SCIENCE 3D

WEST COAST WHITE SHARK

In this packet, sample student answers are provided in red and notes to teachers are in blue.

In this **Science Mission**, students will explore how gillnets, and a gillnet ban, have affected white shark populations in California. Then, they will determine if genetic material in the environment (eDNA) can be used to detect the presence of white sharks. Finally, they will investigate how the warm water from a power plant affects round stingray populations and, in turn, how stingray populations might affect the number of young white sharks in the area.

Note: Students may need two different colors or patterns for bar graphs.

ACTIVITY I: WHAT HAS HAPPENED TO WHITE SHARKS?

People can have a big impact on the environment. Even though the oceans seem huge, people can influence the populations of the species that live there. In fact, when populations of fish decrease too much, even fishing more often won't help fishers catch more fish. There just are not enough fish to catch.

Gillnets are one way people catch fish. But, gillnets catch more than just the fish that people want to keep. Turtles, dolphins, whales, seals, and sea lions can all get caught in gillnets. Most don't survive. It is even worse if a gillnet is lost and drifts in the ocean for years catching marine animals. People in California didn't try to catch young white sharks in their gillnets, but when they accidentally did, they sometimes sold them to fish markets or restaurants.

In 1994, white sharks were protected from fishing in California waters. That same year, gillnets were also banned in southern California waters because people were worried about the negative effects they were having on marine life. We can investigate white shark catches in gillnets to see what effect they might have had on white shark populations.

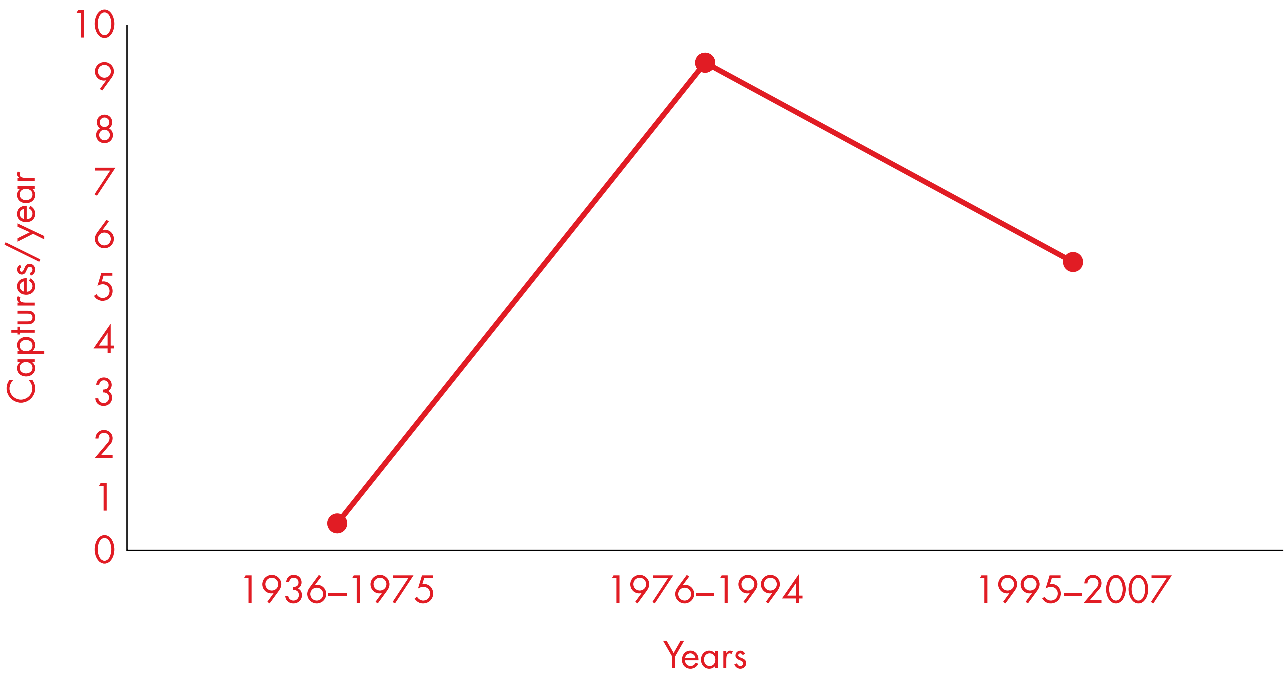
Extend the Lesson: Have students read the article at the link below. Then have them write a paragraph about why the gillnet ban is controversial. Have them take a position on the ban and support their position.
https://www.nbcbayarea.com/news/local/ca-bans-controversial-fishing-gear/63479/

1. **Complete** Table 1 by calculating the average number of white sharks captured each year. Round the number to the nearest hundredth of a shark.

Table 1. Number of white sharks caught in gillnets off California

Time Period	Total Caught	Years	Captures Per Year
1936–1975	18	40	0.45
1976–1994	177	19	9.32
1995–2007	72	13	5.54

2. **Draw** a line graph to show the change in the average number of white sharks caught in fisheries per year during the three time periods. Remember to label the axes and caption the figure.



