WEST COAST WHITE SHARK

A SCIENCE 3D ADVENTURE

MIDDLE SCHOOL

By MIKE HEITHAUS Ph.D

symbio education

KEY WORDS

ANALOG SIGNAL

AUTONOMOUS

BIODIVERSITY

CONDUCTOR

DIGITAL SIGNAL

ECTOTHERM

ENDOTHERM

INSULATOR

INTERNAL FERTILIZATION

KINETIC ENERGY

NON-RENEWABLE RESOURCE

PALEONTOLOGIST

PINNIPED

POTENTIAL ENERGY

PREDATOR

RENEWABLE RESOURCE

SCAVENGER

SENSOR

TRADE-OFF

TRANSITIONAL FORM

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THE PERFECT PREDATOR?

When you hear the word **predator**, what do you imagine? On land, it might be a lion, tiger, wolf or bear. For many people, the first thing they think about might be a great white shark (*Carcharodon carcharias*)! Predators, or animals that eat other animals, come in many sizes. But some predators have no predators themselves. These are the top predators. People used to think that white sharks were the top predators in the ocean. But, we now know that even adult white sharks have to fear killer whales! Still, white sharks are amazing predators and are near the very top of food webs where they are found.

Many traits make white sharks incredible ocean predators. These traits have been passed down through generations from parents to offspring. White sharks grow to around 6 meters (20 feet) long and almost 2,000 kilograms (over 4,000 pounds). Female white sharks are larger than males.

White shark

Carcharodon carcharias

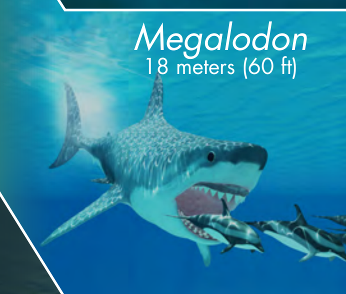
MASTERS OF THE OCEAN

Geologic Time Scale

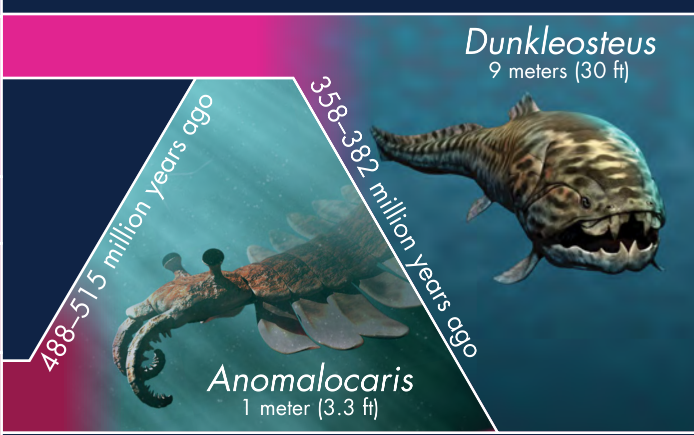
CENOZOIC Present day - 65.5 million years ago
- Quaternary
- Neogene
- Paleogene

MESOZOIC 65.5 - 245 million years ago
- Cretaceous
- Jurassic
- Triassic

PALEOZOIC 245 - 570 million years ago
- Permian
- Carboniferous
- Devonian
- Silurian
- Ordovician
- Cambrian



White sharks and killer whales may be top predators in the oceans today, but fossils show that the seas have had some impressive predators for millions of years!



RISE OF WHITE SHARKS

Relatives of white sharks, like the extinct giant *megalodon*, appear in the fossil record around 15 million years ago. Modern white sharks first appeared in the Pacific Ocean around 6 million years ago. By 4 million years ago, they could be found in oceans around the world. Some scientists think that the extinction of *megalodon* 3.5 million years ago may have been caused by competition from modern white sharks and killer whales, along with changes in the climate and oceans. For many years, white sharks were believed to be very close relatives of *megalodon*. Then **paleontologists** found fossils from an animal that they named *Carcharodon hubbelli*. This species is a **transitional form**. How has this fossil changed our view of white shark relatives? It will be your mission to find out!

Carcharodon hubbelli **is an ancient relative of today's great white sharks. It is an important transitional form. Transitional forms help paleontologists figure out relationships between ancient and modern species.**

WHITE SHARK RELATIVES

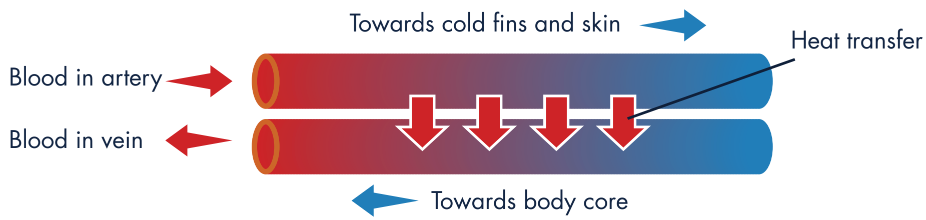
White sharks are part of a family known as the mackerel sharks, or Lamnidae. Mackerel sharks share many traits. Their bodies tend to be torpedo-shaped and the upper and lower lobes of their caudal fins (tail) are about the same size. They are very heavy for their length compared to other sharks.

The bodies of most sharks can't make heat to warm up. They are cold-blooded, or **ectotherms**. That means that their bodies are the same temperature as the water around them. The only way cold-blooded sharks can warm up is to find warm waters. This is one reason why most sharks stay in warmer waters closer to the equator or only move into some areas in the summer when the waters warm up.

