Shark Lab:

Great White Migration

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Great White Migration
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Background information

Meet the white shark

1

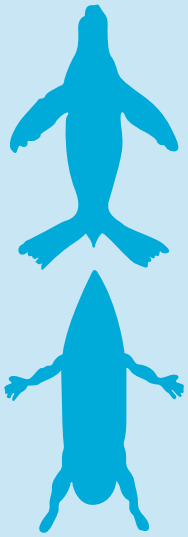
- The **white shark** (also known as the great white shark) is one of the top **predators** in the ocean.
- White sharks are enormous, growing up to 20 feet long and weighing up to 4,500 pounds.
- They have around 300 sharp teeth in their mouth at any one time, and each tooth can grow to 3 inches long!

2

- White sharks hunt for many different types of **prey**, including large fish, squids and cuttlefish, sea birds and sea turtles, and marine mammals like seals and sea lions.
- As top predators, white sharks play an essential role in marine ecosystems by preventing mid-level predators from becoming too abundant, which can cause ripple effects through the entire ecosystem.
- For example, when white shark numbers declined off the coast of South Africa, seals expanded into new feeding areas. This led to more fish being eaten and to penguin displacement.

Human encounters with white sharks

- White sharks have a reputation as terrifying monsters that frequently attack and kill humans. But white shark attacks on humans are quite rare.
- Since the year 1580, there have been 351 recorded attacks on humans by white sharks around the globe. Of these, only 59 were fatal. Lightning kills more people each year than sharks do!
- Scientists think white sharks attack when:
  - They mistake humans for prey. Surfers and sea lions look similar from underneath.
  - They are curious about foreign objects and inspect them using exploratory test bites of limited force.



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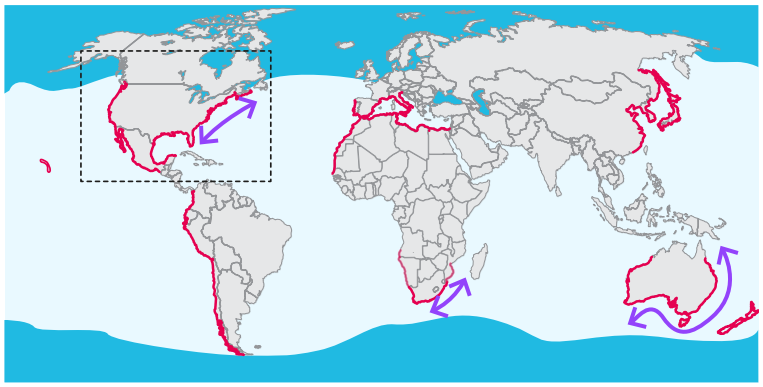
White shark migration

1

- White sharks live in all ocean waters, except the Arctic and Antarctic.
- They spend much of their time near the shore where food sources are abundant.
- White sharks can also spend time in the open ocean, perhaps to hunt fish species that are not found near shore.

2

- White sharks are also known to migrate seasonally along coastal waters.
- **Migration** is the long-distance movement of animals, often between habitats and seasons, to survive, reproduce, and/or avoid predators.
- Scientists think this seasonal migration helps sharks stay within their preferred temperature range of 50-80 °F and/or follow seasonal food sources.



Open oceans inhabited by white sharks.

Open ocean uninhabited by white sharks.

Coastal waters inhabited by white sharks.

Known coastal migratory routes.

Map Credit: Simplemaps

Background: Stop and think

Q1. Why might white sharks migrate? Select all plausible answers.

A. To follow seasonal food sources
B. To avoid predators
C. To reproduce
D. To stay in a preferred temperature range

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Identifying individual sharks

1

- Scientists still have many questions about white shark migration. For example, which waters do they inhabit? What migration routes do they use? How far, fast, and deep can they swim?
- Moreover, scientists wonder if white sharks can migrate between different coastal regions by swimming across entire oceans.
- To answer these questions, scientists need to track the movements of individual sharks.
- Understanding these details about white shark migration is critical to identify habitats that need protection. The conservation status of white sharks is listed as Vulnerable on the **IUCN Red List** and they are protected in many waters.

