TCM Teacher Created Materials

Smithsonian

STEAM Readers

Science ▪ Technology ▪ Engineering ▪ Arts ▪ Mathematics

Lessons and Activities

Physical Science

Table of Contents

tcmpub.com | 800.858.7339

Smithsonian

STEAM Readers

Science ▪ Technology ▪ Engineering ▪ Arts ▪ Mathematics

Management Guide

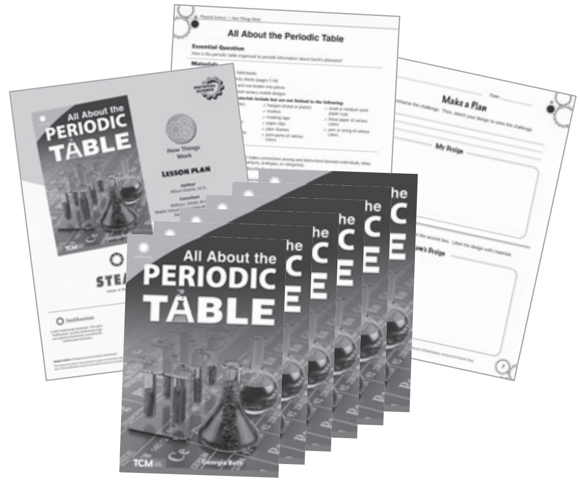
PHYSICAL SCIENCE

TCM Teacher Created Materials

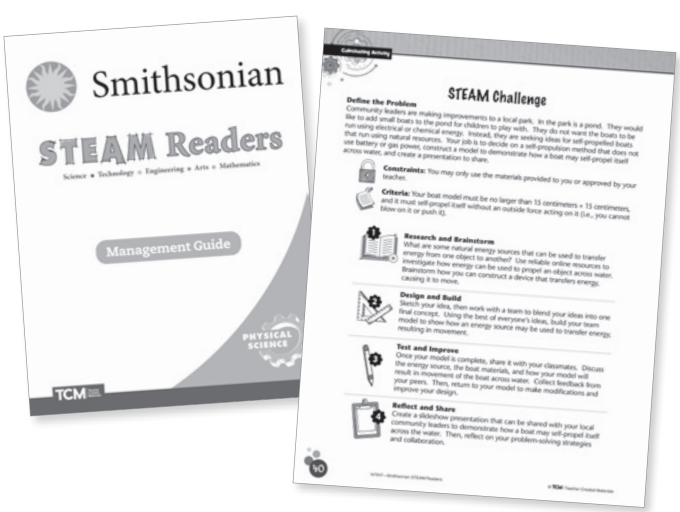
Table of Contents

Kit Components

16 lesson plans with 6 copies of each text



Management Guide with Culminating STEAM Challenge



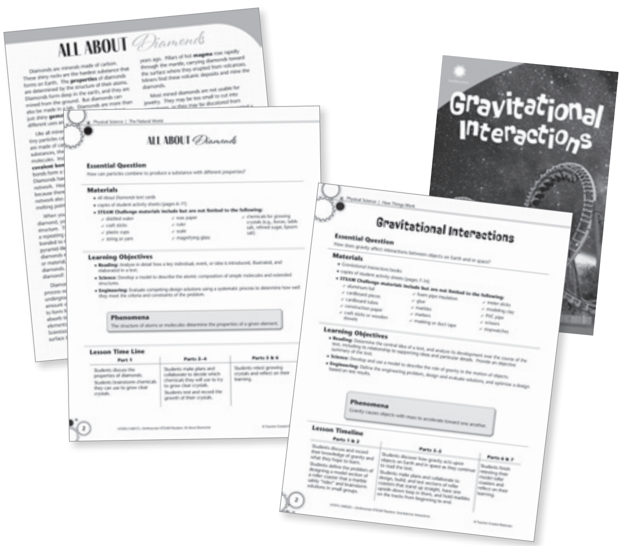
Digital Learning Resources

Lesson Plan Components

Each lesson sequence is organized in a consistent format for ease of use.

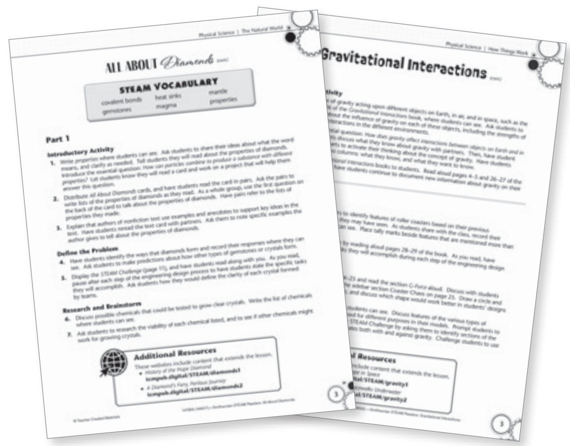
Overview

- The overview page includes the essential question, learning objectives, a materials list, and a suggested time line for lessons.



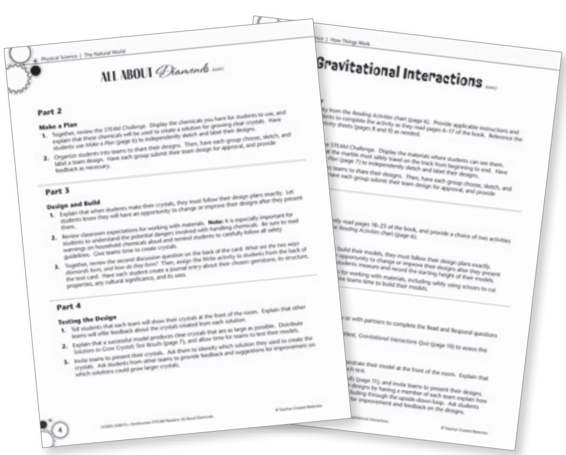
Introducing and Defining the Problem

- Students are presented with the essential question and science concepts in the text.
- Students are introduced to the STEAM Challenge, then actively read and research to help complete the challenge.



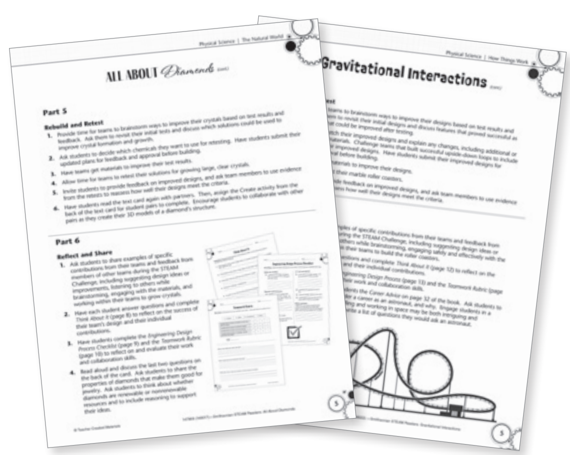
Designing, Building, and Testing the Solution

- Students create plans to solve the STEAM Challenge.
- Students apply their plans to design, build, and test their solutions.



Rebuild, Retest, Reflect, and Share

- Students take what they've learned and apply it to rebuild and retest their solutions.
- Students reflect, share work, and take assessments.



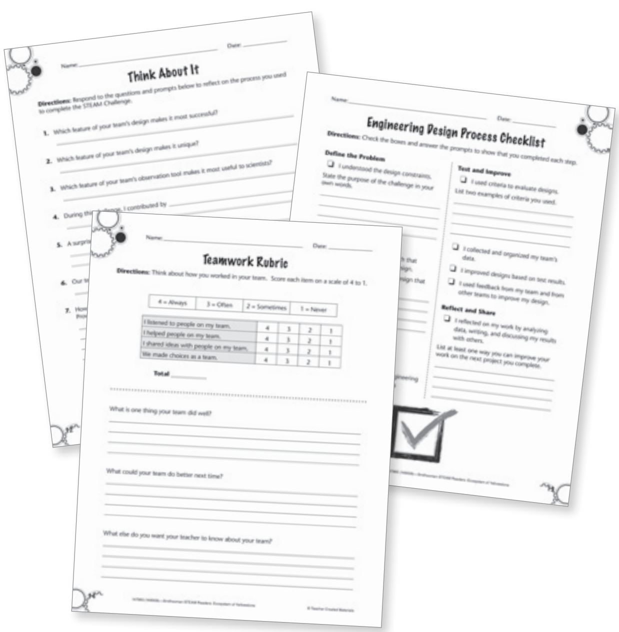
Lesson Plan Components *(cont.)*

Student Activity Sheets

Literacy skills are supported with meaningful activities that promote higher-order thinking skills.

STEAM Challenge activity sheets support students throughout the engineering design process.

Reflection activities provide opportunities for students to consider collaborative processes.



Appendix C includes quick reference sheets for students and teachers.

Smithsonian

Sonar and Submarine Technology

Eric Braun

TCM Teacher Created Materials

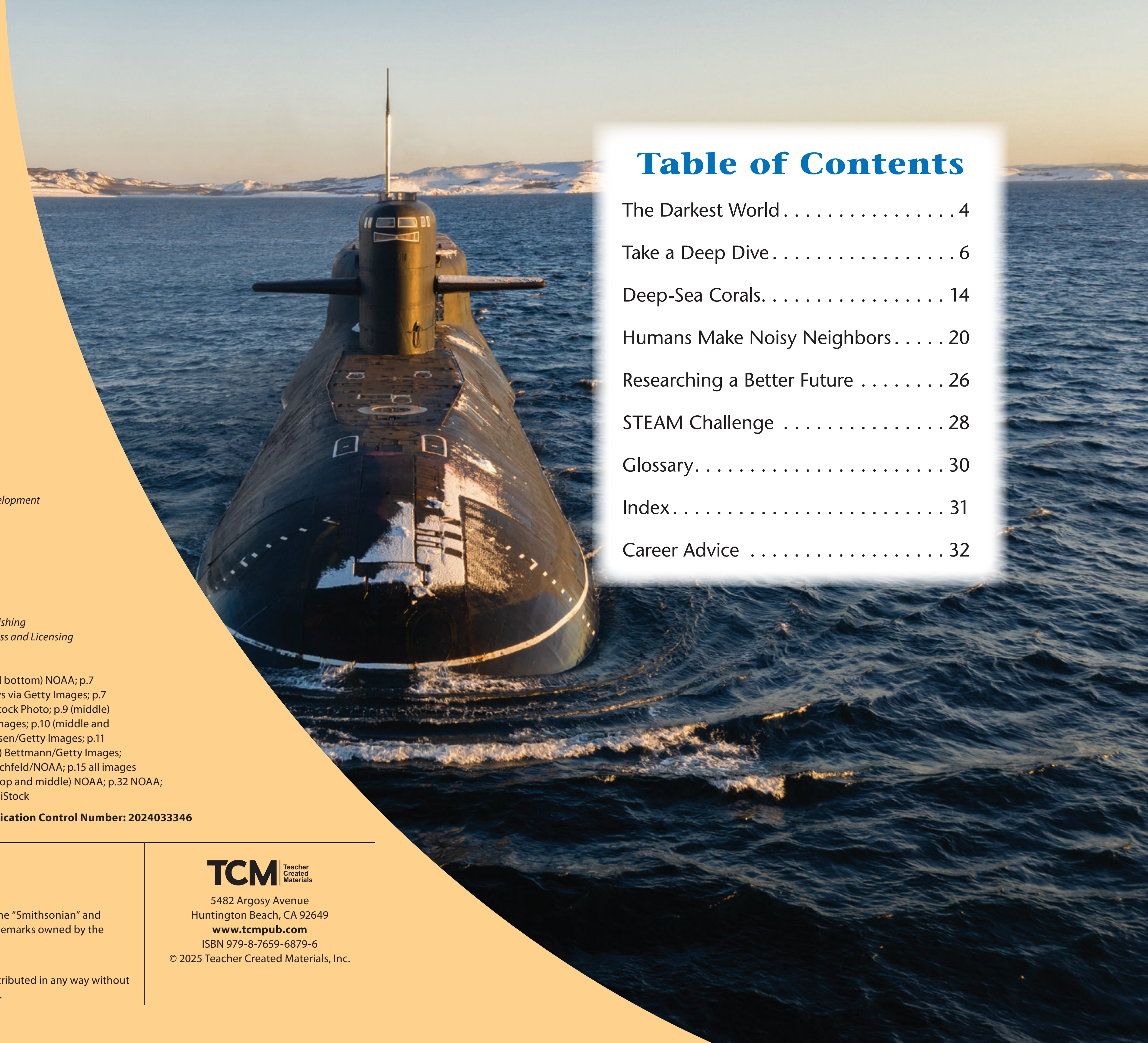


Table of Contents

Consultants

Dr. Aaron O'Dea
Staff Scientist
Smithsonian Tropical Research Institute

Cheryl Lane, M.Ed.
Seventh Grade Science Teacher
Chino Valley Unified School District

Michelle Wertman, M.S.Ed.
Literacy Specialist
New York City Public Schools

Publishing Credits

Rachelle Cracchiolo, M.S.Ed., *Publisher*
Emily R. Smith, M.A.Ed., *SVP of Content Development*
Véronique Bos, *VP of Creative*
Dani Neiley, *Editor*
Robin Erickson, *Senior Art Director*
Kevin Pham, *Senior Graphic Designer*

Smithsonian Enterprises

Avery Naughton, *Licensing Coordinator*
Paige Towler, *Editorial Lead*
Jill Corcoran, *Senior Director, Licensed Publishing*
Brigid Ferraro, *Vice President of New Business and Licensing*
Carol LeBlanc, *President*

