

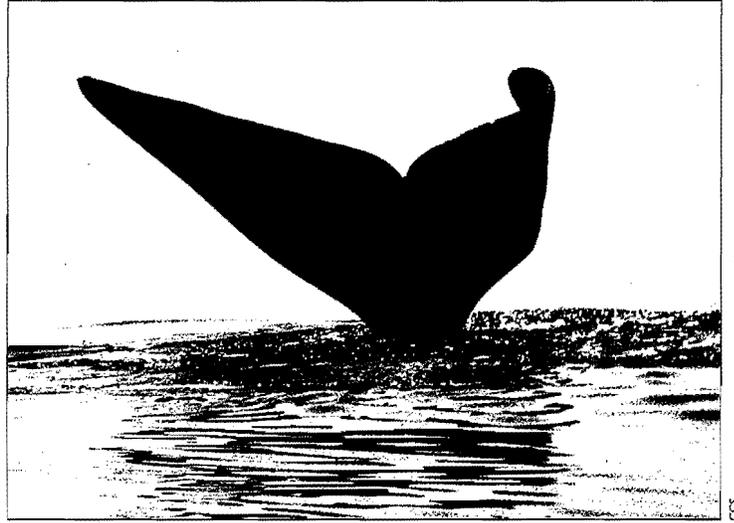
MODULE NUMBER 2

GRADES 6-8

FROM WHALING TO WATCHING

The Northern
Right Whale





THE NORTHERN RIGHT WHALE: FROM WHALING TO WATCHING

CREDITS

Sincere gratitude goes to Will Hon, a remarkable educator and artist, who developed the northern right whale poster. Will's enthusiasm and ability to synthesize seemingly unrelated information has inspired countless followers.

Many thanks are extended to "Stormy" Mayo and Marilyn Marks (Center for Coastal Studies), Al Sanders (The Charleston Museum), Mike Harris and Barb Zoodsma (Georgia DNR, Coastal Resources Division), Scott Kraus, Philip Hamilton, Greg Stone and Chris Slay (New England Aquarium), Bob Ziobro (NOAA, NMFS), Hans Neuhauser (Right Whale News) and especially Dr. Robert Kenney (University of Rhode Island) for their document review and technical expertise. Great appreciation goes to Edwin Schiele and Debbie Craven for their invaluable review comments.

I am most appreciative of the art direction and design contributions of Cheryle Chapline, and thanks go to Moving Pictures Studio for the illustrations in this publication.

Scrimshaw and whale memorabilia were photographed at the Ships of the Sea Maritime Museum, Savannah, GA. Thanks to Jeff Fulton for his assistance. Whale skeleton was photographed at the Charleston Museum, Charleston, SC. Whale photographs provided by the Center for Coastal Studies (CCS), Chris Slay, New England Aquarium (NEA) and Hans Neuhauser. Students were photographed at St. Andrew's School by Brad Boyd of ImageMasters. Arrangements for student photographs were coordinated by Elizabeth Allen at St. Andrew's School, Savannah, GA. Photograph of the baleen was taken by John "Crawfish" Crawford. Scrimshaw, whale memorabilia, baleen, whale skeleton, and the activity "Jaws" were photographed by the author (SVM).

Activities were field tested in middle school classrooms across Georgia. Final revisions of the activities resulted from working with the bright and enthusiastic students at St. Andrew's School in Savannah. In addition to his on-going technical assistance, Hans Neuhauser generated inspiration for many of the activities and conceived the idea for the activity "No Jonah." Thanks to Liane Green for evaluation contributions.

Special thanks to Dave Mattingly, founder of The Ocean Society, whose enthusiasm and commitment to whale education and research is unending.



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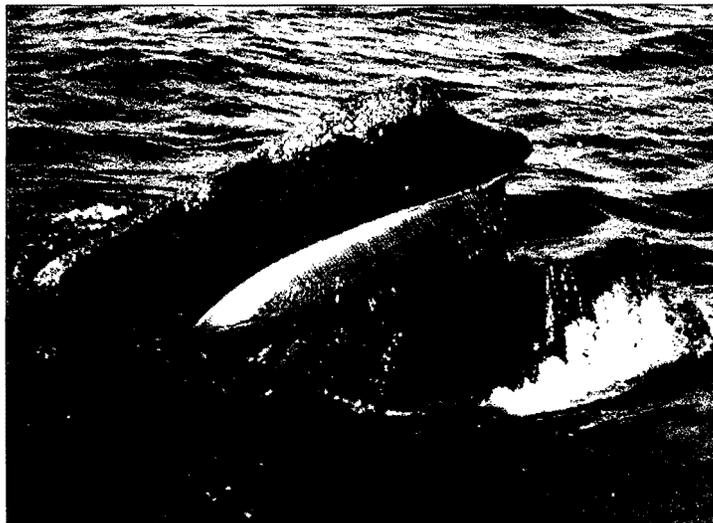
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Second Edition 1996

MAKING A SPLASH



CCS

Whales... for many the earth's most magnificent animals; certainly the largest and unquestionably majestic creatures. Sarah Mitchell, Education Coordinator here at the Gray's Reef National Marine Sanctuary has designed this handbook which was coauthored with Ann Smrcina, Sarah's counterpart at the Stellwagen Bank National Marine Sanctuary. It explores the life history of the most endangered large whale, the northern right whale, and our history with the whale from exploitation to conservation.

The handbook is designed for the classroom. Sarah has developed four engaging teaching activities that the students will thoroughly enjoy and remember. The activities have been classroom tested and stamped with the preteen seal of approval in my daughter's 7th grade class. But in addition to having fun learning about this fascinating animal, students will be awakened to the presence of this rare and endangered ocean neighbor and discover how we as the domineering species on the planet may navigate more carefully to protect the right whales' future.

The companion to the guide is the beautifully rendered poster of the northern right whale migration and anatomy by Will Hon. We dedicate this book to Will, an inspiring teacher, deft artist and enormously generous personality. Will's illustrated seminars, chalktalk chats, storytelling, expedition leading are legend to the hundreds of teachers, students, birders, and bewildered that were fortunate enough to learn about Georgia's fantastic coast through Will's nonlinear lectures.

The right whale handbook is one unit in a more comprehensive education module developed by Sarah about key endangered and threatened species in Georgia. The Coca-Cola Foundation has supported this effort and will distribute the module to every middle school and science center in the State. The next module in the series will look closely at our coastal ocean environment and carry the reader from the marshes and sandy beaches of the barrier islands offshore to the panoramic seascapes of Gray's Reef National Marine Sanctuary. Stay Tuned.....

Reed Bohne
Manager
Gray's Reef National Marine Sanctuary





Chris Stry

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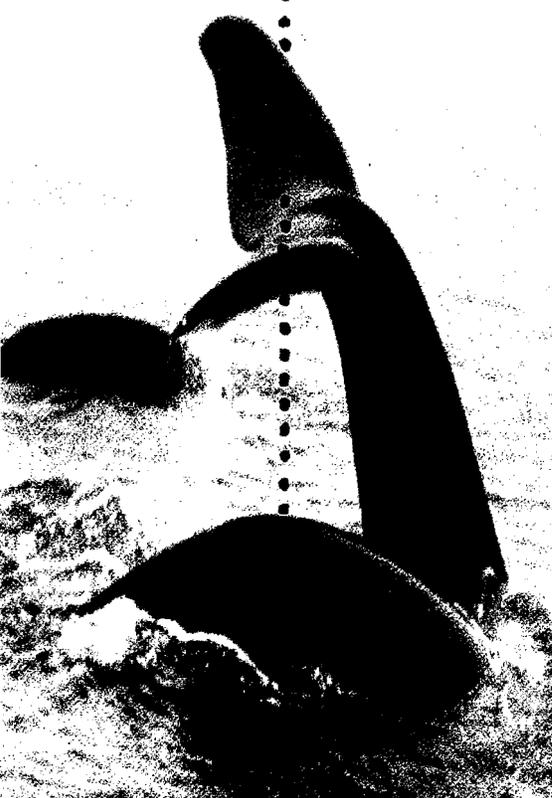
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WHALES GREAT AND SMALL

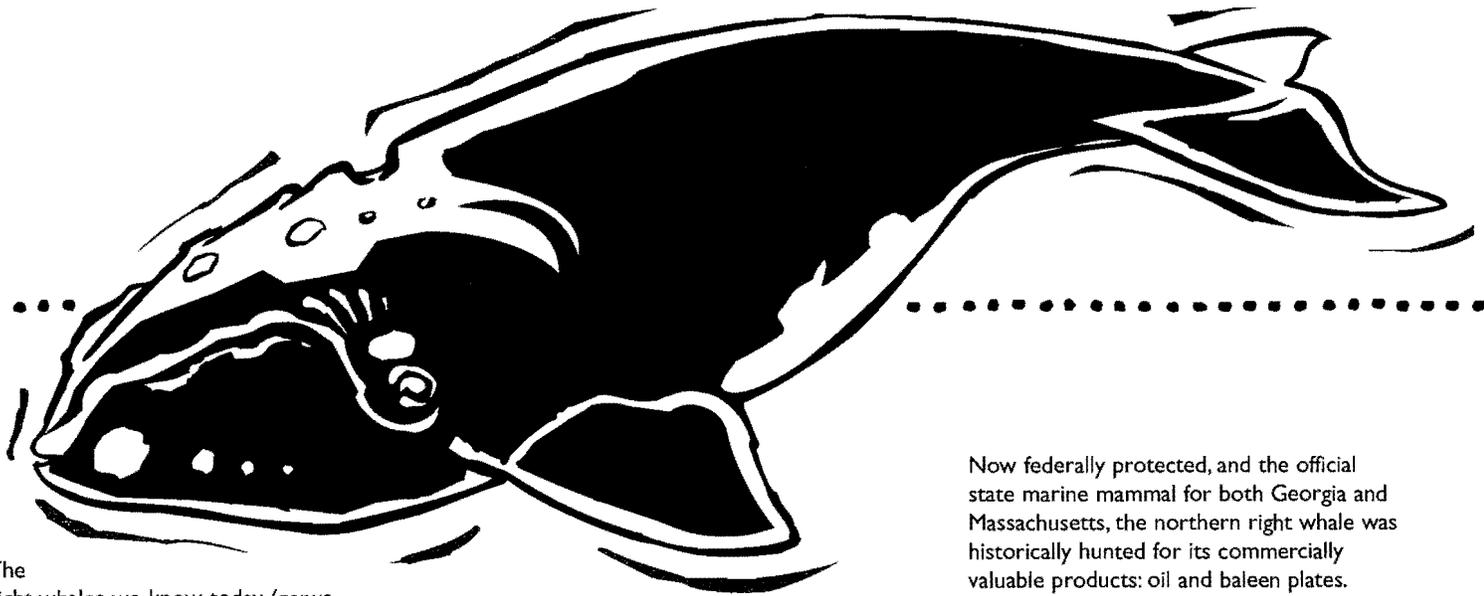
Whales both great and small have always been a marvel to people around the Earth. Throughout history, superbly adapted marine mammals have inspired countless myths and legends. Whales have survived for millions of years, but today, many people are concerned about the future of this cetacean species. Human threats, ranging from commercial hunting to habitat degradation, have pushed some species close to extinction. Of all the great whales, the northern right whale (*Eubalaena glacialis*) has been hit the hardest. They were the first of the large whales to be commercially hunted, and despite over 60 years of protection, current populations remain dangerously low. The search for whales continues today along the east coast of the United States and Canada. But now the hunters are the scientists trying to save the whales.

However, there are not many northern right whales left to track. Scientists estimate that fewer than 325 remain in the North Atlantic Ocean. The northern right whale was initially placed in this precarious position due to overhunting, which started more than 800 years ago. Although a 1935 League of Nations resolution banned the hunting of right whales, the population remains at risk.

The story of the right whale begins about 30 million years ago when the first baleen whales arose. Shortly after that in evolutionary time, some 20-22 million years ago, the earliest members of the right whale family (Balaenidae) appeared. But the genealogical history of whales, according to scientists, begins quite a bit earlier than that, with the first species of cetaceans appearing about 50 million years ago, evolving from ancient land mammals with hind legs. Many scientists now believe that the cetaceans evolved from an ungulate ancestor (of the Order Condylarthra, family Mesonychidae) which were carnivores about the size of a large dog. The now extinct forerunners to whales had teeth, fur, and probably some adaptations that let them use the water environment. Gradually, the oceans became their full-time homes, as other adaptations made the terrestrial environment less appealing. The whales filled a niche that other mammals could not use. In the case of the baleen whales, teeth no longer became important for catching prey, and disappeared. Fossils of some now extinct species indicate that the first baleen whales did have teeth. Hair became a hindrance rather than a help, and disappeared too except for a few individual hairs on their heads, making the animals more hydrodynamically designed. For protection from the cold, fat reserves (blubber) took on new significance.



Hans Neubauer



The right whales we know today (genus *Eubalaena*) appeared 5 million years ago, while other baleen whales came before or after. For example, humpbacks (genus *Megaptera*) appeared 15 million years ago and gray whales (genus *Eschrichtius*) appeared two million years ago.

The early Latin word for whale, “cetus” (and the Greek “ketos” which means whale or seamonster) served as the root for the scientific name of the order, Cetacea. Like other mammals, cetaceans are endothermic (sometimes referred to as warm-blooded), give birth to live young, breathe air through lungs, and have hair at some time in their development.

Baleen whales are of the suborder *Mysticeti*, which refers to the characteristic mustache-like fringe of the baleen (from the Greek *mystax*—mustache or upper lip and *cetus*—whale). *Mysticeti* includes four families: *Balaenidae*, right whales and bowheads; *Neobalaenidae*, pygmy right whales; *Eschrichtiidae*, gray whales; and *Balaenopteridae*, rorquals (which include blue, finback sei, and whales). Baleen whales are often referred to as the “great whales”. The blue whale is not only the largest whale in the world, it may be the largest animal organism ever. But despite their large size, baleen whales consume primarily krill (small shrimp-like animals), small fishes, and copepods (microscopic marine crustaceans), the smallest food of any whale.

Toothed whales are in the suborder *Odontoceti*, which refers to the presence of teeth. (From the Greek *odon*—“toothed”) *Odontoceti* includes nine families of whales. The more than 65 species of toothed whales exhibit greater diversity in body forms and behaviors than do baleen whales. Examples of toothed whales include: sperm whales, orcas, dolphins and porpoises.

Northern right whales are black, sometimes with white or gray patches on their throats and bellies. Identifying features include the absence of a dorsal fin, a deeply notched tail with a smooth trailing edge a large head (more than one-quarter of the body length). The flippers are short and very broad. Tough cornified dark skin patches, called callosities, are used with other markings to identify individuals. Callosities are located on the top of the head, above the eye, behind the blowholes, and along the lower jaw. These areas of callused skin begin to develop soon after birth and are observed on very young right whales. Sparse hair appears on the tips of the chin and upper jaw, often associated with callosities. Large amounts of blubber, about two-fifths its body weight, give the right whale a particularly rotund appearance. Adult whales, which average 12-16.5 meters (40-55 feet) can weigh up to 63.5 metric tons (139,700 pounds).

Now federally protected, and the official state marine mammal for both Georgia and Massachusetts, the northern right whale was historically hunted for its commercially valuable products: oil and baleen plates. Characteristics of the right whale—floating when dead, a slow swimming speed, and proximity to the coast—inspired whalers to designate this whale the “right” whale to kill.

In recent decades, Northern right whales have been sighted from Iceland to Florida, but the only known calving area is the coastal waters of Georgia and Florida. The area, designated as “critical habitat”*, extends from the mouth of the Altamaha River in Georgia south to Sebastian Inlet, Florida, and from the shoreline out to 15 miles off Georgia and northern Florida and five miles off central Florida. Peak abundance of right whales in this area, as well as calving, occurs from December through March.

In March and April, right whales congregate in the plankton-rich waters of Cape Cod Bay, off Massachusetts to stock up on much needed nutrients. These areas have been designated the northeastern “critical habitat” for the northern right whale. These whales continue their northward travels to the Bay of Fundy and off the southeastern coast of Nova Scotia where they spend the summer and fall.

Blowholes of right whales are divided on the surface, forming two holes typical of baleen whales. (Toothed whales have a single blowhole.) Visible from a distance, the blow is identified by a nearly vertical “V” shape. When viewed from the side or affected by wind, however, this double blow may appear as one.

