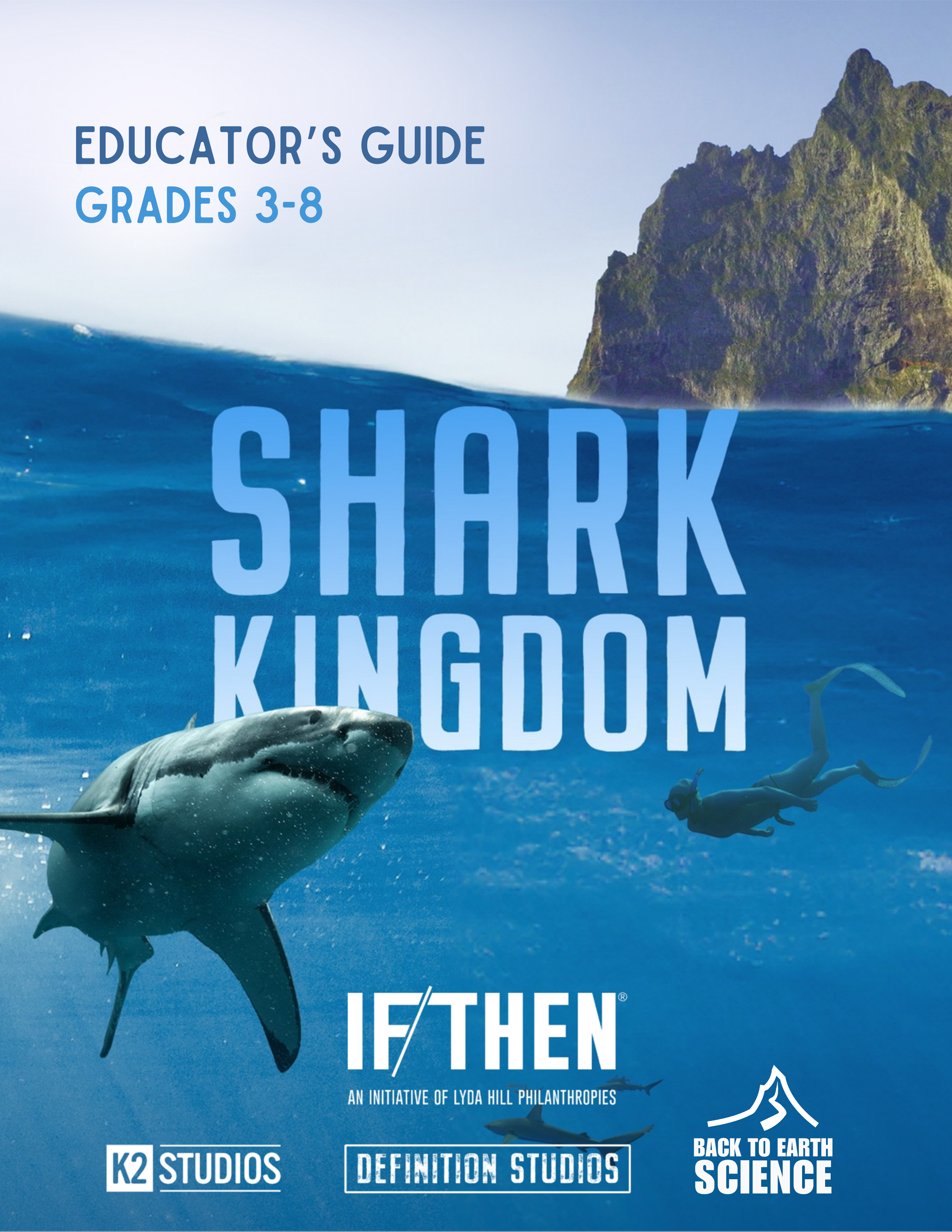
EDUCATOR'S GUIDE
GRADES 3-8

SHARK KINGDOM



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K2 STUDIOS

DEFINITION STUDIOS

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SHARK KINGDOM

WELCOME

Shark Kingdom is a large format documentary made for IMAX®/Giant Screen and other specialty theaters located in science centers, museums, zoos/aquariums and other cultural destinations and attractions worldwide. This epic family adventure reveals how diverse shark species wield unique powers to help them survive and protect their habitats. In some of the world's best diving locations like The Bahamas and Cook Islands, get up close to these awe-inspiring creatures and be immersed in the larger story of our shared oceans.

This educator's guide for grades 3-8 offers experiential learning opportunities for students who watch ***Shark Kingdom***, through outdoor activities, scientific experiments, large group simulations, and creative activities in art or drama. In each grade level, students will dive into the hidden life of sharks as caretakers of the oceans and explore ways to protect these extraordinary fish. All lessons connect to the Next Generation Science Standards (NGSS), covering interdependent relationships in ecosystems, the flow of energy in an ecosystem, environmental impacts on animals, and more. While watching the film is not required to carry out the lessons, experiencing the immersive film at a science center or aquarium near you can greatly enhance the learning experience.

TIPS FOR TAKING STUDENTS OUTSIDE

Create a code of conduct with students on safety and care for the natural world.

Ensure students work in pairs or small groups.

Set clear boundaries on where students can go.

Create a call or a signal to indicate when it is time to rejoin the group.

Have extra clothing available to help students dress for the weather.

GLOSSARY

ADAPTATION A physical or behavioural change that helps an animal survive in their environment.

CORAL The outer skeleton secreted by tiny marine invertebrates called polyps.

COMPETITIVE (ECOLOGY) An interaction where a living being requires the same limited resource as another living being in the same area.

CRUSTACEANS Invertebrates such as lobsters, shrimp, crabs, crayfish, and krill.

DRAG (PHYSICS) A force that slows down the movement of an object or living being in a fluid, by acting in the opposite direction of the object or being's motion.

ECOSYSTEM A group of living beings interacting with each other and with the physical environment.

HABITAT A place where living beings can meet their needs to survive.

ICHTHYOLOGIST A scientist who studies fish.

MIGRATION Movement of animals from one place to another to get what they need to survive.

MUTUALLY BENEFICIAL (ECOLOGY) An interaction where two species interact with each other in a way that benefits both species.

NATURAL SELECTION A process where a certain trait becomes more or less common in a species over many generations to help the species survive.

PHYTOPLANKTON Microscopic algae.

POPULATION A group of living beings of the same species in the same place.

PREDATION An interaction where a living being - like a shark - eats another living being - like a squid. In this example, the **predator** is the shark.

PREY A living being that is a source of food for another living being.

SENSES Different ways in which animals take in information about the environment, such as through sight or hearing.

TRAIT (ECOLOGY) A specific characteristic of a living being, like the shape of a shark's teeth.

A Note on Common Names

Common names of species are capitalized throughout this guide to honor the life and importance of each individual belonging to that species. Common names vary by region, as does the language and writing convention used for common names.

GRADE 3

A SHARK'S LIFE

LESSON SUMMARY

Students will learn the life cycle of sharks by making shark eggs, comparing habitats, and identifying migration hazards.

NGSS DISCIPLINARY CORE IDEAS

LS1.B Growth and Development of Organisms

LS2.C Ecosystem Dynamics, Functioning, and Resilience

LS4.D Biodiversity and Humans

LS4.C Adaptation

LESSON LENGTH

2 hours

DIPPING IN

45 MINUTES

MATERIALS

- Modeling clay (or equivalent)
- Pipe cleaners
- Photos from a web search: Shark eggs and eggs of other animals

OPENING

Shark babies - called pups - arrive into the world in a variety of ways. For example, some sharks lay eggs while others keep eggs safe inside their body until the pups hatch. For sharks who lay eggs, what do you think a shark's egg looks like?

COMPARE EGGS

Show photos of different shark eggs and compare with photos of eggs from birds, reptiles, amphibians, and other fish.

DISCUSSION QUESTIONS

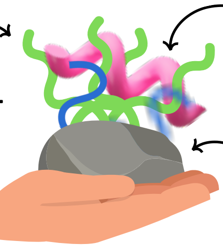
Why do you think shark eggs are shaped so differently from the eggs of other animals?

Why might the different shapes help the egg (and pup inside) stay safe?

MAKE A SHARK EGG

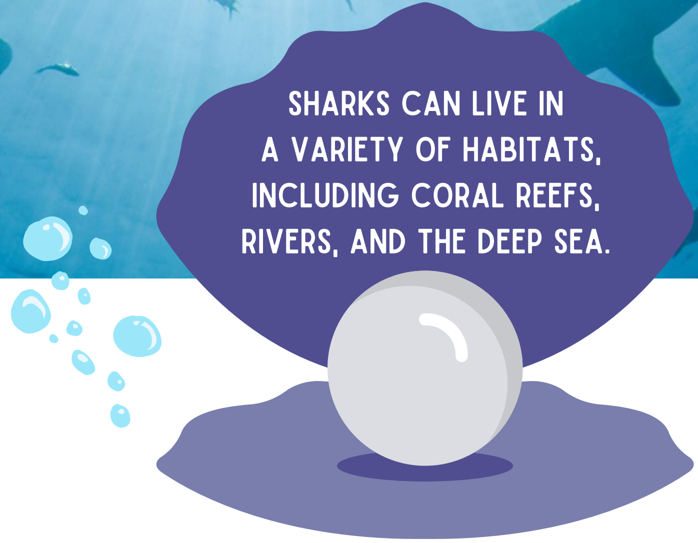
The unique shape of shark eggs helps the egg stay safely anchored to rocks, plants, or **corals** until the egg hatches.

Using modeling clay and pipe cleaners, students will design and mold a palm-sized scene of rocks, plants or corals.



GRADE 3

A SHARK'S LIFE



Next, students will design and mold a shark egg that will anchor into their scene. It must have hooks, horns, or another feature that will help the egg stay put when gently tugged.

Once complete, half of the students will walk around looking at the egg designs. The other half will stay with their designs, demonstrating how their egg shape helps it stay anchored in the rocks, plants, or corals. Students will switch roles after 5-10 minutes.

DEEPER DIVE

35 MINUTES

MATERIALS

- Stopwatch x 1
- Large rope x 1

OPENING

Recall from ***Shark Kingdom*** that once born, some sharks like Blacktip Reef Sharks stay in shallow water for the first part of their life, in places with rocks, plants, and corals, rather than swimming out into the deep, open ocean.

COMPARING HABITATS

OUTDOOR

Take students outside to visit two different **habitats** near the school. Habitat #1 should be a wide open space, with sparse vegetation. Habitat #2 should have a lot of vegetation that give animals cover. Keep track of the number of animals observed in each habitat. If no animals are observed, look for signs of animals in these areas, like tracks, scat, chews, fur, feathers, etc.

DISCUSSION QUESTIONS

Which habitat had more animals or had more signs of animals? Why might that be?

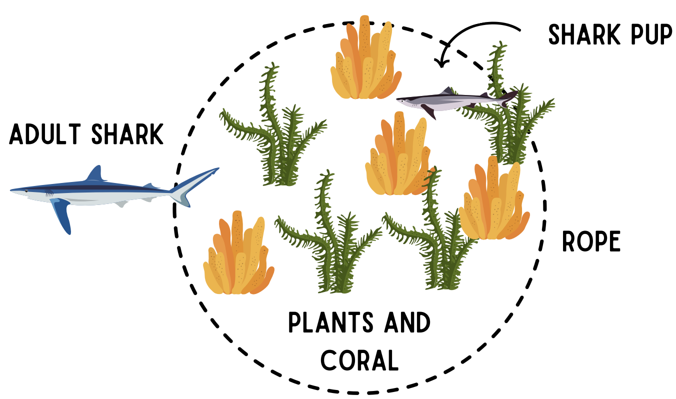
Compare these habitats to an ocean habitat. Why do you think shark pups stay in places with rocks, plants, and corals instead going to the open ocean?

