigration, and trends toward larger families.

U.S. Population Growth

1900-2020



Date	Population in millions
1900	76
1910	92
1920	106
1930	123
1940	132
1950	152
1960	180
1970	205
1980	227
1990	249
2000	280
2010	
2020	

Source

F. Hobbs and N. Stoops, "Demographic Trends in 20th Century," U.S. Census 2000. www.census.gov/prod/2002pubs/censr-4.pdf. Accessed Jan. 2005.

Name **Date**

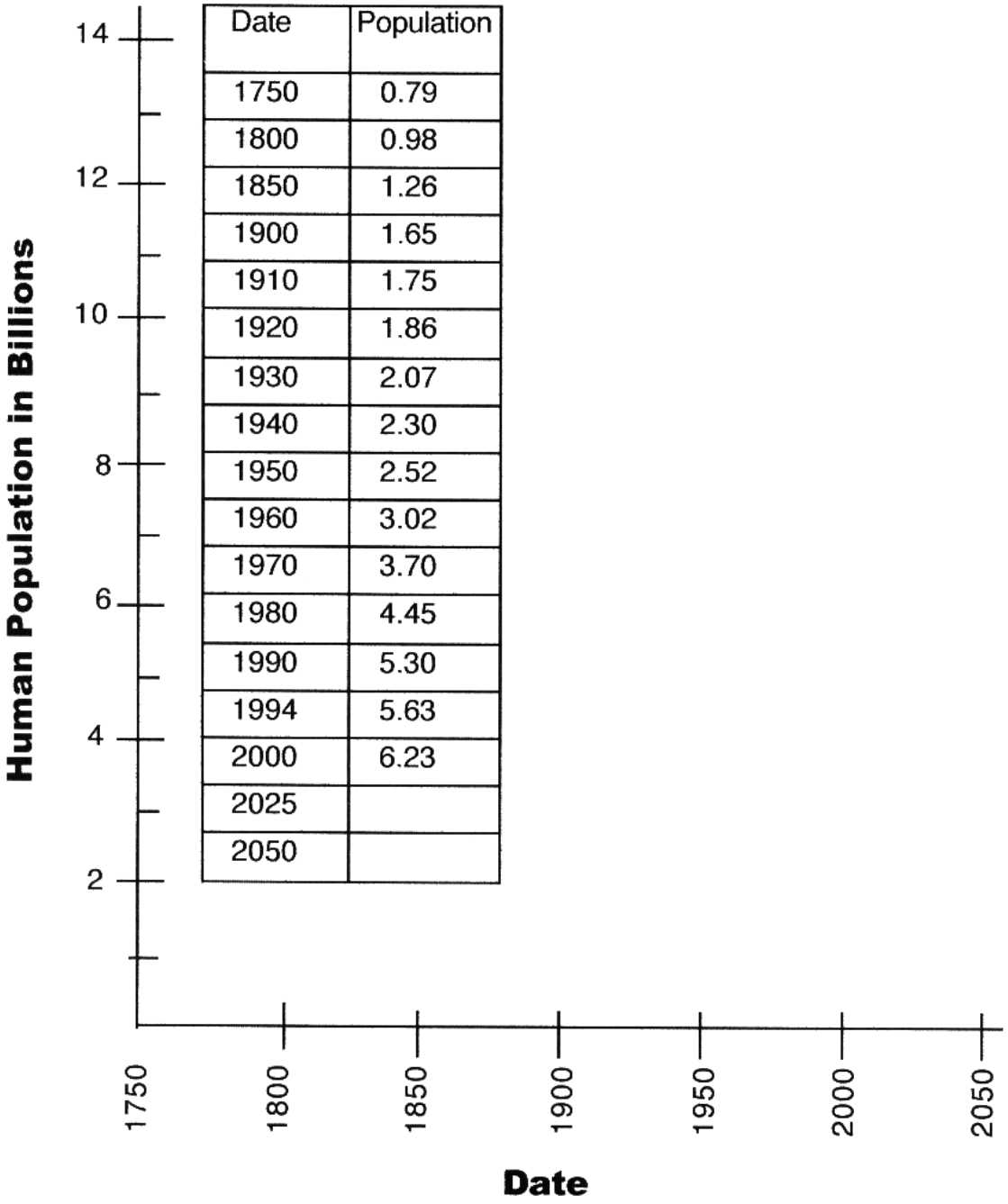
Student Worksheet #13-1

World population growth

1. Plot the date and the number of people to create a graph of world population growth.

World Population Growth 1750–2050

Date	Population
1750	0.79
1800	0.98
1850	1.26
1900	1.65
1910	1.75
1920	1.86
1930	2.07
1940	2.30
1950	2.52
1960	3.02
1970	3.70
1980	4.45
1990	5.30
1994	5.63
2000	6.23
2025	
2050	



Name **Date**

Student Worksheet #13-1 continued

2. a. One billion people were added between 1927 and 1960. On average, how many million people were added each year? _____

   b. The next billion people were added between 1960 and 1974. On average, how many million people were added each year? _____

   c. The next billion were added between 1987 and 1999. On average, how many million people were added each year? _____

3. Why is there an increase in the average number per year?

4. Analyze the data you just gathered and extrapolate how many years will it take to reach the next billion. _____

5. Demographers estimate that, by 2050, the Earth's human population will reach 11 billion. List three effects you think that will have on the oceans.

   a.

   b.

   c.

   What do you think may happen to whale habitats?

6. What are some of the factors that are making the population grow so fast?

   a.

   b.

   c.

7. What are some things that might slow world population growth?

   a.

   b.

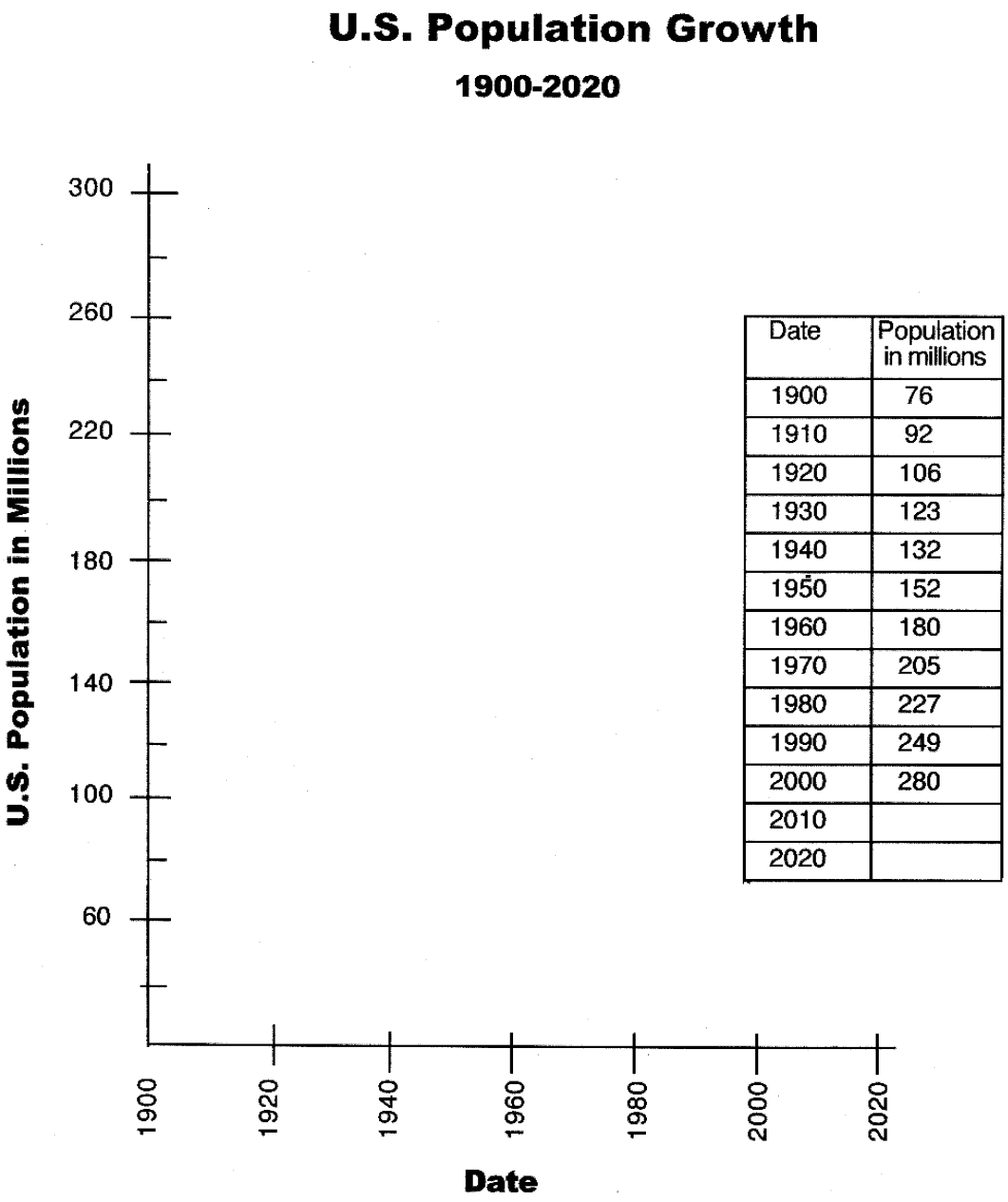
   c.

Name **Date**

Student Worksheet #13-2

U.S. population growth

1. Complete a graph of U.S. population growth by plotting the population size of the U.S. for each decade and connecting the dots.



Date	Population in millions
1900	76
1910	92
1920	106
1930	123
1940	132
1950	152
1960	180
1970	205
1980	227
1990	249
2000	280
2010	
2020	

2. Compare the graph of U.S. population growth with the graph of world population growth.
   a. Do the graphs look similar? ☐ Yes ☐ No
   b. Is either graph leveling off, or getting steeper (indicating faster growth)?

Name **Date**

Student Worksheet #13-2 continued

3. a. From 1900 to 1930, how many people were added to the U.S.? _____
   b. From 1980 to 2000, how many people were added to the U.S.? _____
   Why was there such an increase in the rate of growth?

4. Which decade had the most rapid growth rate? _____
5. One decade had slower growth than the others. Why did the rate slow during that period?

6. Can the upward spiral of growth continue indefinitely? What will slow or level off the growth?

7. What factors could speed population growth in the U.S.?

8. What are the implications of rapid population growth on U.S. ocean habitats and terrestrial habitats?

ACTIVITY 14: Whale Conservation Issues

Concepts
Human activities and population growth have negative impacts on whales.

Materials
- ☐ Reading materials
- ☐ Chart below
- ☐ Pencil

Time
15 minutes

Subjects
- ■ Biology

Procedure
Look at the graphs of human population growth both globally and in the U.S. alone. If the human population continues to grow and put pressure on habitats for marine animals, what measures could we take to help protect whale habitat?

Column 1—consider whether population growth will increase or decrease threats to whales, and circle your choice.

Column 2—possible solutions: Encourage students to discuss and develop possible solutions. Compare their work with the solutions list below.

Solutions list
Select from the list and add the numbers to column 2.

Short-term solutions

1. Develop ropes and nets for fishing that will rot away quickly.
2. Put a limit on the number of recreational boats that can be docked on the coastline.
3. Move shipping lanes to avoid whale habitats.
4. Pass strict laws to protect rivers and beaches from pollution.
5. Purchase canoes, kayaks, or sail boards for recreational boating.

Long-term solutions

6. Encourage only two children per family. Fewer people would reduce demand for oil and gas and other natural resources.

Threats to whales—issues and solutions

Will increasing human population growth increase or decrease this problem?

	Circle one choice below	Possible solution
Oil and gas exploration	Increase or decrease	
Fishing gear entanglement	Increase or decrease	
Shipping collision	Increase or decrease	
Sound pollution in oceans	Increase or decrease	
Tourism (land based and boats)	Increase or decrease	
Climate change	Increase or decrease	

Long-term solutions continued

7. Purchase house close to place of employment, to reduce commuting. Drive less—reduces $C0_2$ emissions thought to cause climate change.
8. Support aid to developing countries to provide family planning. Fewer people would reduce demand for oil and other natural resources.
9. Reduce demand for oil and gas—drive fuel-efficient cars: Less demand for oil reduces need for exploration and building oil drilling platforms.
10. Introduce land-use laws that would prohibit development within $^1/_8$ mile of the coastline. Reduces runoff of toxic pollutants and protects habitats.
11. Use biodegradable products.
12. Encourage strict pollution regulations for industries.

Population growth extension activity

Population growth creates negative issues for the environment. Are there benefits from population growth? Direct students to think through what benefits may result from population growth. Suggest the three issues below to help them along.

- More workers to support retirees
- More demand for products to build strong businesses
- More demand for housing, creates higher housing costs that bring profits to home owners and developers.

Debate pros and cons of population growth.

ACTIVITY 15: Bioaccumulation of Toxic Chemicals

Concepts
Toxic chemicals accumulate in top predators through the food chain.

Materials
- ☐ Index cards
- ☐ Magic marker

Student participation
All class members

Subjects
- ■ Biology

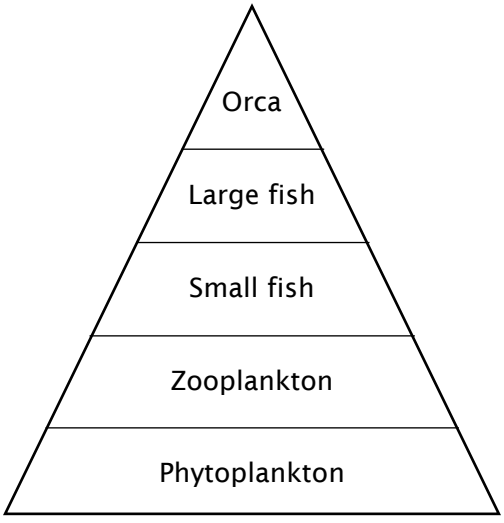
Time
15 minutes

This activity simulates the passing of food and energy through an ocean food pyramid

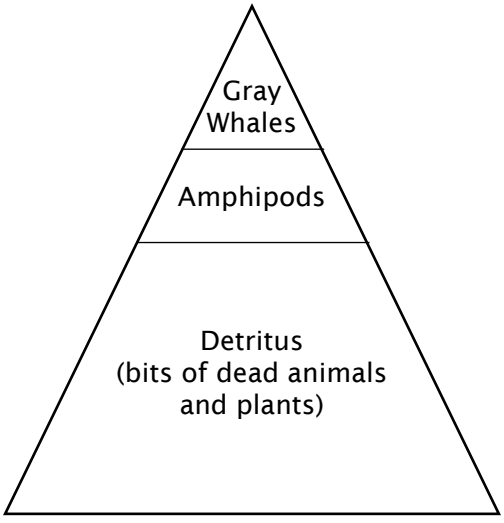
Procedure
1. Remind students that this is a simulation and the numbers and ratio of organisms in the food pyramid cannot be realistically represented.
2. Based on a classroom of 30 students, divide them into ocean organisms in the following numbers. This will give a crude approximation of the ratio of numbers of organisms in a food pyramid.

# of students	Organism
13	phytoplankton
8	zooplankton
5	small fish
2	large fish
1	orca
1	student will be firstborn orca calf

3. Divide the students into various organisms of the food pyramid. Have students stand in a pyramid formation. All should face the front of the room.
4. Pass out one index card to each student at the phytoplankton level of the pyramid. The card represents the organisms as food in the food chain.
5. Phytoplankters pass their index cards over their shoulders to the zooplankters to simulate zooplankton feeding on phytoplankton. Not all phytoplankters will be eaten by the zooplankton, so you



Killer Whale Food Pyramid



Gray Whale Food Pyramid

may choose for two phytoplankters to keep their cards.

6. The zooplankters pass all but one of the cards over their shoulders to the small fishes. The small fishes then pass all but one of their cards to the big fishes.
7. The big fishes pass all cards to the orca.

   Results: All in the food pyramid had a nice meal for the day.

Round 2: Food chain, with toxic chemicals added

1. Mark half the index cards with a magic marker to represent toxic persistent chemicals such as DDT or PCBs, or metal contaminants such as mercury. Repeat the feeding exercise.
2. Check at the first stage (zooplankton) to see whether any of the toxic chemicals have accumulated (accumulation has occurred if one student is holding two marked cards).
3. Pass on to the small fishes. Check again for any accumulation.

   Do any of the fishes have two or more cards with toxic chemicals?
4. Finish the exercise and see how many marked cards, "accumulated chemicals," the killer whale has eaten.
5. After the orca has fed, pass the index cards to a student selected to be the firstborn baby of the mother orca. This simulates passing contaminated chemicals stored in the fat of the mother whale on to the baby. The chemicals are released into the milk of the mother as she nurses her new calf. The firstborn calf may die. The concentration of toxins in the dead calves is high and is thought to be the cause of their death.

The 15-year accumulation of toxic chemicals is released into the new mother's milk.

Gray whale food pyramid

1. Compare the gray whale food chain to the orca's. How does it differ? *Small fish and large fish stages are missing.*
2. Will the gray whale gather as much of the pollutants as the orca, as there are fewer steps to concentrate the toxins? *There will be less accumulation of toxins, due to loss of the two stages in the food chain.*
3. Conduct the food chain experiment again, using the same number of students to represent phytoplankton and zooplankton. Pass only half the cards from the zooplankton to the gray whale. This represents the huge amount of plankton available for whales.

Discussion

Discuss how chemicals are diluted in the ocean waters but can accumulate in the food chain. *Phytoplankton absorb the chemicals through their cell walls.*

Discuss how chemicals become concentrated in the fishes, in the big fishes, and finally into the whales. *The chemicals are stored in the fat of the whales and passed into the milk that feeds the newborn calves. Orca mothers give birth to their first calf at about age 11. West coast orcas give birth to their first calf at age 15. Scientists speculate that the first-born orcas may die from PCBs and other contaminants passed to the calf in the womb and through the milk of the mother. Subsequent calves usually survive because they get a smaller dose of toxins, as the accumulation has been transferred to the first calf.*

6. Whale Investigations

This section is organized with a short reading section on each species of whale. It provides information about some of the current research and conservation concerns for each species of great whale. The reading sections are followed by activities that relate to and support the information about each species of whale.

Students should read through each reading section before doing the activities.

Sperm Whales

Physeter macrocephalus (physeter = spouter, macro = large, cephalus = head), "big-headed spouter."

Sperm whales, the only toothed whales that grow large enough to be considered among the great whales, live throughout the world's oceans, usually in deep waters more than 600 feet deep. Several different stocks of sperm whales are known. One stock is found off California, Washington, and Oregon; different stocks are found off Hawaii, the north Pacific, the western north Atlantic, the northern Gulf of Mexico, and the southern hemisphere. Sperm whale females and young live in warmer waters year round, and only the males move into colder areas.

Sperm whales are the champions of deep dives. They have been known to dive for 1 hour at a depth of 3.2 kilometers (2 miles). They make loud clicking sounds that are probably used for navigation and searching for food. Sperm whale sounds are so intense, they may have shattered the first satellite tags that were attached to them! These whales are thought to use their sonar for catching squid. The inside of the sperm whale's mouth is white, leading to speculation that its color may attract squid.

Sperm whales occur in small groups called pods, which number from 15 to 50 whales each. Older male sperm whales are solitary and seek out females only when it is time to mate. Younger males stay with the pod until about 5 years of age, then they form small groups with other young males. The breeding and calving areas have yet to be identified for any sperm whale stocks.