*“critical habitat” = habitat deemed critical for the survival of the species; special Federal protections apply

HUNTING THE RIGHT WHALE

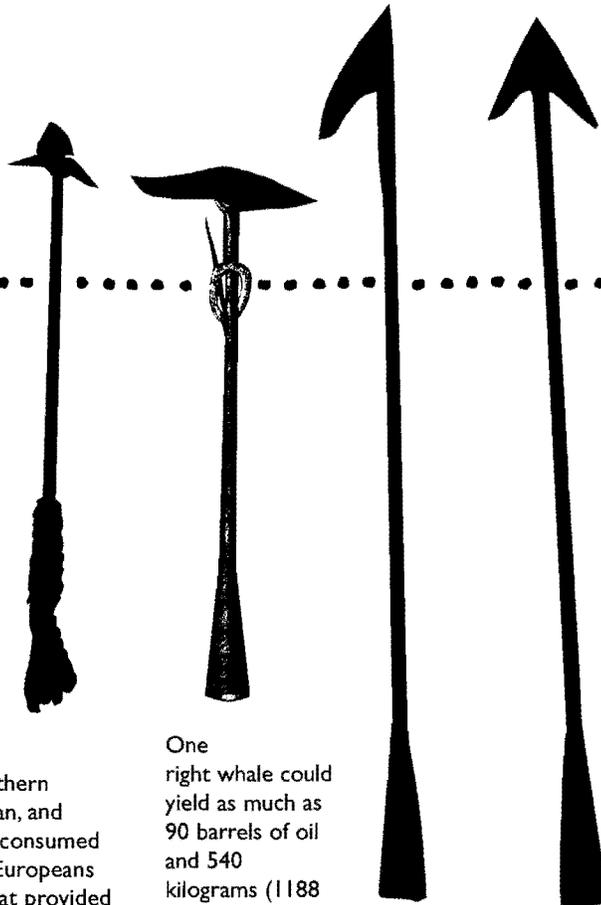
For centuries, right whales provided valuable materials to cultures around the globe. Baleen and blubber, the main resources once harvested from whales, now have substitutes that are readily available.

Inuit (peoples of the northern latitudes), Native American, and other indigenous people consumed whale meat long before Europeans began whaling. Whale meat provided an important source of protein in areas of the world with a limited number of land animals available as food, and in northern regions affected by a growing season too short to support a base of agriculture. Inuit hunted whales in kayaks with stone harpoons. They harvested only a few whales each year and used every part of the animal for food, fuel, tools and even building materials. The small annual number of whales killed by Inuit (for more than 1000 years) had little impact on whale populations. European whalers, with the advantage of more advanced technologies, devastated the population of Northern right whales in just a few centuries.

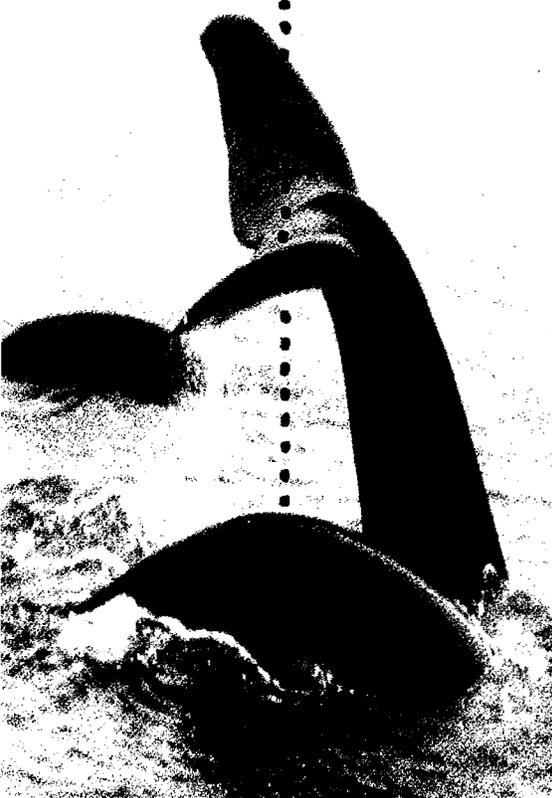
Terrestrial sources of meat were available to the European and New World whalers. They were interested in the blubber and whale bone (baleen). Oil is produced from the meat and blubber, and is used in lamps and as a lubricant. Blubber contains over 60% oils, and once the process of hydrogenation was developed, whale oil was used in the manufacture of margarine, lard and shortening.

One right whale could yield as much as 90 barrels of oil and 540 kilograms (1188 pounds) of baleen, which is also known as whalebone. Manufacturers fashioned the strong and highly flexible baleen into buggy whips, umbrella stays, skirt hoops, strapping for beds, brushes, and caning for chairs. The baleen from one whale could pay for many of the expenses of the voyage. Additional whales harvested generated clear profits.

The Basques of northern Spain were hunting right whales in the Bay of Biscay by the 12th century. Spotters manned watchtowers along the shore and alerted waiting boats to nearby whales. Fishermen could immediately launch rowboats from shore to kill whales with hand-held harpoons. But as the whales became scarcer, the fishermen had to venture further from their home waters. By the 16th century, the whalers traveled as far as Newfoundland. In 1610, the English launched their first whaling enterprise to the northern coast of Norway. The voyage was profitable. Dutch, French, Danes Norwegians, Germans, and Portuguese also started whaling. Competition among the countries resulted in divisions of the coast. The Dutch had 300 ships and 18,000 men involved in whaling, more than any other country. As the



Sarah Mitchell



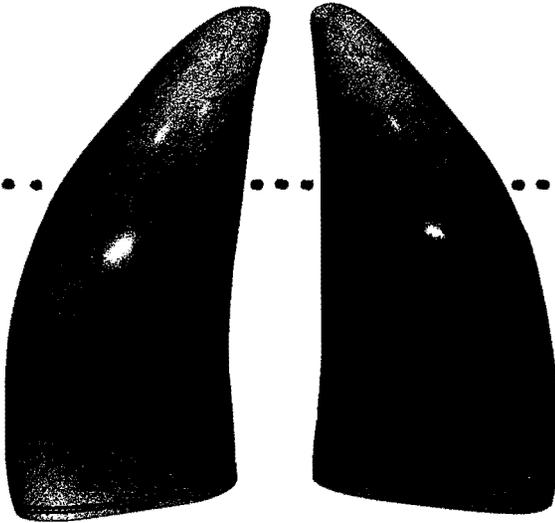
Hans Neuhauser

number of boats increased, so did the number of northern right whales caught. By the 1700s, the English and French became the dominant forces in the Atlantic Ocean. Hunting these large animals required

organized expeditions with skilled harpooners and expensive equipment. As the whale populations declined, the voyages moved further out to sea and into deeper waters.

Government bounties spurred the establishment of an American whaling industry. Nantucket, Long Island, Plymouth and Massachusetts Bay colonies profited from beached whales as early as 1644. Whaling boats began operating close to the New England shore in the late 1600s. Watchtowers were used to spot whales, and boats were launched from a shore base. Right whales were hunted in the early 1700s along the coast, towed to shore, and processed into oil and meat on the beaches. By the mid 1700s, right whales close to shore were becoming scarce. As the right whale population dwindled, commercial whalers turned their attention to sperm whales. Sperm whales (*Physeter catodon*) were first killed as a substitute when right whales were scarce, but whalers soon found them profitable

Sarah Mitchell



(the quality of sperm whale oil is higher than that of the right whale.). To occupy their time during long

whaling voyages, the crew often made carvings on whale bone, particularly sperm whale jaws and teeth. These carvings, called scrimshaw, were made as gifts for the whalers mothers, wives and sweethearts.

By the early 1800s, New England whalers were exploring the remotest corners of the oceans searching for whales. Many areas in New England were engaged in whaling, including Gloucester, New Bedford, Nantucket, Martha's Vineyard, Cape Cod, Salem, Sag Harbor, Providence, and New Haven. Whaling was at its peak in New England from 1800-1860, and whaling profits made these sea ports some of the wealthiest in America. Two inventions, in 1865, gave birth to modern whaling: the harpoon cannon with grenade harpoons and steam powered catcher boats, which would begin an era of efficiently killing an unprecedented number of whales.

In 1876, a whaling vessel from New Bedford, Massachusetts, arrived in Brunswick, Georgia, to unload cargo of whale oil and baleen. While in the area, the schooner captured a whale off the coast, prompting other whalers to use Brunswick as their winter base of operation. Within six years, 25 to 30 whales were recorded to have been killed off the coasts of Georgia and northern Florida.

By the time northern right whales were given protection in 1935, some scientists estimated that there were fewer than 100 right whales left in the North Atlantic Ocean. Many feared that the northern right whale would become extinct.

The population of right whales in the western North Atlantic along the North

American coastline now number 300 to 325 individuals. Additionally, there is a population of right whales in the South Atlantic which numbers about 1700. These numbers are small compared to the total once estimated for the right whale — before the 15th century and the era of intensive whaling. It is estimated that there was a world-wide right whale population of 100,000 to 300,000. But are the populations in the North and South Atlantic the same species? Scientists don't think so.

According to a paper that appeared in the 1991 Report of the International Whaling Commission: "The South Atlantic right whale is similar in appearance and breeding biology to the North Atlantic right whale, but, because of its geographical distribution, its reproduction cycle is six months out of phase. [Northern right whales give birth during the northern winter, generally December-February, whereas southern right whales give birth during the austral winter, from June-August.] As a result, northern and southern right whales are assumed to be reproductively isolated and are considered to be separate species." The northern right whales have been labeled *Eubalaena glacialis*, while the southern right whales have been named *Eubalaena australis*. In addition, there is a third population of whales in the north Pacific — these whales have been designated *glacialis* too, but they are often referred to as a subspecies called *Eubalaena glacialis japonica*.

A study using skin samples from northern and southern right whales showed that the DNA differed enough to suggest that the two species diverged between 0.9 and 1.8 million years ago.

CONSERVATION

The cumulative effects of humans have contributed to degradation of coastal marine habitats along the eastern seaboard. The historical impact of early whaling off the east coast decimated the population of right whales, and recently, collision with ships, entanglement with fishing gear and degradation of water have clearly affected the ability of this population to sustain itself.

Sarah Mitchell

WHALES GREAT AND SMALL, CONT.

NOAA (National Oceanic and Atmospheric Administration) established the National Right Whale Recovery Team to identify the human-induced risks to the species. In decreasing order of severity the team identified the following risks: 1. collisions with ships, 2. entanglement in certain types of fishing gear, 3. habitat degradation and 4. disturbance from vessels.

Northern right whales swim slowly, spending a considerable amount of time at the surface, skim feeding and resting, which makes them susceptible to collision with vessels. Although collisions with ships remain a constant threat, entanglement in fishing gear looms as an ever-present hazard. Inevitably, some of that gear, such as gill nets and lobster gear, entangles whales, including right whales. A whale disentanglement team, led by the Center for Coastal Studies in Provincetown, MA, has successfully freed several whales over the years. One such rescue is documented in the Center's video production "Sanctuaries: Stories of Stellwagen Bank."

The Southeast United States Implementation Team for the Recovery of the Northern Right Whale is charged with coordinating right whale recovery activities throughout the Southeast. The team is made up of representatives from the Georgia Department of Natural Resources, the U.S. Navy, the U.S. Coast Guard, the U.S. Army Corps of Engineers, NOAA's National Marine Fisheries Service, the Florida Department of Environmental Protection, and the Port Authorities.

The Implementation Team has also developed an early warning system to help reduce the number of vessel collisions. The New England Aquarium makes daily flights over the calving grounds from December to March, and forwards the location of right whales to ships passing through the area. These surveys are funded by the U.S. Coast Guard, the U.S. Army Corps of Engineers, and the U.S. Navy. The Georgia Department of Natural Resources and the Florida Department of Environmental Protection sponsor workshops in which they share information on how to best alert

mariners to the location of whales and on the best way mariners can respond.

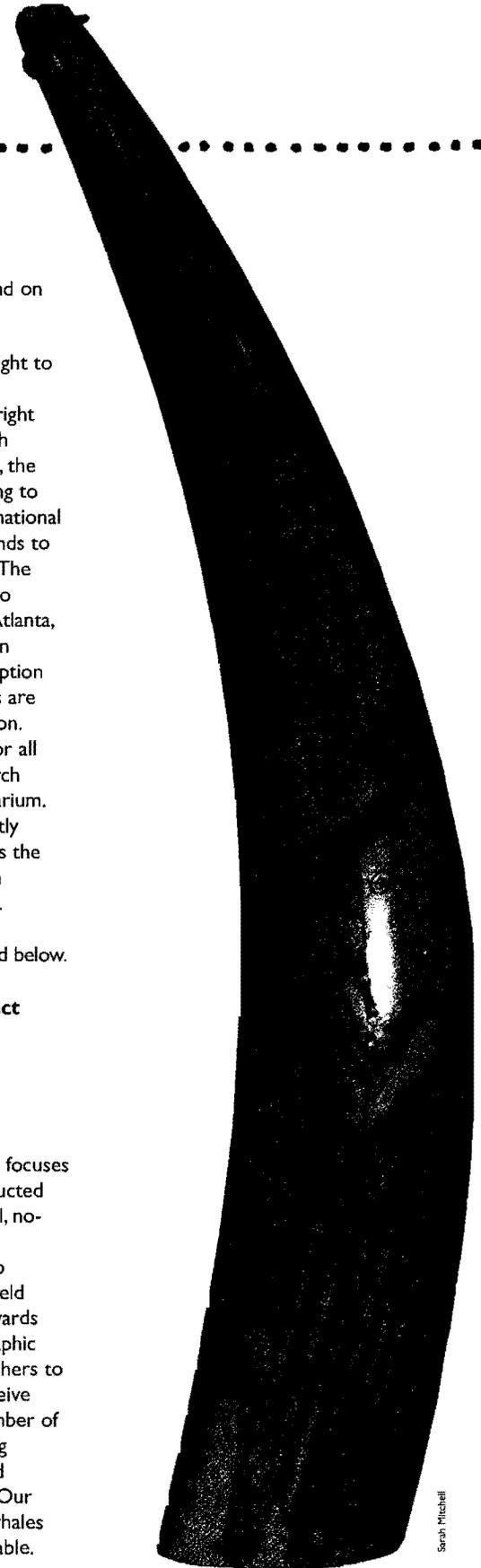
One way individuals can help in the fight to save the northern right whale is by sponsoring a whale. There are three right whale sponsorship programs in North America. The New England Aquarium, the primary research organization working to save the northern right whale, has a national sponsorship program which raises funds to partially support this research effort. The Aquarium's work is augmented by two organizations. The Ocean Society in Atlanta, Georgia and East Coast Ecosystems in Freeport, Nova Scotia; both have adoption programs in place. All three programs are well coordinated and share information. Photographs and sightings histories for all the programs come out of the research database which is housed at the Aquarium. These three programs all have a slightly different focus but their overall goal is the same—to benefit the species through research, education and conservation.

A brief description of the three is listed below.

The Right Whale Research Project New England Aquarium

Central Wharf
Boston, MA 02110
(617) 973-6582

The Aquarium's sponsorship program focuses primarily on the research being conducted on this vulnerable species. It is a small, no-frills program run by the researchers themselves and the funds collected go directly to defray the cost of future field work. Your contribution could go towards the purchase of film for our photographic database or to get one of the researchers to an injured animal. The packet you receive includes a 3X5 photo taken by a member of the research team, a thorough sighting history of that animal and background information on right whale research. Our published catalog of individual right whales and our project T-shirts are also available.



Sarah Mitchell

Our team studies these animals during more than half the year in areas ranging from their calving ground along the southeastern U. S. to nursery and feeding areas off Maine and Nova Scotia. First hand reports on this ongoing research effort and updates on individual whale sightings are the focus of our biannual newsletter published in the late fall and early spring of each year.