Image Credits: p.4 NOAA; p.5 (middle and bottom) NOAA; p.7 (top) MediaNews Group/The Mercury News via Getty Images; p.7 (middle) NOAA; p.8 Homer Sykes /Alamy Stock Photo; p.9 (middle) James MacDonald/Bloomberg via Getty Images; p.10 (middle and bottom) NOAA; p.11 (top) Imeh Akpanudosen/Getty Images; p.11 (bottom) Art Howard/NOAA; p.12 (bottom) Bettmann/Getty Images; p.13 (top and bottom) NOAA; p.14 Deb Gochfeld/NOAA; p.15 all images NOAA; p.16 NOAA; p.17 (top) NOAA; p.27 (top and middle) NOAA; p.32 NOAA; all other images from Shutterstock and/or iStock

Library of Congress Cataloging in Publication Control Number: 2024033346

Smithsonian

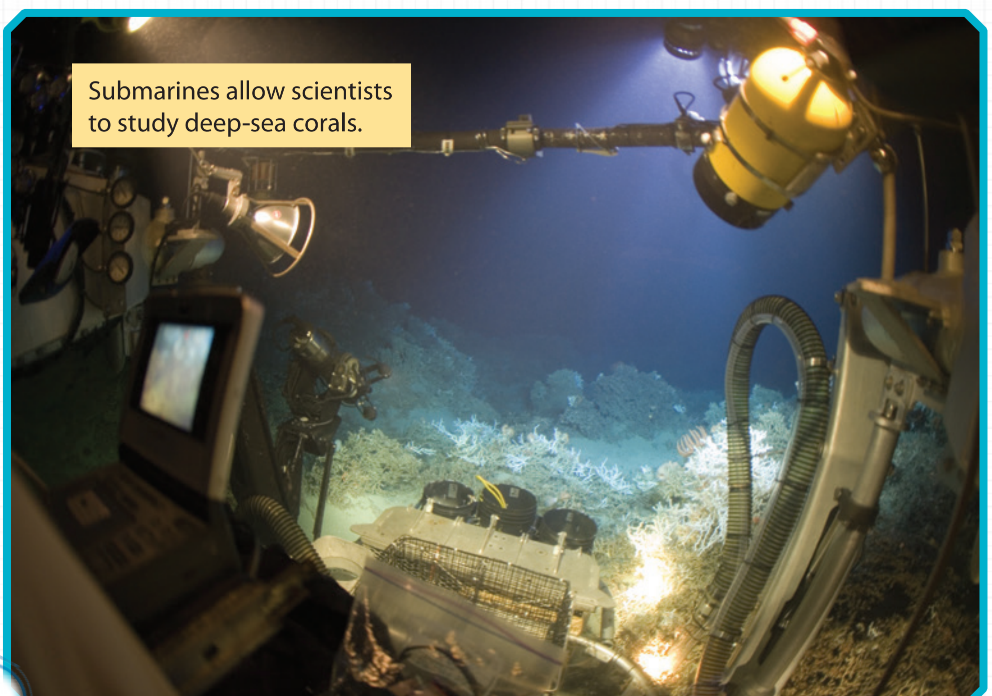
TCM Teacher Created Materials

5482 Argosy Avenue
Huntington Beach, CA 92649
www.tcmpub.com
ISBN 979-8-7659-6879-6

The Darkest World

Imagine that you are a **marine** biologist. You want to learn about underwater life and see what the seafloor looks like. So, you put on your wet suit and plunge into the icy waters to look around. But there's just one problem. As you sink, it gets darker and darker, until you can't see your hand in front of your face! How are you supposed to study the plants and wildlife if you can't even see them?

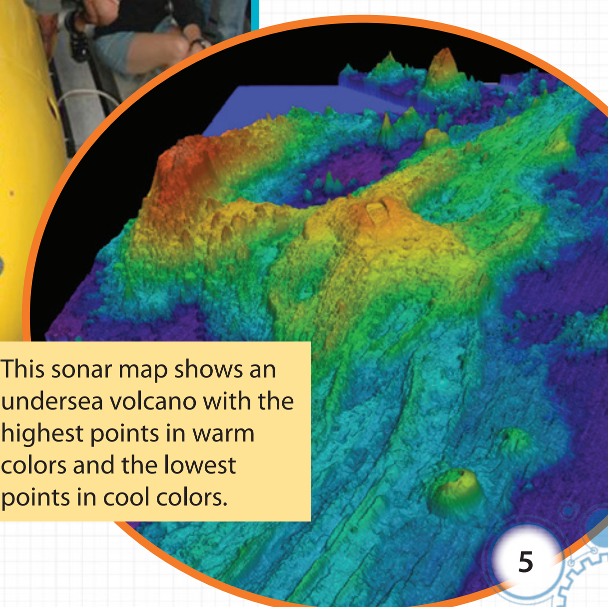
The answer is a type of technology called *sonar.* Scientists all over the world use sonar to learn about what they can't see with their own eyes. First, they send sound waves into the water. When the sound waves hit an object in the water or on the ocean floor, they bounce back. Computers record the bounces and produce a video or image that scientists can study. This allows scientists to identify fish and mammal species and track their movements and sizes. Scientists can also learn about predator and prey interactions.



Submarines allow scientists to study deep-sea corals.

Sonar can be **deployed** from different vessels, such as boats or **submarines**. When sonar is combined with submarine technology, it allows scientists to unlock many secrets of our oceans. For example, sonar and submarines have been used to map the seafloor, study deep-sea **corals**, and examine how humans affect whales.

Scientists prepare to launch a submarine that will map the oceans.

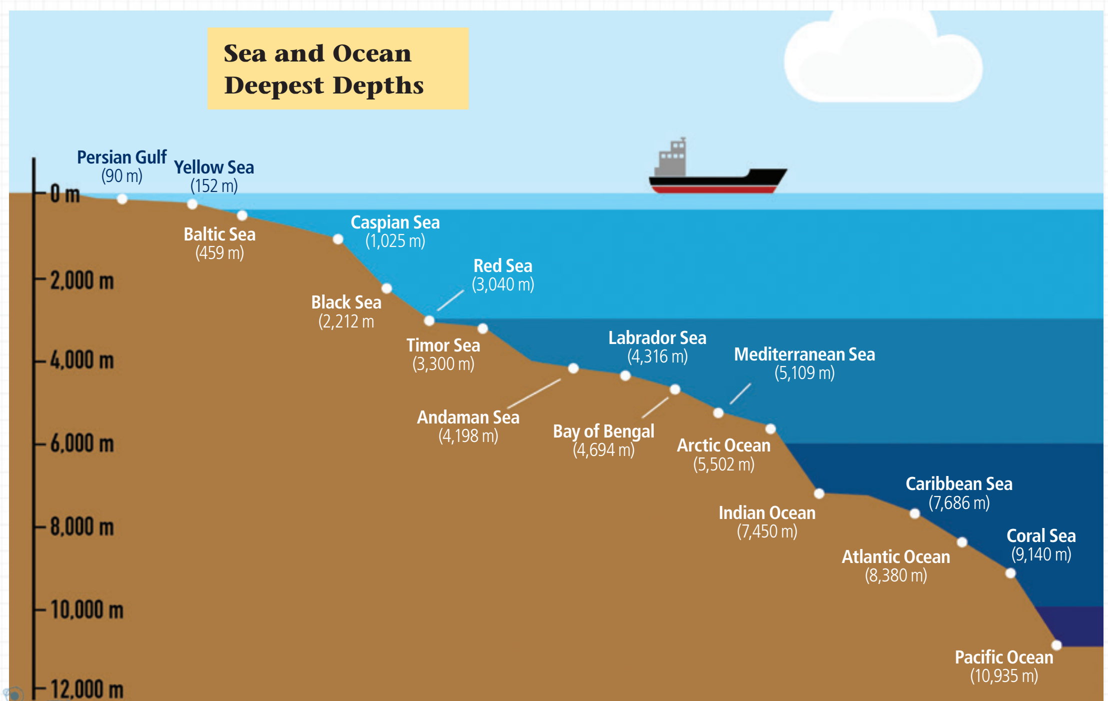


This sonar map shows an undersea volcano with the highest points in warm colors and the lowest points in cool colors.

Take a Deep Dive

You may know that oceans cover more than two-thirds of Earth's surface. But did you know that they make up about 95 percent of Earth's living space? That's because they're so deep. A vast and mysterious world lies beneath the oceans. Humans have only been able to explore a very tiny part of it.

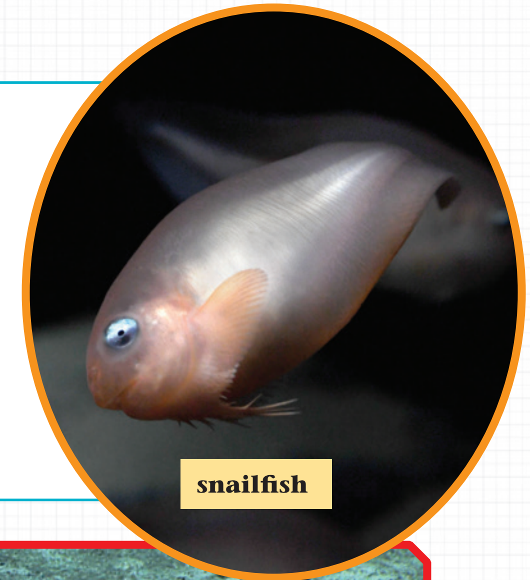
It's easy to see why most of the oceans have gone unexplored. Near the surface, some sunlight penetrates the water. But go deeper, and the light quickly begins to fade. The deepest that light has been seen is 700 meters (2,297 feet). Go deeper still, and the pressure of the water is a massive force. It takes great protective measures to withstand that force. The average depth of the oceans is 3,729 m (12,234 ft.). The water here is colder than the temperature of your refrigerator. The deepest parts of the oceans are more than 10,973 m (36,000 ft.) below the surface. That's almost 11 kilometers (7 miles)!



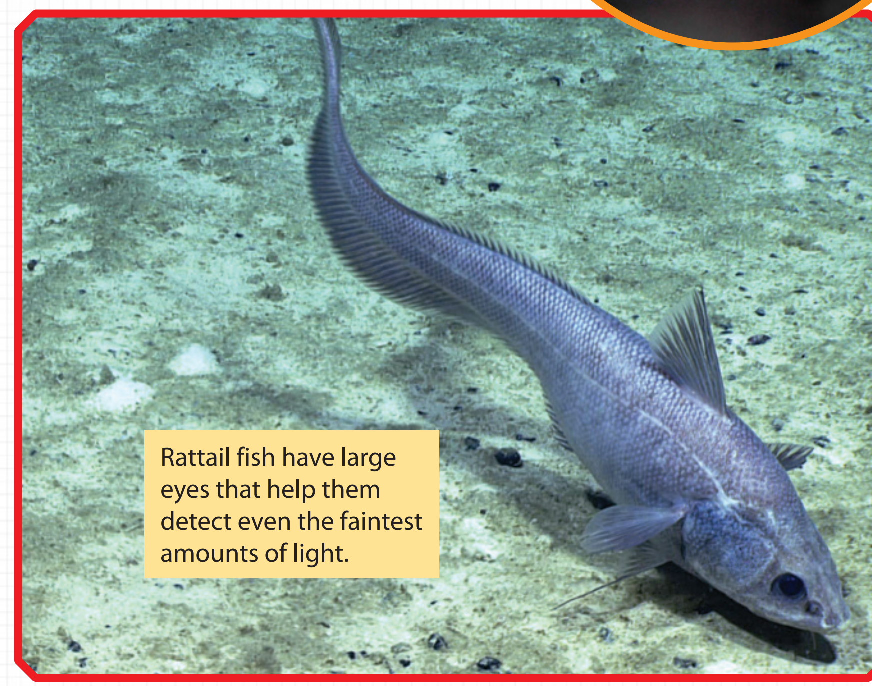
SCIENCE

Deepest Known Creature

Scientists discovered a snailfish swimming 8,178 m (26,832 ft.) below sea level. These pink, slimy fish are about 22.6 centimeters (8.9 inches) long. Their skulls have evolved to withstand the incredible water pressure at that depth.



snailfish



Rattail fish have large eyes that help them detect even the faintest amounts of light.

The farther away the water's surface is, the less food and light are available. However, life finds a way to exist in these depths. Animals that can stand the pressure include certain octopuses, sharks, rattail fish, and angler fish. Countless **microscopic** creatures survive there, too. And many creatures, such as sea cucumbers, can create their own light. This is done through a chemical reaction in their cells.

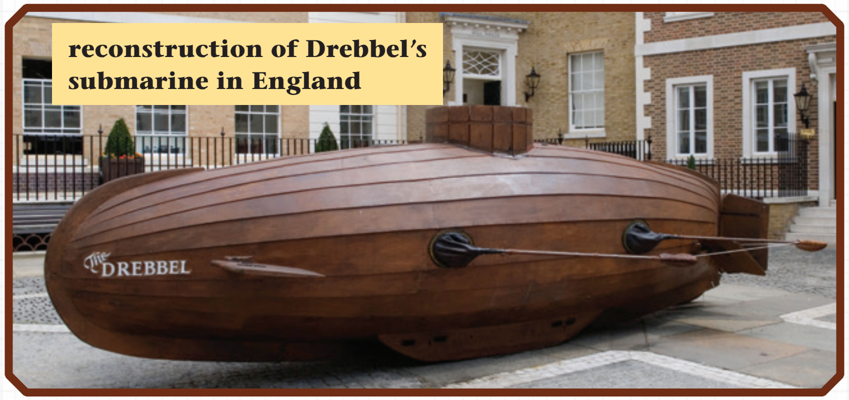
Studying Marine Life

Scientists study the oceans and marine life for many reasons. Scientists can learn about the **adaptations** of deep-sea creatures and how species in the oceans live. Learning about the oceans can also teach us to better manage the resources they provide. That helps us make sure they are still around for future generations. Finally, the oceans can reveal new plant and animal species.

