Pinnipeds: Monitoring and Management

Dr. Bob DeLong

Research Biologist
National Marine Mammal Lab
Alaska Fisheries Science Center,
Marine Fisheries Service

Research Focus

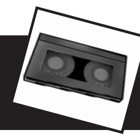
Where do elephant seals and sea lions go when they migrate, how deep do they dive, and why?

Tony Orr

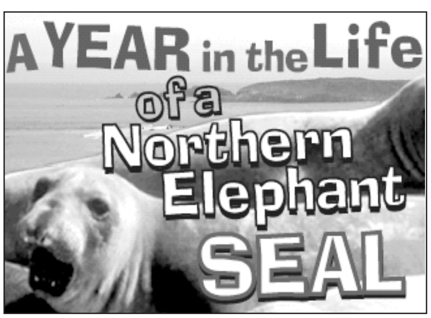
Research Biologist
National Marine Mammal Lab
Alaska Fisheries Science Center,
Marine Fisheries Service

Research Focus

What types of prey do pinnipeds feed on, and where in the ocean do they feed on them?


Team JASON Online	Video	Live Broadcast
• **Digital Lab:** A Year in the Life of a Northern Elephant Seal • Pinnipeds Story Page • Chat Sessions • Message Boards	• Surf, Sand, and Survival: Northern Elephant Seals	Use JASON XIV components to prepare for the live broadcast. Visit Team JASON Online for the latest details.



The appealing **pinnipeds (seals and sea lions)** are the stars of Story 5. What's the difference between a seal and a sea lion? How deep do they dive and where do they migrate? You'll learn the answer to these questions and more with help from host researchers Bob DeLong and Tony Orr. You'll also learn about the astonishing adaptations that allow these marine mammals to flourish in their watery environment.

Story 5

Pinnipeds: Monitoring and Management

> *"There is a wildlife legacy of several hundred thousand seals and sea lions living in these islands within 100 miles of downtown Los Angeles."*
>
> **—Bob DeLong,**
> **JASON host researcher**

> *"What I like best about my job is working with animals that are dynamic, mysterious, and sometimes, for lack of a better word, entertaining. I'm constantly learning something new about them."*
>
> **—Tony Orr,**
> **JASON host researcher**

STANDARDS AND ASSESSMENT

Student Name: ______________________________

National Education Standards	Exercise
Science Standard A: Science As Inquiry Students should understand scientific inquiry and develop the abilities necessary to perform it.	Pinniped Adaptations Pinniped Diving Dynamics Pinniped Feeding and Diving Behavior
Science Standard B: Physical Science Students should develop an understanding of properties and changes of properties in matter, motions and forces, and the transfer of energy.	Pinniped Diving Dynamics
Science Standard C: Life Science Students should develop an understanding about the structure and function of living systems, reproduction and heredity, regulation and behavior, populations and ecosystems, and the diversity and adaptations of organisms.	Pinniped Adaptations Pinniped Diving Dynamics Pinniped Feeding and Diving Behavior
Math Standard: Data Analysis and Probability Students should develop an understanding about how to collect, organize, display, and interpret data.	Pinniped Adaptations Pinniped Diving Dynamics Pinniped Feeding and Diving Behavior
Math Standard: Measurement Students should develop an understanding of different units of measure, be able to convert among systems, and become proficient in selecting the appropriate size and type of measure for a given situation.	Pinniped Adaptations Pinniped Diving Dynamics
Geography Standards 4–6: Places and Regions Students will learn about the physical and human characteristics of places and regions.	Pinniped Feeding and Diving Behavior
English Language Arts Standard 3: Students should apply strategy to comprehend, interpret, evaluate, and appreciate text.	Pinniped Adaptations

Performance Indicators: Pinniped Adaptations	Novice	Apprentice	Researcher
Evaluates information; generates, records, and analyzes experimental data.			
Generates hypotheses of pinniped behavior based on simulations of pinniped attributes.			
Performance Indicators: Pinniped Diving Dynamics	**Novice**	**Apprentice**	**Researcher**
Conducts experiment to learn about the effect of body shape on speed of movement through a fluid.			
Collects, records, displays, and analyzes data.			
Performance Indicators: Pinniped Feeding and Diving Behavior	**Novice**	**Apprentice**	**Researcher**
Duplicates the processes scientists use to determine the feeding habits of pinnipeds.			
Collects and analyzes stomach contents and scat data to determine the diet of pinnipeds.			
Performs mathematical analysis of pinniped diving records.			
Compares the foraging behavior of northern elephant seals and California sea lions.			

Self-Assessment: If I Were a Pinniped . . .
Skills: Comparing and Contrasting, Communicating

	Score
Multiple Choice Test—Team JASON Online at www.jasonproject.org	

Teacher Notes: ______________________________

Pinnipeds on Land and at Sea

Focus *questions*

How do California sea lions and northern elephant seals differ, and how are they similar?

How are these two species uniquely adapted to their environments?

What is the story of these species' interaction with humans?

Between 25 million and 30 million years ago, the bear-like ancestors of today's seals and sea lions were land mammals living along the coasts of the prehistoric continents. Gradually, they spent more and more time in the water, feeding on fish and other marine animals. Over millions of years, these land-based, coastal **carnivores** evolved into **pinnipeds**—the fascinating and beautiful seals, walruses, and sea lions that we recognize today. But what are the different kinds of pinnipeds and how do we tell them apart? What are the remarkable **adaptations** that allow them to live for months at a time in the deepest oceans? Why were they hunted until they were nearly all gone? How did they make a comeback? And why do so many thousands of them make their home on the beaches of San Miguel in the Channel Islands?

JASON host researchers Bob DeLong and Tony Orr devote their energies to answering these and other questions about these mysterious and appealing marine mammals.

What are pinnipeds?

The great Swedish scientist Carolus Linnaeus (1707–1778) spent his life developing a **taxonomy** for categorizing and naming plants and animals. It was Linnaeus who placed seals, sea lions, and walruses into the family he called *pinnipedia*, from the Latin words *pinna* (feather or wing) and *pedes* (feet). This is a perfect description of pinnipeds' "feet" and "arms," which allow them to "fly" through the ocean at speeds up to 40 kilometers (25 miles) per hour.

There are three families of pinnipeds: odobenids, which are walruses; **otariids**, the family that includes eared seals like the California sea lion *(Zalophus californianus)*; and **phocids**, which are the true seals, like the northern elephant seal *(Mirounga angustirostris)*.

The northern elephant seal lives up to its name: males have an enormous trunk-like proboscis (an extended nose or snout) that they use in competitive dominance displays. Northern elephant seals are the biggest of all the phocids: full-grown males can grow to over 4 meters (13 feet) long and weigh as much as 2,000 kilograms (4,400 pounds). That's as much as a large automobile! Male California sea lions grow to 2.4 meters long (8 feet) and weigh up to 400 kilograms (880 pounds). These are just a few of the differences between the phocid elephant seal and the otariid California sea lion.

How do pinnipeds live on land and sea?

Other marine mammals, like whales and porpoises, spend all their lives in the sea. But pinnipeds have a closer relationship with the land.

Male California sea lions "haul out" (come ashore) frequently when they migrate north from the Channel Islands. Females stay close to shore for several months after giving birth, frequently returning to the beaches to feed their pups.

