Issue 2:
Marine Mammals

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Investigating Communication

Ocean News Reference: Sound Ideas and Whale Speak, page 2; Will the ATOC Hurt Whales?, page 3.

Main Idea:
Communication takes place between animals in a variety of ways.

Objectives:
Students will:
• learn about marine mammal communication
• investigate the development of language and other forms of communication

Parts of this activity were adapted from: Whales. ORCA (Ocean Related Curriculum Activities) from the Pacific Science Centre, Seattle, Washington.

Materials:

- recordings of humpback whale or killer whale sounds. See resources, p 28. Highly recommended is the tape "Blackfish Sound: Underwater Communication of Killer Whales in British Columbia" from the Vancouver Aquarium.

- slips of paper with messages for communication (I'm hungry; I'm tired; Danger!; Help me; I'm happy; Be careful; Come with me; Let's go to the mall; Let's run; Would you like to dance?; Let's go on a holiday; I like you; etc.) Try to have a mix of practical, easy to interpret messages and some that are more abstract.

Procedure:

1. Divide the class in pairs. Give each student a message to communicate to his or her partner. For the first round, the students cannot vocalize at all. Anything is O.K. except sound.

2. Now have students try to communicate the messages using sounds, but not using English or any other language.

3. Discuss the messages students were trying to communicate. Were some harder to "send" than others?

4. Discuss the nature of the messages marine mammals might communicate to one another.

5. Listen to the recordings of whale communication. The "Blackfish Sound" recording is narrated by Dr. John Ford who provides an interpretation of killer whale sounds.

Discussion:

• Why is sound an important means of communication in marine mammals?

Sound travels well in water, most of the ocean is dark or near-dark, mammals are often widely dispersed , etc.

• What are other means of communication in animal societies?

Smell (odour); visual; vibrations (a form of sound - the lateral line of fish, whiskers of seals or cats, are some examples of the receptors)

• Do plants communicate?

Chemical (hormonal) communication occurs with other plants and animals; plants have also evolved visual cues that attract pollinators.

• What are some other sources of sounds in the sea and do these effect marine mammal communication?

All ships and boats including supertankers, the largest human-made source of ocean noise; seismic exploration ships (they fire air guns at the ocean floor);blasting for construction of piers and other facilities; ice cracking; background noise of wind and waves, etc.

Extensions:

• Use the Ocean Explorer 2 Macintosh™ computer program to analyze killer whale sounds.

Whale Hieroglyphics

Main Idea:

A system of "hieroglyphics" is useful to help interpret cetacean sounds.

Objectives:

Students will:
- interpret a popular song to find common rhythms and themes in the music
- learn how scientists interpret whale sounds

Background:

Read "Whale Speak", page 2 in *Ocean News* Issue 2

Materials:

- a recording of a short segment of music without lyrics

Procedure:

1. Play the short segment of music. Have students listen closely and try to hear sounds, notes or a series of sounds ("phrases") that are repeated.

2. Play the recording again and have the students develop a series of symbols (straight lines, jagged lines, circles, zig-zags, etc.) that can be used to identify the different sounds or phrases that are repeated. Try to note timing, pitch, cadence, etc. If necessary repeat the music segment.

3. Working in small groups students can compare the patterns they developed. What are the similarities in their notations?

4. Examine the sheet music. Compare patterns in the music notation with their hieroglyphics.

5. Put this hieroglyphic on the board:

Have students compare the hieroglyphic with the sonogram on page 2 of Ocean News. This hieroglyphic is the actual notation used by Dr. John Ford for this call by killer whale pod I-11.

Extension:

- Use the Ocean Explorer 2 Macintosh™ computer program to analyze killer whale sounds.
- Watch the film "Island of Whales" (available from the National Film Board). You'll see Dr. John Ford using his system of hieroglyphics to research killer whale communication.
- A valuable reading about animal communication can be found in the August 1989 National Geographic article, Elephant Talk, by Katharine Payne, who is also an expert on humpback whale communication. The article includes an extensive sonogram of elephant sounds, and a discussion of frequencies used by many animals for communication and finding food.

How Many Are Too Few?

Main Ideas:

Given information such as birth rate, gestation, age of maturity and life span of animals it is possible to estimate population growth rates. Some endangered populations may have declined too far to recover.

Objectives:

Students will:
- learn how to estimate population growth
- learn about the Allee Effect which says that some organisms may have reduced survival rates if they become too rare

Background:

Ecologist W.C. Allee demonstrated that some animals may have a reduced survival rate if their populations become too low. Whales are probably particularly vulnerable to this "Allee Effect" for a number of reasons: some species rely on cooperative hunting; the experience of older group members may be needed for successful migration; and since whales are dispersed quite widely across the oceans, when they become rare, more time and effort must be spent finding a potential mate. In populations that are small it is conceivable that low pregnancy rates and decreased calf survival may reach a point where birth rate is cancelled out by death rate.

Note: The data presented in this activity are based on approximations. The activity is a simplified model for population change estimations and should be considered with caution when discussing actual populations of marine mammals.

Materials:

- data sheet, page 55

Procedure:

1. Discuss what you would need to know about a species to calculate its population growth rate.

Reproduction rate; how many young are born at each birth; average life-span; estimate of adult females of reproductive age; age of sexual maturity; success rate of sexually mature females; at what age does the animal become sexually mature; number of years fecundity, etc.)

2. In small groups, have students calculate population growth rates for blue and Gray whales in the North Pacific Ocean using the data sheet.

Blue Whale:

death rate = .06 x 2000 =120 individuals/year
birth rate = [2000 (total pop) - 120 (deaths)] x .50(%females) x .30 (% reproductive) x .40 (% successful) = 113 (births per year)
Growth = 113 (births) - 120 (deaths) = **-7**
(population is in decline)

Gray Whale:

death rate = .06 x 20000 =1200 individuals/year
birth rate = [20,000 (total pop) - 1200(deaths)] x .50 (%females) x .30 (% reproductive) x .60 (% succesful) = 1692
Gsrowth = 1692 (births) - 1200 (deaths) = **+492**
(population is growing)

Discussion:

1. In this model, what is happening to populations of the two whale species?

Blue whale populations are declining - death rate exceeds birth rate. Gray whale populations are increasing.

2. In this model, what is leading to the difference between Gray whale and blue whale population growth?

Success of reproduction in sexually mature females is low in blue whales, but sufficient in Gray whales to maintain growth.

3. Hypothetically, what factors might be involved in the low reproductive success of blue whales?

Inability to find mates; disturbance at breeding areas; physiological stress from such things as sounds or pollution; etc.

4. The recovery of the Gray whale has been a remarkable success story. Populations went from near extinction to over 20,000 animals in the North Pacific. What factors might have helped Gray whales recover so well? *Cessation of hunting; a varied food supply - Gray whales eat a variety of food from herring spawn to bottom invertebrates to small fish; protection of breeding habitat in Baja California, Mexico.*

Activity:

Whale Populations; Growing or Not?

In the blocks below you will find information about populations of two different whale species in the North Pacific: blue whales and Gray whales. The values and percentages given are rough approximations for the real world, but are still useful for the following exercise:

Use the information in each block to calculate the approximate growth (or decline) of each population in the current year (births-deaths). Then calculate the ratio of the births to deaths for each population:

Blue Whale

Total Population (in North Pacific) - 2,000

50% of all individuals in the population are females

Each year there is a 6% overall death rate in the total population

30% of the Females are of reproductive age

40% of the potential reproductive females actually breed and give birth in a year

What is the growth rate?

What is the birth rate/death rate?

Gray Whale

Population 20,000

50% of all individuals in the population are females

Each year there is a 6% overall death rate in the total population

30% of all females are of reproductive age

60% of the potential reproductive females actually breed and give birth each year

What is the growth rate?

What is the birth rate/death rate?

Endangered Marine Mammals

Main Ideas:

The Committee on the Status of Endangered Wildlife in Canada has established a list of threatened and endangered species. Several marine mammals are included on the list.

Objectives:

Students will:
• differentiate between endangered, extinct, extirpated, threatened and rare
•learn about endangered marine mammals

Vocabulary:

endangered: any indigenous (naturally occurring) species whose existence in Canada is threatened with immediate extinction or extirpation throughout all or a significant portion of its range

extinct: any species formerly indigenous to Canada but now no longer existing in Canada or elsewhere

extirpated: any indigenous species no longer existing in the wild in Canada, but existing elsewhere

rare: any indigenous species that, because of its biological characteristics, or because it occurs at the fringe of its range, or for some other reason, exists in low numbers or in very restricted areas in Canada, and so is vulnerable, but is not a threatened species

threatened: any indigenous species that is likely to become endangered in Canada if nothing is done to reverse their decline

Materials:

- resource materials and readings on endangered species. Of particular value are pamphlets from the Wildlife Branch, Ministry of the Environment on a number of threatened or endangered species. You can also obtain the official red list from the Ministry, listing species in the province that are either endangered or threatened, and the blue list, listing species that are vulnerable or sensitive.