Mackerel sharks are not ectotherms. They are **endothermic**, or warm-blooded. Like humans, other mammals, and birds, they can generate and retain heat in their bodies. That means white sharks can stay warmer than the water around them.They can live in colder waters than most other sharks.

Because water is a good **conductor** of heat, a warm shark living in cold water might lose its heat quickly. But, mackerel sharks have traits that help with this. For example, their blood vessels are arranged to keep the heat near their body core. Similar traits are found in penguins and other warm-blooded animals that live in cold environments.

COUNTER CURRENT HEAT EXCHANGE



Warm-blooded species can retain body heat because of the arrangement of blood vessels. Heat flows from warm to cold areas. By having veins and arteries close to one another, the heat from arteries (flowing towards body parts where heat is lost) is transferred into colder blood flowing back from those parts. Less heat is lost to the environment. The blood coming back to the body isn't as cold as the blood vessels without heat exchange.

Salmon shark
Lamna ditropis

Thresher shark
Alopias

Mako shark
Isurus oxyrinchus

Mako and salmon sharks are other mackerel sharks closely related to white sharks. Thresher sharks aren't mackerel sharks, but they are also warm-blooded. These warm-blooded sharks are able to live in habitats that most cold-blooded species cannot. It also means they can move around faster to chase swift and elusive prey in colder waters. Being warm-blooded, however, has its difficulties. To stay warm, white sharks and their relatives need more energy than cold-blooded sharks. That means they need to eat more prey than ectothermic sharks.

White shark
Carcharodon carcharias

Mackerel sharks, like white sharks, mako sharks, and salmon sharks are warm-blooded. Thresher sharks aren't mackerel sharks, but they are warm-blooded too. These sharks are able to live in colder waters than many other sharks.

WORLD OF WHITE SHARKS

White sharks are found in cool waters near the coast in many parts of the world. For years, most scientists thought that white sharks stayed in these nearshore waters all year. But, scientists have found that big white sharks sometimes swim into the middle of the ocean in warm tropical waters, like those near Hawaii. The reason is still not clear. Maybe these are rich feeding grounds. Maybe they are places where sharks can reproduce. Scientists are still trying to test these hypotheses!

White sharks can live in colder waters than many sharks because they are warm-blooded.

Some places around the world have become famous for their white sharks. In most of these places, people can see white sharks hunting near colonies of seals or sea lions. In some locations, people can even go underwater in cages to see these magnificent sharks in their own environment.

In some places, like the northeastern United States, white sharks are becoming more common. Their populations had been nearly wiped out through overfishing and possibly the loss of their favorite prey. But, with less fishing pressure and increasing seal populations, white sharks are being seen much more often.

Tourists cage diving with white sharks at Isla Guadalupe, Mexico.

WHITE SHARK MENU

A white shark's meal depends on its size. Baby white sharks need the kids' menu. We still don't know a lot about what baby white sharks prefer to eat. Fish, squid and stingrays are all possible prey. Sometimes they also might eat smaller sharks.

Like other sharks, white sharks continuously lose their teeth and get new ones. There are multiple rows of teeth inside their jaws. When they lose a tooth, another one slides into place! As white sharks grow, they get teeth with different shapes. When they are young, they have pointy teeth – perfect for holding onto slippery prey. Bigger sharks have teeth that are more triangular. These teeth are built for cutting through big prey.

As they grow and their teeth change, white sharks start to eat more seals, sea lions, and dolphins. They also start eating bigger fish. Occasionally, white sharks eat sea otters, sea birds, and sea turtles. In some places, they may get a lot of their food by eating dead whales. White sharks are **scavengers** and won't pass up a free meal. The specific prey of large white sharks depends on where they live. In some places, like South Africa, white sharks leap out of the water as they launch sneak attacks on unsuspecting fur seals swimming at the surface! Because fur seals are so much more maneuverable underwater, the white sharks need to catch them by surprise.

As white sharks grow, they start to eat larger prey, like seals and sea lions.

WHITE SHARK REPRODUCTION

Like many other large sharks, great white sharks grow fairly slowly. They grow much slower than bony fish. In fact, great white sharks may be more than 20 years old before they reproduce! Males mature earlier than females. It is hard for scientists to measure the life span of white sharks. But they may live to be more than 70 years old!

White sharks have **internal fertilization**. Males use modified pelvic fins, called claspers, to mate. During mating, male sharks bite the females and can leave scars on their bodies.

Male sharks have dual claspers, used for mating.

Male white sharks use their teeth to hold onto females while they mate, leaving behind visible scars that heal through time.