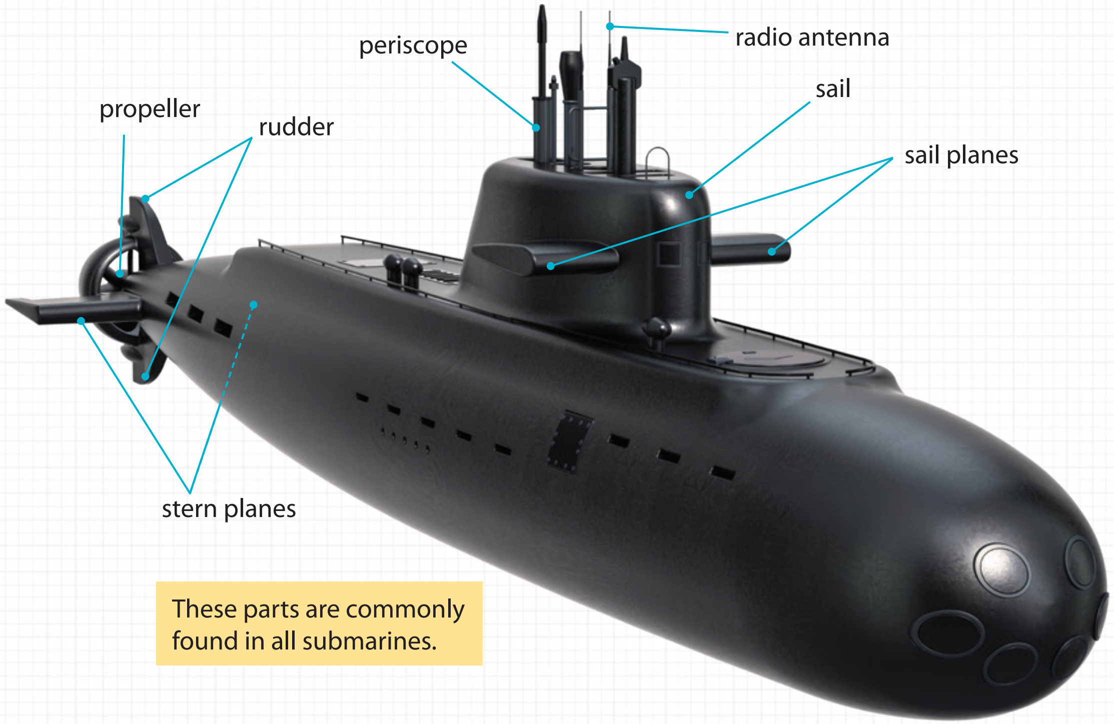
What else can the oceans teach us? We won't know unless we explore them. But the deepest parts of oceans are distant, alien worlds. They are very hard to explore. This is where underwater vehicles come in. They allow people to safely explore the depths.

The world's first submarine was created by a Dutch inventor named Cornelis Drebbel in 1620. It was a rowboat that was covered with greased leather to seal it against the water. Tubes that went up to the surface provided air. Drebbel used it to dive about 3.7 to 4.6 m (12 to 15 ft.) below a river's surface.

Submarine technology has come a long way since then. Since the late nineteenth century, motor-powered submarines have been navigating the seas. Today, scientists use a variety of technologically advanced underwater vehicles to help them explore the deepest parts of the oceans.



reconstruction of Drebbel's submarine in England



These parts are commonly found in all submarines.

ENGINEERING

Seaweed Savior?

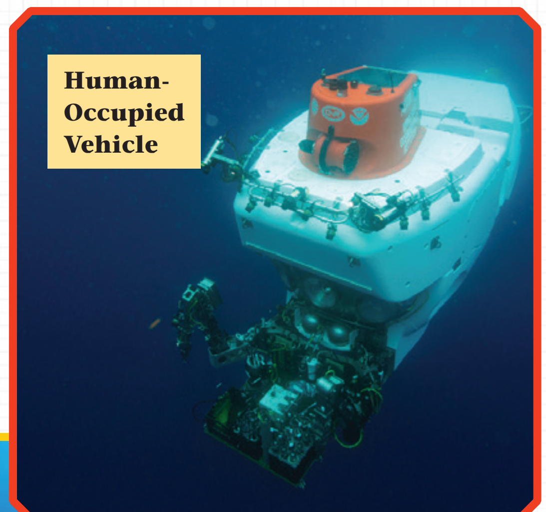
Scientists in Iceland are growing seaweed on buoys in the ocean. They think it might help fight **climate change**. That's because seaweed absorbs carbon from the atmosphere. Eventually, the buoys will be sunk to the seafloor. If everything goes according to plan, the carbon will be stored underwater for at least 800 years!

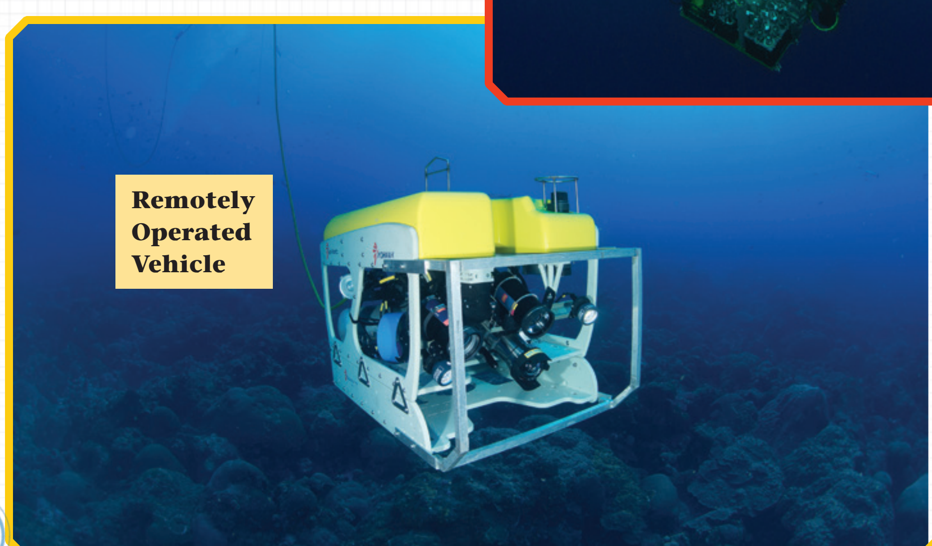
Underwater Vehicles

The underwater vehicles scientists use fall into three categories. Each type of vehicle is important for ocean research. Together, they form a super-useful toolkit.

Human-Occupied Vehicles (HOVs) carry a crew of scientists beneath the water's surface. These vehicles are used when scientists want to directly observe or work on something. They can collect samples and conduct experiments in real-time. This ability sets HOVs apart from other underwater vehicles.

Remotely Operated Vehicles (ROVs) are uncrewed, and scientists operate them from the surface. These vehicles are best for very precise tasks. They're also good in situations that require **endurance** and an extended time underwater. For example, they can collect samples from extreme depths or steer through tricky terrain. All the while, they provide a continuous stream of **data** and imagery.


Human-Occupied Vehicle


Remotely Operated Vehicle

ARTS

Film Director in the Abyss

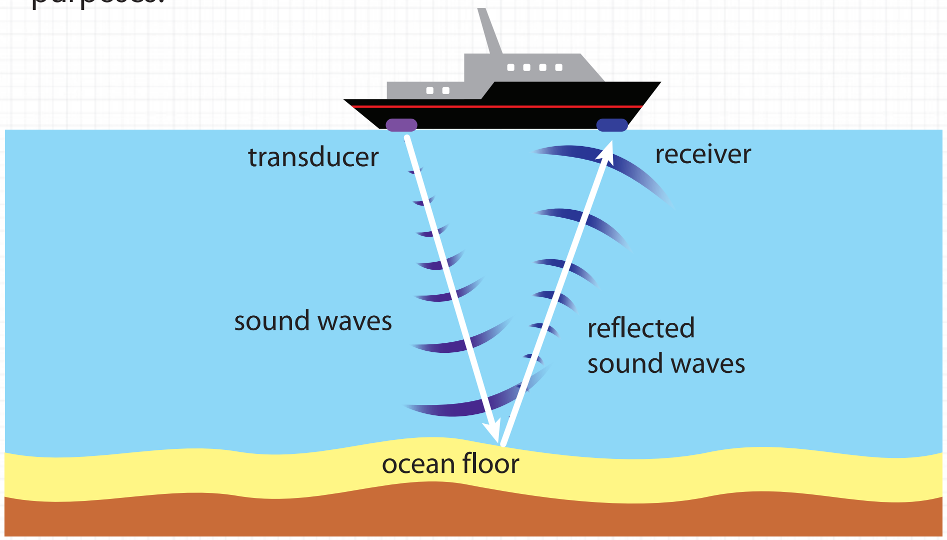
In 1989, film director James Cameron released the film *The Abyss*. It explores the challenges of deep-sea exploration and run-ins with unknown marine creatures. In 2012, he furthered his love of deep-sea exploration. He piloted a solo submarine trip nearly 11.3 km (7 mi.) underwater!

Autonomous Underwater Vehicles (AUVs) are also uncrewed. But unlike ROVs, they are not directly controlled by humans. Instead, they go on preprogrammed missions. These vehicles can cover large areas efficiently. That makes them best for jobs like mapping the seafloor. Plus, they stay on task for a long time without any help from people. They are a cost-effective way to gather huge amounts of data.


Autonomous Underwater Vehicle

Seeing What Can't Be Seen

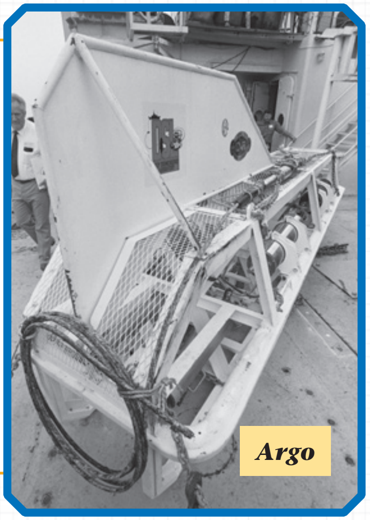
Most underwater vehicles have lights that scientists use to see in the dark. But some vehicles have another way of seeing: sonar. *Sonar* is a shortened word for "sound navigation and ranging." This technology uses sound waves to find the locations of objects. First, a part called a ***transducer*** sends out sound waves into the water. The sound waves hit any objects and bounce back as echoes. Then, the echoes are sent to a display where scientists can see them on a screen. Scientists study these echoes for many purposes.



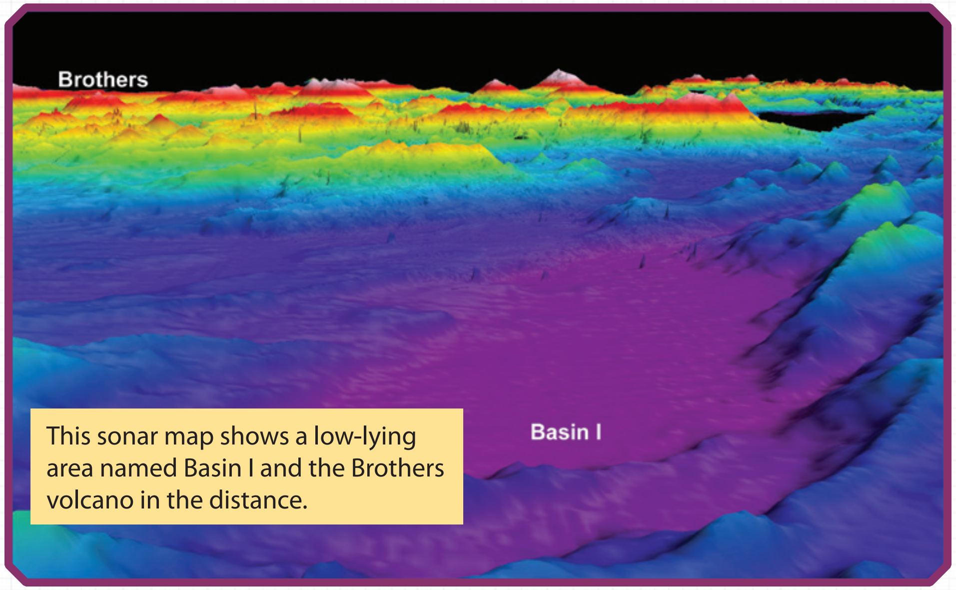
TECHNOLOGY

Shipwreck Site

In 1912, a luxury cruise ship called the *Titanic* sank in the ocean. In 1985, scientists used sonar to locate the remains of the sunken ship. A ROV called *Argo* was used to find the *Titanic*. *Argo* was equipped with various sensors, including sonar sensors. *Argo* sent detailed sonar images of the shipwreck's location to scientists working on the surface.