Another source of information is:

World Wildlife Fund
60 St. Claire E
Suite 201
Toronto, Ontario
M4T 1N5

- copies of the chart "Endangered Marine Mammals of Canada", page 57.

Procedure:

1. Have students research an endangered, extinct, threatened or rare species of animal in the province or in Canada. If possible, this can be a Canadian marine mammal. Among the possible species for this research are the Vancouver Island Marmot, the burrowing owl, the Pacific giant salamander, the sea otter, the Dall's sheep, the wood bison, and the white-headed woodpecker.

Have students identify the main cause of their decline and, if possible, create an "action plan" to help increase the population. This can include ideas for educating the public about the species, ideas for protecting or restoring habitat, and ideas for reducing the disturbance to the habitat.

2. Have students research an extirpated Canadian marine mammal (Atlantic Gray Whale or Atlantic Walrus (N.W. Atlantic population). Investigate what factors have caused this animal to exist elsewhere but not in Canada.

3. Investigate what is being done to protect endangered species in your community and province.

Discussion:

• In Canada, as of 1994, only three species - the White Pelican, the Wood Bison and the Arctic Perigrine Falcon - have been delisted from COSEWIC's endangered species list. What are some "pros" and "cons" to delisting a species?

The list provides a certain degree of protection for some endangered or threatened species, but if populations grow to the point where they no longer need the listing, they may loose that protection. An example is the Gray whale - recently removed from the U.S. threatened species list and now the subject of pressures from Japanese whaling interests for permits to renew whaling.

* A valuable resource aimed at grade 4-7 is Backyard Biodiversity and Beyond, available from the Environmental Education Coordinator, Ministry of Environment, Lands, and Parks, Public Relations Branch, 810 Blanchard St., Victoria, B.C. V8V 1X4.

Endangered Marine Mammals in Canada

Species	Critical Habitat	Comments	Reasons why endangered
Beluga St. Lawrence River stock	St. Lawrence Estuary	long-term declining population	hunting; primarily human disturbance through shipping and commercial fishing; loss of habitat through dredging, port development, dam construction, dumping and resource exploration; pollution and contaminants
Southeast Baffin stock	shallow coastal waters and river mouths; complete range unknown	declined from more than 5 000 to about 400 since the 1920s	Overhunting by local people and previously by whalers
Ungava Bay stock	Ungava Bay; northern Quebec	long-term declining population	Overhunting by local people
Bowhead Whale	winter; southern edge of pack ice	long-term population decline; only 2 300 remain	This Arctic whale was commercially overhunted
Right Whale	coasts of N. America, both Atlantic and Pacific, from tropics to sub-arctic	long-term population decline	Overhunted. Long periods of hunting in Atlantic and Pacific.
Sea Otter	Pacific Coast	Basically extirpated from Canada by the 1930s; re-introduced to coastal waters of Vanc. Is.; pop'n is now growing & stable	Overhunted. Hunted for fur by many nationalities from 1700s to early 1900s
Extinct Marine Mammals			
Steller's Sea Cow			Initially low populations were quickly hunted out in Alaska. Earlier, aboriginal hunting may have been a factor.
Sea Mink			
Extirpated Marine Mammals			
Gray Whale (Atlantic Populations)			Hunted by whalers in all parts of its Atlantic range.
Atlantic Walrus (N.W. Atlantic population)			Low populations.Hunted out.

Source: Committee on the Status of Endangered Wildlife in Canada (COSEWIC)

Getting A "Sense" of Populations — Marine Mammal Censusing

Main Ideas:

Marine mammal researchers use a variety of techniques, including photographic identifications, to census marine mammal populations.

Objectives:

Students will:

• learn how researchers census marine mammals

Background:

Getting an accurate census of marine mammal populations is difficult at the best of times. In the past, verbal accounts and whaling catch records have been used to estimate populations.

In the 1960s, when killer whales were first captured for display in aquariums, the Canadian Department of Fisheries and Oceans (DFO) decided to determine the actual size of killer whale populations in B.C. waters. Researchers tried to estimate the population by surveys, questionnaires and observations from viewing stations but they were never certain that whales were recorded only once in the same day or area, or whether certain individuals were recorded several times at different survey sites. The study was modified to take a census on three specific days only. Eventually, these surveys gave a fairly accurate population estimation and, most importantly, they showed that the population of killer whales in B.C. had been vastly overestimated.

Whale researchers Michael Bigg and Graeme Ellis were among the first to use photographic identification to enable population estimates of killer whales. From their photographs, they noticed that each whale has a distinctively shaped dorsal fin. Patterns, notches, and scars on both the dorsal fin and saddle patch (the grey patch behind the dorsal fin) can act as a sort of natural identification tag.

Gradually, a genealogy of British Columbia killer whales was compiled. New whales continue to be added to the list of known whales and the genealogies of killer whales continue to be refined. As recent as the early 1990s, the known population of B.C. killer whales almost doubled due to the "discovery" of large, previously-unrecorded groups now called 'offshore killer whales'.

Materials:

- One or more copies of *Killer Whales: The Genealogy and Natural History of Orcinus orca in British Columbia and Washington State* by John Ford, Graeme Ellis, and Kenneth Balcomb (1994, University of British Columbia Press)

- Pictures of British Columbian killer whales from back issues of popular nature magazines, books or calendars

Procedure:

1. In small groups, have students attempt to identify the individual killer whales in different photographs using the Ford, et. al. book.

2. Discuss with the class the following questions:

• Why is it important for researchers to have fairly accurate records of marine mammal populations?

Monitoring our own activity that may disturb or endanger them; planning management of fisheries related to the whales; etc.

• Why is it so difficult to census marine mammals? Brainstorm (or research) ways that researchers might get estimates of mammal populations.

Many marine mammals are widely dis-

persed throughout the ocean; they only spend a short period of time at the surface; they are highly mobile; etc. Research methods in use include:

- Photographic identification of distinctive features such as the dorsal fin and saddle patch in killer whales; the callosities on the heads of right whales; or the patterns on the underside of humpback whale tail flukes. These features enable researchers to identify individual animals. Over time, catalogues of individual animals allow researchers to determine every individual in a population. When a portion of whales in a population is known individually, the frequency of sightings of known whales allows for estimating the entire population.

- Counting marine mammals using a variety of counting methods such as counts in aerial photographs, field counting using a coordinated number of observers, or counting numbers through a migration corridor. For example, pinniped rookeries contain most or all of the breeding individuals in the population. Total counts of individuals of rookeries in aerial photos, added to estimates of numbers of non-breeding individuals, will give total population numbers.

- tagging — a known number of animals are tagged with colourful tags that can be seen from a distance; number of tagged animals seen again are recorded. Populations are then estimated.

• What types of information can a scientist gather from these photographic records of individual animals? *(lifespan; number of young born and their rate of survival; reproductive rate (how often females have young); migration; the nature of relationships in social groupings; information about the behaviour of individuals; etc.)*

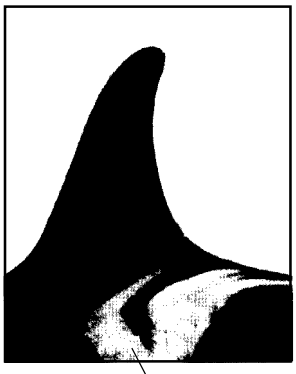
Extension:

• Use the Ocean Explorer 2 computer program for the Macintosh™ to investigate the identification of humpback whales.

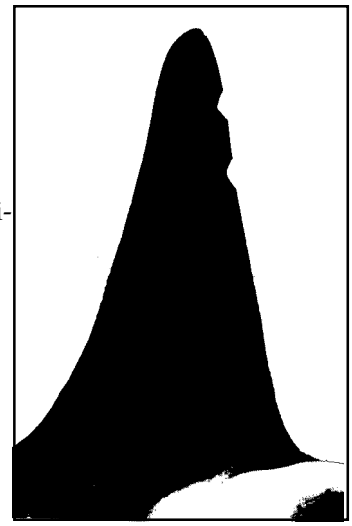
• Help organize the school or class to 'adopt' a killer whale through the Vancouver Public Aquarium (a class or school fundraising event may help to finance and draw attention to this project). Information about the program, which supports research on wild killer whales, can be obtained by writing:

Killer Whale Adoption Program
Vancouver Aquarium
P.O. Box 3232
Vancouver, B.C. V6B 3X8
or by calling the Aquarium at:
(604) 685-3364
FAX: (604) 631-2529.

With your membership you receive an official adoption certificate, a biographical sketch and identification photo of your adopted whale, a cassette of killer whale sounds and a copy of the annual newsletter, The Blackfish Sounder.



Dorsal fin and saddle patch of female orca, L11. Notice the distinctive saddle patch.