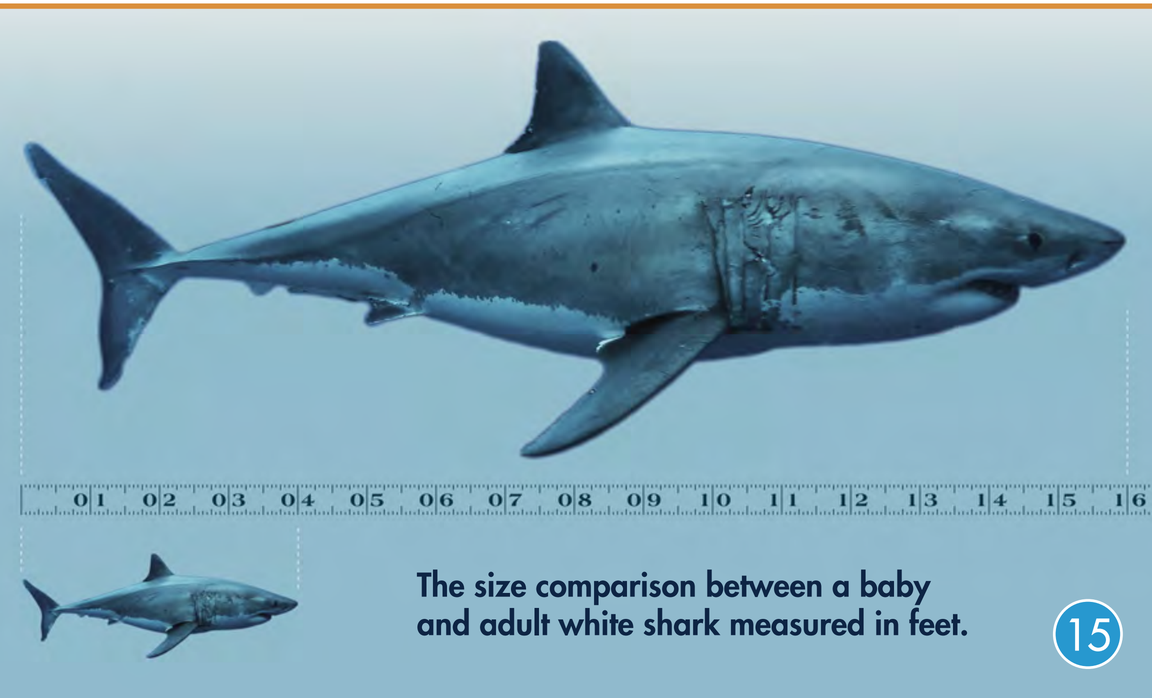
Scientists rarely see pregnant white sharks. But, their porbeagle shark relatives are often caught by fishers. This is what a baby porbeagle shark looks like while inside its mother. This is probably similar to what white sharks would look like as embryos.

Fertilized eggs develop and hatch inside female white sharks. The newly hatched sharks stay inside their mother and feed on unfertilized eggs until they are born.

After 12 months of pregnancy, the pups are born in litters of about ten. Each pup is about 1.5 meters (4.5 feet) long. The mothers do not care for the young. They are ready to swim and eat as soon as they are born. Female white sharks only give birth every other year.

A young white shark.

We don't know much about the lives of baby white sharks in most parts of the world. In California, baby white sharks stay close to the shore. Sometimes they swim into the waves where people are surfing! But baby white sharks won't attack. They are too small and their narrow pointy teeth aren't built for taking on big prey. Why are baby white sharks found near the waves of California's shore? Do they travel together or live alone? These are some of the questions that marine biologists are investigating. You are about to help!



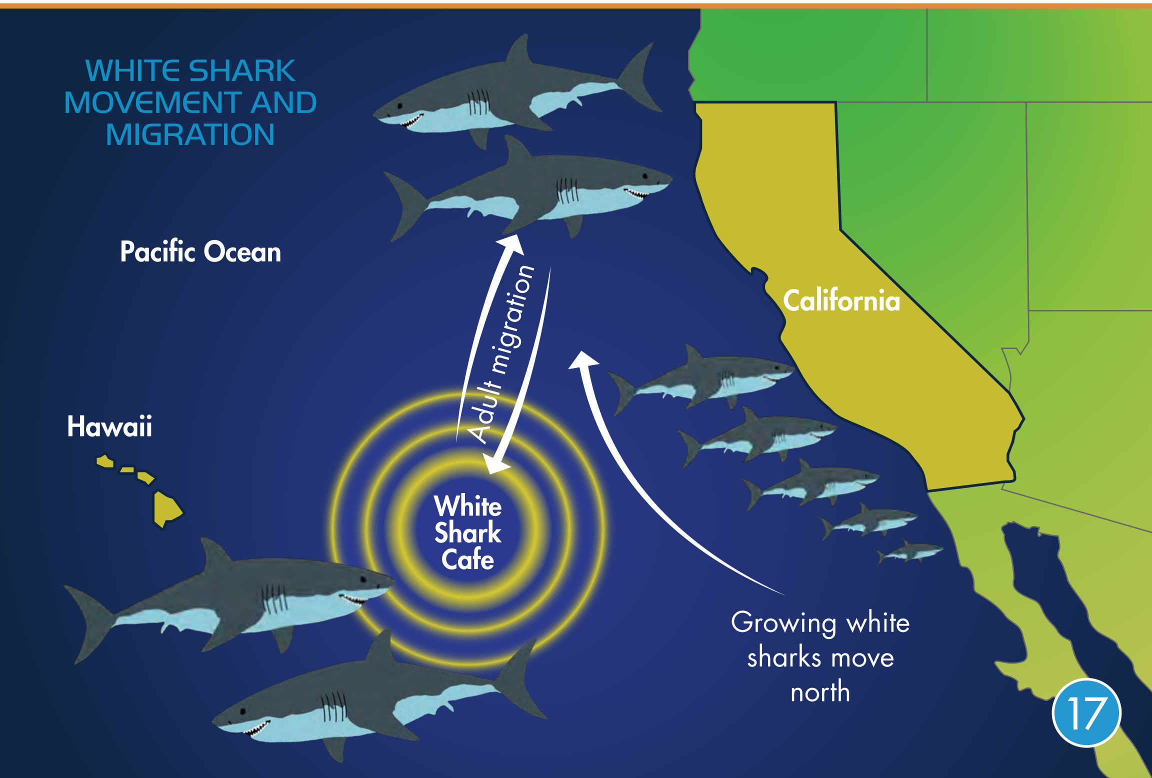
The size comparison between a baby and adult white shark measured in feet.