We know that one group of sperm whales is frequently sighted in the Gulf of Mexico. How many use the Gulf, where their feeding areas are located, and whether they give birth in the Gulf are questions that have yet to be answered.

Researchers from Oregon State University (OSU) and Texas A&M University are interested in Gulf sperm whales. OSU researcher Dr. Bruce Mate has tagged and tracked Gulf sperm whales. His goal is to discover their feeding and calving areas and migration routes. Texas researchers search for Gulf of Mexico sperm whales using ships and hydrophones (listening devices) to locate them by their sounds, and then they sample the waters in areas where the whales are found.

Even if we know how many whales there are, protecting the whales that use the Gulf of Mexico is another difficult problem. The Gulf is a busy place with exploration, oil and gas drilling, construction of oil platforms for pumping oil, busy shipping lanes, and commercial- and sport-fishing activities—all of which are potential hazards for sperm whales.

What have we learned about Gulf sperm whales and where they live? Examine the maps that are provided. Locate on the map, water circulation patterns, whirlpools, or eddies (in the Gulf, called anticyclones and cyclones).

The anticyclone eddy (clockwise-rotating) has a core of warm water. Smaller eddies spin off the warm anticyclones but rotate in the opposite direction (counterclockwise) and are called cyclones. We now think that these circulation patterns are important to the sperm whales.

In an anticyclone, warm surface water is drawn into the (clockwise) eddy center and is pushed downward to the seafloor (downwelling). Anticyclones contain few nutrients to support plant and animal life. They can be thought of as "ocean deserts."

Cyclones spin in the opposite direction (counterclockwise) and draw cold, nutrient-rich water

Continued

Sperm Whales continued

upward (upwelling) from the sea floor toward the surface. Near the surface, the combination of sunlight and the abundance of nutrients creates an "ocean oasis," with abundant plankton. Scientists think that whales like the cool-water cyclone areas because of the rich sources of food.

Sperm whale breaching near oil platform. (Bruce Mate photo.)

Sources

"Sperm Whales, *Physeter macrocephalus*." U.S. Department of Commerce/NOAA/NMFS/AFSC/NMML. http://nmml.afsc.noaa.gov/education/cetaceans/sperm1.htm. Accessed January 2005.

"Ocean Surface Topography." http://sealevel2.jpl.nasa.gov/jr_oceanographer/oceanographer-biggs.html. Accessed January 2005.

ACTIVITY 16: Sperm Whales in the Gulf of Mexico

Sperm whales are known to live in the Gulf of Mexico. This activity is designed to allow students to use data collected from a research project, plot the data, and draw conclusions about whale habitats, just as the researchers conducting the studies have done.

Concepts

- Whale habitats are complex, and a variety of methods are used to collect information and data about these habitats.
- Latitude and longitude are used to locate points on a map.

Materials

- ☐ Blank map of Gulf of Mexico, showing anticyclones and cyclones
- ☐ Overlay map of the Gulf, showing recent oil-leasing area
- ☐ Colored pencils (blue and red)
- ☐ List of latitude and longitude readings for sperm whale locations
- ☐ Pencils
- ☐ Rulers

Sperm whales have been known to dive for 1 hour at a depth of 3.2 kilometers.

Subjects

- Geography
- Life science
- Mathematics

Time

40–60 minutes

Procedure

This activity is a simulation of an actual research project and data gathered by satellite tagging and surface investigations of sperm whale habitats in the Gulf of Mexico. Have students plot and track the whale. Make a transparency of the oil leasing area to overlay the gulf map. Note where the leasing area lies in relation to the eddies. Project the map with the overlay leasing area and have students think about whale habitats and how they are changed by human activities.

Teachers

1. Provide students with "Sperm Whales" as a reading assignment.
2. Provide students with maps of the Gulf and have them follow the student directions.
3. Review "latitude" and "longitude," and demonstrate one round of plotting a whale's location on the maps.
4. Have students finish plotting the locations of the whale on the map, using the latitude and longitude readings.
5. Review their plots of the tagged whales movements in the gulf and have them answer the study questions.
6. Review answers for the last question on the worksheet only after students have developed their own solutions.

Teacher key to student worksheet

10. Seven to 8 days. Upwelling in the cyclone produced an abundant food supply.
11. Overlay the map showing the leasing area for oil and gas leasing and exploration.
12. Right over the cyclone.
13. Yes.
14. Probably. Researchers are trying to answer that question.
15. What other human activities might disrupt sperm whales in the

Gulf? (Fishing, shipping, toxic chemicals that drain out of the Mississippi River into the Gulf.)

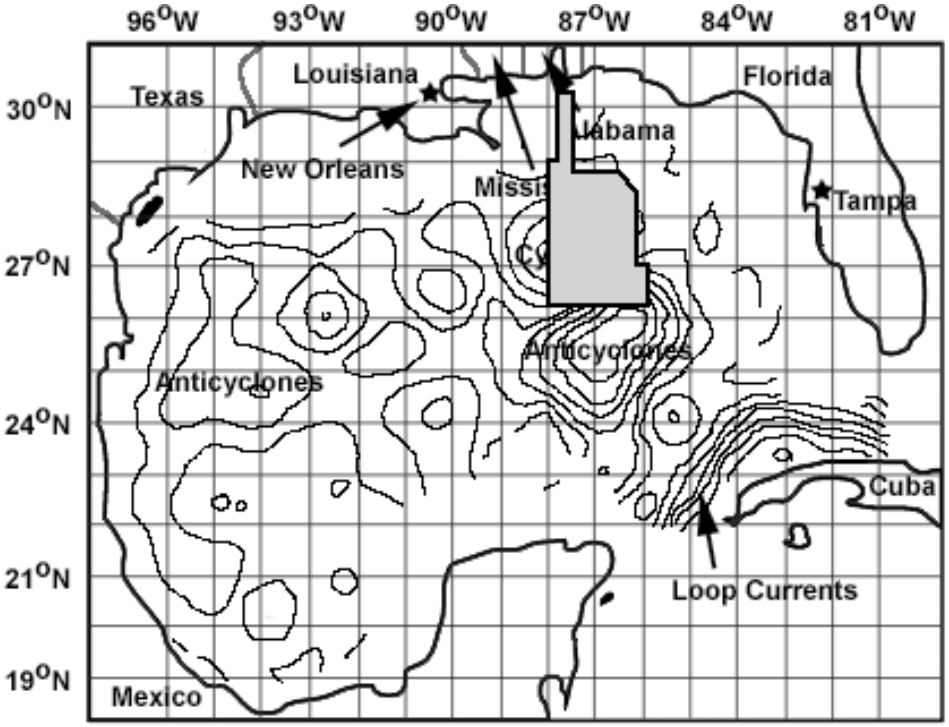
16. List one way to reduce human impact on sperm whales in the Gulf. Check your answers with these suggested options.

    Suggested answers:

    a. Set aside a reserve for sperm whales in the Gulf.

    b. Are there seasons when sperm whales are not in the Gulf or are fewer in number? Explore for gas and oil at those times of the year.

    c. Reduce demand for gas and oil. Drive fuel-efficient cars.



Teacher discussion

The whale began its journey in the cyclone region and lingered there for 10 days. Then it traveled west to southwest. As it neared the western boundary of the Gulf of Mexico, it turned south and then southeast toward the Gulf of Campeche.

The whale spent more time in and near the cyclone (these are areas of upwelling).

We know the cool water areas are productive. Squid (the primary food of sperm whales) probably gathers in the high-nutrient waters of the cyclone to prey upon the abundant zooplankton generated by the upwelling water. The squid in turn attracts the whale.

Tagging studies plus Texas A&M observers confirm that sperm whales were most abundant in or near the cyclone.

These pieces of information help us to understand whale habitat needs. But we still need much more information if we are to protect whale habitats.

The government gives out leases to oil and gas companies that wish to explore the areas. Exploration activities use loud explosions to send sound waves through the water. The sound waves bounce back off the different rock strata, and geologists can determine which may contain oil.
If favorable areas are found, drilling and oil platforms will be built in those areas. There are concerns these activities will disrupt and harm whales, especially sperm whales that we think use sounds extensively for feeding and navigation. The 1997 lease is just one example. The Gulf is intensely surveyed for oil and gas and exploration, and drilling is moving into deeper waters. How the sperm whales are affected by all this activity needs to be explored.

There are concerns these activities will disrupt and harm whales, especially sperm whales.

Name **Date**

Student Worksheet #16

- Label the states surrounding the Gulf of Mexico.
- Locate the cyclones and anticyclones on the map. Draw arrows on the cyclone lines indicating the direction of water movement in the anticyclones and cyclones (these areas are ONLY within the lines that make complete circles).
- The list below is latitude and longitude readings of simulated radio tagging results from sperm whales in the Gulf of Mexico. Information is based on a real tagging event as well as research into movements of whales in the gulf. Plot the latitude and longitude of each reading.
  1. Find the longitude number across the top of your map. Longitude lines run from pole to pole and is measured in degrees.
  2. Use a ruler to draw a straight line down from the top of the map starting at the first longitude reading.
  3. Find the latitude number on the left side of the map. Latitude lines run east and west, parallel to the equator.
  4. With a ruler, draw a straight line across the map from the latitude reading.
  5. Where the lines cross is the location of the whale on that day.
  6. Plot all the locations on your maps.
  7. Place a dot for each day's reading, then connect each dot with a straight line to show the path of the tagged whale.

Latitude and longitude reading of movements of a tagged sperm whale in the Gulf of Mexico

Date	° West Longitude	° North Latitude
8/8	87.0	27.0
8/10	86.0	27.8
8/12	87.0	27.5
8/14	88.5	28
8/16	88.0	28.0
8/17	89.0	27.8
8/19	89.1	27.4
8/21	90.1	27.8
8/23	92.7	27.2
8/26	93.0	27.2
8/28	96.0	25.5
8/30	96.3	24.5
9/2	95.6	21.2

8. Color the cyclone blue (cool waters) and the anticyclones red (warm waters). These are the areas within the lines that make complete circles.
9. Note where the path of the whale moved in relation to the cyclones and anticyclones.
10. Answer the following questions.
    - How many days did the whale stay near or in the cyclone? _____
    - Why do you think the whale stayed in or near the cyclone?

11. Overlay the map showing the leasing area for oil and gas leasing and exploration.
12. Where did the oil and gas exploration for 1997 lie?
13. Did it cover areas that are used by the tagged whale? _____
14. Could the oil and gas exploration disrupt sperm whales? _____
15. What other human activities might disrupt sperm whales in the Gulf?

16. List two human-caused problems for sperm whales in the Gulf.

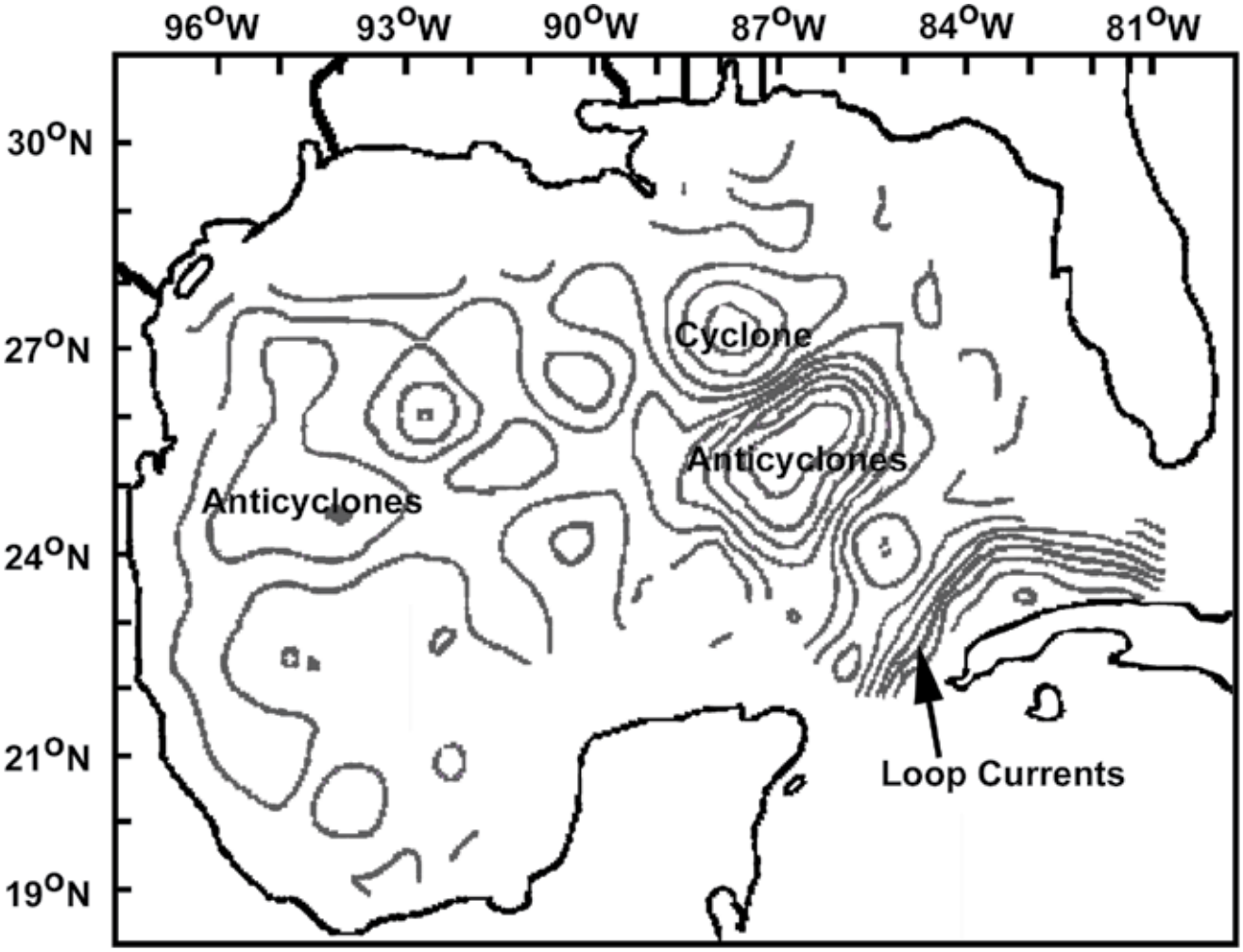
17. List one way to reduce human impact on sperm whales in the Gulf. Check your answers with these suggested options.

Name **Date**

Student Worksheet #16 continued

Gulf of Mexico map

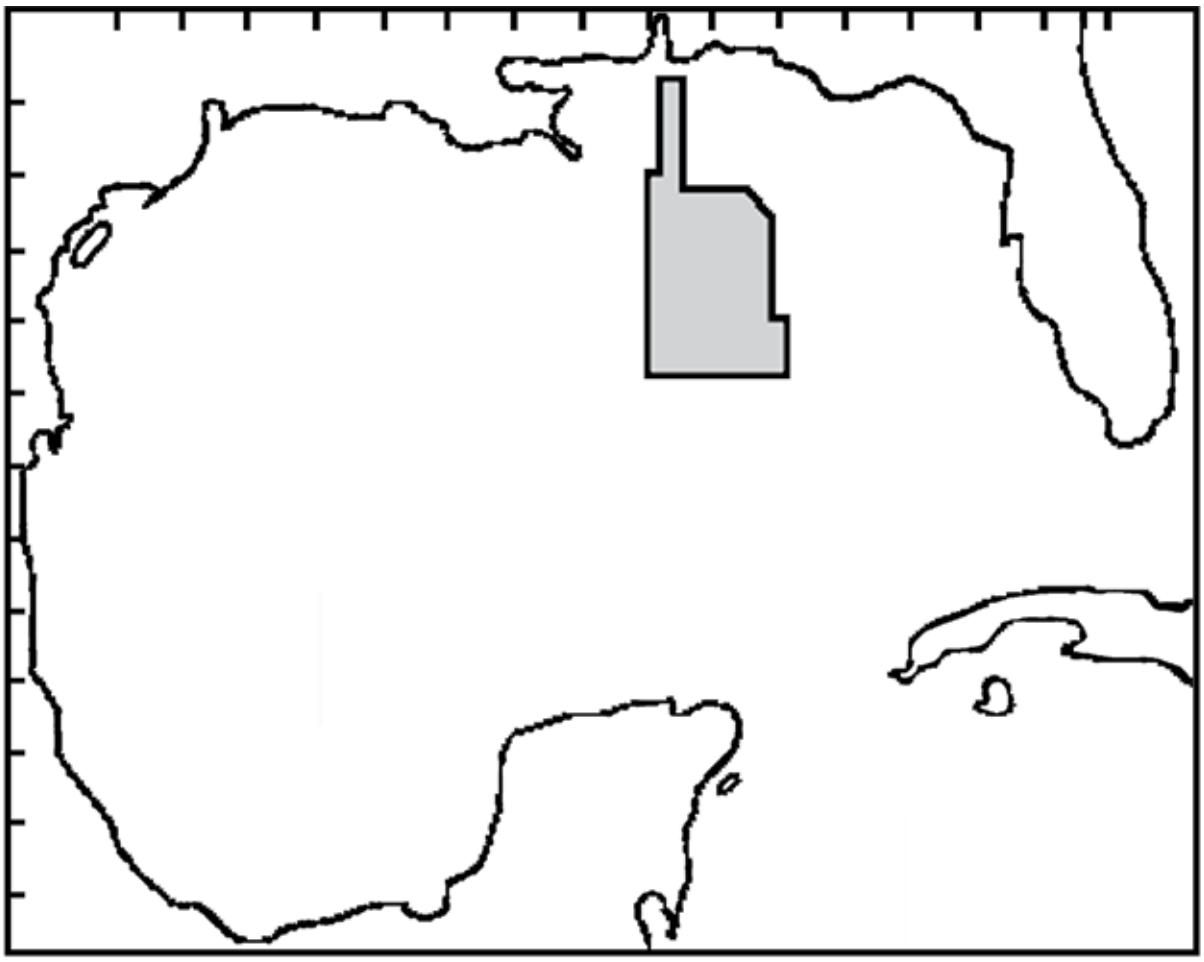
Cyclone and anticyclone lines are isotherms.



Map by Craig Toll. Circulation patterns based on research by D. Biggs, Texas A&M University.

Gulf of Mexico map, teacher overlay

(Oil exploration permit area for 1997)



Map by Craig Toll.

Sperm whale identification

Counting and studying whales by visual means is especially difficult. Specific studies often require that individual whales be identified. For example, are the same whales using the same calving grounds year after year? How often does a female have a calf? Questions like these and many others require the identification of individual whales.

Scientists have developed ways to identify individual whales. For example, right whales have rough patches of thickened skin called *callosities*, which are white in color and covered by whale lice—a small, crab-like animal. These rough patches on the whale's head, over its eyes and around its mouth, are different on each animal and are used by researchers to identify individual whales. Bowhead whales are scarred by encounters with ice, and these scars are used to identify individual whales. Sperm whales have notches and tears on their flukes—from attacks by predators such as sharks and killer whales—that are used to distinguish individual animals.

ACTIVITY 17: Whale Tails

This activity simulates the problems researchers encounter when gathering data.

Concepts

- Individual whale identification helps researchers to gather important information.

Subjects

- Biology
- Research

The actual identifications are done at sea under even more challenging conditions than in the classroom.