The Ocean Society

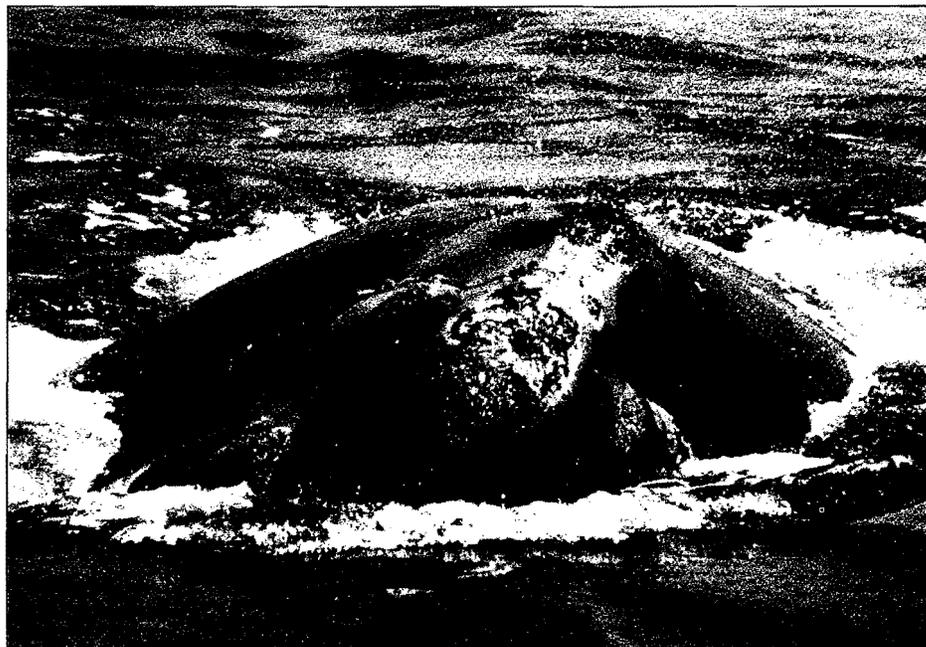
441 Ridgewater Drive
Marietta, GA 30068
770-977-1838

In Georgia, the Ocean Society, in cooperation with the New England Aquarium, sponsors an adopt-a-whale and marine education program. David Mattingly, a commercial airline pilot, founded this Atlanta-based conservation organization. Mattingly had previously helped gather the data that established the southeast coast as a right whale calving area. The Ocean Society continues his commitment to saving endangered whales by contributing to right whale research and education.

East Coast Ecosystems

P. O. Box 36
Freeport, Nova Scotia, Canada BOV 1B0
(902) 839-2962

East Coast Ecosystems is a Canadian organization involved with right whale research, education and advocacy programs. Since 1968, East Coast Ecosystems has been conducting shipboard surveys in collaboration with the New England Aquarium. These surveys, which take place in the Bay of Fundy and on the southern Scotian shelf, enable researchers to study the seasonal distribution, abundance, and behavior of the right whale.



New England Aquarium

In Canada, funds from this whale adoption program help promote awareness among mariners to the presence of right whales as well as introducing these rare animals into the classrooms of thousands of Canadian school children every year. East Coast Ecosystems works with Fundy Vessel Traffic Control of the Canadian Coast Guard, providing them with assistance in alerting ships transiting the Bay of Fundy to locations of right whales in an attempt to reduce the number of ship collisions involving whales.

WHALE WATCHING

It is difficult to get a good look at right whales, since they often are barely visible above the surface. However, the V-shaped blow of the right whale is easy to recognize. If you are one of the few that happens to spot a right whale, record latitude and longitude, LORAN coordinates, or position in regard to buoys, then move away from the whale. Report right whale sightings by calling 1-800-2-SAVE-ME, in Georgia, or 1-800-DIAL-FMP, in Florida.

If you are interested in whale watching, avoid the calving area, off the coast of southern Georgia and northern Florida from December through March. This is the most vulnerable time in the entire life of a right whale. Any disturbance could affect the calving, nursing or other behaviors critical to the survival of the species. This courtesy will increase the chances of seeing these endangered whales in their spring and summer feeding and breeding grounds. If you want to see whales off the southeast coast in winter, look for a smaller cetacean, the bottlenose dolphin, which can lift your spirits with joyful wonder, disproportionate to their size.

ANATOMY AND PHYSIOLOGY

Right whales range in length from about 17 meters (55 feet) maximum for adults, 9 meters (30 feet) for one year olds, and 4-5 meters (12-15 feet) for newborns. Weighing in at about 45,500 kg (100,000 pounds), the adult right whale has a very large girth relative to its length giving it a marked rotund appearance. One 13.6 meter whale had a girth measurement of 9.2 meters.

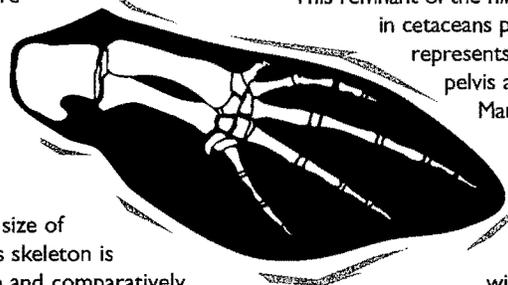
A remarkable feature about the right whale is that its head is approximately 1/3rd of its body length — one skull was measured at 5.2 meters and weighed 1,000 kg (2,200 pounds).

Despite the great size of the right whale, its skeleton is surprisingly simple and comparatively light. Overall, the skeleton accounts for only about 14-15% of the whale's total body weight, whereas in humans, the skeleton is about 18% of body weight.

(The internal organs of a right whale also take up 14-15% of the animals weight.) The whale's spine consists of 55-57 vertebrae including 7 cervical, fused in the neck region, 14-15 thoracic, 10-11 lumbar, and 25 caudal; in comparison humans have 33 vertebrae — 7 cervical, 12 thoracic, 5 lumbar, 5 sacral, and 4 coccygeal. Interestingly, almost all mammals have seven cervical, or neck vertebrae (manatee and the two-toed sloth are exceptions), no matter how long the neck, including giraffes, horses, hippos, whales and humans.

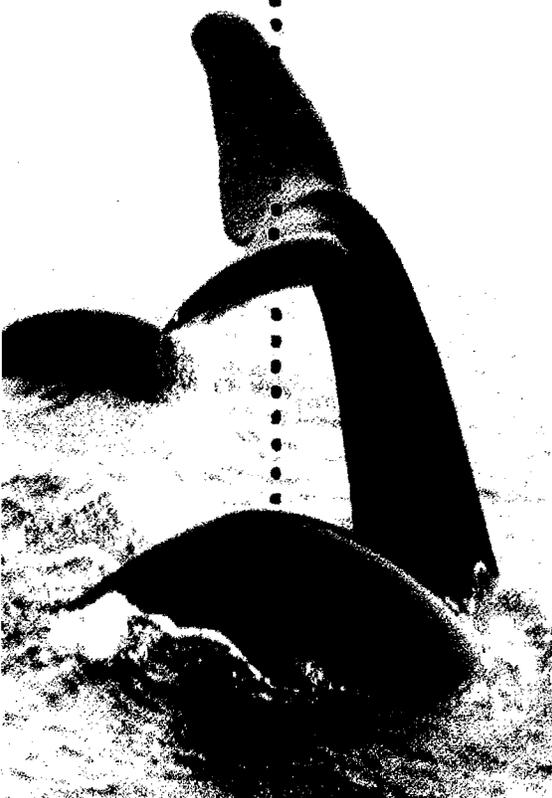
Right whales have 14-15 pairs of ribs while humans have 12 pairs. The whale's rib cages are flexible and can protect the internal organs while the animal is in the water at various depths; they are not so successful on land. If a right whale were to beach itself for any length of time, its great weight would collapse the ribcage and lead to internal organ damage. The arm-bones humerus, radius and ulna in the right whale are extremely short compared to human proportions; and the pelvic region in the whale is reduced to a vestigial bone buried deep in the muscle.

This remnant of the hind limb skeleton in cetaceans probably represents a combination of pelvis and limb bones. Mammals, including humans and whales, evolved from the same bottom-crawling fishes with five digits on each limb. We share the same ancestors through more than 300 million years, until primate and ungulate ancestors split only about 75 million years or so ago.



Therefore it is not surprising that the flipper of the right whale is similar to the human hand. There are five digits, as there are in human hands, although the phalanges (finger sections) range from 2-6, while humans have 3 in each of the fingers and two phalanges in the thumb.

The whales we know today evolved from four-footed mammals that once roamed the land. In the course of natural selection, the whale's ancestors with adaptations for the water environment survived and began to use the oceans exclusively. These adaptations included a



Harv Neelhauser

strong tail which became more important for locomotion than limbs. The two “wings” or flukes that developed on the sides of the tail are filled with tendons and connective tissue. This is an extension from the base of the spine and not an adaptation of the legs. The tail muscles are the largest in the whale’s body and are so powerful that they can propel a 50 ton right whale out of the water into a full breach.

Right whales, like other cetaceans, move their tails up and down, rather than side-to-side like fish. This motion evolved from the natural flexing of the backbone in a running mammal. However, unlike its ancestors that stayed on land, the whale lost its hind limbs and its front limbs evolved into flippers which are used for steering and stabilization but not for propulsion. Scientists believe that the dorsal fin, absent in the right whale, may be used for stabilization in fast-moving cetaceans.

Both the up and down strokes of the up-and-down oscillation of the tail is what powers the whale’s forward progress. The down stroke returns the fluke to the starting position. If you’ve ever gone sculling in a boat you’ve used the same principle — the oar (which stays underwater the whole time) is pulled upward, powering the vessel forward with the follow through returning the oar to the original position.

If you can get to a swimming pool, try swimming like a whale, then like a fish. A whale swims with its tail going up and down. Try it. Keep your legs together and move them up and down together. You’ll find you’ll be doing the traditional dolphin kick used in the butterfly. Now try swimming like a fish. You can’t do it. Mammalian bodies just don’t have enough power that way. Our spines and musculature are designed for up and down motion, not side-to-side.

SKIN, CALLOSITIES AND WHALE LICE

The skin on right whales is several millimeters thick. This layer of smooth, black skin can be easily rubbed off, yet offers an important protection for the whale, serving as a barrier between the whale and the salty ocean water. Researchers have observed numerous white marks on right whales, indicating scarring from such hazards as entanglements with ropes and netting, collisions with boats, and encounters with orcas. Some 60% of all known right whales show entanglement scars.

The skin covers a thick layer of blubber, strong muscles, and a lightweight skeleton. Cetacean skin shapes the package into its streamlined, torpedo-like shape which is hydrodynamically suited for locomotion through the ocean environment. Few appendages interrupt the flow. Slits in the skin on the ventral (bottom) side of the whale cover its genitalia (birth canal in the female and a retracted penis in the male). The whale’s genital slit is located further back along the central ventral line from the navel but before the anus.

One unusual feature on right whales that seems to interrupt its streamlined appearance is the formation of callosities. These areas of cornified epidermis (thick skin patches), which are visible even on newborns, are unique to each whale. Researchers use these callosity patterns to identify individuals; photographs taken since the 1950’s have helped in the identification process.

Callosities occur on right whales heads in many of in all the same areas that humans have hair — on the top and sides of their heads, over their eyes, near their ears, around their blowholes and under their lips and chins. Identifications are made by photographing the whales and then describing the shape, position, and surface topography of the callosities. Matching a pattern to a known whale can be very time consuming. Sometimes, waves or spray can hide part of the pattern, or the photo’s orientation may obscure part of the head. Glare from the sun may also be a factor.



Sarah Mitchell

In addition, callosity patterns can change. Although scientists have found that most patterns tend to stay unchanged in adult male right whales, nearly two-thirds of the cows displayed minor changes in the callosity pattern of the “bonnet” area at the top of the head in front of the blowhole. Most calves displayed changes in callosity patterns during the first few years.

Living on these callosities are some unusual creatures. These “hitchhikers” are whale lice (or cyamids) which are less than an inch long and spend their entire lives aboard whales — with each whale species hosting specific cyamid species. For the right whale, it’s *Cyamus ovalis* and *C. gracilis* in particular, and occasionally *C. ceti*, *C. erraticus*, and *C. catadontis*.

No one really knows the function of these whale lice. They were first described in 1675 by Friederich Martens, a surgeon on a whaling ship. He categorized them as a type of crayfish but wrote that “they can hold fast as well in the skin of man as of the whale...and hence...are given the name of louse.” But although they look like the human pest, these lice are amphipod crustaceans (not insects). The nearest relative to the family Cyamidae is the skeleton shrimp. The cyamids may be consuming sloughed skin in a natural cleaning process. Some scientists speculate that the lice may also play a role in cleaning wounds and aiding the healing process.

Each cyamid has 10 legs, each with a sharp curved hook at the end. Unlike stationary barnacles, cyamids walk about the whale's surface in a forward motion (not sideways like crabs) and when not moving about, dig in with their hooks for the ride. They can withstand the force of a full breach. Since they can only survive on whales, cyamids would find that getting dislodged could be a fatal mistake.

Whale lice also play a role in whale identification — or misidentification. Most callosities are naturally gray or black, but the growth of whale lice in these areas gives them a white, pink or yellowish color. As the whale lice move around the callosity, they may change the appearance of the callosity without changing the actual shape.

The few hairs on right whales may be functional as vibrissae (tactile “whiskers” just like in a cat or sea lion). These hairs are usually associated with the callosities. Why did the whale's hair disappear when other marine mammals, such as seals, retained their fur coats? The answer lies in the percentage of time each animal spends out of the water. Seals can often be found out of the water on the ice where bare skin would be damaged in subfreezing temperatures. Whales live their whole lives in water, where temperatures never get below the freezing point; therefore their skin does not need that extra protection.

BLUBBER

No wonder the whalers loved the right whale. It's a storehouse of blubber in one nice package. About 40% of the whale's body weight is composed of this layer of fat. Why so much fat? The blubber layer plays a three-fold role in the whale's survival in the marine environment. First, the blubber serves as a barrier, keeping the warmth inside the whale and preventing loss to the much colder ocean water. Second, the blubber serves as a food reservoir, especially important when the whales cannot find large patches of zooplankton in northern waters or when pregnant whales move to warm southern waters. During this calving period, cows (mother whales) spend all of their time nursing and caring for their young, expending large amounts of their blubber. The southern waters are ideal for their calves which need the warm water since they cannot thermoregulate well, but the waters are poor in zooplankton. The third function of blubber is as a fairing material. Webster's describes “fairing” as: “a member or structure whose primary function is to produce a smooth outline and to reduce drag (as on an airplane).” This streamlining is also found on the whale. Blubber smooths out the body proportions and heightens hydrodynamic properties in the whale. But compared to other whales, the right whales have gone a bit too far — they have a relatively large girth to their length. Perhaps that's why they are one of the slowest swimming whales.

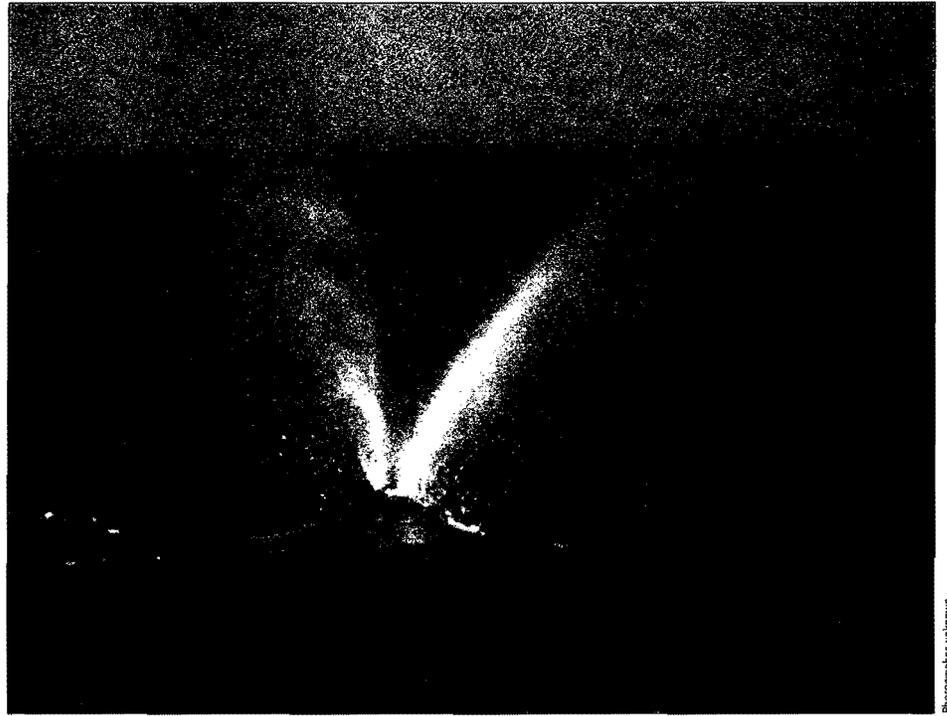
BALEEN, MOUTH AND DIGESTION

The right whale does not have teeth. For feeding, the whale uses a mouthful of fringed plates called baleen. This baleen — smooth on the outer edge and looking a lot like a bushy head of hair on the inside — can be up to three meters long in a mature whale. The fringed appearance of the inner edges of the baleen plates inspired the name Mysticeti, from “mystax,” which is Greek for mustache. Newborn right whales have baleen plates that measure about one meter long. Each whale has approximately 220 to 250 of these plates in its high-arching mouth. Distinguishing right whale baleen from other baleen is relatively easy. Most mysticetes have stiff, broom-like baleen, whereas the right whale has a greater amount of very fine hair-like-strands — important for filtering out the very small prey that it seeks (copepods versus small fish for humpbacks and other balaenopterids). It is believed that the baleen grows fastest between the time when the animal is weaned, when it is about 11 meters long (33 feet) and when it reaches 13.5 meters (40 feet). Right whale baleen is also some of the longest baleen known. Only the bowhead whale (another species in the family Balaenidae) has longer baleen, measuring approximately 4 meters (13.2 feet).