The California coast is made up of different, diverse habitats. It is home to many organisms, including young and mature white sharks!

CALIFORNIA LIVING

One of the best places to find white sharks of all sizes is California. But sharks of different sizes are not usually found in the same place. Newborns and young sharks are found in nurseries in southern California. Nurseries are areas where baby sharks live. They are relatively safe and provide the resources young sharks need to grow. What could put the baby sharks in danger? Big mako sharks and killer whales could eat them if they move too far from shore.

As the great white sharks sharks get older, they start moving further along the coast. Larger adults are usually found in central and northern California. They like to spend time near places with a lot of seals and sea lions (their favorite food) when they are near the coast. They also begin to make trips far offshore to the middle of the Pacific Ocean. Some people call this area the "White Shark Cafe."



Around the world, large white sharks like to eat **pinnipeds** including seals, sea lions, and fur seals. In California, northern elephant seals and California sea lions are the most common white shark targets. Why would sharks want to eat animals that can be so difficult to catch and can fight back with nasty bites? Because they are such a good meals! The layers of fat that **insulate** a pinnipeds' body are full of energy. A bite of pinniped (or a whale or dolphin) gives a shark more energy than the same size bite of fish. Seals and sea lions, though, are different kinds of pinnipeds and present different challenges for white sharks to catch.

Seals and sea lions are the preferred prey of white sharks around the world, but they aren't always easy to catch!

CALIFORNIA OCEANS AT RISK

These days, populations of white sharks and their favorite prey are pretty healthy. But it wasn't always this way. Several decades ago, populations of elephant seals, sea lions and white sharks all collapsed. Elephant seals almost went extinct. Why? First, people killed too many of them. Second, pollution increased in California's waters.

The waters of California became polluted because of people's need for energy. Cars, electronic devices, and homes are powered by energy. The energy comes from resources in the natural environment that can be **renewable** or **non-renewable**. Non-renewable resources can only be used once. Fossil fuels, including oil, natural gas, and coal are non-renewable resources. Until recently, energy came primarily from these fossil fuels. To get them, people have to dig them up or pump them out of the ground. Once they are all used, they will be gone. Renewable resources don't run out if used appropriately. Renewable energy sources include energy from the sun or power from wind or moving waters. Even when in use, more energy is being continuously produced. Plants can be used to make renewable fuel. But, people can't use the energy plants create faster than plants grow or the resource won't be renewable!

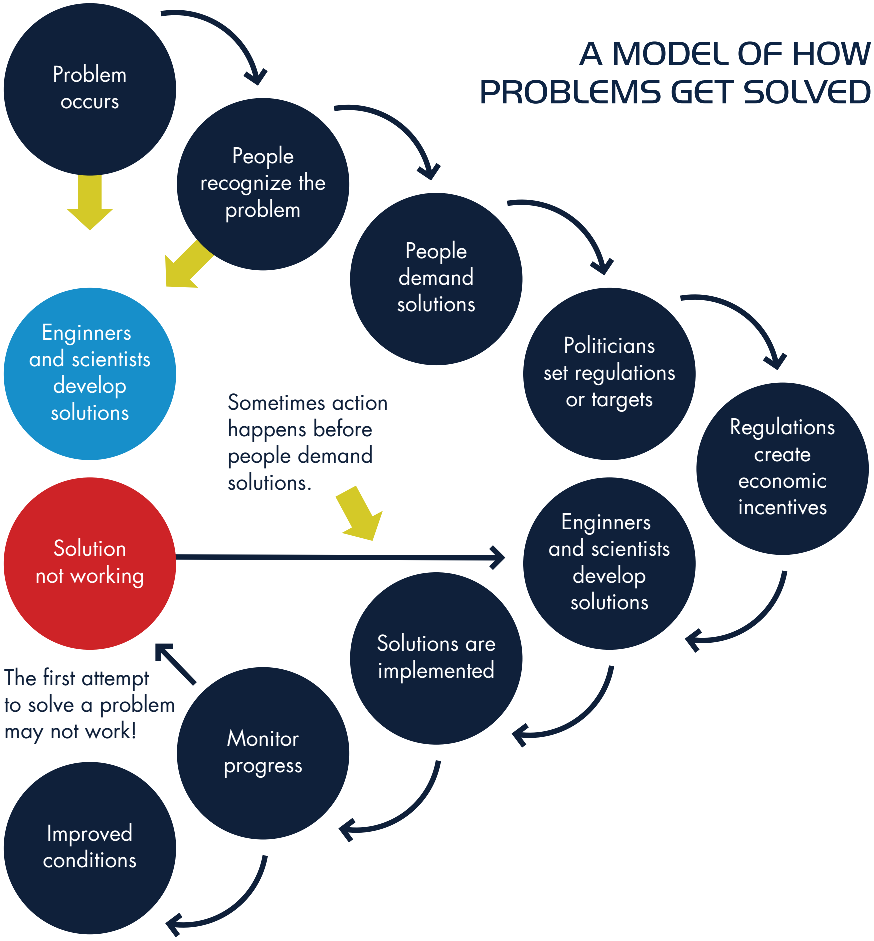
Decades ago, people pumped a lot of oil out of the ground in California. They were not careful about what was being put in the water and air. Oceans became very polluted. Populations of many species, including white sharks, decreased. Some species disappeared from polluted areas.
The **biodiversity** in coastal oceans went way down.