Northern elephant seals haul out twice a year, once to mate and give birth to pups and once to molt. Early every winter, the bulls (males) arrive at San Miguel Island and compete with each other for mating territory. These 2 ton animals mostly posture and bluff each other. Occasionally, however, they fight by slamming against and biting each other's necks. These violent fights can leave scars, but they rarely result in death.

NOAA

Northern elephant seals.

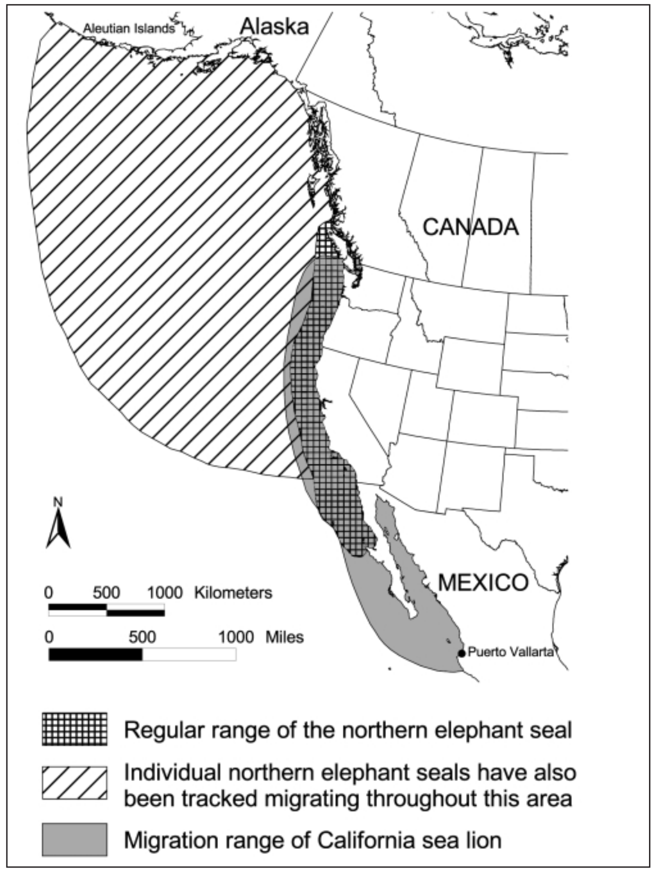
Research *article*

Elephant seal cows (females) arrive at the rookery (breeding ground) after the bulls and give birth to the pups that were conceived in the previous mating season. Newborn elephant seal pups are big babies—they're about 1.2 meters (4 feet) long and weigh close to 36 kilograms (80 pounds). They nurse for 3 to 4 weeks, after which their mothers mate with a male and reenter the sea. The pups stay onshore for another 1 to 2 months, living off their blubber while they begin to venture into the sea and develop their diving and feeding skills. Then they, too, head into the open ocean. The bulls stay onshore for up to 3 months; like the weaned pups and cows, they do not eat while onshore. In fact, adults lose as much as a third of their body weight during their onshore breeding season!

The elephant seals next come ashore to **molt,** beginning with the immature seals in late winter and ending with the bulls in mid-summer. Molting takes about 3 weeks, during which the seals' skin comes off in large sheets. Afterward, the seals go back to sea. They do not return to shore until the next breeding season. For the ones that molted early, that can be as long as 10 months away.

When northern elephant seals enter the sea to hunt for food, their onshore clumsiness disappears. They become diving machines, reaching average depths between 300 and 760 meters (between 1,000 feet and 2,500 feet). Some have been recorded as deep as 1,570 meters (5,150 feet, nearly a mile!). They stay under water for an average of about 20 minutes, though they have been recorded to stay down for up to 1.5 hours. They spend little time at the surface, just about 3 minutes to breathe, before plunging into the depths again. They eat and sleep during these dives, while migrating thousands of miles from the Channel Islands. The elephant seal is the only animal known to make a **double migration:** two long journeys to and from the Channel Islands each year.

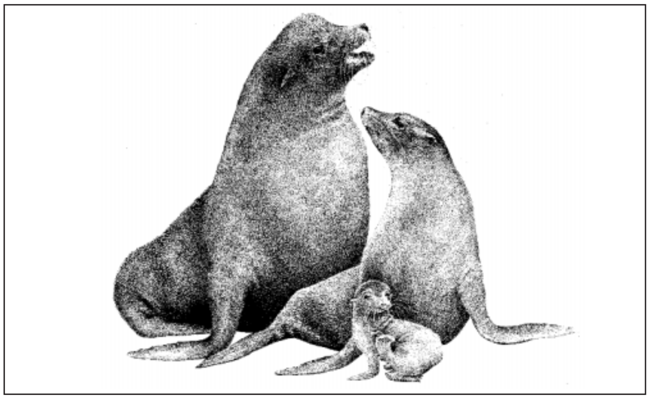
How do we know so much about the elephant seal's behavior at sea? Host researcher Bob DeLong and his colleagues take advantage of the seals' consistent habits to glue radio transmitters and data recording equipment to their backs. This equipment records how deep the elephant seals dive and how long they surface. In addition, by measuring the light and time of day when they surface, Bob DeLong's team can calculate their location as they migrate. When the seals haul out again on San Miguel Island, the radio transmitters emit signals that allow the scientists to find each animal and recover the equipment. Before Bob DeLong's project, elephant seals' behavior at sea was a mystery. They were rarely seen by anyone on the surface, because they spend so much time diving to the ocean's depths.



Migration ranges of the northern elephant seal and California sea lion.

How do California sea lions differ from northern elephant seals?

While the northern elephant seal may seem sluggish and clumsy on land, the female California sea lion is familiar to us as the graceful, intelligent, acrobatic, and amusing performer in many aquariums and marine parks. The female is often chosen as the star of these shows because of her manageable size, friendly disposition, and great capacity for learning. In fact, the intelligence of sea lions is so marked that their learning skills are being extensively studied by scientists at the University of California at Santa Cruz.



Diana Dee Tyler

Zalophus californianus is distinguished by the large crest on the forehead of the adult male.

One of the scientists' subjects has learned to recognize over 7,000 different complex commands!

In nature, sea lions display similar qualities of playfulness and intelligence. California sea lions lead lives that we might see as more relaxed than those of elephant seals. They do not dive nearly as deep or as long. The deepest recorded dive for a sea lion is 376 meters (1,234 feet), and the longest is 8 minutes. They do not travel as widely when they migrate, and they migrate once a year instead of twice. They eat 12 kilograms (26 pounds) of fish and squid a day, while elephant seals eat 34 kilograms (75 pounds) or more. There are also important differences in how the two animals reproduce and care for their newborns.

Elephant seal females nurse their pups for 30 days after giving birth. They then mate with a male and leave the island for several months to feed at sea.

California sea lions nurse their newborns for up to 11 months. During this time, they will go out and feed for a few days, then return to land to nurse their pups for a couple of days.

What is the story of pinnipeds and humans?

Today, it is a thrill to see California sea lions and northern elephant seals hauled out by the thousands on the beaches of San Miguel Island, resting, mating, giving birth, and caring for their young.