Right whales are known to filter feed both at the surface and underwater. The surface feeding or “skim feeding” has been seen in waters near Massachusetts (and is associated with a “rattling” sound), while subsurface feeding occurs both in Cape Cod Bay and in the Bay of Fundy and Browns Bank. (Feeding has occurred observed at a depth of 130 meters (430 feet) in the Bay of Fundy.) As the whale swims, water passes through the opening at the center of the whale's mouth (there is no baleen here). Water flows into the mouth and out through the baleen. Any

small animals, such as copepods, juvenile krill, and other small zooplankton, are caught in the fine hairs. When the whale has collected enough food, the short but thick tongue pushes out the excess water, closes off the opening, and sweeps the food from the baleen plates. The whale has a narrow, ridged palate in the roof of its mouth between the baleen plates.

In the spring, many northern right whales migrate to food-rich areas in Great South Channel, Cape Cod Bay, and the southern section of Stellwagen Bank National Marine Sanctuary. Continuing north, the whales spend summer and fall in the lower Bay of Fundy and on the continental shelf off the southern tip of Nova Scotia. Here, subsurface feeding predominates. The colder New England and Canadian waters provide dense concentrations of copepods. The greater the concentration of food in an area, the fewer hours required to stock up on calories. Baleen whales have a remarkable ability to locate dense patches of plankton in a vast ocean. Scientists still don't know how the whales accomplish this feat. The northern right whales spend four to five months of a year in these northern areas, increasing their amount of blubber. Compared to northern waters, there is little food off the southeast coast, and feeding behaviors have not been recorded while right whales are in the calving area. However, right whales have been observed defecating in the southern grounds, implying that they have been ingesting something.



Photographer unknown

Food passes through the whale's mouth into its esophagus, on its way to the whale's multi-chambered stomach. Scientists believe the baleen whales have three major chambers (and perhaps a fourth smaller chamber which may be an extension of the intestine). This similarity to ungulates is not by chance. Whales are descended from the same line of land animals that gave rise to ruminants — even-toed, hooved animals, with four-chambered stomachs (usually) like cows, sheep, giraffes, camels, and deer. Food then passes through the intestine, with the remaining waste materials being eliminated into the ocean.

The total capacity of the stomach of a large whale is about 760 liters (200 gallons). This is relatively small compared to the cow with a capacity of 209 liters (55 gallons) and the human with a capacity of 1.7 liters (4.5 pints). The first chamber in all whales is a dilatable, sac-like extension of the esophagus with no digestive glands. In baleen whales, the first compartment is quite small (little need to "chew" since their prey is so small), while in toothed whales the compartment is relatively large. The second chamber is where digestive juices are released — pepsin and hydrochloric acid have been found in this part of the stomach of some

whales. Most cetaceans have a third large chamber which is the pyloric part of the stomach. The intestine is quite large, usually five to six times the length of the body (human intestines run about two times body length or about 12-13 feet in an adult). Baleen whales also contain a distinctive caecum and colon, and, as with other mammals, have a pancreas and liver which deliver digestive enzymes by way of a duct into the digestive tract (there is no gall bladder in contrast to humans).

These large mammals, eating some of the smallest prey, need upwards of a million calories a day. That amounts to about 2,000 kilograms (4,400 pounds) of plankton daily. In contrast, the average human requires only 3,000 Calories for maintenance. But these numbers can be deceiving. A million calories to a 50 ton animal is equivalent to 1,500 calories to a 150 pound person.

ACTIVITY 1: JAWS

ASSEMBLE YOUR OWN BALEEN AND TOOTHED WHALE JAWS

All whales are predators, but each of the approximately 80 species is adapted to catching different types of prey. Although scientists have divided whales into toothed and baleen, there is a lot of diversity within these groups.

Toothed whales chase and capture individual prey. They swim quickly and often hunt in groups. Giant sperm whales (*Physeter catodon*) can grow up to 18 meters (60 feet). They dine on squids and fishes, often at depths of 500 meters (1,640 feet). The bottlenose dolphin (*Tursiops truncatus*) grows to a maximum of 4 meters (13 feet) and pursues small fish, eels, and shrimp. Orcas, also known as killer whales, have been known to capture seabirds, turtles, seals, sea lions, and even team up to capture giant baleen whales, although their primary diet is fish.

Baleen whales range from the 6.4 meter (21 foot) pygmy right whale to the 26+ meter (85 feet or more, possibly up to 100 feet) blue whale, which is thought to be the largest animals ever to have lived on Earth. An adult northern right whale commonly reaches 15 meters (50 feet) in length and can weigh 45,000 kilograms (100,000 pounds).

Remarkably, many of these large animals eat large quantities of small-sized food, primarily plankton. Right whales prefer to eat copepods (microscopic marine crustaceans). Humpback whales target krill (small shrimp-like animals) and small schooling fish such as herring and sand lance. Gray whales, found on the west coast of the United States, eat a variety of amphipods from the sea bottom.

To meet the tremendous energy requirements of a right whale, they must ingest 2,000 kilograms (4,400 pounds) of food per day. Although the metabolism of baleen whales is slightly lower than that of humans, the ratio of body size and caloric intake is similar in the two animals.

In this activity, students will compare the physiological characteristics and behavioral methods that toothed and baleen whales use to eat.

OBJECTIVES: Students will:

1. Identify physiologic differences between toothed and baleen whales.
2. Compare feeding strategies between baleen and toothed whales.
3. Evaluate the relationship between the physical characteristics of toothed and baleen whales and their feeding behaviors.

MATERIALS:

- 1 5-gallon aquarium or large clear container
- 2 sets of kitchen tongs, preferred type shown below
- 2 pieces of window screen 15 X 15 cm
- monofilament fishing line
- 2 100-ml beakers
- fish-shaped crackers (represents toothed whale food) called fish in activity
- dried parsley or any other dried leaf finely crushed (represents baleen whale food) called plankton in activity
- duct tape (a small piece of any strong tape will aid in construction of baleen jaws)
- scissors

Toothed whales will be represented by one set of unmodified tongs. Tongs representing baleen whales will require the addition of window screening (baleen).



Brad Boyd/ImageMasters

1. Assemble baleen jaws.

- Choose the upper jaw and place the center of the square of screening on the end of the jaw.
2. Fold the top of screen over the top of the upper jaw and hold it in place with a piece of duct tape.
 3. Fold the screen around the sides of upper jaw. The bottom of the screen should remain at right angles to the upper jaw.
 4. Fold the corners, which should now be sticking up above the upper jaw, flat on top of upper jaw. Trim screen corners with scissors if desired for a neat appearance.
 5. Secure screen in place with monofilament line. Thread line through screen openings just below upper jaw and wrap around top. Repeat as needed to hold screen in place.
 6. Remove horizontal pieces of screen from the area below upper jaw. A fork may help you pull these strands out.
 7. To create thicker baleen, repeat the above steps with a second square of screen.
 8. Gently bend screen away from center of upper jaw to make an opening in the screen baleen. This is where the water enters as the right whale skim feeds.

Review feeding patterns of toothed and baleen whales, include the differences in preferred foods and forage methods.

1. Fill the aquarium with water. Measure 20-ml of goldfish crackers in a beaker. Have one student try to capture the goldfish with the unmodified tongs. A second student will record the length of time it takes for the toothed whale to retrieve the crackers from the aquarium head first, one at a time. (Grabbing the fish head first provides a greater sense of "chase", which would be a significant factor in the ocean.) Sprinkle the 20-ml of goldfish crackers onto the water in the aquarium and begin timing.

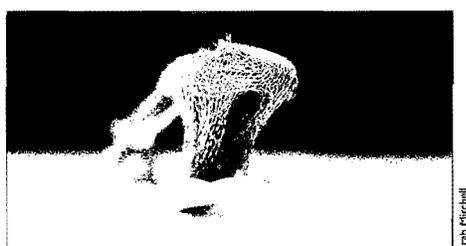
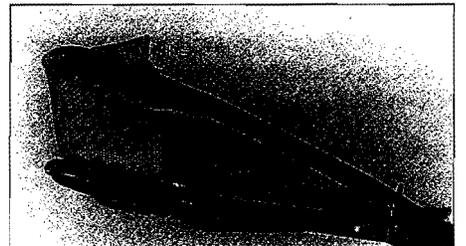
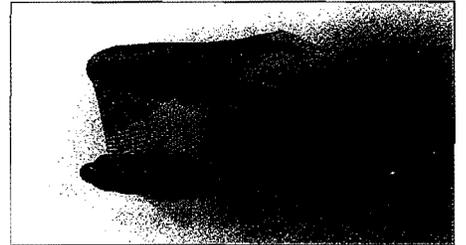
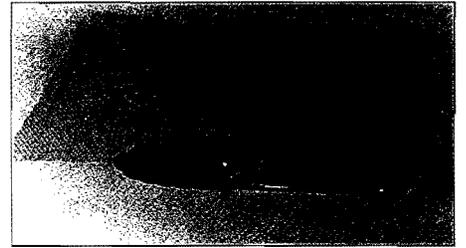
Compare the foraging efficiency of the toothed whale and baleen whale by repeating the procedure with the baleen jaws. It will be much more cumbersome to extract the goldfish with the baleen blocking much of the mouth opening. (Remind your students that baleen whales do occasionally swallow a variety of sea organisms, such as fish, and larger invertebrates, in addition to their targeted food source.)

2. Sprinkle 20-ml of dried parsley on top of the water in the aquarium. Have the toothed whale student attempt to capture the dried leaves from the aquarium by closing the jaws on the small leaves. It is practically impossible for the toothed whale jaws to forage in this manner, so record the length of time required for the toothed whale to realize the gross inefficiency.

Have the baleen whale student gather the dried plants in the skim feeding method. Time this process until most of the dried plants have been removed, whales cannot completely ingest all available plankton.

Contrast the physical adaptations of a toothed whale to a baleen whale.

Researchers continue to study the caloric needs of these large, elusive animals. Although it would be interesting to compare the length of time the toothed whale required to retrieve the goldfish crackers with the length of time the baleen whale required to retrieve the majority of the dried plants, this may not represent equivalent energy intake needs in the oceans.



Sarah Mitchell

ACTIVITY 2: NO JONAH

BALEEN WHALE FEEDING ACTIVITY
STUDENTS ARE SWALLOWED BY A LIFE-SIZED RIGHT WHALE

Photographs from books and magazines can't begin to give people an appreciation of the enormous size of baleen whales. In this activity, students representing different parts of a whale assemble themselves into a life-sized model of a right whale and a humpback whale, and simulate how the two whales use their baleen to capture prey.

Baleen is composed of material similar to keratin—the protein found in human hair and fingernails. Numerous plates of baleen extend down from the upper jaws. The size and shape of the skull and the length and consistency of the baleen varies from species to species and dictates what type of prey the whale eats and the strategy the whale uses to capture the prey. All baleen whales need large heads to accommodate the baleen and engulf huge quantities of food-rich water. In fact, the head can measure one-fourth to one-third of the body length.

Right whales and pygmy right whales feed by swimming open-jawed through swarms of copepods. In Cape Cod Bay and Stellwagen Bank Sanctuary, scientists have seen right whale skim feeding at or near the surface. The ocean water and food enter through a one meter gap between the baleen plates. Then the water exits through the baleen, trapping the plankton in the silky fronds. Periodically, the whale sweeps the food from its mouth with its tongue and swallows.

Humpback whales feast on krill, small fish such as herring and sand lance, and invertebrates by gulp feeding. These whales have a series of pleats or grooves around the throat that expand to accommodate a gulp of sea water and then contract, expelling the water, filtering the prey through the baleen. Efficient gulp feeding, sometimes called “lunge feeding,” requires dense concentrations of food. Humpback whales use a variety of techniques. A fascinating method is called “bubble netting.” The humpback circles below a concentration of fish and releases a cloud of bubbles. Scientists speculate that this bubble net induces the fish to clump together so the

whale can engulf its prey in a single gulp.

Gray whales, found on the west coast of the United States, slurp up amphipods from the sea bottom. Swimming parallel to the sea floor, the gray whale turns on its side and vacuums the top layer of sediment. It sucks up water, mud, and amphipods into the downside of the mouth and ejects everything but the amphipods through the baleen on the up side.

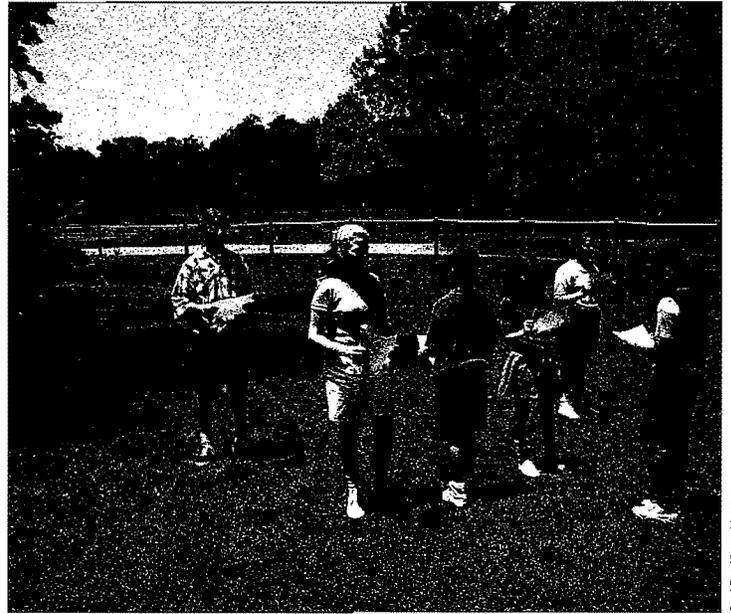
In this activity, students compare two feeding strategies. Students representing plankton and sea water move through the mouth of a skim-feeding right whale and a gulp-feeding humpback whale. Other students represent various parts of the whale, from baleen to the tail. The whale students then move forward as a unit and strain the plankton students from the sea water.

Have your students compare right whale and humpback whale feeding strategies. Review preferred foods of the two whales; right whales mostly consume copepods; humpback whales eat krill, small fish, and squid.

This activity works well outdoors, in a gym, or in a hallway, where students can appreciate the full size of the whale. Right whales can reach 15 meters (50 feet) in length, so students will need room to move around.

OBJECTIVES: Students will:

1. Compare the sizes between baleen whales and humans.
2. Demonstrate the feeding methods of right whales and humpback whales.



Brand Boyd/ImagineMatters

MATERIALS:

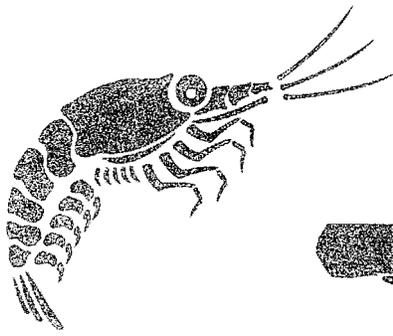
Copies of sheets: water, baleen and plankton on page 35. Five copies of page for a class of 30. (One card per each student.) You may want to laminate the cards and put them on a string for students to wear around their neck. Hula-hoop
18 meters of line (parachute cord, rope, string or measuring tape)

RIGHT WHALE—FILTER FEEDING

1. Assemble the whale by directing students holding cards depicting the whale parts to the appropriate places in the room, as shown in the drawing. Hand one end of a whale-length measuring line to the student in the tail and the other end to a student in the baleen to establish the length. The students representing the baleen plates then form a semi-circle in the front of the whale, leaving an opening for the ocean water students to enter. A hula-hoop represents the entrance to the stomach.

2. Students with the plankton and ocean water cards stand in front of the whale. (See diagram 1.)

3. Whales propel themselves with their powerful tails. The student representing the tail moves his or her arms up and down, simulating the vertical pumping of the whale tail. (Remind students that fish tails move side to side for propulsion.) The whale, as a unit, moves forward, and the plankton and water flow into the whale's mouth between the gap in the front of the baleen, one student at a time.



4. As the whale continues to move forward, the water exits freely between the baleen plates. The baleen, however, traps the plankton. When the mouth is full of plankton (students), the whale moves its tongue, sweeping the food through the hula-hoop entrance into the stomach. The plankton move one at a time through the hula-hoop, and remain in the stomach.