WIDE OPEN OR UNDER COVER

Go to a large open play area (gymnasium or a field) and place the rope in a large circle.

Assign one student to be a shark pup (the **prey**) and one student to be a **predator** - a large adult shark. Remaining students will be plants and corals in shallow water.

The predator will stand at the edge of the rope with their back to the group. Plants and corals will huddle loosely together within the rope. The shark pup will start anywhere among the plants and corals, inside the rope.



MAKING WAVES IN SCIENCE

It was once believed that all sharks were carnivores, only eating other animals like fish, squid, and seals. However in 2018, scientists at the University of California-Irvine (USA) made an incredible discovery. Led by ecologist Dr. Samantha Leigh, it was found that the Bonnethead Shark is an omnivore! They eat animals *and* plants. Their plant of choice is seagrass.[1]

DR. SAMANTHA LEIGH

Round 1: Say "go" and start the stopwatch. The adult shark will turn around and move through the plants and corals, looking for the shark pup to eat. The shark pup can move around within the rope circle. When the adult shark tags the shark pup, the round ends. Stop the timer and reveal how long it took for the adult shark to catch the shark pup.

Round 2: Plants and corals will leave the circle and stand along the outside edge of the rope. The space inside the rope circle is now the open ocean. The adult shark will once again stand at the edge of the rope with their back turned. The shark pup will choose a spot to stand within the rope.

Say 'go' and start the stopwatch.

The shark pup can move around within the rope while the adult shark tries to tag them. When the adult tags the shark pup, the round ends. Stop the timer and reveal how long it took for the adult to catch the shark pup.

DISCUSSION QUESTIONS

In which habitat did it take longer for the adult shark to catch the shark pup - shallow waters with plants and corals or open ocean? Why?

Why might the open ocean be unsafe for baby sharks?

What special **adaptations** would help a shark pup survive in an open ocean habitat?

What special adaptations would an adult shark need to survive in shallow water and find shark pups - or other fish - to eat?

KEEP SWIMMING

35 MINUTES

MATERIALS

- Writing utensils
- Paper
- Plain craft sticks x 12 per student
- Paper bags x 1 per student

OPENING

As sharks get older, some species move to the open ocean. When it is time to start a family of their own, they **migrate** to different areas of the ocean to mate and to lay eggs or give birth.

GRADE 3

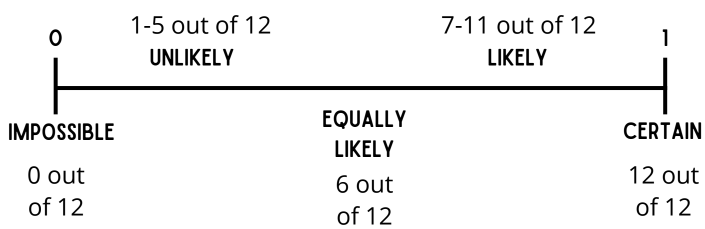
A SHARK'S LIFE

MIGRATION HAZARDS

Recall from ***Shark Kingdom*** that migrating is not always safe for sharks. There are hazards like fishing, ships, and litter that can hurt sharks.

Give each student a paper bag and 12 craft sticks to place in front of them. Craft sticks represent migration paths in the ocean. Students will choose 5 of their sticks and write or draw a hazard on each stick: fishing, ships, or litter. Place all 12 sticks in the paper bag and mix them up.

Introduce the probability scale. Based on the number of hazards (5) and total number of migration paths in the bag (12), students will determine the probability of pulling a hazard out of their bag in the first round and record this on blank paper. Students should conclude that in Round 1, it is unlikely they will pull a hazard.



Round 1: Each student pulls a stick from their bag (without looking) and places it in front of them.

Round 2: The probability has changed. Some students have fewer hazards in their bag and some have fewer safe paths. Determine the new probability of drawing a hazard with 11 sticks left in the bag and record this on paper. Students will then draw a stick and place it front of them.

Round 3: Students will determine the probability of drawing a hazard with 10 sticks left in the bag and record this on paper. Students will draw a stick and place it front of them.

RIPPLE OUT

Dr. Samantha Leigh's actions not only change our understanding of shark diets, but also help protect the habitats where sharks find their food.

Like Dr. Leigh, your actions can ripple out! Help sharks - and other animals - stay safe with everyday choices like picking up litter or using less plastic. Your choices matter!

DISCUSSION QUESTIONS

How many students had one hazard along their path? Two hazards? Three hazards?

For sharks in the ocean, although the probability of running into a hazard may be unlikely in some areas, it's still possible. How could sharks be protected along their migration path? Time permitting, remove 1-2 hazards based on the solutions presented and repeat the activity. Did the sharks run into fewer hazards overall with this change?

REFLECTION

5 MINUTES

CLOSING

What are the ways sharks keep themselves safe throughout their life?

In what ways can you help protect sharks in all stages of their life - from eggs or a newborn pup to an adult?

GRADE 4

TRACKING SHARKS

LESSON SUMMARY

Students will learn about shark senses, experiment with buoyancy in the ocean and decode messages from shark tags.

NGSS DISCIPLINARY CORE IDEAS

LS1.A: Structure and Function

LS1.D: Information Processing

PS4.C: Information Technologies and Instrumentation

LESSON LENGTH

2.5 hours

DIPPING IN

30 MINUTES

MATERIALS

- Letter-sized signs:
  - “Eyes” x 2
  - “Ears” x 2
  - “Lateral Line” x 8
  - “Ampullae of Lorenzini” x 2
- Large child-safe magnets x 2 sets
- Small flashlights x 14
- APPENDIX A - Shark Senses

OPENING

Recall from ***Shark Kingdom*** that sharks have a variety of senses that give them information about the world around them. This data helps them hunt, find mates, and stay safe.

DISCUSSION QUESTIONS

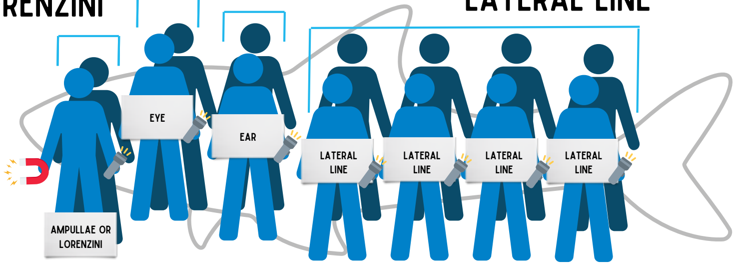
What senses do you think sharks have? Do humans have the same senses as sharks?

SHARK SENSES SIMULATION

Show the Shark Senses image and introduce shark sense organs of eyes, ears, the lateral line, and Ampullae of Lorenzini.

Assign half the class as sense organs. Give these students a pre-made sense organ sign along with a flashlight. Ampullae of Lorenzini students also receive one half of a magnet set.

Arrange organs as they appear on a shark’s body, with ampullae of Lorenzini at the head, then eyes, ears and the lateral line along the body to the tail. Assign an additional student to be a prey animal (a smaller fish). Give the prey fish the second half of the magnet set.



GRADE 4

TRACKING SHARKS

TO HELP STAY BUOYANT, SAND TIGER SHARKS GULP AIR AND STORE IT IN THEIR STOMACH.[2]

Dim the lights. The prey fish will slowly move around the shark. When the shark 'senses' the prey, they will turn their flashlight on and off as follows:

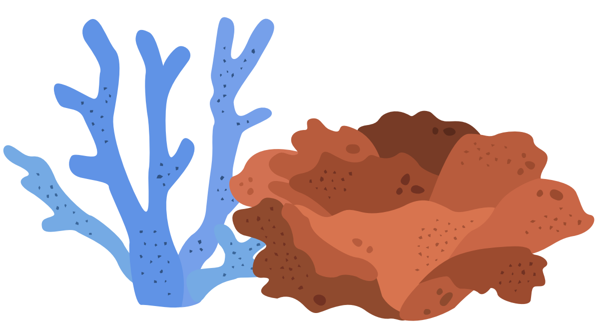
- Eyes - When they see the fish.
- Ears - When they hear the fish.
- Ampullae of Lorenzini - When they feel the magnet pull. *Note: At the ampullae of Lorenzini, the prey fish will bring their magnet close to the shark's magnet before moving on.*
- Lateral Line - When they feel the vibration of the fish. *Note: Prompt the prey fish to stomp near the lateral line so vibrations can be felt through the ground.*

The remaining students observe the senses lighting up as the prey moves around the shark. After 1-2 minutes, the class will switch roles.

DISCUSSION QUESTIONS

Were senses lighting up in one area of the body only or all over the body when the prey was near? Why might it be helpful to have senses all over the body?

How might a shark act if they can hear their prey but cannot sense the movement of their prey? How might they act if they sense the electrical field of their prey but cannot see their prey ?



DEEPER DIVE

1 HOUR

MATERIALS

- Salt
- Water
- Vegetable oil
- Scissors x 10
- Tablespoon x 10
- Measuring cup x 10
- Sharpies or markers x 10
- Biodegradable kitchen compost bags or biodegradable dog cleanup bags x 3 per pair
- Large, deep bowls x 2 per pair
- APPENDIX B - Staying Afloat Experiment

OPENING

Having exceptional senses is not enough for a shark to survive. They also need fins to swim, gills to breathe, *and* they need to be buoyant, or they will sink to the bottom of the ocean.

STAYING AFLOAT

Shark livers contain a special liquid that helps them stay afloat - or buoyant - in the ocean. Is that liquid fresh water, salt water, or oil?

Arrange students in pairs and hand out the "Staying Afloat Experiment" sheet to each pair. Students will conduct the experiment, following the instructions on the sheet.

MAKING WAVES IN SCIENCE

Jess Cramp is a shark scientist who founded Sharks Pacific - an organization that works with local communities to research sharks in order to protect them and promote coexistence. With a team of scientists and local knowledge holders, Jess collects data using electronic tags that track their movements and observation through camera deployments, fishing and diving. This data helps Jess and the team set up actions that help both fishers and sharks thrive together.[3]

JESS CRAMP
Featured in Shark Kingdom

DISCUSSION QUESTIONS

Which liquid floated in the water? Does this mean it is lighter or heavier than the water?

Which liquids were heavier or as heavy as the fresh water? How do you know?

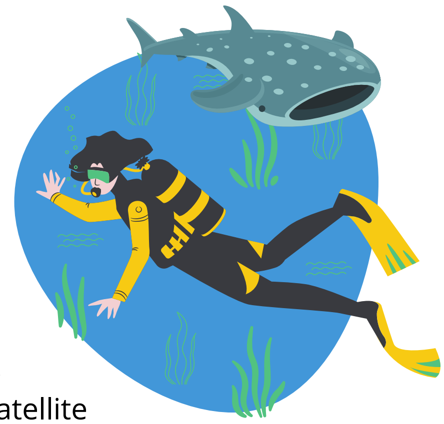
Which liquid do you think is in a shark's liver to help them stay buoyant and why? *A shark's liver is filled with oil. Since oil is lighter than water, it helps the shark stay afloat.*

How does staying afloat help a shark survive?

How would sharks need to change the way they track or find food if they were not buoyant? Why might that be?

KEEP SWIMMING

50 MINUTES



MATERIALS

- Blank paper
- Writing utensils
- APPENDIX C - Satellite Tagging Code Key Template

OPENING

While sharks are using all their senses and buoyancy to track their food, sharks are also being tracked - by humans! Recall from ***Shark Kingdom*** that by studying the movement of sharks, researchers like Jess Cramp can help protect the places sharks go.

ACOUSTIC TAGGING

Some researchers put "acoustic tags" on sharks. When the shark swims by a "receiver" installed in the water, the receiver hears a unique audio message from the tag, like a sequence of "pings." The researcher decodes the "pings" to find out which shark swam by.