Another enviornmental problem in California was the loss of sea otters. Sea otters almost disappeared because they were hunted for their fur. With no otters to eat sea urchins, the urchin populations exploded. The urchins destroyed kelp forests. Many species that depended on the kelp forest ecosystem had to move or nearly died out.

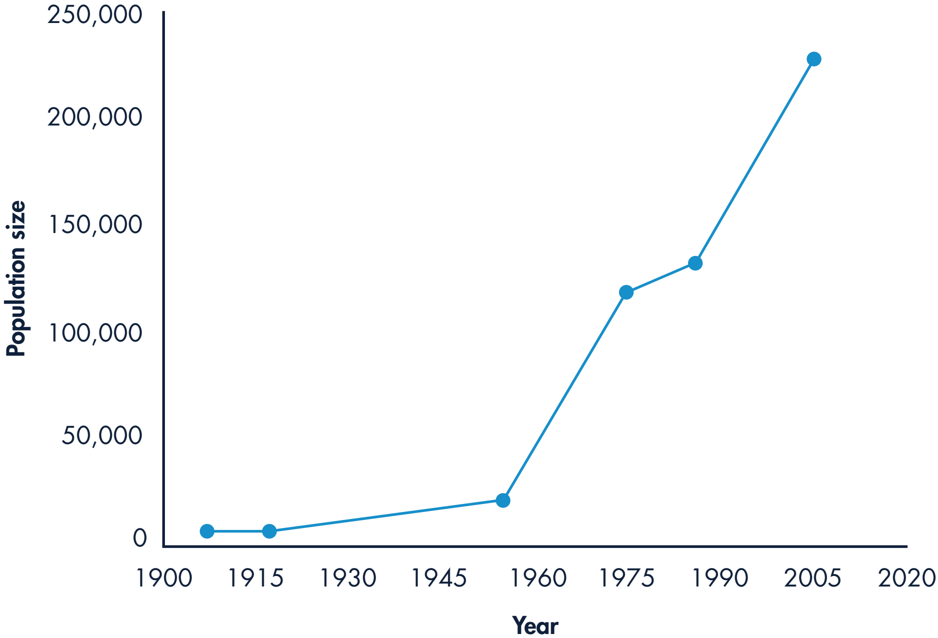
BOUNCING BACK

Californians became alarmed that the water quality was bad and species were disappearing. They demanded that politicians and the government act on the problem. Laws were passed to protect and improve air and water quality. Scientists and engineers developed solutions. Seals, sea lions, sea otters and white sharks were protected. Engineers developed solutions to reduce pollution and clean up dangerous chemicals from the water. People also started to recycle materials they used to throw away. Another way they conserved Earth's resources was to use less. This results in less trash and less pollution! Over time, water quality has improved and species populations have recovered. Now, the oceans off California are teeming with life again!

A MODEL OF HOW PROBLEMS GET SOLVED



ELEPHANT SEAL POPULATION OVER TIME



Elephant seals are a species that made a comeback in California! Larger populations of seals and sea lions lead to more food for white sharks. Are white shark populations also growing? Scientists are trying to find out. More white sharks would mean that people will need to learn how to live with them!

Elephant seal populations have recovered in recent decades. That means more food for sharks!

SHARKS AND PEOPLE

Because white sharks are big and they eat big prey, very large white sharks can be dangerous to people. Sometimes they do bite people, but it doesn't happen very often. Why do white sharks bite people? They probably mistake them for prey.

People are learning to live with white sharks. In some places, people pay to get in a cage to see white sharks in their natural habitat. Surfers and other people in the oceans try to avoid places and times where big great white sharks might be found. Lifeguards keep an eye out for big sharks and let people know when to get out of the water. In some places, aircraft (including drones) are used to keep an eye out for sharks that might be dangerous.

Not all white sharks are dangerous to people. In southern California, more and more baby white sharks are being seen near beaches. This may be because their populations are growing after years of decline. Dr. Chris Lowe, software engineer Darnell Gadberry, and the rest of the Shark Lab team at California State University, Long Beach study these sharks. How long do the baby sharks stay in one place? Why do they like certain areas? How does water temperature, the amount of available food, and safety from predators affect where sharks are found? How do the young sharks behave near surfers and swimmers? Will baby white sharks keep stingray populations in check? Do certain baby white sharks spend time together? Those are just some of the questions that the Shark Lab is trying to answer. They need to use a lot of technology to help them!