5. Students in the stomach can exit the whale, run around to the front, mix with the water students, and get ingested again. Your students (plankton and water) can continue to cycle through the whale just as water and nutrients cycle through nature.

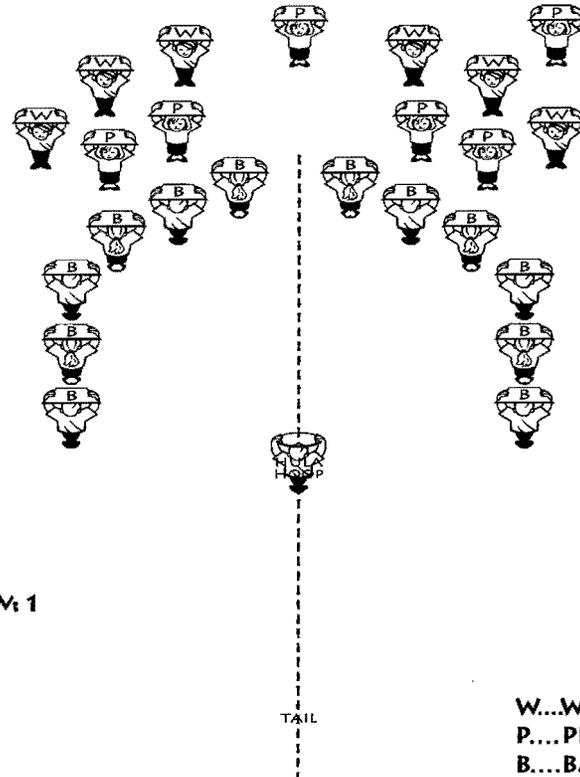


DIAGRAM 1

HUMPBACK GULP FEEDING

1. Set-up the same configuration of students with cards, except this time, close the gap in the front of the baleen. Humpback whales are an example of the baleen whales that gulp feed. These whales move forward and gulp large quantities of water containing krill, other planktons and small fish. The throat plates expand to accommodate the water. Then the whale releases the water through the baleen, filtering and swallowing the food.

2. Whale students move toward the plankton and place a rope or line (the same 18 meter line used to measure whale length) waist high around the plankton students. Then have them pull prey into the front of the mouth and drop the line. The person who is the tongue directs the water back out of the mouth through the sides of baleen, and the food through the hula-hoop into the stomach area.

3. As in the previous baleen feeding activity, students cycle back through the whale again and again.

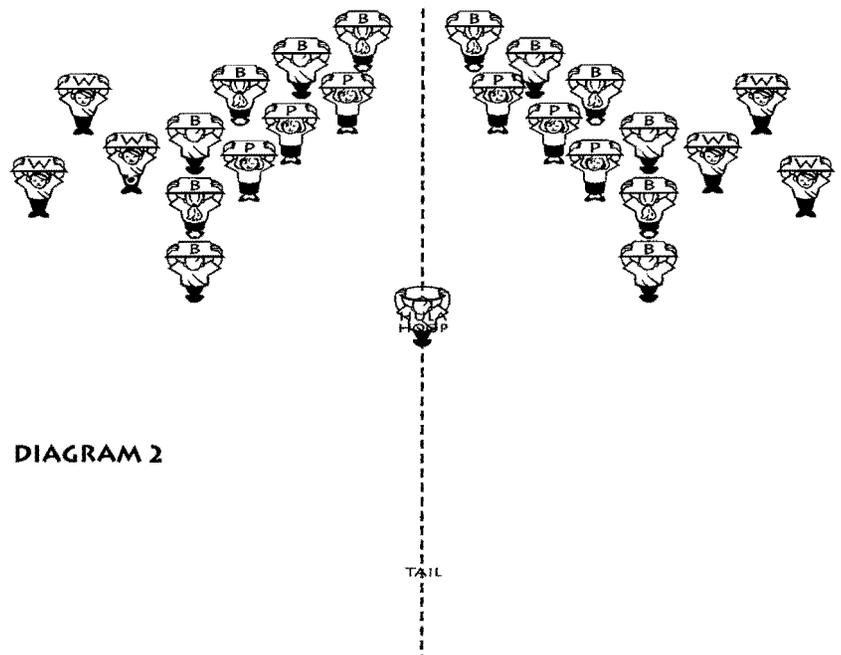


DIAGRAM 2

W...WATER
P....PLANKTON
B....BALEEN

ACTIVITY 3: HIGH SEAS FAST FOOD

Whales consume great quantities of food which they need to power their enormous bodies and to maintain body heat. All mammals must expend energy to maintain a stable body temperature, but this is especially important for whales who stand to lose a considerable amount of body heat to cold ocean water. The larger whales must consume from 500,000 to a million calories per day—a substantial amount compared to a typical human diet of 3000 calories per day. To get these calories, baleen whales consume 2,000 Kg (4,400 pounds) of food per day during the summer. About 25% of the food is stored as fat, called blubber, which serves as insulation and as energy reserves necessary for surviving potentially food-scarce winters.

OBJECTIVES: Students will:

1. Calculate rates of feeding for right whales.
2. Compare energy requirements of whales with humans.

PROCEDURE:

Using the information below calculate the rate that right whales ingest food (see page 38 for answers):

A right whale swims at speeds of 1.5 m/sec while feeding. Its mouth opening is 1.5 square meters. Right whales feed where copepods occur in densities of 4,000 to 15,000 per cubic meter.

1. How many cubic meters of water enter the open mouth of the right whale each minute as it moves through the water at 1.5 m/sec?
2. How many copepods can a right whale ingest per second if the density is 4,000/ cubic meter? How many copepods can a right whale ingest per second if the density is 15,000/ cubic meter?
3. How many copepods can a right whale ingest per minute if the density is 4,000/ cubic meter? How many copepods can a right whale ingest per minute if the density is 15,000/ cubic meter?

4. Investigate your own consumption figures.
 - a. Estimate the number of minutes you spend per day feeding.
 - b. Estimate the number of calories you ingest per day.
 - c. Calculate the number of calories per minute you ingest.

A typical human weighs 67.5 Kg (150 pounds) and takes in 3,000 calories per day. A typical right whale weighs 45,000 Kg (50 tons) and needs 395,000 calories per day. A right whale may spend 15 hours per day feeding in the summer months.

5. If a right whale ingests 500,000 calories per day how many calories is it ingesting per hour? How many per minute?

QUESTIONS:

Compare your caloric intake per minute with that of a right whale.

1. What factors account for the difference in intake?
2. How does the availability of food differ for baleen whales and humans?



John "Crawfish" Crawford



Sarah Mitchell



THERMOREGULATION AND CIRCULATION

What happens on a cold day when you forget your gloves and wear only a thin coat? Naturally, your hands get cold, as does the rest of your body. What happens when you spend too much time in the ocean off Cape Cod even in the middle of the summer? Most people start to shiver. Heat loss in the water is more than 25 times greater than in air. That's why people who fall overboard in cold water can get hypothermia so quickly, sometimes in only a matter of minutes.

So why don't whales get cold in the ocean, where water temperatures can reach close to freezing? The answer here is blubber and body shape. The whale's layer of fat, up to one-and-a-half feet thick in right whales, acts like an overcoat. This blubber layer does not keep the cold out — its purpose is to keep the animal's body heat in. (This can be related to one of the important laws of thermodynamics — heat flows, cold is the absence of heat.)

In land-based animals, hair or fur or feathers create a barrier, trapping warm air against the skin. For humans, it is recommended that people dress in layers on cold days — again to trap the heat and prevent it from escaping to the outside. During the course of evolution, whales lost most of their hair, but the protective layer moved internally to the blubber beneath the skin. In right whales, two-fifths or 40% of their body weight is blubber — the largest percentage among all whales (blue, fin and humpback whales all carry about 25% blubber)

The rotund body with few extremities also keeps most of the heat near the inner core. If the whale were to have long appendages, such as our arms and legs, with blood vessels located closer to the surface, it would naturally lose more heat. (Take a survey of other animals found in cold versus warm locations — you'll probably find that the majority of animals in hotter regions have longer legs, arms, tails, and ears than animals found in colder climes.)

But what seems to be an ideal solution to a heat loss problem can also turn out to be troublesome. What about times when the animal has excess heat — perhaps when it's in warmer waters, as in the Georgia/Florida calving grounds or during times of prolonged exercise. For right whales this is especially critical since the surface to volume ratio is the lowest among cetaceans (they have the greatest volume for their skin surface area and therefore cannot lose heat as efficiently).

For humans and many land animals, condensation is a cooling process. We sweat. But this option is unavailable in the watery world of the whale. Instead, the animal must lose heat to the environment through conduction. Whales also have some sections on their bodies where the blubber layer is thinner and blood vessels are closer to the surface, as in the flippers and tail of the right whale. Other whales also use their dorsal fins but right whales have none.

HOT FOOT OR HOT FLIPPER

You can do this little experiment at home. Have you ever gotten warm under too many blankets in bed at night? Maybe you've stuck your foot out from under the covers to cool off. That uses the same cooling mechanism as the whale's flipper. With less blubber (covers), the whale's flipper can more readily conduct heat to the environment, just as your uncovered foot does to the air in your bedroom.

But the amount of heat lost to the environment can be controlled in a variety of ways. A countercurrent heat exchange process can also retain body heat. Veins and arteries in the flippers and flukes of right whales are intertwined — the warm arterial blood, fresh from the central core of the whale, passes some of its heat to the colder venous blood which is returning from the outer areas of the appendages. Therefore, heat stays in the body. Also, when a whale dives (usually into colder water), blood is shunted away from the surface. In contrast, when the whale needs to release heat to the environment, its circulatory system increases

blood flow in veins near the surface of the flippers and flukes and decreases the amount of blood flowing back to the body core.

Scientists from the New England Aquarium and Boston College have reported on one other adaptation in right whales that may be important in thermoregulation. Scott Kraus and T.J. Ford report finding a rete in the upper jaw of a right whale. According to these scientists: "A rete, a body of convoluted blood vessels commonly found in mammals to store blood and regulate blood flow connects arteries and veins, arteries to arteries, and veins to veins." The rete they described was Y-shaped, running the length of the internal upper jaw and ending in two large lobes in the gap between the baleen plates. They believe the right whale flushes this area with cold water when the mouth is open while it relaxes internal muscles to increase the flow of warm blood. As cold water flows over the uninsulated surface, heat is efficiently lost. Having a rete located in the head area is important because of the sensitivity of the brain to excessive heat.

Another way humans cool off is to take off layers of clothing, thereby reducing the amount of heat trapped at the surface. Whales lose inches of blubber when food is not available. This is what usually happens in the southern calving grounds. The mother whale draws on fat reserves from the blubber layer as it expends all its energy feeding its calf. Data suggests that water temperature off New England in summer is about the same as water temperature off Georgia and North Florida during winter. For the calf, the warm southern environment is essential for survival, since its blubber supply is minimal and its thermoregulatory mechanism immature. This is an important reason why whales move to southern, warmer waters for calving. However, when these new mothers and calves make the annual migration north they must replace the lost blubber and produce new stores to maintain normal body temperature or die from heat loss.

ACTIVITY 4: KEEPING THE HEAT IN

Whales, and right whales in particular, have a very low surface to volume ratio. That's why they look the way they do — a fusiform (torpedo-like) body shape and reduced limbs. Evolution has decreased the amount of surface area exposed to the external environment while increasing volume. Although they spend a lot of time in cold water, their bodies are well adapted to the cold and for preventing heat loss to the environment. Right whale adaptations include: heavy, round bodies; short, stubby limbs; no dorsal fin; and a thick layer of blubber.

Here is a simple experiment which will let you explore why it is important for a whale to have lots of blubber and no legs.

OBJECTIVES: Students will:

1. Compare heat loss in objects with different surface-to-volume ratios.
2. Evaluate the relationship of physical characteristics to environment.

MATERIALS: hot and cold water (tapwater temperatures are fine); 2 plastic sandwich bags; a disposable plastic glove (available from pharmacies, or your local hospital, doctor or dentist); a styrofoam cup; a dishpan, bucket or similar container.

PROCEDURE:

1. Fill the dishpan half full with cold water. Pretend this is the cold "ocean."
2. Put the same amount of hot water into the glove and each sandwich bag (use enough water so the fingers of the glove are filled out). Tie or tape the bags and glove shut.
3. Feel each bag and the glove and remember how hot each felt. They should all feel the same.
4. Put one of the bags of hot waters in the styrofoam cup. Bend the tops of the cup in like a lid to seal the bag tightly inside.
5. Place the glove, hot bag, and closed cup into the basin of cold water. Leave them in for about five minutes.

6. Remove the glove, plain bag and styrofoam cup from the water. Remove the bag from the cup. Feel each again. They will now feel quite different. The glove will feel the coolest and the bag from the cup will be the warmest.

7. **OPTIONAL:** Do the experiment again but use a thermometer to record the actual "before" and "after" temperatures of the basin, bags, and glove.

The glove is like an animal with long legs. It has a lot of surface area and very little volume. If a whale had long legs its body would cool quickly in the cold ocean. The plain sandwich bag shows how having no legs helps a sea animal. It remains warmer than the glove. But by far the warmest bag is the one from within the cup, showing the advantage of insulation. This is a model of a whale...no legs and a layer of styrofoam which acts like blubber.

FOLLOW-UP: Make a list of mammals that live in the sea. How many of them have long legs? Where in the world's oceans do they live (arctic, temperate, tropic, coastal or open ocean)?

ACTIVITY 5: KNOW THE HEAT FLOW

One of the basic tenets of thermodynamics is that heat flows and that cold is an absence of heat. Heat energy can be transferred by conduction, convection and radiation. The countercurrent flow in the blood vessels in whale flippers and flukes is an example of conduction. Warm blood in arteries passes by the veins where heat is transferred and returned to the central core of the body. This experiment will duplicate the whale's countercurrent heat exchange system.

OBJECTIVES: Students will:

1. Demonstrate heat transfer in a countercurrent system.
2. Explain the importance of conduction in heat energy transfer.

MATERIALS: 2, 5-foot sections of thin plastic tubing; 2 funnels; hot and cold water in gallon jars; 2 buckets; 2 thermometers.

PROCEDURE:

1. Get two one-gallon containers. Fill one with hot water and one with cold water. Measure the temperature of each.
2. Keeping the tubes separate, use the funnel to pour the water from each container into its own tube. Make sure that the end of the tube is placed in its respective bucket.
3. Measure the temperature of the hot water as it exits. There should be a minimal amount of change in temperature from start to finish for both the hot and cold water (heat loss or gain from the environment).
4. Twist the two tubes together. Make sure the respective ends are placed in the correct bucket — cold tube in cold bucket, hot tube in hot bucket.
5. Repeat steps 1 and 2.
6. Measure the temperature of the water as it exits. The cold water should have gained some heat from the hot water. This is an example of how the whale can bring heat back into its core. The hot water will have cooled off significantly. This demonstrates how heat can be dissipated to cool off an animal.
7. **OPTIONAL:** Try the experiment with different thickness tubes. A thicker tube provides more insulation and less heat transfer.

KIDNEYS AND URINATION

Among mammals, cetaceans and pinnipeds have the most lobes in their kidneys. One researcher compared this organ to a bunch of grapes. In a comparison between other baleen and toothed whales, researchers have found that the right whale has up to five times the number of lobes (or reniculi). As in humans, the kidneys are used for cleaning the blood, separating out the waste products for later removal from the body. A lobulated kidney design effectively divides a kidney into a bunch of mini-kidneys. Only the number actually needed to process the amount of blood circulating need to be used during a dive, so the blood flow to the other lobules can be shut down. In one juvenile right whale (12 meters or 36 feet), a kidney (there are two) weighed in at 32.4 kilograms (about 71.3 pounds). In an adult human male, a kidney (there are also two) weighs about 140 to 187 grams (4.5 to 6 ounces).

Eliminating the waste products extracted by the kidney (mainly urea) requires water. All mammals require a certain amount of water intake in order to function properly. Not only is water necessary for the production of urine, but for feces, oxygen extraction in the lungs, and in most mammals for sweating (temperature regulation). Without the need for large amounts of water for perspiration, whales take in (proportionately) a lot less water than other animals. But how can whales, living in a salt water environment, get the fresh water their bodies need?

It is well known that a person who drinks seawater will become even more thirsty. The body, attempting to eliminate the excess salt, will draw upon its own fluid supply, thereby increasing dehydration. Most air breathing vertebrates cannot tolerate seawater; but some are less restricted than others, including whales.