Dorsal fin and saddle patch of male orca, K1. Notice the distinctive notches on the fin. In this case the notches were actually surgically placed there when the whale was previously captured. However, natural scars, tears and notches are common among killer whale populations.

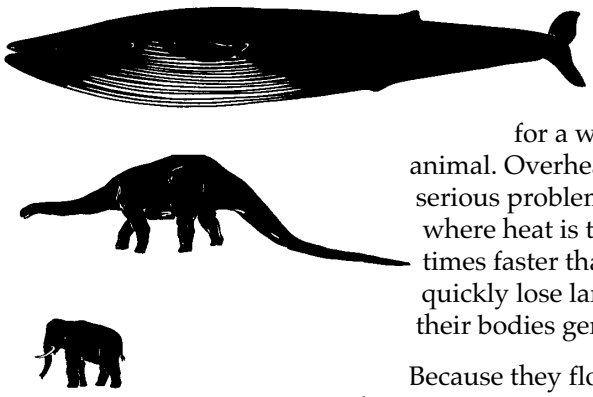
On Being Big

Ocean News Reference: page 10; Hot Potato & Blubber Mitts, page 11

Main Ideas:
Cetaceans have many adaptations enabling them to live in the ocean.

Objectives:
Students will:
• be able to list several adaptations of cetaceans to the marine environment
• calculate why a large animal can conserve heat better than a small animal

Vocabulary:
cetacean - marine mammal group that includes whales, porpoises and dolphins



The relative size of a blue whale, a dinosaur (*Camarosaurus*) and a modern African elephant.

Background:

Evolutionary biologist J.B.S. Haldane expressed the cost of being a large animal graphically when he said: "You can drop a mouse down a 1,000 yard mine shaft, and on arriving at the bottom, it gets a slight shock and walks away, provided that the ground is fairly soft. A rat is killed, a man is broken, a horse splashes." A whale, of course, is one or two orders of magnitude larger!

An animal as large as a blue whale can simply not survive on land - its body structure would be insufficiently strong to withstand the force of gravity. Water bouyancy has allowed whales to attain their enormous sizes.

Nature writer and ecologist Adrian Forsyth writes that "a single blue whale is as massive and burns as much energy as the entire human population of a 2,000 resident North American town". Whales have a small surface area relative to their size. This would present difficulties for a whale-sized land animal. Overheating would be a serious problem. Living in water, where heat is taken away up to 20 times faster than in air , whales quickly lose large amounts of heat their bodies generate.

Because they float in water, whales have evolved bodies with delicate bones, relative to their size. If available, marine mammal bones can be used to demonstrate these adaptations.

Materials:

- sugar cubes

Procedure:

1. As preparation, discuss general marine mammal adaptations with the class.

2. In small groups, have the students work on the following problems:

• Make a list comparing marine mammals to other aquatic animals such as fish or invertebrates. Consider how they get oxygen, how they reproduce, how they swim, etc.

• Whales are the largest animals ever to have lived on earth. What one characteristic allowed them to attain sizes even larger than dinosaurs?

• Why is it so important to get large stranded cetaceans back into the water? *(Their lungs and ribcage are not designed to support their weight.)*

3. Using sugar cubes, have students prove this statement: As an animal increases in size, there is proportionately less skin area exposed relative to total body mass, and therefore, less heat loss to the environment. (Give students this hint: they should examine the surface area to volume ratio of cubes made from different numbers of the sugar cubes. Assume the cubes measure 1 cm x 1cm).

(In one sugar cube, the surface area is 6 cm^2 and the volume is 1 cm^3 - the surface area to volume ratio is 6:1. If the students make a new cube using 8 sugar cubes, the surface area to volume ratio is now 24:8 or 3:1. So proportionately, there is less surface area exposed in the larger cube structure. If these cubes were animals, it would be harder to keep the small one warm, because of the increased heat loss across the body surface, than it would be to keep the larger cube warm.

Cetacean Evolution

Background:

The earliest mammals appeared on earth about 200 million years ago. About 60 million years ago, whales began to evolve from small land mammals quite unlike modern whales. Using fossil evidence, researchers are attempting to trace the history of whale ancestors. Fossils important to whale evolution can be dated, helping to piece together the story. Skeletons of ancestors thought to lead to modern whales indicate a progression of characteristics between ancient and modern whales. Modern cetaceans, for example, have a blowhole on the top of their head. In 35-million-year-old fossil whale ancestors the blowhole was still on top of the head but it was slanted forward. As we go further back in time, the blowhole appears in successively more forward positions. A 50-million-year-old whale ancestor skull shows nostrils at the tip of its nose.

Some researchers think that about 55 million years ago (following the Creataceous Extinction, when large sea-going reptiles were virtually eliminated) a group of land-dwelling mammals may have started to utilize the sea as a place to gather food and avoid enemies. They may have lived near beaches and fed on small fish or crustaceans such as crabs or shrimp living in the shallows. The 52 million year old fossil of *Ambulocetus* (see page 2-11) apparently represents this stage of evolution. Over time there was selection for foraging further and further out to sea. Eventually the whale ancestors developed abilities for more efficient predation and swimming. As successive generations of whale ancestors spent more time in the water, changes in body form, like the placement of the blowhole, were slowly selected for as adaptations to ocean life. Eventually the five fingers of whale ancestors became bound together into a flipper. The hind limbs, held motionless against the body, were less and less adaptive, so they finally disappeared. Eventually the modern whale form evolved some 20 million years ago and, over time, species radiated out into the available ocean niches.

Materials

-Handout "Whale Evolution", page 2-11

Procedure:

After answering the following three questions, have the students use the handout to hypothesize about the evolution of cetaceans.

• Name at least three characteristics that cetaceans (whales, dolphins and porpoises) share with land mammals. *(breathe air, have similar skeletal structures, are warm-blooded, bear live young, use mammary glands to nurse young, have hair (usually not too noticeable in cetaceans).*

• Examine the modern cetacean skeletons to determine bones which may not have present function. Speculate on the derivation of the bones of the whale flipper. *(The tiny bones in the pelvic region of the body.)* What might they have been for? *(These are the vestigial hip bones of the cetacean. Through years of evolution and the gradual loss of hind limbs, they have decreased in size. Flipper bones are vestiges of the terrestrial ancestor leg-foot bones.)*

• Using the graphics, compare how skeletons have changed during whale evolution.

Main Ideas:

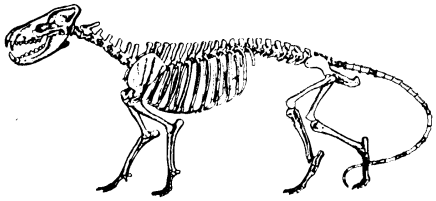
Hints of the evolutionary origins of whales can be seen in their skeletons.

Objectives:

Students will:

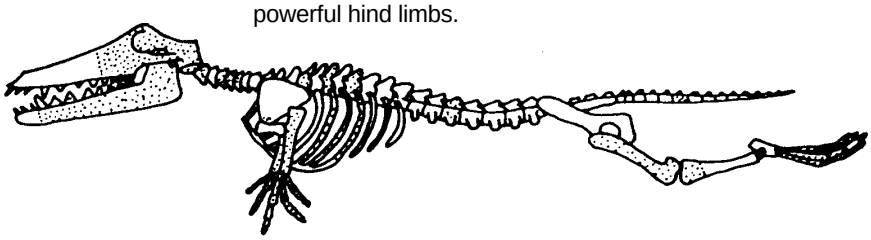
• examine whale skeleton drawings to learn about whale evolution

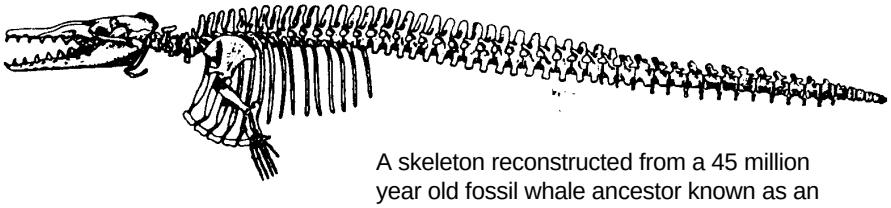
Whale Evolution



This animal, a 'Mesonychid', lived 60 million years ago. Animals like this may have been ancestors to both whales and modern ungulate animals.

A skeleton reconstructed from a 52-million-year old fossil, this animal, *Ambulocetus* (meaning 'walking whale'), is thought to have both walked on land and swam in the water. While swimming it probably wagged its body and stroked with its powerful hind limbs.