2

- One way to track individual sharks is to use fin photos. Each shark has unique markings, notches, spots, or even scars on its **dorsal fin**.
- If scientists can demonstrate that the same fin shows up in different places, they can infer that the shark must have swam from one place to the other!

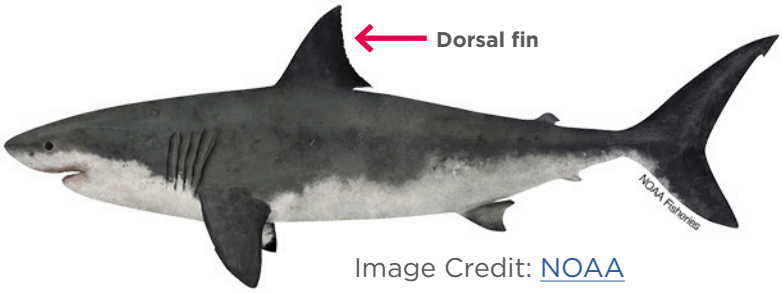


Image Credit: NOAA

Fin 1

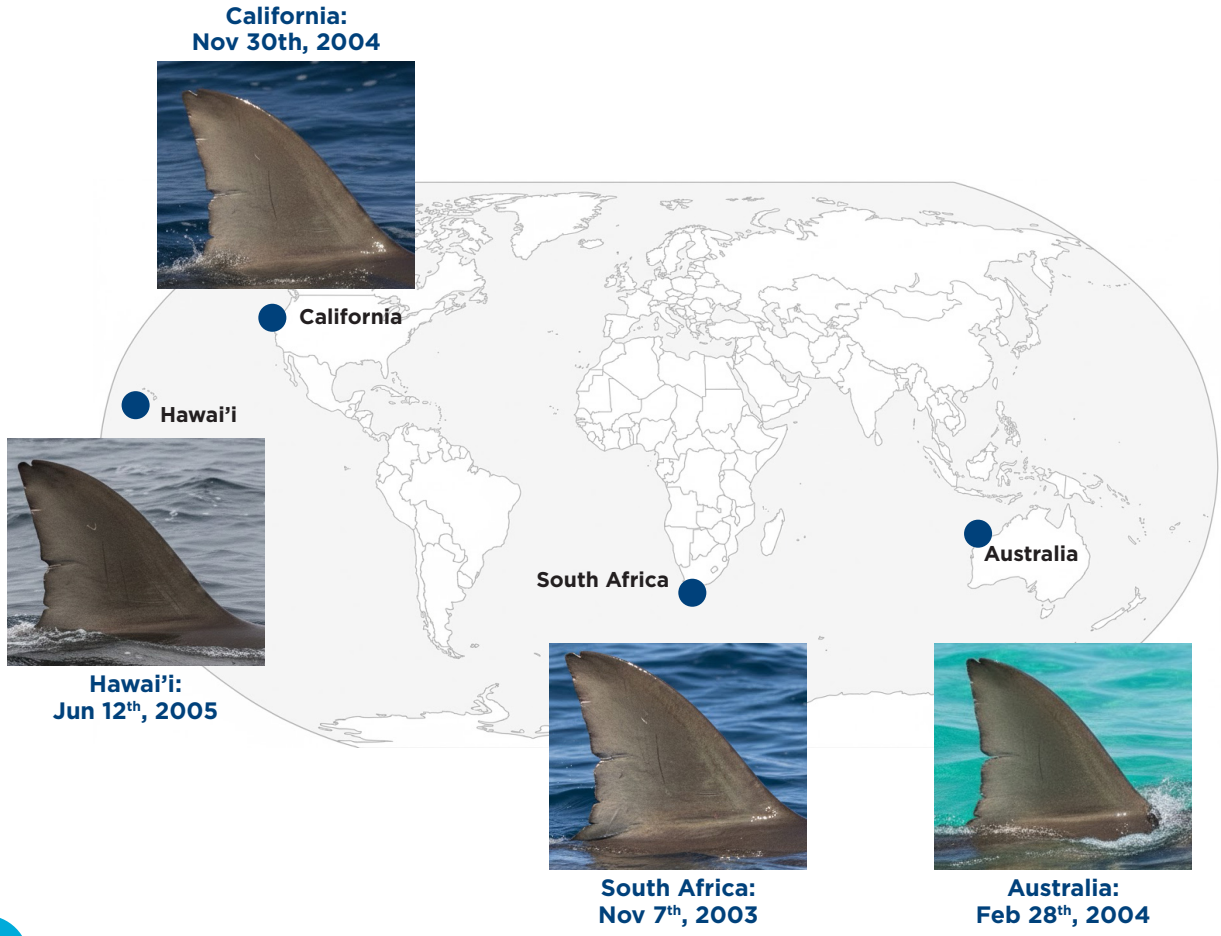
Fin 2

Today's lab

Curious sightings of white sharks

1

- You work with an international research team studying migration in white sharks.
- The team observed a shark with very similar fin markings in four very different locations: off the coasts of Northwest Australia, California, Hawai'i, and off the Western Cape of South Africa.



2

- Your goal is to determine whether a single shark is migrating across the globe, and you will do so using **DNA** testing!
- Your team collected water samples directly around the sharks when the fin photos were taken. The shark's DNA can be isolated from these samples and used for identification.

Background: Stop and think

Q2. Look closely at the fin photos on the previous page. Which fins, if any, do you think belong to the same shark? Explain your reasoning.