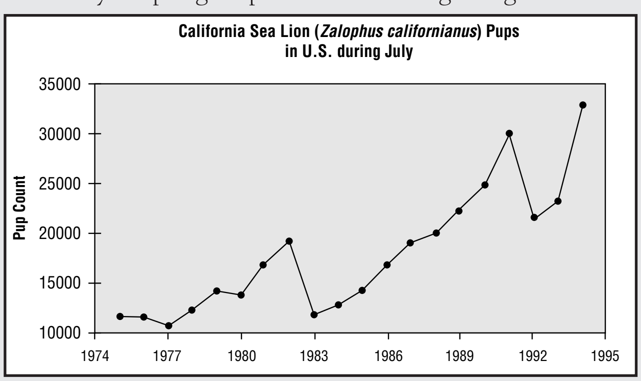
It hasn't always been this way. Before European settlers came to California, the native Chumash hunted in ways that changed the abundance and distribution of animals. Then, from the early 1800s, pinnipeds encountered hunters and fishermen using modern methods, and their numbers in California diminished rapidly. Hunters killed pinnipeds in part for their blubber (which was turned into oil), but also to use some body parts for home medical remedies and for their whiskers (which were used as pipe cleaners). People and pinnipeds competed for fish in the same waters, and the seals and sea lions often became entangled in fishing nets and died.

Research *article*

How Does El Niño Affect Pinniped Populations?

Every few years, the warming currents of El Niño create a floating "lid" of warmer water on top of vast stretches of the Pacific ocean. The warmer water has less nutrients, which means there are fewer of the smaller creatures that pinnipeds eat in the waters near the Channel Islands.

This means that females about to give birth or nursing pups have a hard time getting enough nutrients to raise healthy offspring. Pups are not as strong and grow more slowly. Many more fail to survive than is usual. Major storms often wash weaker pups out to sea.



This chart shows times when the population of California sea lion pups declined. In which years do you think El Niño occurred?

Year	Northern Elephant Seal Population
1925	1
1938	13
1946	21
1950	50–70
1958	455
1964	1,922
1965	3,000
1966	3,000
1967	3,700
1969	3,000
1970	3,833
1971	3,200
1972	4,297
1973	3,600

Census of northern elephant seals on San Miguel Island, 1925 to 1973.

The hunting of the sea lion herds was so unrestrained that in 1908, only one lonely sea lion was found on the Channel Islands. The state of California passed a law in 1909 that forbade the killing of sea lions, and the government of Mexico began protecting sea lions in 1911. But the California law was repealed in 1927, and by 1938, a survey found only 2,020 sea lions along the entire California coast. Eventually, however, protection of the species began to take effect: by 1967 there were an estimated 40,000 sea lions in California, mainly on the Channel Islands. Today, approximately 200,000 California sea lions use the Channel Islands (primarily San Miguel) as their home base. This population has been increasing steadily since the passage of the Marine Mammal Protection Act in 1972.

The northern elephant seal population developed in a similar pattern. They were hunted close to extinction and for a time they were thought to be extinct. Conservation has saved this species, so that now there are an estimated 150,000 northern elephant seals. Fifty thousand of them haul out on San Miguel Island each year.

Journal Question

Why is it important to protect species like the northern elephant seal and the California sea lion?

Scientists track northern elephant seals on their dives and migrations by securing radio transponders to their backs.

Fact or *Fallacy?*

Because northern elephant seals are mammals and breathe through lungs (like whales and porpoises), they can only spend a few minutes under water before coming up for air.

Fallacy: *Northern elephant seals have adaptations that allow them to conserve oxygen in their blood. They can dive close to a mile under the surface, and stay down for over an hour at a time.*

Vocabulary

Adaptation *n.* A physical feature or ability, developed over many generations, that helps a species survive in its environment.

Carnivore *n.* A flesh-eating animal.

Double migration *n.* Two annual round trips made by the northern elephant seal between its feeding grounds in the north Pacific and the Channel Islands.

Molt *v.* To shed the skin, fur, or feathers periodically. Northern elephant seals are said to do "radical molting," because their skin comes off in sheets.

Otariid *n.* Any of approximately 14 species of pinnipeds, including the California sea lion, that have outer ear flaps and hind flippers that can be rotated underneath the body.

Phocid *n.* Any of approximately 19 species of pinnipeds known as "true seals," including the northern elephant seal. Phocids do not have extended ear flaps. They do not use their flippers for moving on land. Instead they wriggle from side to side or hunch their bodies like caterpillars.

Pinniped *n.* A walrus, sea lion, or seal.

Taxonomy *n.* The science of classification and categorization of living things. Linnean taxonomy categorizes all plants and animals into the following seven subgroupings, each more specific than the one before: kingdom, phylum, class, order, family, genus, species.

Pinniped Adaptations

Over millions of years, pinnipeds have developed some remarkable ways to survive in the harsh ocean environment. In this exercise, you will rotate between **four stations** and learn more about what it's like to be a pinniped, and how elephant seals and sea lions have adapted to life under the sea. You'll find out how it feels to be protected by blubber and get an idea of what it's like to be under millions of tons of water!

Focus *questions*

How are pinnipeds adapted to living on land and at sea?

How do pinniped adaptations function?

What's it like to be a pinniped?

Conclusion

After you've visited the four stations you will have some firsthand experience of what it feels like to be a pinniped.

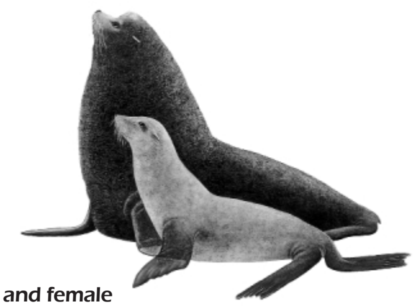
1. Discuss the pinniped adaptations you think are most interesting and most important.
2. Discuss how the pinnipeds' behavior might be different if one or another of their adaptations were absent. For instance, what if elephant seals couldn't dive so long on one breath? What if the California sea lion's layer of blubber were thinner?

For Further Exploration

What are some of the disadvantages that pinnipeds experience because of their adaptations to living in cold environments? Think about what it may be like for them when they haul out on San Miguel Island.

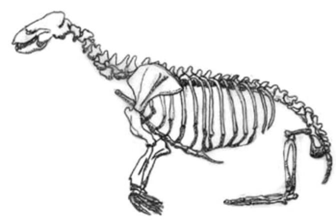
California Sea Lion
Otariid

Peter Folkens



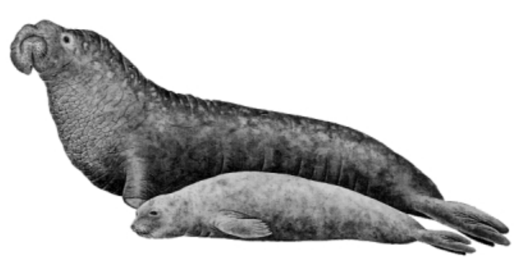
Adult male and female

Otariid Skeleton



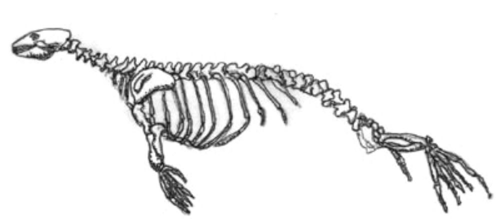
Northern Elephant Seal
Phocid

Peter Folkens



Adult male and female

Phocid Skeleton



Exercise 5.1

Station 1

How do northern elephant seals and California sea lions move on land and in the water?