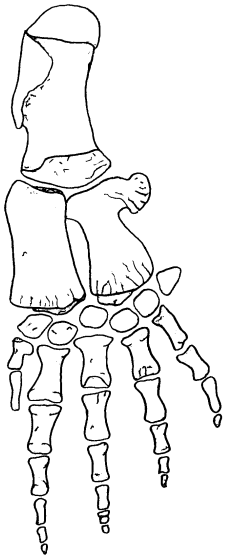




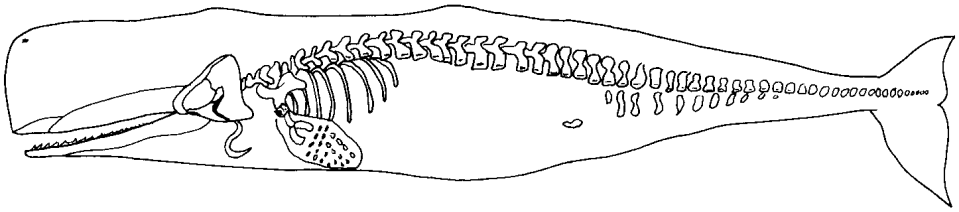
A skeleton reconstructed from a 45 million year old fossil whale ancestor known as an 'archaeocetes' (or ancient whale).

Modern Whale Skeletons

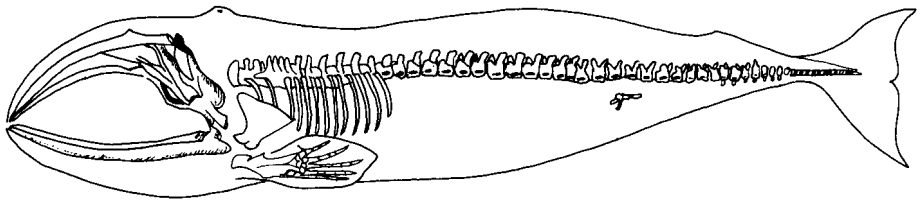
Sperm Whale flipper bones



Skeleton of a Sperm Whale



Skeleton of a Bowhead Whale



Marine Mammal Feeding

Ocean News Reference: Sound Ideas, page 2; Meet A Scientist, page 4; Keystones in a Kelp Bed, page 9 and Blowing Bubbles for Dinner, page 12. See also, the Teacher's Guide for Ocean News, Issue #4: Marine Pollution.

Main Idea:

Marine mammals use a variety of methods to search for and capture food. The diversity of feeding styles has allowed marine mammals to exploit a variety of prey items.

Objectives:

Students will:

• investigate the various methods that marine mammals use to locate and capture food

Background:

Some examples of feeding styles:

- rorqual whales (blue, fin, sei, Bryde's, minke) are "gulpers". They gulp huge amounts of water and plankton, forcing the water out the sides of their mouths with their enormous tongues and capture prey on their baleen.

- humpbacks use bubble nets and their flukes to corral prey.

- right whales (includes right, bowhead and pygmy right whales) are known as "skimmers"; they swim near the surface capturing plankton such as copepods in their fine baleen.

- gray whales are bottom feeders. Swimming along the bottom they dig with their mouths in the sand or mud, sucking up the substrate and its contents. Then they force the sand out through their baleen to strain out the animals.

- toothed whales, including dolphins and porpoises, use their teeth to capture prey which is swallowed whole. These species may also herd prey, using loud noises or sound, and may work as a team to capture prey.

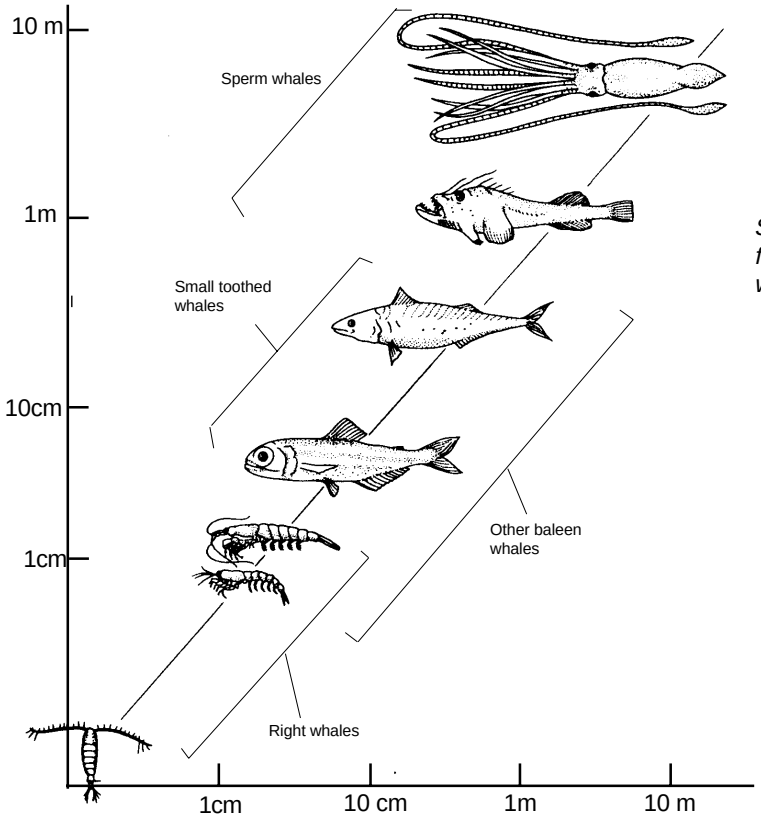
- sea otters use rocks to break open clams, urchins and crabs.

Materials:

- resource books and videos on marine mammals

Procedure:

1. Have students choose a species of marine mammal and investigate the variety of methods it uses to locate and capture food.



Size ranges of foods for some whale groups.

Marine Mammal Feeding *(continued)*

Some ideas to investigate: capturing prey as a "team"; using sound to capture, or even stun, prey; feeding strategies of baleen whales; prey utilization within a species (e.g. the different prey items of transient and resident killer whales); changing diets (e.g. sea otter's changes in diet); using tools, etc.

2. Have students construct a food chain for the animal they investigate and display it through a poster.

Discussion:

• Why are large predators such as killer whales not as abundant as filter-feeding whales? *(With each link in a food chain there is an energy loss of 80 to 90%. The lower an animal eats on the food chain the more food energy is available to it. In the food chain of a baleen whale there are only two links, because the whale feeds as low as it possibly can on the food chain. A killer whale's food chain would have four or five links.)*

• Why are there no "super killer whales" as large as a blue whale? *(Killer whales are larger than any other dolphin but are only about one tenth the size of a baleen whale. A larger predator would have to bear the "energetic cost" of building and maintaining its huge body. The bigger the animal gets, the larger the cost and the less energy that is available for reproduction. Killer whales are already big enough to eat anything in the ocean so there is really no need to grow any larger. A larger size would increase the energetic costs of body maintenance without any benefit.)*

Sample Food Chains:

Phytoplankton → Copepod → Herring → Seal → Killer whale

Phytoplankton → Copepod → Herring → Minke whale

DEEP DIVING DYNAMOS

Ocean News Reference:

Anatomy of a Whale Tag; Meet a Scientist - page 4; Whale Tag Challenge - page 5; The Elegant Elephant Seal - page 11.
Also see: Under Great Pressure - page 1-23 Issue 1 Teacher's Guide.

Background:

Marine mammals come in many shapes and sizes, each with different food preferences and habitats, but they must all come to the ocean's surface to get recharged with oxygen. Although people have known for centuries that whales could dive very deep for long periods of time, it has only been recently that scientists have begun to really understand the diving physiology of marine mammals. A diving mammal has to descend several hundred metres, locate a fish or squid in near total darkness, chase, catch and eat it and then swim back to the surface. All of this is done with one breath. Diving mammals do this routinely, then take a few breaths and go down for more. Here's some more information on what physiological changes occur during a dive. Keep in mind that the major goal of almost all of these adaptations is to conserve what little oxygen is present in the blood.

System Shut Down

During a dive the metabolic rate drops and the body goes into a sort of slow motion. This includes a reduction in the heart rate (called bradycardia) to about 10-50% of surface rate. Bradycardia can also be measured in human divers. Blood flow is also restricted to the brain and heart so that fresh oxygenated blood supplies only the vital organs.

Oxygen Debt

When we breathe in, our lungs incorporate oxygen from the air into blood vessels in the lung tissue. At the same time, the waste product of respiration, CO_2, is released from the blood into the lungs and exhaled. At times when our breathing is curtailed, the human body has an automatic response to inhale at certain levels of CO_2 in our blood. No matter how hard we try, we can't suffocate by holding our breath. Marine mammals can tolerate the build-up of CO_2 in their blood, essential since they can't take a breath underwater. Their tolerance level to CO_2 is sufficient to allow them to stay underwater until their oxygen is used up.

Oxygen Stores

Since marine mammals breathe oxygen for short intervals interspersed with long periods of breath holding, they have had to devise some ways to store oxygen for use during long dives. First of all, they have more blood. Total blood volume and volume of red blood cells (which contain oxygen-carrying haemoglobin) is proportionately much greater than in land mammals.