Materials

- ☐ Pictures of sperm whale flukes on overhead transparencies
- ☐ Whale fluke illustrations for each student
- ☐ Pencils

Time

10 minutes

Related activity

Activity 8, "Identifying Whale Habitats"

Fluke identification answers

1. SW 5 2. SW 13 3. SW 15 4. SW 10 5. SW 12

Procedure

Give each student a page of illustrations of sperm whale flukes. Overhead transparencies of sperm whale flukes will be placed on the overhead projector to the count of 4 seconds, then removed. This is approximately the length of time researchers see flukes before whales submerge. From this brief glimpse, students are to match the overhead image to one of the illustrations on their work page. Write the number from the transparency onto their worksheets.

At the end of the exercise, place the transparencies back on the overhead and reveal the correct numbers, noted on the bottom of the transparency. Have students check their sheet to see how many they identified correctly.

Discussion

Since the length of time is short, accurate identification will be difficult. Remind students that the actual identifications are done at sea under even more challenging conditions than in the classroom. Have students discuss ways they could improve their identification of whales at sea. Examples: using high-powered binoculars, photographing the flukes for analysis later in a laboratory, etc.

Fluke #1

OSU Marine Mammal Institute

SW 13

Fluke #2

OSU Marine Mammal Institute

SW 5

Fluke #3

© International Fund for Animal Welfare (http://www.ifaw.org)

SW 15

Fluke #4

SW 12

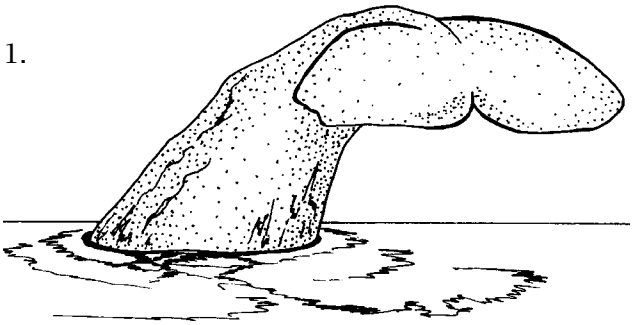
Fluke #5

SW 10

Name **Date**

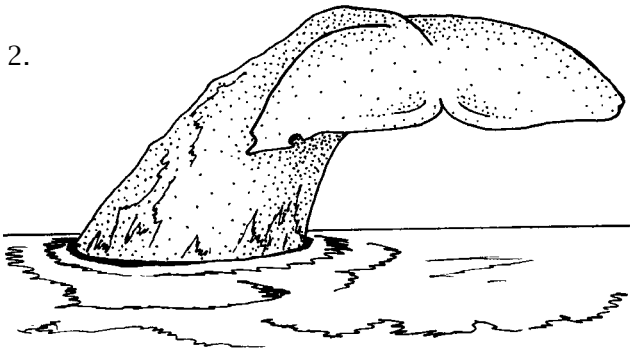
Student Worksheet #17

1.



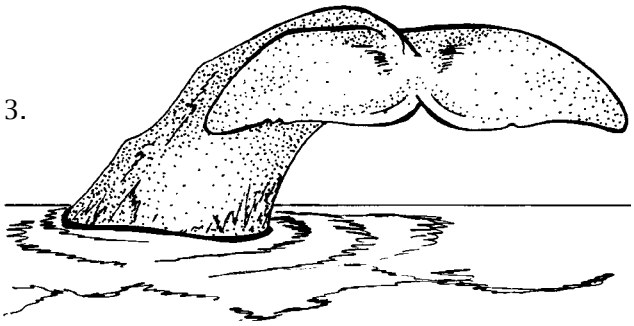
Fluke # _____

2.



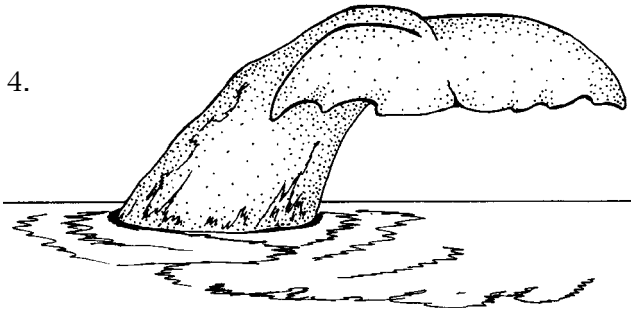
Fluke # _____

3.



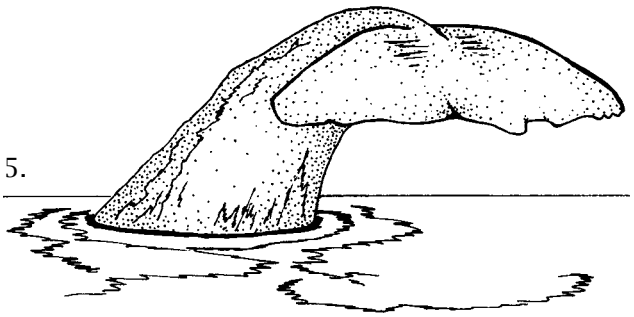
Fluke # _____

4.



Fluke # _____

5.



Fluke # _____

Humpback Whales

Megaptera novaeangliae (mega = big, ptera = wings, nova = new, anglaie = England), "big-winged New Englander."

Stocks of humpbacks

Three different stocks have been identified and are located in the following areas: the eastern Pacific, the north Atlantic, and Antarctic (southern hemisphere stock). North Atlantic ocean humpbacks are found near Newfoundland and the waters off Cape Cod. This population migrates to the Bahamas and the Dominican Republic during winter months. Southern hemisphere humpbacks are known to visit the island of Tonga for their winter calving season.

The eastern Pacific divides into the Alaska/Canadian group, which migrates to Hawaii, and a group off Oregon, Washington, and California that migrates to Central America. There is yet another stock off the coast of Japan.

Scientists study these stocks of whales in several ways: by tagging and satellite tracking, with hydrophones to listen to their sounds, and with research vessels to directly observe the animals.

Summer feeding habitats

The Alaskan humpbacks can be sighted in Alaskan and Canadian waters from April through October. These areas provide cold, food-rich waters. Upwelling and storms stir the shallow waters, bringing nutrients to the surface to fertilize plant plankton that makes up the base of the marine food chain. These rich waters support huge schools of small fish and tons of zooplankton, including krill. An abundance of marine life, in addition to the humpbacks, inhabit these waters.

Winter habitats and calving areas

Alaskan humpbacks migrate to Hawaii and are known to be present there in the months of November to May. This is their calving and breeding season. Since whales are traveling in small groups or singly, the arrival and departure dates are spread out over the winter months. Although the length of time needed to make migrations is not well known, one whale that was identified in Alaska was seen 39 days later in Hawaii—4,500 kilometers away.

Hawaii's warm, shallow, inshore waters offer the newborn whales warmth and protection from predators, but food supplies are sparse for the adult whales. Babies suckle and build up body fat for their journey back to summer feeding areas. Newborn calves are 4.5 meters (15 feet) in length and weight a metric ton (2,204 pounds).

Feeding

Humpbacks feed on herring and on swarms of small shrimp-like animals, called krill, by gulping or lunging. They have an interesting manner of feeding called *bubble-net feeding*. They blow curtains of bubbles, to trap their food (see Activities 5 and 6). An individual whale can make a bubble-net, or a team of up to 20 humpbacks working together can make huge nets to encircle the fish. The humpbacks are believed to use their long, white flippers to herd fish. They then open their mouths and swim up through the bubble net to gulp up the fish. We also know that humpback mothers and their calves return to the same feeding habitat year after year. Why do they do that? We think that mothers have taught their calves where there is plentiful food and the young remember that information.

Continued

Humpback Whales continued

Hazards

Current threats to humpbacks are entanglements in fishing gear, and fluctuations in food supplies due to north Pacific climate shifts.

One of the many mysteries of the humpbacks is that there are more of them wintering in Hawaii than the Alaskan/Canadian populations can account for. So we have the case of the missing humpbacks. Scientists have guessed that the extra whales may be an unidentified group that uses Siberian waters as feeding grounds. A recent tagging research project conducted by Oregon State University researchers followed a tagged whale from Hawaii to the Kamchatka Peninsula off Russia, where it stayed for several weeks. They speculated that it was probably feeding in this area. This is one confirmation for the theory that a group of humpbacks may use these waters for feeding, but further work is needed to establish this fact. The same tagging study discovered that another humpback returning to Alaska tended to linger several days near a seamount located about halfway between Hawaii and Alaska. Why the seamount? Perhaps because seamounts are productive areas and may have food supplies that attract the whales.

Humpbacks are known for their complex sounds or "songs." Once thought to be associated with breeding, the songs have now been recorded outside of the breeding grounds. Current song research shows that when another humpback joins a singing whale, the "joiner" is always male. Whale "songs" are composed of themes, which in turn are composed of phrases. The songs vary geographically; Hawaiian humpbacks sing different songs than the Cook Island humpbacks (see Activity 26, "What's that Sound?").

Note: Mileage between Anchorage and Honolulu = 4,800 kilometers (3,000 miles).

Sources

Alaska Department Fish and Game Wildlife notebook. http://www.state.ak.us/local/akpages/FISH.GAME/adfghome.htm

Humpback Eastern Pacific Stock NOAA http://www.nmfs.noaa.gov/prot_res/PR2/Stock_Assessment_Program/Cetaceans/Humpback_Whale

ACTIVITY 18: Humpback Whale Migration Game

The purpose of this activity is to take students through a year in the life of a north Pacific humpback whale population. Students will follow the whales from winter calving areas to the summer feeding area. They will experience the potential hazards humpbacks encounter during a year of their life, and they will examine the two diverse sets of habitats that these whales depend on.

Students will work in groups, follow "student instruction" sheets, gather cards from bowls placed at the front of the room, and fill in their maps and whale logs.

Concepts

- Whales use different habitats from winter to summer for feeding and calving.
- Whales encounter a number of hazards during their lives.

Subjects

- Biology
- Math
- Geography

Materials

- ☐ Game materials:
  —Whale Logs
  —Map of the Pacific and Hawaiian Islands
  —Game cards (in teacher/student section)
- ☐ Six small bowls
- ☐ Ten rulers

Homework reading assignment

"Humpback Whales"

Time

45 minutes

Teacher instructions and background

1. Students will conduct a simulated 1-year migration of humpback whales. The whale population size will total 30. One card selected from the bowl will apply to each individual in the group. One hazard or one birth is only one event for the whole group.
2. Have students read the background information, "Humpback Whales," and refer to it as they fill out their whale logs.
3. Divide students into 10 groups of three to do the activity. Have students divide up the duties so all participate in the activity: one keeps the whale log, another does the mapping, etc.
4. Set up six bowls around the rooms with information cards and labels.

   Bowl #1: *Winter habitats*—Hawaii locations for wintering and calving ground locations

   Bowl #2: *Reproduction*—number of calves born

   Bowl #3: *Winter hazards*

   Bowl #4: *Summer feeding areas*—summer feeding grounds destinations (Alaska)

   Bowl #5: *Feeding*—feeding and food information

   Bowl #6: *Summer hazards*
5. Give each group a blank map of the Pacific Ocean and an enlarged map of the Hawaiian Islands.
6. Direct students through the instructions for their group of three whales.
7. Place a labeled map on the overhead projector or have classroom maps available so students may refer to it to find the locations of their migration.

Whales use different habitats from winter to summer for feeding and calving.

8. At the conclusion of the activity, tally the whale log information on the blackboard. Use the log information as the guide.
9. Discuss the life cycle and what the whales encountered. Did the whale population increase or decrease?

Extension

- Calculate the distance traveled from Hawaii to Alaska. Measure the distance and use the scale on the map to calculate the result.
- Ask students to calculate the percent increase in population growth. Take the number of live births and divide by 30 whales.
- Repeat for the number of deaths to calculate the percent decrease in population. Compare the two numbers to see whether the population increased or decreased.

Challenge question: Since only one tagged whale made it to Kamchatka, how might scientists gather further proof that humpback whales are using this area for feeding? Have students think of different methods to prove or disprove that humpback whales use this area as a summer feeding habitat. Let them work up their own list, then check out the list below.

- Surface observations of whales
- Listening with hydrophones for whale sounds
- Aerial photography

Whales encounter a number of hazards during their lives.

Student Instructions #18

Winter habitat for humpback whales

- Bowl #1: One representative from each group picks up a Hawaii location card.
  - Return to the group, find your location on the Hawaii map, and label it. If your card reads "Kauai," your whales will be using the waters off Kauai.
  - Describe the Hawaii habitat areas: water temperature (warm or cold); food supplies (abundant or sparse); water depths (shallow or deep for protection of young).
  - Write on your whale log the location of your whales in Hawaii.
  - Enter on the log the months that humpbacks spend in Hawaii (check the reading assignment).
- Bowl #2: Send one member of your group to pick up one reproduction card.

  Record on your Whale Log if there were any births in your group (note that one birth card will indicate only *one* birth event for the whole group). Also record the size of the newborn humpback calf.
- Bowl #3: Send one member of the group to pick up a winter hazard card. Record results on Whale Log.

Summer habitat for humpback whales

Your whales are preparing to leave the Hawaiian Islands to migrate to summer feeding grounds.

- Bowl #4: Send a group member to pick up a summer destination card.
  - Locate and label the location on the map.
  - Describe your destination: temperature of water (warm or cold); food supplies (abundant or sparse); water depth (shallow or deep).
  - Enter the summer location on your Whale Log.
  - Enter on your log the months you will spend in the feeding grounds (check the reading assignment).
- Bowl #5: One member picks up one feeding card. This will indicate if the whales in your group are well fed or did not get enough food to be in good health. Enter on the log if your whales feed, and if they are well fed and have built up stores of blubber to make the long migration to the Hawaiian Islands. Humpbacks have little or no food from the time they leave until they return to their summer habitats.
- Bowl #6: Send one member of the group to pick up a hazard card. What hazard, if any, was encountered? Record the hazard and death or no death on your Whale Log.

Name **Date**

Student Whale Log

Complete this log using the reading assignment, maps, and information drawn from bowls 1–6.

Names of students in this group: _____

_____

Bowl #1: Humpback winter habitat "calving areas"

Our whales' Hawaii location _____

Describe our whales' winter habitat _____

The months our whales will spend in Hawaii _____

Bowl #2: Reproduction

Number of baby whales born in our group _____

Size of baby whale (enter size even if your group has no baby) _____

Bowl #3: Winter hazards

Hazards our whales encountered in Hawaii _____

Bowl #4: Summer "feeding areas"

Summer feeding areas location _____
(Label on the map your summer location)

What months will our whales spend in summer feeding grounds _____

Describe the summer habitat _____

Bowl #5: Feeding

What our whales ate _____

Are our whales well fed or hungry ? _____

Bowl #6: Summer hazards

What hazards did our whales encounter? _____

Summary

Review Summary of Activity. Did the whole whale population increase or decrease? _____

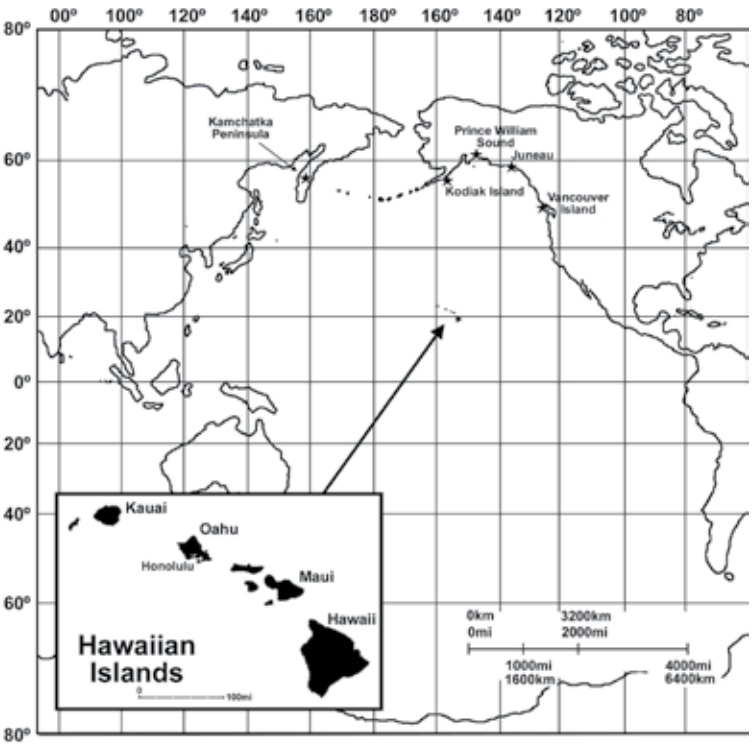
What was the most common hazard? _____

Teacher Tally Sheet

Humpback data tally (for teachers)

Group number	1	2	3	4	5	6	7	8	9	10
Wintering areas										
# of calves born										
Winter hazards										
Summer areas										
Feeding success										
Summer hazards										
Total pop. (30+ calves)										
Total deaths										
Increase/decrease in pop.										

Pacific Basin map key

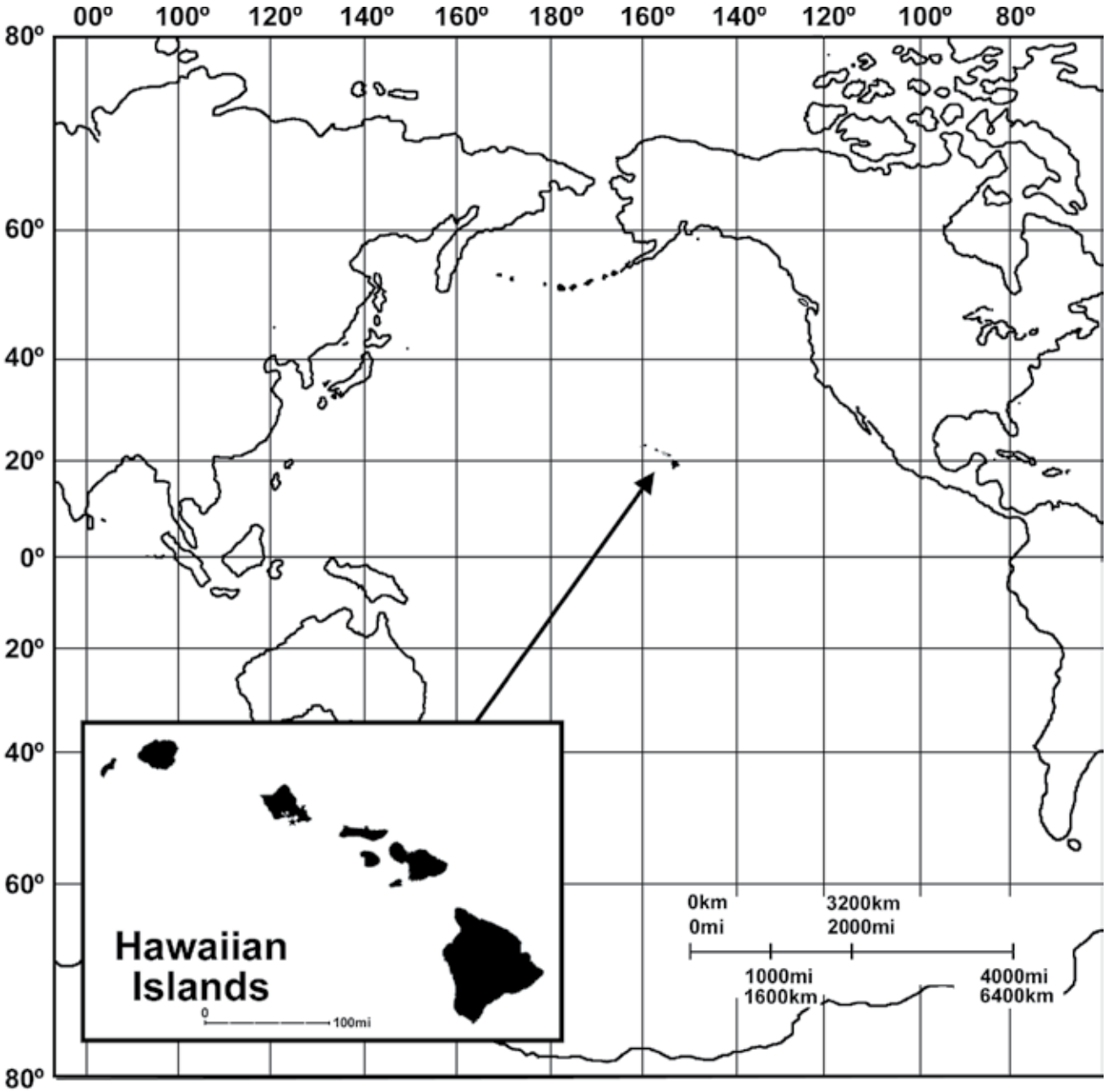


Map by Craig Toll.