Materials

Several pairs of scuba or swimming fins

Pictures of sea lions and elephant seals, under water and on land

Procedure

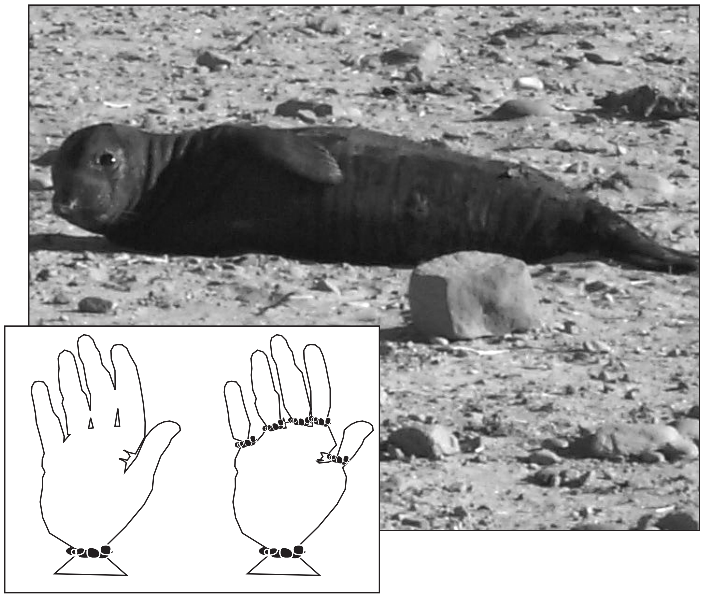
1. Measure your height, your hand's length and width, and the length and width of your foot. Calculate the ratio between your hand length and your height. Calculate the approximate surface areas for your hand and foot, and for the pinnipeds' front and back flippers. Enter your data in a chart.
2. Measure the fins you would put on your hands and on your feet to imitate a sea lion or elephant seal. Add that information to your chart and calculate the same ratios.
3. Examine the photographs and drawings throughout this story of sea lions and elephant seals. Notice the position of the flippers.
4. Wear the flippers on your hands and feet, and walk around a bit. Try to walk like a sea lion, then like an elephant seal. Pick up a book from a desk, or a pencil. Watch your classmates try to do so. Imitate a sea lion or an elephant seal at sea.
5. Discuss with your group how sea lions, elephant seals, and humans move on land and in the water. Also, discuss how the length and shape of arms and legs affect movement on land and in the water.
6. Draw up a list of hypotheses about what pinnipeds' movement might mean about their vulnerability to predators on land and at sea.
7. Compare your group's ideas with the information provided below.

Check Out the Facts!

- On land, otariids must walk on their hind flippers; phocids must either rear back and lunge forward or wriggle from side to side. Neither family's method is very efficient.
- On land, pinnipeds' lack of mobility has made them vulnerable to hunters and, in frozen regions, to polar bears. Pinnipeds are also sometimes eaten by killer whales just as they are emerging from the surf onto the beach.
- In the sea, pinnipeds are terrific swimmers. Otariids propel themselves with their front flippers and steer with their back flippers; phocids do the opposite, swimming with their hind flippers and steering with the front.
- In the sea, pinnipeds can maneuver away from their predators, sharks and killer whales. Along with their other adaptations, their flippers help them dive deep enough to stay out of range of predators.

Station 2

How does a pinniped's body shape conserve warmth?



Materials

Plastic or latex gloves

Supply of warm water (37 degrees Celsius/ 100 degrees Fahrenheit)

Graduated cylinder or measuring cup

Laboratory thermometers

Plastic tub filled with ice water

Stopwatch String Graph paper

Procedure

1. Use string to tie off the fingers of one of the plastic gloves. This will be the "pinniped body"; the other glove will be the "human body".
2. Measure equal amounts of warm water and pour them into the pinniped glove and into the human glove.
3. Insert a lab thermometer into the top of each glove. Using string, tie off the glove around the thermometer, leaving enough of the thermometer sticking out so you can read it. Create a chart to record the temperature of the water in each glove.
4. Plunge the gloves into the ice water at the "start" signal. Record the thermometer reading for both gloves every minute for 7 minutes.
5. Create a line graph showing the temperature readings for both gloves.
6. Analyze your group's data and hypothesize why the water temperature in the two gloves cooled at different rates. Explain how the shape of a pinniped helps to keep it warm in cold water. Write down your hypotheses and explanations. Which keeps your hands warmer, gloves or mittens? Why?

Check Out the Facts!

- Water conducts heat very well. That means a warm body in cold water will cool very quickly (unless insulated).
- The less surface area a body has, the less heat it will lose when under water. Are pinnipeds shaped to conserve heat? (Hint: they're big, but do they have any nooks and crannies that can lose heat?).
- Pinnipeds also have limited blood circulation in their flippers (which aren't insulated), so the heat lost from them is limited.
- Pinnipeds' streamlined shape means they require less energy to move through the water than other animals (like humans). Less energy spent in moving means more energy available to stay warm.
- Blubber does more than keep pinnipeds warm. It helps to streamline their body shape.

Station 3

How does blubber work?

Materials

"Blubber" mitt

Regular (skin protected) mitt

Tub of ice water

Stopwatch

Procedure

1. Put one hand into each of the two mitts prepared for you by your teacher.
2. Put both mitted hands into the ice water at the same time. Have a classmate time you with the stopwatch.
3. Leave both hands in the ice water for at least a minute. Report as soon as you feel a difference in temperature between the "blubber-protected" hand and the other hand. Another student should record the time. Which hand gets colder first?
4. Take your "skin-protected" hand out of the water before you think your fingertips are about to go numb. Have a fellow student record the time. Record the information on a chart.
5. Take the blubber-protected hand out of the water just before you think your fingertips are going numb, or after another minute, whichever comes first. Have another student record that time, too.
6. Calculate your group's average times in the ice water for the blubber-protected hand and for the other hand.
7. Write an explanation of how pinnipeds are adapted to living in cold waters.

Exercise 5.1

Check Out the Facts!

- Blubber accounts for as much as a third of an elephant seal's body weight. For a large male, that could be well over 450 kilograms (1,000 pounds) of blubber.
- A pinniped's entire body, except for flippers and head, is enveloped in a thick layer of blubber.
- Blubber is a very poor conductor of heat, which makes it a very efficient insulator.
- Blubber is also less dense than muscle or other body tissue. It helps keep pinnipeds buoyant in the sea. Blubber floats!

Station 4

How do humans and pinnipeds compare when it comes to holding their breath, how fast their hearts beat, and their breathing rates? Guess what the human records are for holding one's breath and diving deep without equipment.

Materials

Stopwatch or clock with second hand

Easel pad (or blackboard)

Procedure

1. Copy the chart.
2. Team up with a partner. Using the stopwatch, determine the following for each person while they are sitting still (at rest):
   - Number of breaths per minute (breathing normally).
   - Number of heartbeats per minute (pulse rate).
   - How long a person can hold his or her breath.
   - Number of heartbeats per minute while holding breath.
3. Take these same measurements for each person while they are walking in place and while jogging in place.
4. Compare your measurements with other group members' measurements. Discuss the patterns you see in your group's data.
5. Compare your data with the information below.
6. Write an explanation of how pinnipeds have adapted to staying submerged so long.