Oxygen is also stored in the muscles, where another oxygen-carrying molecule, myoglobin, is present. Marine mammal muscles have as much as ten times the myoglobin of terrestrial mammals. Even though blood is

Vocabulary:

aerobic - with oxygen

anaerobic - without oxygen

bends - also known as caisson disease; a serious and sometimes fatal condition, characterized by cramping pain and paralysis; induced by too rapid a return to normal atmospheric pressure after a period in a compressed atmosphere; it is caused by bubbles of gas forming in the blood during decompression.

bradycardia - reduction of the heart rate

haemoglobin - respiratory pigment that carries oxygen in the blood

myoglobin - oxygen-storing molecule in muscles

shunted to vital organs during a dive, strong swimming muscles can continue working because of the supply of oxygen stored in the myoglobin. When that supply runs out, muscles can work anaerobically, without the need for oxygen. In humans, this anaerobic respiration occurs when we exercise extremely hard. As muscles run out of oxygen, they begin to utilize energy stored in fat tissue. Lactic acid is produced as a waste product, and as it builds up in muscles it causes muscle aches and cramping. The aches subside when you stop exercising and your heart and lungs have a chance to catch up with the oxygen supply and balance things out again. Diving mammals have a high tolerance for lactic acid, so their muscles can work anaerobically for a long time. The limited oxygen carried down from the surface is shunted to vital organs, the heart and brain, allowing the animal to function fully during long periods of breath holding.

Avoiding the "Bends"

Something that bothered researchers for a long time was how diving mammals avoid getting "the bends". The bends is a condition that threatens a scuba diver breathing pressurized air. The condition occurs when a diver returns to the surface too quickly from depths greater than 14 metres. Under pressure, nitrogen gas dissolves into the blood and body fluids. During ascent, if the pressure is released too suddenly, the nitrogen comes out of solution and forms bubbles. These bubbles may obstruct small blood vessels, interfere with proper functioning of the joints, or block blood flow to the brain. SCUBA divers must resurface slowly so that nitrogen can be expelled via the breath. Since diving mammals are breath-hold divers, they are not breathing air under pressure like a scuba diver. They take down very limited amounts of nitrogen and the risk of getting the bends is low. As marine mammals dive, air in the lungs compresses and is forced into safe areas in the nasal passages. Here, little gas exchange into the blood can take place.

All of these specializations work together to allow marine mammals to stay under water, dive deeper and remain active longer than any land mammal could ever hope to do (even with scuba gear!)

Although scientists now have a fairly good picture of the special diving adaptations of marine mammals there is still much to discover. A recent innovation has given researchers new insight into their lives. By gluing a data logger and satellite transmitter onto diving animals, scientists receive information beamed from the antennae to a satellite and then to a computer. Over time this technology will give us a better understanding of how marine mammals can perform their amazing diving feats.

The Dive Response

Background:

Anyone who has taken a First Aid course knows the "A B Cs". An open airway, proper breathing and circulation are all vital for life. Proper functioning of the A B Cs ensures that oxygen reaches our tissues while carbon dioxide is removed. But not all animal tissues need to be continuously supplied with fresh oxygen. Many parts of the body will tolerate some anaerobic (without oxygen) operation. Portions of an arm or leg deprived of fresh blood can survive without damage for an hour or more. However, the heart and brain are very sensitive to a lack of oxygen. Suffocation or heart failure can kill a human within minutes. The brain suffers irreversible damage if its circulation is cut off for more than five minutes.

When marine mammals dive they use a variety of oxygen-conserving adaptations. Bradycardia (slow heart) is one such method. An animal in a state of bradycardia is able to restrict the movement of fresh blood to only the regions of the heart, brain and lungs. Bradycardia occurs in many marine mammals, especially near the bottom of a deep dive.

Humans also exhibit a dive response. When our face or body is submerged in water (particularly ice cold water) our heart beat slows down considerably.

Materials:

- stopwatches (or watch with second hand); one for each group
- dishpans
- towels
- cold tap water
- ice cubes
- graph paper
- pencil

Procedure:

1. Divide the class into groups of four: one to record the data, one to operate the stopwatch, one to take the pulse of the "diver" and one to be the "diver". Practise finding and counting one another's pulse.

2. Have the "diver" sit quietly for two minutes then take her or his pulse for 15 seconds. Multiply this number by four to find the number of beats per minute. Repeat this step two more times and determine the average resting pulse for the three trials. Record the data.

3. Have the diver hold his or her breath for 35-second periods while sitting still. The person taking the diver's pulse should measure and record the pulse for the last 15 seconds of the breath hold. Have the diver rest quietly for two minutes and then repeat twice more and determine the average for the three trials. Record the data.

4. Fill the dishpans with cold water and ice.

5. Have the "diver" submerge her or his face up to the ears in the water for 35 seconds. The person taking the diver's pulse should measure and record the pulse for the last 15 seconds of the breath hold. Have the towel ready. Have the person rest at least two minutes between trials. Repeat this step two more times and determine the average for the three trials. Record the data.

6. To report the results, each student

Main Idea:

Bradycardia (slow heart) is one dive response that occurs in mammals during deep dives.

Objectives:

Students will:
- demonstrate the presence of bradycardia in humans
- learn how to measure heart rates

Vocabulary:

bradycardia - reduction of the heart rate

Adapted from an activity by James Kolb in Marine Biology and Oceanography: Grades 9-12, Volume 1, Poulsbo, Washington: Marine Science Center, FOR SEA Project.

The Dive Response (continued)

should make a bar graph or line graph showing pulse rate against the three conditions of pulse measurement.

Discussion:

• How does the resting pulse compare with the breath holding and diving pulse?

• A reduction in pulse from the average range to less than 50 beats per minute is said to be bradycardia. Did your diver exhibit bradycardia?

Extensions:

• Investigate cold-water drowning and why so many people, particularly children, can be revived after long periods submerged in frigid waters.

The Bends

This activity should be done as a class demonstration.

Main Ideas:

Nitrogen in the air we breathe represents a risk to scuba divers. Dissolved in the blood stream under pressure, it may cause the bends if ascent is too rapid.

Objectives:

Students will:

• learn the action of dissolved gas under pressure and when pressure is released quickly

• transfer this information to learn how scuba divers are susceptible to getting the condition called the "bends"

• investigate whether marine mammals get the "bends"

Background:

Breathing air under increased pressure results in a surplus of nitrogen being absorbed into the body tissues and bloodstream. Since nitrogen is not used chemically in the body like oxygen is, it is more readily stored in the tissues. The longer and deeper the dive, the more nitrogen is absorbed by fluids of the body. If this excess nitrogen is not slowly eliminated through respiration during ascent, bubbles may form in a diver's blood and/or tissues. Nitrogen bubbles form when ascent is too rapid. Dive tables are used to determine the amount of time allowable at depth before more nitrogen becomes dissolved than can be released during a normal ascent. Longer dives require stopping at certain depths for a period of time during ascent. This procedure is called decompression, and the dives are "decompression dives".

Symptoms of the bends can vary depending on where the bubbles are formed. Certain parts of the body absorb nitrogen at different rates. Fast absorption occurs in blood and tissues of the brain, for example. In most cases of the bends, bubbles accumulate in the joints, causing great pain. Sufferers bend their joints to relieve the pain, leading to the name of this condition.

Materials:

- two cans of pop
- two clear glasses

Procedure:

Do this activity as a class demonstration.

1. Discuss the behaviour of nitrogen in a diver's body.

(NB. If the cans of pop have been shaken at all, let them settle before proceeding.)

2. Open one can of pop and leave it undisturbed for 15 minutes.

3. After 15 minutes, open the other can of pop. Immediately pour each pop into a separate glass. Tilt the glasses to reduce the amount of foam.

4. Which can produced the most bubbles?

Discussion:

• How is this demonstration analogous to a diver ascending quickly and a diver ascending slowly? *In the can that was left with its lid off for 15 minutes, the dissolved gases were allowed to release over time (analogous to a slowly ascending diver). In the second can, the gases were released quickly.*

• Try to explain why there were differing amounts of bubbles in the two different pops. *The behaviour of the gas bubbles in the pop is similar to their behaviour in the body. Before the cap is placed on a can of pop at the factory, carbon dioxide is dissolved into the pop under high pressure. When the pressure is released quickly by the rapid removal of the top, bubbles of carbon dioxide form due to the fast drop in pressure.*

• Why don't deep diving marine mammals get the bends? *Students may ponder this one for a while and tend to overlook one obvious difference between a diving marine mammal and a diving human. Marine mammals are not breathing pressurized air as they dive. What little air is present is forced into nasal and tracheal passages and other areas where few blood vessels are present. Diving mammals have evolved many strategies to use what little oxygen is available very efficiently.*

Extension:

• Investigate why divers should not fly within 24 hours after diving

Reduced pressure in an airplane cabin may lead to nitrogen bubble formation in the blood stream.