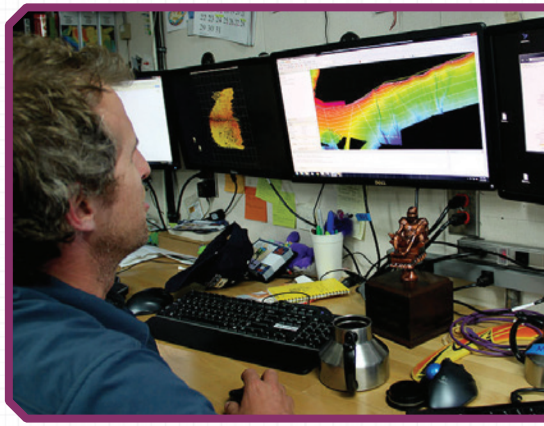
Argo



This sonar map shows a low-lying area named Basin I and the Brothers volcano in the distance.

Scientists have used sonar to map the seafloor. Ships or submarines send sound waves deep into the ocean. The returning echoes help create precise maps. The transducer can determine the range of objects based on how long the echoes take to bounce back. Maps created with sonar can show undersea mountains, volcanoes, valleys, and other features. These maps help scientists understand what Earth's crust looks like. They also help scientists understand ocean activity. That includes factors such as currents, tides, and temperature variations.

Scientists also use sonar to study marine life. Scientists use AUVs that have sonar to track the behavior of marine animals. For instance, researchers use sonar to study the **migration** patterns of whales. Sonar data provides insights into the whales' behavior and how they travel. This helps scientists protect them and their **habitats**.



Deep-Sea Corals

When you think of ocean corals, you probably think of shallow-water species. These corals are colorful and beautiful—and important. One-quarter of all ocean species depend on coral reefs for food and shelter. That's why corals are known as the rainforests of the sea.

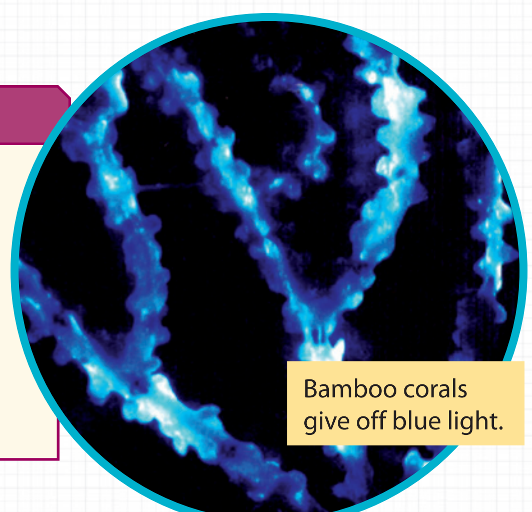
What might surprise you is that corals also live in the deepest parts of the ocean. Scientists have discovered almost as many deep-sea corals as they have shallow-water corals. Deep-sea corals do not need to depend on sunlight to survive. Instead, they get **nutrients** by trapping tiny organisms from passing ocean currents. These corals can also thrive in the coldest ocean water. They have even been found off the icy coast of Antarctica.

As recently as the turn of the century, scientists did not know very much about the existence of deep-sea corals. They didn't know where these corals could be found. But in the last 20 years, they have learned a lot. For example, they have discovered more than 3,300 species of deep-sea corals.

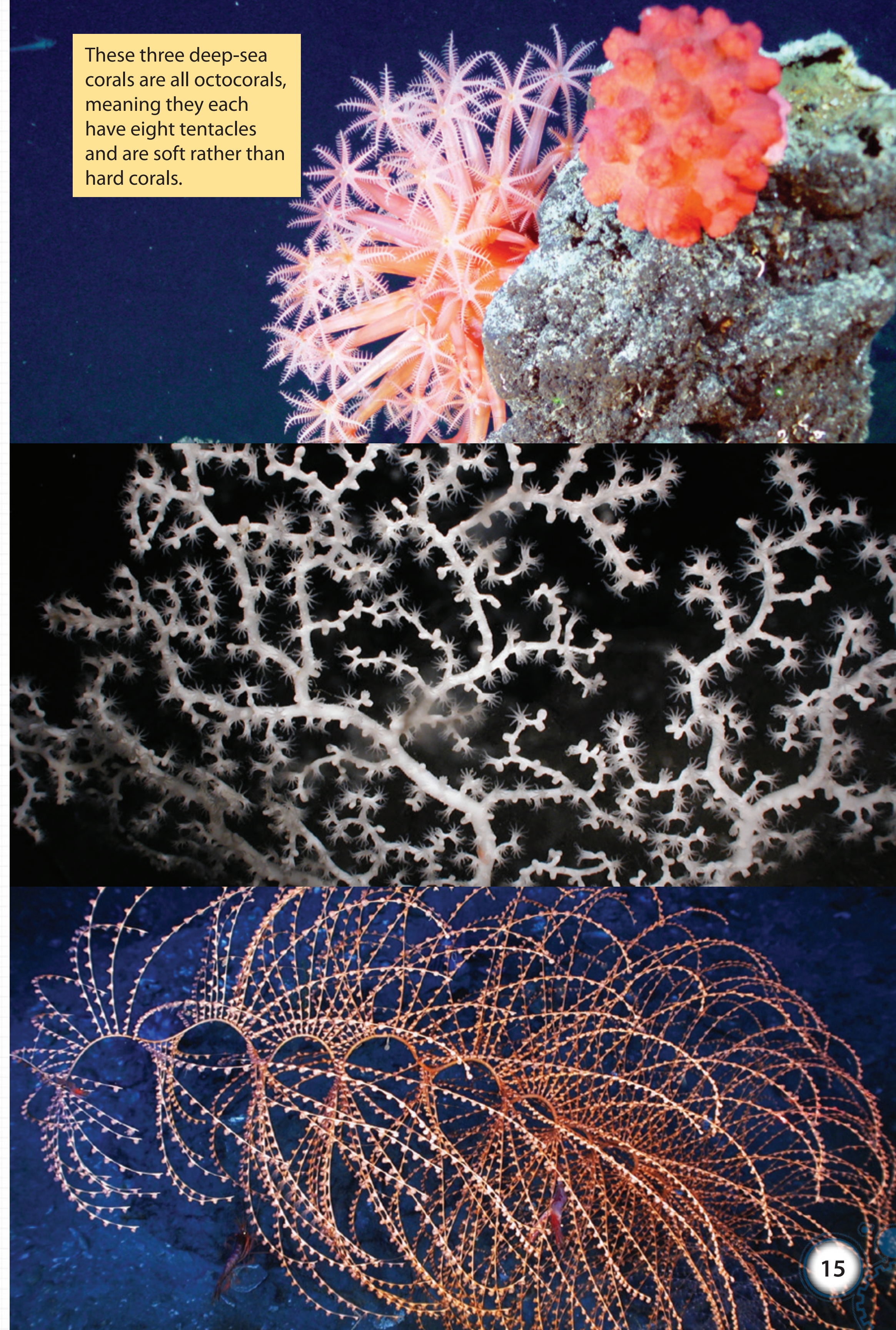
How have scientists learned all this new information about deep-sea corals? You guessed it—submarines and sonar. Both technologies have unlocked many mysteries about these marine organisms.

FUN FACT

Some species of deep-sea corals glow in the dark! This ability helps them attract prey, which are drawn in by the light. Scientists also think that this ability may serve as a form of communication among corals.



Bamboo corals give off blue light.

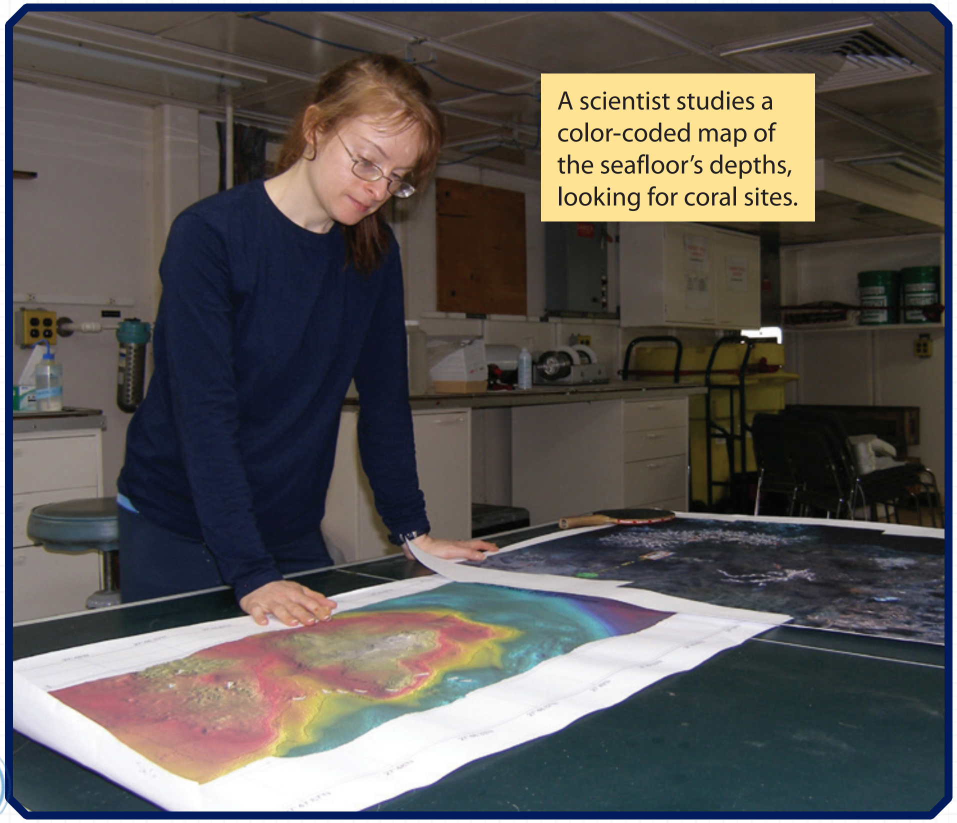


These three deep-sea corals are all octocorals, meaning they each have eight tentacles and are soft rather than hard corals.

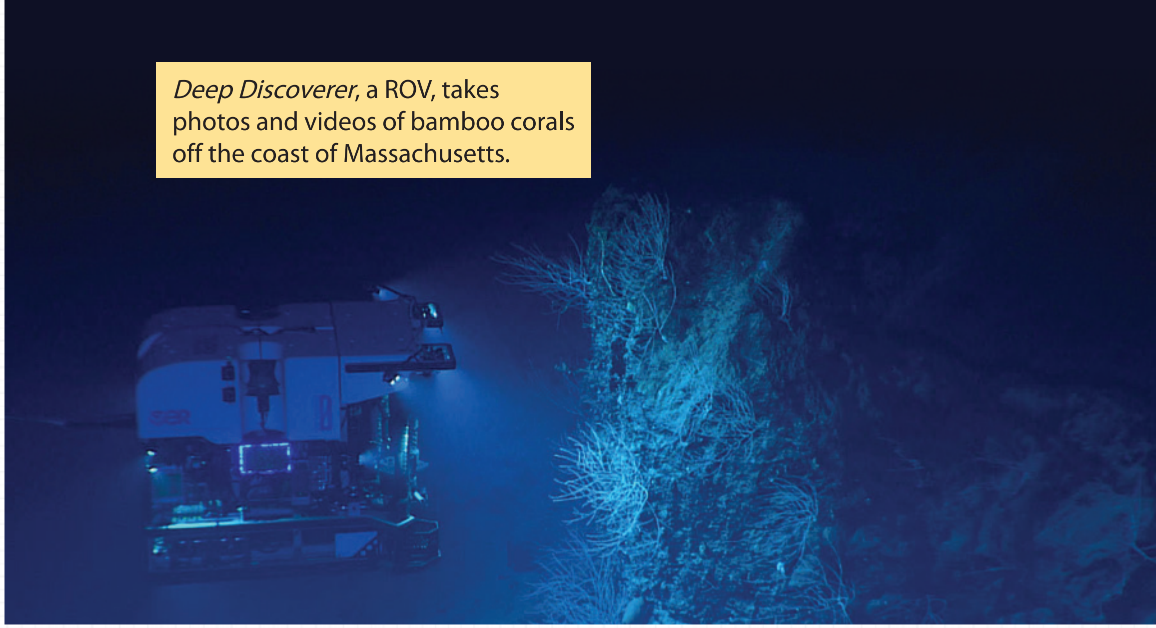
Studying Corals

Underwater vehicles are the key to studying deep-sea corals. These vehicles are used to help create 3D maps of the seafloor. To do this, the vehicles are equipped with sonar devices. The devices are put into watertight shells that are mounted on the vehicles. Then, the devices send pulses of sound waves into the water. Computers measure how long it takes for the sound waves to travel to the seafloor and bounce back. All these measurements are put together into one image. Colors are used to show different depths. In this way, sonar can create colorful maps of the seafloor.

Scientists use these maps to pinpoint areas where deep-sea corals might be found. Then, they can figure out where to do additional research. The sonar maps also provide information about the conditions where these corals live, which is useful to scientists.



A scientist studies a color-coded map of the seafloor's depths, looking for coral sites.