Exercise 5.1

Check Out the Facts!

- Pinnipeds don't actually hold in their breath when diving. They expel the air from their lungs, collapsing them. They then "shut down" the transport of oxygen to outer parts of their bodies, reserving the oxygen for use by their brain. This also protects their lungs from the enormous pressure they are under during deep dives.
- Pinnipeds also slow down their breathing and heart rates. While on land they sometimes breathe only twice a minute. This helps them adapt to long periods without drawing a breath underwater. While diving, their heart rate also drops to 10 beats per minute or even less. This conserves energy.
- Everything about the pinnipeds is adapted for diving deep and staying underwater: their light-sensitive eyes, their "hydrodynamic" body shape, their pressure-protective layer of blubber, and their ability to shut down oxygen use by all but the most critical parts of their bodies.
- The human record for breath-holding is over 7 minutes. The deepest single-breath free dive by a human was to a depth of approximately 111 meters (365 feet).

Exercise 5.2

Pinniped Diving Dynamics

In this exercise, you and your classmates will make a shape out of clay and measure how well it dives. Then you will compare your shape to the shapes of pinnipeds and other marine organisms.

Focus *questions*

What features of the pinniped's body design enable it to dive and swim so efficiently?

Materials

For each pair of students

Modeling clay

Pictures of pinnipeds and other marine animals

Metric ruler

Calculator

Chart for recording data and averages

String

Paper clip

For the entire class

Stopwatch

Diving pool made of 2-liter plastic bottles

Procedure

1. With a partner, make a clay model of the geometric shape assigned to you: a cube, a sphere, a cylinder, a rectangular solid, or a cone.
2. Embed a paper clip into the top of each clay model and tie a 1½-meter (5-foot) length of string to it. This will let you retrieve the model from the bottom of the diving pool.
3. Predict which geometric shape will dive the fastest. Mark that geometric shape on the chart.
4. Drop your model shape into the diving pool and time its descent. Calculate the rate of descent for your model and add it to the class chart. Average your class's results for each shape.
5. Compare your prediction from step 3 to the class's data. Discuss why some shapes are better divers than others.
6. Make a clay model of your assigned animal: a sea turtle, a starfish, a sea urchin, a shark, a pinniped, or a human. Repeat the diving, recording, and calculating procedures with the model animals. Which animal dived the quickest?
7. Use the information you have learned so far to design one more model. Attempt to create the fastest diver. Display your model for everyone to see. Predict which model will have the fastest rate of descent. Now test your models.

Conclusion

1. What shape is best suited for diving deep below the ocean's surface? Which shape is least suited? Why?
2. What can an observer guess about these animals' behavior by their body shapes? Give examples for each animal.
3. Other physical characteristics, not just body shape, can give you clues about an animal's behavior. Discuss this in class and try to give examples of how it is true for other animals.

Descent Rate	Cube	Sphere	Cylinder	Rectangular Solid	Cone
#1					
#2					
#3					
Average					

Descent Rate	Sea Turtle	Sea Star	Sea Urchin	Shark	Pinniped	Human
#1						
#2						
#3						
Average						

Pinniped Feeding and Diving Behavior

Scientists can learn a great deal about what pinnipeds do at sea, how healthy they are, and where they travel by looking at what they've eaten—their prey remnants. This is done without hurting the animals by two methods: lavage and scat analysis. In this exercise, you and your classmates will examine the prey remnants of California sea lions and northern elephant seals. You will explore the techniques scientists use to learn about these animals' prey, feeding areas, and diving depths.

Focus *questions*

How do scientists learn about the feeding habits of pinnipeds?

Do California sea lions and northern elephant seals compete for the same prey?

Materials

For each student

Copy of Master A (student data sheet)

For each group

Copy of Master B (pinniped prey species)

Copy of Master C (diving depths)

Calculator

Procedure

1. Read the information in the text box and discuss these research techniques with your classmates.
2. Now you'll try working with the same techniques. Your class will be divided into six groups. Your teacher will assign each group a sample of "prey remnants" from either a California sea lion or a northern elephant seal.
3. Analyze the prey remnants of your assigned pinniped. Report your findings on Part I of **Master A.** Calculate the percent of the total prey remnants taken up by each species. Determine the ocean region and depth where each prey species is found by referring to **Master B.**
4. Analyze the diving depth graphs on **Master C,** then answer the questions on Part II of **Master A.**
5. Participate in a "scientific conference" with fellow pinniped researchers—your classmates. Share your group's findings with the rest of the conference members.

Conclusion

1. How do scientists learn about the feeding habits of pinnipeds?
2. How do the feeding habits of California sea lions and northern elephant seals compare, in terms of prey, foraging areas, and depths?
3. Which is a better indicator of these two pinnipeds' feeding habits: stomach contents or scat analysis? Explain your answer.

Exercise 5.3

Scat analysis (for California sea lions)

The preferred method for finding out what California sea lions eat is to examine their fecal droppings, called scat. *Otoliths* (rock-like pieces of calcium from the ears of bony fishes), fish scales, and fish bones are sorted, identified, and counted, as are squid beaks. The seal lion's main prey species are market squid, North Pacific hake (a fish), pilchard (sardines), rockfish, mackerel, and northern anchovy.

Stomach lavage (for elephant seals)

Scientists collect scat because it is easier to pick up droppings than to pump out a pinniped's stomach. But the northern elephant seal's scat does not contain much identifiable material. To get prey samples for these seals, scientists have to remove the contents of their stomachs using a process called stomach lavage. First, the seal is given a powerful anaesthetic that puts it to sleep, but is harmless to healthy animals. Then, a plastic tube is put through the seal's mouth into its stomach, and the stomach contents are flushed out with about 3 to 5 liters (about a gallon) of seawater. The most important clues to the elephant seals' diet are found in otoliths, scales and bones of fish, mouthparts and beaks of *cephalopods* (specifically squid), and shells of crustaceans (like crabs). The seals' primary prey animals are different kinds of squid, North Pacific hake, and red crabs. All in all the scientists found remains from 53 kinds of animal, including other fish like smooth lumpsucker, slender blacksmelt, highsnout melamphid, and dogfish.

Part I: Student Data Sheet

Group Number: _____ **Group Members:** _________________ **Stomach Contents Sample Number:** ______

Prey Remnant Analysis

Name of Prey Species	Frequency of Occurrence (F-O) *(Number of Each Species Found in Sample)*	Percent of Total Prey	Ocean Region of Prey Species	Depth Range of Prey Species
	Total Prey = ________			

Stomach Contents Findings

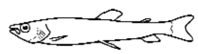
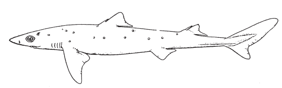
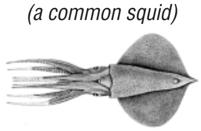
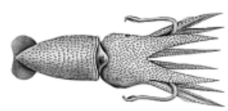
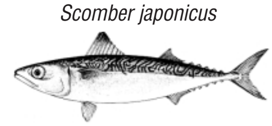
1. The prey remnants probably came from a
   ___ California sea lion.
   ___ northern elephant seal.
2. The pinniped probably fed
   ___ in coastal waters.
   ___ in the open ocean (pelagic zone).
   ___ in coastal and pelagic zones.
3. Describe how you came up with the decisions you made for questions 1 and 2.