In pairs, student A will be the acoustic receiver and researcher. Student B will be the sharks. On a sheet of paper, student A will create three different "ping" sequences for three different sharks. The sequence should be 5-7 "pings" In length, and have a combination of short and long "pings." "Pings" are represented by dashes.

EXAMPLE: – —— – – —— SHARK 1
– – – – —— SHARK 2
SHORT PING LONG PING

GRADE 4

TRACKING SHARKS

Student B - the sharks - will copy the three sequences onto their own sheet of paper, with the same labels of shark 1, shark 2, and shark 3. Student B will randomly choose a shark and say the ping sequence out loud. Student A will look at their original sheet and try to guess which shark has swam by the receiver. When the shark is correctly guessed, student B will choose a different shark and say their ping sequence. Repeat two more times and then students will switch roles.

SATELLITE TAGGING

Researchers also use satellite tags to track sharks. These tags send messages to satellites in the form of 1s and 0s. Computers back on Earth decode the messages for researchers.

In the same pairs, student A will be a researcher who needs to manually decode the satellite message. Student B is a shark. Student A will create a code key for an 8-digit satellite tag using the Satellite Tagging Code Key Template.

FIRST TWO DIGITS OF THE 8-DIGIT CODE

EXAMPLE: 00 = SHARK IS IN SHALLOW WATER
01 = SHARK IS IN DEEP WATER

On a piece of paper, student B will create an 8-digit sequence using the code key that will tell the researcher where they are in the world.

EXAMPLE:	00	11	10	11
	SHALLOW WATER	PACIFIC OCEAN	WARM WATER	MOVING SLOWLY

Student A will read the 8-digit sequence using the code key to learn where the shark is. Once they have decoded the information, student B will create one more sequence before switching roles.

RIPPLE OUT

Jess Cramp's actions not only protect sharks, but also protect animals like rays and corals living among sharks.

Like Jess, your actions can ripple out! Name a quality you have that can help your actions impact others in a good way. For example, you might be caring, creative, or brave.

DISCUSSION QUESTIONS

Which method of gathering information on the movement of sharks did you prefer - acoustic tagging or satellite tagging ? Why?

Why might shark scientists choose one method over the other?

REFLECTION

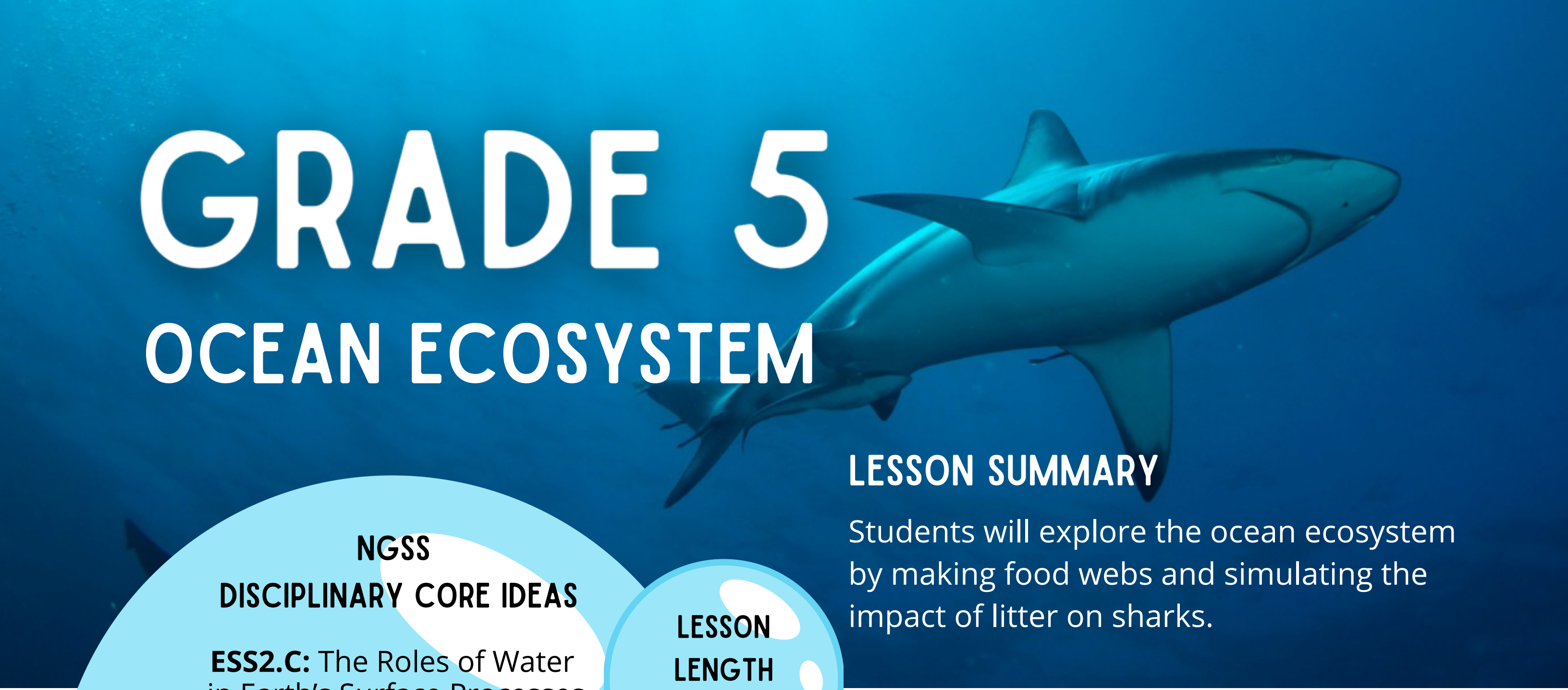
10 MINUTES

CLOSING

How might it feel to have a lateral line or ampullae of Lorenzini on *your* body? How could they help you survive?

How might humans move or behave differently if we had an oil-filled liver like a shark?

If you were a shark researcher, what information would you want to gather when tracking sharks? How would this information help protect the places they live?



GRADE 5

OCEAN ECOSYSTEM

LESSON SUMMARY

Students will explore the ocean ecosystem by making food webs and simulating the impact of litter on sharks.

NGSS DISCIPLINARY CORE IDEAS

ESS2.C: The Roles of Water in Earth's Surface Processes

PS3.D: Energy in Chemical Processes and Everyday Life

LS1.C: Organization for Matter and Energy Flow in Organisms

LS2.A: Interdependent Relationships in Ecosystems

ESS3.C: Human Impacts on Earth Systems

LESSON LENGTH

2.5 hours

DIPPING IN

20 MINUTES

MATERIALS

- Blank paper
- Rulers x class set
- Writing and drawing utensils
- Math compasses or equivalent x class set

OPENING

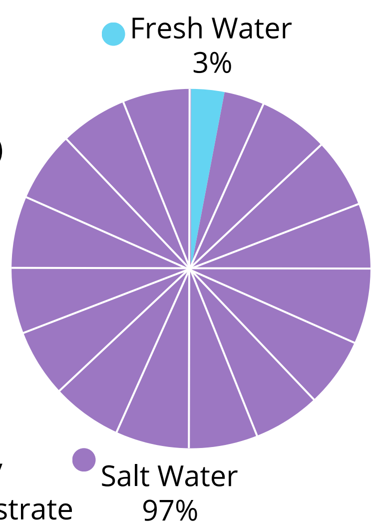
Recall from ***Shark Kingdom*** that our world is a water world. But, not all water is the same. Some water is salty - like water in the ocean - and some water is fresh - like water in lakes and rivers. Each type of water creates a unique ecosystem that is home to a variety of plants and animals, including sharks.

SALT WATER VERSUS FRESH WATER

On blank paper, students will make a pie chart by drawing a large circle with a math compass. Using a ruler, divide the circle in half. Keep dividing the circle until there are 16 equal slices in the circle. Each slice represents approximately 6 out of 100 or 6%.

Share that 97% of water on the planet is salt water and 3% is fresh water.[4] Students will illustrate these percentages on their pie chart by coloring the slices (one color for salt and another color for fresh) and adding labels.

Share that there are more than 500 shark species. At least 4 species (less than 1%) tolerate fresh water, while roughly 99% are saltwater species.[5] Students will now draw a second pie chart with 16 slices (each slice equals approximately 6%). Students will illustrate the percentage of freshwater species and saltwater species with two different colors and add labels to the chart.



GRADE 5

OCEAN ECOSYSTEM

SHARKS THAT TOLERATE FRESH WATER INCLUDE THE BULL SHARK, AND THE GANGES SHARK.[6]

DISCUSSION QUESTIONS

Compare the two charts. What do you notice? Why do you think there are more shark species living in salt water than fresh water?

What might happen to fresh water ecosystems if there are too many sharks species present?

How might fresh water sharks be different from saltwater sharks? Think about their diet, where they take shelter, etc.

DEEPER DIVE

1 HOUR

MATERIALS

- Scissors
- String
- Drawing utensils
- Push pins x 2 per student
- Large art paper x 2 per student
- APPENDIX D - Ocean Food Web Cards

OPENING

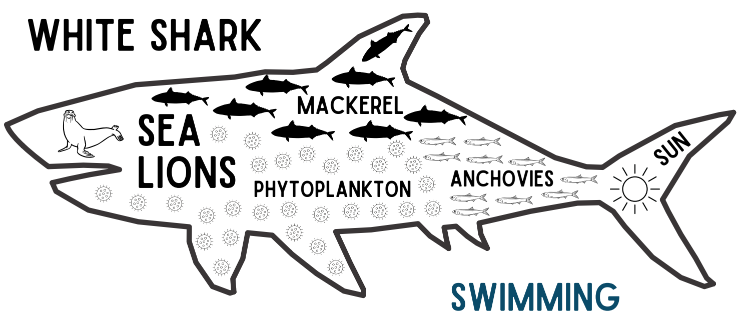
Recall from ***Shark Kingdom*** that 80% of all life on the planet lives in oceans (saltwater ecosystems). Sharks play an essential role in keeping the oceans balanced, but they are just one of many key players in the ecosystem.

OCEAN FOOD WEBS

Distribute any two Ocean Food Web Cards and two large sheets of art paper to each student. Share that like all animals, sharks get energy from the food they eat.

On each sheet of paper, students will draw the following:

1. An outline of the plant or animal shown on one Ocean Food Web card.
2. Inside the outline, write and/or draw what the animal or plant eats to gain energy.
3. Continuing in the outline, write and/or draw how the animal or plant in step 2 gets *their* energy and continue this pattern until you draw the sun. Fill the entire outline with words and/or images.
4. Outside the outline, label the animal or plant with their species name and add an action the plant or animal takes that requires energy (i.e., swimming).



Once complete, cut out the plants and animals and pin them on a bulletin board. Pin duplicates together in a cluster. Add an image of the sun.

Students will now create an ocean food web. Tie string to each pin. Attach the other end of the string to the main plant, animal, or sun that they need to gain energy. For example, White Shark would connect to Sea Lion.

GRADE 5

OCEAN ECOSYSTEM

MAKING WAVES IN SCIENCE

For the past 30 years, professional diver and shark behaviorist Cristina Zenato has formed a unique bond with sharks in The Bahamas, where she can relax them with her touch. This skill allows her to remove fish hooks and parasites from the sharks, as well as collect data on the sharks for scientific research. She most often works with Caribbean Reef Sharks.[7]

CRISTINA ZENATO

Featured in Shark Kingdom

DISCUSSION QUESTIONS

What would happen to the ecosystem and to sharks if **phytoplankton** disappeared?

How does phytoplankton make energy from the sun? *Photosynthesis - energy from light transforms water and carbon dioxide into food*.

Choose an animal on the board. What would happen to the ecosystem if they disappeared? How would sharks be impacted?

What kind of activities/actions require sharks to gain energy from food? Look at all the plants and animals illustrated in a shark outline that have contributed to their energy. Could a shark do an activity like swimming or hunting without the sun or phytoplankton?

KEEP SWIMMING

1 HOUR

MATERIALS

- Red marker x 1
- Bucket x 1
- Large hoops x 6
- Plain craft sticks x 150
- Clipboards x 1 per pair
- Graph paper and writing utensils
- Reusable cleaning gloves x 1 pair per student
- Recycling bins or equivalent x 1 per pair

OPENING

Gaining energy safely (finding food) is not an easy task for sharks when the oceans are full of litter like fishing nets and hooks. Some litter is dropped directly in the ocean, while other litter starts on land.

NEIGHBORHOOD LITTER SURVEY

OUTDOOR

Arrange students in pairs and hand out gloves and a recycling bin to each pair. Students will go outside for roughly 15-20 minutes to a designated area and collect litter. If students find any sharp objects, they must ask an adult for assistance before collecting the item.

Arrange the litter into categories: plastic, metal, food, string/netting, and other. Hand out clipboards, graph paper and writing utensils to each pair. Students will make a bar graph to show how much of each litter type was found in their neighborhood.

GRADE 5

OCEAN ECOSYSTEM

The quantity of litter will be on the Y axis, and the type of litter will be on the X axis. Once complete, correctly dispose of the litter.

DISCUSSION QUESTIONS

What type of litter was found the most in the neighborhood? How might this litter end up in the ocean?

TANGLED IN THE OCEAN

In advance, take 60 craft sticks and color one side red. Take 90 additional sticks and set aside.

Recall from ***Shark Kingdom*** that shark behaviourist Cristina Zenato removes fishing hooks stuck in sharks while she dives in The Bahamas.

Take students to a large open space for a simulation. Spread out six large hoops and distribute craft sticks at random - plain side face up - in each hoop.

One student will be a diver like Cristina. All other students are sharks. Sharks need to gain energy by collecting food - the craft sticks. When they pick up a stick, they will flip it over to see if it is plain or red. If the stick is plain, they have safely found food and will continue collecting from another hoop. If the stick is red, they freeze. A red stick means they have been caught in a net or a hook. Sharks are unfrozen when the diver taps them on the shoulder. Sharks need 5 plain craft sticks by the end of the game to survive.

Begin the simulation. After 1-2 minutes, pause. Tell any frozen students that they have lost energy while caught in the net or hook.

RIPPLE OUT

Cristina Zenato's actions not only save *individual* sharks, but also save sharks as as species by helping end misunderstandings about the temperament of sharks.

Like Cristina, your actions can ripple out! Small acts of kindness toward an individual (including yourself) impacts others too. How will you spread kindness today?

Take away 2 craft sticks from each frozen shark and place in a bucket. Continue playing for about 10 minutes, pausing every 1-2 minutes to take away energy from frozen sharks.

DISCUSSION QUESTIONS

How many sharks had 5 or more sticks (and therefore had enough energy to survive)?

What impact does litter have on sharks?

How do sharks lose energy when they are trapped in litter?

REFLECTION

10 MINUTES

CLOSING

How do sharks keep ecosystems in balance?

What personal actions can you take to reduce the amount of garbage you make or reduce the amount of litter in your neighborhood? How will these actions protect freshwater and saltwater ecosystems?

GRADE 6

SHARK ANATOMY

LESSON SUMMARY

Students will explore the aerodynamics of a shark's body, how sharks sense the world, and how traits change in natural selection.

NGSS DISCIPLINARY CORE IDEAS

LS1.B: Growth and Development of Organisms

LS1.D: Information Processing

LS4.B: Natural Selection

LS4.C: Adaptation

PS2.A: Forces and Motion

LESSON LENGTH

2.5 hours

DIPPING IN

45 MINUTES

MATERIALS

- Scrap paper
- Writing utensils
- Photos from a web search: Whale Shark and Caribbean Reef Shark
- Masking tape
- Tape measures x 1 per pair

OPENING

Recall from ***Shark Kingdom*** that while all sharks share common features like having flexible cartilage instead of bones, each species varies in size and shape. Looking at a shark's body gives clues as to how the shark moves and gets their food.

DISCUSSION QUESTIONS

How might a narrow-bodied shark move or hunt compared to wide-bodied shark?

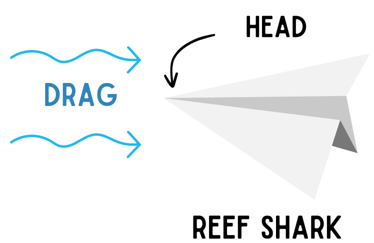
SHARK SHAPE EXPERIMENT

Show students an image of a Caribbean Reef Shark and Whale Shark. Ask students what they notice about their body shapes.

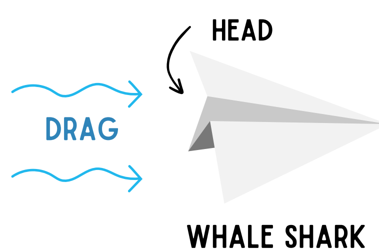
Share that when sharks move through water, they are slowed down by a force called **drag**. The same force impacts birds flying in the air.

Arrange students in pairs. Provide each pair with 4-6 sheets of paper and writing utensils.

Students will make two paper airplanes. Share that the point at the front is like the narrow head of a Caribbean Reef Shark.

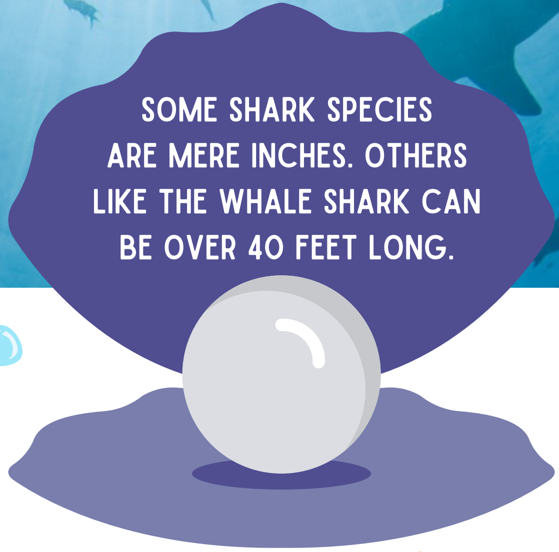


If they turn their airplanes around, the front resembles the wide head of a Whale Shark.



GRADE 6

SHARK ANATOMY



On blank paper, students will hypothesize how drag will impact the movement of each shark based on the shape of their head (narrow or wide). Students will now test their hypotheses:

1. Mark a starting spot on the ground where the airplane thrower will stand.
2. Stand on the start spot and throw the Reef Shark shape. Mark where it landed with a piece of tape and label it "reef 1."
3. Stand on the start spot and throw the Whale Shark shape. Mark where it landed with a piece of tape and label it "whale 1."
4. Measure each distance from the starting spot to the marked tape and record these results on the hypothesis sheet.
5. Throw each shape again. Label tape "reef 2" and "whale 2" and record the results.

Students will calculate the average distance traveled by each shape by adding up the two results and dividing by two. Calculate a class average <u>for each shape</u>.

DISCUSSION QUESTIONS

Which head shape allowed the shark to move further, meaning drag had less of an impact? *Drag depends on surface area. A smaller surface area at the front of the shark (a narrow head) means they experience less drag.*

Do you think water has more or less drag forces than air? With more drag in water, which body shape do you think would allow a shark to chase and hunt prey easier in the water? Why?

Knowing that drag slows down wide-headed Whale Sharks, how do you think they feed and survive? *They are filter feeders, gulping water and straining out plankton and other small organisms like anchovies to eat.*

DEEPER DIVE

50 MINUTES

MATERIALS

- Blank paper
- Writing utensils
- Clipboards x class set
- APPENDIX A - Shark Senses
- APPENDIX E - Ocean Scenes

OPENING

Recall from ***Shark Kingdom*** that in addition to having varied body shapes, sharks have many senses that help them hunt and stay safe.

SENSING YOUR NEIGHBORHOOD

OUTDOOR

Provide each student with blank paper, a clipboard, and a writing utensil. Go outside.

For 5-7 minutes, students will walk around, writing what they see, hear, smell, and safely touch in detail.

GRADE 6
SHARK ANATOMY

MAKING WAVES IN SCIENCE

Dr. Allison Bronson studies the anatomy of living and fossil sharks using CT (computed tomography) scans. One part of her research examines the inner ear of sharks and their relatives to learn when the trait of detecting low frequency sounds appeared in sharks' evolutionary history. She also wants to learn how evolutionary history and living in different habitats might affect sharks' ear structures.[8]

DR. ALLISON BRONSON

DISCUSSION QUESTIONS

What kind of information did your nose gather? Eyes? Ears? Touch? Where did that data travel to in your body? *Along nerve cells to the brain.*

What information might sharks need to gather to stay alive? What senses might they use?

SENSING THE OCEAN

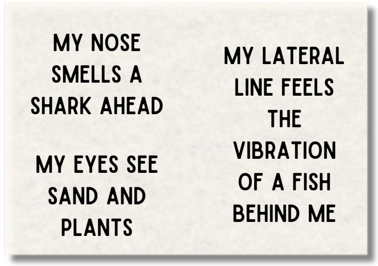
Show the image of Shark Senses and introduce shark sense organs of eyes, ears, nose, the lateral line, and ampullae of Lorenzini.

In pairs, students will secretly choose a photo from the Ocean Scenes. Each student will imagine they are the shark in the photo and will recreate the photo by answering the following prompts on paper using words only.

My eyes see... **My ears hear...**
My nose smells... **My lateral line feels...**
My ampullae of Lorenzini senses...

Once complete, students will swap their paper with their partner. They will now compare the sense descriptions from their partner with the original images and guess which image their partner was recreating (i.e, A, B, C, etc.).

EXAMPLE



DISCUSSION QUESTIONS

Which information taken in by the shark's senses might prompt them to immediately change their behaviour (i.e., hide, hunt, etc.)?

Which information might sharks store in their brain as memories? How might this help them survive?

KEEP SWIMMING
45 MINUTES

MATERIALS

- Blank paper
- Writing utensils
- Craft sticks x 10 per student
- Paper bags x 1 per student

GRADE 6

SHARK ANATOMY

OPENING

Sharks have adapted over millions of years to survive in today's environment. These **adaptations** have led to unique body shapes, senses, behaviours, and more.

NATURAL SELECTION GAME

Hand out blank paper, writing utensils, a paper bag, and 10 craft sticks to each student. Introduce **natural selection.**

Share that in a fictional shark **population**, 60% of the sharks have sharp teeth to catch and eat fish, while 40% of the population has flatter teeth, which are better at catching and eating **crustaceans**. There used to be more fish than crustaceans where the sharks live, but the environment has recently changed. Many fish have perished. Now, there are more crustaceans than fish.

Students will start by writing "fish" on 3 craft sticks, and "crustaceans" on 7 craft sticks. On their blank paper, they will calculate the probability (in percentage) of a shark catching a fish, using the following formula where P equals the probability of an event:

$$P\text{ (event)} = \frac{\#\text{ of favorable outcomes}}{\#\text{ of total outcomes}}$$

EXAMPLE

$$P\text{ (CATCHING A FISH)} = \frac{3\text{ FISH}}{10\text{ TOTAL FOOD}}$$

$$= \frac{3 \times 10}{10 \times 10} = \frac{30}{100}$$

$$= 30\%$$

RIPPLE OUT

Dr. Allison Bronson's actions not only teach us about sharks of the past, but inspires new generations of scientists to care about sharks alive today.

Like Dr. Bronson, your actions can ripple out! How do you want to inspire others to care about sharks or the ocean?

Next, students will calculate the probability (in percentage) of a shark catching a crustacean.

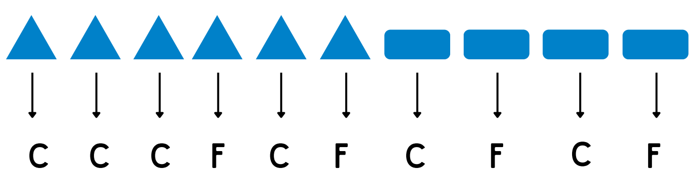
Share that there are currently ten sharks in the population. How many sharks have sharp teeth? *Six*. How many have flatter teeth? *Four*.

On their paper, students will draw six symbols to represent the sharp-tooth **trait** and four symbols to represent the flatter-tooth trait.

EXAMPLE ▲ = SHARPER ▬ = FLATTER

Round 1: Students will draw one stick from the bag and record whether they caught a fish or a crustacean under the shark's symbol. Put the stick back in the bag. Shake the bag and draw another stick. Record the next result under the next shark's symbol. Repeat until all sharks have caught food.

YEAR 1 EXAMPLE F = FISH C = CRUSTACEAN



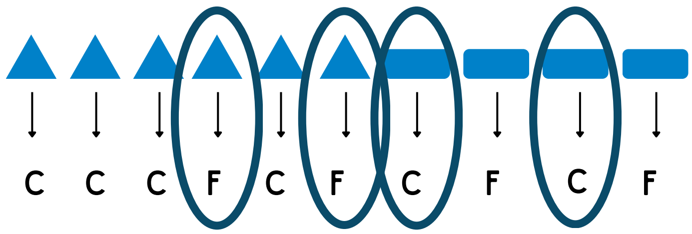
GRADE 6

SHARK ANATOMY

SHARKS HAVE ROWS OF REPLACEMENT TEETH. WHEN THEY LOSE A TOOTH, A NEW ROW MOVES IN. [9]

If a sharp-toothed shark caught a fish, they have survived. If a flat-toothed fish caught a crustacean, they have survived. Circle the survivers. Note how many sharp-toothed sharks remain and how many flat-toothed sharks remain.

YEAR 1 EXAMPLE RESULTS

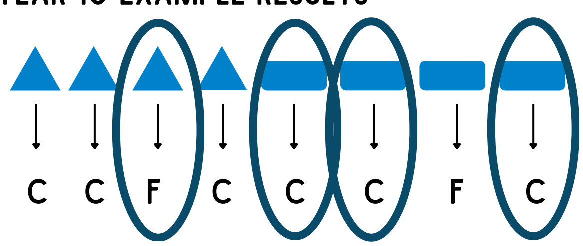


Round 2: Share that each surviving shark has reproduced. It is now 10 years later. Redraw the population and add an extra shark for each shark that survived.

YEAR 10 EXAMPLE

Students will draw one stick from the bag and record whether they caught a fish or a crustacean under the shark's symbol. Put the stick back in the bag. Continue drawing sticks and recording the result under each shark.

YEAR 10 EXAMPLE RESULTS



Circle the surviving sharks. Note how many sharp-toothed sharks remain and how many flat-toothed sharks remain.

Round 3: Share that each surviving shark has reproduced. It is now 20 years later. Redraw the population and add an extra shark for each shark that survived. Circle the survivors and note how many sharp-toothed sharks remain and how many flat-toothed sharks remain.

DISCUSSION QUESTIONS

Which adaptation allowed the sharks to eat crustaceans? What was the probability that a flat-toothed shark would survive in each round?

Is there a pattern to the number of sharp-tooth and flat-toothed sharks that survived in each round (did one trait increase in the population while the other decreased)?

At the end of 20 years, did the population have more sharks with sharper teeth or flatter teeth? Why?

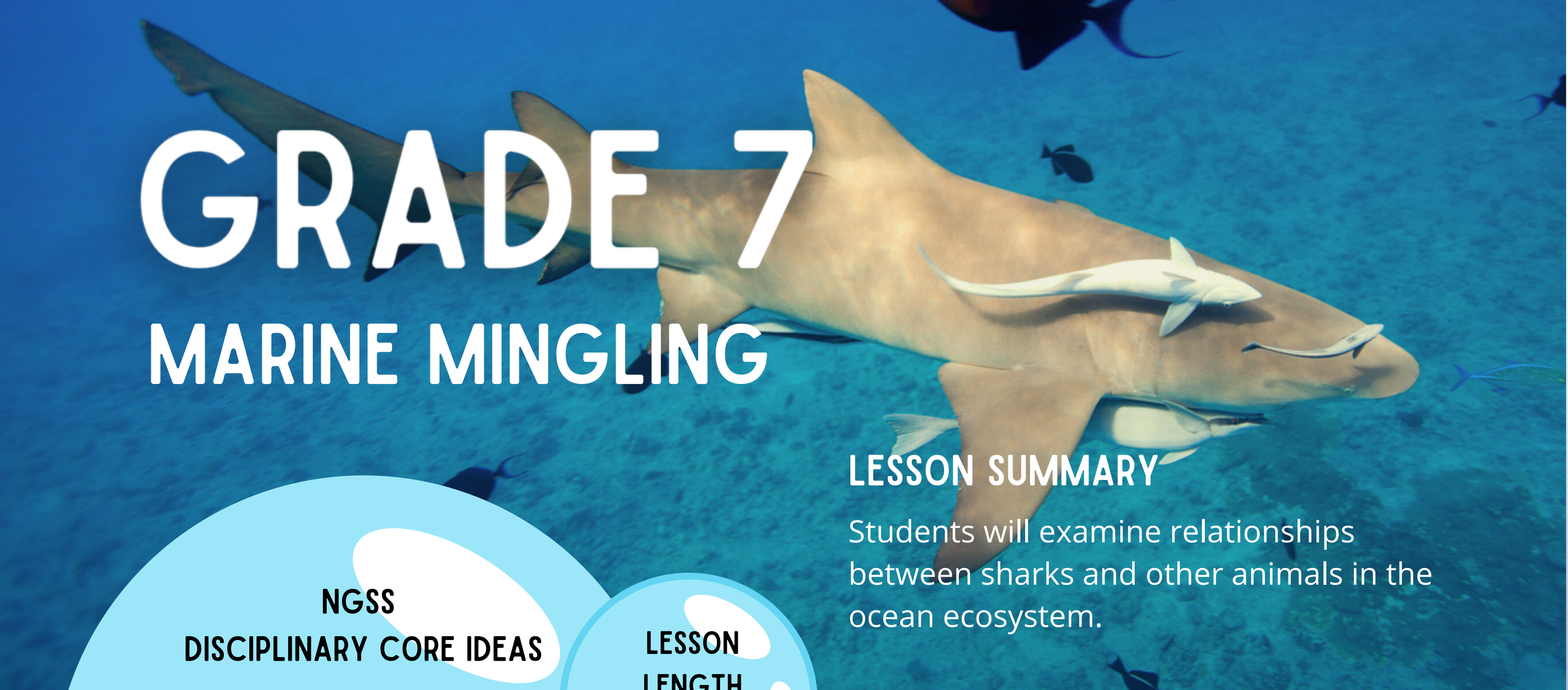
REFLECTION

10 MINUTES

CLOSING

What features or traits of a shark might make them a better hunter and/or increase their population over time?

What environmental changes happening today could impact traits in both shark and human populations? What actions could reduce the impact of these changes?



GRADE 7
MARINE MINGLING

LESSON SUMMARY

Students will examine relationships between sharks and other animals in the ocean ecosystem.

NGSS DISCIPLINARY CORE IDEAS

LS1.B: Growth and Development of Organisms

LS2.A: Interdependent Relationships in Ecosystems

LS2.C: Ecosystem Dynamics, Functioning, and Resilience

LESSON LENGTH

2 hours

DIPPING IN
30 MINUTES

MATERIALS

- Cue cards x 1 per student
- Writing and drawing utensils
- Craft sticks labeled "Food" x 30
- Craft Sticks labeled "Oxygen" x 30
- Craft Sticks labeled "Salt Water" x 30
- Craft Sticks labeled "Warm Water" x 30

OPENING

In an ocean **ecosystem**, sharks interact with a variety of living beings and non-living features to survive. Three types of relationships between sharks and other living beings are **competitive**, **predatory**, and **mutually beneficial**.

MARINE MINGLE

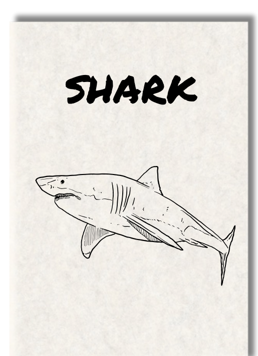
Provide each student with one cue card and drawing utensils. Assign students to draw the following on their card:

- 4-5 students draw a shark and label it "shark"
- 7-8 students draw a small fish and label it "prey"
- 2-3 students draw a small fish and label it "mutually beneficial fish"
- 1-2 students label their card "oxygen"
- 1-2 students label their card "salt water"
- 1-2 students label their card 'warm water"

Place the craft sticks in piles around the room. Put all cards in a pile and have students randomly draw <u>one</u> card and <u>one</u> food stick.

In this game, students are in an ecosystem in the Caribbean. They will represent the being on their card as they interact with sharks.

Students will then walk around the room, pausing at each student they meet. They will reveal their card to one another and take the actions listed below.



GRADE 7

MARINE MINGLING

REMORAS ARE FISH THAT SUCTION THEMSELVES TO SHARKS AND EAT PARASITES OFF THE SHARK'S BODY.[10]

GAME ACTIONS

- *Shark -- Shark*. You've met competition! Play rock, paper, scissors. The winner takes <u>one</u> food from the other shark if they have food.
- *Shark -- Prey*. Play rock, paper, scissors. If the shark wins, they take <u>one</u> food from the prey if they have food. If the prey wins, both move on to meet other students.
- *Shark -- Mutually Beneficial Fish*. A shark has kept the fish safe, while the fish has removed parasites from the shark. Both pick up a stick from a food pile.
- *Prey -- Mutually Beneficial Fish*. Both students take a food stick.
- *Any living being -- Oxygen/Warm Water/Salt Water*. Living beings pick up the corresponding oxygen, warm water, or saltwater stick from a pile.
- For all other interactions, no action is taken.

In order for sharks to survive, they need a food, oxygen, warm water, and saltwater stick by the end of each round. Play for 5 minutes, end the round, and ask how many sharks survived.

Reset the game after each round, allowing students to randomly draw a new card for the next round. End the game after 3-4 rounds.

DISCUSSION QUESTIONS

How might the interaction between sharks have changed if one shark was significantly larger than the other shark?

How else might a non-shark fish benefit a shark and how might a shark benefit that fish?

Recall what non-living features of the ecosystem the sharks needed to survive. Compare these needs with an animal in your neighborhood.

DEEPER DIVE

1 HOUR, 10 MIN

MATERIALS

- Blank paper
- Tape
- Writing and drawing utensils
- Clipboards x class set
- Cue cards x 2 per student
- Photos from a web search: White Shark, Sea Lion, Nurse Shark, Remora, Blacktip Reef Shark, and Grey Reef Shark

OPENING

Recall from ***Shark Kingdom*** that sharks interact with a variety of other animals including sea lions, other fish, and humans too. The types of interactions observed in the ocean can also be observed in your own neighborhood.

RELATIONSHIP PATTERNS

OUTDOOR

Each student recieves a clipboard, paper, and writing utensils. They will make five columns on their paper: *Animal Observed, Predator, Prey, Competitors,* and *Mutually Beneficial*.

Students will go outside in a designated area, looking for wildlife or signs of wildlife, noting each animal they see (or see signs of) in the *Animal Observed* column.

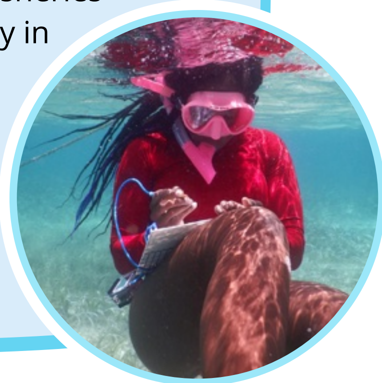
GRADE 7

MARINE MINGLING

MAKING WAVES IN SCIENCE

Carlee Jackson is a shark and sea turtle scientist who co-founded Minorities in Shark Sciences (MISS). Carlee's shark research examines the impact of tourist activities on Nurse Sharks in Belize, while her sea turtle research explores the link between trap fisheries and sea turtle safety in Florida. At MISS, Carlee runs youth programs and communications.[11]

CARLEE JACKSON



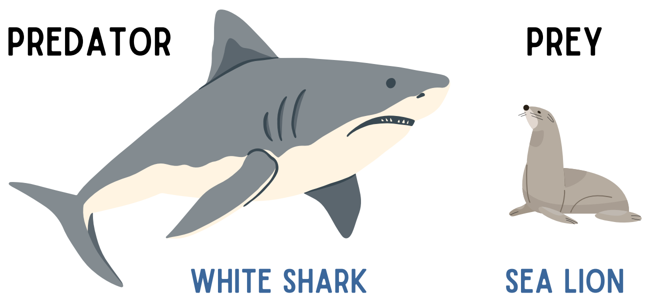
For each animal observed, they will continue exploring, guessing which other animals in this area could be predators, prey, competitors, or mutually beneficial to this animal and then recording their answers on their paper.

After 10-15 minutes, bring students inside. Hand out two cue cards per student. Each student will choose two animals observed (or known to be in the area) and draw them on separate cards.

On a board or equivalent, write four columns: *Predator-Prey, Competitive, Mutually Beneficial*, and *Other*. Students will now mingle. When they meet a student, they will look at the animals they have drawn and decide if their relationship is Predator-Prey, Competitive, or Mutually Beneficial. Once decided, they will put tape on the back of their cards and stick the pair of cards on the board under the appropriate column.

Once complete, invite the class to decide whether any animal pairings should be shifted to other columns and why.

Stick the White Shark and Sea Lion images in the *Predator-Prey* column, Blacktip Reef Shark and Grey Reef Shark under *Competitive*, and the Nurse Shark and Remora under *Mutually Beneficial*.



DISCUSSION QUESTIONS

What patterns do you notice in each of the columns? For example, is there a size pattern or diet pattern between the pairings? Does this pattern match the ocean examples provided?

What physical or behavioural changes would any prey species on the board need to hunt/eat a species larger than themselves?

How can two competitors co-exist in either the ocean or your neighborhood ecosystem with limited resources (i.e., food)? Consider when they eat, how they eat, etc.

In the case of a mutually beneficial relationship, what would happen to one species if the other species disappeared from the relationship?

Which relationships might increase the probability of a shark surviving and reproducing? Explain why.

GRADE 7

MARINE MINGLING

KEEP SWIMMING

1 HOUR

MATERIALS

- Graph paper
- Cue cards x 45 per pair
- Scissors x 1 per pair
- Writing utensils x 3 colors per pair
- APPENDIX F - Sharks, Turtles, and Seagrass

OPENING

Reproductive success depends on many factors, including the availability of food. If sharks are not able to reproduce, there can be big impacts on the ecosystem.

SHARKS, TURTLES, AND SEAGRASS

In pairs, students will cut 45 cue cards into four pieces. They will write “Tiger Shark” on 60 card pieces, “Seagrass” on 60 pieces and “Turtles” on 60 pieces.

In this simulation, Tiger Sharks eat Green Sea Turtles and Sea Turtles eat Seagrass. Start the ecosystem with six seagrass cards and four turtle cards face down. Mix them up and place one shark card in front of the ecosystem pile, face up.

Following the directions on the Sharks, Turtles, and Seagrass sheet, play through the simulation and record results in the table.

Once the simulation is complete, students will make a line graph, using three different colors to show the starting numbers for Tiger Sharks, Green Sea Turtles, and Seagrass in each round.

RIPPLE OUT

Carlee Jackson’s actions not only support shark and turtle research today, but makes sure future researchers will carry on this important work.

Like Carlee, your actions can ripple out! What knowledge will you pass on about sharks to younger members of your community?

DISCUSSION QUESTIONS

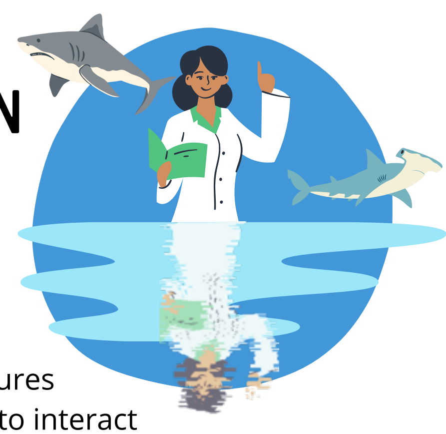
In general, what patterns do you notice with the population sizes for all three beings? Are they constant or do they fluctuate? Why?

How was the Seagrass population impacted by the Tiger Shark population? What pattern do you notice?

What might happen to the ecosystem if Tiger Sharks disappeared? What others animals might be impacted by this change?

REFLECTION

10 MINUTES



CLOSING

Which living beings and non-living features does a shark need to interact with to survive?

How are sharks just like you? Which of their needs overlap with yours?

GRADE 8

INNER ICHTHYOLOGIST

LESSON SUMMARY

Students will channel their inner ichthyologust and pose research questions that support shark conservation.

NGSS DISCIPLINARY CORE IDEAS

PS4.C: Information Technologies and Instrumentation

LS1.B: Growth and Development of Organisms

ETS1.B: Developing Possible Solutions

ESS3.C: Human Impacts on Earth Systems

LESSON LENGTH

4 hours

DIPPING IN

50 MINUTES

MATERIALS

- Device with access to Google Earth
- Blank paper
- Writing utensils

OPENING

Many species of sharks travel long distances - called **migration** - to find what they need to survive, like food or a certain temperature of water. Some species also migrate to give birth.

WHERE IS THE SHARK NURSERY?

Recall from ***Shark Kingdom*** that the location of Tiger Shark nurseries is unknown to the scientific community. However, nurseries for other species like Lemon Sharks *are* known.

On a device with internet, students will open Google Earth and turn on the gridlines under "View." Students will become junior **ichthyologists** and try to uncover the location of a Lemon Shark nursery. Reveal the six clues below one at a time in the order shown. Before revealing the next clue, students will narrow down the location on Google Earth and write 1-2 research questions that they think need to be answered to help them narrow down the location. Note that not all clues below will help!

CLUES [12]

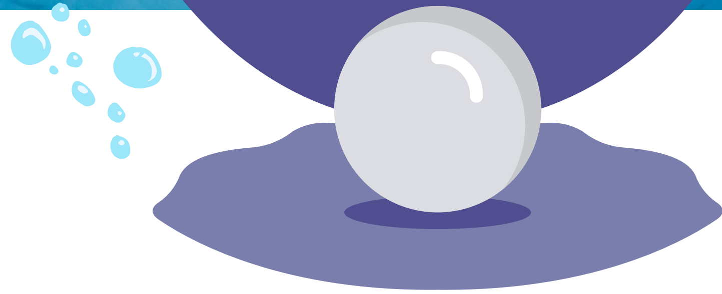
1. *Scientist* - "Lemon Sharks give birth to their pups among mangroves. Mangroves are found around the world roughly between the latitudes of 33° N and 40° S."

2. *Tourist* - "While I was snorkelling, I definitely saw a Great White Shark. I've never heard of a Lemon Shark."

GRADE 8

INNER ICHTHYOLOGIST

IN THE MALDIVIAN SHARK SANCTUARY, MOST OF THE FEMALE TIGER SHARKS ARE PREGNANT, BUT NO ONE KNOWS WHERE THEY GIVE BIRTH.



3. *Scientist* - "Juvenile Lemon Sharks eat Yellowfin Mojarra. These fish live roughly between 55-100°W longitude and 5-33°N latitude."

4. *Local resident with strong knowledge of sharks* - "I've noticed that there are Lemon Shark nurseries in the north and south islands."

5. *Tourist* - "I'm pretty sure none of the sharks here are pregnant."

6. *Scientist* - "Once the baby Lemon Sharks get a bit bigger, we've tracked many moving from the mangroves at the north western edge of the Great Bahama Bank to nearby inshore reefs."

Students will now drop a pin on their Google Earth map where they think the Lemon Shark nursery is and note the latitude and longitude. Students will write an explanation for their choice. Project Google Earth for all students to see. Input all student guesses on this map.

Select a few pins and invite students to share how they chose their location. Reveal that Bimini in The Bahamas is the nursery location. This is one Lemon Shark nursery among many in the eastern Atlantic Ocean, Gulf of Mexico, Caribbean, and south down to Brazil.[13]

DISCUSSION QUESTIONS

Which sources provided the most helpful information? Why are credible sources - like scientists and local knowledge holders - so important when conducting scientific research?

Why do you think Lemon Sharks choose Bimini as a nursery location? How does having a nursery help sharks' reproductive success?

Which of your research questions were not answered by the clues? Which research questions do you think could help find Tiger Shark nurseries?

DEEPER DIVE

35 MINUTES

MATERIALS

- Writing utensils
- Appendix G - Migration Mapping

OPENING

Recall from ***Shark Kingdom*** that scientists like Jess Cramp track the migration of sharks. One tracking method involves putting a tag on a shark that sends location messages to satellites in the form of 1s and 0s.

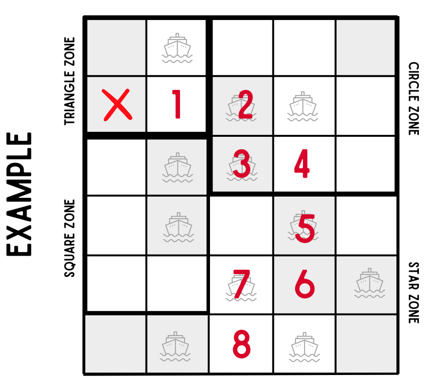
MAKING WAVES IN SCIENCE

Ariana Agustines is a scientist and shark conservationist who uses low-impact and non-invasive research methods to study sharks, primarily in the Philippines. On a special project with the Ocean Exploration Trust in Hawaii, she used remote underwater videos to study shark diversity and population size. She also examined environmental DNA from sea water samples to find out if certain species were present in the area.[14]

ARIANA AGUSTINES

Share that students will practice reading (fictional) location messages from satellite tags on sharks. Arrange students in pairs and provide each student with two copies of the Mapping Migration sheets.

Each student will draw an X in any square on one of their maps to represent the tagging location. From this start point, they will choose 8 squares to represent the shark's migration path. Path squares are labelled 1-8.



Using the code template, students will create a 6-digit code using 1s and 0s for each of the migration path squares to indicate the shark's location.

Once complete, pairs will keep their maps hidden, but will swap codes and provide their partner with the tagging location (starting point) on a blank map.

Students will then decipher their partner's code one square at a time and write numbers on the blank map corresponding with the code line number to show where they think the shark has traveled.

DISCUSSION QUESTIONS

What other information do you think would be helpful to receive from a shark tag when tracking their migration?

Why is it important to know the migration path of sharks? How can this information lead to the protection of sharks, especially where shipping or fishing boats are present?

KEEP SWIMMING

2.5 HOURS

MATERIALS

- Blank paper
- Writing utensils
- Device with internet and/or library access

OPENING

Installing tags on sharks often involve catching the shark and releasing them. For some species, the stress of being captured and handled by humans is too much and they do not survive long after being released.[15]

GRADE 8

INNER ICHTHYOLOGIST

EVALUATING STUDY METHODS

Students will research and evaluate two different methods of studying sharks (i.e., satellite tagging, camera traps, etc.). At least one method must involve catching sharks. Students will answer the following questions:

- Describe how the sharks are studied.
- Are the sharks caught? If yes, how? Is their body harmed (i.e., are hooks used)?
- Is there a chance that hooks or nets are lost the ocean or that coral reefs are damaged?
- Are the sharks in or out of the water? Note that sharks cannot breathe out of water.
- What data is gathered with this study method? Do you believe this data is worth the stress on the shark? Explain.
- What do you like about the method and what would you change?

FISH HAVE FEELINGS CONFERENCE

Students will design a new or revised method of studying sharks that minimizes the shark's stress. They have been asked to present their findings at the prestigious (fictional) "Fish Have Feelings Conference" that aims to bring compassion to fish in the field of ichthyology. The conference organizers have asked each student for the following:

- A drawing of the new/revised study method in action, highlighting any new equipment.
- A 2-minute presentation of the method:
  - What is the new/revised method and how does it differ from current methods?
  - What makes it less stressful for sharks?
  - How is littering or reef damage prevented?
  - What data does it gather on the sharks and why is this data important for shark conservation?
- One paragraph summary of the method.

RIPPLE OUT

Ariana Agustines' actions not only have a low impact on sharks while they are studied, but also have a minimal impact on the marine environment.

Like Ariana, your actions can ripple out! What change will you make to have a lower impact on the land, water, and wildlife in your community?

DISCUSSION QUESTIONS

How can shark researchers balance the wellbeing of individual sharks studied with the need to collect data for shark conservation? Why is this balance important?

How can shark researchers balance the wellbeing of ocean and river ecosystems with the need to collect data on sharks for conservation? Why is this balance important?

REFLECTION

5 MINUTES

CLOSING

What questions do you still have about sharks? How could you find the answers to your questions?

Why should an individual shark's wellbeing be the top priority during research studies that involve a shark? Put yourself in the individual shark's position while reflecting.

CREDITS

Shark Kingdom is produced by Definition Studios, and distributed by K2 Studios in IMAX®/Giant Screen and other specialty theaters located in science centers, museums, zoos/aquariums and other cultural destinations and attractions worldwide.

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Shark Kingdom Educator's Guide (Grades 3-8) is written and designed by Back to Earth Science Inc. www.backtoearthscience.com

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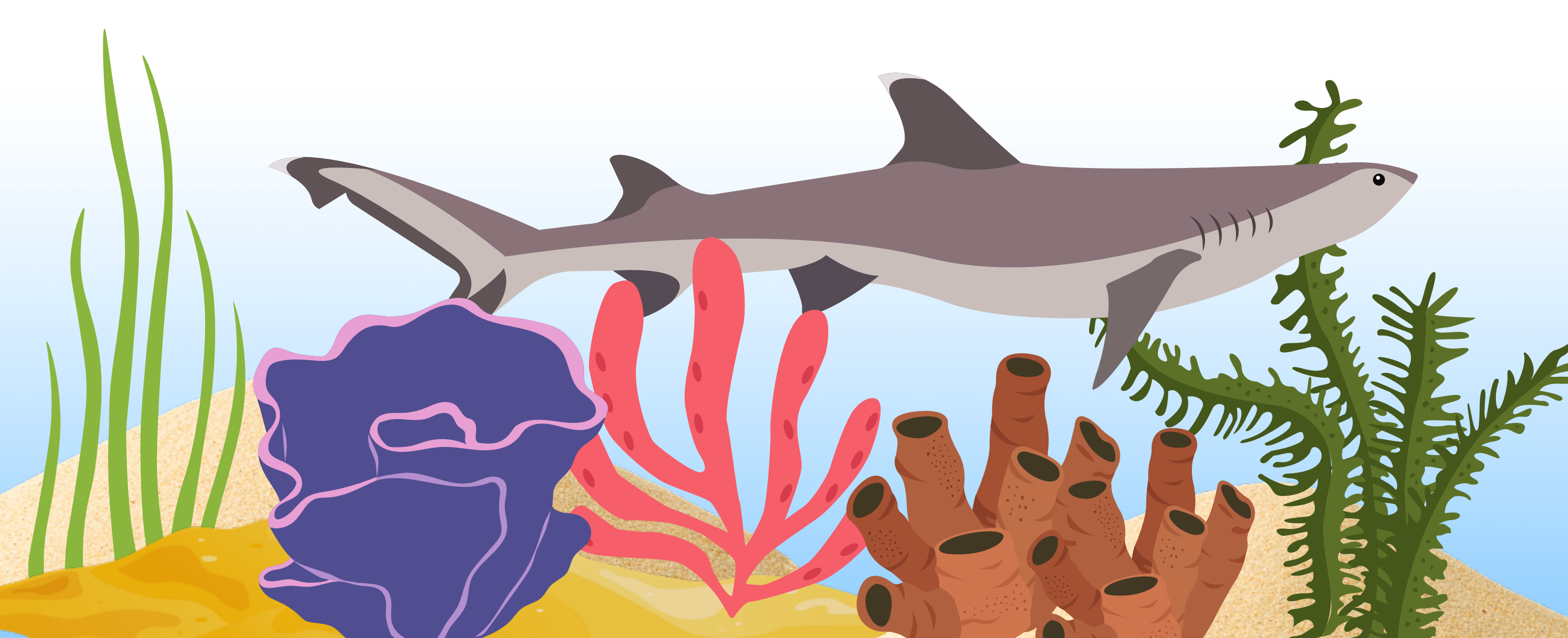
Learn more about ***Shark Kingdom***, a giant screen format film at www.sharkkingdomfilm.com.



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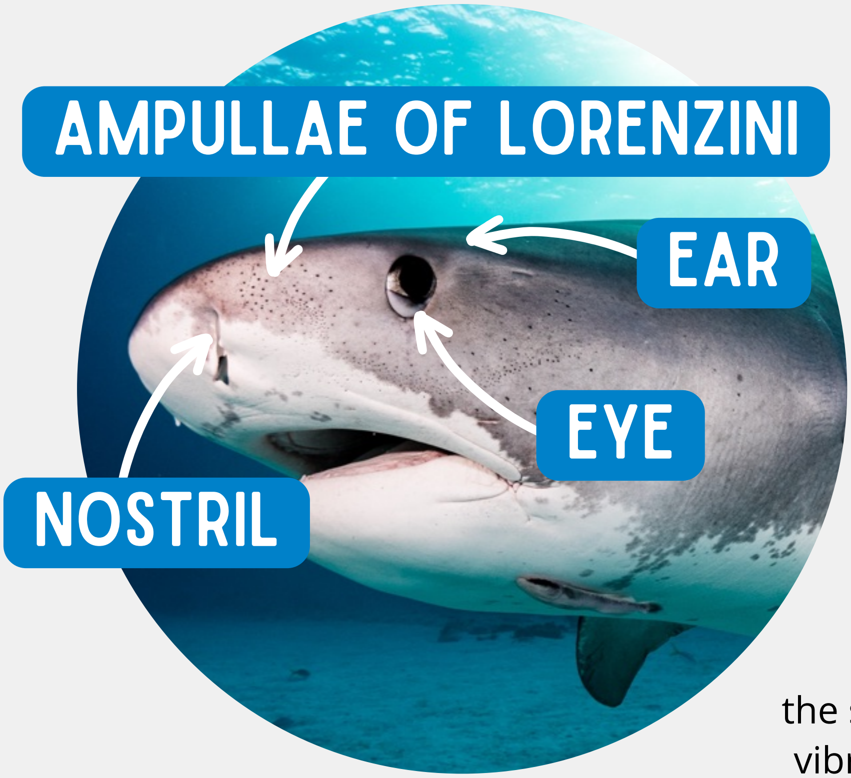
APPENDIX A

SHARK SENSES



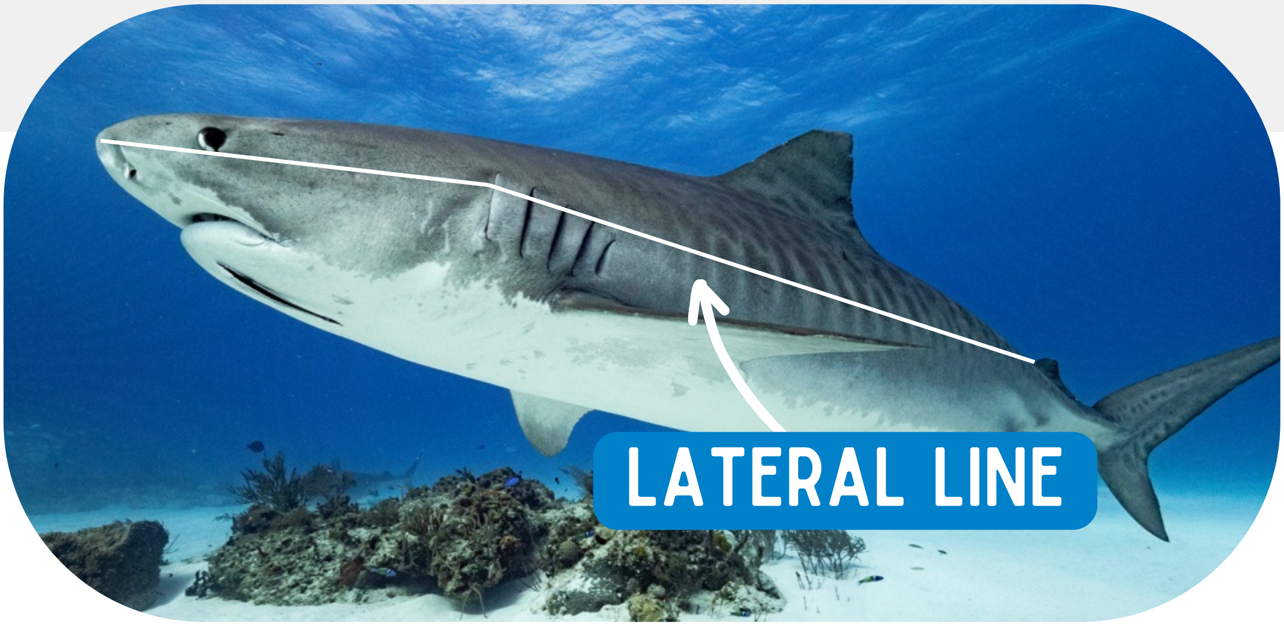
Ampullae of Lorenzini: Small gel-filled pores around the head that sense electrical fields from other animals.

Ear: Small openings behind each eye, leading to an inner ear that senses sound.

Eye: Sense of sight.

Nostril: Sense of smell.

Lateral Line: Small canals along the side of a shark's body that sense vibrations and changes in pressure.



APPENDIX B

STAYING AFLOAT EXPERIMENT [16]

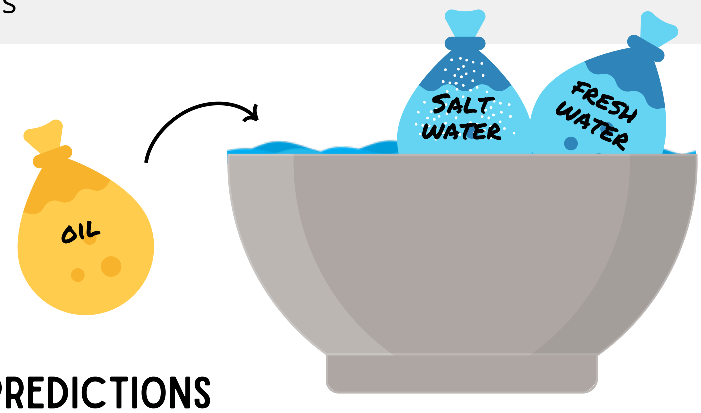
MATERIALS

Shared Materials Among All Groups

- Tablespoon
- Measuring cup
- Vegetable oil
- Water
- Salt
- Sharpie/marker
- Scissors

Individual Group Materials

- Biodegradable kitchen compost bags x 3
- Large, deep bowls x 2



INSTRUCTIONS

1. Place a compost bag in a bowl (to catch spills). Fill this bag with 1 cup of water. Add 2 tablespoons of salt to the water. Tie the bag as if tying a balloon, as close to the water as possible. **Aim for <u>no</u> air bubbles**. With a marker, write "salt water" on the bag and leave it in the bowl. *Optional: Cut the bag a pinky-finger length above the knot.*

2. Place a second bag in the same bowl. Fill this bag with 1 cup of water. Tie the bag like above. Write "fresh water" on the bag and leave it in the bowl.

3. Place a third bag in the same bowl. Fill this bag with 1 cup of oil. Tie the bag like above. Write "oil" on the bag and leave it in the bowl.

4. Make predictions.

5. Fill the second bowl with water. Place each bag into the bowl with water and observe what happens.

6. Fill in the results.

PREDICTIONS

Which bag of liquid will float when placed in fresh water? (circle below)

Salt Water   Fresh water   Oil   None

Which bag of liquid will sink when placed in fresh water? (circle below)

Salt Water   Fresh water   Oil   None

RESULTS

Which bag of liquid floated in the fresh water? (circle below)

Salt Water   Fresh water   Oil   None

Which bag of liquid sank in the fresh water? (circle below)

Salt Water   Fresh water   Oil   None

APPENDIX C

SATELLITE TAGGING CODE KEY TEMPLATE

INSTRUCTIONS Fill in the blank spaces below with any combination of 1s and 0s.

FIRST TWO DIGITS OF THE CODE Is the shark in shallow water or deep water?

Example 0 0 — Shallow Water

0 1 — Deep Water

SECOND TWO DIGITS OF THE CODE Is the shark in the Atlantic Ocean or Pacific Ocean?

___ ___ Atlantic Ocean

___ ___ Pacific Ocean

THIRD TWO DIGITS OF THE CODE Is the shark in warm water or cold water?

___ ___ Warm Water

___ ___ Cold Water

LAST TWO DIGITS OF THE CODE Is the shark moving fast or slow?

___ ___ Fast

___ ___ Slow

APPENDIX D

OCEAN FOOD WEB CARDS

PHYTOPLANKTON

Energy Source: Sun

KRILL

Energy Source:
Phytoplankton → Sun

MACKEREL

Energy Source:
Anchovies → Krill
Phytoplankton → Sun

SEA LION

Energy Source: Mackerel →
Anchovies → Krill
Phytoplankton → Sun

WHITE SHARK

Energy Source: Sea Lion →
Mackerel → Anchovies →
Krill → Phytoplankton → Sun

WHALE SHARK

Energy Source: Krill →
Phytoplankton → Sun

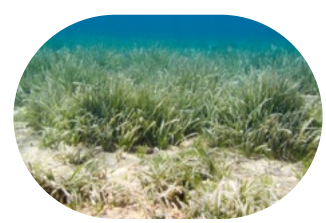
TIGER SHARK

Energy Source:
Green Sea Turtle →
Seagrasses → Sun

GREEN SEA TURTLE

Energy Source:
Seagrasses → Sun

SEAGRASSES



Energy Source: Sun

CARIBBEAN REEF SHARK

Energy Source:
Squid → Anchovies →
Krill → Phytoplankton → Sun

SQUID

Energy Source:
Anchovies → Krill
Phytoplankton → Sun

ANCHOVIES

Energy Source: Krill →
Phytoplankton → Sun

APPENDIX E

OCEAN SCENES

APPENDIX F

SHARKS, TURTLES, AND SEAGRASS (PART 1)[17]

INSTRUCTIONS

1. Mix the pile of face down cards. Each shark picks up **three** cards from the ecosystem and places them next to the shark card. Flip the cards over to see if they are turtles or seagrass.

2. If a shark has caught **less than two turtles,** they did not survive. Record this on your chart. If a shark has **two or more turtles**, they survived! Calculate the total number of surviving sharks by subtracting the "Starting # of Sharks" from the "# of Sharks that Did Not Survive."

3. **Every** turtle picked up by a shark has been eaten. Record the total number of turtles eaten on the chart and **remove these turtle cards from the ecosystem**. Calculate the number of turtles that survived by subtracting the "Starting # of Turtles" with the "# of Turtles Eaten."

4. For every turtle eaten, seagrass has grown back. **Add one seagrass** card to the ecosystem for each turtle eaten and record the number of seagrass that grew back on the chart.

5. If a shark **picked up any seagrass**, return the seagrass cards to the ecosystem pile now.

6. For every turtle that **survived**, **remove one seagrass** card from the ecosystem (flip over cards to find them) and record the number of seagrass eaten by turtles on the chart. Calculate the number of seagrasses that survived by adding the "Starting Number of Seagrass" to the "# of Seagrass that Grew Back" and then subtract the "# of Seagrass Eaten."

NOTE: If there is not enough seagrass to feed all surviving turtles, put a zero in the "# of Surviving Seagrass" on the chart.

CALCULATING THE STARTING NUMBERS FOR THE NEXT ROUND

TURTLES: Each surviving turtle produces **one** offspring. Add one additional turtle card to the ecosystem pile now for each surviving turtle. On the chart, the starting number of turtles for the next round will be the "'# of Surviving Turtles" multiplied by two. If the turtle population becomes zero, start the next round with **four** turtle cards.

SHARKS: Each surviving shark produces **two** offspring. Multiply the "# of Surviving Sharks" by 2 and note the value on the chart. The starting number of sharks for the next round will be the "# of Surviving Sharks" **plus** the "# of Offspring." Keep track of the number of sharks that will draw cards in the next round by placing a shark card, face up, in front of the ecosystem pile. If the shark population becomes zero, start the next round with **one** shark.

SEAGRASS: The "# of Surviving Seagrass" is the "Starting # of Seagrass" for the next round.

Once the starting numbers are filled in, start back at instruction #1. Stop the simulation after 18 generations (rounds) or when any value exceeds 60.

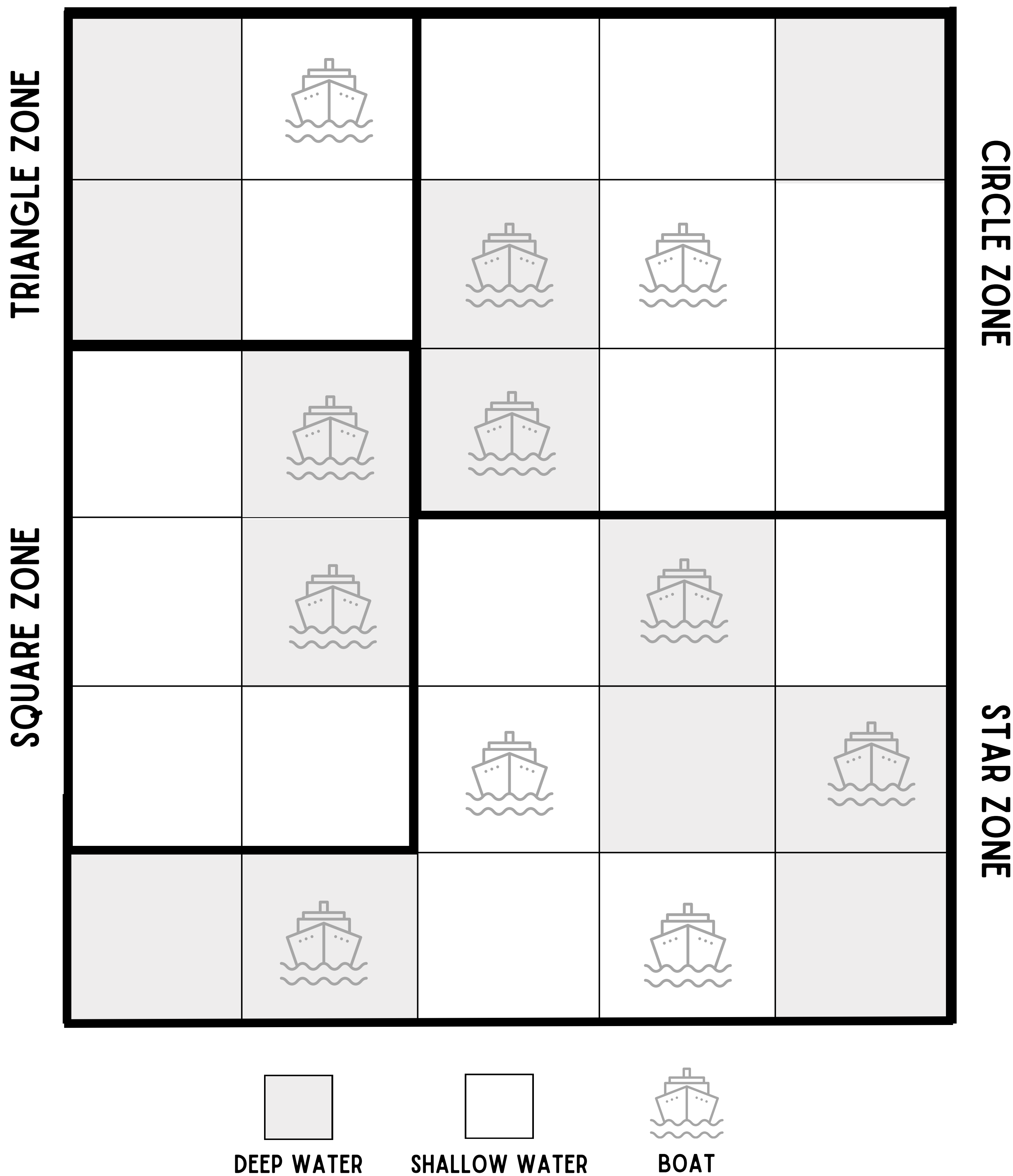
APPENDIX F

SHARKS, TURTLES, AND SEAGRASS (PART 2)[18]

GENERATION	STARTING # OF SHARKS	# OF SHARKS THAT DID NOT SURVIVE	# OF SURVIVING SHARKS	# OF OFFSPRING	STARTING # OF TURTLES	# OF TURTLES EATEN	# OF SURVIVING TURTLES	STARTING # OF SEAGRASS	# OF SEA-GRASS THAT GREW BACK	# OF SEA-GRASS EATEN	# OF SURVIVING SEAGRASS
1	1				4			6			
2											
3											
4											
5											
6											
7											
8											
9											
10											
11											
12											
13											
14											
15											
16											
17											
18											

APPENDIX G

MIGRATION MAPPING (PART 1)



APPENDIX G

MIGRATION MAPPING (PART 2)

	Ocean Zone		Boat		Water Depth	
1.	___	___	___	___	___	___
2.	___	___	___	___	___	___
3.	___	___	___	___	___	___
4.	___	___	___	___	___	___
5.	___	___	___	___	___	___
6.	___	___	___	___	___	___
7.	___	___	___	___	___	___
8.	___	___	___	___	___	___

CODE KEY

Ocean Zone
00 = Triangle Zone
01 = Square Zone
10 = Circle Zone
11 = Star Zone

Boat Intercepts with Shark's Path
00 = No
01 = Yes

Water Depth
00 = Shallow
01 = Deep