• Have students investigate the symptoms and cause of nitrogen narcosis (also called "rapture of the deep") experienced by scuba divers. *Nitrogen is an inert gas which is inhaled and absorbed by the body, but it does not react chemically with the materials that make up blood or tissues. When inhaled under pressure, nitrogen will induce an anesthetic action that affects the central nervous system. The greater the pressure under which the gas is breathed, the more severe the symptoms and anesthetic effects. The symptoms produced by breathing nitrogen at depth are thought to be caused by interference with the signals sent along nerve fibers to and from the brain. The signs of nitrogen narcosis are characterized by general feelings of euphoria, elation and a sense of well-being. Other signs are over-confidence; tingling or numbness of the arms, legs, lips and gums; impaired coordination and concentration; laughter, lightheadedness, memory impairment and vertigo. Narcosis can result in disaster as divers become over confident and put themselves in dangerous situations.*

Vocabulary:

bends - also known as caisson disease; a serious and sometimes fatal condition, characterized by cramping pain and paralysis, induced by too rapid return to normal atmospheric pressure after a period in a pressurized atmosphere. It is caused by bubbles of gas forming in the blood on decompression.

The Sea Otter - Shaper of Pacific Northwest History

Main Ideas:
Sea otters played a vital role in the shaping of Pacific Northwest history.

Objectives:
Students will:
• learn about the role of the sea otter in shaping B.C.'s history

Vocabulary:
scurvy - a disease characterized by skin spots, swollen gums, bleeding of the mucous membranes and general debility, caused by a deficiency of vitamin C in the diet for a long period

Materials:

- resource books

- handout - The Sea Otter - Shaper of Pacific Northwest History, page 2-20

Procedure:

1. Distribute a copy of the handout to each student.

2. After the students have read the article, as a class discuss the role of the sea otter in Pacific Northwest history. Emphasize the effect the sea otter trade had on native people (trade, contact with the "outside world", disease, etc.) and the potential for ecological change.

3. In small groups, brainstorm for ideas on how B.C.'s history might have been different if the sea otter had never been exploited.

Discussion:

• As a class, brainstorm for ideas on kelp forest ecology if sea cows had never been exterminated from the Pacific northwest. (Review Keystones in a Kelp Bed for a refresher if needed and provide information on the life of the Steller's Sea Cow).

The Steller's Sea Cow

When Bering and his crew shipwrecked on Commander Island in 1741, they spent the winter eating whatever they could find. This included seabirds, seals, sea otters and a species of marine mammal called the sea cow whose flesh was considered to taste like fine veal. These sea cows weighed over 4,000 kg (9,000 lbs.) and were almost 8 m (26 feet) in length. They foraged in large family groups on the kelp of the offshore kelp beds. Other animals in this group include the manatee of Florida and the dugong of the South Pacific and Indian Oceans. All members of the group feed on vegetation.

Sea cows were very docile and were easy meat for sea otter hunters who returned to the Commander Islands year after year. *Once, probably a few hundred years ago, the sea cow ranged along the Pacific coast from Japan to California, but by 1741 it seemed to be restricted to the waters around the Commander Islands. Within 30 years this sea cow, which eventually bore Steller's name, was hunted to extinction.*

The Sea Otter - Shaper of Pacific Northwest History

In 1741, under instruction from the Russian monarch, Catherine the Great, Captain Vitus Bering set sail from Okhotsk in Siberia on a voyage of discovery. His mission was to discover if North America and Russia were connected and to investigate the resources of the area. On board his ship *St. Peter*, was a German surgeon and naturalist, Georg Wilhelm Steller. After exploring the area and making notes on the flora and fauna, Bering and his crew started home, but the *St. Peter* was wrecked in the Commander Islands. Over the next few months many crew members contracted scurvy. Thirty of them died, including Bering. They were buried on the island that would eventually be named Bering Island.

One of the first animals encountered by the shipwrecked crew was at first thought to be a bear or wolverine. But Steller recognized it as an animal new to science — he named it the sea otter. He wrote: "They covered the shore in great droves. They would come up to our fires, and would not be driven away until, after many of them had been slain, they learnt to know us and run away." Gradually, the sailors recovered their health by eating sea otters. The meat was tough but contained the vitamin C required to treat scurvy.

While they waited for help, Bering's crew relieved their boredom by gambling. At first they used the limited money they brought, but later they gambled for sea otter pelts, recognizing the value of the fur. Steller wrote "Such is the beauty of the animal and especially of its skin that this otter alone is incomparable and without equal, for in the amazing beauty and softness of its fur it surpasses all other creatures of the vast ocean." Sea otter pelts made excellent clothing for the crew in the harsh winter of the North Pacific.

Over time, the sailors also built a boat that carried them and 300 sea otter pelts back home. In Russia, Catherine the Great was overwhelmed by the beauty of sea otter fur. She immediately commissioned a cloak to "sweep from her throat to her ankles." More ships were soon sent off in search of sea otters. The Russian sea otter fur trade was on.

In 1745 two ships landed on Bering Island. The crews killed 1500 otters. Season after season, ships harvested the sea otters moving from island to island as otters became more difficult to find.

The hunt would likely not have been so successful without the special skills of local Aleuts. The Russians exploited Aleut men to the point of slavery. Aleut women and children were held hostage until the men returned with sea otter pelts. Diseases were also spread to the local native people with disasterous results. Before 1750, Fox Island probably supported 10,000 - 12,000 Aleuts, but by 1790 there were only 1,900 left.

A lucrative market for sea otters was found in China and Japan where the skins were made into full-length robes, belts, sashes, hats and mittens sold at substantial prices.

While the Russian hunt continued, another attack on the west coast sea otter began. In 1776 Captain James Cook set out on a voyage to find a passage between Great Britain and China. In 1778 he reached the shores of Vancouver Island at Yuquot (called Friendly Cove by Cook). Here he spent time surveying the area and repairing his ships. The crew also traded with native people of the area, collecting 300 sea otter pelts.

Cook wrote: "Sea otters, which live mostly in the water, are found here. The fur of these animals ... is certainly softer and finer than that of others we know of, and therefore the discovery of this part of the continent of North America, where so valuable an article of commerce may be met with, cannot be a matter of indifference." In 1779 Cook and his crew continued on to Hawaii where Cook was killed. The crew eventually carried on towards Asia. With their clothes becoming ragged, many of the crew made coats out of sea otter pelts. When they arrived in China, the prized furs were soon sold for high prices and the crew realized the money that could be made trading sea otters. In 1783 one sea otter pelt was worth $50 - a phenomenal amount in those years. Soon the "soft gold rush" was well underway, with British, American, French and Portuguese trading ships plying west coast waters in search of sea otters.

By the mid-1800s most of the sea otters had been exterminated from the Pacific Northwest. An estimated sea otter population of more than 300,000 in 1750 was brought to the brink of extinction in less than 100 years. In 1867 "Russian Alaska" was no longer considered commercially valuable to Russia and it was sold to the United States.

Mystery of the Missing Beach

Main Idea:
The presence or absence of a keystone species such as the sea otter makes a dramatic difference in the local environment.

Objectives:
Students will:
• use the concepts learned about sea otter biology and ecology to solve an ecological mystery

Background:

See Ocean News, Issue 2 pages 8 & 9

Materials:

- a copy of Mystery of the Missing Beach for each student

Procedure:

1. Have students read the articles: Return of the Sea Otter, Meet a Scientist and Keystones in a Kelp Bed, in Ocean News, Issue 2.

2. Divide the class into small groups. Have students read "The Mystery of the Missing Beach". Try to solve the mystery.

3. Have the class present their solutions to the mystery.

4. Present St. Claire's hypothesis.

Discussion:

What St. Claire decided is that historically, while sea otters were still present in this area, there had been a large kelp bed just off the village site. The presence of a kelp forest would provide a "wave break" and would create a calm area between the kelp forest and the shoreline. A sandy beach could have formed and made an ideal site for habitation, providing shelter, food and a safe place to store and launch canoes. Once the otters were hunted out, the kelp forests were grazed away by sea urchins and other herbivores. This left the beach open to wave exposure and the sandy area was swept away during storms, leaving the boulder beach that is present today.

(Copy this reading for each student:)

The Mystery of the Missing Beach

In 1984 archaeologist Denis St. Claire had a mystery on his hands. He was given the task of surveying the historic native village sites in the Broken Group Islands — an archipelago of islands on Vancouver Island's west coast. St. Claire and his colleagues searched for possible village sites by boating along the shoreline, looking for areas that seemed like a good place for a village. Was there a good beach for landing a canoe? Was the bay sheltered? Was there protection from the fiercely pounding waves of the Pacific Ocean storms?