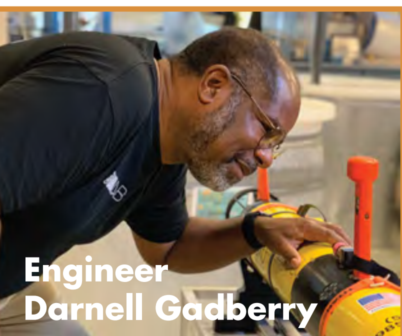

The Shark Lab team

SHARK TECH

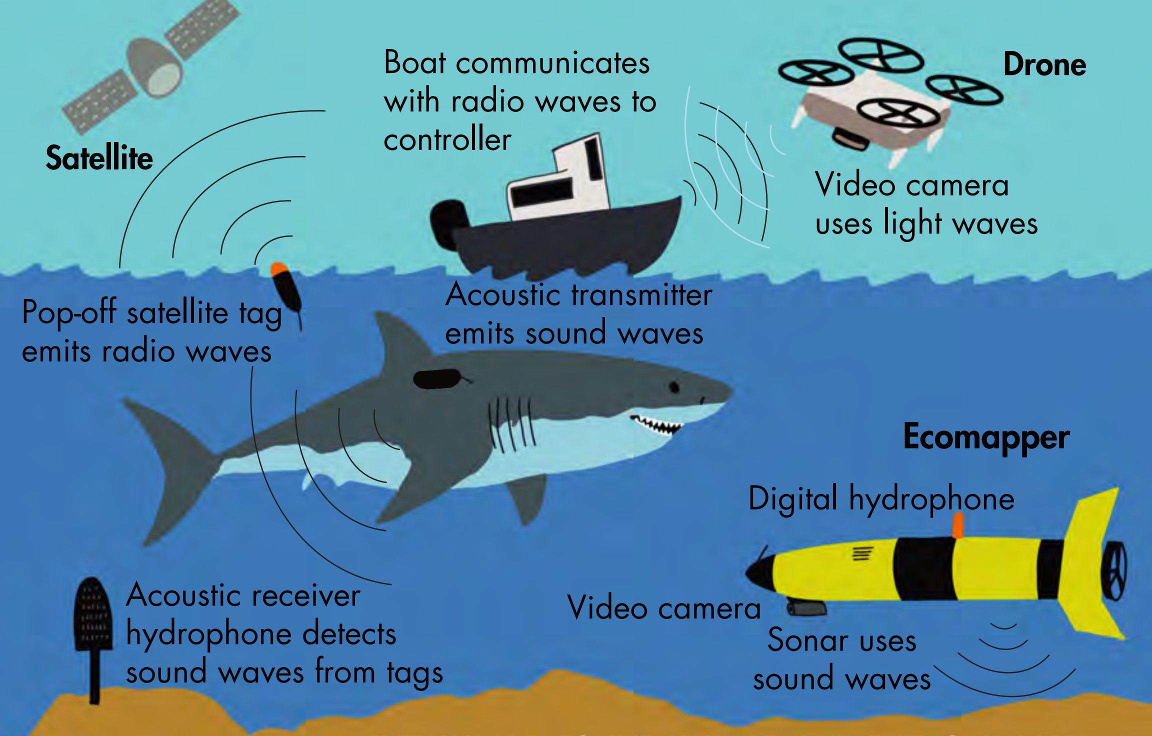
Baby white sharks live very close to the shore and can swim for miles along the coastline. The waves are big and the water is murky. These conditions make it hard to study the sharks, their potential prey, and their habitats. But, the Shark Lab team has found solutions to these problems! And to implement these solutions, they need to use math, computer science, and engineering skills!

One of the first challenges to study is the baby white sharks' habitat. How many stingrays are there for them to eat? What is on the bottom? What is the water depth and temperature? To gather these data, Darnell and Chris have customized a mini-submarine, called the Ecomapper, that they can operate remotely! The submarine has to use energy efficiently to collect as much data as possible and operate **autonomously** for long periods of time. Its electronics and computer need to be built and programmed effectively.

The Ecomapper can be programed to drive along a course and collect data on the environment. It uses the reflection of sound waves that it emits into the environment to map the bottom. This sonar is similar to the way that bats and dolphins use echolocation to "see" with sound. It has **sensors** that can measure water temperature, salinity (the salt level in the water), and other conditions. The data from these sensors is recorded in the memory of a computer. The sub also uses video cameras to capture images of potential white shark prey and what is on the bottom. Hours and hours of data can be used to piece together a picture of the white shark nursery areas!


Engineer Darnell Gadberry

The Ecomapper

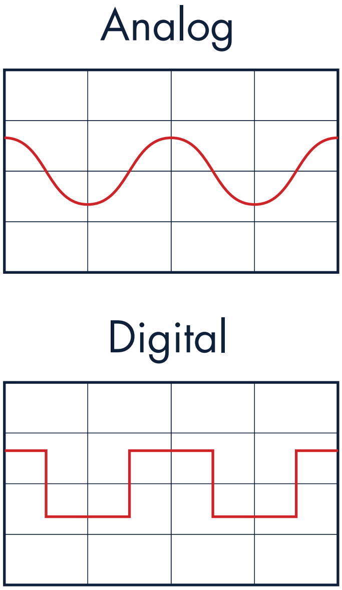


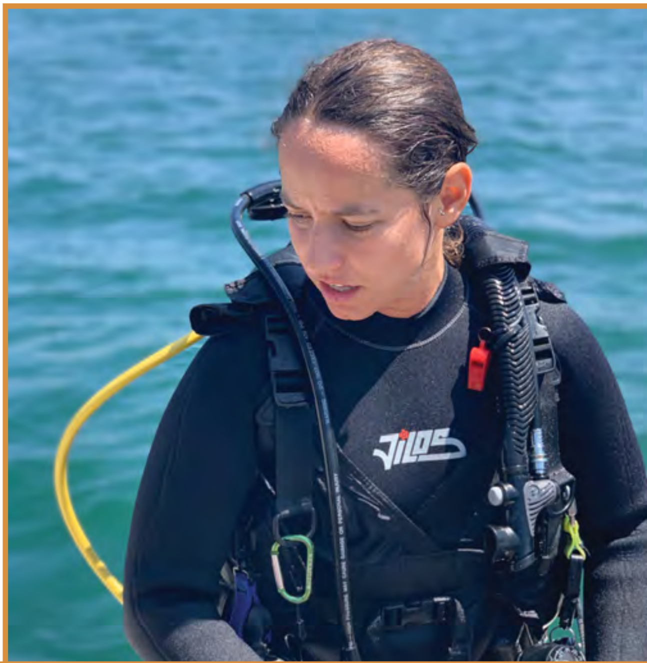
LIGHT WAVES, SOUND WAVES, AND RADIO WAVES!