Q3. Now look at the dates when those fins were spotted. Based on the dates and your answer to the previous question, what migratory route, if any, did the shark or sharks travel? Draw the migratory routes onto the map below.

DNA fingerprinting

1

- Members of the same species share most of their DNA, but some regions of the **genome** vary in length between individuals.
- **DNA fingerprinting** examines these variable regions of the genomes to generate a unique DNA profile that can identify an individual.

2

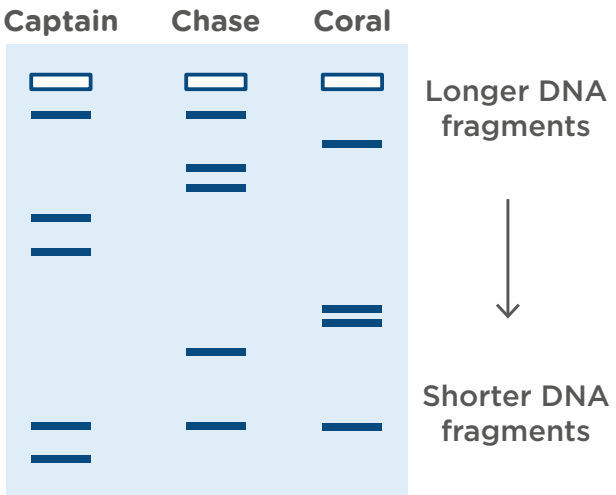
- Other members of your research team have already prepared the shark DNA samples for analysis by:
  (1) Collecting DNA from the water samples.
  (2) Using a method called **PCR** to copy regions of the shark genome that vary in length between individuals.
- Because each individual has a unique genome, these steps will create a distinct profile of DNA fragments of different lengths.

3

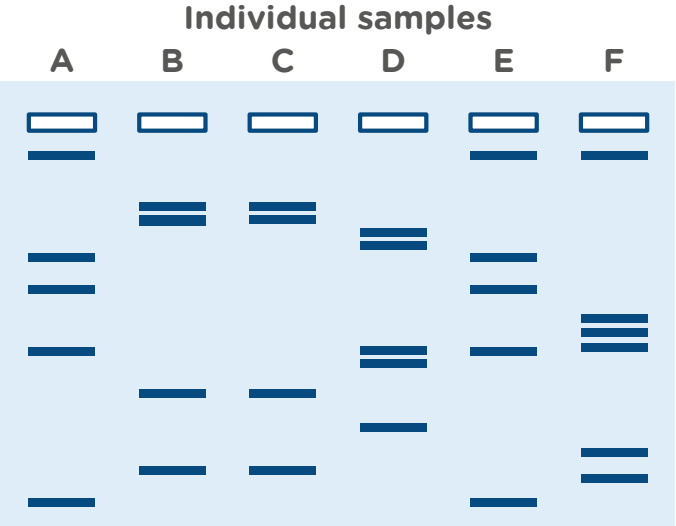
- You will perform the final step and use **gel electrophoresis** to interpret the DNA fingerprints.
- During gel electrophoresis, DNA fragments are separated by size. Larger DNA fragments travel more slowly through the gel, while smaller DNA fragments travel faster.