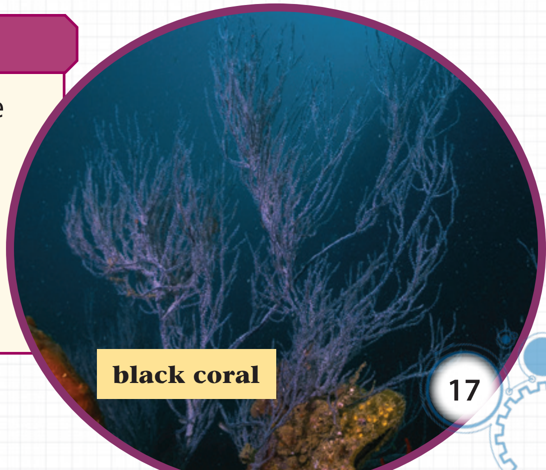
Deep Discoverer, a ROV, takes photos and videos of bamboo corals off the coast of Massachusetts.

Underwater vehicles allow scientists to learn about the most remote deep-sea coral habitats. Some of these vehicles are HOVs, like the *Pisces V*. Scientists use this vehicle to study the waters around the Hawaiian Islands. But HOVs can also travel deep into the oceans. Once there, scientists can observe deep-sea corals in person. With ROVs and AUVs, scientists can study regions that they couldn't reach otherwise.

These vehicles have underwater cameras. They take close-up photos of deep-sea corals. Super-precise robotic arms on these vehicles can collect samples of water, coral, and more. When these vehicles return to the surface, scientists study the samples in a lab.

FUN FACT

Deep-sea corals and sponges can live for thousands of years. Scientists have found a black coral that was more than 4,250 years old. The oldest sponge ever found is estimated to be between 11,000 and 13,000 years old!

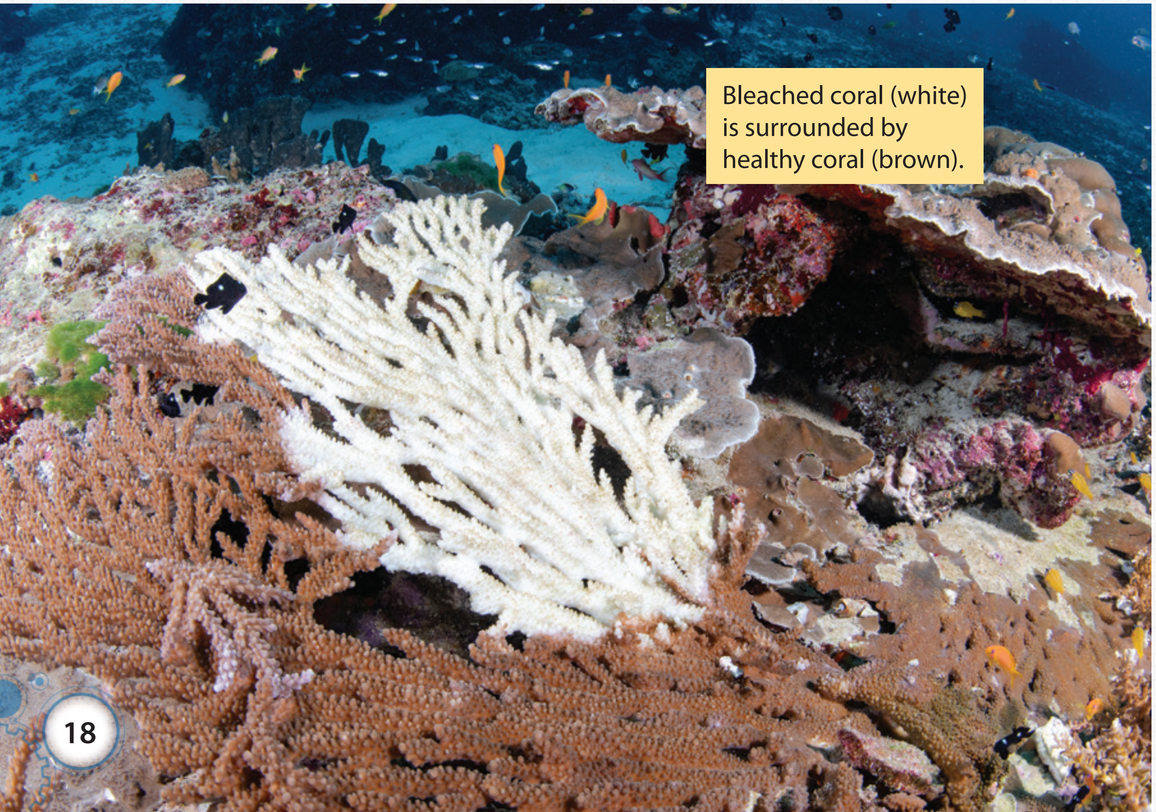


black coral

Identifying Threats

With sonar and submarines, scientists have learned about many threats to deep-sea corals. For starters, the rise in **carbon dioxide** levels in oceans is a big threat. These increased levels are a result of human pollution. Higher levels of this gas cause the oceans to become more acidic at a fast pace. If the water has too much acid, it can weaken the skeletons of corals.

Warm water is a huge threat to corals. And the temperature of ocean waters is rising due to the use of **fossil fuels**. This increased warmth causes the algae that live on coral to die out. Corals depend on algae for food. As colorful algae disappear, corals are left ghostly white. This is called *coral bleaching*. While corals can survive in this state, they are at higher risk of death. Sometimes, only a section of a coral will become bleached while the rest of it remains healthy.



Bleached coral (white) is surrounded by healthy coral (brown).

Humans affect the health of corals in other ways, too. **Overfishing** of corals disrupts reefs. Boat anchors and divers can scar reefs if they get too close. Plus, some sunscreens that wash off swimmers' bodies are also harmful.

The good news is that scientists keep learning more about these threats. They spread the word about protecting corals. As a result, some countries have passed laws to create protected areas. In these waters, fishing and boating activities are not allowed.

An abandoned anchor chain from a boat damaged the corals it fell on.

MATHEMATICS

Rising Ocean Temperatures

Before gas engines were invented, average global sea temperatures were lower. But the average global temperature has been steadily rising. Scientists have discovered that ocean temperatures rise 0.28 °C (0.5 °F) every decade.

Humans Make Noisy Neighbors

Humans use sonar to create maps that help them navigate oceans. Did you know that some animals use sound waves to locate objects, too? For example, bats use a process called ***echolocation*** to guide them and locate food as they fly in the dark. Certain ocean mammals do the same thing.

Imagine a pod of dolphins swimming gracefully through the ocean. As they swim, they make clicking sounds. These sound waves spread out into the water and bounce back when they hit an object. Dolphins receive these sound waves, which travel into their brains so they can interpret the sounds as images. In a way, this allows dolphins to "see" with their ears. One of the main reasons why dolphins use echolocation is to find food. Their clicks bounce off fish or other prey in the water. This allows dolphins to know exactly where to catch their next meals.

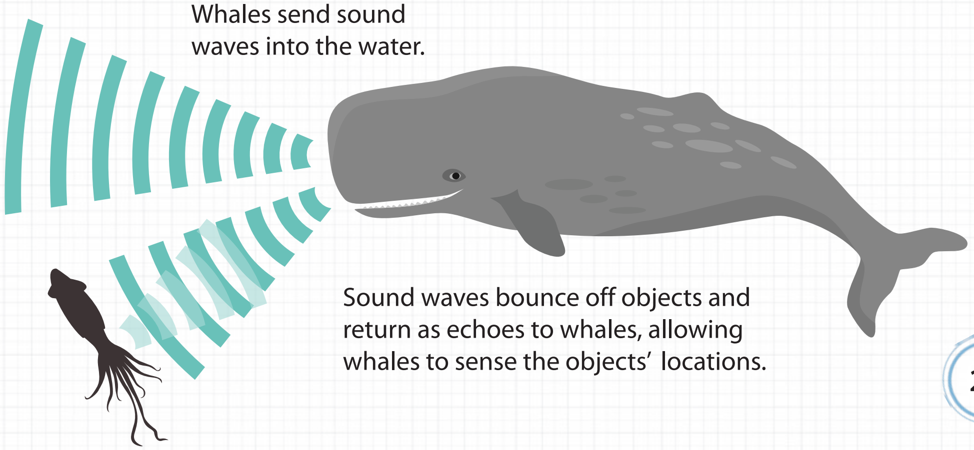
Dolphins work together in their pods to find schools of fish to eat.

FUN FACT

Blue whales can create intense, low-frequency sounds. These sounds can travel for thousands of kilometers. This is one of the longest-distance communication methods in the animal kingdom!

Like dolphins, whales use echolocation for their daily tasks. Whales produce clicks and sounds that serve useful purposes. They use echolocation to find food and communicate with others. Whales create patterns of clicks and calls to send messages to other whales in their pods. This helps them stay connected with their families and communities in the vast ocean. Whales also use echolocation to navigate through the water. Using their clicks and other sounds, they can detect the seafloor and other obstacles. This ensures safe travels during their long migrations or daily movements.

Echolocation Process



Human Effects

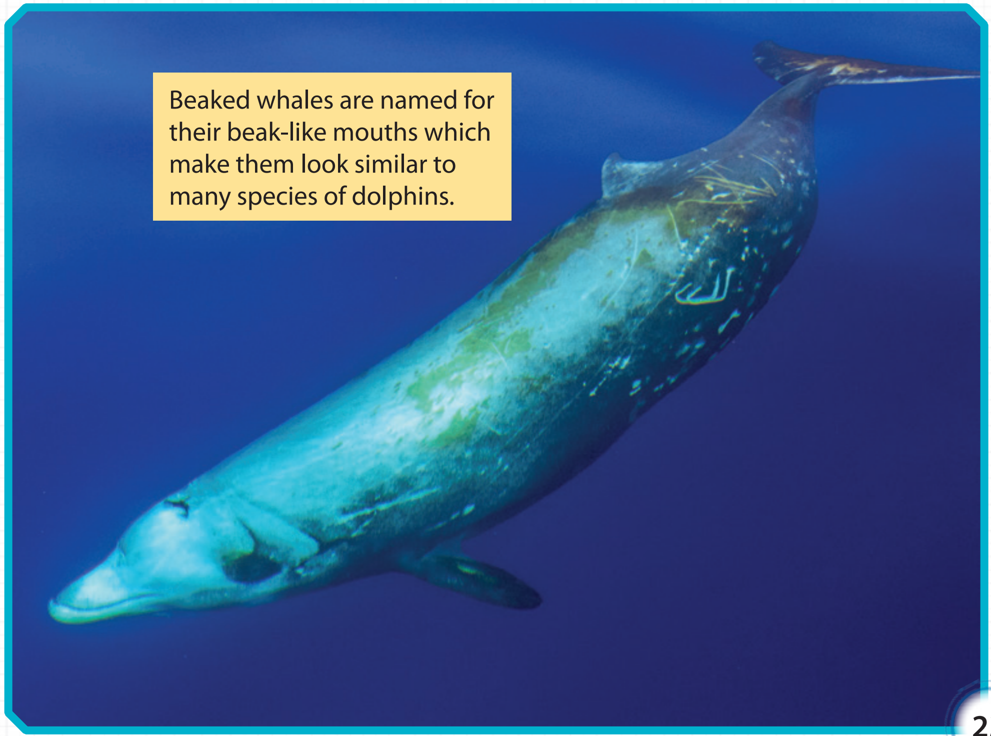
For animals that depend on echolocation to survive, human activity can be a real problem. Extra noise caused by humans disrupts the life of marine animals. Large container ships make a constant hum as they travel, which drowns out whale calls. Stress from human sounds can also affect seals, tuna, and oysters.

Military use of sonar is known to cause beaked whales to **ascend** rapidly. They try to escape from the sonar pulses. However, ascending too fast can cause dangerous blood clots in the whales. And some of these whales have stranded themselves on beaches after surfacing.

U.S. Navy ship

In the mid-2000s, scientists wanted to learn more about this behavior. They knew that beaked whales are a deep-diving species. They were likely to be in deep canyons below areas where the U.S. Navy conducted training exercises. And sonar was used as a part of those exercises. Scientists figured out that the echoes from the sonar might be bouncing around the canyons, deeply affecting the whales.

Scientists wanted to know exactly what happened to whales when they encountered sonar. So, they developed a plan for safely testing sonar sounds on marine animals. They first went to a Navy training range in the Bahamas. There, scientists used the Navy's high-tech tools to find and track beaked whales. Scientists tagged the whales with suction-cup listening devices. Then, they played simulated sonar sounds to the whales and listened to their responses. As they expected, beaked whales had negative reactions.