Other technology is used to study the sharks. One tool is an unpiloted aerial vehicle (UAV), or drone. Drones can be programmed to fly along set routes or can be controlled from a distance using radio waves. Video cameras can record what is below the drone. The cameras detect light waves. They also transmit the video to a pilot on the ground or boat for observation. The Shark Lab team uses drones to count the number of sharks in different places along the coast and to record shark behaviors.

Tagging a baby great white shark.

Some technologies need to be attached to the sharks. Acoustic tracking uses a set of tags and receivers. The tags are small and transmit sound waves. These sound waves are detected by receivers that are placed underwater. The tags each transmit a unique code so the Shark Lab team can identify specific sharks swimming by the station. One challenge with these codes is that noise can disrupt the signal. Until recently, most acoustic tracking used **analog signals**. Now, more people use **digital signals**. Digital signals are expressed as a 0 or a 1. They are more reliable because they have distinct signals. They can also be detected from further distances (around a kilometer underwater). The only drawback to digital signals is that noise can interfere and cause the whole signal to get lost. Analog signals are disrupted more easily, but some of the information can still be retrieved when there is noise. Whether they are digital or analog, most acoustic receivers need to have divers bring them out of the water to download their data, replace the batteries, and then put them back in place.





Most electronic devices use digital signals. Digital signals are more reliable than analog signals because they have two distinct levels.

Satellite tags are bigger than acoustic tags. They record data onto a small computer. When the tag is done recording, it releases from the shark, floats to the surface and then downloads its data to a satellite! Then, the satellite transmits the data to Chris and the team. Satellite tags can provide information on sharks' location, even if they are far from a receiving station. But, satellite tags are very expensive, which limits the number of sharks that can be tagged.

A final technology that the Shark Lab uses is called environmental DNA, or eDNA. White sharks, like other organisms, continuously shed cells into the environment. Scientists collect water samples, isolate DNA, and then survey all the DNA in the sample. They look for matches to sequences of DNA from specific species to see if specific organisms are in a particular area. That means that the Shark Lab can collect water along the coast of California and see if white sharks have been there recently. But, they can't tell how big the shark was or how long it was there for.