Name **Date**

Student Worksheet #18

Pacific Basin map



Map by Craig Toll.

Humpback Migration Game Cards

Winter habitat Oahu	Reproduction card One live birth	Winter area hazard No hazard
Winter habitat Oahu	Reproduction card No births	Winter area hazard No hazard
Winter habitat Kauai	Reproduction card No births	Winter area hazard No hazard
Winter habitat Kauai	Reproduction card No births	Winter area hazard No hazard
Winter habitat Maui	Reproduction card No births	Winter area hazard No hazard
Winter habitat Maui	Reproduction card No births	Summer feeding grounds Prince William Sound
Winter habitat Maui	Reproduction card No births	Summer feeding grounds Prince William Sound
Winter habitat Molokai	Reproduction card No births	Summer feeding grounds Prince William Sound
Winter habitat Hawaii	Summer areas hazard No hazard	Summer feeding grounds SE Alaska, Juneau area
Winter habitat Hawaii	Summer areas hazard No hazard	Summer feeding grounds SE Alaska, Juneau area
Reproduction card One live birth	Summer area hazard No hazard	Summer feeding grounds SE Alaska, Juneau area
Reproduction card One live birth	Summer area hazard No hazard	

Continued

Humpback Migration Game Cards continued

Summer feeding grounds
Kodiak Island

Summer feeding grounds
Kamchatka Peninsula,
Siberia

Summer area hazard
Killed and eaten by orcas
One death

Summer area hazard
Collision with ship
Injury but no death

Summer area hazard
Entangled in fishing gear
Stress but no death

Summer area hazard
Entangled in fishing gear
Stress but no death

Summer area hazard
Tourism interaction
Stress but no death

Summer area hazard
Entangled in fishing gear
One death

Summer feeding grounds
Vancouver Island, Canada

Winter area hazard
Entangled in plastic
Stress but no death

Winter area hazards
Tourism boat interaction
Stress but no death

Winter area hazard
Complications giving birth
Stress but no death

Winter area hazard
Disease and parasites
Stress but no death

Winter area hazard
Tourism boat interaction
Stress but no death

Feeding success
Too few herring/anchovies
Hungry whales

Feeding success
Herring and anchovies
Well-fed whales

Feeding success
Good supplies of krill
Healthy, well-fed whales

Summer feeding grounds
Vancouver Island, Canada

Feeding success
Good supplies of krill
Healthy, well-fed whales

Feeding success
Good supplies of krill
Healthy, well-fed whales

Feeding success
Herring and anchovies
Healthy, well-fed whales

Feeding success
Herring—
Healthy, well-fed whales

Feeding success
Anchovies and sardines—
Healthy, well-fed whales

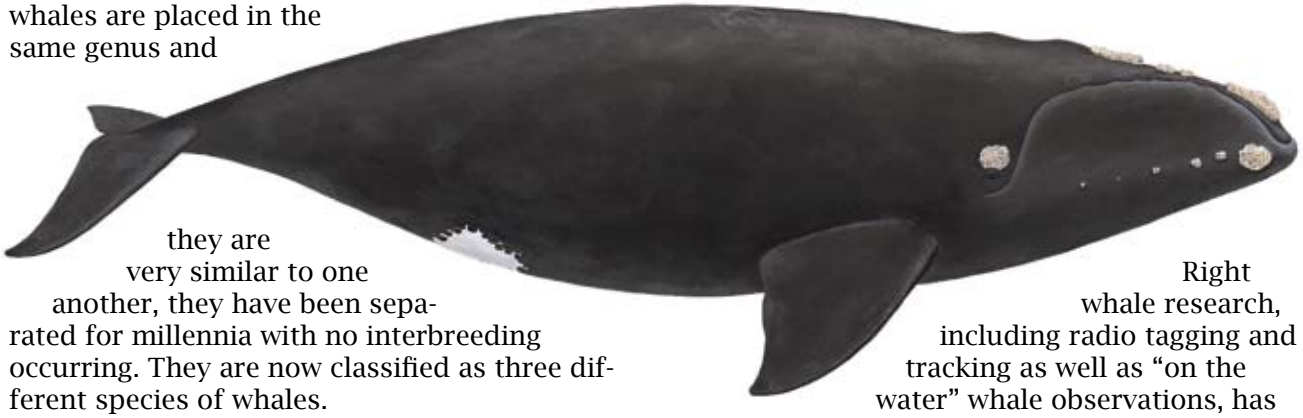
Feeding success
Herring—
Healthy, well-fed whales

Feeding success
Herring—
Healthy, well-fed whales

Right Whales

Three species: North Atlantic right whale—Eubalaena glacialis (eu = true, balaena = baleen or whale, glacialis = ice), "true ice whale"; South Pacific right whale—Eubalaena Australis = "Australian true whale"; North Pacific right whale—Eublaena Japonica = "Japanese true whale."

Right whales are found in various parts of the world's oceans. The International Whaling Commission's Scientific Committee now recognizes three separate species of right whale: the southern right whale (sighted in the waters off South Africa and Australia), the north Pacific right whale (Alaskan waters and Japan), and the north Atlantic right whale (found in the Gulf of Maine and near Nova Scotia). Although these whales are placed in the same genus and they are very similar to one another, they have been separated for millennia with no interbreeding occurring. They are now classified as three different species of whales.



Right whales spend a lot of time at the surface as their feeding behavior is to skim near the surface, but we now know they can feed while diving. These whales float when killed, making them the "right" whale to hunt. Even their scientific name means "true whales." They were heavily hunted and their numbers were rapidly depleted. Whaling has stopped for right whales, but they are still at risk from a variety of hazards.

North Atlantic right whales have decreased to such critically low numbers that they are virtually at the brink of extinction. They have a very slow birth rate, as females give birth to one calf every 5 years. The habitat of the north Atlantic right whales is in the very busy north Atlantic U.S. and Canadian waters. Injuries from ship collisions and entanglement in fishing gear are currently the greatest concerns for these whales. We know that 58% of the right whale population is scarred from fishing-gear entanglements and that half of right whale deaths have resulted from ship strikes. When a ship hits a whale, the impact or cuts from the propeller can kill the whale. Such a collision can also damage the vessel, causing it to be laid up in dock for expensive repairs.

Southern right whale populations, found off Australia, South America, and South Africa, are in better shape and are increasing in numbers. Very little is known about the north Pacific right whales, including how many there might be and where they are most likely to be found. All three species are severely depleted.

Right whale research, including radio tagging and tracking as well as "on the water" whale observations, has been used to establish their preferred summer feeding grounds. Winter habitat is now known for at least 15% of the population in the waters off Georgia. Where the remaining 85% winter is still unknown. More tracking studies should help to identify other wintering locations.

Use of this research data has enabled fish and wildlife agencies to recommend regulations to route ships around whale habitat areas and to set speed limits when in whale areas. The actions to save this whale could not have happened if we had not located their feeding areas.

Continued

Right whale with callosities on its nose. (Photo © International Fund for Animal Welfare/T. Gordon)

Sources

"Northern and Southern Right Whales." U.S. Department of Commerce/NOAA/NMFS/ AFSC/NMML. http://nmml.afsc.noaa.gov/ education/cetaceans/right1.htm. Accessed September 2004.

Dr. Bruce Mate, Oregon State University. Personal communication, May 2004.

Gray Whales

Eschrichtius robustus (Eschrichtius = zoologist Daniel Eschricht, robustus = robust, hearty), common names "devilfish" and "California gray whale."

Gray whales are split into three stocks, each with very different experiences. The Atlantic stock of gray whales is extinct. In the Pacific there are two stocks, one that migrates along the west coast of the U.S. and the other off the coast of Asia. The Asian stock follows a migration path from the Chukchi Sea between Russia and the U.S., down to the waters off Japan and the south China Sea. The Asian stock of gray whales numbers only about 100. With such a low population and no signs of recovery, it is the most critically endangered population of great whales.

The eastern north Pacific population (west coast of the U.S. and Mexico) has recovered to numbers equal to historic levels before whaling began. It is the first species to be removed from the endangered species list and is the only large whale to have been delisted. The population now has reached over 20,000 animals, recovering from a low of 4,000 animals.

North Pacific gray whales feed in the Arctic and migrate to the warm, shallow lagoons of Mexico—a distance of 20,000 kilometers (13,000 miles) round trip—to give birth. This is one of the longest migrations of any mammal. During that migration, they come close to the shoreline, which makes it easy to observe, count, and study these whales. As a result, quite a lot is known about their life habits, feeding behaviors, and life cycle.

The north Pacific grays were hunted in the shallow Mexican lagoons that serve as their calving grounds. They earned the name "devilfish" because the whales would charge whalers' boats during whaling activity. A mature female gives birth every other year to one calf. In size they are a medium-sized whale, reaching 9 to 15 meters (30–50 feet) long, and they may weigh up to 32,000 kilograms (35 tons). Newborns are 4.5 meters (15 feet) long at birth and weigh an estimated 680 kilograms (1,500 pounds).

Although gray whales have recovered to healthy numbers, there is still concern for them. The population uses four lagoons for calving grounds. Laguna Ojo de Liebre hosts the highest numbers of whales; progressively smaller numbers use Laguna San Ignacio, Bahia Magdalena, and Laguna Guerrero Negro. When a species is dependent on a specific and limited habitat for part of its life cycle, destruction of that habitat can severely deplete or eliminate the population.

Such is the experience of gray whales, as they are vulnerable to habitat changes in these lagoons. San Ignacio Lagoon has few permanent human residents, due to a lack of fresh water. Consequently, it is the only primary breeding/calving area that is largely unaltered by human activities and has been set aside as a reserve. However, Bahia Magdalena has been changed by industrial and mining activities, and the other two lagoons are under threats of development. The Mexican government is taking steps to set lagoons aside as reserves and to establish rules to protect the gray whales.

In their northern feeding grounds in the Bering and Chukchi Seas, and on their migration paths along the west coast of the U.S., there are threats from entanglement in fishing gear. Also, oil exploration and drilling are of concern.

Source

Dedina, S., and Emily Young. Conservation and development in the gray whale lagoons of Baja California sur, Mexico Report to the U.S. Marine Mammal Commission, http://scilib.ucsd.edu/sio/guide/z-serge.html. Retrieved March 2004.

ACTIVITY 19: Recovery or Loss?

Concepts

- Small population size and low birth rates combine to hamper whale population recovery.
- Whales that give birth more frequently have a better chance of increasing their numbers.

Subjects

- Biology
- Math

Materials

- ☐ Pencils
- ☐ The problem described below

Time

45 minutes

Procedure

Students will analyze the population information for north Pacific gray whales and north Atlantic right whales. They will then interpret their data to analyze which whales have the best chance to survive.

Refer to the feeding and reproduction chart below. While gray whales have fully recovered, northern right whales are in serious trouble. What might be some of the causes for the difference? Work through the problem below to identify some of the issues that are keeping right whale numbers low.

Right whale females have calves only once every 5 years, so all the females will not be producing babies. They also do not reach maturity until they are 5 to 9 years of age. Gray whales reach sexual maturity at age 8. There are years that some of the females are not giving birth, which makes it difficult to include such information precisely in this activity. Remember that this exercise is a simplification.

Discussion

The population of right whales grew by only 7 new calves, compared to 18 grays. When 3% = 9 animals that are lost through mortalities in each population, the result is a decrease in right whale population and growth in the gray whale population. The combined factors of very slow birth rates plus mortalities bring the survival of north Atlantic right whales into very serious jeopardy.

Extension

Use this activity with Activity 12, "Lessons Learned from the Whaling Experience."

While gray whales have fully recovered, northern right whales are in serious trouble.

Teacher key to student worksheet

Comparison of right whale and gray whale populations

Whale	# animals	Whale	# animals
Right whales	300	Gray whales	300
Females (50% male, 50% female)	150		150
Mature females (50% of all females)	75		75
Births Give birth every 5 years	15	One calf every 2 years	37
Survival rate of calves (50% of calves survive)	7		18
Adult mortality 3%	9 lost		9 lost
Growth or loss in pop.	2 lost		9 gained

Answers to "recovery" questions:
1. Orcas 2. Humpbacks 3. Grays 4. Blues 5. Rights 6. Sperms

North Pacific grays earned the name "devilfish" because they would charge whalers' boats during whaling activity.

Name **Date**

Student Worksheet #19

Right whales

At the beginning of the year, there are 300 right whales.

Half the population is female. How many will be female? A. _____

Half the females are sexually mature. How many females can bear a calf? B. _____

Sexually mature females have one calf every 5 years. How many calves will be born each year? C. _____

Calf survival rate is only 50%. How many calves will survive each year? D. _____

The mortality rate for the entire population is 3% due to natural mortality collisions with ships and/or entanglement in fishing gear. How many from the entire population will die this year? E. _____

How many right whales were added or lost this year? _____

Has the population increased or decreased? _____

Gray whales

At the beginning of the year, there are 300 gray whales.

Half the population is female. How many females are in the population? _____

Half the females are sexually mature. How many females can bear a calf? _____

Females have one calf every 2 years. How many calves will be born each year? _____

How many of the calves will survive (they have a 50% calf mortality rate)? _____

How many animals were added to the population this year? _____

The mortality rate for the entire population of 300 whales is 3%, due to natural mortality and other problems. How many whales died this year? _____

How many whales will die this year? _____

How many gray whales were added or lost this year? _____

What was the main factor that lowered reproductive rates between the right whale population and the gray whale population? _____

Continued

Name **Date**

Student Worksheet #19 continued

Based on the right whale/gray whale activity, review the chart below and choose which whales may have the best chance for recovery and which may experience a much slower rate of recovery. Assume that food supplies are stable for all stocks.

Which whales have the best chance of recovery?

1. _____ 2. _____ 3. _____

Which whales will experience the slowest rate of recovery?

4. _____ 5. _____ 6. _____

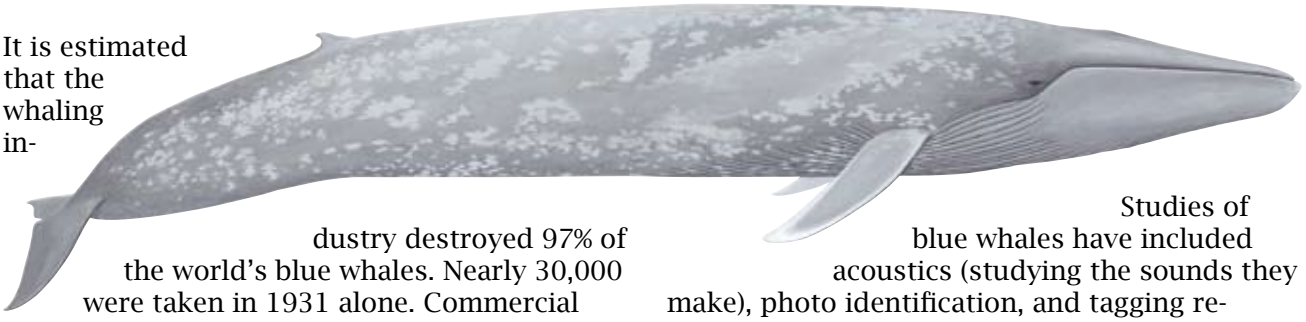
Feeding/reproduction chart

Feeding	Stocks	Foods	Reproduction rates
Sperm	Gulf of Mexico	Medium to large squid Fish of various species	One calf every 5–6 years
Right	New England	Copepods	One calf every 5 years
Blues	Mexico/S. Calif.	Krill	One calf every 4 years
Gray	Alaska/Mexico	Bottom amphipods, mysids	One calf every other year
Humpbacks	Alaska/CA/Hawaii	Fish/krill	One calf every 2–3 years
Orca	Eastern Pacific	Fish—Puget Sound, WA Seals/sea lions—West Coast	One calf every 2 years

Blue Whales

Balaenoptera musculus (balae = whale, optera = wing or fin, musculus = muscular), "Muscular finned whale." (Musculus is also the species name for the house mouse.) The blue whale's common name—"sulphur bottom whale"—is from the yellowish algal coating on its belly.

Blue whales are found in most oceans. Separate stocks are found off California/Mexico and Hawaii, and in the north Atlantic and Antarctic. Blue whale stocks were severely reduced during the whaling days. A subspecies of blue whales, *Balaenoptera musculus brevicauda*, is found in the southern hemisphere.



It is estimated that the whaling industry destroyed 97% of the world's blue whales. Nearly 30,000 were taken in 1931 alone. Commercial whaling for blues was banned in 1964, leaving their numbers severely depleted. Presently, 2,200 blue whales are found off California, accounting for 25% of the world population of blues. It is the largest remnant stock of blues and is believed to be increasing.

Blue and fin whales are the largest of the great whales, but we know relatively little about them. They travel in small groups, are not usually close to shorelines, and are fast swimmers—all of which increase the difficulty of gathering information about their life cycles. Blues are the largest of the great whales. It is difficult to imagine a creature as huge as these. They are more enormous than even the biggest dinosaurs and reach up to 30 meters (100 feet) in length. Their heart weighs 907 kilograms (2,000 pounds), as much as a small compact car. Although they have great size, it does not protect them from predators. Pods of Orcas hunting in packs have been known to kill and eat young blue whales.

Baby blues at birth are 7 meters long (23 feet) and weigh 30 tons—almost as large as adult gray whales. They can add 91 kilograms (200 pounds) a day (8 pounds an hour) and grow to an estimated 14.6 meters (48 feet) in 6 months. Their milk is very rich (50% fat) and they eat an estimated 189 liters (50 gallons) of it a day. Baby blues nurse by nuzzling their mother's belly; the milk is squirted into the baby's mouth. It is so thick that it catches on the baleen and must be licked off.

Blue whales make deep, rumbling sounds—sounds so deep that they must be sped up for humans to hear them. These low-frequency sounds travel great distances in the oceans. Blue whales travel in small groups of two to three animals. Perhaps their sounds are to help them locate one another.