St. Claire also gathered information about site locations by talking with elders from the Native bands who had traditionally occupied this area. From one of these interviews he learned of a possible village site that his team had not found. When St. Claire arrived at the site, he couldn't believe that it had once been a village. The beach was composed of large boulders, with no place to land a canoe. The whole site faced the open ocean and was exposed to storms and high seas. Sure enough though, when he went ashore to have a look there was clear evidence of a village site.

What do you think could have caused the change in the composition of the beach? Can you explain how the village could have occupied this location historically?

Advertising for Otters

Background:

Since sea otters were eliminated from most areas in the Pacific Northwest, populations of crab, sea urchins, abalone and other 'shellfish', have changed in the absence of one of their major predators. Also, humans have entered these ocean food chains in a serious way, developing fisheries for many of the same species otters eat.

Sea otters keep warm by eating about one quarter to one third of their weight in food daily. As sea otters begin to occupy areas along the coast following their re-introduction, their eating habits pose possible impacts on pop-ulations of shellfish. There are many scientific, environmental, political and economic considerations that come into play when humans alter ecosystem dynamics through actions such as the reintroduction of sea otters.

Materials:

- art supplies and equipment such as video cameras or tape recorders.

Procedure:

1. Read "Keystones in a Kelp Bed" in Ocean News #2. What are some positive benefits to fishermen of the reintroduction of sea otters?

2. As a class or in small groups discuss the following statements, carefully analysing who made the statement; upon what knowledge or information it is probably based; and how you could check that information:

• Some fishermen, concerned about a proposal to reintroduce sea otters to an area of coastal B.C. said that the motive behind the plan was more "sentimental than sensible". Some were "worried that populations will grow to the point that the shellfish and things the sea otter feeds on will become as extinct as the sea otter became when it was slaughtered in the fur trade."

• Members of a conservation group argue that the population of shellfish in areas without sea otters is unnaturally high because a major shellfish predator has been missing for years. They argue that sea otter reintroduction will bring shellfish populations back to more "normal" levels.

• In 1991 the abalone fishery on the B.C. coast was closed indefinitely due to over-fishing and a serious depletion of abalone stocks.

• Preliminary research by a university research team on abalone predation by sea otters suggests that abalones survive better in areas of dense kelp forest than in areas without kelp forest, when both areas have approximately equal densities of sea otters.

3. Have the students develop an advertising campaign to educate the public about sea otters and their role in the environment. It can be a graphic, audio or video campaign.

Main Ideas:

Sea otters eat many species that are commercially harvested, such as sea urchins, crabs and abalone. Conflicts in resource use may arise in which the sea otters are ill-equipped to argue their position.

Objectives:

Students will:

• think about how the re-establishment of sea otter populations may effect commercially harvested species

• develop an advertising campaign (print, video or audio) to educate people about the return of sea otters

Otter Archaeology

Main Ideas:

The recent near-extinction of sea otters on the Northwest Pacific coast was probably not the only such event. Archaeological evidence indicates the long-term removal of sea otters in at least in one area of Alaska about 2000 years ago.

Objectives:

Students will:

• interpret archeological evidence to develop a picture of changing population dynamics in the relationship between sea otters, kelp beds, and humans.

Background

When archaeologists working in the Aleutian Islands* sorted through Indian middens (piles of shells and bones left behind at village sites) they found layers with sea otter bones that also contained high quantities of fish bones. In layers with few or no otter bones, there are quantities of sea urchins spines and other invertebrate remains, yet there are few fish bones.

Interpretation of the data collected from digging in this midden (see the graph on page 75) tells a picture of long-term changes in the ecosystem dynamics of this environment, with otters as the keystone species, and kelp beds as the likely habitat for quantities of fish, otherwise missing in the absence of otters and kelp beds.

The Aleuts utilized the resources available, and they may have been responsible for shifting the ecosystem dynamics.

Materials:

- resource books
- handout - Otter Archaeology, page 75
- handout - The Sea Otter - Shaper of Pacific Northwest History, page 2-20

Procedure:

1. Distribute copies of the handouts to each student. Also read Keystones in a Kelp Bed and Meet a Scientist from pages 8 and 9 of *Ocean News* Issue 2.

2. Working in small groups, have students discuss the handouts and answer the questions.

3. As a class discuss the role of the sea otter in Pacific northwest history. Emphasize the dynamic ecological changes possible when keystone species such as the sea otter are removed from the area and how this might affect the lifestyle of aboriginal hunter-gatherer societies. The evidence does not conclusively prove that sea otter populations were eliminated from the area by Aleuts around 2000 years ago, but rather that the loss of these populations did affect the diet of these people. It is possible that the Aleuts overhunted the sea otters at that time, or that a natural disaster occurred to wipe out the local sea otter population.

Discussion:

• If kelp remains were actually preserved in middens, where would they show up in the midden profiles shown in this activity?

Kelp remains would probably occur in the same strata as the sea otter and fish bone concentrations.

* Simenstad, C.A., J.A. Estes & K.W. Kenyon, 1978. Aleuts, Sea Otters, and Alternate Stable-State Communities, *Science*, 200 (28): 403-410.

Otter Archaeology

Researchers working in the Aleutian Islands of Alaska found the site of a former village on one of the islands, Amchitka Island. At this site was a large mound of earth and other materials built up over hundreds of years as the people of this village threw away their discarded bones, shells and so forth. In other words, this mound, or 'midden' as it is called, was the village dump for many hundreds of years. By digging up this dump, and carefully recording what they found, the researchers were able to determine what animal remains were discarded - and thus they could learn what the people of the village were eating long ago.

These researchers also used carbon dating procedures to determine the age of each layer of dirt and bones excavated from the midden.

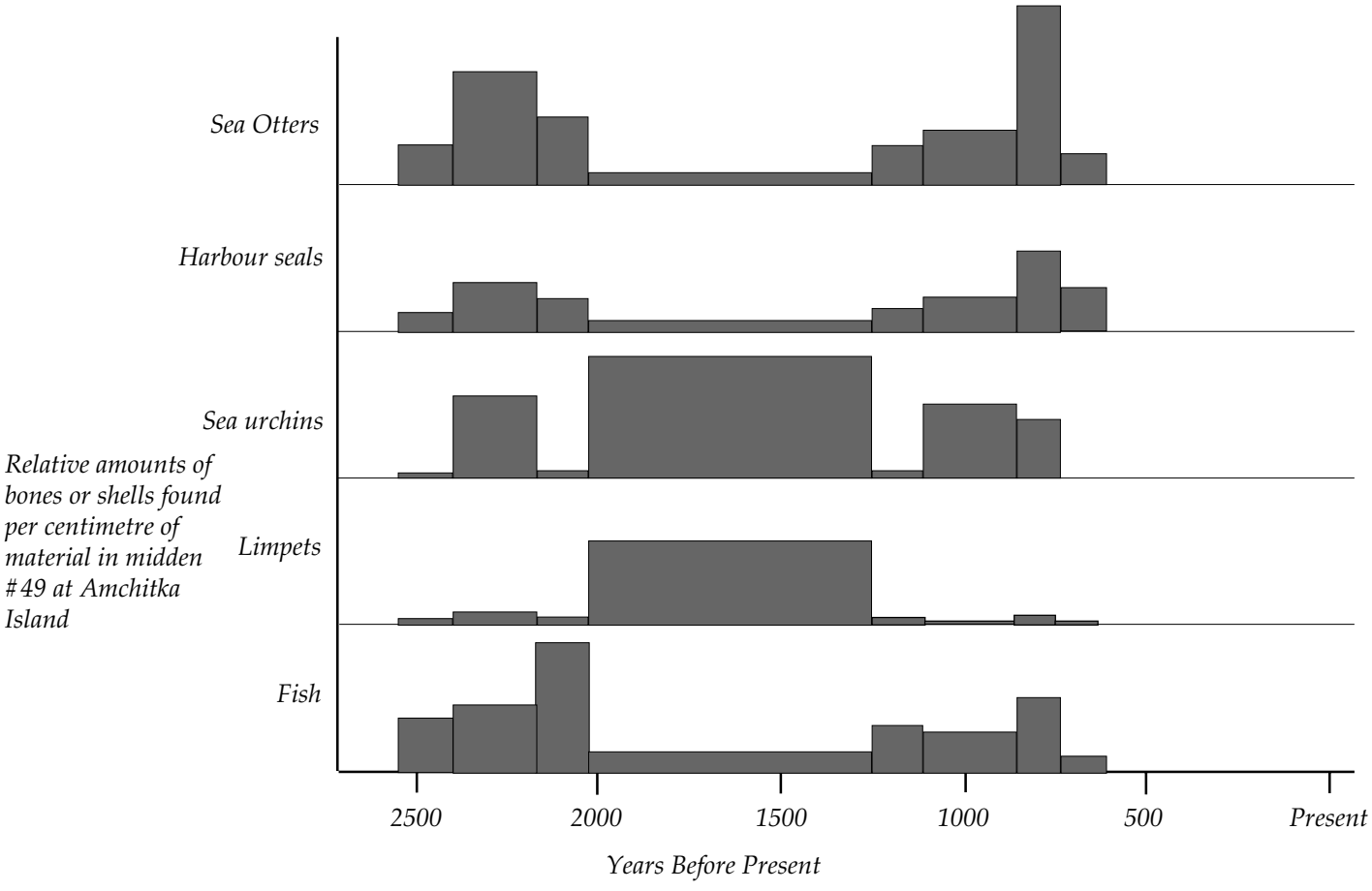
In the graph below, you will find information on the remains of different animals found in the midden: sea otters, harbour seals, sea urchins, limpets, and fish. (A limpet is a small flatened type of snail that lives firmly attached to rocks in the ocean, where it feeds on small algae growing on the rocks.) The approximate date of the layers of dirt in the mound is provided along the bottom of the graph.