Change in the number of white sharks caught in gillnets from 1936—2007

3. **Describe** why you think you see this pattern of catches through time.

Accept reasonable answers. Examples: Maybe if there were more people in California between 1976 and 1994, then more people were fishing and more white sharks got caught. Maybe the gillnet ban reduced the number of sharks caught. Maybe a decrease in the shark population resulted in fewer caught.

Extend the Lesson: Have students discuss the importance of calculating the average number of sharks captured per year instead of the total caught during a time period. (The time periods were different lengths of time.)

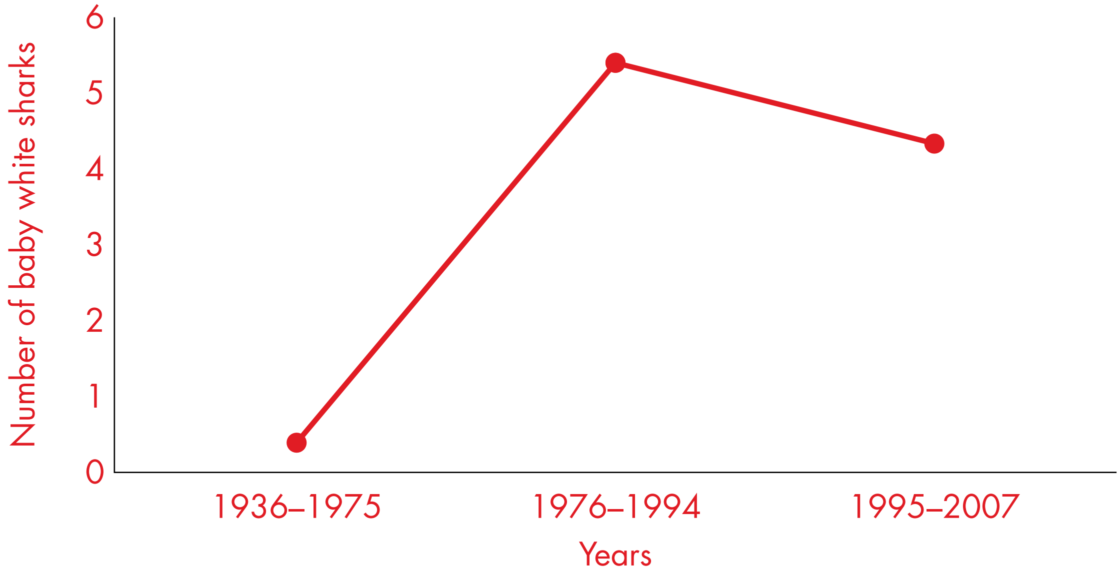
To understand what is happening to the white shark population, it is important to know whether the number of baby white sharks (sharks less than one year old) is increasing or decreasing. Table 2 shows how catches of these young sharks have changed through time.

4. **Complete** Table 2 by calculating the average number of white sharks captured each year. Round the number to the nearest hundredth of a shark.

Table 2. Total number of white sharks that are less than one year old caught in fisheries during three different time periods.
There was a ban on gillnets in nearshore waters of southern California that went into effect in 1994

Time Period	Total Caught	Years	Captures Per Year
1936–1975	13	40	0.32
1976–1994	101	19	5.32
1995–2007	56	13	4.30

5. **Draw** a line graph to show the change in the average number of baby white sharks caught in fisheries per year during the three time periods. Label the axes and caption the figure.



Change in the number of baby white sharks caught in gillnets from 1936—2007

6. **Compare** and **contrast** the patterns in catches of baby white sharks and other white sharks based on the figures and tables.

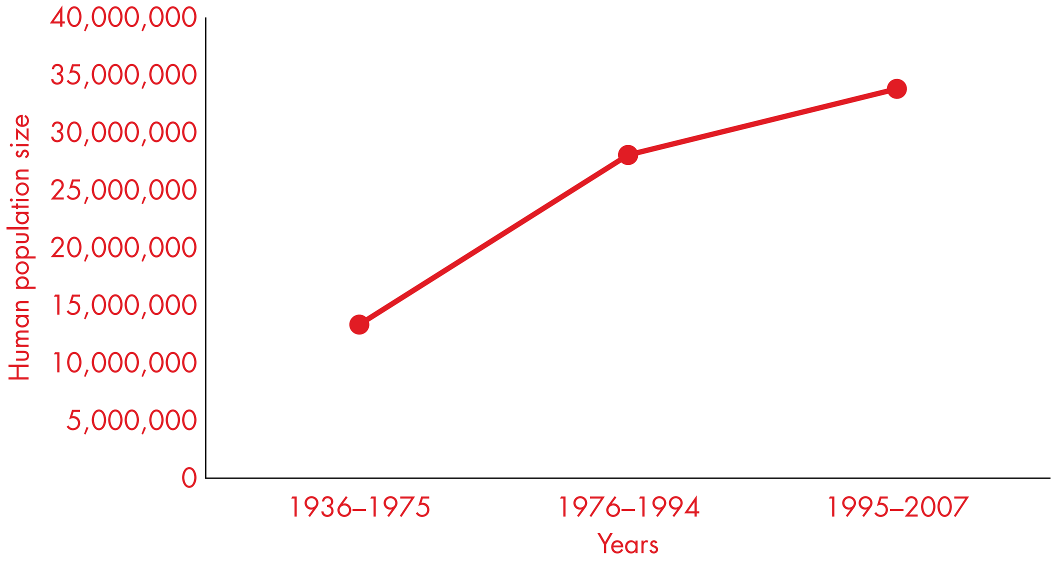
The patterns are similar. Not many baby sharks or sharks overall were caught before 1975. Then, the numbers went up. After 1995, the number of sharks caught per year went down. The number of baby sharks per year did not go down as much after 1994 as it did for all white sharks.

Could the changes in the number of white sharks caught be caused by changes in the number of people living in California? Use the data in Table 3 to explore this hypothesis.

Table 3. Average human population in California during the years white shark catches were measured

Time Period	Average Population
1936–1975	13,754,598
1976–1994	26,694,72
1995–2007	34,122,034

7. **Draw** a line graph to show the change in the average number of people living in California during the three time periods. Remember to label the axes and caption the figure.



Change in the number of people living in California from 1936—2007

8. **Describe** whether you think the changes in human population size are responsible for the change in catches of young white sharks. Cite evidence from the data to support your claim.

Answers may vary. It's important that students make a well-reasoned argument. For example, they may say that increases in the number of people might help explain why there are so many more sharks caught per year in 1976-1994 compared to 1936-1975. But, the drop after 1994 is not because the population of people went down. Instead, there were even more people. The drop may be because populations of white sharks went down or there were fewer fishing nets after the ban.

Sometimes lumping data together can hide important patterns! Figure 1 shows how many baby white sharks were caught each year during the time just before and just after the gillnet ban.

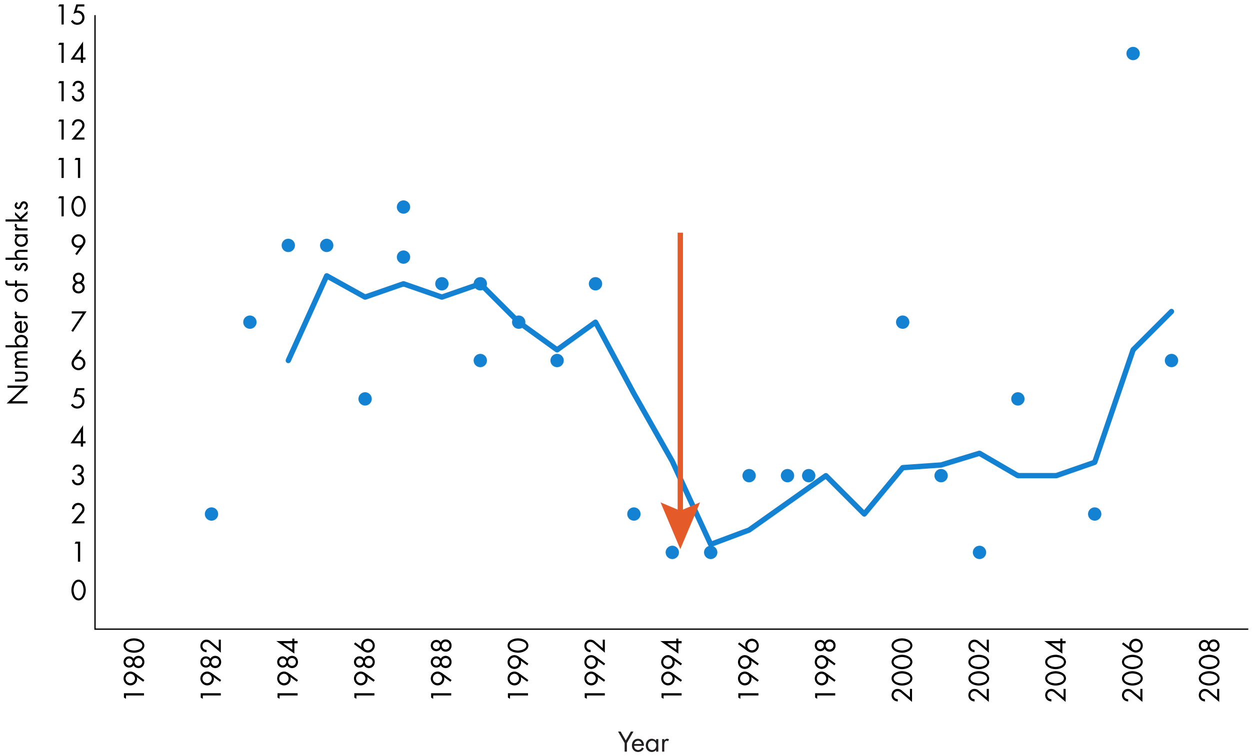


Figure 1. Number of baby white sharks caught each year from 1982-2007
The orange arrow shows when gillnets were banned in nearshore waters of southern California. Blue dots show the number of sharks caught each year. The line shows the average number over a three year period.

9. Use Figure 1 to **construct an argument** about whether the number of baby white sharks was influenced by fishing and the nearshore gillnet ban. Cite evidence to support your argument.

I think that gillnet fishing caused the number of baby sharks to decline. The number caught per year went way down before the gillnet ban. After the ban, it looks like the number of baby white sharks started to increase, but only after five or more years.

ACTIVITY 2: WHERE ARE THE WHITE SHARKS?

California is a big place! The Shark Lab has a lot of ground to cover if they are going to figure out where the baby white sharks are spending time and, more importantly, why they prefer certain places. They have to use multiple techniques to study the sharks. They use surveys of the population to count the number of white sharks are in an area. There are two main methods: drones and eDNA (environmental DNA). Basically, whenever a white shark or any other species swims through the water small bits of skin flake off. That skin has DNA in it. Water sample collections can reveal if there was a white shark in the area.

Drones with cameras make it is possible to determine the number and size of white sharks in a given area, but there are challenges. The water clarity and weather can make it difficult to see sharks. Drones also run on batteries, which limits the amount of sampling time.

Attaching electronic tags on sharks is another way to locate young white sharks. Receivers on the bottom listen for the signals from the tags and then record when a tagged shark is present. They also record which shark was around. However, the receivers can only hear tags that are within about one to two kilometers of them, and California is a BIG place. Also, not all white sharks are tagged. So not hearing a shark at one location doesn't mean that there are no sharks there.

While eDNA may sound useful, it is still a new technique. It is important to make sure that it detects where sharks are and doesn't detect them where there are no sharks. The Shark Lab team has conducted a test. The team collected water from areas next to receivers that were on the bottom. They then determined if a tagged shark was near the monitor when they collected water. Next, they collected water from locations where white sharks were not typically observed. They flew a drone to make sure they didn't see a white shark when they collected water. The data from this study are in Table 1. Use these data to see if eDNA is an effective technique for surveying sharks.

Table 4. Presence of white shark eDNA in water samples at 10 locations

Location	White shark observed on drone or detected on monitor?	White shark eDNA detected?
Receiver 1	Yes	Yes
Receiver 2	Yes	Yes
Receiver 3	No	No
Receiver 4	Yes	Yes
Receiver 5	Yes	Yes
Control 1	No	No
Control 1	No	No
Control 1	No	No
Control 1	No	No
Control 1	No	No

1. **Describe** whether you think the team can use eDNA to determine if white sharks are present at a location. Use evidence from Table 4 to support your answer.

I think eDNA can be used to determine if sharks are present at a location. In every spot where there were white sharks, eDNA detected sharks. Wherever they didn't see sharks eDNA did not detect sharks.

Extend the Lesson: Have students brainstorm other important questions about how eDNA works and what it might tell scientists. For example, how long does eDNA last before it can't be detected? Is it 2 hours, 2 days, 2 weeks, or more? How far can the current carry the eDNA from where the shark was swimming? Is it 10 meters, 50 meters, 100 meters, or 1 kilometer? Have students discuss how different answers might influence how eDNA can be used. Have students propose experiments that would help answer these questions. You can also have students discuss if there might be ways to determine how many individuals were in an area (this could lead into a discussion of how different individuals have different genetic sequences. You might use this article on how eDNA was used for whale sharks to support the discussion.
https://www.theatlantic.com/science/archive/2016/11/the-worlds-biggest-fish-in-a-bucket-of-water/508316/

ACTIVITY 3: WHY DO THEY LIKE TO SPEND TIME THERE?

Stingrays are one type of prey for juvenile white sharks. But stingrays are not defenseless! They have a sharp spine on their tail that they can use to stab a predator.

The most common stingray along the shore in southern California is the round stingray (*Urobatis halleri*). It grows to about 20 centimeters across its body. It appears that stingray populations have increased significantly based on the increasing number of people that are injured by stingray spines. When a person steps on a ray, the ray mistakes the foot as a predator and stings it with its spine. Recently, more than 150 people were stung in just one day on one beach! If you are ever in a place where there might be stingrays, shuffle your feet. You will scare them away before they sting!


Round stingray
Urobatis halleri

Why have stingray populations increased? It may be due to decreasing numbers of white sharks. Populations of other stingray predators have also gone down. Areas with a lot of stingrays might be a great place for young white sharks to hang out. Factors that attract many rays might cause young white sharks to concentrate in an area. The temperature of the water may be another important factor for round stingrays.

The Shark Lab has studied stingrays near Seal Beach, a place where many people are stung by rays. There is a power plant on the San Gabriel River that flows into the ocean at Seal Beach. The power plant warms the waters up in the river and along Seal Beach. Does this human activity influence stingrays? It might if stingrays like warm water! To study this question, Shark Lab measured conditions and counted round stingrays at two locations along Seal Beach. *Seal Beach 1* is close to the river. *Seal Beach 2* is farther from the river but still gets warm water flowing past it. The team also studied Sunshine Beach. Sunshine Beach is close to Seal Beach and has similar conditions, but the temperature of its water is not influenced by the power plant. At each location they measured conditions and counted rays close to the shore (0 to 30 meters from shore) and farther from shore (31 to 60 meters from shore).

1. **Identify** which location is the control for this study. **Explain** why it is the control.

Sunshine Beach is the control because the water temperature there is not affected by human activity.

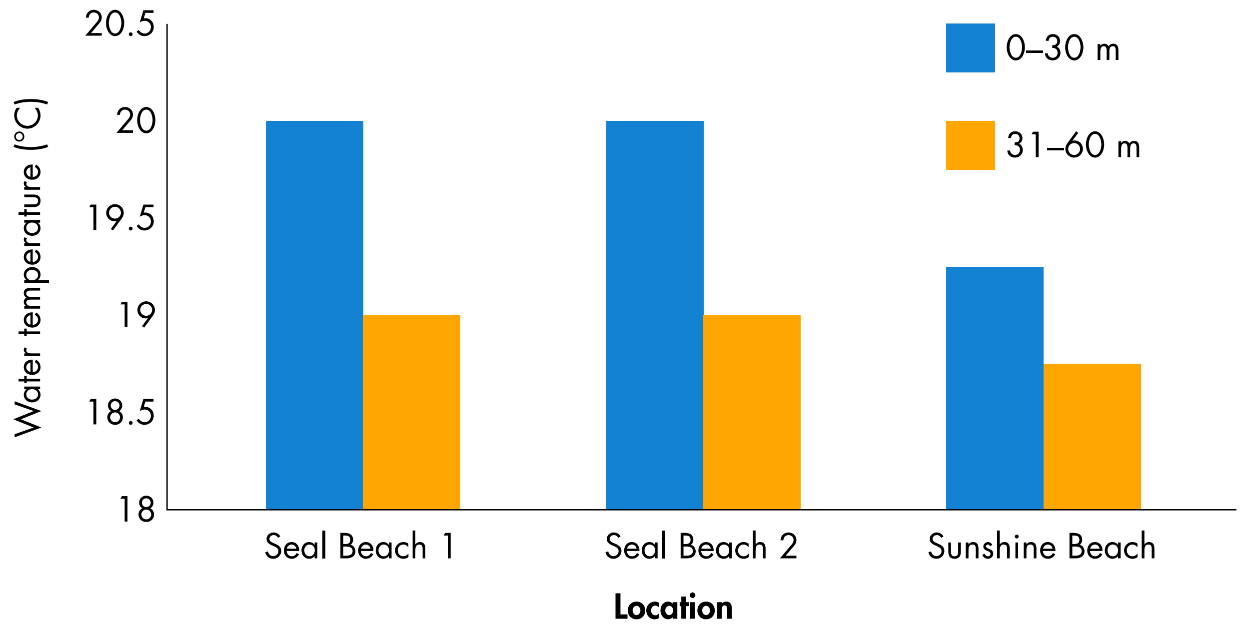


Figure 2. Water temperatures at three study sites in waters close to shore and further offshore

2. **Write** a hypothesis for how the density of rays (the average number of rays found in each square meter) should differ across Seal Beach 1, Seal Beach 2, and Sunshine Beach) if round stingrays prefer warm waters.

If rays prefer warm waters, then I think there will be the most stingrays at Seal Beach 1 and Seal Beach 2. There will be fewer at Sunshine Beach.

3. **Write** a hypothesis for how the density of rays (the average number of rays found in each square meter) should differ between areas close to shore (< 30 meters) and farther from shore (31- 60 meters) if round stingrays prefer warm waters.

If rays prefer warm waters, then I think that there will be more stingrays close to shore than offshore.

4. **Complete** Table 5 by calculating the average density of rays in each location closer to shore.

Table 5. Stingray densities (rays per square meter) counted in three locations within 30 meters of shore

	Seal Beach 1	Seal Beach 2	Sunshine Beach
1	0.6	0	0.4
2	0.2	0.5	0.1
3	0.4	0.1	0.1
4	0.2	0.2	0
5	0.3	0.3	0
6	0.7	0.4	0.2
7	1.8	0.3	0
8	0.5	0.1	0.1
9	0.2	1.9	0.1
10	0.1	0.2	0
Average	0.5	0.4	0.1

5. **Complete** Table 6 by calculating the average density of rays in each location farther from shore.

Table 6. Stingray densities (rays per square meter) counted in three locations 31-60 meters from shore

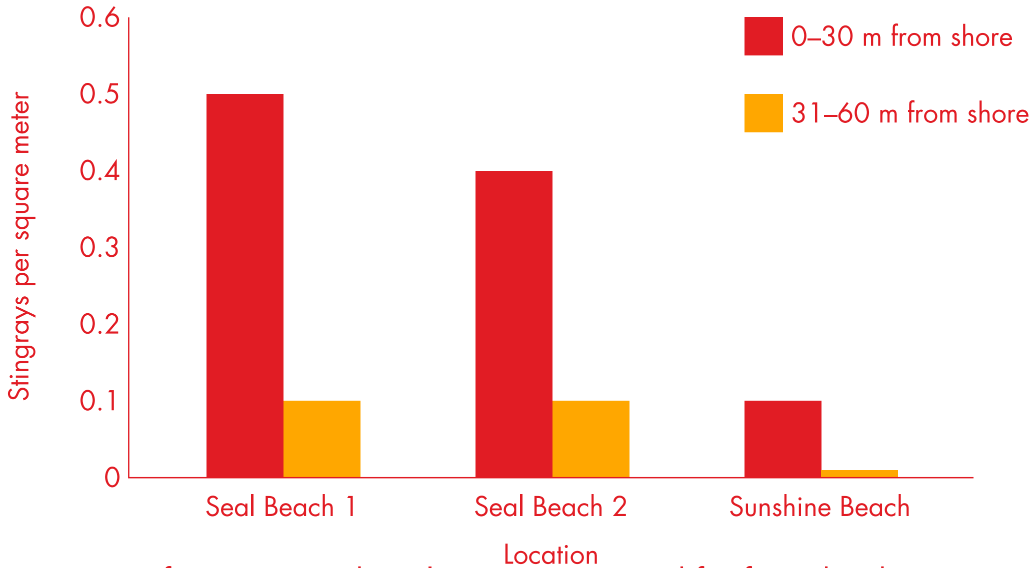
	Seal Beach 1	Seal Beach 2	Sunshine Beach
1	0.1	0.2	0
2	0	0	0
3	0.7	0	0
4	0	0.1	0
5	0	0	0
6	0.1	0	0
7	0.1	0	0
8	0	0.6	0
9	0	0	0
10	0	0.1	0.1
Average	0.1	0.1	0.01

6. **Complete** Table 7 using the data from Table 5 and Table 6.

Table 7. Average stingray densities (rays per square meter) counted in three locations

	Seal Beach 1		Seal Beach 2		Sunshine Beach	
	0–30 m	31–60 m	0–30 m	31–60 m	0–30 m	31–60 m
Average	0.5	0.1	0.4	0.1	0.1	0.01

7. **Draw** a bar graph that shows how the density of stingrays (rays per square meter) differs between locations and distances from shore. Remember to label the axes and write a figure caption.



Densities of stingrays in three locations near and far from the shore

8. **Describe** the pattern you see for stingrays.

Stingrays were most common near shore at Seal Beach 1 and 2. They were less common at Sunshine Beach, especially further from shore.

9. Based on this evidence, do you think water temperature matters to round stingrays?

Answers may vary. Some may say the evidence is weak and there were less stingrays at Sea Beach 2 even though there were similar temperatures near shore. Others may say that there is good evidence because Seal Beach near shore was the warmest location and also where there were the most stingrays.

Another way to look at how water temperature might affect stingrays is to compare the temperature during a survey to the density of rays that were seen. The data from these comparisons is shown in the figure below.

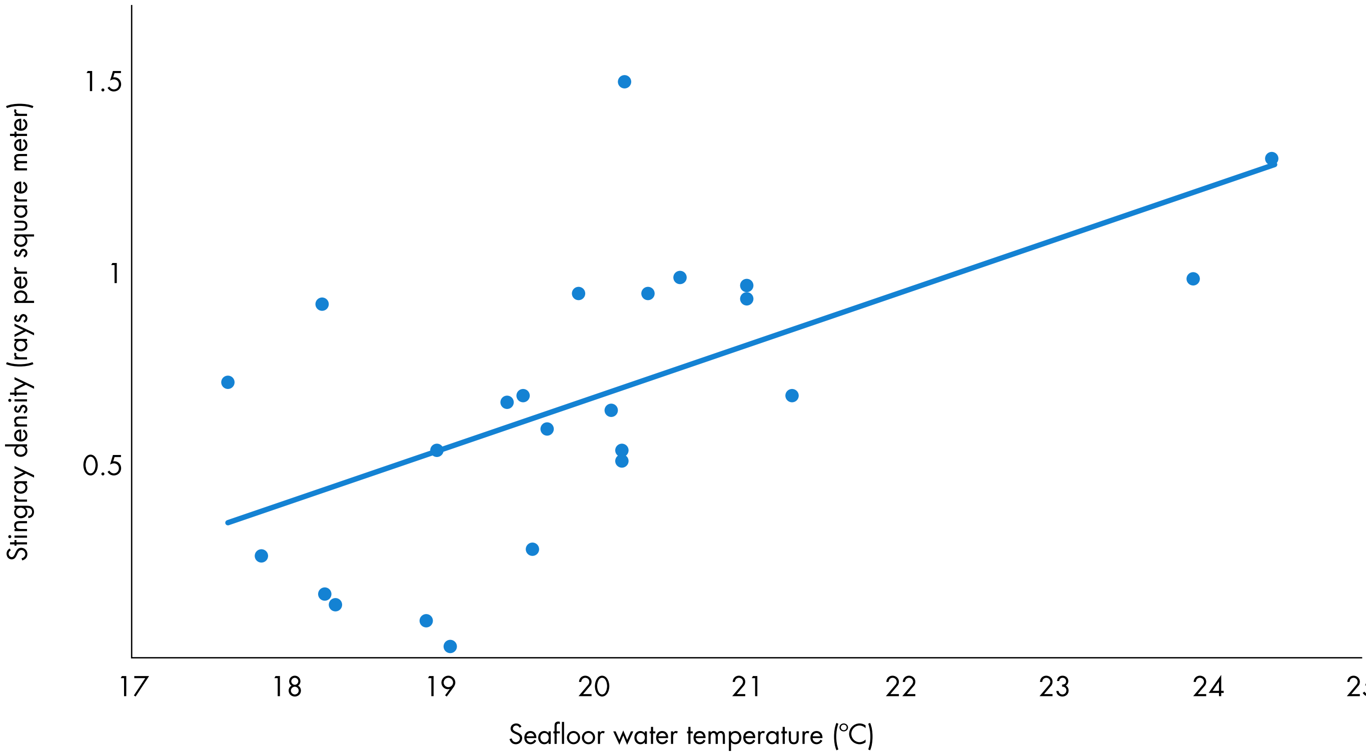


Figure 3. The relationship between stingray density within 30 m of shore and water temperature off Seal Beach

10. **Describe** the relationship between water temperature and the density of stingrays.

As the temperature of the water increases, the density of stingrays increases.

11. Based on Figure 3, **describe** whether you think water temperature is the only factor that influences the number of stingrays found off of the beach. Use evidence from the figure to support your answer.

Answers should suggest that it is not the only factor because at a certain temperature there may be different densities of stingrays. But, full credit should be given for logical arguments. This question could also be used as a discussion question. Have students observe that the data are variable and lead a discussion of why replication is important.

12. Do you think that the presence of the power plant affects the number of stingrays in the area? **Cite** evidence from the figures to support your answer.

Yes, I think the power plant causes there to be more stingrays in the area because it warms the water. Places or times with warmer water have more stingrays.

13. If white sharks choose where to spend their time based only on where stingrays are found, **predict** where young white sharks will be most common (Sunshine Beach or Seal Beach and close to shore or farther from shore). **Describe** why you made this prediction.

White sharks should be found close to shore and off Seal Beach because that is where there are more stingrays.

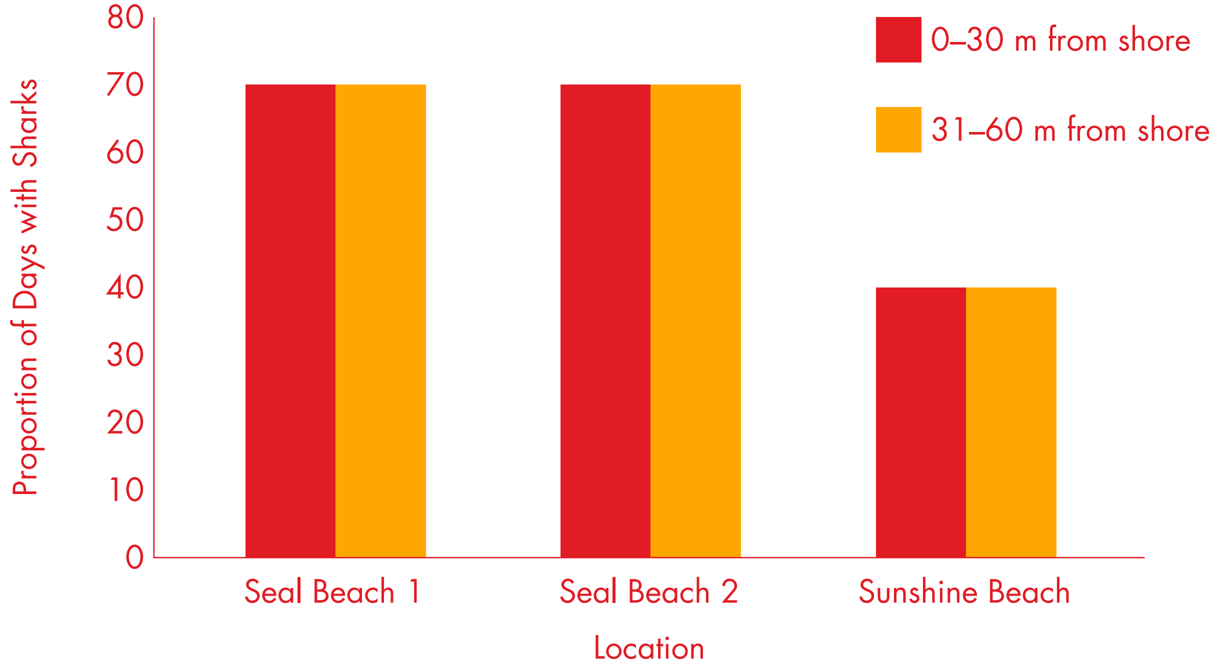
Shark Lab collected water samples and flew drones to see when white sharks were in the area. Use the data below to test your prediction.

14. **Complete** Table 8 by calculating the percent of days that sharks were present in each location.

Table 8. Presence or absence of white shark based on eDNA in water samples taken on 10 days

	Seal Beach 1		Seal Beach 2		Surfside Beach	
Day	0–30 m	31–60 m	0–30 m	31–60 m	0–30 m	31–60 m
1	present	present	present	present	present	present
2	present	present	present	present	absent	absent
3	present	present	present	present	absent	absent
4	absent	absent	absent	absent	absent	absent
5	present	present	present	present	absent	absent
6	present	present	present	present	absent	absent
7	present	present	present	present	present	present
8	absent	absent	absent	absent	present	present
9	absent	absent	absent	absent	absent	absent
10	present	present	present	present	present	present
Percent of Days Detected	70	70	70	70	40	40

15. **Draw** a bar graph of the data in Table 8. Remember to label the axes and caption the figure.



Percent of days with sharks observed

16. Describe if the eDNA data in your figure were consistent with your hypothesis.

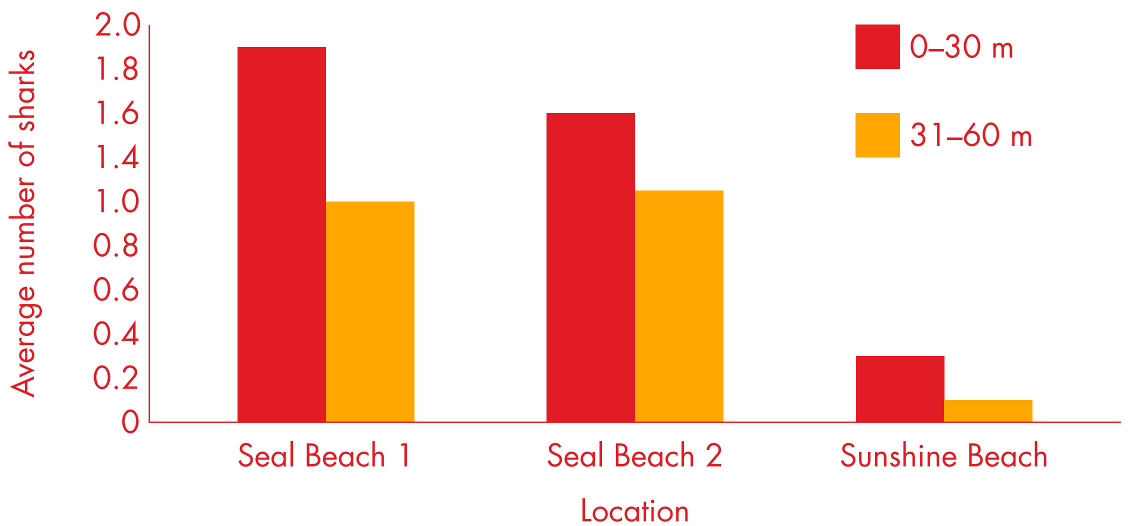
Responses should relate to students' predictions in question 13. For example: The data were not consistent with my hypothesis that sharks would be most common near shore. A similar proportion of sharks was seen near shore and offshore of Seal Beach. Seeing fewer sharks at Sunshine Beach was consistent with my hypothesis.

17. **Complete** Table 9 by calculating the average number of sharks cited by drones in each location.

Table 9. Drone counts of white sharks on 10 days where water samples were taken

	Seal Beach 1		Seal Beach 2		Sunshine Beach	
Day	0–30 m	31–60 m	0–30 m	31–60 m	0–30 m	31–60 m
1	2	0	2	1	1	0
2	1	0	2	2	0	0
3	6	2	1	4	0	0
4	0	0	0	0	0	0
5	2	1	5	1	0	0
6	1	2	2	2	0	0
7	1	0	1	0	1	0
8	0	0	0	0	0	1
9	0	0	0	0	0	0
10	6	5	3	1	1	0
Average number of sharks	1.9	1	1.6	1.1	0.3	0.1

18. **Draw** a bar graph of the data in Table 9. Remember to label the axes and caption the figure.



Drone counts of sharks at each location close to shore and offshore

19. **Describe** whether or not the drone data in your figure were consistent with your hypothesis.

Responses should relate to students' predictions in question 13. For example: It is consistent with my hypothesis because the most rays were seen near shore at Seal Beach and the least were at Sunshine Beach.

20. **Speculate** on why the different methods gave different results.

This question is more to generate ideas than to get specific answers. It could be a good discussion question about the importance of using multiple methods. The reason for the difference is: eDNA only tells you if sharks are generally in the area as the DNA may move with currents. The drone only sees where sharks are at a specific time.

Extend the Lesson: Have students think about why white sharks need more energy to run their bodies than most sharks, even if they are the same size. It is because white sharks are warm-blooded (endothermic) so they need a lot of energy to run their bodies and stay warmer than the cold water they swim in. Most other sharks are cold-blooded. They don't need energy to keep their bodies warm. Then, have students think about whether this means white sharks might have a greater or lesser influence on the numbers of their prey than other species of sharks.

21. **Predict** what might happen to the stingray population if the number of young white sharks continues to grow. **Describe** why you made this prediction. **Describe** how these changes might influence the number of people that are stung by stingrays at Seal Beach.

I predict that stingray populations would go down because white sharks would eat so many of them. This should lead to fewer stingray stings because there are fewer stingrays overall.

22. **Describe** how you would test your prediction from question 13.

Example answers include: 1) I'd monitor the population of white sharks and the population of stingrays. 2) I'd do a more in-depth study of what white sharks eat.