Studies of blue whales have included acoustics (studying the sounds they make), photo identification, and tagging research to discover their migrations. Blue whale sounds have been a subject of much study. Researchers have discovered that the sounds are not the same for different groups of blue whales. Other studies have involved tracking to discover their migration and winter habitats. Oregon State University tagging studies on blue whales followed them from California to waters off Costa Rica in an area called the Costa Rica Dome. Although blue whales were known to use the Costa Rica Dome, this was the first time that blue whales from California have been tracked to Costa Rican waters. They arrived at Costa Rica during the winter months, and this study may have answered one question about their wintering areas, but many other questions remain. Do they have their calves in this same region? Are they dependent on these same waters for feeding?

The Costa Rica Dome is a unique habitat that is created by a combination of water density and wind patterns off Central America. The Dome is a unique and special place in the ocean, with a

Continued

Blue Whales continued

wide variety of animals that can be sighted there. Not only are blue whales known to use the Dome, but many other marine animals are attracted to these food-rich waters, including marlin, tuna, spinner dolphin, pygmy killer whales, short-finned pilot whales, humpbacks, and seis. Bryde's and beaked whales are also known to occur in the Dome area. These creatures are just part of a longer list of many dolphins and fish that use this region.

The Dome is actually a distinct, dome-shaped body of water consisting of a shallow lens of warm water that sits over a mass of colder, oxygen-poor waters. Winds blowing from Nicaragua move the water offshore, and cold, nutrient-rich waters well up to the surface. This upwelling forms the Dome by forcing cold, deep water to the surface, leaving a thin layer of warm water over the top. The upwelling brings bottom nutrients to the surface and creates a rich oasis in the warm, subtropical waters. Because of this, the area is so rich with food it is thought that blue whales visit and feed here in the winter months.

Sources

Pacific Marine Environmental Laboratory Whale Acoustics Project. http://newport.pmel.noaa.gov/whales/bluecall.html. Accessed July 2004.

"Blue whales." Wikipedia encyclopedia. http://en.wikipedia.org/wiki/Blue_Whale. Accessed July 2004.

ACTIVITY 20: Baby Blues

Concepts

- Blue whales are the largest animals to have ever lived on the planet.
- Blue whales consume great quantities of food and grow rapidly during their first months of life.

Materials

- Blue whale background information

Time

20 minutes

Subjects

- Math
- Biology

Procedure

Baby blue's food

a. Visualize how much food it takes to support a blue whale.

- Baby blues are fed 189 liters of milk per day. Have students bring empty 1-liter soft-drink bottles to school and pile in a corner to see how much milk that would be.
- Recycle the bottles at the end of the experiment and research what materials the plastic bottles are made into (insulation fiber for ski jackets, sleeping bags, rulers, coasters, shoe laces, bookmarks, etc.). Point out that plastics in the oceans are a hazard for whales and other sea life. Plastic buckets and bottles have been found in the digestive tracts of whales and has been the cause of death for a number of marine mammals.

b. Mix equal parts of butter and whipping cream to create "whale milk" (the fat content—50%—will approximate that of whale's milk). Pass a comb through the milk to illustrate how it clings to the baby whales' baleen.

Size and growth

c. Divide students into groups and have them measure out the length of a newborn blue whale. Mark that length on the rope with a ribbon. Then stretch out the rope to measure the length of a 6-month-old calf. Conduct the math calculations below and figure out how much baby blues grow each month. Tie a ribbon on the rope to mark each month's growth on the rope.

d. Discuss how much milk and energy it has taken for the mother to feed that 6-month-old calf. Blue whales stay with their mothers until they are a year old. With 1 year of pregnancy and 8 months of nursing, it is understandable that blue whale mothers give birth to only a single calf every 3 to 4 years. With such a low birth rate, the recovery of these great whales can be expected to be very slow.

Teacher key to student worksheet #20

1. Newborn blue whale calf size: *7 meters (23 feet)*. Six-month-old blue whale calf size: *14.6 meters (48 feet)*.
2. How many meters did the calf grow per month? *1.3 meters (4.2 feet)*
3. Newborn calves weight 30 tons (60,000 pounds), and they add 200 pounds (91 kilograms) per day. What is the weight of a baby blue at 6 months? *36,000 pounds (16,329 kilograms)*

Blue whales are the largest animals to have ever lived on the planet.

4. How many tons will the 6-month calf weigh? (There are 2,000 pounds in a ton.)

5. How many liters of milk has the calf consumed in 6 months? (189 liters/day) *34,020 liters (8,987 gallons)*

Blue whale mothers give birth to only a single calf every 3 to 4 years.

Name **Date**

Student Activity #20

1. Newborn blue whale calf size: _____ meters (_____ feet). Six-month-old blue whale calf size: _____ meters (_____ feet).
2. How many meters did the calf grow per month? _____ meters
3. Newborn calves weigh 30 tons (60,000 pounds), and they add 200 pounds (91 kilograms) per day. What is the weight of a baby blue at 6 months? _____ pounds
4. How many tons will the 6-month calf weigh? (There are 2,000 pounds in a ton) _____ tons
5. How many liters of milk has the calf consumed in 6 months? (189 liters/day) _____ liters (_____ gallons)

ACTIVITY 21: Build a Costa Rica Dome

Concepts

- Different temperatures and salinity of water combine to create the unique area called the Costa Rica Dome.
- Temperature and salinity both affect the density of water. Warm, fresh water is less dense than cold, salty water.

Subjects

- Physics
- Geography

Materials

- ☐ Ice
- ☐ Hot water
- ☐ Clear soda straws
- ☐ Salt
- ☐ Small paper cups (the smaller the better)
- ☐ Red, blue, and yellow food coloring
- ☐ Maps of Central America and the Costa Rica Dome

Time

30 minutes

Procedure

Geography—mapping activity

Blue whales found off California migrate from California to Costa Rica.

- Label the countries of Central America and locate Costa Rica and the Costa Rica Dome area.

Water density activity—build a Costa Rica Dome

Divide the class into five groups of students. For each group of students, set up the following:

- Four small, bathroom-size paper cups, three of them labeled A, B, and C (the fourth one left blank), with the following contents:
  Cup A: hot fresh water and 2 drops of yellow coloring
  Cup B: icy cold, salty water and 2 drops of red coloring
  Cup C: room-temperature fresh water and 2 drops of blue coloring
  Cup 4: empty
- Clear plastic straws (one for each student)

Challenge students to trap water in the clear plastic drinking straws in the right sequence to create a rainbow of colored water in their straws. The different densities of water won't mix, if conducted in the proper sequence. In effect, students are creating a miniature Costa Rica Dome.

Note: The correct sequence to get a rainbow is: 1. hot water; 2. room-temperature water; 3. cold, salty water.

Discussion

The Costa Rica Dome has a shallow lens of warm surface water that sits on colder water that has been carried up by upwelling from deep, cold, salty waters. It is the combination of saltiness and temperature that forms the Costa Rica Dome. Explain to students that their experiment with small amounts of water requires that the temperatures and salinities be exaggerated to build the Dome. In reality, the Dome does not have such extreme differences in temperature or salinity, but there is enough difference in density that the Dome is formed. Point out to students that the dome will also have the gradient of water from warm, less salty, to cold, high-salinity waters near the ocean floor.

It is the combination of saltiness and temperature that forms the Costa Rica Dome.

Exploring the Dome activities

The maps and questions for this activity let the students take a close look at one unique ocean habitat. The goal is for students to understand that, due to atmospheric and oceanic conditions, habitats in the ocean can be quite different from the surrounding ocean.

Analysis of the Costa Rica Cross-Section map will allow students to discover what the Dome really looks like. The Dome is an area of water that is colder than the surrounding water. The temperatures are indicated by *isotherms*, lines that connect areas of the same temperature. The *thermocline* is an area where the temperature changes quickly and the isotherms lie very close together. It is the thermocline that shows the Dome, in that we can see how the cold water is pushed up under the warmer surface water.

The Costa Rica Dome map

The Costa Rica Dome is created by winds that blow from Nicaragua across the ocean waters, moving the surface water away. This action causes deeper, colder water to well up to the surface. Students should draw arrows to indicate how the winds blow across the ocean waters.

The Costa Rica Dome map looks down on the surface of the water, and the isotherms show surface water temperatures. The isotherms can again be used to define the boundary of the Costa Rica Dome. From the surface, it is a pool of cooler water caused by the cold, upwelled water.

The Dome was discovered by oceanographers taking temperature and salinity readings of water from various depths. Oceanographers also check for chlorophyll content of the water, which indicates plant growth and gives a measure of productivity. Scientific surveys of creatures that use the area were also used to describe this habitat. All the data pointed to a unique area that eventually was defined as the Costa Rica Dome.

The Dome is an area of water that is colder than the surrounding water.

Name **Date**

Student Activity #21—Build a Costa Rica Dome

Instructions

1. Put the straw straight down into the first cup of water. Place your thumb tightly over the top of the straw and lift it out of the cup. There should be a band of colored water in the straw .
2. Move to the second cup and stick the straw straight down into the cup of water. Remove your thumb. The second color of water should move into the straw, making a layer. Place your thumb tightly over the top of the straw and lift it out of the cup. If the colors mix, try again, but reverse the order that you used to collect the water. Try different sequences until all three colors do not mix.
3. Dump failed attempts into the empty cup and try again.
4. Keep trying until you get the proper sequence and the three colors of water do not mix but form three separate layers of water in the test tube.

   Generally, would the same order of temperatures and densities be found in the Costa Rica Dome?

Central America teacher key

Map by Craig Toll.

Name **Date**

Student Worksheet #21

Central America map

1. Label the countries of Central America on this map.
2. Circle the area where the Costa Rica Dome occurs and provides a unique habitat for blue whales.

Map by Craig Toll.

Name **Date**

Costa Rica Dome Cross-Section Worksheet #21

1. Examine the illustration of the Costa Rica Dome Cross-Section. Examine the pattern of the lines on the drawing. These connect areas of water that are the same temperature and are called *isotherms* (*iso* = same; *therm* = temperature. Where the isotherms are close together, there is a rapid change in temperature. This area is called the *thermocline*. It is this area where the cold water is meeting the warm. Above the area of dense lines is warm water; below is cold.
2. Label the area that is the thermocline.
3. Label which parts of the Dome are warm water and which are cold. Color the areas that are 24 degrees and above pink (warm), and the areas that are 18 degrees and below blue (cold).
4. Draw arrows in the Dome to indicate the movement of upwelling water, which creates the Dome.

Costa Rica Dome Cross-Section

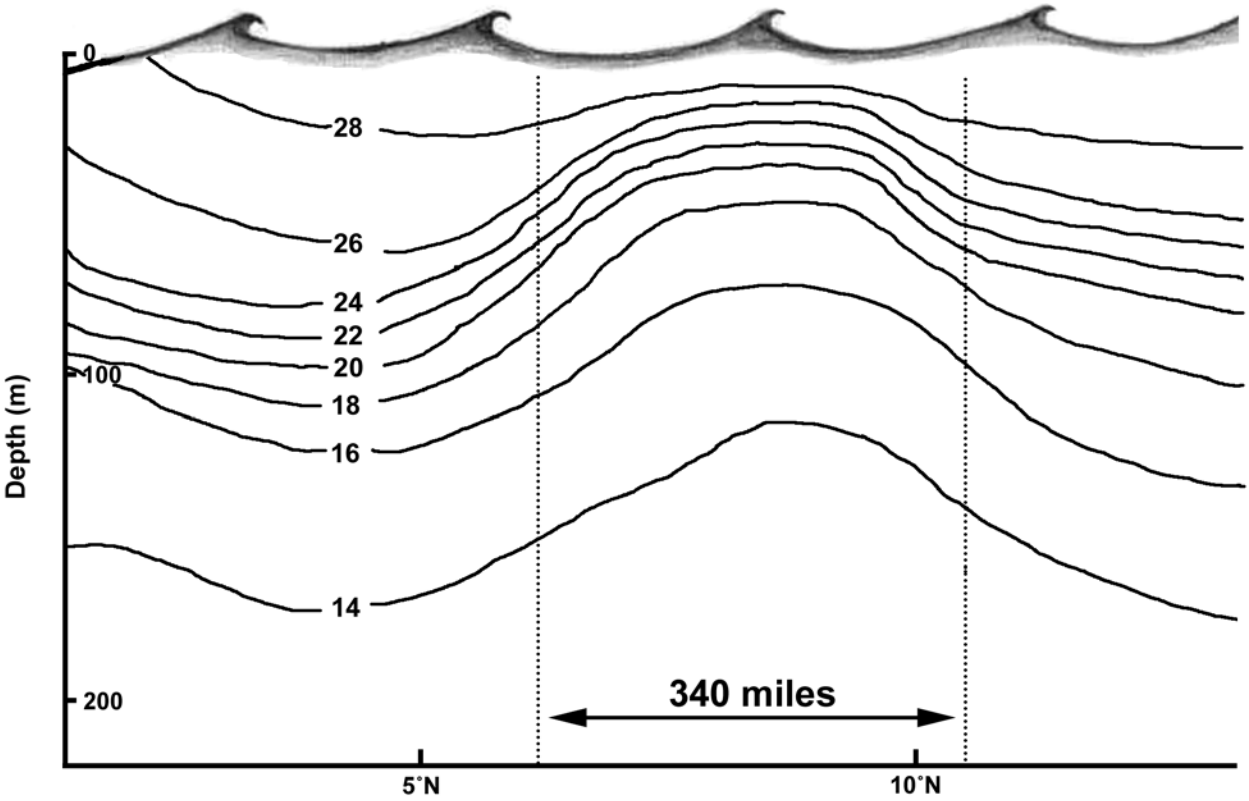


Illustration by Tai Kreimeyer (from data supplied by William S. Kessler, National Oceanic and Atmospheric Administration Pacific Marine Environmental Laboratory).

Name **Date**

Costa Rica Dome Map Activity #21

1. Locate Costa Rica and Nicaragua.
2. Using the Sea Surface Temperatures, SST isotherms (lines marked in Fahrenheit), locate the Costa Rica Dome. It is the cool-water area off Costa Rica. The Dome lies within isotherms of 50 degrees or less. Color it blue.
3. Check the isotherms and locate the waters that are 60 degrees and above. Note that the surrounding waters in this area are mostly warmer.
4. Draw an arrow on the map to indicate the direction of the winds that blow and stir the waters to create the Dome.
5. In the margins of the map, list five or six animals that are attracted to the rich waters of the Dome.

Costa Rica Dome map

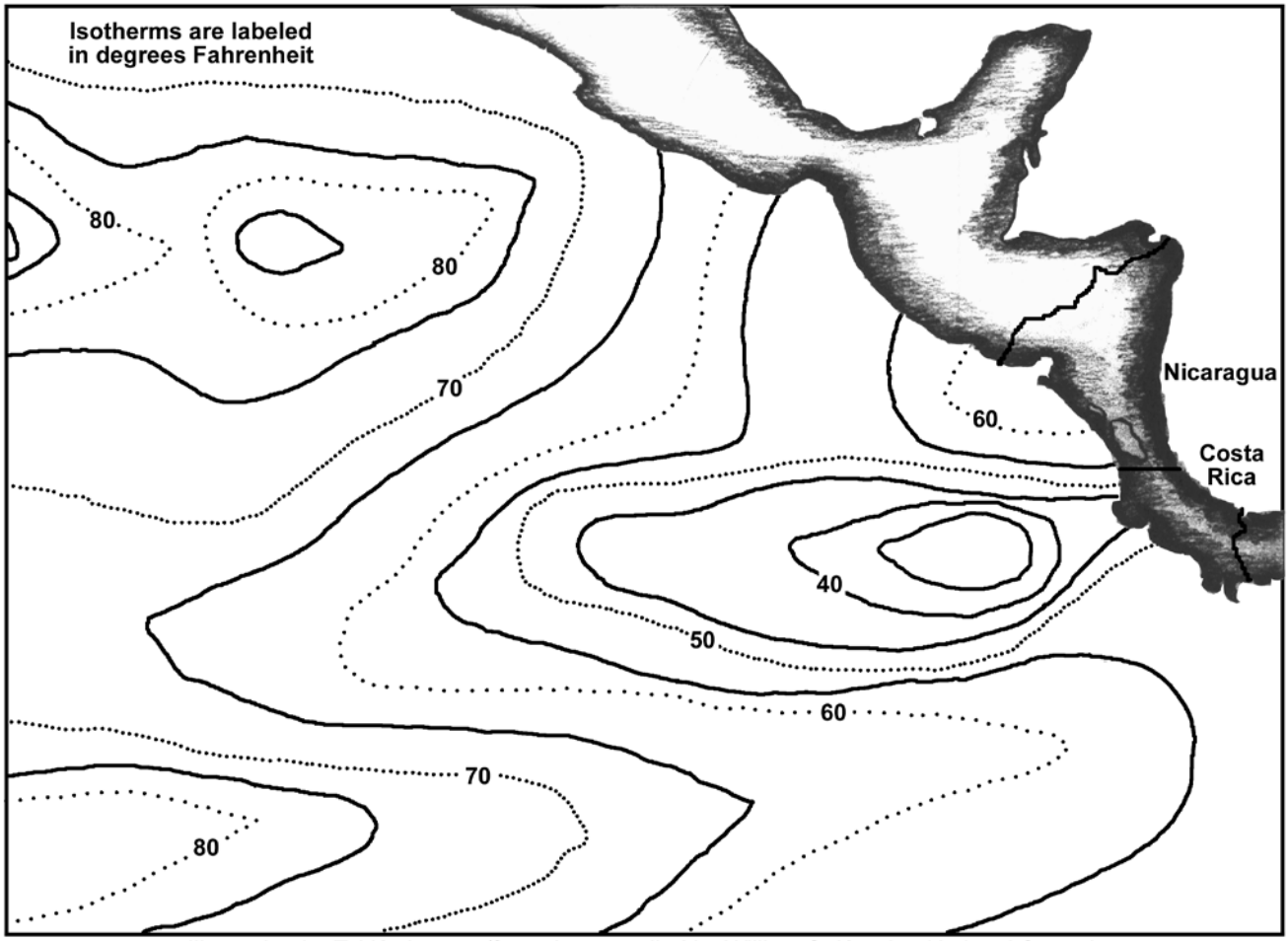


Illustration by Tai Kreimeyer (from data supplied by William S. Kessler, National Oceanic and Atmospheric Administration Pacific Marine Environmental Laboratory).

Fin Whales

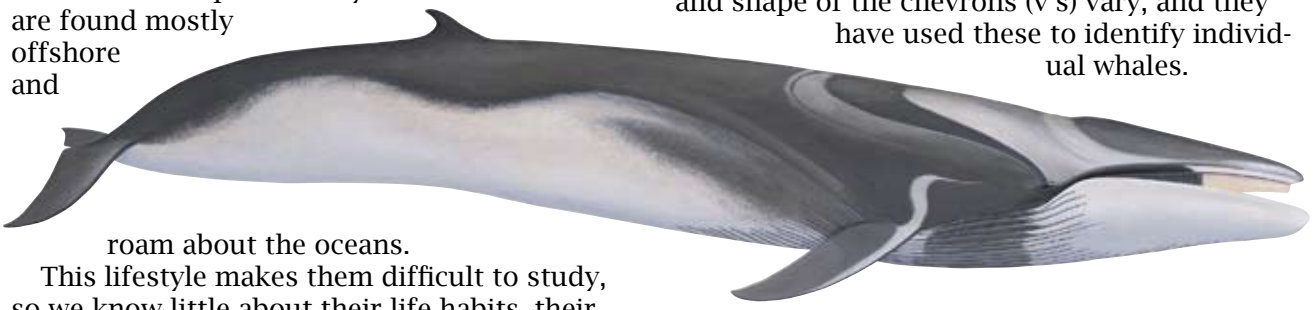
Balaenoptera physalus (balaena = baleen or whale, and Greek pteron = fin, and Greek physa = bellows), "finned whale with bellowing spout."