Using the graph, discuss and answer the following questions:

1) Describe the patterns in the diet of the villagers over the period between 2500 and 600 years ago.

2) Describe any patterns where groups of animals were part of the village food for periods of time. Which animals were eaten at the same time?

3) What might explain the pattern(s) shown in the food of the village over long periods of time?



Native Whaling

Main Ideas:
Native whaling was a demanding and dangerous activity, which incorporated elements of social and spiritual traditions.

Objectives:
Students will:
• learn about the nativewhaling methods and uses for whales

Background:

The movement of whales along the Pacific northwest coast marked the whaling season to native people living in the area. Gray and humpback whales arrived in the spring and most were gone by summer to parts unknown. Whales would occasionally die and drift ashore, providing oil, meat, bones and sinew for the native people. A dead whale was so valuable that families had rights to certain stretches of shoreline and all that washed ashore there.

Natives of the west coast of Vancouver Island and the Olympic Peninsula in Washington are known to have hunted whales, and it is now believed that other aboriginal groups also had some skills at whale hunting.

To prepare for the whale hunt whalers held elaborate ceremonies and rituals. Preparation took many months, often lasting from November to April or May. The preparations involved magic, fasting, and strict codes of conduct.

The actual hunt utilized two or more large dugout canoes. The harpoon was made with a blade of sharpened mussel shell and two elk antler barbs attached to a shaft of yew wood . The harpoon head was attached to a rope six to seven metres long made of sinew and nettle fibre. Inflated seal skin floats were attached to the rope. When the whale was harpooned, these floats slowed the whale and made it easier to track. When the whale died, the floats helped to keep it afloat.

One canoe in the hunting fleet would have the chief acting as the leader of the expedition, and it would be his choice to thrust the first harpoon. The canoe would approach the whale as close as possible before the harpoon was plunged into the animal. Immediately, the paddlers would steer the canoe away as the whale thrashed. When the whale finally died, its lips were sewn together so it would not sink as it was towed to shore.

A ceremony would follow a successful hunt, at which time the blubber would be stripped off and divided among those who participated in the hunt. A particular piece of meat from the whale's back, referred to as the 'saddle' was given to the chief. The remainder of the meat was divided among the people according to rank. Some meat was smoked for storage.

Materials:

- reference materials (see reference list in Appendix 2 for a place to start)

Procedure:

1. In teams, research the history of native whaling in coastal British Columbia, in another part of Canada or elsewhere in the world. For a report, prepare a presentation involving posters, models, or a play to show the entire cycle of native whaling.

2. Compare native whaling with modern whaling. In each case, what powered the boats, what rituals were involved, how many whales were killed, how did this affect the whale populations, etc?

How Whales Were Once Used

Background:

Before plastics and other synthetics, whales provided the raw materials for a number of products that brought economic gain to whalers, whaling companies and subsequent players in the consumption cycle of these products. Many useful, fascinating, and occassionally unusual products were prepared from whale parts as can be seen in the table on page 2-27.

Unfortunately, whales live in an environment belonging to no single nation or people - they are part of the great ocean "commons". Consequently, management of whale hunting and hunters has not taken place until recent years, and even now management is not completely accepted by all nations of the world. As recently as 20 years ago, wanton harvesting of whales in parts of the world brought many species or populations to the brink of extinction. The graph on this page shows the recent decline of whales from whaling in a large sector of the Antarctic seas.

Peter G. Evans, in his book, The Natural History of Whales and Dolphins, wrote: "The relentless pursuit of whales first for essential food but later for additional products is a blot on man's history. Yet we can see how economics have encouraged it, particularly in the last two centuries. The blame does not lie with the Japanese or the Russians, the two main whaling nations today; it lies with everyone. The more developed a nation has been, the more damage it has wrought."

Today, alternatives are available for all whale products.

Materials:

- handout - How Whales Were Once Used, page 78

Procedure:

1. Have students work in small groups to research, discuss, and complete the table. There are no 'right' answers to the questions about the value of some products, but it is important to have students examine consumption and its relation to such activities as 'harvesting' whales or other animals.

2. Display the accompanying graph to the class and discuss what has happened to these populations. Students may pick out the short recovery periods during WW II and the rise in Minke whale populations, probably as a result of lowered competition for food, as other whales have been removed. Minke whales, previously considered too small for whaling, are now sought by the whaling nations who argue that their populations are large enough to be harvested.

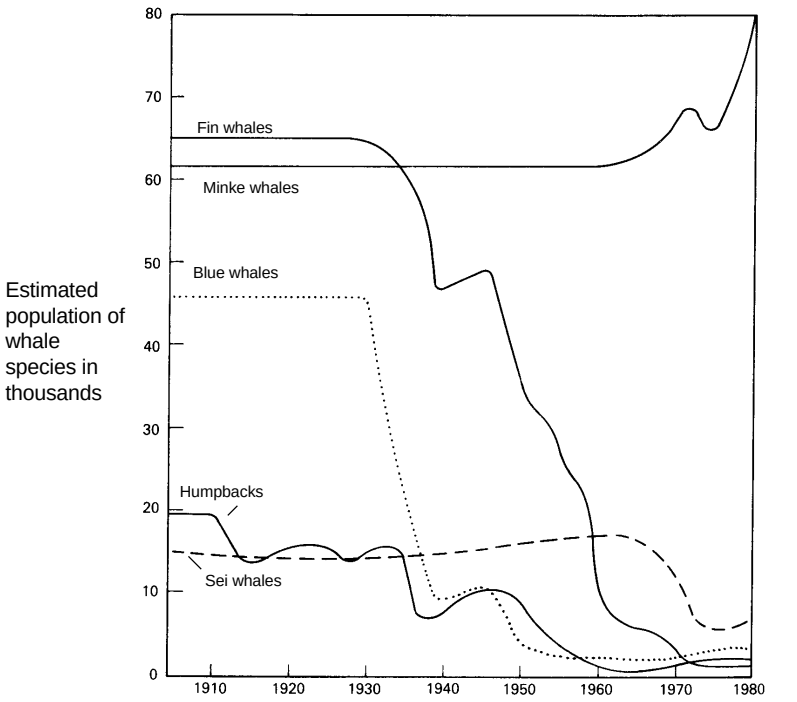
Main Ideas:

Modern whaling was undertaken largely for the purpose of economic gain. The products made from parts of whales were varied - many of them are no longer useful, while others are now made from alternative natural resources.

Objectives:

Students will:
- learn about the human uses for whales during the 'modern' whaling periods
- consider products made from whale parts; their value to the quality of life; and alternative resources that can be used to manufacture these products.

Estimated populations of whales in Area IV of the Southern Oceans between 70°E and 130°E. From Evans, 1987 after Beddington and May, 1982.



Activity:

How Whales Were Once Used

The table below describes some of the parts of whales used during the days of active whaling, and how these parts were used. Think about each product, discuss this with your team, and then check whether the product is absolutely essential for modern life, simply useful, or a luxury. For the last column, research the natural resources that are used today to make this product. You can refer to lists of ingredients on the products for much of this information.

Part of whale Used	Product made from this part	Today, This Product Is:				The modern substitutes for whale parts in making this product are
		No Longer Used	A Luxury	Useful Product	Essential Need	
whale oil	oil for lamps, street lights, lighthouses, headlights for trains					
	high-grade lubricant for motors and machines					
	soap					
	margarine, lard					
	cold creams and lotions					
baleen	corset stays, umbrella ribs, brushes, combs, brooms					
	horsewhips, sofa and carriage springs					
	hoop skirts					
skin	shoe laces (beluga skin)					
	handbags and shoes					
bones and teeth	jewelry; used for a type of elaborate engraving called scrimshaw					
	decorative items: crib boards, umbrella handles					
	piano keys					
	bones also used for fertilizer					
	ground for feed for chickens, cattle, farmed fish and farmed mink					
meat	human food					
	pet food					
ambergris (from intestines of sperm whales)	soap, perfume					
blood	adhesives in plywoods					
liver	Vitamin A and D					
pancreas	insulin					
glycerin (from blue whales)	used in explosives					