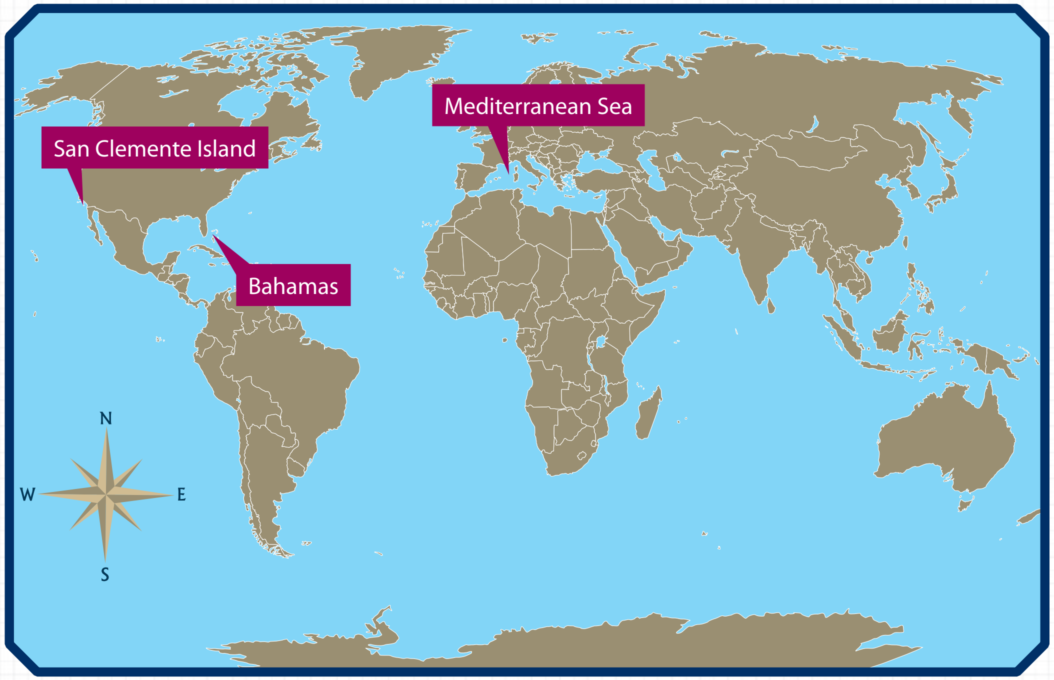


Beaked whales are named for their beak-like mouths which make them look similar to many species of dolphins.

Testing Results

Scientists worked on this project for two years in the Bahamas and one year in the Mediterranean Sea. They tracked the responses of several types of whales as well as seals. Then, they went to the coast of California. They focused on the waters around a U.S. Navy training range near San Clemente Island. There, they monitored 21 species of whales, dolphins, seals, and sea lions.

Of all the animals scientists tested, they found that beaked whales were the most sensitive to the sounds. Blue whales, on the other hand, showed almost no reaction. While other mammals tried to avoid the sounds, they did not change their behavior patterns. All this data confirmed scientists' original theories that sonar negatively affected beaked whales.



Cargo ships like this one can hold thousands of containers' worth of goods.

Years later, scientists collected more evidence that human noise stresses out whales. Researchers tested samples of whale feces during the COVID-19 pandemic. During the early stages of the pandemic, cargo ships were mostly stopped from traveling. Compared to samples from earlier and busier times, the COVID-19 samples showed a big drop in stress hormones. Scientists learned that whales were less stressed when there were fewer ships in the oceans.

Scientists have more work to do, but these findings help them better understand ocean mammals. The more they learn, the better they will know how to protect and conserve these animals.

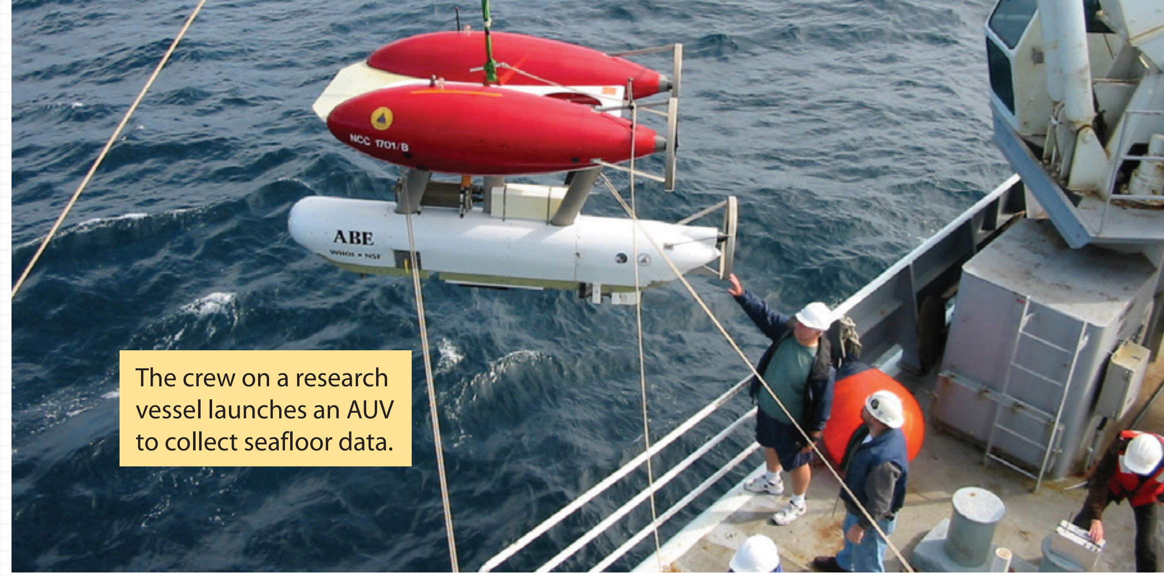
Researching a Better Future

Sonar and submarine technology continues to advance in exciting ways. New projects help scientists learn more about the ocean. For example, scientists have trained teams of sonar-equipped AUVs to work together. These vehicles act like packs of animals in the wild. They communicate with one another and learn as they collect data. This allows them to make decisions about where to go. They produce detailed seafloor maps quickly and efficiently.

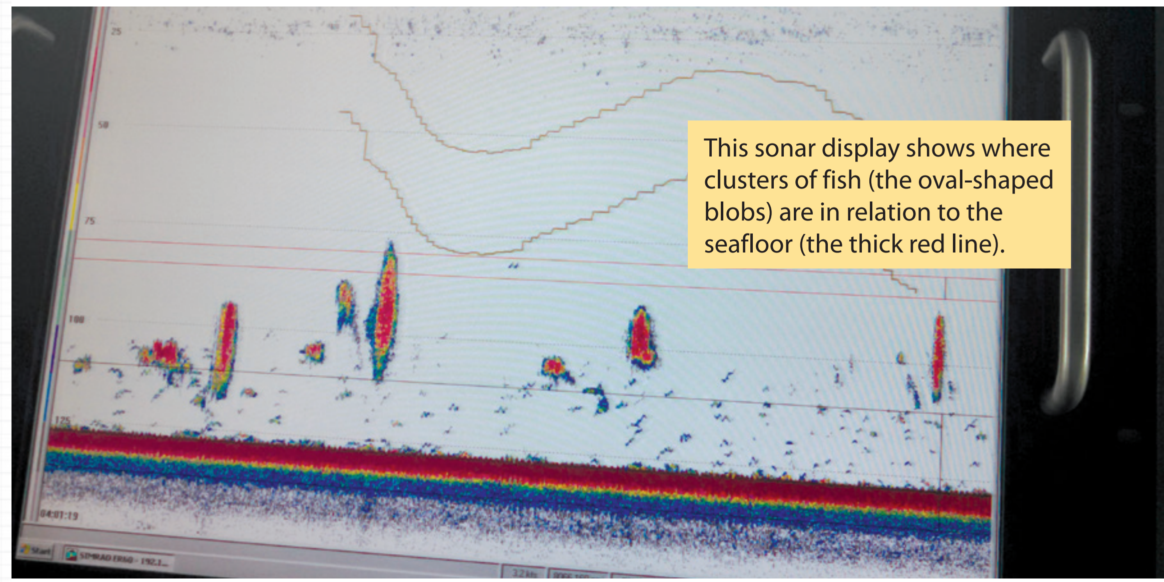
Scientists are also developing smaller, more portable sonar sensors. These are used on AUVs. Smaller sensors make these vehicles easier to maneuver. It allows them to collect data in areas that larger vehicles can't access.

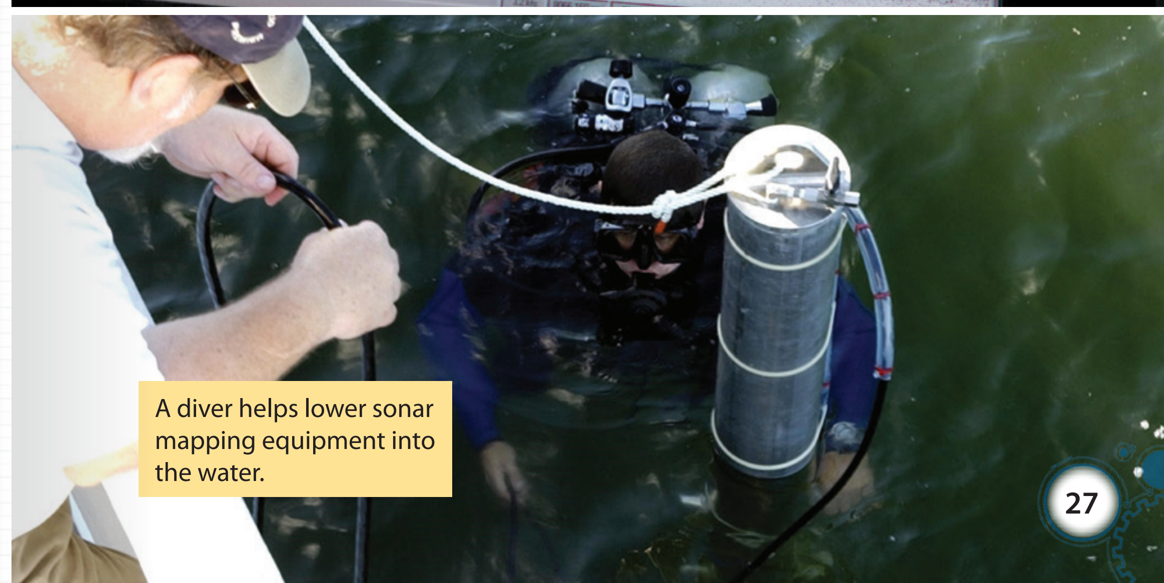
However, advances are not all about AUVs. New, super-light **ultrasound** sonar devices are coming soon. They will help humans communicate underwater. Since traditional radio does not travel well in water, communication is difficult. But these new devices use ultrasound sonar. They will allow people to judge distances, find obstacles, and communicate in a similar way to dolphins and other sea mammals. They can even be used to communicate through objects, such as steel.

Oceans make up the vast majority of Earth's living space. Scientists are using underwater vehicles and sonar to learn more about them every day. The hope is that these cutting-edge tools can help people preserve them.



The crew on a research vessel launches an AUV to collect seafloor data.


This sonar display shows where clusters of fish (the oval-shaped blobs) are in relation to the seafloor (the thick red line).


A diver helps lower sonar mapping equipment into the water.

STEAM CHALLENGE

Define the Problem

Submarines travel throughout the oceans, sinking and rising to different depths. But their engines can have a negative effect on marine life due to the sound waves they create. So, marine biologists are partnering with naval architects to address this problem. They want to create a new protective material that can be used to make submarines. They want this material to help reduce engine sound waves from bouncing off submarines and spreading. Now, they've asked you to test your ideas for a sound-reducing submarine.

Constraints: You may only use the materials that are provided for you.

Criteria: Your submarine must be large enough to fit a cell phone inside but small enough to carry in your hands. The submarine must open and close.

Research and Brainstorm

What is amplitude, and how is it measured? How can sound waves be reflected, absorbed, and transmitted through various materials? What types of materials help reflect or absorb these waves the best? How can your design reduce sound waves to prevent them from reaching the exterior?

Design and Build

Sketch two designs for your sound-reducing submarine. Be sure to label the materials you intend to use. Partner with a small group of classmates to share your ideas. Then, design and build a final submarine that incorporates everyone's ideas.

Test and Improve

Play a song on a cell phone, turning the volume up all the way. Then, put the cell phone inside your submarine and close the opening. Using a laptop or tablet, go to a sound level meter website. Test all four sides of your submarine, recording the decibel reading at each location by setting the laptop or tablet 30 centimeters (12 inches) from the submarine. How can you reduce the noise even more? Modify your design, rebuild it, and test your second prototype with the same sound level check.

Reflect and Share

How did your knowledge of sound waves help you when constructing your model? What part of the process did you enjoy the most during this challenge? Was anything difficult for you and your group? How did you overcome it?

Glossary

adaptations—the ways living organisms change over time to better survive in their environments

ascend—to go up or climb

autonomous—capable of controlling itself without outside help (like from humans)

carbon dioxide—a colorless, odorless gas that is produced by burning carbon and organic compounds; contributes to global climate change

climate change—the ongoing increase in average global temperatures that affects Earth's climate

corals—marine invertebrates that live in colonies as individual polyps or as reefs

data—facts and statistics collected to be studied

deployed—used for a specific purpose

echolocation—a process for locating distant or invisible objects by sound waves reflected back to the animal from the objects

endurance—the ability to sustain a prolonged stressful effort or activity

fossil fuels—fuels such as coal, oil, or natural gas that are burned for power, heat, or electricity

habitats—the natural homes or environments of animals, plants, or other organisms

marine—having to do with the sea

microscopic—only able to be seen through a microscope

migration—the movement of animals from one location to another

nutrients—substances that provide nourishment for living things

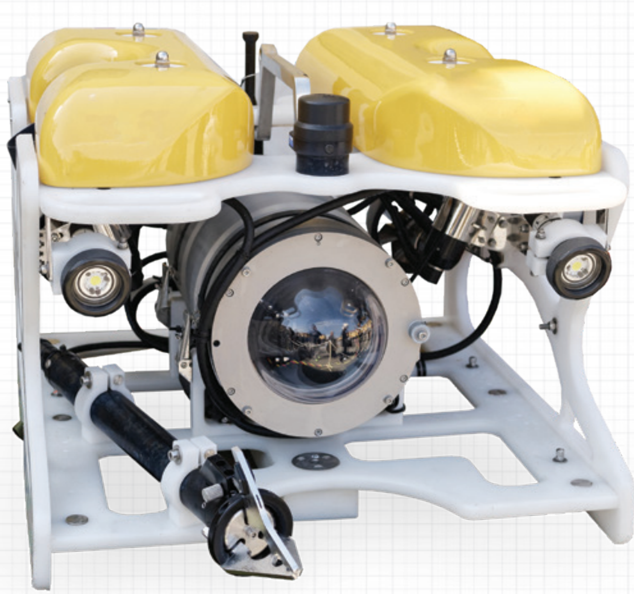
overfishing—removing a species of fish from an area by too much fishing

submarines—watercrafts that can go underwater; also known as underwater vehicles

transducer—device that converts energy from one form to another

ultrasound—sound that has a frequency above 20,000 hertz

Index



CAREER ADVICE
from Smithsonian

Do you want to work with sonar or submarines?

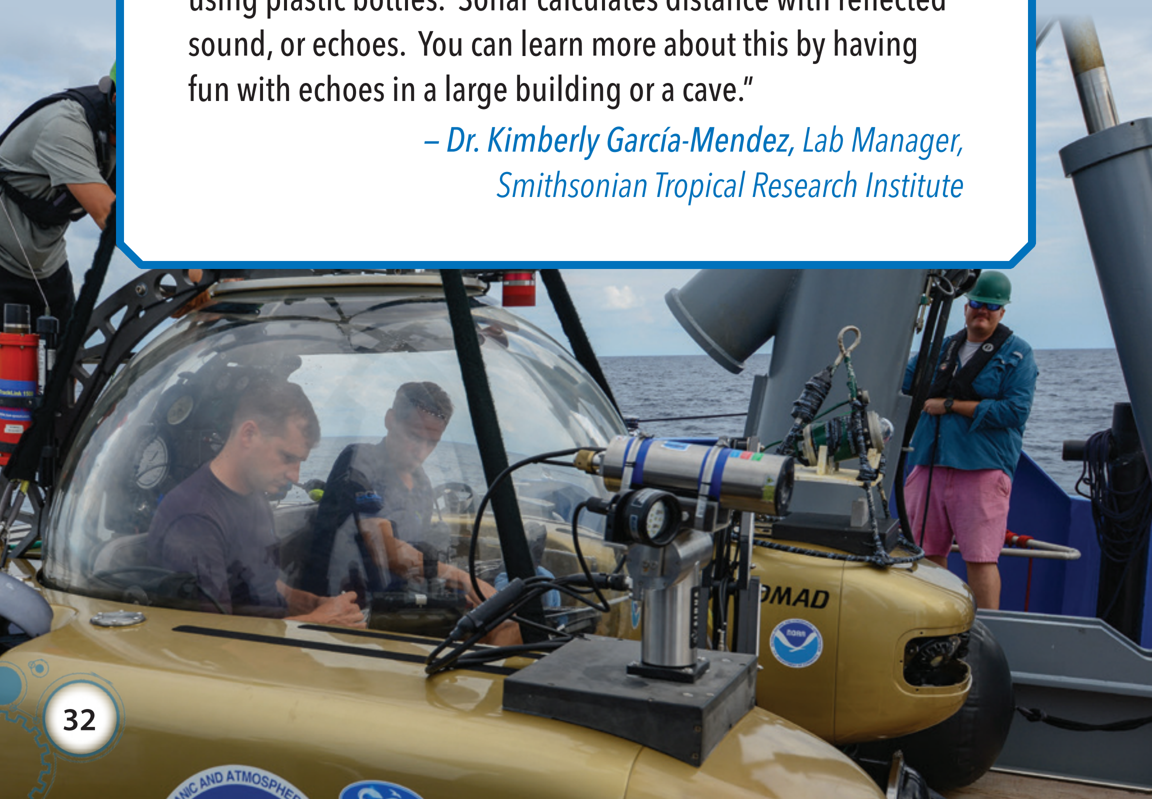
Here are some tips to keep in mind for the future.

"Read as much as you can about the ocean and its creatures. Books open up the world hidden beneath the waves. Plus, YouTube has countless wonderful documentaries that inspire a passion in the oceans."

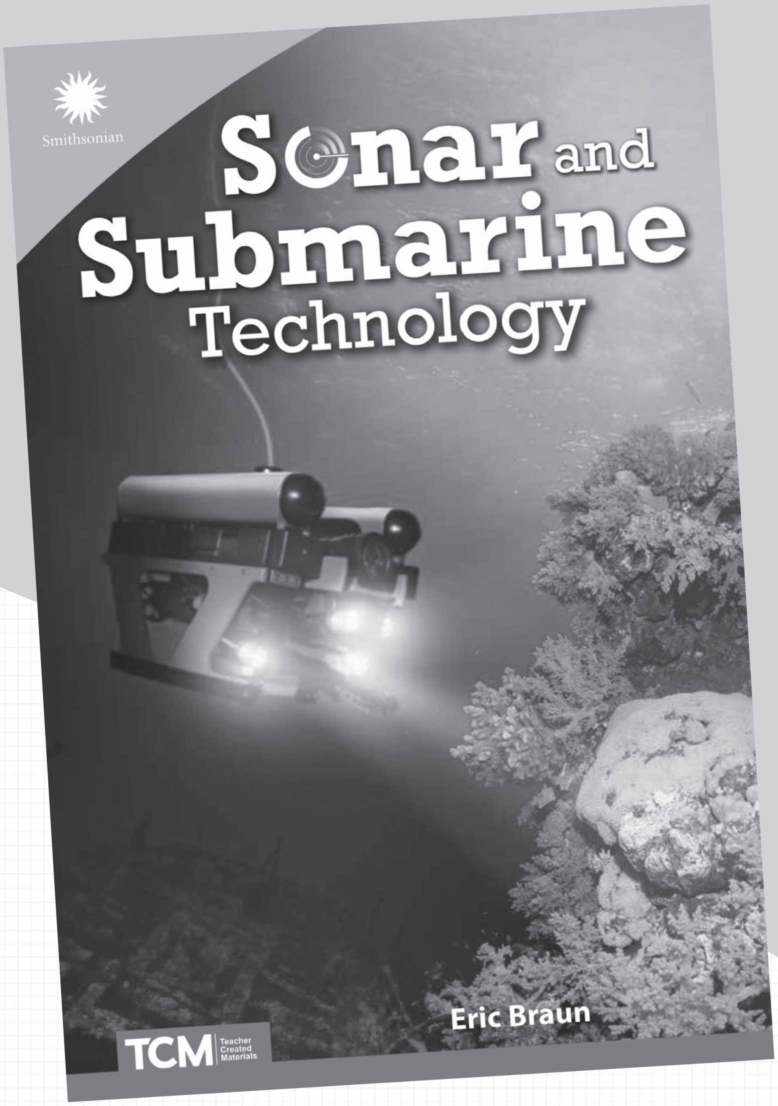
*– **Dr. Jonathan Cybulski,** Postdoctoral Researcher, Smithsonian Tropical Research Institute*

"Explore how submarines work by building your own models using plastic bottles. Sonar calculates distance with reflected sound, or echoes. You can learn more about this by having fun with echoes in a large building or a cave."

*– **Dr. Kimberly García-Mendez,** Lab Manager, Smithsonian Tropical Research Institute*



PHYSICAL SCIENCE



Technology Triumphs

LESSON PLAN

Author
Melissa L. Devlin, M.A.T.

Consultant
Cheryl Lane, M.Ed.
Seventh Grade Science Teacher
Chino Valley Unified School District

Smithsonian

STEAM Readers

Science ■ Technology ■ Engineering ■ Arts ■ Mathematics

Smithsonian

TCM Teacher Created Materials
5482 Argosy Ave.
Huntington Beach, CA 92649
www.tcmpub.com

ISBN-13: 979-8-7659-6967-0
90000
9 798765 969670
147981 (148029)

Image Credits: all images from iStock and/or Shutterstock

Sonar and Submarine Technology

Essential Question

How can humans use sound waves to make a positive impact on marine life?

Materials

- *Sonar and Submarine Technology* books
- copies of student activity sheets (pages 7–14)
- **STEAM Challenge materials include but are not limited to the following:**
  - ✓ small plastic bottles with caps, lids, and other recycled plastics
  - ✓ coins
  - ✓ rubber bands
  - ✓ paper clips
  - ✓ thumbtacks
  - ✓ pencils or markers
  - ✓ popsicle sticks
  - ✓ glue
  - ✓ straws
  - ✓ weights
  - ✓ paper
  - ✓ balloons

Learning Objectives

- **Reading:** Determine the meaning of key terms and other domain-specific words and phrases as they are used in a specific scientific context.
- **Science:** Develop and use a model to describe how sound interacts with various materials and how this energy impacts living things within an ecosystem.
- **Engineering:** Define an engineering problem, design and evaluate solutions, and optimize a design based on test results.

Phenomena

Sound waves produced by submarines and sonar technology can have a negative effect on marine life.

Lesson Time Line

Parts 1 & 2	Parts 3–5	Parts 6 & 7
Students analyze and interpret sounds around them to construct an explanation of what sound is and how it occurs. Students define the problem of designing a sound-reducing submarine and brainstorm solutions.	Students explain how sound interacts with various materials and the impact it has on living things. Students make plans and collaborate to design and build sound-reducing submarines that are large enough to fit a cell phone, small enough to carry in their hands, and can open and close. Students demonstrate their understandings of sonar and submarine technology by taking the book quiz.	Students test their sound-reducing submarines and redesign, rebuild, and improve their designs. Students reflect on their learning and share their findings with others.

Sonar and Submarine Technology *(cont.)*

Part 1

Introductory Activity

1. Have students close their eyes, or look down if they are more comfortable, and focus on listening to the sounds they hear around them. Walk around students, making sounds with three different items (e.g., closing a door). Before you make each sound, announce *Sound 1, Sound 2,* or *Sound 3.* Have students open their eyes and guess what they believe each of the sounds was, using evidence to support their answers. Ask students the essential question: *How can humans use sound waves to make a positive impact on marine life?*
2. Distribute the *Sonar and Submarine Technology* books to students. Read aloud pages 4–5 of the book. While reading, have students begin to consider how sound travels through water and the ways in which water limits what we see and hear.
3. Work with students to complete the Making Connections activity from the *Reading Activities* chart (page 6).

Part 2

Define the Problem

1. Ask students, how does marine life impact humans? How do humans impact marine life? Ask students to recall how sonar works.
2. Reveal the STEAM Challenge by displaying and reading aloud pages 28–29 of the book. As you read, have students state the specific tasks they will accomplish during each step of the engineering design process.

Read and Brainstorm

3. Ask students, how deep is the ocean? How deep can humans travel? How deep can submarines travel? Allow them time to share and discuss. Have students read pages 6–13 of the book.
4. Introduce the concept of *noise pollution* as unwanted sounds in the environment that affect the health of living things (both humans and animals). Prompt students to think of sources of noise pollution. Ask students to list ways to reduce noise pollution.
5. Prompt students to think about how they may use the STEAM Challenge materials to create sound-reducing submarines. Students should consider which materials could be used, and how these materials will reduce sound. Students will need to think about the size of these materials and how the submarine will be able to open and close.

Additional Resources

These websites include content that extends the lesson.

- *Sonar's Effects on Marine Mammals*
  tcmpub.digital/STEAM/sonar1
- *How This Ship Handles Seas Loaded with Icebergs*
  tcmpub.digital/STEAM/sonar2

Sonar and Submarine Technology *(cont.)*

Part 3

Reading Activity

1. Choose an activity from the *Reading Activities* chart (page 6). Provide applicable instructions and materials for students to complete the activity as they read pages 14–25 of the book. Reference the corresponding activity sheets (pages 8 and 9) as needed.

Make a Plan

2. Together, review the STEAM Challenge, and display the materials where students can see them. Discuss how the various materials could be used for different parts of their sound-reducing submarines.
3. Organize students into teams to share their designs. Then, have each group choose, sketch, and label a team design. Have each group submit their team design for approval, and provide feedback as necessary.

Part 4

Reading Activity

1. Have students read pages 26–27 of the book with partners, and provide a choice of two activities from the *Reading Activities* chart (page 6).

Design and Build

2. Tell students that when they build their sound-reducing submarines, they must follow their design plans exactly. Explain that they will have an opportunity to change or improve their designs after they present them.
3. Review classroom expectations for working with materials. Give teams time to build models.

Part 5

Reading Assessment

1. Have students work independently or with partners to complete the Read and Respond questions from the book. Invite students to share their responses aloud.
2. Have students complete a short posttest, *Sonar and Submarine Technology Quiz* (page 10), to assess this lesson's reading objective.

Testing the Design

3. Tell students that each team will demonstrate their sound-reducing submarine at the front of the room. Explain that other teams will offer feedback after each test.
4. Distribute *Sound-Reducing Submarine Test Results* (page 11), and invite teams to present their designs. Ask them to explain which materials were used and how these materials reduce sound. Each team should share how the materials and designs meet the size criteria while also allowing the submarine to open and close. Ask students from other teams to provide suggestions for improvement and feedback on the design.

Sonar and Submarine Technology *(cont.)*

Part 6

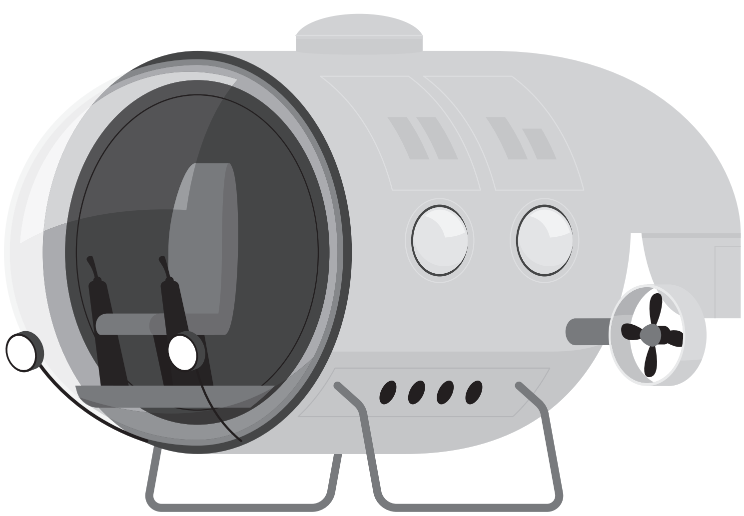
Rebuild and Retest

1. Provide time for teams to brainstorm ways to improve their designs based on test results and feedback. Ask them to revisit their initial designs and discuss features that proved successful as well as features that could be improved after testing.
2. Ask students to sketch their improved designs and explain any changes, including additional or different types of materials. Have students submit their improved designs for feedback and approval before building.
3. Have teams get materials to improve their designs.
4. Allow time for teams to retest their sound-reducing submarines.
5. Invite students to provide feedback on improved designs, and ask team members to use evidence from the retests to reassess how well their designs meet the criteria.

Part 7

Reflect and Share

1. Ask students to share examples of specific contributions from their teams and feedback from members of other teams during the STEAM Challenge, including suggesting design ideas or improvements, listening to others while brainstorming, engaging with the materials, and working within their teams to design, test, and build sound-reducing submarines.
2. Have each student answer questions and complete *Think About It* (page 12) to reflect on the success of their team's design and their individual contributions.
3. Have students complete the *Engineering Design Process Checklist* (page 13) and the *Teamwork Rubric* (page 14) to reflect on and evaluate their work and collaboration skills.
4. Read aloud and discuss with students the *Career Advice* on page 32 of the book. Ask students to share whether they would consider a career in sonar engineering or marine biology, and why. Engage students in a discussion about the ways in which the work of sonar engineers and marine biologists intersect.



Sonar and Submarine Technology *(cont.)*

Reading Activities

Select one or more of these activities to do with students as they read the book.

Studying Words

Have each student draw a beaked whale in their marine habitat with a submarine using sonar nearby. Challenge students to use as many vocabulary words as they can to label and describe their illustrations. Encourage students to utilize the glossary on page 30 of the book. Invite students to share their illustrations.

Summarizing

Provide students with materials to create infographic posters that can spread the word about the threats to coral and what humans can do to protect coral. Have students summarize details from the text using visual elements (e.g., charts, graphs, icons, images) to share complex information in more simplified and appealing ways.

Making Connections

Invite students to share situations in which they wanted to reduce the sound around them. Ask students to recall details about the experiences, including where they were, sources of the sounds, and how these sounds impacted them. Ask students to consider what could have been done to reduce the sound they experienced (other than leaving). Have students share their stories aloud to partners, small groups, or the class.

Writing

Ask students to create step-by-step guides detailing how sonar allows humans to study what they cannot see. These guides should include words and illustrations, using details from the book. Students can use *See the Unseen* (page 8) to plan their guides.

Modeling

Students will work in pairs with one student sitting blindfolded and their partner standing near them. Have the standing student clap their hands. The blindfolded student must guess from which direction the clap came. The non-blindfolded student will record their partner's response on *Echo Say What?* (page 9) after each clap. Have students switch places and repeat the procedures.

Comparing and Contrasting

Have students use the text to complete Venn diagrams to compare and contrast HOVs, ROVs, and AUVs. Ask students to compare and contrast the three underwater vehicles using writing and visualizations. Have them include who uses them, when they are used and for what, and their limitations. Provide students with resources to conduct additional research on underwater vehicles.

Name: ______________________________ Date: ____________

Make a Plan

Directions: Summarize the challenge. Then, sketch your design to solve the challenge.

Challenge: ____

____

____

My Design

Directions: Sketch your team's improved design in the second box. Label the design with materials needed and the purpose of each part.

Team's Design

Name: ______________________________ Date: ______________

See the Unseen

Directions: Create a step-by-step guide with at least four steps that details how sonar allows humans to study what they cannot see. Include words and illustrations, using details from the book.

Step 1: ______________________________

____

____

Step 2: ______________________________

____

____

Step 3: ______________________________

____

____

Step 4: ______________________________

____

____

Name: ______________________________ Date: ______________

Echo Say What?

Directions: Follow the prompts, and record your answers.

- Pair up with a partner.
- One student will close their eyes while the other stands nearby.
- The standing student will clap their hands in various directions: in front, behind, to the left, or to the right of their partner.
- The blindfolded student must guess the direction of each clap.
- Record each guess—use a check mark for correct guesses and an X for incorrect ones.
- Repeat the process for each of the four directions, clapping twice in random order.
- Switch roles, and repeat the activity for both partners.

Front

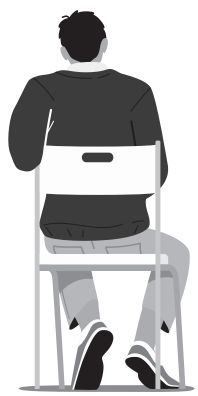
Test 1 result: ______________

Test 2 result: ______________

Left

Test 1 result: ______________

Test 2 result: ______________



Right

Test 1 result: ______________

Test 2 result: ______________

Behind

Test 1 result: ______________

Test 2 result: ______________

1. Which location had the most correct gueses? ______________________________
2. Which location had the least correct guesses? ______________________________
3. Why do you think some locations were easier to guess than others?

   ____

4. How difficult do you think it would be for humans to use echolocation to communicate underwater? Cite evidence to support your answer.

   ____

   ____

Name: ______________________________ Date: ____________

Sonar and Submarine Technology Quiz

Directions: Read each question. Fill in the bubble for the best answer.

1. Underwater sonar and submarine technology have taught us more about which of the following? (*choose all that apply*)

- (A) deep-sea coral
- (B) all marine life species
- (C) seafloor mapping
- (D) impact of sonar on whales

2. Which type of underwater vehicle is best for precise tasks that require extended time underwater?

- (A) Remotely Operated Vehicles
- (B) Human Occupied Vehicles
- (C) Autonomous Underwater Vehicles
- (D) cargo ships

3. How do sea cucumbers survive in deep water where there is less light?

- (A) They are microscopic and do not need light.
- (B) They create their own light.
- (C) They float to the surface.
- (D) They rely on other organisms that produce light.

4. Which of the following is not a threat to deep-sea coral?

- (A) rising CO2 levels
- (B) rising temperatures from fossil fuels use
- (C) laws preventing fishing and boating in certain areas
- (D) overfishing

5. Explain the process of seafloor mapping using sonar technology. What does seafloor mapping tell us?

____

____

____

____

____

____

Name: ______________________________________ Date: ____________

Sound-Reducing Submarine Test Results

Directions: Use the tables to assess and provide evidence for how each team's model meets the STEAM Challenge criteria.

Team:	**Sketch of Submarine:**
Test Results: ❏ large enough to fit a cell phone inside ❏ small enough to be carried in hands ❏ can open and close	

Team:	**Sketch of Submarine:**
Test Results: ❏ large enough to fit a cell phone inside ❏ small enough to be carried in hands ❏ can open and close	

Team:	**Sketch of Submarine:**
Test Results: ❏ large enough to fit a cell phone inside ❏ small enough to be carried in hands ❏ can open and close	

Which team's sound-reducing submarine was most successful? What about the design or materials used make this submarine most successful? Provide evidence to support your claim.

____

____

____

____

____

____

Name: ______________________________ Date: ______________

Think About It

Directions: Respond to the questions and prompts to reflect on the process you used to complete the STEAM Challenge.

1. Which feature of your team's design makes it most successful?

____

2. Which feature of your team's design makes it unique?

____

3. Which materials absorbed sound best?

____

4. During this challenge, I contributed by ______________________________

____.

5. A surprise or issue that our team encountered during this challenge was ______________

____.

6. Our team solved the issue by ______________________________

____.

7. How would you modify your sound-reducing submarine to reduce the impacts of an even higher-pitch or higher-amplitude sound? Provide specific details about how you would change the design and/or materials.

____

____

____

____

____

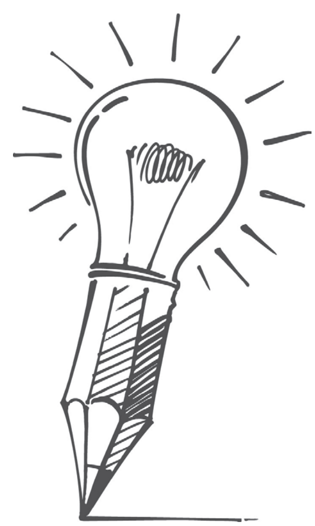
____

____

____

____

____



Name: ____________________________________ Date: ______________

Engineering Design Process Checklist

Directions: Check the boxes and answer the prompts to show that you completed each step.

Define the Problem

❑ I understood the design constraints.

State the purpose of the challenge in your own words.

____

____

____

____

Research and Brainstorm

❑ I identified and used research that helped inform my team's design.

List two features of your team's design that used ideas from research.

____

____

____

____

Design and Build

❑ I designed and built a model.

❑ I practiced each step of the engineering design process to complete this challenge.

Test and Improve

❑ I used criteria to evaluate designs.

List two examples of criteria you used.

____

____

____

____

❑ I collected and organized my team's data.

❑ I improved designs based on test results.

❑ I used feedback from my team and from other teams to improve my design.

Reflect and Share

❑ I reflected on my work by analyzing data, writing, and discussing my results with others.

List at least one way you can improve your work on the next project you complete.

____

____

____

____

Name: ______________________________ Date: ____________

Teamwork Rubric

Directions: Think about how you worked in your team. Score each item on a scale of 4 to 1.

4 = Always	3 = Often	2 = Sometimes	1 = Never

I listened to people on my team.	4	3	2	1
I helped people on my team.	4	3	2	1
I shared ideas with people on my team.	4	3	2	1
We made choices as a team.	4	3	2	1

Total __________

What is one thing your team did well?

____

____

____

____

What could your team do better next time?

____

____

____

____

What else do you want your teacher to know about your team?

____

____

____

____

Name: ______________________________ Date: ______________

STEAM CHALLENGE

Define the Problem

Submarines travel through the oceans, sinking and rising to different depths. But their engines can have a negative effect on marine life due to the sound waves they create. So, marine biologists are partnering with naval architects to address this problem. They want to create a new protective material that can be used to make submarines. They want this material to help reduce engine sound waves from bouncing off submarines and spreading.

Constraints: You may only use the materials that are provided for you.

Criteria: Your submarine must be large enough to fit a cell phone inside but small enough to carry in your hands. The submarine must open and close.

1

Research and Brainstorm

What is amplitude, and how is it measured? How can sound waves be reflected, absorbed, and transmitted through various materials? What types of materials help reflect or absorb these waves the best? How can your design reduce sound waves to prevent them from reaching the exterior?

2

Design and Build

Sketch two designs for your sound-reducing submarine. Be sure to label the materials you intend to use. Partner with a small group of classmates to share your ideas. Then, design and build a final submarine that incorporates everyone's ideas.

3

Test and Improve

Play a song on a cell phone, turning the volume up all the way. Then, put the cell phone inside your submarine and close the opening. Using a laptop or tablet, go to an online sound level meter website. Test all four sides of your submarine, recording the decibel reading at each location by setting the laptop or tablet 12 inches (30 centimeters) from the submarine. How can you reduce the noise even more? Modify your design, rebuild your submarine, and test your second prototype with the same sound level check.

4

Reflect and Share

How did your knowledge of sound waves help you when constructing your model? What part of the process did you enjoy the most during this challenge? Was anything difficult for you and your group? How did you overcome the hardship?

Answer Key

Example responses are provided.

See the Unseen (page 8)

Step 1: A transducer sends sound waves into water.

Step 2: Sound waves hit an object and bounce back as echoes.

Step 3: Echoes are measured, interpreted, and sent to a display for scientists.

Step 4: The transducer determines the range of different objects.

Echo Say What? (page 9)

1. Students will include the location with the most correct guesses.
2. Students will include the location with the least correct guesses.
3. Our minds determine where sound is coming from based on which ear the sound reaches first and how loud the sound is when it reaches each ear.
4. It would be very difficult for humans to use echolocation to communicate underwater. Water is denser than air so sound travels much faster underwater. This makes it difficult for us to detect sounds underwater, as our ears have adapted to hearing sound in the air. Also, our lungs and brain can only withstand so much pressure, and the deeper you go into the ocean, the higher the pressure is on the body.

Sonar and Submarine Technology Quiz (page 10)

1. A, C, D
2. A
3. B
4. C
5. Underwater vehicles have sonar devices that are put into watertight shells on the vehicles. The devices send sound waves into the water. Computers measure how long it takes for the sound waves to travel to the seafloor and bounce back. These measurements are put together into one color-coded image that show different depths. Scientists use seafloor maps to determine what Earth's crust looks like and understand ocean activity, such as currents and tides.