4

- Let's compare DNA fingerprints from three white sharks: Captain, Chase, and Coral.
- Notice that each shark has a unique pattern on the gel, representing their DNA fingerprint.
- This type of analysis allows you to determine if two samples come from the same individual.



Background: Stop and think



The gel above shows DNA fingerprints from six different samples (A-F). Use this image to answer the questions below:

Q4. Annotate the gel to indicate any samples that came from the same individual.

Q5. How many individual sharks are represented on this gel?

A. 2
B. 3
C. 4
D. 5
E. 6

DNA-based methodologies

In this activity, you are using DNA fingerprinting to identify individual sharks. DNA fingerprinting is relatively straightforward and cost-effective, but recent technological advances have made the use of DNA sequencing more common. With DNA sequencing, scientists can read an organism's entire genome rather than examining a handful of variable regions that differ in length among individuals. In addition to identifying individuals, DNA sequencing data can answer a wide range of other questions about the organism being sampled. However, DNA sequencing is more resource intensive than DNA fingerprinting, which remains an effective choice for distinguishing one individual from another.

Glossary

White shark (*Carcharodon carcharias*): A species of cartilaginous fish and one of the top predators in the ocean. Known commonly as the great white shark.

Predator: An organism that eats another organism, called the prey, to obtain nutrients.

Prey: An organism eaten by another organism, called the predator.

Migration: Long-distance travel by animals, often between seasons and across habitats, to escape harsh conditions and/or find better resources, such as food, mates, and breeding grounds.

IUCN Red List: A database that assesses the extinction risk of animal, fungal, and plant species, managed by the International Union for Conservation of Nature (IUCN).

Dorsal fin: The top fin on the back of most fish, sharks, and whales.

DNA (deoxyribonucleic acid): The molecule that stores and transmits genetic information in living organisms and contains the instructions for how the cell works.

Genome: All of the genetic information present in an organism. It includes all of an organism's DNA.

DNA fingerprinting: A laboratory technique that identifies individuals by analyzing unique patterns in their genomes, typically by measuring DNA fragment length.

Polymerase Chain Reaction (PCR): A technique used to make multiple copies of a specific DNA segment for further study. For more detailed information on PCR, refer to https://www.minipcr.com/polymerase-chain-reaction/.

Gel electrophoresis: A method that separates pieces of DNA by length. For more detailed information on electrophoresis, refer to https://www.minipcr.com/gel-electrophoresis/.

Electronic tags: Electronic devices used in scientific research that are affixed to animals that collect or transmit data about the animals' location, speed, and other relevant information.

Population: A group of individuals of the same species that live in the same geographic area at the same time, and are capable of breeding together.

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Student lab protocol

Protective gloves and eyewear should be worn for the entirety of this experiment.

1. Place the prepared gel into the electrophoresis chamber.

2. Add enough electrophoresis buffer to fill the chamber and just cover the gel.
   - You will need 30 ml of TBE buffer for a blueGel™ or Bandit™ electrophoresis system. Do not overfill the chamber.
   - If using another electrophoresis system, refer to the manufacturer's instructions for the recommended buffer type and volume.

3. Use a micropipette to load samples in the following order. To prevent contamination, use a new tip for each sample.
   - Well 1: 10 µl Australia sample (tube A)
   - Well 2: 10 µl California sample (tube C)
   - Well 3: 10 µl Hawai'i sample (tube H)
   - Well 4: 10 µl South Africa sample (tube S)

4. Run the gel for 15-20 minutes.
   - The blueGel™ and Bandit™ electrophoresis systems run at a fixed voltage.
   - If using another gel electrophoresis system, set the voltage in the 70-90 V range.

5. To visualize the DNA samples, turn on the blue light in your electrophoresis system, or move the gel to a transilluminator.