Acoustic tags help track the movement of sharks

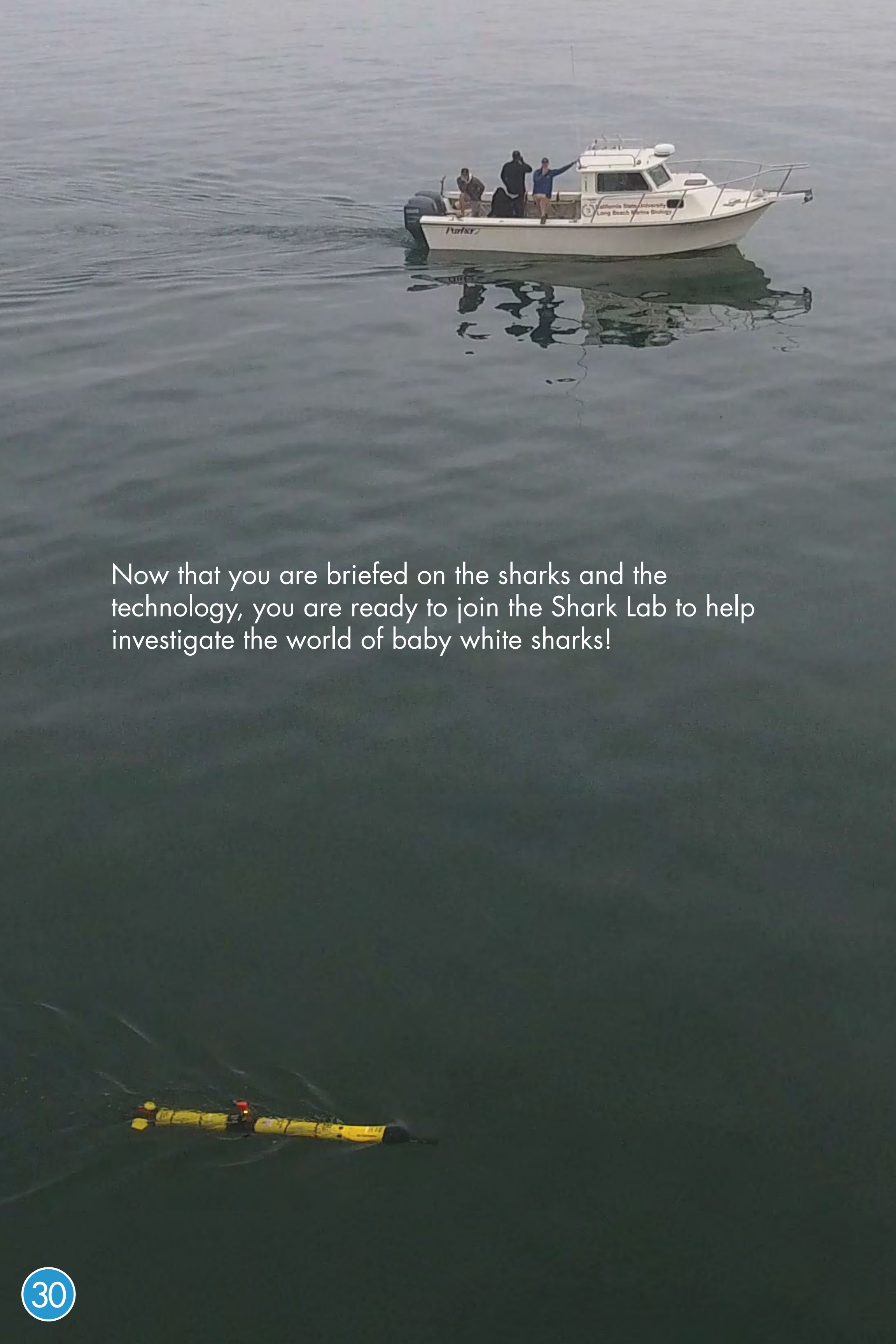

Dr. Chris Lowe


Camera tags can record video and track sharks

IT TAKES ENERGY

Energy is critical for the technology used to study white sharks. energy is critical. Energy is the ability to do work. There are two major kinds of energy: **kinetic energy** and **potential energy**. Kinetic energy is the energy of an object in motion. Potential energy is the energy stored within an object because of its position (like a ball at the very top of a hill about to roll down) or its condition (like the chemical bonds in a molecule). Some objects may have both potential and kinetic energy. When the Ecomapper moves forward and is near the bottom it has both kinetic and potential energy. Its forward movement is kinetic energy. Because it is positively buoyant, it will float towards the surface if it stops moving. That is potential energy.

One of the big challenges for the members of the Shark Lab team is gathering as much data as possible when in the field. To do that, they want their drones to fly and the Ecomapper to run for as long as possible. They also want their tags to transmit for as long as possible. All of these are determined by the amount of potential energy in their batteries, which is stored as chemical energy. Bigger batteries would allow them to record longer lengths of time. But, they face **trade-offs**. Bigger batteries make the tags bigger, and they don't want to put anything too big on sharks. Bigger batteries also weigh more. If the drone is too heavy it won't be able to fly. That means that the team has to use energy efficiently! For example, they can program tags to only collect data that they need. As engineers develop batteries that can store more potential energy in the same size, the Shark Lab and other scientists will be able to collect even more data!



Now that you are briefed on the sharks and the technology, you are ready to join the Shark Lab to help investigate the world of baby white sharks!

GLOSSARY

ANALOG SIGNAL
a signal expressed as a continuous variable

AUTONOMOUS
able to work without direct human control

BIODIVERSITY
the number of species in an area

CONDUCTOR
a substance that transmits heat, electricity, or sound

DIGITAL SIGNAL
a signal expressed as a value of 0 or 1

ECTOTHERM
an animal that gets its heat from the environment; cold-blooded

ENDOTHERM
an animal that can generate its own heat

INTERNAL FERTILIZATION
the process of an egg and sperm cell joining inside a body

INSULATOR
a substance that does not easily allow the passage of heat, electricity or sound

KINETIC ENERGY
energy in an object based on its movement

NON- RENEWABLE RESOURCE
a natural substance or material that cannot be quickly replaced by nature

PALEONTOLOGIST
a scientist that studies the fossils of animals and plants

PINNIPED
seals, sea lions, fur seals, and walrus

POTENTIAL ENERGY
energy in an object based on its position or condition

PREDATOR
an animal that eats another animal

RENEWABLE RESOURCE
a natural substance or material that can be quickly replaced by nature

SCAVENGER
an animal that feeds on dead animals

SENSOR
a device that detects or measures a physical property

TRADE-OFF
the act of having to give up one thing to gain another

TRANSITIONAL FORM
fossils that show a state between an ancestor and its descendants; an intermediate state

PHOTO CREDITS

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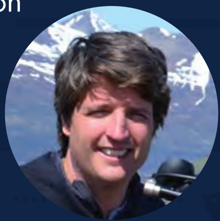
SCIENCE 3D

Thanks for exploring with us! Our science adventures take us around the world to uncover secrets of the most amazing animals and places. Our mission and passion is to share these scientific discoveries with you. There are so many cool things to see out there, even in your own backyard, so get outside and explore!

MIKE HEITHAUS PH.D.

Dr. Mike Heithaus is a scientist, explorer, author, educator, and television host. He is a professor of biology and Dean of the College of Arts, Sciences & Education at Florida International University. Mike and his students study sharks, whales, sea turtles, and other large marine animals around the world. They also work with people to help protect these species. Mike loves sharing his work with others. He has written text books and helped create programs for students in elementary, middle, and high school. He has been on television programs including on PBS, National Geographic, and Discovery Channel's Shark Week.

PATRICK GREENE



As a wildlife filmmaker, Patrick has always had a passion for animals. He started to draw pictures of sharks and whales when he was just five years old. Later, he went to college to become a marine biologist and learned a lot about science. Then he got a job in television and learned how to make videos, too. Since then, he's gone all over the world studying and filming wild animals. He's made shows for National Geographic, PBS and ABC, and even won an Emmy Award. He loves making videos to teach students about science and about the many creatures that share our world.

WEST COAST
WHITE SHARK

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