LET'S INVESTIGATE
SHARK BEHAVIOR AND ECOLOGY

LESSON PLAN & TEACHING GUIDE
VOCABULARY
SUGGESTED ACTIVITIES

Lesson: Let's Investigate Shark Behavior and Ecology

Grades: 9 - 12

Objective: Students will be able to name species scientifically and identify based on morphological features. Students will be able to understand the role sharks play in the ecosystem and how humans play a part in their survival. Students will investigate reproductive strategies and evaluate how these and adaptive features relate to population abundance and survival. Students will be able to explore social behaviors and symbiotic relationships between sharks and other organisms. Students will explore personal attitudes toward and knowledge of sharks.

Teaching Methods: Cooperative learning, Discussions, Evaluating, Interpreting, Multimedia instruction

Next Generation Science Standards: HS-ESS3, HS-LS2, HS-LS3, HS-LS4, HS-ETS 1

Ocean Literacy Essential Principles and Fundamental Concepts: OLP 1, OLP 2, OLP 3, OLP 5, OLP 6

Activity Time: 45-90 MINS

Preparation: Whether in person or virtual, save all visual resources to scroll through during lesson. For outdoor groups, you may choose to print and laminate. Small group discussions can be modified by using virtual breakout rooms or having students do this as a homework assignment prior to this lesson. Post list of terms for students to define and take notes on during the lesson.

Directions

1. Discuss shark numbers.

Ask: How many different types of sharks do you think there are? Encourage students to count how many they can silently name. Visit https://sharksrays.org/ and explain that Chondrichthyes includes sharks as well as skates, rays, and chimaeras. Direct students to the image of various species and explain that there are over 500 different types of sharks that we know about.

Optional: Name sharks via the alphabet or see how many they can each name in 60 seconds.

Ask: Can you guess the length of the smallest species? The largest? Can you name the smallest? The largest? Explain that sharks range in size from 6 inches to 50 feet in length. The whale shark is the largest shark in the sea averaging 12m (39ft.), while the pygmy shark is presently the smallest shark averaging 15cm (5.9 in.) long.

2. Discuss where sharks can be found.

Ask: Where do we find sharks? Inquire if anyone has ever seen a shark either in the ocean or maybe in an aquarium. Have students consider if sharks can be found the open ocean, seagrass beds, coral reefs, mangroves and even rivers. If applicable, have students consider if there are sharks in the waters near them. Direct students to image which shows sharks in different environments and explain that sharks are found in every ocean around the world. Sharks can be found in various communities and ecosystems depending on the species. They can be

found in cold water, warm water and even in freshwater rivers. If students inquire about the freshwater, explain that this will be discussed later.

Optional extension: As a class, you can research what shark species can be found in your area.

Ask: Do you think sharks stay in the same area or move around? Have students provide reasons why animals would move vertically and/or horizontally on a daily or long term basis. Elicit from students that migration is a strategy sharks and other organisms use in response to changes in ecosystems, including temperature, tides, availability of food and potential mates. Direct students to figure of Young-of-Year (YOY) white shark movement and explain that vertical movement can mean swimming up and down in the water column from one zone to another over a 24 hour period. Now direct students to the figure showing tiger shark migration and explain that horizontal can be swimming across great expanses of ocean or from one ocean to another. Some species of sharks stay in one area while others are highly migratory.

3. Discuss adaptation.

Remind students that we said sharks can survive in freshwater. Ask: How might sharks be able to swim in freshwater? Have students consider what they have learned about osmosis. Elicit from students that osmosis is the passive diffusion of water across a cellular membrane and osmoregulation is the process by which cells counteract the natural trend and maintain stable salt and water gradients between the external environment and their internal body fluids. Direct students to the bull shark image and explain that bull sharks can actually swim in brackish (fresh and saltwater mix) and freshwater. They have been found thousands of miles up rivers around the world with some up the Mississippi River in Illinois.

Ask: What does thermoregulation mean? Encourage students to break the word up. Elicit from them that thermo hints at temperature and regulate means to control. Direct students to the cross section figure. Explain that some sharks can regulate or alter their internal temperature, species like the great white, salmon and mako can warm parts of their body to be able to swim faster.

Direct students to the shortfin mako picture and point out the color variation on the ventral (bottom) and dorsal (top) side. Explain that countershading is a type of camouflage in which the dorsal side is darker than the ventral side. Have students brainstorm as to why this adaptation would be useful. Elicit from students that the dark blends in with the dark depths when viewed from above while the light with the lighter surface of the sea when viewed from below.

Optional: Direct students to the velvet belly lanternshark picture. Explain that this shark lives in the deep sea and these photophores act as a bioluminescent, so on a moonlit night, while fish swimming through the water would normally produce a shadow that predators would see, the glowing underside reduces or eliminates this shadow, making it less conspicuous to predators.

Optional Extension: Have students think of other survival adaptations or special features that sharks may have. Elicit from students that they do come in various shapes and sizes depending on their habitat and behavior. Provide a few examples as follows. Direct students to the spiny dogfish and japanese spurdog picture. Point out the spines associated with their dorsal fins. Explain that these spines are an adaptation for defense against

predators. Direct students to the great hammerhead picture. Point out the distinctive shaped head. Explain that it is called a cephalofoil and its true function is still unclear to scientists, but hypotheses include that it serves in maneuverability and lift, helps increase olfactory, vision, and electro- or mechanoreception.

4. Compare and contrast reproductive strategies.

In small groups, assign each a species to investigate how they are born. (Group A: Horn, Group B: Lemon, Group C: Nurse, Group D: Sandtiger)

Facilitate a class discussion and emphasize that reproductive strategies are complex and there is still a great deal unknown, but the following is what has been reported thus far. Direct students to the hornshark picture, and conclude that they are oviparous. Oviparous sharks lay eggs, which are protected by an egg case and can be referred to as "mermaid's purses". Explain that egg cases come in a variety of shapes and sizes, each unique depending on the species.

Direct students to the lemon shark picture, and conclude that they are viviparous. Viviparity literally means "giving live birth". In placental viviparity there is a connection between the embryo and its mother, it is via this connection that nutrition is provided to the developing pup.

Direct students to the video https://www.youtube.com/watch?v=hdQoBbGLGZ8, which shows the birth of a lemon shark. Ask: Do you think sharks move as a family unit? Have students consider whether this mother will nurture or protect its young. Explain that they do not nurse, protect, or move as a family group in any manner.

Direct students to a picture pointing out the cloaca and claspers. Ask: What is the picture pointing out? Elicit from students that the claspers are male reproductive parts and while the cloaca is where young or eggs expel, it is also the universal chamber at the rear of a shark's body cavity through which waste is released.

Continue the discussion, direct students to the nurse shark picture, and conclude that they are ovoviparous. This term is also known as aplacental viviparity meaning that these embryos will develop within an egg, which will hatch inside the female's body.

Continue the discussion, direct students to the sandtiger picture, and conclude that they are oviphagy. This term is also known as oophagy, which means "egg eating". Oophagy is a means of providing nutrition by which the developing embryos are provided unfertilized eggs (potential siblings) whilst still in the womb.

Conclude the discussion by explaining that the life cycle or fecundity of sharks is very different from other fish, they are slow growing and do not lay thousands of eggs or give birth to a large quantity of offspring, which makes them vulnerable. One way scientists attempt to help them is by protecting nursery grounds or areas found to be particularly suitable for young to grow and live.

Optional extension: Direct students to the zebra shark picture and explain that these and many others are reported to have reproduced via parthenogenesis, which also means virgin birth.

5. Discuss social behavior and symbiosis.

Remind students that we have established that they do not move together as a family unit. Ask: Do you think sharks in general are solitary or social? Explain that some sharks are solitary, while others are social. Juvenile lemon sharks have friends and spiny dogfish hunt together like a pack of dogs, which is how they earned their common name. Some sharks aggregate for mating, cleaning, feeding, and other needs. A group of sharks is called a shiver.

Direct the students to the nurse shark picture. Ask: Does anyone know why these fish are attached to or swimming around the shark? Does anyone know what they are called? Elicit from students that they remora fish and they have a relationship with the sharks called symbiosis. Direct students to the lemon shark picture and explain that many fish, such as the wrasse (swimming above the shark), clean the inside the mouth of sharks. Direct students to the hammerhead picture and explain that other fish, such as the barber fish seen here, eat parasites off of the shark and get bits of food from whatever the shark eats.

6. Ask students what they know and have learned about ecology?

Ask the students to come up with words they associate with ecology. Record answers by having students write their answers down or say aloud and assign one student to be a recorder. Explain to students that they should express anything that comes to mind about the topic. If students are struggling to make connections, suggest that they consider what makes an ecosystem, a food web or chain. Words will vary.

Direct students to the pyramid graphic. Facilitate a class discussion and inquire if students know the terms used to describe the ways organisms obtain energy or food. If students are struggling, ask students the difference between plants and animals. Conclude that there are producers or autotrophs and consumers also called heterotrophs. Explain that some organisms are photoautotrophs, which use the sun but are also chemoautotrophs, which use chemicals such as methane similarly. Continue the discussion by asking students to come up with examples of producers and consumers in the ocean. Elicit from students that producers are aquatic plants, such as seagrass, algae and phytoplankton, while consumers are all other organisms. Finally, inquire whether the students know the difference between abiotic and biotic factors; additionally, that they can provide examples for each. Conclude that all factors previously described are biotic as they are living, whereas abiotic are nonliving factors such as salinity, temperature, substrate, and sunlight. The total mass of those living organisms in a given area is called biomass and the variety of different living organisms is called biodiversity.

7. Investigate why sharks are important.

Ask: What it would be like if sharks did not exist? Engage in a class discussion and elicit from students some of the following. Ecologically, some sharks are known as apex predators and are responsible for maintaining the health of certain ecosystems as well as maintaining ocean biodiversity. Economically, sharks are vital for many ecotourism industries, studies have found that they are worth more money alive than dead. Biomedical researchers are investigating how sharks heal so quickly, which is being used to investigate immunity and certain diseases. Biomimic scientists and inventors are inspired by shark dermal denticles in reducing drag of products. Additionally, in areas, they are fished as a source of food.

8. Discuss how humans impact shark populations.

Remind students that sharks are slow growing, spend many years before they reach maturity and when they do, they lay few eggs or give birth to few pups. All these factors combined do not allow many species to replenish populations that are declining. Multiple species are on the International Union for Conservation of Nature (IUCN) list and at risk of extinction.

Direct students to the need help picture. Engage in a class discussion by having the students consider what impact humans have on sharks and why they would need help. If students are struggling, offer the concepts of bycatch and finning, inquire if anyone has ever seen it on the menu or know someone who has eaten shark, and ask them to consider if they have seen pictures of people holding them on social media. Elicit from students that sharks are fished for their meat and fins. Explain that the practice of shark finning, while it is illegal in many countries, is still practiced. It is a cruel practice of removing the fins of a live shark and discarding the rest of the body. Shark fins are used to make shark fin soup. Explain that sharks are fished for their cartilage, skin and liver as they are believed to have medicinal properties. Sharks can get cancer and grow tumors. While some species are legally caught and eaten, many studies warn consumers about bioaccumulation. Explain that mercury (a heavy metal) accumulates in marine animals and because sharks are at or near the top of the food chain they can have toxic levels in their systems. Studies have found high levels of neurotoxins, those destructive to nerve tissue, are linked to diseases such as Alzheimer's and Parkinson's. Explain that many are caught as bycatch by commercial fisheries. Studies have shown that sharks are also at risk due to habitat destruction and loss. Scientists have only begun to investigate the detrimental factors they undergo from absorbing man-made pollutants and plastics, as well as changes in temperature and acidity.

Optional: Ask students if they have any idea how people catch fish in the open ocean. Elicit methods and examples from the students. Conclude that there are various forms such as hook and line, gill and drift gill nets, longlines, and trawling. Have students provide pros and cons for each.

Informal Assessment

1. Cover the scientific names on each picture, have them listed elsewhere, have students match them with the common names.
2. Present each species individually and have students provide a fact.