Fin whales are found in all parts of the oceans, from the cold southern and northern hemisphere latitudes to warmer tropical areas. They are found in the north Atlantic off Iceland, in the Pacific off California and Mexico, and in the southern hemisphere. They are found mostly offshore and roam about the oceans.

This lifestyle makes them difficult to study, so we know little about their life habits, their habitats, and their calving grounds or migration patterns.

We know that fin and blue whales both use the Sea of Cortez in Mexico. The methods used to study these elusive whales are tagging and listening to their sounds (acoustics studies). Questions as basic as "Do fin whales migrate in and out of the Sea of Cortez, or are they year-round residents?" have yet to be answered.

Fin whales are included in the rorqual family and have the characteristic deep throat grooves of that group. Second in size only to the blue whales, fins are unique in that they have odd coloration. On the right side of the head, the lips and a 2-foot front section of the baleen are white or pale gray. The lips and baleen of the left side are all dark. Why these whales have a section of white baleen is unknown. The white color of the right lip continues over the back, from the corner of the jaw to behind the blowhole, forming a wide V along the back and upper side. Scientists have discovered that the color and shape of the chevrons (v's) vary, and they have used these to identify individual whales.



Fin whales feed on both krill and small fish. Along with the sei whales, fins are the fastest-swimming whales. Next to the blue whales, fins have the deepest voice of all the whales. The sounds are so low, they cannot be heard by humans until recorded and sped up.

Source

Pacific Marine Environmental Laboratory Whale Acoustics Project. http://newport.pmel.noaa.gov/whales/finwhale.html. Accessed July 2004.

ACTIVITY 22: Whales: The Inside Story

This activity focuses on information gathered during whale studies. Beached whales provide opportunities to learn about whale anatomy and physiology. Most beached whales are dissected and examined to determine the cause of death. The fin whale used for this activity was one of the few in which every organ was measured and weighed during the dissection.

Concepts

- A whale's internal anatomy is different from other mammals and its organs are very large.

Materials

- ☐ Scissors
- ☐ Glue
- ☐ Whale outline
- ☐ Whale organ illustrations
- ☐ Table of whale parts sizes

Subject areas

- Math
- Biology

Time

45 minutes

Procedure

Participating in a whale dissection is next to impossible for students, but this activity allows them to cut and paste the internal organs of a whale into their proper positions in the whale outline. Ask students to place the organs into the whale in the sequence indicated. Students review the chart of the sizes of fin whale organs as they relate to the size of a 6-foot (182.8 centimeters) tall, 200-pound (90.7 kilograms) human.

Most beached whales are dissected and examined to determine the cause of death.

Have students add each organ or set of organs, system by system, in the order given below:

- Digestive system
  —Stomach and intestines
  —Liver
- Excretory system
  —Kidney
- Reproductive system (this specimen is a male)
  —Testes and penis
- Circulatory system
  —Heart
- Respiratory system
  —Lungs and trachea
- Nervous system
  —Brain and spinal cord

Digestive system

- The *stomach* of baleen whales consists of three main compartments. The first and second compartments (forestomach and main stomach) are wide and can hold at least 200 gallons and possibly up to a ton of krill. Whales have a stomach similar to that of cattle, deer, and sheep, which also have three stomach compartments. The intestines do not show a difference in size between the large and small intestine as in most other mammals.
- The liver is two-lobed, whereas humans have a four-lobed liver. The lobes of both human and whale livers are of unequal size. Whale liver is sold as food in Japan.

Respiratory system

- *Lungs*—Note that the trachea leads to the nostrils on the top of the head.

  The lung capacity of a 22-meter (71-foot) fin whale is about 2,000 liters. It sounds like a lot, but relative to the fin whale's size it isn't greatly different from that of other mammals.

Circulatory system

- The *heart* is four-chambered like that of other mammals. There are left and right ventricles and auricles, a pulmonary artery and vein, and an aorta. Among mammals, the whale has the widest heart, and it is slightly flattened and rounded at its apex (tip). The muscle walls of the ventricles (two lower heart chambers) of several large whales have been measured from 7.6 to 12.7 centimeters (about 3–5 inches) in thickness.

  The pulse rate has been estimated at 60 to 140 beats per minute, dropping to 4 to 15 beats per minute when diving.

Excretory system

- Kidneys are located in the top of the body cavity, one on each side of the spinal cord area. They are *lobulated*, which means they look like a huge bunch of grapes tightly packed together.

Testicles and ovaries

- Located near the kidney areas.

Fin whale organs

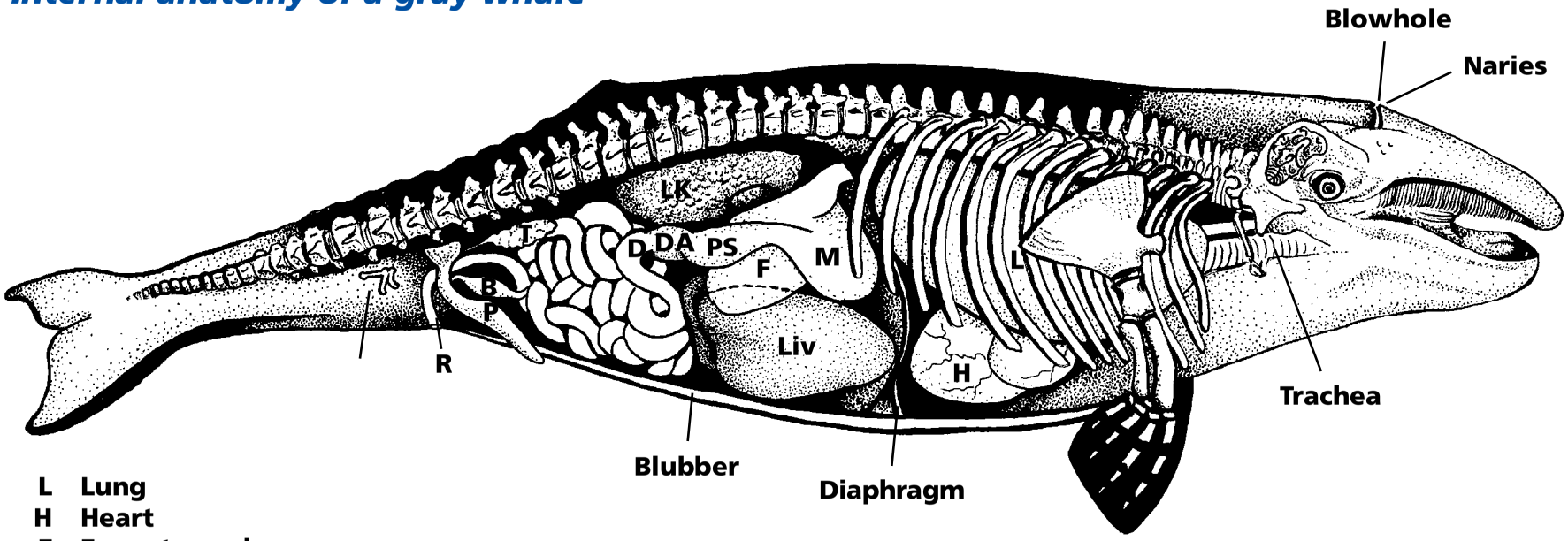
The size of each internal organ has been determined from an actual dissection of a fin whale.

Organs from a 22.6-meter (71-foot) fin whale

Organ	Weight in pounds	in kilograms	How many 6-foot, 200-pound humans
Brain	18.4	8.3	.09
Kidney	461	209	2.3
Heart	842	382	4.2
Lung	868	394	4.3
Spleen	15	6.8	.08
Pancreas	60	27.2	.3
Eye	3.7	1.7	.02
Ovary	11.3	5.1	.06
Ovary + uterus	215	97.5	1.1
Stomach	685	310.7	3.4
Intestine	2,255	1022.9	11.2
Tongue	2,707	1,227.9	13.5
Testes	no data		
Penis	9 feet long	2.7 meters	2.5

The first and second stomach compartments can hold at least 200 gallons and possibly up to a ton of krill.

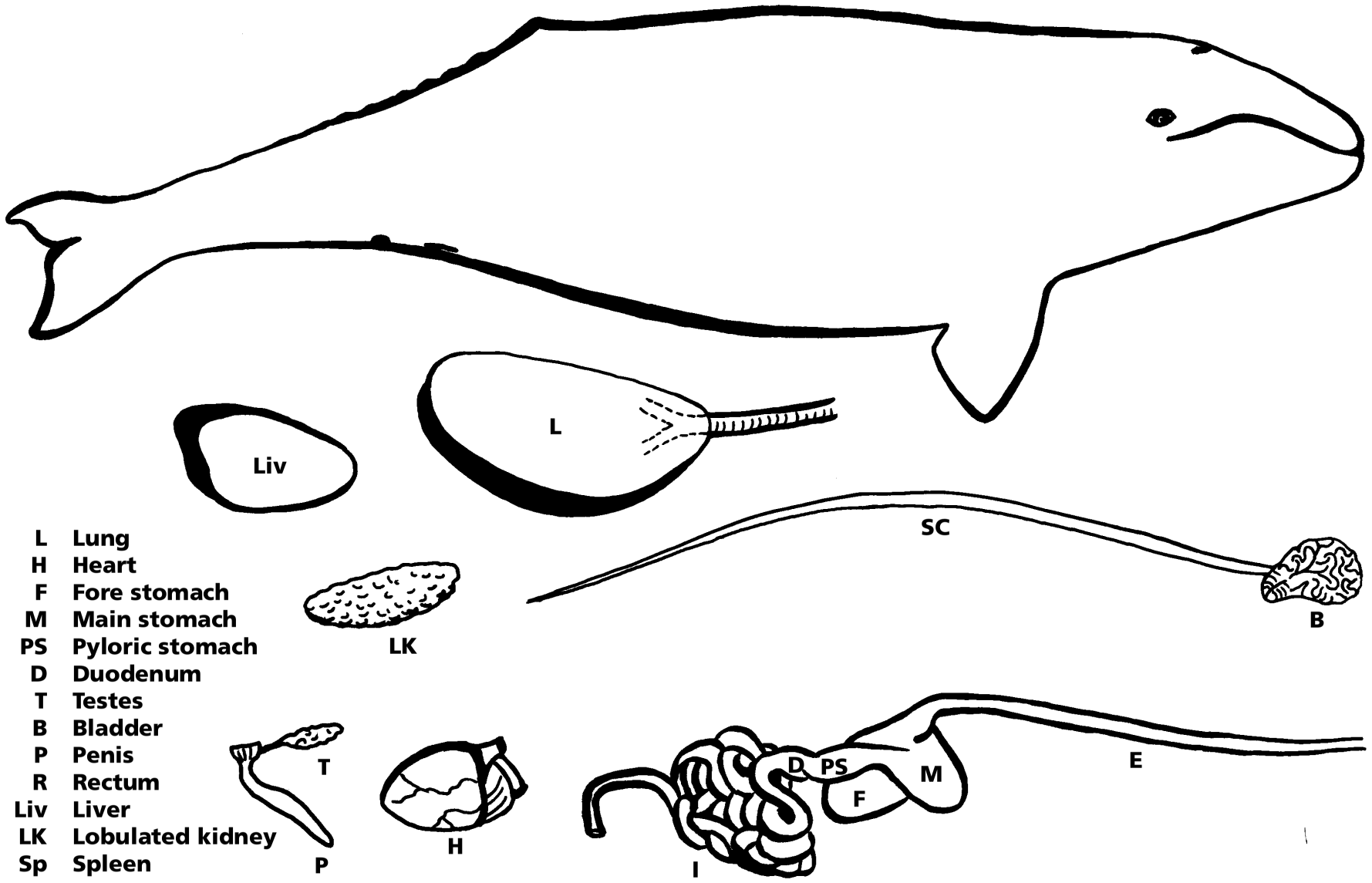
Internal anatomy of a gray whale



L	**Lung**
H	**Heart**
F	**Fore stomach**
M	**Main stomach**
PS	**Pyloric stomach**
DA	**Duodenum ampula**
D	**Duodenum**
T	**Testes**
B	**Bladder**
P	**Penis**
R	**Rectum**
Liv	**Liver**
LK	**Lobulated kidney**
Sp	**Spleen**

Illustration by Laura Hauck, with assistance from the Whale Museum, Friday Harbor, Washington ("for full access to the skeleton as I perched on a ladder in the museum for a day"), Tamara McGuire and the Marine Mammal Stranding Network ("for dissection access"), and Jan Hodder ("for striped dolphin dissection and knowledge regarding marine mammal internal anatomy").

Student Worksheet—Build-a-whale activity

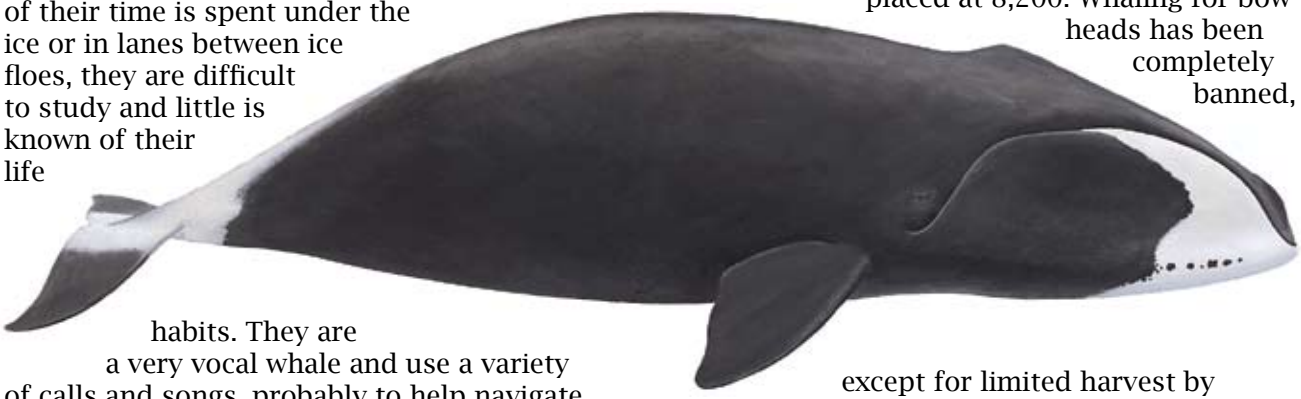


L	Lung
H	Heart
F	Fore stomach
M	Main stomach
PS	Pyloric stomach
D	Duodenum
T	Testes
B	Bladder
P	Penis
R	Rectum
Liv	Liver
LK	Lobulated kidney
Sp	Spleen

Bowhead Whales

Balaena mysticetus (balaena = baleen or whale, mysticetus = mustache), mustachioed whale.

Bowhead whales are the ice whales. They live in the northern polar waters, spending most of their lives under or near pack ice. They are known to break through 60-centimeter (23.6-inch) thick ice to breathe. Their encounters with ice leave scars that scientists use to identify individual whales. Only during brief periods of the summer do they find ice-free waters. So much of their time is spent under the ice or in lanes between ice floes, they are difficult to study and little is known of their life habits. They are a very vocal whale and use a variety of calls and songs, probably to help navigate around the ice.



In appearance, they are much like the right whales, with enormous heads and long baleen. Bowheads have the longest baleen of any of the whales—up to 4 meters (13.1 feet). At the peak of the whaling period, bowheads were heavily hunted. When the price of oil dropped, they were hunted only for their baleen, which was used in buggy whips, ladies' corsets, and umbrella stays. Spring steel eventually replaced baleen, literally saving bowheads from being hunted to extinction.

Bowheads grow to be quite old. The recent discovery of stone harpoon tips in the blubber and aging studies on the tissues of their eyes has increased their estimated age to over 100 years.

There are five different stocks of bowheads, identified by the areas of the oceans in which they live. All five stocks are distributed in the far north waters of the Atlantic and Pacific oceans. None occur in the southern hemisphere.

They are known to migrate between summer feeding grounds and wintering areas. Oil exploration and drilling in Arctic waters is one of the major threats to these animals. Identification of migration routes of bowheads is of importance to protect this species.

Their numbers today remain severely depleted. The only reliable population estimates are for the western Arctic stock, whose number is placed at 8,200. Whaling for bowheads has been completely banned, except for limited harvest by native Alaskans. These people have hunted bowheads for generations, and the whales are important to their cultural practices. Whaling has been incorporated into many aspects of the daily lives of Eskimos. The whale provides plentiful supplies of meat, skin, and blubber that are used as food by all the community. Bowhead population growth rates are estimated to be about 3% per year, even with the harvest by Alaskan natives.

The U.S. Marine Mammal Protection Act banned taking of all whales, and the U.S. has encouraged other nations to do likewise. The Eskimos' limited harvest has drawn criticism from other countries and especially from marine mammal conservation groups.

Source

"Overview of Alaskan Eskimo Whaling Commission," http://www.uark.edu/misc/jcdixon/Historic_Whaling/AEWC/AEWC.htm

ACTIVITY 23: Whaling Debate

Concepts

- Protecting whales is more than just protecting endangered species.
- Native cultures have evolved around whales.

Materials

- ☐ Reading information about bowheads

Subject areas

- Sociology
- Biology

Time

30 minutes (presentation and discussion; homework to prepare arguments for or against whaling)

After the U.S. adopted the policy of protecting all marine mammals under the Marine Mammal Protection Act, the harvest of bowheads by Alaskan Eskimos was also to cease. It quickly became a hotly debated topic. Alaskan natives had long harvested bowheads for food, and the hunting, preparation, and use of the whale became a central part of their culture. At the heart of the bowhead controversy was the need to save an endangered species or to save an endangered culture—or, more importantly, to find a balance between the two.

Read the background information about the Eskimos' harvest of bowhead whales. Discuss the information from the reading to build an understanding of native cultures and the importance of natural resources to their livelihoods and their culture. Conduct a mock hearing to determine the policy for bowhead protection.

Procedure

- Read "Bowhead Whales."
- Divide students into three groups:

  Group A: Native Alaskans

  Group B: Whale conservationist organizations that wish to protect all marine mammals from being harvested

  Group C: The U.S. Marine Mammal Commission, which must make the decision to permit or ban the taking of bowheads by native Alaskans

Part A of the debate

Divide students into three groups and assign each group a role to play in the dispute over the bowhead harvest. Allow the students to research and develop their own arguments about bowhead harvest. Have each group present their arguments for or against bowhead harvest to the central body of the Marine Mammals Commission. Include their rationale as to why or why not the whales should be harvested.

Place the U.S. Marine Mammal Commission at the head of the room to conduct the hearing. Allow each group to present their arguments. The Commission may question the presenters, discuss their decision, and present it to the class. Have them develop their arguments for the first part of the debate for or against the take of bowhead whales.

Part B of the debate

After the first round, have the students reconsider their positions and develop a compromise statement. Allow each side to present their compromise statement. The Commission should again settle on a ruling and present it to the opposing sides.

Open discussion for a class debriefing about the bowhead controversy. Does the commission ruling satisfactorily

At the heart of the bowhead controversy was the need to save an endangered species or to save an endangered culture.

resolve the issue? Arrive at a class decision about allowing bowheads to be harvested for cultural purposes. Was the students' conclusion and resolution of the issue similar to the actual agreement that was reached?

Bowhead Whales and Native Alaskans

Bowheads are found in the far north Pacific in the Arctic ice sheets. They have been hunted and harvested by Eskimos for thousands of years. The harvest and use of the bowhead was so important to these people that many ceremonies and cultural practices became associated with the hunt and preparation of the meat. Various parts of the whale were prized for its flavor and would be divided and distributed among all members of the community.

Bowhead harvest came to provide livelihood, meaning, and identity to the Eskimo whalers and their communities. The communal nature of the hunt became an important part of and remains today a spiritual and cultural center of the community.

Butchering and sharing the whale with the whole community are a ritualized and highly valued cultural practice. Select parts of the whale are divided among the whaling crews at the butchering site. Shares are set aside for important members of the community, including the elders and widows. Some parts of the whale are stored to be used at important festivals, such as the traditional feasts of Nalukataq and Qagruvik. Everyone at the festival can take part in the ceremony and has access to the whale meat. Eventually, the tons of meat find their way throughout the region, all year long.

In 1977, due to concerns over the decreasing numbers of bowheads, the International Whaling Commission imposed a ban on the harvest of bowhead whales by Alaskan natives. The Eskimo community, dismayed by the loss of such an important resource, responded quickly and formed their own whaling commission, which they called the Alaska Eskimo Whaling Commission (AEWC). They worked to organize the native Alaskan whaling communities to begin managing the harvest of bowheads themselves.

At first, there was much discussion and conflict between the two whaling commissions. The conflict peaked with a bitter standoff in the fall of 1980. Out of this conflict came an agreement between the National Oceanic and Atmospheric Administration (NOAA), the federal agency responsible for managing whales, and the AEWC. They signed a Cooperative Agreement on March 26, 1981, in which NOAA delegated to the AEWC management authority for the Eskimo whale harvest. This allowed the AEWC to manage the hunt without the presence of federal agents in the whaling communities. The AEWC Management Plan governs the whales, and the AEWC reports to NOAA on the results of each spring and fall whaling season.

The agreement was a victory for the Eskimos, as they succeeded in replacing the ban with a small quota. Scientific studies showed that the population of bowheads was higher than previously thought. Better methods for estimating the population of bowheads have helped the whalers to eventually secure an increased quota, based on the established historic need of the whaling communities.

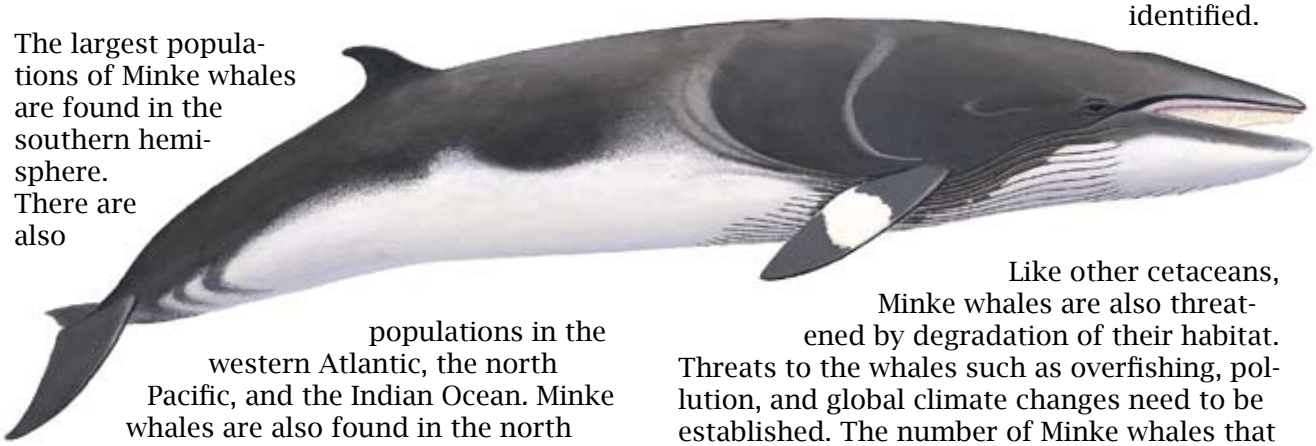
Source

Henry Huntingon, *Inuit Whaling*. Published by Inuit Circumpolar Conference, June 1992. Special issue http://www.highnorth.no/Library/Hunts/Other/al-es-wh.htm. Retrieved February 2004.

Minke Whales

Balaenoptera acutorostrata (balae = baleen or whale, optera = fin or wing, acuto = sharp, strata = layer); Minke = the name of an infamous Norwegian whaler

The Minke (pronounced minky) is one of the smallest of the baleen (filter-feeding) whales, seldom growing larger than 32 feet (10 meters) in length. Its sharp, pointed head and the white band on its flippers are distinctive for this species. Minkes are found all across the world's oceans, ranging into the icy polar regions.



The largest populations of Minke whales are found in the southern hemisphere. There are also populations in the western Atlantic, the north Pacific, and the Indian Ocean. Minke whales are also found in the north Atlantic and are commonly sighted off the coasts of Ireland, Great Britain, and Scotland. They are also sighted in the Pacific off Alaska and the northwest U.S. coast.

Minkes are rorqual whales and have the same expandable throat pouches as the larger species of rorquals. They feed on larger prey than most baleen whales, searching out a variety of fish, squid, and krill for food.

They are one the most abundant of the world's whales, with the total population estimated to be at least 1 million. They are currently being hunted and used for food in the Scandinavian countries and in Japan and Siberia. In the mid-1990s, several hundred Minkes were taken in 1 year by Norway. There is concern and discussion about harvesting Minke whales, as sustainable harvest levels have not been established.

The name "Minke" was the name of a Norwegian whaler who was known for breaking rules and taking smaller whales than was allowed. All small whales came to be called Minke, but eventually the name was used solely for this one small whale.

Research interest: Since Minkes are being harvested, establishing reliable population data about the stocks is of interest, and the responses of Minke population numbers to the harvest are important. Their migrations and calving and feeding grounds have not been identified.

Like other cetaceans, Minke whales are also threatened by degradation of their habitat. Threats to the whales such as overfishing, pollution, and global climate changes need to be established. The number of Minke whales that become entangled in fishing nets each year is not known.

Sources

Stocks of Minke Whale. http://www.highnorth.no/Library/Hunts/Norway/ci-no-dr.htm. Retrieved April 2004.

Minke whales. http://ourworld.compuserve.com/homepages/jaap/minke.htm. Retrieved April 2004.

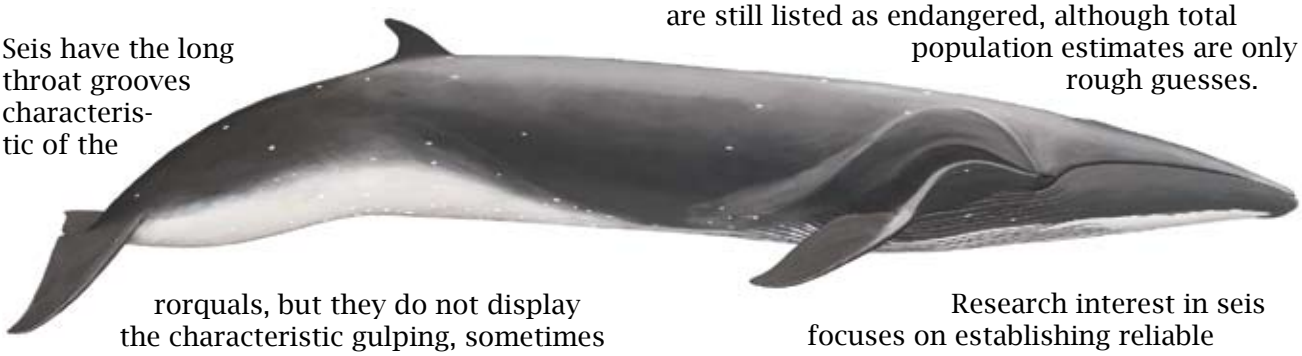
*The next reading sections deal with lesser-known whales. One activity at the end applies to all three whales—Minke, sei, and pygmy right whales.

Sei Whales

Balaenoptera borealis (balaen = baleen, optera = fin, borealis = boreal* region), "Finned whale of the boreal region." Common names: sardine whale, pollock whale, and coalfish whale.

*Boreal = northern temperate climate with cold winters and warm summers.

The sei (pronounced "say") whale may grow from 25 to 50 feet (8 to 25 meters) in length and weighs up to 40 tons (40.6 metric tons). Norwegians used the name sei as this whale arrived in Norwegian waters at the same time as Sei, the Norwegian name for coalfish. It is the third-largest baleen whale, smaller only than the blue and finback whales.



Seis have the long throat grooves characteristic of the rorquals, but they do not display the characteristic gulping, sometimes called lunge-feeding behavior. Rather, they feed by skimming on their sides at the surface for small crustaceans and fish (copepods, krill, and small fish). The sei's baleen is gray with a lighter-colored area near the tip of the snout that is similar to that of the fin whales.

Seis live in all oceans of the world in temperate regions. These are the areas of the oceans with moderate temperate ranges. The whales feed in the summers in the subpolar waters of both hemispheres and migrate to warmer, subtropical waters during the winters. They are rarely sighted in polar and tropical latitudes. They spend their time offshore in deeper waters, near the margins of continental shelves, and seldom venture into more shallow areas. Sei whales usually appear alone or in groups of two to five. This fact, coupled with their preference for deep-water habitats, makes them less accessible and therefore more difficult to study.

Seis mature at 6–10 years of age and are believed to grow to 65 or 70 years of age. They give birth to one calf every 2 or 3 years.

Seis frequent the same waters as blue and fin whales, which were once heavily hunted. Once the populations of blues and fins were depleted, whalers turned to sei whales, taking large numbers of them in the mid-1960s. One year's harvest of over 25,000 whales occurred during that period. By the late 1970s, the harvest had caused the sei's numbers to fall so low that in 1979 they were assigned protected status. They are still listed as endangered, although total population estimates are only rough guesses.

Research interest in seis focuses on establishing reliable population estimates and identifying birthing grounds and migrations. Threats to these whales are also poorly identified. There are few, if any, recorded fisheries interactions, and mortalities from collisions with ships are poorly documented.

Sources

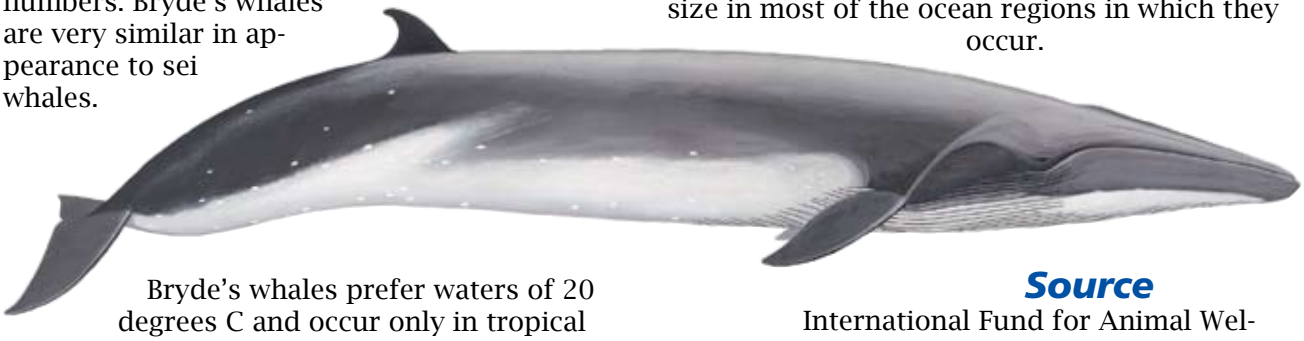
Hebridean Whale and Dolphin Trust. http://whales.gn.apc.org/whale5.shtml. Retrieved April 2004.

New York State Department of Environmental Conservation, Fish, Wildlife and Marine Resource Division. http://www.dec.state.ny.us/website/dfwmr/wildlife/endspec/sewhfs.html. Retrieved April 2004.

Bryde's Whales

Balaenoptera edeni (balaen = whale, optera = wings, edeni = Eden), Eden's whale. Named for Johan Bryde, pioneer of whaling in South Africa in 1913. Common names: tropical whale, sardine whale.

The Bryde's whale and the pygmy right whale are the smallest of the great whales. Little is known about their life styles and population numbers. Bryde's whales are very similar in appearance to sei whales.



Bryde's whales prefer waters of 20 degrees C and occur only in tropical or subtropical waters. They are known to be deep divers. They feed on schools of small fish, such as herring or anchovies, and krill.

The Bryde's whale is sometimes called "sardine whale" because it feeds on small fish.

The Bryde's whale has not been heavily hunted. Very little is known about this species of whale. It has no known long migrations and is different from most baleen whales in that it often feeds in groups of up to 100.

Research interest in the Bryde's whale is focused on identification of stocks, their locations, and population sizes. Big gaps in information remain about Bryde's whales regarding population size in most of the ocean regions in which they occur.

Source

International Fund for Animal Welfare. http://www.ifawct.org/whaledb/whale12.htm. Retrieved April 2004.

Pygmy Right Whales

Caperea marginata (Caperea = to wrinkle, refers to the earbone; marginata = margin, refers to the dark border on the baleen of this species)

Pygmy right whales are found only in the southern hemisphere. They are usually found in temperate to sub-Antarctic waters. They inhabit both open ocean and shallow bays and are common in waters off Tasmania and Australia.

They've also been sighted off the coasts of South Africa, southern Australia, New Zealand, and Chile. They have a low profile in the water, an insignificant blow, and a short surfacing period, making them difficult to observe. That, coupled with low numbers and a secretive nature, makes them a very difficult animal to study.

Pygmies are the smallest of the great whales, reaching 5 to 6 meters (16.4 to 19.7 feet) in length. In appearance, the pygmy is similar to the right whale in that it has a high, arched jaw and the head makes up 1/4 of its body length. But pygmies are more closely related to the rorqual whales.

The pygmy's baleen is fine, indicating that small food prey such as copepods and krill are most likely its primary source of food.

There are big gaps in the amount of information known about pygmy right whales. We know little about their reproductive cycles, feeding and social behaviors, and feeding areas. The pygmy right whale is so rare and unstudied, it is not even known how rare it really is.

Source

Pygmy right whale, *Caperea marginata*. http://www.cetacea.org/pright.htm. Retrieved April 2004.

ACTIVITY 24: Design a Research Project

This activity allows students to select and design major aspects of a research project.

Concepts

- There are a number of steps involved in conducting a research project.
- Students will develop inquiry skills by designing a research project on one of the smaller, less-known whales.

Materials

- ☐ Writing materials

Subject

- Biology

Time

One period, or homework

Design your own research project for one of the lesser-known whales such as the Minke, sei, pygmy right, or Bryde's. Research on these whales may be as simple as answering questions about what they eat, where their favorite feeding areas are, whether they migrate from summer to winter areas, how often they have calves, how old they are, whether they live in groups or alone, etc.

Research projects often follow much the same format, which includes some or all of the following:

- Develop questions to be answered.
- Determine who might finance your study. (States or countries with whale populations may fund research, or research grants may be obtained from fisheries management agencies.)
- Conduct a literature search to find out what is known about the whale to be researched. (Check out Web sites on the whale you are researching. Scientists use libraries and literature searches of past research projects.)
- Develop a plan:
  —Where to conduct the work. Check the Internet to see where stocks of the whales are located.
  —Will you conduct field work? Lab work?
  —How long do you estimate the study will take?
  —What equipment will be needed to conduct the research? Whale research might require the use of ships, radio tags, satellite time, nets and water bottles to test water, high-resolution binoculars, cameras, etc.
- Conduct the project—list the steps you will take to gather the data you will need.
- Analyze the data.
- Disseminate the results of the project. For example: write papers to be published in scientific journals, give presentations at meetings to other scientists, write fact sheets for distribution to the public, or set up a Web site.

  How will you extend to the public the information you have gathered?

How will you extend to the public the information you have gathered?

7. Whale Research

Whale Research and Technology

Tailing the whales—using satellites

We know we could never put enough ships in the ocean to watch all of the ocean and find out where whales live! So we need another way to watch for whales. Scientists are adopting the most sophisticated technology to study whales. Dr. Bruce Mate, of Oregon State University, has pioneered the use of radio tags and satellites to unlock mysteries of whale behavior and carries on active tagging research. Satellites high above the Earth can pick up radio signals and record broad areas of ocean at one time. Some satellites carry cameras to photograph and transmit digital information to computers. The information is made into pictures and reveals a lot about the ocean habitat. But more is needed than just taking pictures of the ocean. Pictures can't show where whales go throughout their lives. Once scientists know which parts of the ocean and which habitats the whales use, then photos can be used to find out more about those places.

To track a whale, the scientist attaches a radio transmitter called a *radio tag* to the animal's body. The radio tag sends a signal to the satellite, and the satellite relays the signal to computers.

Attaching radio tags to whales seemed pretty crazy when scientists first thought about it. But it was really the only way they could keep track of whales over a series of months. Big problems had to be solved to make this work. The first thing to consider was how to keep the tag attached to whales that swim over thousands of miles and rub against rocks, the ocean bottom, and other whales. Also, whatever was designed must not hurt the whale. Once those problems were solved, the next issue was how to power the tags so they could send signals to the satellites.

What do the data from tags and satellites tell us? Some of the sensor-rich tags Dr. Mate has used on whales have given answers to these questions:

- Where do the whales go and what is the temperature of the water there?
- How long are their dives?
- How long does a whale stay at the surface?
- How often do they dive?
- How deep do they go on a dive?
- What percentage of their time do they spend at specific depths?

Another battery-operated tag Dr. Mate will use is smaller and much simpler. It gives location data and a count of the number of surfacings a whale makes. The tag transmits data that is collected by "ARGOS" receivers onboard NOAA satellites overhead. However, the tag can transmit only when out of water, so the placement of the tag on the whale's back is critical. The tag will be exposed to air when the whale comes up to breathe. If all goes well, the data will reveal the whale's migration path and other movement patterns until the tag falls off or the battery runs down.

Tagging is done from a small (often inflatable, Zodiac-style) boat about 15 to 24 feet long. The researchers use a compound crossbow or air-powered line thrower to dart the tags from close range.

After experimenting with different tag designs and improving the design over a number of years, researchers developed a tag that is about the size of a cigar. The tag has an antenna wire, which sends the signal to the satellite, and a *conductivity switch*, which keeps the antenna from sending signals when the whale is under water. This saves battery power. The tag sends its signal (a *transmission*) to an overhead satellite, which then sends tag data down to a data processing center in North America. The tags are programmed to send a signal only when

there is a receiving satellite overhead, again saving battery power.

Radio tag (about 1/2 actual size).

The tag is implanted into the whale's upper side, where the blubber layer is thick. When it is implanted, only the antennas stick out from the whale's skin. Since the blubber layer has little or no blood vessels and nerve endings, the process is believed to be painless to the whale. Many whales don't even flinch when they are tagged. To some whales, it probably feels like getting a vaccination. If the tag is attached long enough, it *encapsulates* like a splinter would in your finger. Again, this doesn't seem to hurt the whale at all.

Dr. Bruce Mate "darts" a whale with a radio tag.

OSU researchers have tagged gray, humpbacks, blues, fins, bow-heads, right, and sperm whales. The data from this research always gives new information about whale migrations and habitats. Tags help to locate their winter and summer habitat areas and migration routes.

Satellite tracking is being used on more than whales. Birds, sea turtles, and elephants are just a few of the creatures scientists are following around with satellites.
The U.S. National Oceanic and Atmospheric Administration (NOAA) operate the satellites. They are the same satellites used to track global weather patterns, and they do much more than monitor radio tags. These satellites are *polar orbiting*—they circle the planet over both the north and south poles. They have special instruments designed to listen for transmissions from radio tags and determine their location. This might seem simple to do, but it isn't. Each satellite circles the earth every 101 minutes, meaning it is over any one place on Earth for only about 10 to 15 minutes. Then, the whale must be on the ocean

Whale with radio tag implanted.

surface when the satellite is overhead. The more transmissions received from a satellite passover, the more accurate the location of the whale. Also, the transmissions come with an estimate of how accurate, or reliable, the location data is. So the locations can be a little off at times. Using computer mapping programs or hand plotting the location data, scientists can visually see where the whale is, the route it is travelling, and roughly how fast it is swimming.

The radio signals also transmit a digital code, from which scientists can determine information about the whales' diving behavior—how deep they dive, how long they dive, and how much time they spend on the surface. We can download this data in Oregon State University's laboratory at Newport, Oregon.

We can use the satellites for more than just tracking the whales. The SeaWIFS satellite provides important data on ocean productivity. SeaWIFS stands for the Sea-viewing Wide Field of View Sensor, designed to measure the amount of phytoplankton in the ocean and the seasonal changes in distribution. They can also measure surface currents, water temperatures, salinity, the amount of sediment in ocean water, ocean ice cover, and much more. The observations are made with radar, lasers, and color- and infrared-sensing scanners. The maps these satellites produce translate ocean temperatures into color patterns. Infrared patterns show false colors, but different temperatures can be assigned to each color to identify masses of cold and warm waters. The same can be done with plankton blooms, and the satellites can sense the amount of chlorophyll (green pigments) in the plants. Chlorophyll maps of the ocean can identify areas of productivity and plankton blooms, and on land the changes of the seasons can be recorded.

These methods rely on electromagnetic radiation, which can't penetrate ocean water very well. This means that all these observations are limited to the upper few meters of the ocean. So we still have to use ships to get many of the measurements needed from below that depth.

Using sounds to study whales

Technology now allows us to put listening devices (hydrophones) into the ocean to listen to sounds. Researchers are using sounds to further explore the oceans and learn more about whales.

Animals make sounds for many reasons. Birds sing to attract a mate or mark a territory, dogs growl in threat, humans speak to communicate complex ideas and emotions. In the ocean, sound is more important than in most places. This is because vision is not of much use in the dark ocean depths, and the sense of smell is very limited in water. So marine animals, especially whales and dolphins, have developed very sophisticated ways to both make and hear sounds in the water, and use them to communicate and "see" their surroundings.

The toothed whales (sperm whales, orcas, belugas, dolphins, porpoises, etc.) use all kinds of sounds to communicate with each other—grunts, whistles, chirps, and squeals. They also use very high-frequency sounds, called *echolocation*, to find prey. They send out the sounds and wait for the echo to return to their ears. The echo tells them how far an object is from them and what it is—the same way we use vision.

The baleen whales (blues, grays, humpbacks, fins, Minke whales, etc.) are not thought to use the type of echolocation used by toothed whales. The sounds scientists have recorded from baleen whales are low frequency, as opposed to the high-frequency sounds used in echolocation. Baleen whale sounds are usually described as moans or thumps. These are probably used for communication and possibly to probe the environment for navigation, to hear echoes off seamounts, continental shelves, icebergs, etc. Humpback whales seem to have the most complex calls of any of the baleen whales. Male humpback whales sing "songs" that consist of a series of sounds put together and repeated over and over. This sometimes goes on for hours.

Other species have their own distinctive calls that allow us to identify them. Bryde's whales make slow, low-frequency grunts; right whales make a querulous, rising moan; and fin whales make a short pulse. Sometimes there are differences between stocks of whales as well. Each humpback stock seems to have its own song, and the songs change from year to year. Researchers have also discovered that the eastern Pacific (west coast of the U.S.) blue whales make different sounds than those in the western

Pacific off Japan, which in turn are different from those off South America or Antarctica.

Scientists studying whales by analyzing hydrophone data can learn about the seasonality and distribution of whale calls, and in the case of some species, what they may be doing. Certain call types are made only by males or only by females and are probably related to breeding or mother-calf communication. Other sounds are associated with feeding. When combined with tagging and other ways of studying whales, sound gives us a clearer picture of the life of the whales.

Whale call research is trying to relate their behavior (singing) to sound pollution in the oceans. One researcher discovered that humpback whales change their songs when loud Navy sonar sounds are present. Do their songs change when powerful explosions are released into the oceans? When noisy oil-exploration ships go by? These are all topics of research.

Sperm whales produce the most intense sounds. Scientists believe the first attempts to tag sperm whales failed because the intensity of the sounds shattered parts of the radio tag.

Some scientists believe humpbacks sing to attract a mate or defend their territory, but they don't know for sure. In fact, they don't know very much about what many whales' sounds mean.

Whales don't have vocal cords like humans do. If they tried to make sounds the same way humans do, they would probably swallow lots of water! Whales make sounds by moving air around in the larynx and throat area. Sperm whales create clicks that are amplified as they pass through the spermaceti and the junk. The constant stream of clicks is used for echolocation and communication.

Toothed whales receive sounds very differently than you do. Humans hear very poorly under water because the air trapped in our ears acts as a plug or barrier to the sound. Whales do not have external ears, but the internal parts of the ear are connected to the outside of the whale by the lower jawbone. The sound travels up the jawbone to the bones inside the ear. After that, it works just like our ears.

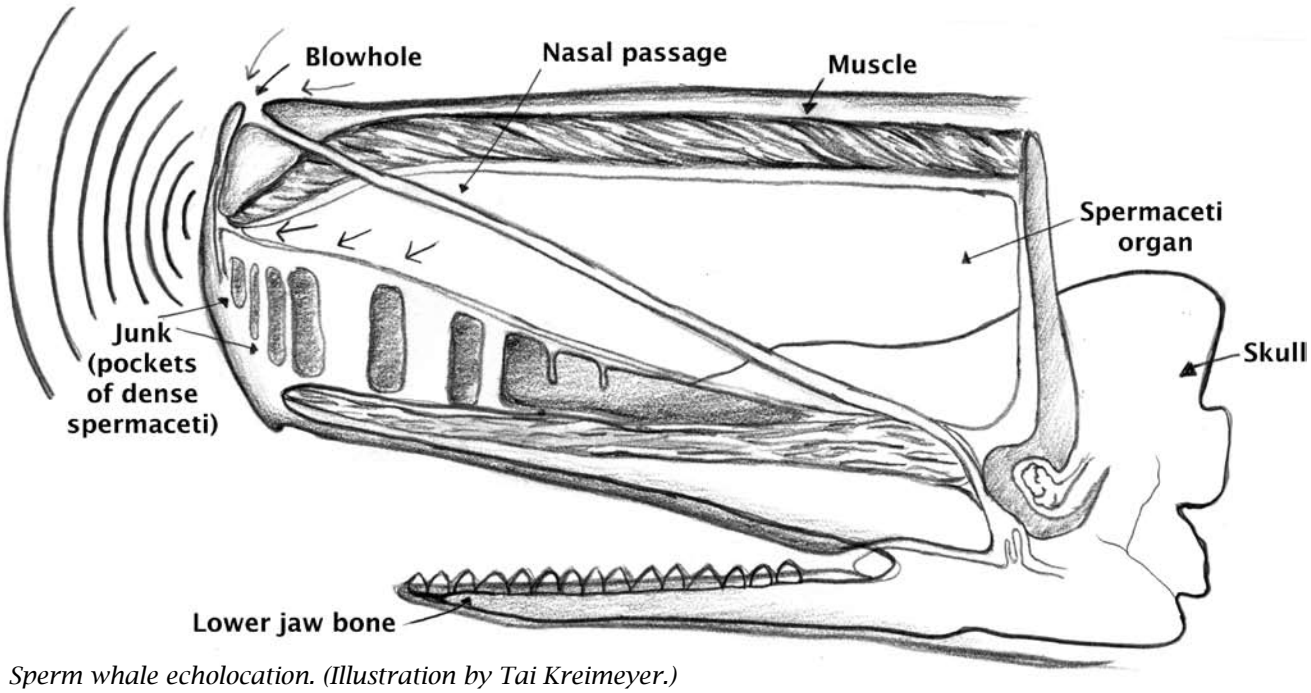
Along with whale sounds, hydrophones pick up many other noises such as earthquakes, ships, and drilling noise. With all these overlapping sounds, it is sometimes difficult to tell whale sounds from other sounds on hydrophone recordings. Because blue, right, and sperm whale calls are very distinct, filters have been developed that isolate these calls from the ocean's other noises. The filters are applied to digitized hydrophone recordings that isolate and identify the whale calls.

Once the whale calls have been identified in the recordings, it is sometimes possible to "track" a calling whale's location. If a particular call is picked up by at least three hydrophone stations, the position of the whale can be calculated

Sound is caused by a pressure wave, meaning that it is transmitted as a vibration from molecule to molecule. Think of a vibrating guitar string, which causes the air molecules around it to vibrate, with the vibration being passed on from molecule to molecule until it reaches your ears. This is true whether the sound is traveling through air, water, bone, or steel. Sound travels almost five times faster in seawater than air. The higher the salinity or pressure, the faster the sound travels. The lower the temperature, the slower the sound travels.

In seawater, different temperatures, salinity, and pressures work together to create layers of water in the ocean. Scientists have discovered a kind of sound pipeline, which they called the SOund Fixing and Ranging channel, or SOFAR channel. The laws of refraction work to trap sound in the channel. Sounds are trapped and focused in this layer, continually being bent back into it by water layers with different temperatures and densities. Sound introduced into this SOFAR channel thus can travel thousands of miles horizontally with minimal loss of signal.

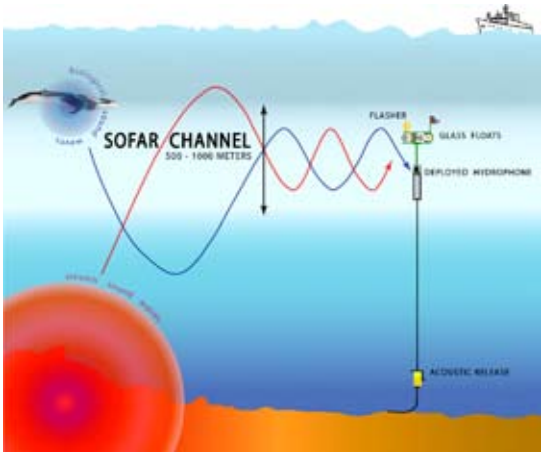
What a useful tool to begin to explore sounds in the oceans. For instance, sounds from a loudspeaker in the SOFAR channel west of Australia were detected near Bermuda in the north Atlantic ocean! Scientists studying whales by analyzing hydrophone data from the SOFAR channel can learn the seasonality and distribution of whale calls, and in the case of some species, what they may be doing. For example, hump



Sperm whale echolocation. (Illustration by Tai Kreimeyer.)

backs make specific calls when bubblenet feeding.

Humans have used the SOFAR channel in a number of ways. In fact, the channel has been important to submarines and submarine warfare since World War II. Sound waves, including sonar, are bent when they encounter the edges of the SOFAR channel. Submarine captains figured out that if they could get just under the SOFAR channel boundary, the sonar waves would be bent away from them and they could remain hidden in a "shadow zone." This was pretty clever, except that if a submarine hunter, like a navy destroyer, knew the depth of the SOFAR channel, it could set its depth charges (underwater explosive devices) to go off at that depth, where the submarine was likely to be. Today, naval ships monitor the depth of the SOFAR channel, as do submarines.



SOFAR channel map.

Scientists are sorting through the vast number of sounds they are recording from the sea. Many they can identify, but there are just as many that are still a mystery. From ice cracking in icebergs to the rumblings of earthquakes and volcanic activities, sorting through the many strange and just plain weird sounds is a fascinating task.

Habitat studies

Once areas are identified where whales feed and give birth, these habitats are investigated. Sampling is conducted to gather data on water temperature and chemistry, using state-of-the-art equipment. Bottom studies are conducted using sonar or robots to define water depth and bottom topography. Other issues to be investigated are sources of food, including krill, copepods, or schools of fish that we know the various species of whales rely on, and what human impacts are present in the areas these whales inhabit. All these studies are brought together to build a picture of whale habitats.

ACTIVITY 25: The SOFAR Channel (a Demonstration)

Concept

- Sound is reflected off materials of different density, creating a special channel in the ocean.

Materials

- ☐ Megaphone

Subject

- Physics

Time

10 minutes

Compare the SOFAR channel to a megaphone that cheerleaders use. The megaphone funnel is denser than the air. Sound is trapped and bounces off the denser material of the sides, focusing the sound—similar to what happens in the SOFAR channel.

Law of Refraction: the turning or bending of a wave when it passes from one medium into another of different density.

Reference

National Academy of Sciences, Beyond Discovery: "Sound Pipeline." http://www.beyonddiscovery.org/content/view.page.asp?I=224.

Sound is reflected off materials of different density, creating a special channel in the ocean.

ACTIVITY 26: What's that Sound?

Concepts

- Sound studies are expanding our knowledge of the oceans.
- Sound is important for whales to survive in the ocean.
- Explosions and loud sounds may harm marine mammals.

Materials

- ☐ Computer
- ☐ Pencils
- ☐ List of sounds for each student

Grouping of students

Work individually

Time

10 minutes

Subject

- Physics

Play the sounds of the whales and other sounds recorded by researchers. The NOAA Vents Acoustic research Web site, at http://www.pmel.noaa.gov/vents/acoustics.html, offers both a tutorial about acoustics and a number of recorded sounds that can be played. Each sound is accompanied by a spectrogram (picture of the sound). Students can see the sounds as well as listen to them. Explore the many underwater sounds as well as whale songs recorded on this Web site. Encourage students to match the tones of the sounds to the spectrogram patterns.

A number of sounds are available on the Web site:

- Boat
- Humpback song
- Blue whale
- Fin whale
- Unknown sound
- Earthquake
- Volcanic eruption

There is an abundance of other Web sites that have recordings of dolphins,

whales, and other aquatic mammals such as hippos. Any Web search should yield plenty of sites that have recorded marine mammal sounds for students to explore.

.

NOAA acoustics research Web site with sound recordings: http://www.pmel.noaa.gov/vents/acoustics/sounds.html.

ACTIVITY 27: Mapping Hidden Objects

Concept

- Sound and radio waves can be used to locate and map invisible items.

Materials

- ☐ Stud sensors
- ☐ Wood blocks (any small pieces of wood will work, 3/4 inch by 3 inches is ideal,)
- ☐ Large sheets of construction paper

Subject

- Physics

Time

20 minutes

Many stud sensors use radio waves to locate hidden wooden wall supports. The process is similar to whales using sound to locate masses of krill, or schools of fish. This activity allows students to experience locating and mapping invisible items.

Teacher instructions

Divide students into pairs. Give each pair six small blocks of wood and one piece of paper.

- Teams of students arrange the blocks of wood on the desk in a formation such as an X, a circle, a square, parallel lines, etc.
- Cover the arrangement with the construction paper or manila folders so the formation is not visible.
- Rotate teams of students to a new station. Each team will have an invisible formation to explore.
- Press the on button of the stud sensor and move it slowly in a grid pattern over the paper. When the sensor reaches the edge of a block, the light will blink. Mark on the paper the point where the light came on.
- Completely cover the area of the puzzle and connect the dots with lines to reproduce the pattern of the blocks.
- Lift up the paper to compare the pattern they created with the blocks under the paper.

Discussion

The experience of locating and mapping invisible objects is a simulation of how whales locate objects in the oceans using sound. Stud sensors create a weak radar signal (radio waves) that can detect the capacitance of materials. Capacitance is the ability of a material to store electrons. When passed over one material to another, the change in capacitance is measured. As the sensor detects the edge of the wooden block, the measurement changes and activates the sensor to flash and beep.

Whales make sound waves that travel through the water and bounce back from the object. The echoes are picked by the whales and used for navigation.

Note: Radar uses radio waves that are part of the electromagnetic spectrum. Sound waves are not electromagnetic.

Whales make sound waves that travel through the water and bounce back from the object.

8. National Science Education Standards for Great Whales

Unifying Concepts and Processes Systems, order, and organization Evidence, models, and explanation Change, constance, and measurements Evolution and equilibrium Form and function	**Section #**	**Activity #**
Content Standards *Science as Inquiry* Content Standard A: 5–12 Understanding about scientific inquiry Abilities necessary to do scientific inquiry	6, 7	 16, 17, 24 24, 17
Life Science Content Standard C 5–8 Structure and function in living systems Reproduction and heredity Regulation and behavior Populations and ecosystems Diversity and adaptations of organisms	3, 2, 6	 4, 5, 6, 22 5, 18, 20 8, 16, 18, 19, 20, 21 1, 4, 5, 6, 22
Content Standard C 9–12 Interdependence of organisms Matter, energy, and organization of living systems Behavior of organisms	4, 5, 7	 15 8, 21 8, 18, 16, 27
Science and Technology 9–12 Content Standard E 5–12 Abilities of technological design Understandings about science and technology	6, 7	 16, 21, 26
Science in Personal and Social Perspectives Content Standard F 5–8 Populations, resources, and environment Natural hazards	4, 5	 12, 13, 14, 16, 22 18
Content Standard F 9–12 Population growth Environmental quality Natural and human-induced hazards	4, 5	 13, 14 15 9, 13, 14, 15, 18, 19
Think critically and logically to make relationships		10, 11
Use mathematics in all aspects of scientific inquiry		9, 19, 24

Science Process and Essential Learning Skills

Activity	Predicting	Analyzing	Observing	Comparing	Applying	Estimating	Classifying	Problem solving	Inferring	Recalling	Inquiring
#1 Whale Facts											
#2 Are Whales Mammals?							√			√	
#3 Whale Families							√			√	
#4 Whale Adaptations			√		√				√		
#5 Suckers, Skimmers, Etc.		√	√						√		
#6 Baleen Types	√	√	√								
#7 How Much Do they Eat?								√			
#8 Identifying habitats		√		√	√						√
#9 Whales Then and Now		√			√						
#10 What's your Opinion?					√						
#11 Managing Whales					√						
#12 Lessons Learned					√				√		√
#13 People and Whales	√					√		√	√		
#14 Conservations Issues								√	√		
#15 Bioaccumulation			√		√						
#16 Sperm Whales		√			√						
#17 Whale Tails			√					√			
#18 Humpback Migration		√			√						
#19 Recovery or Loss?		√			√				√		√
#20 Baby Blues		√									√
#21 Build a Dome		√	√								
#22 Inside the Whale				√		√					
#23 Whaling Debate								√			
#24 Design a Project											√
#25 The SOFAR channel			√								
#26 What's that Sound?		√									
#27 Mapping Hidden Objects											

Fin whale (© International Fund for Animal Welfare, www.ifaw.org).

Oregon State
UNIVERSITY