Part II: Analyzing Data from Diving Pinnipeds

To answer the following questions, carefully look at the four diving depth charts on **Master C.** They show the actual data recorded from two individual pinnipeds by equipment that Bob DeLong's team attached to the animals.

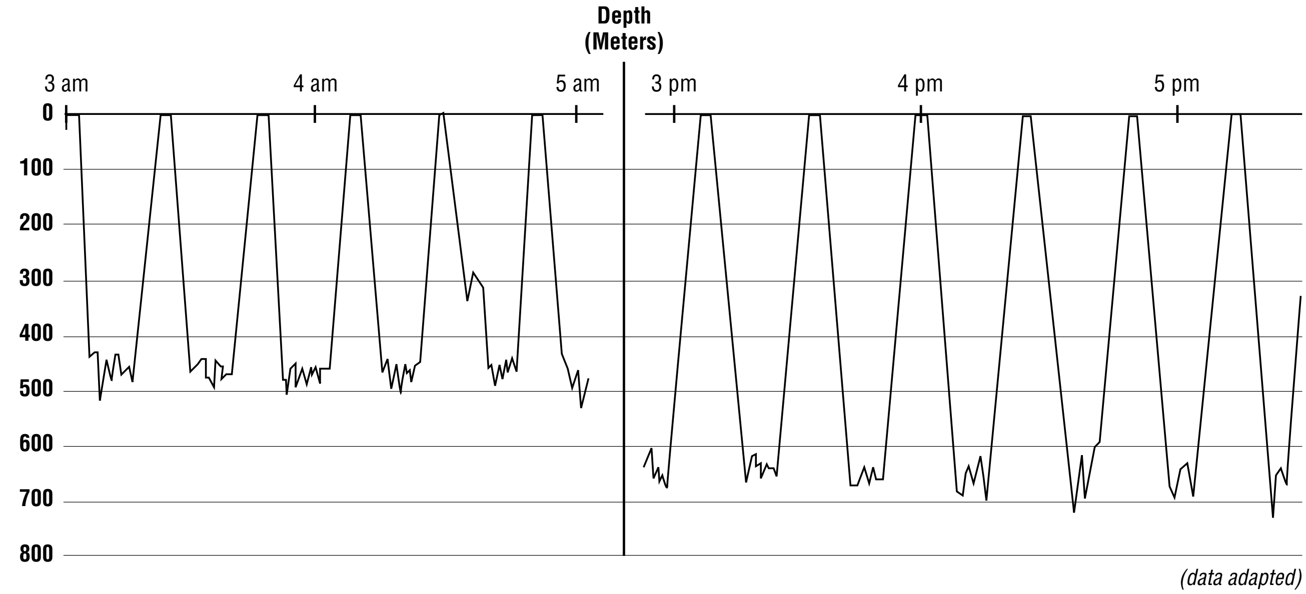
1. Which pinniped dived deeper?
2. How did each pinniped's diving behavior change over the course of the day and night?
3. How many dives per hour did the California sea lion make, and how many did the northern elephant seal make?
4. When it's diving, where does the northern elephant seal spend more time, at the surface or at the bottom of its dive? What about the California sea lion? Do you think the northern elephant seal was feeding when it was at the deepest part of its dive, at the surface, or on its way up or down? How about the California sea lion? Explain your answers.

Pinniped Prey Species

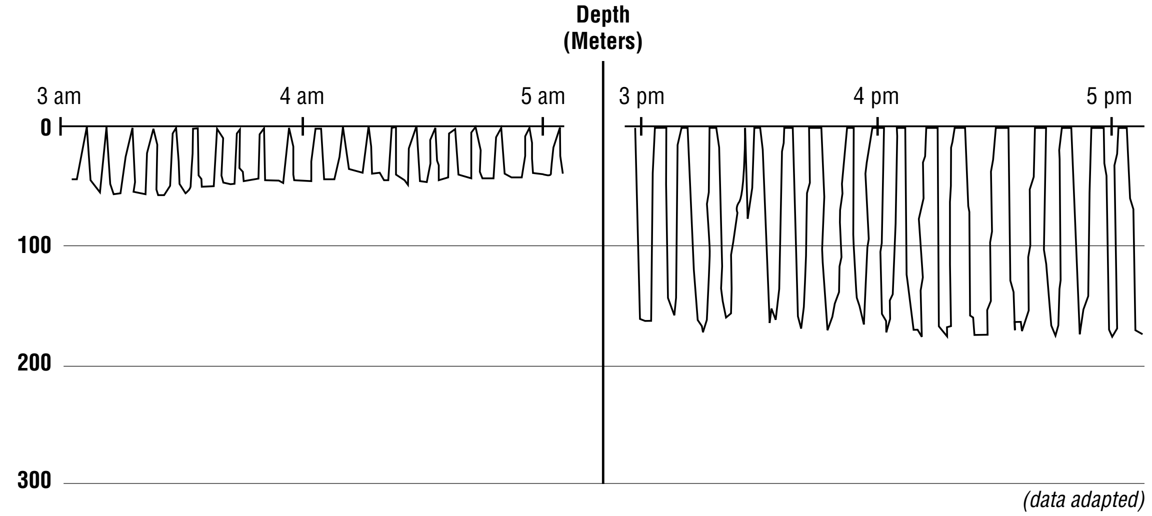
Smooth lumpsucker *Aptocyclus ventricosus*  Ocean region: pelagic Depth: surface to 1,500 m Size: up to 27 cm	**Slender blacksmelt** *Bathylagus pacificus*  Ocean region: pelagic Depth: 230 m–7,700 m Size: up to 25 cm	**Highsnout melamphid** *Melamphaes lugubris*  Ocean region: pelagic Depth: 50–1,200 m Size: 6.8 cm
North Pacific hake *Merluccius productus*  Ocean region: pelagic and coastal Depth: 0–1,000 m Size: up to 91 cm Nocturnal feeder	**Spiny dogfish** *Squalus acanthias*  Ocean region: pelagic Depth: 0–1,460 m Size: 160 cm	**Northern anchovy** *Engraulis mordax*  Ocean region: pelagic and coastal Depth: 0–300 m Size: up to 24.8 cm
Octopoteuthis deletron *(a common squid)*  Ocean region: pelagic Depth: 200 m–1,000 m Size: mantle length 10 cm	**Histioteuthis heteropsis** *(a common squid)*  Ocean region: pelagic Depth: day—mostly 400 m to 800 m night—mostly surface to 400 m Size: mantle length 13 cm	**Market squid** *Loligo opalescens*  Ocean region: coastal Depth: surface to 800 m Size: mantle length 19 cm
South American pilchard *Sardinops sagax*  Ocean region: pelagic Depth: surface to 200 m Size: up to 39.5 cm	**Bank rockfish** *Sebastes rufus*  Ocean region: semi-pelagic Depth: 31–247 m Size: up to 51 cm	**Chub mackerel** *Scomber japonicus*  Ocean region: pelagic and coastal Depth: surface to 300 m Size: up to 64.0 cm

Master B

Diving Depths



Northern Elephant Seal, Female, Spring 1992
Location: 43˚ 30' north latitude, 129˚ 12' west longitude
Date: April 11, 1991



California Sea Lion, Female, Winter 1992
Location: 34˚ 12' 30" north latitude, 119˚ 44' 17" west longitude
Date: January 31, 1992

Master C

SHOW WHAT YOU KNOW!