Extension Assignment

1. Each student can write a short piece that informs community members about sharks and the roles sharks play in marine ecosystems. In their pieces, students should address several common shark myths and provide factual information to help readers better understand how those myths came to be popularized and in what ways the myths may affect people's willingness to protect sharks.
2. Have students individually choose one of the species described in the lesson, go to our website, vist the shark fact posters, and present on that species going beyond what was provided.
3. Have students choose one species presented and research a scientist studying this species. Attempt to connect with the scientist to either have a virtual chat as a class or conduct an individual interview and present the answers to the class.
4. Conduct a debate on topics that impact shark populations (e.g. fishing regulations, MPAs, protection, CITES).

Optional Activities

Egg case matching, Shark research, Crossword

Vocabulary

Abiotic: All the non-living things that affect living organisms in the ecosystem.

Adaptation: Change an organism undergoes in order to survive. The change is maintained over time by natural selection. This is a very slow process.

Apex Predator: An animal at the top of the food chain with no natural predators. If removed from an ecosystem, can have large cascading effects on many other species within that system.

Bioaccumulation: The accumulation within living organisms of toxic substances occurring in the environment. (Example: pesticides or mercury)

Biodiversity: The variety of different species within an ecosystem. Coral reefs are one of the most diverse ecosystems on the planet.

Biomimicry: The design and production of materials, structures, and systems that are modeled on biological entities and processes.

Biotic: All the living things that affect living things in an ecosystem. (Example: plants & animals)

Bycatch: Certain fish or other animals (dolphin, sea turtles) that are caught unintentionally while fishing for a specific fish species.

Chemoautotroph: An organism, which derives energy from the oxidation of inorganic compounds, such as methane.

Clasper: Paired organs located on the pelvic fins of males for reproduction.

Cloaca: Chamber at the rear of the body cavity through which waste and young or eggs expel.

Consumers: Are animals that cannot make their own food, so they must eat other animals and plants to survive.

Countershading: A type of camouflage in which the dorsal side is darker than the ventral side.

Ecology: The science that studies the relationships between groups of living things and their environments.

Ecosystem: Animals, plants and nonliving things that make up an environment and impact one another.

Egg case: A stiff capsule that surrounds the embryo in some species.

Fecundity: The ability to produce an abundance of offspring.

Food Chain: A linear network of links in a food web.

Food Web: The whole group of interacting food chains in an ecological community.

Migration: Relatively long distance movement of animals from one area to another and then returning to the original area, often on a seasonal basis. The reason for migration is usually to mate, find food or because of a change in water temperature or climate.

Nursery ground: Areas used by neonates or young juvenile due to the shallow and protective nature of the habitat.

Osmoregulation: The maintenance of constant osmotic pressure in the fluids of an organism by the control of water and salt concentrations.

Oviparity: Oviparous sharks lay eggs, which are protected by an egg case, these are referred to as "mermaid's purses". The female shark deposits egg cases somewhere safe to protect them from being eaten by predators. Some eggs are attached to structures on the seafloor by tendrils to prevent them from floating away. Oxygenation takes place through slits in the side of the egg, some sharks constantly moving its tail from side to side to increase water flow.

Oviphagy: Oophagy, or "egg eating", is a means of providing nutrition by which the developing embryos are provided unfertilized eggs (potential siblings) whilst still in the womb. These embryos are referred to as "intra-uterine" cannibals. The first embryo to hatch will feed on other embryos, not just the unfertilized eggs, which means only two pups will be born, one from each uterus.

Ovoviviparous: Aplacental viviparity is when the embryos develop within an egg sack, which will hatch inside the female's body.

Photoautotroph: Organisms that make their own energy using light and carbon dioxide via the process of photosynthesis.

Phytoplankton: Microscopic organisms that drift on ocean currents and use photosynthesis to make food. They are responsible for producing half of the total amount of oxygen produced by all plant life on Earth.

Producers: Living things that can make their own food. Plants are producers that make food through a process called photosynthesis

Pup: A baby shark.

Shiver: A group of sharks.

Symbiosis: A relationship between two different kinds of living things that live together and depend on each other.

Thermoregulation: A process in which an organism can maintain its core internal temperature.

Viviparity: In placental viviparity there is a connection between the embryo and its mother, it is via this connection that nutrition is provided to the developing pup. In the early stages, the embryo receives nourishment from a yolk sac, once this is used up the sac attaches to the wall of the uterus and forms a placenta. The pup will continue to receive nourishment directly from the mother's bloodstream and waste products will be transferred to the mother for elimination.