6. If needed, continue to run the gel until there is sufficient separation between the bands to interpret the results.

7. If desired, take a photo to document the results.

Detailed operating instructions for miniPCR electrophoresis systems

blueGel
https://links.minipcr.com/blueGelRun

Bandit
https://links.minipcr.com/BanditViewit

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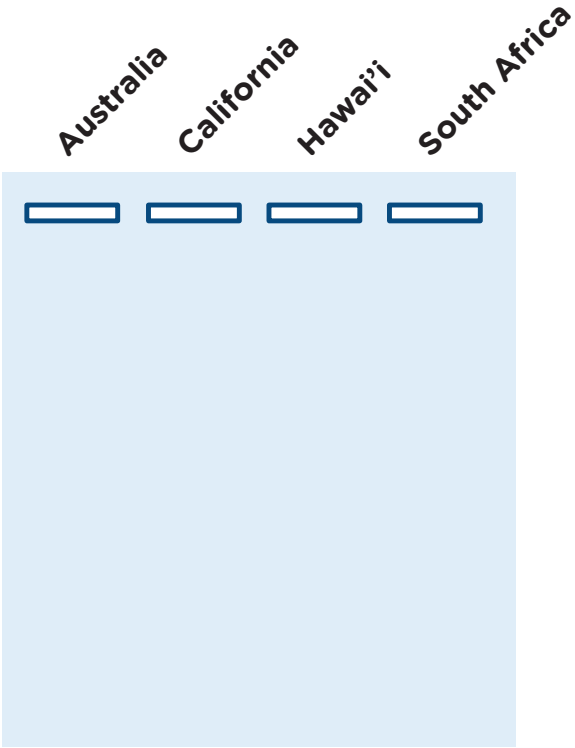
Post-lab questions

Interpreting results

1. Use the image on the right to draw what your gel looks like. For each sample, draw the bands observed on your actual gel.



2. How many individual sharks are on this gel?

3. Which sightings, if any, are of the same shark?

Critical thinking

4. Based on the results of DNA fingerprinting, draw the migratory routes of the shark or sharks on this map.

5. Based on what you have learned, which method of shark identification is more accurate: fin photos or DNA fingerprinting? Explain your reasoning.

6. Recall that scientists previously knew white sharks migrated along coasts, but wondered if they migrated across oceans to reach different coastal waters. Do your DNA fingerprinting results help scientists answer this question? Explain your answer.

7. Conservationists need to know where white sharks spend their time to know which waters to protect. How can your results help conservation efforts for white sharks?

8. Scientists have another powerful tool for studying migration: attaching small electronic tags to individual animals that track their locations over time. Why might scientists also want to use electronic tags to study white shark migration? Explain your answer.

CER table

Fill in the table based on your results from the lab. Refer to the rubric on the next page.

Question:

Which sightings, if any, were of the same individual shark?

Claim

Make a clear statement that answers the above question.

Evidence

Provide data from the lab that supports your claim.

Reasoning

Explain clearly why the data you presented supports your claim. Include the underlying scientific principles that link your evidence to your claim.

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Score	4	3	2	1
CLAIM A statement that answers the original question/ problem.	Makes a clear, accurate, and complete claim.	Makes an accurate and complete claim.	Makes an accurate but incomplete or vague claim.	Makes a claim that is inaccurate.
EVIDENCE Data from the experiment that supports the claim. Data must be relevant and sufficient to support the claim.	All of the evidence presented is relevant and sufficient to support the claim.	Provides evidence that is relevant and sufficient to support the claim. May include some non-relevant evidence.	Provides relevant but insufficient evidence to support the claim. May include some non-relevant evidence.	Only provides evidence that does not support claim.
REASONING Explain why your evidence supports your claim. This must include scientific principles/ knowledge that you have about the topic to show why the data counts as evidence.	Provides reasoning that clearly links the evidence to the claim. Relevant scientific principles are well integrated in the reasoning.	Provides reasoning that links the evidence to the claim. Relevant scientific principles are discussed.	Provides reasoning that links the evidence to the claim, but does not include relevant scientific principles or uses them incorrectly.	Provides reasoning that does not link the evidence to the claim. Does not include relevant scientific principles or uses them incorrectly.