Seals (pinnipeds) and cetaceans must be able to remove excess salt from their systems. Scientists believe these animals do not drink seawater; but satisfy their need for water with the fluids contained in their diets. Fish-eaters, such as humpback whales, would get ample amounts of

water from their food alone. Herring, for example are 80% water and have an osmotic concentration of about one-third sea water, i.e. a low salt content of about 1.2%. (Seawater is 3.5% salt.)

One calculation based on seal studies shows that: 100 calories/1,250 kcal of fish eaten, produces 1,000 gm of water directly and 121 gm of water from the oxidative breakdown of the fat and protein taken in, for a total of 1,121 gms of water; the seal uses 106 gms of water to saturate the air in its lungs and 200 gms for feces production, leaving 815 gms for urine.

But plankton are in osmotic equilibrium with seawater; i.e. their salt content is 3.5%. Plankton-eaters, such as right whales, must produce a urine that is more concentrated than seawater in order to accommodate their invertebrate diet and any incidentally swallowed seawater. Physiological studies of cetaceans suggest that their kidneys are able to dispose of the concentrated salt solution without troublesome effects.

BLOWHOLE, LUNGS AND RESPIRATION

A simple rule of thumb to distinguish baleen and toothed whales is to look at their blowholes. Toothed whales have one hole, baleen whales have two. This difference evolved millions of years ago when odontocete and mysticete ancestors first evolved from archaeocetes. In calm winds, the blow from a right whale has a distinctive V-shape (the two branches veering off at angles from one another). (See photo page 15) Other whales tend to have a bushier blow.

The placement of the blowholes (nostrils) at the top of the whale's head is an important evolutionary development, which allowed the whale to stay almost completely submerged while breathing (unlike other animals who must lift their heads almost completely out the the water to breathe). In addition, the

nasal ridge (or rostrum) in front of the blowhole acts like a splashguard to keep water from entering the nostrils.

The windpipe (or trachea) is also completely isolated from the esophagus—there is absolutely no way water from the mouth can enter the lungs while the animal is eating. In fact, the whale can breathe and swallow at the same time.

Also, breathing has become a voluntary action for whales. Unlike humans, who can breathe even when unconscious, whales must consciously control each breath. Therefore, scientists believe that whales do not sleep like we do. Studies on other cetaceans have shown that the animals shut down half their brain at a time while they “log” or float at the surface.

The blow that we see at the surface is the whale's exhaled breath, which is due in part to the atomization of the water that was left around the blowhole as the whale surfaced. In addition, contributing to the visibility of the blow is condensation of this compressed, warm, moist air from the lungs [just as our breath appears on a cold day]. Blows can be seen and heard almost a mile away on a clear, calm day.

Surface time is minimal for whales. Most of their time is spent underwater — most right whales average 5 to 10 breaths at intervals of 15 to 30 seconds before diving for 5 to 30 minutes. Most deep dives last about 10-15 minutes. The lungs on whales are not as large as one would suppose with animals of this size and the fact that they spend much of their time diving and holding their breath. Proportionally, lung volumes of whales are about one half that of terrestrial mammals. Fin whales have been calculated to have a maximum lung capacity of 2,000 liters while humans measure in at 4-5 liters.

Scientists have also found that cetaceans fill and empty their lungs much more quickly and completely than humans and other

mammals. They can exchange up to 85-90% of the air, as compared to humans who exchange only 15%. This is termed the tidal volume or the amount of air moving in and out with one breath (in humans about 500 ml, in the fin whale, about 1,800 liters).

In whales, oxygen exchange is a lot more efficient than in most other animals. Research also indicates that cetaceans can use about twice as much oxygen from a given volume of air. Whale red blood cells are larger than in humans and other animals, plus there are more red blood cells per unit of blood (almost twice that of humans). These two factors allow for a speedy exchange of oxygen from the lungs to the hemoglobin — the oxygen-carrying, red blood cell pigment. This oxygen supply is then transported throughout the body.

Where whales differ from humans and other terrestrial animals is in their myoglobin content — the oxygen-carrying pigment in the muscle. Whales have 2-8 times as much myoglobin as terrestrial mammals; that's why cetacean muscle is much darker than beef and other animal meats.

The oxygen-holding capacity of the muscle and blood is the secret behind the whale's ability to perform long dives (it is not a factor of held breath as it is with humans). According to one estimate, total oxygen storage in a human diver is: 34% in the lungs, 41% in the blood, 13% in the muscles, and 12% in other tissues. In the whale, the proportionately smaller and compressed lungs hold only 9% of the oxygen, with 41% in the blood, 9% in tissues, and 41% in the muscles.

But why don't whales get the bends like humans do, since they seem to make relatively deep dives with quick returns to the surface (one whale was recorded as routinely diving to 300 meters or close to 1,000 feet)? Dr. Steve Katona writes in his "Field Guide to Whales, Porpoises and Seals" that: "Whales and porpoises always fill their lungs with air before submerging, but they probably never

get the bends, no matter how often or deep they dive. Two factors protect them. First, at depth the air is compressed to a very small volume. As water pressure increases, the ribs, most of which are not firmly connected to the breastbone, collapse inward compressing the lungs and forcing air into nonabsorptive portions of the lung (bronchioles, bronchi, and trachea). Second, lung compression reduces blood flow to the lungs. Both processes (and perhaps others) minimize absorption of air into the blood, preventing excessive quantities of nitrogen from dissolving in the blood. As the whale ascends, the compressed air expands again, refills the lung, and blood flow and gas exchange resume." Also, the air the whale starts off with is the air it comes up with, unlike SCUBA divers who are taking in compressed air (and compressed nitrogen) during the dive. If the diver didn't decompress during the dive and expel some of the nitrogen, the expanding nitrogen would cause dangerous (possibly fatal) consequences upon surfacing.

WATER PRESSURE

The deeper you go, the greater the water pressure. Whales have developed adaptations that allow them to survive in this environment. Take a large can or carton and punch a series (perhaps 3-4) of holes in a vertical row from bottom to top). Place the container in a shallow basin. Plug the holes and fill the container with water. When you unplug the holes you will see that the greater pressure at the bottom of the container forces the water stream out farther from the wall of the container and that the top hole has a weaker stream.

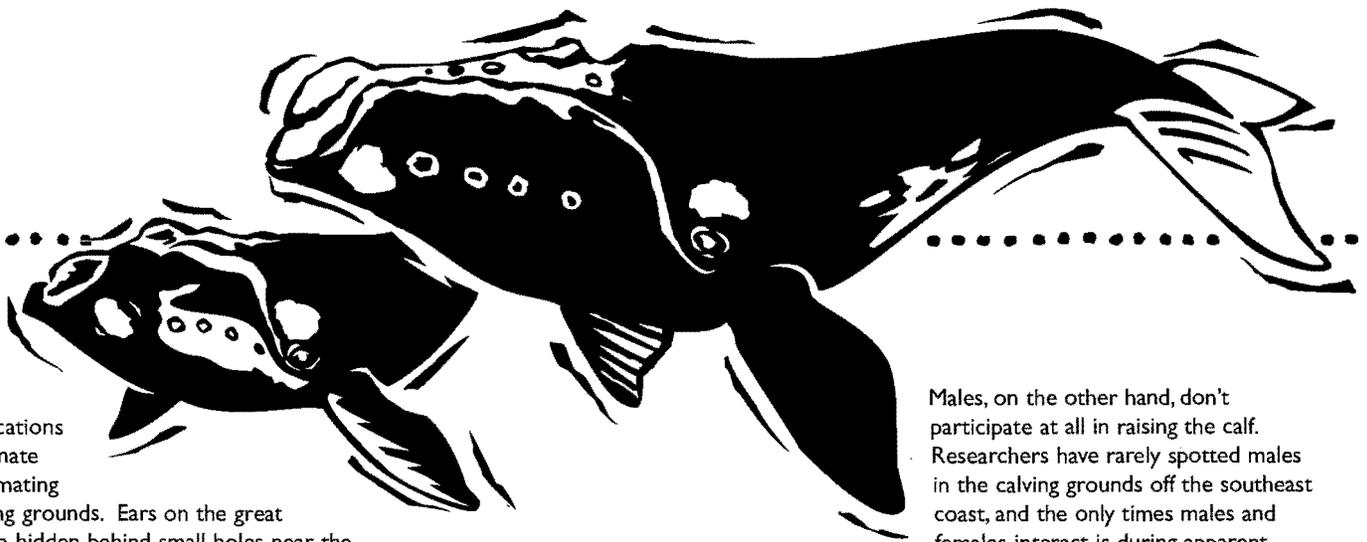
THE SENSES

Whales can open their brownish-red eyes underwater to see, as well as use them above the surface (when they bring their heads out of the water it's called "spyhopping"). (See photo page 4) Protecting these eyes from the salty

seawater are oily tears that constantly coat the eye surface, but without the worry of dust or sweat, whales have no need for eyebrows or eyelashes. However, whales do have eyelids to protect the eye from superficial injury. With eyes widely separated on either side of its large head, the right whale has a blind spot directly in front of it. Might this be a factor contributing to right whale collisions with ships — we don't really know. When a whale is swimming along and trying to stay within a plankton patch, it just may not see the vessel traveling in a head-on direction. But there is also a question of whether the whale actually uses vision to locate and move within a plankton patch, or if it involves another means.

The whale eye has a rounded lens (fish-eye), and contains more and bigger rods (rods are black/white receptors, the light sensitive nerve cells of the retina) than terrestrial mammals. (Researchers have found cones — the color receptors — in some whale eyes.) Whales are also able to compensate for the low light levels of the oceanic environment (at 30 feet, 90% of the light is absorbed) with a special layer near the retina that reflects light like a mirror — just like the glowing eyes of cats and ungulates.

Eyesight is only one of the senses employed by the whale — and in murky waters this sense is probably not very important. Sound seems to be the most highly developed sense in all cetaceans. Although they do not have vocal cords, whales can create a wide range of different sounds, including splashes, clicks, grunts, and, according to early whalers, screams when they are wounded. Odontocetes make these sounds by moving air through nasal air sacs and other passages in the head or by slapping the water. The odontocetes may be using these sounds to navigate, find food (echolocation), or communicate with other whales. The sounds, especially the lower tones, can travel great distances (possibly up to thousands of miles). With its widespread and dispersed migration patterns, the right whale may use these long-



range communications to coordinate travel to mating and feeding grounds. Ears on the great whales are hidden behind small holes near the eyes and under the skin surface.

Scientists also believe that whales have a strong sense of touch. Researchers have repeatedly seen right whales nuzzling and stroking each other with their flippers and tail flukes. Mothers and calves constantly display this touching behavior.

According to researchers, baleen whales may not have lost the ability to smell, but this sense is greatly reduced in adults and probably of little importance in daily living. The sense of taste is also poorly understood in whales.

All of these senses are controlled by the brain. Humpback brains average about 4.6 kilograms (10 pounds) with one large sample weighing in at 6.75 kilograms (15 pounds), right whale brains are relatively small, weighing 2.4 to 3.1 kilograms. Human brains, in contrast, weight about 1.35 kilograms (3 pounds). One scientist, in contrasting brain-weight to body surface, found that humans topped the list with the highest ratio, followed by toothed whales and apes, then ungulates, baleen whales and carnivores, with rodents trailing the field.

REPRODUCTION

While collisions with ships and entanglement in fishing gear are partially to blame for the slow recovery of the right whale population, scientists are also investigating whether a decreasing birth rate may also be a factor. Researchers only spotted seven new calves in 1995, and there are some indications that calving intervals for individuals may be increasing.

Inbreeding depression due to low genetic diversity, bioaccumulation of toxins, and habitat degradation could all contribute to a low birth rate. To determine whether these trends are real, biologists first need to learn about the reproductive biology of right whales. Researchers don't have adequate baseline data with which to compare current birth rates. The low numbers and endangered status of the right whale make it difficult for scientists to study right whale reproductive biology, so researchers must rely on sightings of cows with calves, observations of courtship behavior, examination of stranded whales, and records from whaling ships.

Nobody has ever witnessed a right whale giving birth. Researchers are not sure of the length of the female reproduction cycle or the gestation period, although current estimates for southern right whales, a closely-related species to the northern right whale, are between 350 and 400 days. Females reach reproductive maturity between seven and ten years old, although one female gave birth when she was only five.

Calving takes place during the winter off the coasts of Georgia and northern Florida. The calves are four to five meters (13.2-15.5 feet) long at birth and weigh approximately 800 kg (1760 pounds). The mother nurses the calf for 10 to 12 months during which the calf grows to between 8 and 10 meters (26-33 feet) and 5,000 kg (11000 pounds). This lactation period exacts an enormous energy cost for the mother, and researchers speculate that females require one to three years to recover between calvings. Calving intervals are three to five years, which includes a one year lactation period and a one year gestation period.

Males, on the other hand, don't participate at all in raising the calf. Researchers have rarely spotted males in the calving grounds off the southeast coast, and the only times males and females interact is during apparent courtship behavior.

Because of the disproportionate energy costs between males and females, scientists speculate that the female has an enormous stake in the strongest, healthiest male, and that the males must compete with each other for the opportunity to mate. Researchers have observed what they consider to be courtship behavior throughout the year from the Florida coast to the Bay of Fundy. However, scientists have seen the most intense courtship activity in the Scotian Shelf during August and September. They have observed pairs of whales floating together for up to a couple of hours, occasionally touching each other or rolling around. But more often, researchers have seen whales gathering in groups of between three and 30 individuals.

Scott Kraus, a right whale researcher at the New England Aquarium in Boston, has watched these "surface active groups" and attempted to interpret their dynamics. In situations where he has been able to determine the sex of the individuals, he has found that the groups are most often composed of a single adult female surrounded by multiple males. Typically the female meanders upside-down in slow circles along the surface, her head submerged, and her genitalia above the water. Two males, which Kraus has designated alpha males, swim on either side. These alpha whales are in the best position to mate with the female when she rolls over to breathe, and do so repeatedly until they are displaced. Videos taken underwater show whales mating while the female was rolling over. Other males, designated betas, follow closely behind and attempt to displace the alphas. The males may even use their callosities as weapons—scraping competing

males as they jockey for position. Typically a beta replaces the alpha every 30 minutes. On the outskirts of the group swim the “peripheral” whales who apparently do not compete for the alpha position.

Researchers have yet to see one of these groups form, but these groups stay together for an average of one hour from the time they are spotted, with some groups sticking together for four to five hours. The number of males in the groups increase with time, and researchers have observed males as far as two km away swimming quickly (for a right whale) towards the activity. The groups break up when the female rolls and dives deeply.

Kraus' interpretations of these behaviors are only speculative. According to his theory, this courtship behavior ensures that the male with the greatest stamina succeeds. In other species, females choose males based on visual cues or on which male has acquired the best territory. However, the waters right whales inhabit are too murky for females to see other whales, and dense plankton patches are too variable for males to defend successfully. Instead, it may be a battle of attrition with the male who can get the most sperm into the

female succeeding. Male right whales have the largest testes [for their body size] of any whale, so they are capable of producing copious quantities of sperm. These testes can weigh over a ton—equivalent to a small car.

The female's mammary nipples are hidden within skin slits on either side of the ventral line of her body just forward of the genital slit. The umbilicus (belly button) is forward on this ventral line. The anus is located closer to the tail stem. In males, the penis is coiled within the body cavity. The erect penis may reach a length of 10 to 11 feet.

If Kraus' theories are true, he says that it would be to the female's advantage to gather as many area males as possible to ensure that the strongest succeeds. She may even use vocalizations to attract them. More observations and paternity studies will be needed to determine how many, if any, males emerge as consistently dominant.

MIGRA- TION

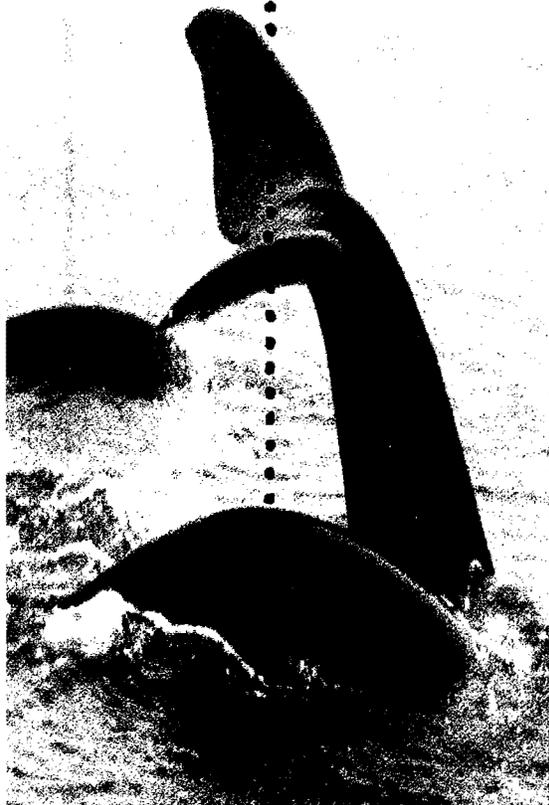
To save the northern right whale, scientists need to gather information on the health of the population as well as basic right whale biology. But in order to study the whales, researchers have to find them first. Such a task has proven difficult given the low number of whales and the enormous size of their range, and the tremendous distances they swim during the year. Although scientists understand the basic seasonal migration patterns, many gaps remain, and researchers rarely know the location of the majority of whales at any one time.

Biologists have pieced together information on the former distribution of right whales from detailed commercial whaling records and from whales bones excavated from 16th century Basque whaling stations in Labrador. Some of the most fertile whaling grounds in the northwest Atlantic included the waters around Newfoundland and Labrador, Massachusetts Bay, Long Island, and the southeast coast of the United States. But as populations plummeted, so did reports of their whereabouts. Today, researchers know of only five locations where northern right whales gather consistently. These areas include the Georgia and Florida coasts, Stellwagen Bank and Cape Cod Bay, the Great South Channel east of Cape Cod, the Bay of Fundy, and the Scotian Shelf. Right whales have sporadically been spotted near Newfoundland, Greenland, and Iceland. Since 1980, a team of scientists from a consortium of research centers have surveyed the northern right whale population to determine how the whales use their habitats and whether other critical areas exist.

To track the whales, researchers had to first learn how to identify and recognize individuals. Such information helps scientists determine whether individual

whales return to the same areas every year, which females have given birth, how whales are related to each other, and which ones may have died. Fortunately, right whales are easy to tell apart. All whales have unique patterns of thickened skin patches, called callosities, on their heads. Many whales also have distinctive scars from encounters with boats. Since 1980, researchers have traveled out to some of the major habitats to photograph the whales. Then they compare the pictures to a comprehensive catalog of right whale photographs housed at the New England Aquarium. The catalog contains photos dating back to 1935, but most of the records were gathered since 1979. Few previously unidentified adult whales have been photographed in recent years, leading researchers to conclude that they have records of most of the whales in the population.

Scientists also have collected tissue samples from the whales to determine both the gender and the lineage of individuals. Darts, fired from a crossbow, penetrate into the whale, extracting a small cylinder of skin and blubber. Although this procedure appears painful, scientists have concluded based on repeated observations that the darts neither hurt the whales nor changed their behavior. The skin samples have provided scientists with valuable insights into the structure of the population. For example, studies of the mitochondrial DNA from 150 animals have led scientists to conclude that there is just one breeding population and that all the whales are descended from only three females. Such low genetic diversity could help account for the slow population growth. Researchers eventually hope to run more genetic tests and determine the paternity of the whales as well. Scientists have performed toxicological studies of the blubber and found that the whales have been bioaccumulating chemical pollutants such as PCBs and DDT. The effects of these chemicals on the whales' health and fecundity is unknown.

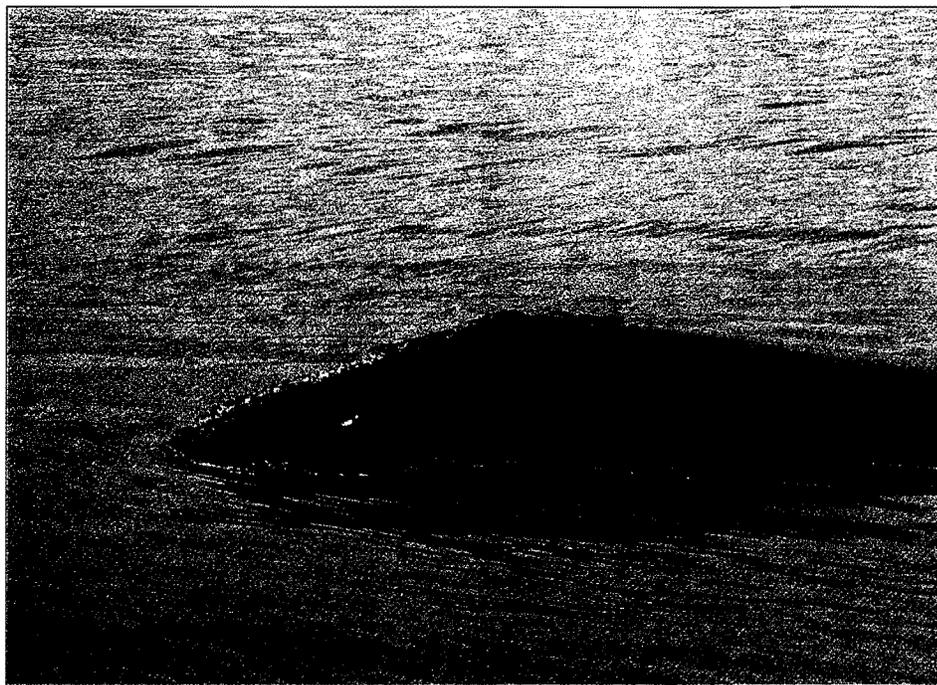


Hans Nijhuis

By logging the location of individuals over the course of a year, scientists have outlined a general migration route. During the winter, pregnant females travel to the warm waters off the Georgia and Florida coasts—the only known calving ground for the northern right whale—to give birth. This area is so broad that despite extensive aerial surveys, researchers often miss newborns. One of the biggest mysteries, however, is where the males and nonpregnant females go during the winter. At this point, nobody knows.

Starting in late February, males and females without calves enter the plankton-rich waters in Cape Cod Bay. Mothers accompanied by their newborn calves begin their northern migration in early spring. A few usually arrive in Cape Cod Bay in early April, although the numbers vary from year to year. For example, in the spring of 1995, researchers spotted a record number of right whales in the region, but no mother/calf pairs. Researchers don't know where they went.

By May, the whales leave Cape Cod Bay and swim out to feed on the dense copepod patches along the Great South Channel southeast of Cape Cod where they are joined by the majority of the right whale population before heading north. In summer and early fall, approximately two thirds of the mother-calf pairs move into the Bay of Fundy to nurse. Many other whales, both male and female, migrate to the Scotian shelf where they feed and engage in courtship behavior. Approximately half of all known females and three-quarters of all known males have been spotted at least once in this region during the 15 years that researchers have studied the whales.



Hans Neubauer

But right whale appearances are never predictable. Scientists also are discovering that right whales can travel great distances during a short period of time. During one six week period, scientists tracked a female and her seven-month calf from the Bay of Fundy to the New Jersey coast, and back to the Bay of Fundy. Another whale, a juvenile male, was found some 160 km (100 miles) up the Delaware River in December 1993 (he eventually found his way out to sea, but not without at least one collision with a boat).

Many researchers speculate that northern right whales' habitat shifts correspond with variations in the availability of prey. Right whales are able to locate dense patches of copepods, their primary food. Researchers have documented right whales feeding on patches containing 2 million organisms per cubic meter of water. The location of these patches varies from year to year, and the whales move to take advantage of them. One study even suggests that right whales compete for food with planktivorous fish

such as sand lance and herring. In 1986, the summer when many right whales stayed around Stellwagen Bank, there were very few of these fish in the area.

In the future, scientists are planning to implant selected whales with satellite transmitters. The transmitter, which is shot from a crossbow, lodges underneath the whale's skin. Several times a day, the transmitter sends a signal to a satellite. Researchers can then download information on the location of the whale. Biologists hope to use this information to locate where non-pregnant females and males go during the winter. However, the short battery life of the transmitters and the overall expense limits the scope of such studies.

ACTIVITY 6: MIGRATION MYSTERY



Brad Boyd/
ImageFlaxters

Researchers still have a lot to learn about the migration patterns of right whales, but gathering information on these elusive mammals is difficult. Most right whales spend the spring off the coast of New England, where they gorge themselves on plankton. In early summer, they head north to breeding and nursery areas in the Bay of Fundy and Browns Bank south of Nova Scotia. Then in the winter, some of the adult females migrate to the coastal waters off the southeastern United States, especially the shallow waters from Savannah, Georgia, south to Cape Canaveral, Florida. Although researchers have spotted a few juveniles and males in the region, most of the records of the last decade are of adult females. Often these females are alone early in the season, but are later accompanied by calves. Scientists believe that the winter calving season begins in September and ends in April, but most births occur from December through March. This area, called the Georgia Bight, is the only known calving area in the North Atlantic Ocean for the right whale. By March, most of the mothers and calves have begun their 2,240 kilometer (1,400 mile) journey north.

But mysteries still remain. For example, researchers don't know where the males and nonpregnant females spend their winters. Scientists also suspect that there may be another northern nursing area. But locating anything as large as a whale is difficult in an area encompassing thousands of square kilometers.

OBJECTIVES: Students will

1. Plot the coordinates for three whales on a map.
2. Use the plotted migration route to determine basic information about each whale.

MATERIALS:

Copy of Migration Mystery data and tracking map per student or pair of students.

PROCEDURE:

Migration routes of three northern right whales can be plotted using the data gathered from sightings listed in the chart below. The routes provide clues that students will need to interpret basic information about the whales.

Using the latitude and longitude from the chart on page 30, plot the coordinates for each of the three right whales. Mark each coordinate on the map with a solid triangle (pointed downward, dots are difficult to relocate) for the route south and an open triangle (pointed upward) for the route north. Draw an arrow to show the direction traveled.

Examine the migration route, note the time of year of each movement, and determine the following for each whale (see page 39 for answers):

1. Is the whale likely to be a male or female?
2. Is the whale less than one year old, a juvenile, or an adult?
3. What advantage does the migration provide for the whale?
4. What are some of the hazards that the whales may encounter during their migrations?
5. Highlight the major seaports within the migration routes. These areas provide greater risks to the whales from vessel collision. Refer to the mileage key on the map to determine the following:
6. Calculate the average distance traveled between sightings.
7. Determine the average rate of speed the whales were traveling.

ACTIVITY 6: MIGRATION MYSTERY, CONT.

WHALE 1

WHALE 2

WHALE 3

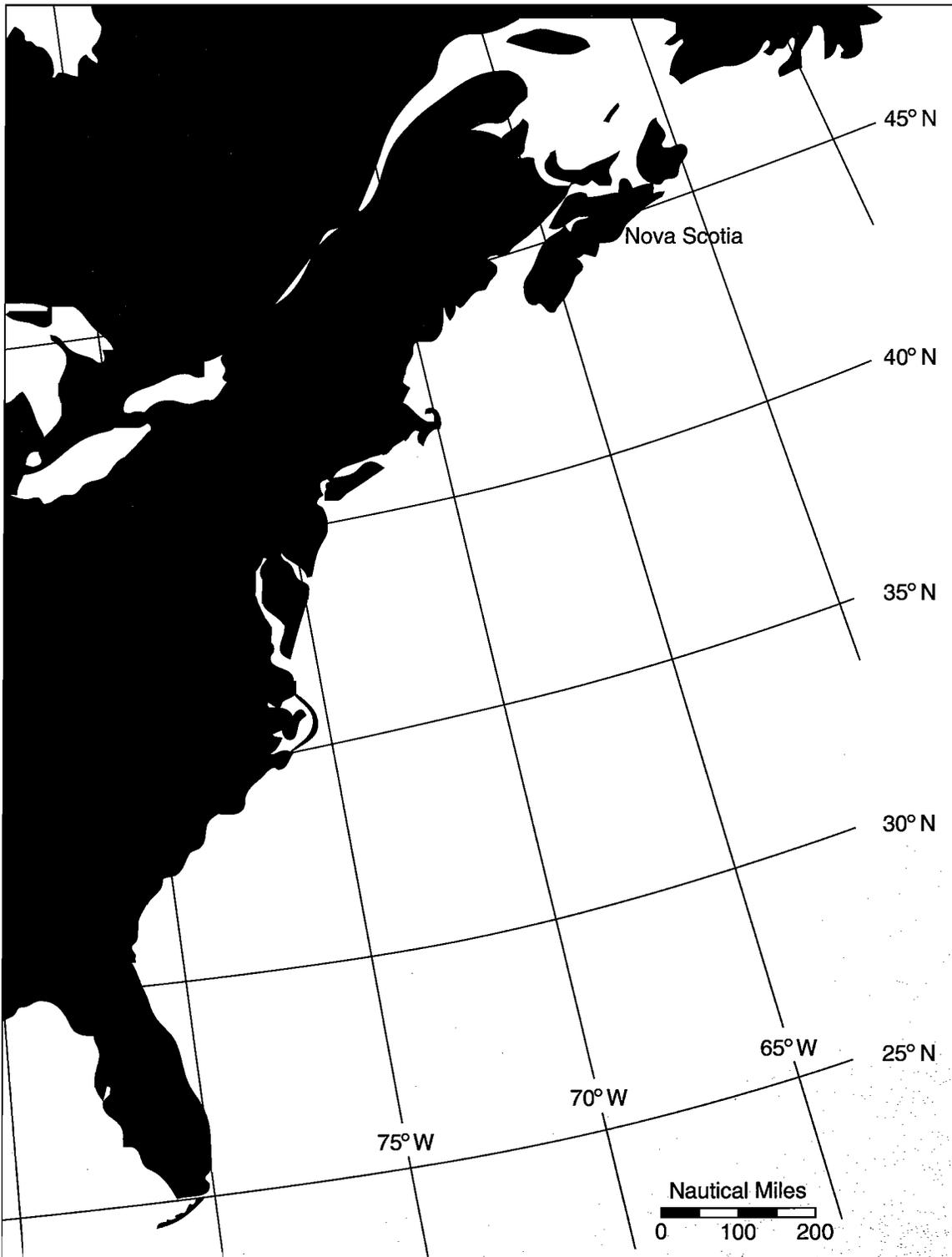
Date	Lat/Long (degrees North and degrees West)
6-1	45/66
7-4	43/69
7-25	40/72
8-19	39/73
9-25	38/74
10-25	34/76
11-3	33/79
11-7	32/80
11-19	31/80
12-2	31/80.5
12-24	30.5/80.5
1-5	30.5/81
2-28	32/80
3-7	34/77
3-17	36/75
4-1	39/74
4-4	41/70
5-1	42/69
5-20	44/68
5-25	44.5/67

Date	Lat/Long
6-2	45/66
6-21	44.5/66.5
7-3	44.5/67
7-27	44/66.5
8-6	43.5/67.5
8-31	42/67
9-5	41.5/64
5-2	43.5/67
5-18	44/66.5

Date	Lat/Long
6-3	45/66
6-21	44/66
7-25	43/69
8-28	41.5/70
9-7	40/72
9-12	37/73
9-14	37/74
10-5	34/76
1-31	31/80
2-12	32/78
2-19	34/74.5
3-17	36/73
4-2	40/72
5-15	43/69
5-18	42/68
5-25	45/66



MIGRATION MYSTERY TRACKING MAP



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FIELD TRIP LOCATIONS AND SOURCES FOR EDUCATION UNITS ON WHALES

American Cetacean Society
P. O. Box 1391
San Pedro, CA 90733
(310) 548-6279

The Center for Environmental Education
1925 K Street, NW
Washington, DC 20006
(202) 466-4996

Center For Marine Conservation
Washington, DC
(202) 429-5609

Channel Islands National Marine Sanctuary
Los Marineros Curriculum Guide
113 Harbor Way
Santa Barbara, CA 93109
(805) 966-7107

The Charleston Museum
360 Meeting Street
Charleston, SC 29403
(803) 722-2996

Cumberland Island National Seashore
P. O. Box 806
St. Mary's, GA 31558
(912) 882-4336

Fernbank Museum of Natural History
767 Clifton Road NE
Atlanta, GA 30307
(404) 378-0127

Jacksonville Museum of Science and History
1205 Museum Circle
Jacksonville, FL 32207-9053
(904) 396-7062

Marine Education Materials System (MEMS)
The Virginia Institute of Marine Science
Gloucester Point, VA 23062

Monterey Bay Aquarium
886 Cannary Row
Monterey CA 93940-1085

Museum of Comparative Ecology
Harvard university
Cambridge, MA

Mystic Aquarium
Coogan Blvd.
Mystic, CT 06355
(203) 536-3323

National Aquarium in Baltimore
Department of Education and Interpretation
Pier 3 / 501 East Pratt Street
Baltimore, MD 21202

New Bedford Whaling Museum
18 Johnny Cake Hill
New Bedford, MA 02740
(617) 997-0046

New England Aquarium
Central Wharf
Boston, MA 02110
(617) 973-5253

The Ocean Society
441 Ridgewater Drive
Marietta, GA 30068
(770) 977-1838

Savannah Science Museum
4405 Paulson Street
Savannah, GA 31405

ORGANIZATIONS

American Cetacean Society
National Headquarters
PO Box 2639
San Pedro, CA 90731-0943
(301) 548-6279

American Fisheries Society
Education Sector Director
5410 Grosvenor Lane, Suite 110
Bethesda, MD 20814-2199
(301) 897-8616

Atlantic Cetacean Research Center
PO Box 1413
Gloucester, MA 01930
(508) 283-2708

Center for Coastal Studies
59 Commercial Street, Box 826
Provincetown, MA 02657
(508) 487-3622

Center for Marine Conservation
1725 DeSales Street NW, Suite 500
Washington, DC 20036
(202) 429-5609

Cetacean Research Unit
Box 159
Gloucester, MA 01930

Cetacean Society International
PO Box 9145
Wetherfield, CT 06109
(203) 793-8400

Cousteau Society
Greenbriar Tower II
870 Greenbriar Circle, Suite 402
Chesapeake, VA 23320
(804) 523-9335

Defenders of Wildlife
1244 -19th Street NW
Washington, DC 20036
(202) 659-9510

Earth Island Institute
300 Broadway
San Francisco, CA
(415) 788-3666

East Coast Ecosystems
P O Box 36
Freeport, Nova Scotia, Canada B0V 1B0
(902) 839-2962

Greenpeace
1436 U Street NW
Washington, DC 20009
(202) 462-1172

International Association of Fish and Wildlife Agencies
444 North Capitol Street NW, Suite 534
Washington, DC 20001
(202) 624-7890

International Whaling Commission
The Red House
135 Station Road
Histon, Cambridge CB4 4NP

National Wildlife Federation
1400 -16th Street NW
Washington, DC 20036
(800) 432-6564

New England Aquarium
Central Wharf
Boston, MA 02110-3309
(617) 973-5253

Plymouth Marine Mammal Research Center
PO Box 3313
Plymouth, MA 02360
(508) 224-8477

Right Whale News
Hans Neuhauser
(706) 546-7507

Sierra Club
730 Polk Street
San Francisco, CA 94109
(415) 776-2211

Sport Fishing Institute
1010 Massachusetts Avenue NW, Suite 320
Washington, DC 20001
(202) 898-0770

The Nature Conservancy
1815 N. Lynn Street
Arlington, VA 22209
(703) 841-5300

World Wildlife Fund
1250 Twenty-Fourth Street, N.W.
Washington, D.C. 20037

FEDERAL AGENCIES

US Department of Commerce
NOAA
National Marine Fisheries Service
Office of Protected Species, Marine Mammal Division
1315 East-West Highway
Silver Spring, MD 20910
(301) 713-2322

US Department of Commerce
NOAA
National Ocean Service
National Marine Sanctuary Program
1305 East-West Highway
Silver Spring, MD 20910
(301) 713-3145

US Environmental Protection Agency
401 M Street SW
Washington, DC 20250
(202) 208-5634

GLOSSARY

ADAPTATION—Physical and behavioral changes that occur slowly over time and help an organism live more easily in its environment.

BALEEN—Rows of horny, triangular plates which hang from the upper jaw of mysticetes. The plates are composed of a protein material, similar to hair and fingernails. The baleen, or whalebone as it is called, filters the planktonic prey and fish from the water.

BLOWHOLE—The nasal opening of a whale, which is located on top of the head. Mysticetes have two external nasal openings, while odontocetes have only one blowhole.

BLUBBER—The layer of fat and oil below the skin, which provides insulation for a whale.

BULL—A mature male whale.

CALF—A newborn or young whale that is still dependent on its mother for protection and/or nourishment.

CALLOSITY—An area of cornified skin, that forms irregular patterns unique to each whale. Found on the bonnet and chin regions, callosities are used by researchers to identify individuals.

CETACEAN—Marine mammals of the order Cetacea which includes the great whales, dolphins and porpoises. Collectively, all members of this order are considered whales.

COPEPOD—Small planktonic crustaceans (shelled marine animals), eaten by right whales.

COW—A mature female whale.

DORSAL FIN—A triangular-shaped structure found along the back of many whales, thought to help stabilize the whale during swimming and diving and possibly aid in maintaining its constant internal body temperature.

ENDANGERED SPECIES—A species that is threatened with extinction.

EXTINCT SPECIES—A species that no longer exists.

FLIPPER—The distinctive forelimb structures found on either side of a whale's body, also known as pectoral fins. They are used primarily for steering, turning, and controlling the whale's vertical position in the water.

INUIT—Peoples of the northern latitudes

IWC—International Whaling Commission: an organization formed in 1946, by an agreement among nations in an attempt to regulate the industry according to principles of sustainable utilization, and to ensure that whales do not become extinct.

KRILL—The common name for euphausiid shrimp, which are small crustaceans that many species of baleen whales feed upon.

MAMMAL—Endothermic (warm-blooded), animals with backbones (vertebrates), with hair, that nurse their young with milk from mammary glands. (Fine hair is found on most juvenile marine mammals, and adult whales show sparse hair in the facial region.)

MIGRATION—Movement from one region or climate to another to feed or give birth, usually an annual pattern established in response to seasonal change.

MYSTICETE—A sub-order of whales which possess baleen instead of teeth. These whales strain their food from the water with their baleen. The mysticetes include the largest animals on earth, including the blue and finback whales.

ODONTOCETE—A sub-order of whales which have teeth of uniform shape and function. Dolphins, porpoises, and the sperm whale are all odontocetes. These whales eat primarily fish and squid.

PLANKTON—Drifting or passively swimming organisms.

SCRIMSHAW—Decoratively carved whale teeth, baleen, whale bone or walrus tusks.

SPOUT—The expired air of a whale that forms mist, often called the "blow."

UNGULATES—Mammals with hooved feet which are almost always herbivores.

VENTRAL GROOVES—A series of pleats found along the underside of many whales. Also known as rorquals, these pleats allow the skin of the throat to expand, accommodating large volumes of water and food.

VERTEBRAE—The bones that make up the backbone of vertebrate animals.

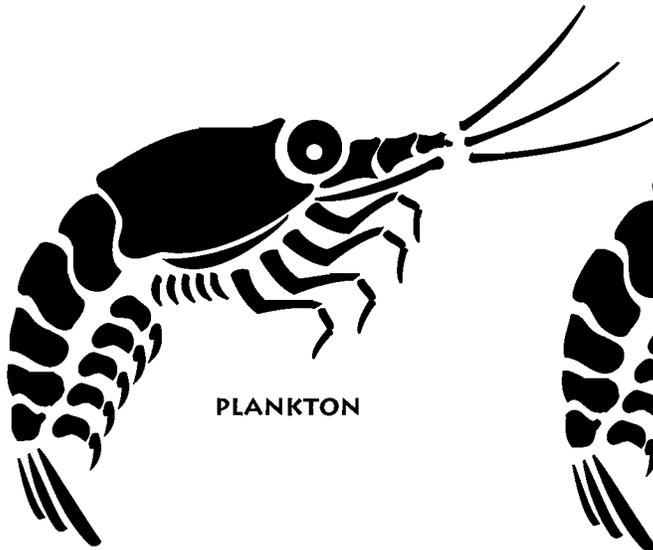
WHALEBONE—The name given to baleen by 18th century whalers.

WHALER—A person who hunts and kills whales.

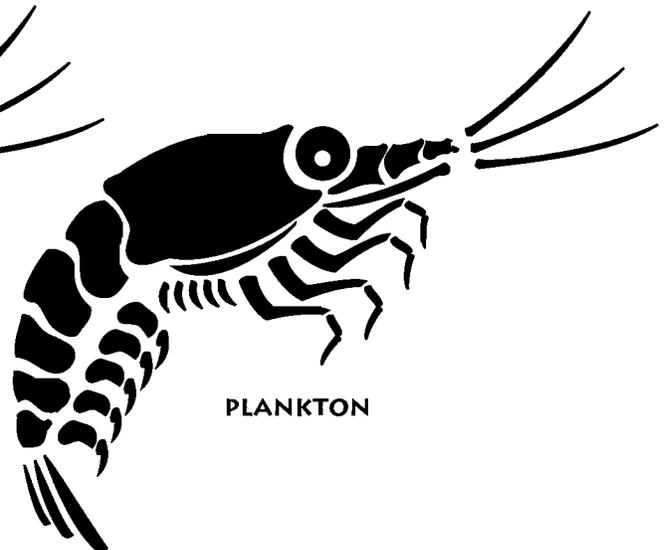
WHALING—An expedition for the purpose of, or act of killing whales.

ZOOPLANKTON—Minute animal plankton.

**ACTIVITY 2: JAWS
CARDS TO COPY**



PLANKTON



PLANKTON



BALEEN



BALEEN



WATER



WATER

THE NORTHERN RIGHT WHALE: FROM WHALING TO WATCHING

ASSESSMENT ACTIVITIES

NAME _____

DATE _____

TRUE/FALSE Decide whether each statement is true or false, and circle the correct response.

- | | | |
|-------------|--------------|---|
| TRUE | FALSE | 1. There are thousands of northern right whales tracked by researchers each year. |
| TRUE | FALSE | 2. Northern right whales are a type of toothed whale. |
| TRUE | FALSE | 3. Whales are mammals. |
| TRUE | FALSE | 4. Whales are found off the coasts of Georgia and Florida. |
| TRUE | FALSE | 5. The ratio of body size and caloric intake is similar in right whales and humans. |
| TRUE | FALSE | 6. Northern right whales give birth in the waters off the New England coasts. |

MATCHING Match the definition with the correct word on the left. Then write the correct letter in the blank on the right.

- | | | |
|------------------------------|-------|---|
| A. adaptation | _____ | 7. the layer of fat below the skin of a whale that helps to maintain body heat |
| B. baleen | _____ | 8. tiny plants and animals that drift with ocean currents |
| C. blowhole | _____ | 9. a species that is threatened with extinction |
| D. blubber | _____ | 10. rows of horny plates that some whales use to strain food from ocean water |
| E. callosity | _____ | 11. annual movement of an animal from one area to another to eat or give birth |
| F. dorsal fin | _____ | 12. an opening in the top of a whale's head that helps it to breathe air |
| G. endangered species | _____ | 13. an endothermic animal with hair that nurses its young |
| H. mammal | _____ | 14. a physical or behavioral change that occurs over time which helps an organism survive in its environment |
| I. migration | _____ | 15. a triangle-shaped structure found on the back of most whale species |
| J. mysticete | | |
| K. odontocete | | |
| L. plankton | | |

SHORT ANSWER

16. What has caused the northern right whale to become endangered?
17. Explain how and what baleen whales eat.
18. Explain how and what toothed whales eat.
19. Where are you most likely to find northern right whales in the winter? Where are the northern right whales in the summer?
20. Suppose that you have a friend who has never heard of northern right whales. Briefly describe them to him or her.

THE NORTHERN RIGHT WHALE: FROM WHALING TO WATCHING

ASSESSMENT ACTIVITIES

ACTIVITY 1: JAWS

1. Provide the students with the “art supplies” listed below. (There are many more things which can be used. Just be creative!) Then have them create a baleen whale mouth and a toothed whale mouth using any of the supplies they wish. The students should also explain, on a sheet of paper or orally, what each type of whale would eat and why.

SUPPLIES:	dried pine needles	tape
	craft sticks	scissors
	pipe cleaners	glue
	paper clips	construction paper
	paper cups	crayons or colored pencils
	cardboard	

2. Provide the students with various pictures of animals including birds, fish, and mammals and have them hypothesize how (and possibly what) that animal eats according to their anatomical features. Pictures should readily show the animals' mouths. Animals might include the following: heron, spoonbill, great white shark, sperm whale, butterfly fish, grouper, and sea otter.

3. *ACTIVITY FOR ADVANCED STUDENTS:* Have the students research the difference between the feeding habits of the basking shark and the spiny dogfish. Then have them compare and contrast the feeding habits of these two sharks to the feeding habits of baleen and toothed whales.

ACTIVITY 2: NO JONAH

1. Write a story about the feeding habits of a right whale or a humpback whale. The story can be as creative as the students like but it should include details about how the whale feeds. Students can take the point of view of the whale, the plankton or even the water or baleen!

2. *ACTIVITY FOR ADVANCED STUDENTS:* Have the students calculate the size difference between humans and right whales. They can calculate the size of a human as a percentage of a whale's size. In addition, students may also come up with some comparisons to these numbers with other objects or organisms.

ANSWER KEY

Answers to Activity 3: High Seas Fast Food, page 20:

1. $\frac{\text{speed}}{\text{speed}} \times \frac{\text{mouth size}}{\text{mouth size}} \times 60 \text{ seconds/minute} = \text{m}^3/\text{min.}$

$$1.5 \text{ m/sec.} \times 1.5 \text{ m}^2 \times 60 \text{ sec./min.} = 135 \text{ m}^3/\text{min.}$$

2. a. $\frac{\text{speed}}{\text{speed}} \times \frac{\text{mouth size}}{\text{mouth size}} \times \frac{\text{\# of copepods/cubic meter}}{\text{\# of copepods/cubic meter}} = \text{copepods/sec.}$

$$1.5 \text{ m/sec} \times 1.5 \text{ m}^2 \times 4,000 \text{ copepods/m}^3 = 9000 \text{ copepods/second}$$

b. $\frac{\text{speed}}{\text{speed}} \times \frac{\text{mouth size}}{\text{mouth size}} \times \frac{\text{\# of copepods/cubic meter}}{\text{\# of copepods/cubic meter}} = \text{copepods/sec.}$

$$1.5 \text{ m/sec} \times 1.5 \text{ m}^2 \times 15,000 \text{ copepods/m}^3 = 33,750 \text{ copepods/second}$$

3. a. $\frac{\text{\# of cop./sec. at 4000 density}}{\text{\# of cop./sec. at 4000 density}} \times 60 \text{ seconds/minute} = \text{copepods/minute}$

$$9000 \text{ copepods/sec.} \times 60 \text{ seconds/minute} = 540,000 \text{ copepods/minute}$$

b. $\frac{\text{\# of cop./sec. at 15,000 density}}{\text{\# of cop./sec. at 15,000 density}} \times 60 \text{ seconds/minute} = \text{copepods/minute}$

$$33,750 \text{ copepods/sec.} \times 60 \text{ seconds/minute} = 2,025,000 \text{ copepods/minute}$$

4. c. $\frac{\text{\# of calories ingested/day}}{\text{\# of calories ingested/day}} + \frac{\text{\# of minutes eating/day}}{\text{\# of minutes eating/day}} = \text{calories/minute}$

Example:

$$2,700 \text{ calories/day} + 90 \text{ minutes/day} = 30 \text{ calories/minute}$$

5. a. $\frac{\text{\# of calories ingested/day}}{\text{\# of calories ingested/day}} + 24 \text{ hours/day} = \text{calories/hour}$

$$500,000 \text{ calories/day} + 24 \text{ hours/day} = 20,833.33 \text{ calories/hour}$$

b. $\frac{\text{\# of calories ingested/hour}}{\text{\# of calories ingested/hour}} + 60 \text{ minutes/hour} = \text{calories/minute}$

$$20,833.33 \text{ calories/hour} + 60 \text{ minutes/hour} = 347.22 \text{ calories/minute}$$

Answers to Activity 6: Migration Mystery Questions, page 29:

- 1/2. Whale #1: Adult pregnant females have been observed traveling this route to a calving area off the coasts of Georgia and northern Florida.
Whale #2: Adult males, non-pregnant females and some juveniles disappear during the winter months as this whale has indicated.
Whale #3: A juvenile whale may be more likely to make this migration down the coast than a non-pregnant adult.
3. Migration to the northern range of the right whale in summer provides a plentiful food supply. Additionally, large numbers of right whales congregate for mating. The warmer, protected waters in the southern range are well suited for calving.
4. Whales may encounter pollution, entanglement in fishing gear, and collision with vessels during their migration.
5. Large cities with active ports, shipping lanes with a high concentration of tanker traffic, military vessels and submarines, smaller commercial and recreational craft pose risks to right whales.

Answers to "From Whaling to Watching: Assessment Activities", page 36:

Questions 1-20 can be used as a pre and /or post test for this whale unit. Answers to question 1-15 follow; responses to questions 16 - 20 will vary (all necessary information is provided within this text).

1. FALSE
2. FALSE
3. TRUE
4. TRUE
5. TRUE
6. FALSE
7. D
8. L
9. G
10. B
11. I
12. C
13. H
14. A
15. F

NOTES