If I Were a Pinniped . . .

Skills: Comparing and Contrasting, Communicating

In Story 5, you studied two different pinnipeds, the California sea lion and the northern elephant seal. You discovered that these marine mammals have many extraordinary adaptations that allow them to survive at sea for long periods of time.

Your Challenge

Use the concepts and skills you learned in Story 5 to write a guided imagery or story of how a human could be magically transformed into a California sea lion or a northern elephant seal. You may wish to draw pictures to illustrate your work. You could also create an audio tape, a video, or a PowerPoint presentation.

Words, Words, Words

Think about the following vocabulary words as you write: *adaptation, foraging, insulator, mammal, pressure, predator, prey, streamlining.*

Helpful Hints

Be sure to include information on the following:

- What internal and external changes would occur in the human body.
- How the new body shape would be able to move on land and at sea.
- Where the animal lives.
- What the animal eats and how it obtains its food.
- What would eat it and how it avoids being eaten.

Assess Your Work

Use this chart to assess your own work.

Skills and Steps	Yes	No	Not Sure
Created a guided imagery or story.			
Showed how a human was transformed into a California sea lion or a northern elephant seal.			
Included appropriate adaptations for life on land and at sea.			
Included food chain information.			

Conclusion

What does an author need to know in order to write an accurate guided imagery or story about a particular animal?

Maureen Kaplan

California sea lions take a break on a buoy near an offshore oil drilling platform.

TEACHER LINKS 5

Mathematics Links

math links

Have students graph the data in the research article's text box on El Niño. After they graph the data, have them analyze them in writing.

Language Arts Links

lang links

Have students choose either a California sea lion or a northern elephant seal. Write the animal's name vertically on the blackboard. Have students come up with adjectives beginning with each of the letters in the animal's name (e.g., "Cute, Affable, Loud, Intelligent . . .").

Arts Links

arts links

When scientists study animals in the field, they often sketch or illustrate the animals, their environment, and their behavior. Have each student role-play a scientist in the field studying northern elephant seals. They can use photographs from the "Tracking the Elephant Seal" Digital Lab for their field notebook sketches. Have students annotate their drawings with dates and locations.

Novel Links

novel links

20,000 Leagues under the Sea. Compare the respiratory systems, diving depths, and submergence time of the *Nautilus* with those of the northern elephant seal. How does the design of the *Nautilus* compare with the body of the elephant seal?

Island of the Blue Dolphins. Reread the pages in Chapter 13 in which Karana describes the sea elephants. List the facts she gives you. Do they agree with what you learned in Story 5?

The Voyage of the Frog. In Chapter 17, David seeks shelter in a cove off Baja California. Are the animals that wake him fish or mammals? Describe their feeding and breathing behavior.

The Case of the Missing Cutthroats. Like some scientists who find fish scales in pinniped stomachs, Al studied fish scales. What can be learned from such studies?

Zia. Compare the motivations for hunting whales in this novel with the Chumash hunt for pinnipeds and the European seal trade.

Web Links

web links

nmml01.afsc.noaa.gov/Default.htm
The National Marine Mammal Laboratory.

www.cinms.nos.noaa.gov/res.stm
Research in the Channel Islands National Marine Sanctuary.

pinnipedlab.ucsc.edu/pinniped/life1.html U.C. Santa Cruz information page on northern elephant seals, with photographs.

parks.ca.gov/default.asp?page_id=1120 Live web cam showing elephant seals at Año Nuevo State Reserve.

Technology Links

tech links

For Exercise 5.1, use a spreadsheet to collect and exchange data among groups. If available, have students use a digital temperature probe attached to a computerized recording device (handheld PDA, graphing calculator with CBL, computer, etc . . .) to create a graph of temperature versus time inside the gloves for Stations 2 and 3.

For Exercise 5.2, place a meter stick behind the diving tower and have students hold the stopwatch next to the tower where the numbers will be visible. Use a video (or digital video) camera to record the movement of the models through the water. Do the models speed up or slow down unexpectedly? Do they rotate? Can students measure speed accurately from the images? If available, use physics image processing software on a computer to help your analysis.

Teacher Preparation 5.1

Pinniped Adaptations

Time Required

1½ hours (two 45-minute periods)

Level of Complexity

Medium

Additional Preparation

1. Divide your class into four groups and have the groups rotate between stations. Each station should take no more than 20 minutes. If you have enough supplies and time, have each student work through every element of every station.
2. Students will need a data table for each station. Have students create their own tables, or copy the tables provided on the next page.

Station 1

1. If scuba fins are not available, create flippers from cardboard or thin boards. Use elastic or rubber bands as straps.
2. Use reference books to find pictures of sea lions and elephant seals under water and on land.

Station 3

1. Regular mitt: Turn a plastic Ziploc® bag inside out. Insert that bag inside a Ziploc® bag of the same size. Align the Ziploc® areas and zip the two bags together (or use duct tape to seal the seam), trapping a bit of air between the two bags.
2. Blubber mitt: Repeat the procedure given above, but trap shortening between the two bags.

Answers to Questions

Procedure questions, Station 1
The ratio of limb to body length for pinnipeds is less than that for humans. Pinnipeds' hind limbs are very short. Pinnipeds are more vulnerable to predators while on land.

Procedure questions, Station 2
Pinnipeds have stubby-limbed, sausage-shaped bodies. This shape has less surface area than a thin, longer-limbed shape. Less surface area means less area for heat loss.

Procedure questions, Station 3
Students should discover that the blubber is a good insulator.

Procedure questions, Station 4
Students will discover that pinnipeds expel air before making their long dives rather than holding in their breath. Unlike pinnipeds' heart and breathing rates, ours increase with activity. Human hearts slow slightly when we hold our breath and while we are sleeping. Pinniped heart rates slow substantially during a dive; their hearts even stop briefly, at times, while they sleep on land.

Conclusion questions

Answers will vary.

Adaptations

For elementary school students
Choose stations appropriate for the age of the students. Consider doing the stations as a class rather than as rotating groups.

For high school students
Research the human "dive reflex" and the effects of submersion in cold water on heart rate. Compare these human adaptations to pinniped diving behavior.

Chart for Station 1

	Height	Hand (Fore Flipper)				Foot (Hind Flipper)			
		Width	Length	Area	Ratio	Width	Length	Area	Ratio
You									
You, with Fins On									
California Sea Lion (Adult Female)	166 cm (5 ft 5 in.)	15 cm (6 in.)	49 cm (19 in.)			14 cm (6 in.)	34 cm (13 in.)		
Northern Elephant Seal (Adult Male)	420 cm (13 ft 10 in.)	26 cm (10 in.)	50 cm (20 in.)			34 cm (13 in.)	55 cm (22 in.)		