We recommend that teachers use the following scale when assessing this assignment using the rubric. Teachers should feel free to adjust this scale to their expectations.

Rubric score	3	4	5	6	7	8	9	10	11	12
Equivalent Grade	55	60	65	70	75	80	85	90	95	100

Extension: Tracking white shark migration with electronic tags

Electronic tagging

- In this lab, you used fin photos and DNA fingerprinting to infer the migration routes of white sharks.
- Scientists can also study shark migration by attaching a small data-collection device to an animal.
- **Electronic tags** can collect data related to shark behavior, such as location, speed, and depth, as well as on shark habitats, including water temperature, light, and oxygen levels.
- Scientists can program electronic tags to collect data every few seconds for weeks or even months.

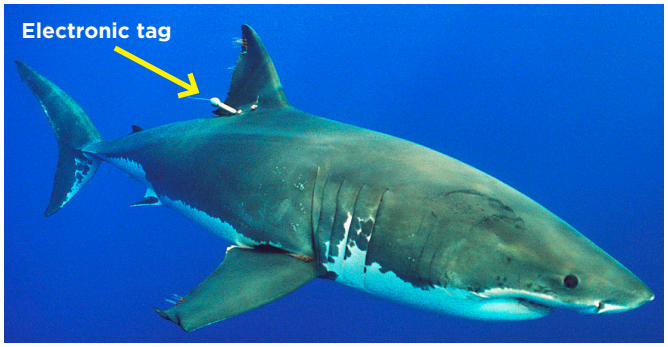


Image credit: Phillip Colla

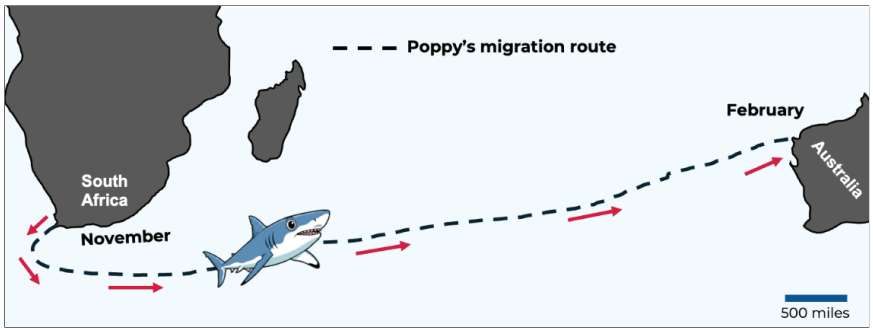
Q1. Scientists can use many methods to study shark migration. Brainstorm pros and cons for the three methods discussed in this activity.

	Pros	Cons
Fin photographs		
DNA fingerprinting		
Electronic tagging		

White shark migration in the Indian Ocean

1

- The white shark from today's lab that migrated from South Africa to Australia is a real animal called Shark P12. We will refer to her as Poppy.
- Poppy was tagged on November 7th, 2003, just off the coast of South Africa's Western Cape.
- Over the course of 99 days, Poppy's tag recorded her crossing the entire Indian Ocean, ending at a location off the coast of northwestern Australia on February 28, 2004.
- At this time, Poppy's tag was programmed to stop collecting data; however, her dorsal fin was spotted off the coast of South Africa that August. This means Poppy likely returned to South Africa between February and August.



Poppy's incredible trip broke many records for her species

- **Fastest round-trip migration across an ocean:** More than 12,000 miles in 9 month!
- **Speediest long-distance swim:** Minimum speed of 2.9 miles per hour!
- **Deepest dives:** 3,200 feet below the surface!
- **Coldest water temperature:** 38.1 °F!

2

- Poppy's migration also raised many new questions. For example, scientists don't know if Poppy's migration was unusual or typical for her **population**. Do other white sharks living off the coast of South Africa regularly migrate across the Indian Ocean?
- Scientists also don't really know why Poppy made this round-trip journey across the entire Indian Ocean.

Q2. Based on everything you have learned in this lab so far, propose one explanation for why Poppy migrated from South Africa to Australia and back.

Q3. Propose a research study to find supporting evidence for your answer to the previous question.