Chart for Station 2

Time	Temperature of "Pinniped Body" (Gloves with Fingers Tied)	Temperature of "Human Body" (Gloves with Fingers Not Tied)
1 Minute		
2 Minutes		
3 Minutes		
4 Minutes		
5 Minutes		
6 Minutes		
7 Minutes		

Chart for Station 3

Name	Difference Detected	Regular Mitt (Seconds)	Blubber Mitt (Seconds)

Chart for Station 4

Name	Activity	Breathing Rate (Breaths per Minute)	Heart Rate while Breathing (Beats per Minute)	Breath-Holding (Seconds)	Heart Rate while Holding Breath (Beats per Minute)
#1	At Rest				
	Walking				
	Jogging				
#2	At Rest				
	Walking				
	Jogging				

Teacher preparation

Teacher Preparation 5.2

Pinniped Diving Dynamics

Time Required

45 minutes

Level of Complexity

Low

Additional Preparation

You can assign the preparation of each geometric shape and animal figure to a pair of students; have each pair in turn drop their clay figure into the diving pool and time its descent. If you wish, you can construct two diving pools and have half the class make and time the “shapes,” while the other half works with the “animals.”

Making a diving pool

1. You will need five empty 2-liter plastic soft drink bottles.
2. Cut off the bottom of a bottle, just below the point at which it begins to curve inward.
3. Fit the cut bottle over the *top* of a second bottle. Draw a line around it with a permanent marker.
4. Cut the top off the second bottle about a centimeter *above* the line you just drew.
5. Fit the first bottle over the second and tape the joint securely with duct tape.
6. Cut the bottom off a third bottle, fit it over the top of the second, cut off the top of the second bottle, and tape the third bottle in place over the second. Repeat this process with two more bottles, creating a tower five bottles high.
7. Tie, tape, or brace the diving pool between two chairs before filling it with water.

Making and using the diving models

1. Create a chart on which students will post descent rates (distance divided by time) for their shapes and, if a shape is tested more than once, calculate the average of the descent rates.
2. Provide each pair of students with a golf ball–sized chunk of plasticine or water-resistant modeling clay.
3. Assign each pair a particular geometric shape to make and test in the diving tank.
4. Lead a class discussion on geometric shapes and diving rates.
5. Repeat the procedure, this time assigning an animal shape: sea turtle, starfish, sea urchin, shark, pinniped, or human. Have students study the images of pinnipeds in this story; find images of the other sea creatures online or in an encyclopedia. (Note: Some of the animals listed are not “divers.” Point out to students that animals that do not dive probably have body shapes not suited to diving.)
4. Have students use what they have learned to create and test their best diving body models.

Answers to Questions

Procedure questions

Streamlined or pointed geometric shapes usually descend faster. (A model’s rate of descent also depends on the way it is dropped: streamlined or pointed models descend faster when they enter the water pointed end first.)

Conclusion questions

Streamlined or pointed models descend faster (when they enter the water pointed end first); animals that have long, thin, tapered or wedge-shaped bodies are more suited to diving. Objects with larger surface areas have more water resistance and descend more slowly.

Adaptations

For elementary school students

Help students time how long it takes for the models to drop. Chart drop time rather than descent rate.

For high school students

Have students determine if geometric shapes made with twice the amount of clay have the same descent rate. Using a spring scale, have students devise a way to determine how much resistance the various models have when ascending. Are the best divers the best ascenders?

Teacher Preparation 5.3

Pinniped Feeding and Diving Behavior

Time Required
1½ hours (two 45-minute periods)

Level of Complexity
Medium to high

Additional Preparation
Split the class into six groups. Give each group one of the samples of pinniped prey remnants: the table to the right shows what each sample contains. (For concrete learners, consider putting construction paper cutouts of each prey item in a paper bag, in the quantities indicated.)

Patterns: California sea lions forage closer to coastal areas. Their dives are more frequent and shallower.

Answers to Questions
Master C

1. The northern elephant seal (NES) consistently dived deeper than the California sea lion (CSL).
2. The NES dived deeper in the afternoon (c. 650 meters) than between 3 a.m. and 5 a.m. (c. 475 meters); the CSL dived deeper in the afternoon (c. 160 m–175 m) than in the early morning (c. 50 meters).
3. The NES made about 5.5 dives in each of the 2-hour intervals recorded, or 2.75 dives per hour; the CSL made 16 dives in the afternoon (8 dives per hour) and 20 dives in the early morning (10 dives per hour).
4. The NES clearly spent more time at the bottom of its dives than at the surface. Though the NES is thought to sleep at those depths, it also probably did much of its feeding there. The CSL spent more time at the bottom of its dives in the early morning hours and more time at the surface in the afternoon hours.

Conclusion questions

1. Scientists use stomach contents, scat analysis, visual observations, tagging, and remote sensing/satellite equipment to track individual pinnipeds as they migrate and forage in the Pacific Ocean.
2. CSLs and NESs feed on some of the same species. However, the diet of the CSL includes more foods common to coastal regions. They do not dive as deep as NESs, which forage mostly on squid while traveling far out to sea.
3. Stomach contents may not show the true feeding patterns of NESs during their time far out at sea. Scat samples and stomach contents both reflect what an animal ate when it was close to shore. CSLs forage mainly in coastal waters, so their prey remnants may represent their actual diet better than NES stomach contents.

Adaptations
For elementary school students
Provide a plastic bag "stomach" or "scat sample" for each group: photocopy the prey pictures from **Master A** onto cardstock, enlarged, and place them into the plastic bags. Take time to discuss how the stomach contents would probably contain partially digested pieces of the prey.

For high school students
Students could research how scientists use scales and otoliths to determine the kinds and ages of various fish species. Students could also learn more about the deep scattering layer of the oceans.

Sample 1 6 market squid 4 North Pacific hake 18 northern anchovy	**Sample 2** 1 spiny dogfish 3 North Pacific hake
Sample 3 12 smooth lumpsucker 10 highsnout melamphid 6 slender blacksmelt 2 *Histioteuthis heteropsis* (squid) 3 *Octopoteuthis deletron* (squid)	**Sample 4** 10 smooth lumpsucker 8 highsnout melamphid 8 slender blacksmelt 12 *Histioteuthis heteropsis* (squid) 4 *Octopoteuthis deletron* (squid)
Sample 5 6 market squid 4 North Pacific hake 13 South American pilchard 2 bank rockfish 1 chub mackerel 10 northern anchovy	**Sample 6** 10 market squid 5 northern anchovy

Stomach Contents Sample	Prey (Percent of Total Prey)	California Sea Lion or Northern Elephant Seal?	Coastal or Pelagic Foraging?
1	Market squid (21%) North Pacific hake (14%) Northern anchovy (65%)	California sea lion	Coastal
2	Spiny dogfish (25%) North Pacific hake (75%)	Northern elephant seal	In transit to foraging grounds (semi-pelagic)
3	Smooth lumpsucker (36%) Highsnout melamphid (30%) Slender blacksmelt (18%) *Histioteuthis heteropsis* (6%) *Octopoteuthis deletron* (9%)	Northern elephant seal	Pelagic
4	Smooth lumpsucker (24%) Highsnout melamphid (19%) Slender blacksmelt (19%) *Histioteuthis heteropsis* (29%) *Octopoteuthis deletron* (9%)	Northern elephant seal	Pelagic
5	Market squid (17%) North Pacific hake (11%) South American pilchard (36%) Bank rockfish (6%) Chub mackerel (3%) Northern anchovy (28%)	California sea lion	Coastal
6	Market squid (67%) Northern anchovy (33%)	California sea lion	Coastal

Teacher preparation

Notes: