Fisher Logs

8.3

Image courtesy of CSULB Shark Lab [Reproduced with permission]

Anchoring Phenomenon

Numerous reports suggest an increase in white shark encounters* in the United States in recent years and the public is worried.

Lesson Concept

Analysis of historical data on white shark captures determines the effect of human activities on current white shark populations.

Investigative Phenomenon

The historical accounts of white sharks have changed over time.

Standards

Refer to Appendix 8.3 for NGSS, CCSS (ELA), California ELD, and EP&C standards.

*Encounters include sightings and census estimates, as well as physical interactions between humans and sharks.

Storyline Link

Prior to this, students investigated the history of white sharks as recorded in the fossil record and determined that shark population estimates cannot be made from fossil evidence. In this lesson, students learn about the population of white sharks as recorded in fisher logs and analyze graphical representations of data to identify temporal relationships. They read an adapted scientific text to describe evidence about fisher logs to clarify claims and findings. They realize, as consumption of natural resources increases with the rise in the human population, so do the negative impacts. They analyze patterns in the data to determine the cause of the negative impacts and learn about the effects of human intervention (through legislation). Although they are able to make some general conclusions, students realize that there are so many variables impacting the data in historical accounts that it is insufficient to fully explain the phenomenon. Finally, collaborative groups integrate quantitative information from written scientific text and visual displays of these accounts to obtain information and describe patterns and engage in early stages of constructing an explanation that includes quantitative relationships between variables to describe, at least, parts of the phenomenon (and will be built on in the next lesson and in lessons 9–10 of the learning sequence). This lesson is part of a series in the learning sequence that will culminate in students revising an explanation over time leading to engaging in argument from evidence about the causes of recent increases in the white shark population with the goal of building public understanding and alleviating concerns.

In the next lesson, students will be introduced to a modern technique that yields more reliable data: tracking devices. Students distinguish between aspects of the anchoring phenomenon and determine information needed to explain the phenomenon. This will lead them on a journey where they will learn about the physics behind tracking devices that allow us to better understand what is happening to the white shark populations and thus better understand their behavior.

Throughout the lesson, a flag (▶) denotes formative assessment opportunities where instruction may change in response to students' level of understanding and making sense of phenomena.

8.3 Fisher Logs

Time

135 Minutes

Part I	45 minutes	Engage
Part II	45 minutes	Explore
Part III	45 minutes	Explain

Materials

Whole Class

- ❑ 8.1.C1: Shark Encounter Claim Chart (from Lesson 8.1: Shark Encounters)

Per Group of 4

- ❑ Chart paper
- ❑ Markers
- ❑ Sticky notes
- ❑ 8.3.G1: Role Cards (one set per group)

Individual

- ❑ Science Notebook
- ❑ 8.1.H2: Scientist Communication Survival Kit (from Lesson 8.1: Shark Encounters)
- ❑ 8.1.H3: My Shark Encounter Claim Chart (from Lesson 8.1: Shark Encounters)
- ❑ 8.1.H4: Crosscutting Concepts for Middle School Students (from Lesson 8.1: Shark Encounters)
- ❑ 8.3.H1: A Fisherman's Story
- ❑ 8.3.H2: Graph of Data from Fisher Logs
- ❑ 8.3.H3: Fishery Logs 1930–2010

Teacher

- ❑ 8.3.R1: Global Perspectives on the Life History of Sharks (Chapter 14)

Advance Preparation

1. Students should be seated in groups of four for the duration of the learning sequence to foster collaboration.
2. Duplicate **8.3.H1: A Fisherman's Story** for each student. (Step 2 of Procedure)
3. Duplicate **8.3.H2: Graph of Data from Fisher Logs** for each student. (Step 3 of Procedure)
4. Duplicate **8.3.H3: Fishery Logs 1930–2010** for each student. (Step 4 of Procedure)
5. Duplicate **8.3.G1: Role Cards** for each group of four and assign roles for adapted literature circles. (Step 4 of Procedure)
6. Gather chart paper and markers.
7. Make sure that **8.1.C1: Shark Encounter Claim Chart** from Lesson 8.1: Shark Encounters, is posted in the room.
8. Students should have **8.1.H4: Crosscutting Concepts for Middle School Students** from Lesson 8.1: Shark Encounters in their Science Notebook.

Procedure

Part I

Engage (45 minutes)

Analyze graphical representations of data to determine the possible causes of data fluctuations and ask questions about the human activities that impacted the white shark population.

1. Review Previous Lessons

   a. Ask students to identify/recall the phenomena they are trying to explain (both the anchoring and the investigative) from the previous lesson. Once these are clearly stated for all, ask students to begin with a quick write to review previous lessons and elicit student thinking about the phenomenon. They respond to the following prompts:

      i. What evidence do you have for establishing a pattern of human population size, shark population size, and encounters between the two populations? (from Lesson 8.1: Shark Encounters)

      ii. What evidence did you find about shark populations from the last activity? Remember to explain your thinking. (from Lesson 8.2: Fossil Evidence)

      Students share their quick write in their small group, and then ask a few students to share with the whole class. ▶ Use this as an opportunity to reinforce more accurate scientifically-aligned ideas that students share, and use probing questions directed to the class to help students that may have some confusion.

   b. As students discuss the interactions between humans and sharks, elicit ideas students have about impacts on the environment when population growth is exponential. Thinking specifically about humans, what are the impacts of the dramatic human population increase over the past few decades? (The discussion should include resource use including food resources like fish.)

   c. When reflecting on Lesson 8.2: Fossil Evidence, it should quickly become evident that while students have learned sharks have a long history, as indicated by the fossil record, it does not provide evidence for population sizes. Ask, "Since we cannot find evidence of past shark populations through fossils, how or where can we find evidence of past shark populations?" and "How can scientists predict future patterns based on smaller patterns they have seen in the past? What are some methods you have learned about in your social studies class?" Elicit ideas or prompt students to think about records that people keep—in this case, records of fish catches (fisher logs).

2. Introduce and Distribute **8.3.H1: A Fisherman's Story**

a. Have students read the fictional scenario. Encourage a group read, where students take turns reading out loud in their group. Allow students access to a quiet space for those who prefer a quiet space to read. While the narrative is fictional, it is based on an actual person's experiences.

b. Encourage groups to discuss some *aha*'s they gained from the reading. As groups discuss, briefly check for understanding by asking questions such as the following:

   i. How did fishing change during Antonio's lifetime?

   ii. Why did his family stop fishing the San Diego waters?

   iii. What is a fisher log?

3. Introduce and Distribute **8.3.H2: Graph of Data from Fisher Logs**

a. Remind students that a figure/graph is a type of model and ask students to share their ideas about the types of information that figures/graphs can provide and why scientists use them so frequently. In what way are figures/graphs similar to other models in science? What is similar/different about how they convey ideas and information?

b. Distribute **8.3.H2: Graph of Data from Fisher Logs** and ask students to read the title, "Graph of Data from Fisher Logs: Frequency and Distribution of Reported White Shark Captures." Ask students what the title means. What will the graph show? Ask students to read the axis titles and give them a chance to ask about the meaning of words. Verify that this figure will show historical accounts of white sharks over time (75 years of history beginning in 1935) by helping us understand frequency (number of sharks reported, how many sharks captured) and distribution (over the years).

c. Direct students to examine the figure and give them several minutes to review it, independently. They should use their Science Notebook to record "True Statements" they observe from the graph. For example, "This graph shows time from 1935–2010." ▶ The format of the graph may be new to students and they may need confirmation of their ideas of what the bars mean. The questions below can help guide them to making sense of the graph.

TEACHER NOTE

All students are familiar with looking at graphs in math. Probe for prior knowledge of how to read and analyze a graph before distributing the handout. Be aware that this graph also has multiple data sets on each bar which may be, at first, confusing to students. Giving students a few minutes to just look and record “True Statements” about what they are seeing gives them time for sensemaking before there is input from others. Following independent think time, allowing for partner discussion prior to class discussion will support language learners.

i. What does the term *temporal trends* mean? (Students’ thinking should be based on their own experience and not on Internet search. Some students may associate it with temperature. Provide students with the hint that it is a Latin word, *tempus* as in music, tempo, and time.) Alternatively define the term for students, “The data we will be looking at are temporal trends, or trends over time.”

ii. Which axis identifies time?

iii. What information does the key tell us? (Students will get their answers from the caption at the bottom of the graph. It notes the key and size of white sharks.) Teachers may want to clarify that *YOY* means *young-of-the-year*, or sharks born during the last year. (Because white sharks have a long gestation period, a **newborn** will be about 4–5 ft. in length).

d. Ask students in each group to generate six questions about the data, and possible answers. Make the stipulation that at least one question has to use the crosscutting concept of Pattern to identify a possible pattern in the graph as it relates to the DCI: *as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise.* Remind students to use **8.1.H4: Crosscutting Concepts for Middle School Students**, modeled in Lesson 8.1 Shark Encounters, Step 7.b.
▶ As students work, utilize **8.1.H4: Crosscutting Concepts for Middle School Students** as a rubric to evaluate student questions and to prompt students to work with items in the On-Target column. Ask students to record this in their Science Notebook. Following this, engage the class in a discussion about their questions and, if they have evidence from the graph, answers. If students do not offer them, be sure to ask the following questions:

i. What does the overall data show?

ii. What does each subset of data show?

iii. What are some possible reasons for the differences from year to year?

(Encourage students to refer to information they tracked in their Science Notebook from Lesson 8.1: Shark Encounters to see if information from there might provide insight on making a connection between human activity and information in the figure.)

iv. Which set, the overall set or the subsets of data, provides more evidence to answer the question, "Are sharks becoming more common along the California coastline? What data supports the patterns you noticed?"

v. What additional questions do you have?

e. Elicit responses from a few table groups and chart student ideas.

TEACHER NOTE

▶ Some students may confuse an increase in sharks being inadvertently caught via gill net use to mean that there were simply more sharks (rather than the fishing method being effective). Questions such as "which patterns in the graph are based on human-made causes?" and "which patterns are based on shark population causes?" may help students.

The graph on **8.3.H2: Graph of Data from Fisher Logs** stops at 2010. For students that are more engaged and would like to go further with the data, invite them to research and extend the data to 2018. If students need help searching for this information, here is a starting place: https://www.wildlife.ca.gov/Conservation/Marine/White-Shark

Procedure

Part II

Explore (45 minutes)

Obtain and evaluate information from a scientific text to analyze patterns in data to learn about the effect of human activities on white shark populations.

4. Introduce and Distribute **8.3.H3: Fishery Logs 1930–2010**

a. This activity uses a technique called *literature circles*, borrowed from literature instruction, to help students access the information, with an emphasis on student interest and productive discussions. To implement literature circles technique, distribute the **8.3.G1: Role Cards** to student groups of four. Review the expectations and duties of each role, as listed on each Role Card.

i. **Pattern Pro.** Patterns are everywhere; we often think of them in terms of events that happen repeatedly. Patterns can be used to identify cause and effect relationships.

ii. **Nature of Science Guru.** This role looks at important aspects of what science is and how it is done, such as, science is how we come to know things/how knowledge is generated, science is a human endeavor, and knowledge is open to revision in light of new evidence.

iii. **Cause and Effect Analyst.** A cause can have one or more effects. Cause and effect relationships may be used to predict phenomena. When this role is being introduced, ask the class for their clarification of causal and correlational (just because two things happen at the same time does not mean one caused the other) to ensure they understand that element.

iv. **Legislative Analyst.** Critically read the text for actions taken by government or organizations that place legal parameters or guidelines on what people can do.

TEACHER NOTE

Roles can be differentiated based on students' interests and abilities. Cause and Effect Analyst and Pattern Pro are roles in which all students should feel comfortable and be able to contribute to the group. Legislative Analyst is a role that takes a more critical eye and someone that can understand how and why government plays a part. The most challenging role is that of the Nature of Science Guru because it requires the student to be well versed in both the science and a big picture of what we do and why.

b. Remind students to use their **8.1.H2: Scientist Communication Survival Kit** to help with group conversation and to make sure everyone has a chance to share.

c. Ask students to reference **8.1.H4: Crosscutting Concepts for Middle School Students**, and take a few minutes to model use with Cause and Effect, similar to what was done for Patterns in Lesson 8.1: Shark Encounters, Step 7.b. as all students will eventually be using this crosscutting concept at the culmination of literature circles. Again, ask students for their clarification for *causal* and *correlational* (just because two things happen at the same time does not mean one caused the other) to ensure they understand that element. As students work, consider where they are in their understanding of cause and effect by using **8.1.H4: Crosscutting Concepts for Middle School Students** as a rubric. Students may need encouragement to utilize prompts in the On-Target column.

d. Group students by their role (Pattern Pro students work together, for example) and direct students to read about research on white shark populations from fisher logs, looking specifically through the lens of their role. When students finish reading, they should go through the article again as a group, pointing out and discussing what aspects of their role are present in each paragraph.

i. Remind students to record the information related to their role in their Science Notebook.

ii. Students should identify the three most important points that the article made through their given lens to take back to their home groups.

iii. As student groups read the article, circulate to answer questions and keep students on task.

e. After students have discussed the article through their expert lens, have them go back to their home groups and share their information. Direct students to set their Science Notebook up to prepare to record details from each expert. (If you have students who tend to record too much rather than listen, it's ok to suggest the group decides the three most important details and that's what the group records.)

Procedure

Part III

Explain (45 minutes)

Construct an explanation, supported by evidence using patterns in data about the effect of human activities on white shark populations.

5. Student Groups Record their Explanation, Evidence, and Reasoning

- As groups finish reading the article and recording information in their Science Notebook, ask students to revisit **8.1.H3: My Shark Encounter Claim Chart** from Lessons 8.1 and 8.2. Add any new information that could be used to support any of the claims and subsequent evidence and reasoning.

> **TEACHER NOTE**
>
> Reminder that "time" in this lesson is different than in the previous lesson exploring fossil evidence. If productive/useful to students when adding to **8.1.H3: My Shark Encounter Claim Chart**, some students may choose to use the lens of the more recent history explored by the fisher logs. A reminder that "time" is a construct and should be agreed upon by the students in the class and may change depending upon usefulness.

- Remind students about the parameters by which we define evidence and reasoning.
  - Evidence: Scientific data (records, observations, etc.) about the frequency of white shark encounters over time that support the claim.
  - Reasoning: Learnings about white sharks' life history that provide a logical connection between the evidence and the claim and explains why the evidence supports the claim.

- Also remind students that data has limitations. Ask students to think about how data from both this and the previous lesson were obtained and the limitations that it might have.

TEACHER NOTE

Possible limitations for data could include random sampling from Fossil Evidence (Lesson 8.2: Fossil Evidence), too many factors that influence the data, inconsistency in data collection (if no one was around when a shark was landed, data didn't get collected). Additionally, there is a gap in the data from 2009 to present. The class should come to the conclusion that the future purposes of using shark tracking technologies in this learning sequence is to retrieve data about sharks and their encounters to fill in these gaps of information.

- Each group must come to a consensus over which of the three claims the evidence shows can now be *excluded*. As a group, they must be able to share with the class which claim they are excluding and provide three items of evidence as justification. Once groups have made their decision and provided evidence, open up the conversation to the whole class.
- For the remaining two claims, ask groups to justify these choices by identifying causes for them. Ask students to have a discussion with their group about which of these claims has the most supporting evidence and reasoning. Ask students to record this in their Science Notebook along with a rationale and remaining questions they have about it. For the claim, what information is missing that would strengthen the explanation. Students do not need to be in agreement with others in their group about their primary claim, but they should be able to have a discussion about their thinking to help process their thoughts.
- ▶ When students are finished, take time to read notebook responses and leave sticky note feedback as described in Lesson 8.2: Fossil Evidence. Return Science Notebooks to students and ask them to review the feedback and, if helpful, to discuss questions they may have with their group. After discussing, ask students to consider the feedback and refine their work. Ask students to identify their revisions in some way so that you can check again to see their progress.

Accommodations

If you have students who need help analyzing the graph, establish the context by asking students to identify the title, key, and description of data, and define any words that are new. Another strategy is to ask students to describe the graph in their own words. Help them identify the horizontal value (time). Help them analyze the vertical value (range). Identify the overall trend. Look for peaks and valleys. Is there a pattern to them?

If you have students who need help with reading tasks, ask the class to skim the article first, and identify any words that might need clarification. Clarify the directions, then ask students to do a group read (have one person in the group read the article out loud), but encourage students to withhold group discussions until everyone has had a chance to do their own thinking and make notes in their Science Notebook first, then discuss with their group, and revise Science Notebook work accordingly.

During literature circles, plan extra accommodations for those who need literacy support. These students can be paired with a peer for the initial attempt at the reading. When expert groups decide on their three pieces of information, encourage the class to allow those that are quiet to speak first. Have the expert group verify that all have information recorded in their Science Notebook before rejoining their home groups.

By seating students in groups (groups of 4 work well) and encouraging regular conversation, students have time to interact more with content and naturally help those that need more support. Use of **8.1.H2: Scientist Communication Survival Kit** helps to make sure that students who don't feel comfortable sharing (often because of language, literacy level, uncertainty of content knowledge, etc.) are prompted to do so in a supportive way.

Use of a sense-making Science Notebook supports student language development, conceptual development, and metacognition. Students should be prompted to use their Science Notebook for

- ❑ prior knowledge of phenomena,
- ❑ exploration of phenomena and data collection,
- ❑ making sense of phenomena, and
- ❑ metacognition.

Consider providing sentence frames for low literacy and second language learners. The use of graphic organizers can help struggling students manage Science Notebook work. To support students learning English, allow conversations and Science Notebook work to happen in the language that the student is most comfortable expressing understanding, and then encourage expression using simple English phrases (or more complex for students with increasing proficiency).

As this lesson is rich with discourse opportunities, consider partnering second language learners with a "language broker" (another student who is bilingual in English and the student's home language) to allow these partners to first discuss ideas in their home language. Monitor this pairing and provide additional language support as needed.

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Role Cards

(Copy and cut apart, one set of 4 cards for each group of 4 students.)

Pattern Pro

Carefully read the text with your fellow experts. Identify central ideas and record in your Science Notebook.

Identify and record patterns from the reading. Use 8.1.H4: Crosscutting Concepts for Middle School to help you think about this. Note (if possible) how long the pattern has been observed. Patterns in science often lead to identification of cause and effect relationships and questions. Feel free to annotate in the margin of your reading to help with your discussion.

Discuss with your group. As a group, choose three examples of patterns you find with evidence from the reading and record in your Science Notebook.

Nature of Science Guru

Carefully read the text with your fellow experts. Identify central ideas and record in your Science Notebook.

Go back and analyze the text for nature of science themes. There are several factors that accurately describe the nature of science (what science is and how it is done):

- ❑ Scientific knowledge is based on evidence.
- ❑ Scientific knowledge is open to revision in light of new evidence.
- ❑ Science is a human endeavor.
- ❑ Scientists are often very creative in their attempts to solve problems.
- ❑ Scientists are influenced by their own personal beliefs and by society.

While reading, look for examples of these factors. Feel free to annotate in the margin of your reading to help with your discussion. Discuss with your group. As a group, choose three examples of these factors with evidence from the reading and record in your Science Notebook.

Role Cards (continued)

(Copy and cut apart, one set of 4 cards for each group of 4 students.)

Cause and Effect Analyst

Carefully read the text with your fellow experts. Identify central ideas and record in your Science Notebook.

Identify cause and effect relationships from the reading; use 8.1.H4: Crosscutting Concepts for Middle School Students to help you think about this. What does the reading suggest are the causes of various events discussed? What are examples of effects that may have more than one cause? How can cause and effect relationships be used to predict what is happening today? Feel free to annotate in the margin of your reading to help with your discussion.

Discuss with your group. As a group, choose three examples of these relationships with evidence from the reading and record in your Science Notebook.

Legislative Analyst

Carefully read the text with your fellow experts. Identify central ideas and record in your Science Notebook.

Go back and reread the text with a very careful lens: what are examples of actions taken by organizations or government (look for language like, *U.S.* or *California*, which implies federal and state government) to place guidelines on what people can do.

What was the action? What was the action designed to protect? Feel free to annotate in the margin of your reading to help with your discussion.

Discuss with your group. As a group, decide on what you think are the three most important examples of these actions (the three that probably had the greatest impact on white sharks), with evidence from the reading, and record in your Science Notebook.

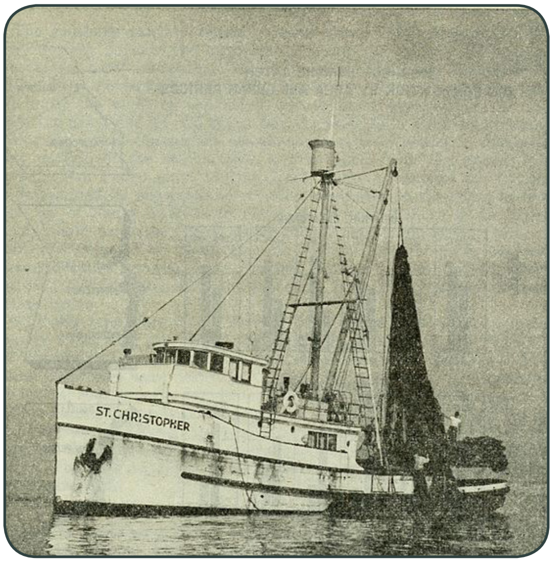
A Fisherman's Story

John Rogers grew up in a fishing family. His father owned a boat and supported their family of five by fishing for big fish, mostly tuna, off the California coast. John learned everything about fishing from his father, and it was only natural that he and his two brothers take over the family business when their father was too old to meet the physical demands of being a fisherman. John has seen his job change in many ways over the years, from the type of gear they were allowed to use, to the types and amounts of animals that showed up in their nets.

When John started working on the fishing boats with his family, he was nine years old. He helped out where he could, washing dishes, cleaning the deck, or managing the ropes (called *lines* in boat terms). His favorite thing to do was to be on the lookout for big groups of birds diving down and gathering at the surface of the water because that indicated a big group of fish was just under the water. Whenever this was spotted, they would quickly head over and drop their fishing lines into the water and try to catch as many fish as possible. The first tuna John hooked weighed more than he did, and almost pulled him overboard. Most of their trips lasted a month or more, and they had to preserve their catch with ice. They had to be careful; if the ice melted before they got back to port, they could not sell the fish, and the trip would have been a waste.

In the 1950s, they started fishing with nets. These nets were so specialized that John's father had to buy a special boat to be able to use these new nets. It was worth it. These nets, called purse-seine nets, allowed them to catch a lot more tuna. However, these nets didn't discriminate among types of fish, so they ended up catching dolphins and sharks, too—a lot of them. These animals were usually dead by the time they were pulled up in the nets, but since they were often not able to be sold in the fish markets, they were usually thrown overboard.

Later, changes were made to try and reduce the amount of dolphins and sharks that were accidentally caught in the nets. John remembers being frustrated with these changes and the extra money it meant he and his family had to pay to get new nets. However, he also remembers seeing a decrease in the number of dolphins and sharks caught. As the years went by, he noticed that the number of boats in the area fishing with these nets rose from about 5 to 50. They found they were catching fewer and fewer fish and it was getting hard to support their families. His own sons and daughters chose not to carry on in their father's footsteps, and he eventually sold his boat.



California Purse Seiner

Image by California Department of Fish and Game via Flicker.com [Public Domain]

The areas in which commercial and recreational boats catch fish are known as fisheries. Beginning in 1933 in California, captains of fishing boats were required to keep a record of all the fish they caught. These records became known as fisher logs. The logs included not only the fish they were trying to catch, such as tuna, but also the bycatch, or the fish they did not mean to catch, such as sharks. A team of researchers from the Shark Lab at California State University, Long Beach, and the Monterey Bay Aquarium collected data from fisher logs and other sources such as state and federal management agencies, research institution records, and news reports. From these, they built a record of white shark catches in southern California. By analyzing data from these sources, these researchers tried to determine how shark populations have changed through time. Look at the graph of their research.

Graph of Data from Fisher Logs

Frequency and Distribution of Reported White Shark Captures

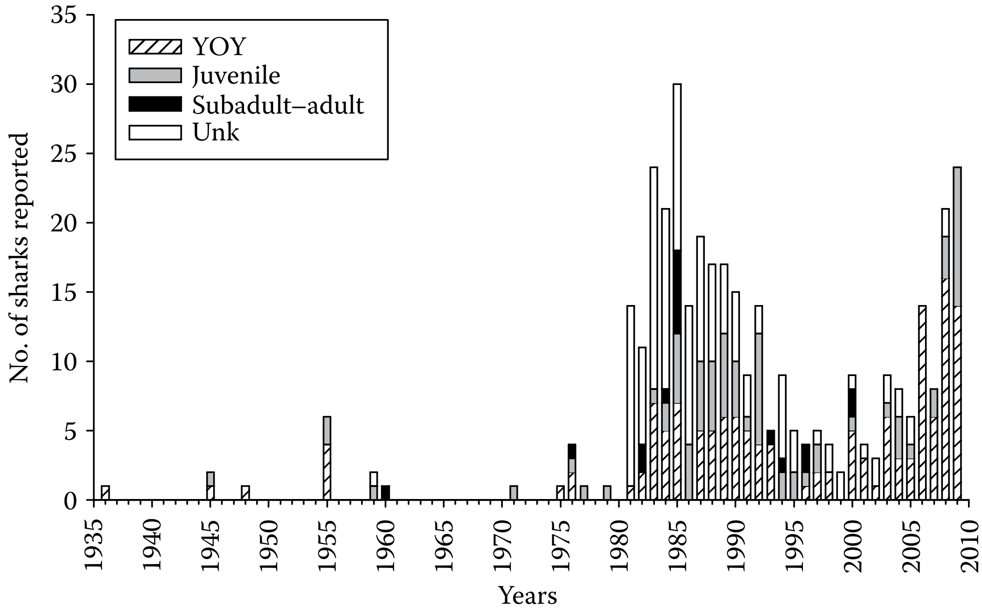
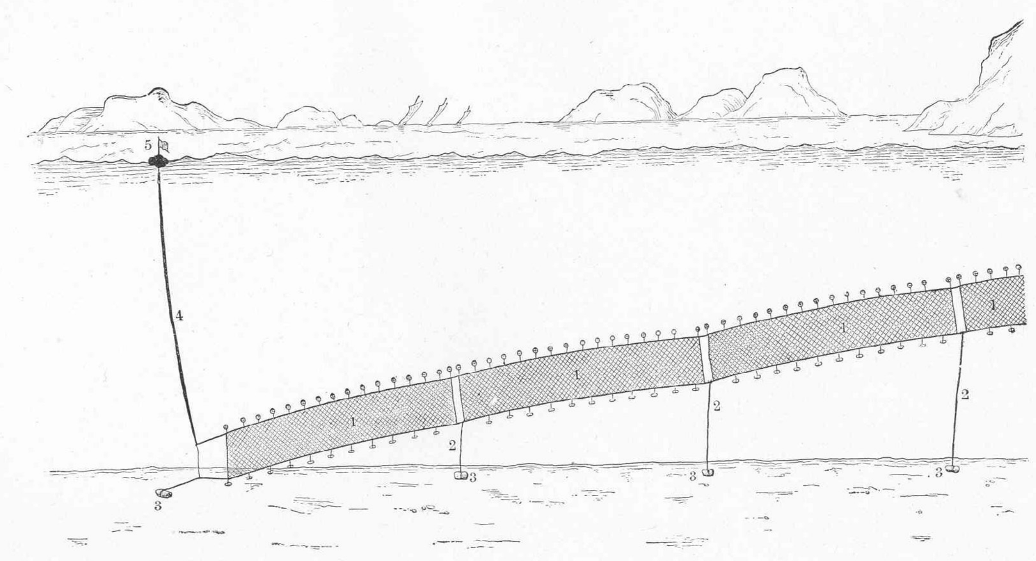


Figure 14.1 Temporal trends in reported Southern California White Shark captures by age class, 1935–2009. YOY, <175 cm TL; juveniles, 176–300 cm TL; subadult/adult, >300 cm TL; and Unk, size unknown.

Fishery Logs 1930–2010

Events affecting fisheries:

- ❑ The U.S. Marine Mammal Protection Act of 1972 protects all marine mammals, including cetaceans (whales, dolphins, and porpoises), pinnipeds (seals and sea lions), sirenians (manatees and dugongs), sea otters, and polar bears within the waters of the United States making it illegal to harass, feed, hunt, capture, collect, or kill any marine mammal. [Marine Mammal Center, 2020]
- ❑ The U.S. Endangered Species Act of 1973 provides for the conservation of species that are threatened throughout all or a big part of their range, and protects the ecosystems they depend on. It made people aware that some species need protection from people hunting them or from destroying their habitats. [EPA, 2019]
- ❑ The movie *Jaws*®, in 1975, made sharks look like killing machines. Thousands of fishers set out to catch sharks after seeing Jaws, causing U.S. populations of sharks to decrease. But the movie also increased interest in sharks, resulting in more sightings and funding for shark research.
- ❑ Fish populations decreased in the 1980s and 1990s in part because of fishing gear, such as gill nets, that made it easier to catch more fish than ever before. Gill nets caught fish to be sold as food, but also caught other animals. This bycatch included sharks, rays, sea turtles, and dolphins and led to the California Gill Net Ban of 1994. It made gill nets illegal to use within 3 miles of shore in central and southern California.
- ❑ In 1994, white sharks became protected within three miles of California's coast. White sharks can not be hunted and, if accidently caught, must be immediately released.



THE GILL-NET COD FISHERY.

Norwegian method of setting nets at different depths to ascertain the vertical position of the fish. (Sect. v, vol. i, p. 228.)

1, Nets. 2, Foot-lines by which the nets are held to the bottom. 3, Stone moorings to the nets. 4, Buoy-line. 5, Buoy.

Image by Goode, George Brown, Freshwater and Marine Image Bank via Wikimedia Commons [Public Domain]

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Fishery Logs 1930–2010 (continued)

Researchers studied fishery logs collected between Santa Barbara and San Diego, California. Many researchers have considered this area a “shark nursery” because young-of-the-year (YOY) white sharks were 60% of the reported catches. Juveniles made up 32% and subadult/adults made up only 8% of the reported catches. Data gathered more recently from shark tags confirm these percentages. In fact, data from tags show that YOY and juvenile white sharks often swim close to shore—within 100 meters!

The logs showed white sharks were captured by many methods—becoming entangled in nets, or caught with set lines, harpoons, and lines with hooks. But most shark captures (81%) came from entangling nets like gillnets. Modern data from satellite images support these records. They give us data from tags, satellite images, and “caught” sharks, confirming this area is a nursery for white sharks.

While young sharks were caught close to shore, adults were caught mostly offshore or near islands. Almost no YOY or juvenile sharks were caught there. Present-day visual sightings of adult white sharks offshore support this. Some researchers hypothesize that white sharks go to islands where seals and sea lions breed. Others disagree because there have been white sharks caught near islands where no seals or sea lions breed.

The time of year white sharks were caught show another pattern. Logs show more YOY and juveniles were caught in summer. There may be several reasons for this. There is more fishing near shore during the summer months when young white sharks could be caught as bycatch. Recently, satellite-tagging data seem to show the YOY white sharks migrate to Mexican waters during winter months. If this is true, then young white sharks would be in southern California during the summer months. Adult white sharks do not appear to migrate, as logs show adults were caught in all seasons.

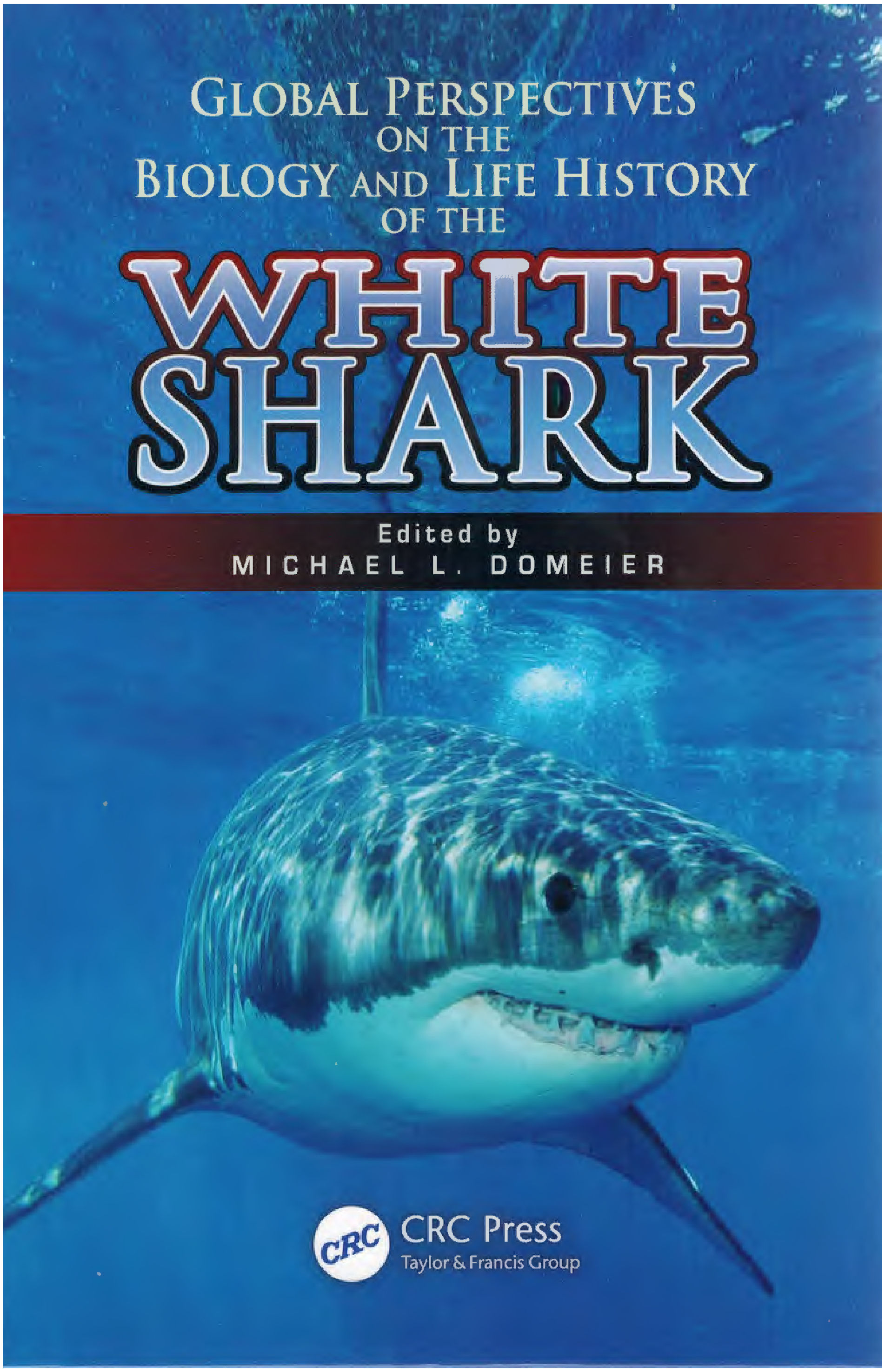
Very few white shark captures were logged before the 1980s in southern California. This could be because people were not interested in white sharks. It could be because there were fewer sharks in fisheries. Or, it could be because of a lower white shark population. One hypothesis is because marine mammal (seal and sea lion) populations were lower before the 1980s, there was less food available for sharks. This decreased the white shark population. Although the Marine Mammal Protection Act went into effect in 1972, it took almost 10 years for marine mammal populations to recover. This may explain the sharp increase in white shark captures in 1985. Many researchers believe the 1975 movie Jaws increased the public’s awareness of white sharks. Because people were more aware of white sharks, they were more likely to report sightings and captures.

The 2009 increase in shark captures could be due to the Monterey Bay Aquarium’s White Shark Program, which started in 2002. The Aquarium paid commercial fishers to tag and release sharks that were bycatch. Before this, sharks caught as bycatch may have been released and not recorded in logbooks. Another reason for the 2009 increase may be that the white shark population is increasing. The first year that YOY and juvenile sharks were not caught in gillnets was 1994. It takes 25–35 years for white sharks to reach maturity and reproduce. Perhaps those first YOY and juvenile sharks are now able to reproduce resulting in more sharks.

There are many problems with using fishery data to estimate population trends. Old records may not be accurate or complete. More modern methods such as tagging, aerial surveys, and observations provide more accurate data, but they have not been used long enough to show long-term trends. However, data shows growing marine mammal populations. The gill net ban protects YOY and juvenile white sharks so they can mature. It also protects the fish that YOY and juveniles eat. More food for young and adult sharks and more protection for the sharks themselves have probably led to the white shark population increasing in California in recent years.

Note: Adapted from “Historic Fishery Interactions with White Sharks in the Southern California Bight” by C. Lowe, M. Blasius, E. Jarvis, T. Mason, G. Goodman-Lowe and J. O’Sullivan. 2012. *Global Perspectives on the Biology and Life History of the White Shark*, Chapter 14. Taylor and Francis Group, LLC, a division of Informa plc. Adapted with permission.

Global Perspectives on the Life History of Sharks (Chapter 14)



CHAPTER 14

Historic Fishery Interactions with White Sharks in the Southern California Bight

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ABSTRACT

The degree to which White Sharks (*Carcharodon carcharias*) have interacted with various fisheries in Southern California is unknown, despite their high public interest and recent protection under state, federal, and international regulations. Data on White Shark fishery interactions in Southern California were mined from news reports, state and federal management agencies, fisher logbooks, and research institutions. Of the 369 records of reported White Shark catch between 1936 and 2009, 39% were categorized as young of the year (YOY), 21% as juveniles, 5% as subadult/

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adults, and the remaining 35% were of unreported size. YOY sharks were caught in nearshore waters (<50-m depth) more often than adult sharks, which were mainly caught in offshore waters (>50-m depth). In addition, entangling net fisheries (e.g., trammel nets, set and drift gillnets) caught more White Sharks (81%) than other fisheries (purse seine, trawl, set line, hook-and-line, harpoon, etc.). Incidental reported catch rates of YOY and juvenile White Sharks have increased in Southern California since the California nearshore-gillnet ban in 1994 and regulation of the offshore drift gillnet fishery, despite a significant decrease in overall gillnet fishing effort since the mid-1990s. This suggests that the White Shark population off California may be increasing because of reduced nearshore gillnet fishing effort and harvest protection in state and federal waters.

INTRODUCTION

Although there have been extensive commercial and recreational fisheries for several species of the nearshore and pelagic sharks off California (e.g., Thresher Sharks, *Alopias* sp.; Shortfin Mako Shark, *Isurus oxyrinchus*; Pacific Angel Shark, *Squatina californica*; Tope, *Galeorhinus galeus*; Basking Shark, *Cetorhinus maximus*; Leopard Shark, *Triakis semifasciata*; and Spiny Dogfish, *Squalus acanthias*), there have been no directed fisheries for White Sharks (*Carcharodon carcharias*) (Holts, 1988). Although attempts were made in the 1970s and 1980s to develop a market for White Shark meat in the United States (Holts, 1988), their low relative abundance and reputation for attacks on humans reduced their marketability and motivation for a directed fishery. Nevertheless, there is a fairly substantial record of incidental and periodically targeted catch of White Sharks over the last 100 yrs., particularly in Southern California.

Klimley (1985) used fishery catch data, observational reports, and museum records from 1935 to 1984 to determine the spatial distribution and ecology of White Sharks along the west coast of North America. Based on size distribution and seasonality from catch records and reports, Klimley (1985) theorized that Southern California was a pupping and nursery ground for White Sharks, because adults were most frequently seen and caught in Central and Northern California in fall and winter months, whereas young-of-the-year (YOY)-sized sharks were only caught south of Point Conception in the Southern California Bight (SCB) during summer months. Stomach content data from museum specimens and fisher reports, along with field observations of marine mammal predation, suggested that YOY and juveniles [<3 m total length (TL)] fed heavily on benthic fishes in nearshore habitats, whereas adults (>3 m TL) fed heavily on marine mammals, which were concentrated at rookeries in central California and offshore islands in Southern California. Interestingly, Klimley (1985) found that over 62% of the reports of White Shark captures came from Southern California; however, there was no correlation between report occurrence and catch per unit effort (CPUE) along the coast of California.

Although previous analysis of historic records has greatly furthered our knowledge of the distribution, life history, and behavior of the White Shark along the west coast of the United States, some of which has subsequently been supported by fishery independent data (Boustany et al., 2002; Dewar et al., 2004; Weng et al., 2007), fisheries in Southern California have changed considerably since 1984 because of overharvesting concerns and increased fisheries regulations. Marine commercial and sport fisheries in Southern California constitute a large portion of the total fishing effort and production for the state of California (Oliphant et al., 1990; Dotson and Charter, 2003). The northern portion of the SCB (coastline including the Channel Islands) constitutes one of the greatest expanses of continental shelf habitat in California. In addition to a large sport fishing community, which reported over 2.7 million angler trips in 2008 (CDFG, 2009), Southern California has supported a wide variety of commercial fisheries over the last 100 years, including trawl, set line, purse seine, trap, and entangling net in both nearshore and offshore habitats (Love, 2006). Entangling net fishing (e.g., trammel nets, gillnets) rapidly increased in popularity in the 1970s in Southern

California with the development of monofilament, where nearshore (<3 nm from shore, <50-m depth) set-gillnet (SGN) fishers targeted California Halibut (*Paralichthys californicus*), Pacific Angel Shark, and White Seabass (*Atractoscion nobilis*) (Barsky, 1990; Richards, 2001; Pondella and Allen, 2008). An offshore (>3 nm from shore, >50-m depth) drift-gillnet (DGN) fishery also developed in the 1970s for Thresher Shark (*Alopias* spp.) and Swordfish (*Xiphias gladius*) (Hanan et al., 1993; Holts, 1988; Holts et al., 1998). These entangling net fisheries enabled commercial fishers to fish virtually the entire SCB; however, large-scale stock declines in the 1980s and 1990s resulted in increased regulations of these fisheries (Holts, 1988; Holts et al., 1998; Pondella and Allen, 2008). Significant declines in nearshore fish species and bird and marine mammal interactions resulted in a ban of nearshore gillnets in California state waters in 1994. The SGN fishery still exists outside state waters (>3 nm offshore and >1 nm of offshore islands) for these nearshore species; however, there are only a few locations in Southern California with sufficient shallow habitat to permit effective fishing for California Halibut, Pacific Angel Shark, and White Seabass. The nearshore SGN ban and increased regulation of the offshore DGN fishery significantly reduced the overall entangling net effort in Southern California after 1994 (Holts et al., 1998; Pondella and Allen, 2008).

In addition to changes in fishery trends in Southern California, the White Shark was protected and could no longer be landed in California waters in 1994 (Heneman and Glazer, 1996) and was listed as a prohibited species in U.S. federal waters in 2005. Therefore, a re-examination of White Shark catch records since 1984 may provide insight into the degree to which nondirected fisheries may have interacted with or impacted White Shark populations in Southern California.

MATERIALS AND METHODS

Data Acquisition

Reports of White Sharks captured in the Southern California Bight came from four primary sources (Table 14.1):

Table 14.1 Sources of White Shark Capture Reports in the Southern California Bight

Source	*n*	Year(s)	Overlap (*n*)
Resource agencies			
CDFG DGN/SGN fishery logbook data	22	1981–2008	19
CDFG shark tagging program	3	1983–2001	
CDFG game wardens	2		
NOAA Fisheries DGN/SGN fishery logbook data	187		78
NOAA Fisheries DGN/SGN fishery observer data	9	1981–2008	1
NOAA Fisheries-*Los Angeles Times* database	1	1990–2008	1
PacFIN	91	1959–1998	29
MBA Juvenile White Shark Tagging Program	77	1979–2005	30
M. Domeier White Shark Tagging Study	3	2002–2009	
Scientific collections		2009	
Natural History Museum of Los Angeles County	33		11
California Academy of Sciences	8		4
Scripps Institution of Oceanography	17		5
Newspaper and scientific journal articles	13		1

Some sources have specific date ranges for when they started recording their data, whereas other sources have no consistent date ranges. *n* represents the number of records obtained from each source. Overlap (*n*) represents the number of reports found in duplication in other source databases.

1. Records/landings from resource agencies California Department of Fish and Game (CDFG) and the National Oceanic and Atmospheric Administration National Marine Fisheries Service (NOAA Fisheries)
2. Data from tagged or dead sharks collected by the authors and associates of the Monterey Bay Aquarium (MBA) Juvenile White Shark Tagging Program
3. Scientific collections
4. Newspaper articles

Commercial-fishing records of White Sharks were obtained from a variety of agencies/programs. CDFG and NOAA Fisheries provided data from logbooks of the commercial DGN and SGN fisheries and from commercial market receipts (landing tickets) reporting landings of catch for a variety of gear types, including entangling nets, trawl, purse seine, harpoon, set line, and trap. Reports of White Shark captures were also obtained from data provided by the NOAA Fisheries Southwest Region Drift and Set Gillnet Observer Program. The observer program for this fishery was initiated in July 1990 (to present) and has provided approximately 21% observer coverage. We also extracted additional reports from commercial market receipt landings made available on the Pacific Coast Fisheries Information Network (PacFIN), a database of Pacific coast-wide commercial-fishing landings obtained from market receipts at the time of landing.

Data collected by the authors and associates of the MBA Juvenile White Shark Tagging Program (initiated in 2002) were primarily from sharks incidentally caught by commercial fishermen, whereas others were caught by MBA personnel and other researchers (M. Domeier) using either longline gear, rod and reel, and purse seine. Data were also obtained from the CDFG shark-tagging program (1983–2001) based on reports from recreational anglers and/or commercial fishermen who voluntarily tagged and released sharks throughout Southern California waters. After 2001, these records were obtained from the CDFG and NOAA Fisheries joint shark longlining and tagging cruises. There were two reports provided by game wardens at the CDFG, where cases had been filed against recreational anglers who illegally landed White Sharks. Additional recreational fishing reports of White Sharks were obtained from the NOAA-*Los Angeles Times* database, which is a daily report of marine-fish landings by commercial-passenger fishing vessels in Southern California between 1959 and 1998. Additional reports were obtained from several museum collections or records, including the Natural History Museum of Los Angeles County (J. Seigel, personal communication), California Academy of Sciences (J. McCosker, personal communication), and Scripps Institution of Oceanography Fish Collection (H. J. Walker, personal communication). Confirmed White Shark captures reported in Los Angeles and Orange County newspaper articles were also included in our analysis.

The following data were tabulated for each verified White Shark record: date, location description, latitude and longitude, TL, weight, sex, capture method, fishing gear, target species, source, and general remarks. Sharks were assigned age classes defined as YOY, individuals <1.75 m TL; juveniles, 1.75–3.00 m TL; and subadults/adults, >3.00 m TL (McCosker, 1985; Francis, 1996; Mollet and Cailliet, 1996; Wintner and Cliff, 1999; Malcolm et al., 2001; Chapter 17, this book). When total length was not available, but a whole weight was given, age class was estimated from total length derived from length-weight relationship developed for White Sharks (Mollet and Cailliet, 1996). When only landing weights were available (dressed weight), whole weight was estimated from a conversion factor (round weight = dressed weight * 1.45) based on a formula for Shortfin Mako Sharks (California Code of Regulations, Title 14, Section 187), which was then converted to a length and age class estimate.

The type of fishery was categorized as recreational or commercial, and gear type was categorized as entangling net (e.g., trammel, SGN, DGN), harpoon, long line, purse seine, trawl, trap, and recreational (hook and line).

Data Analysis

All of the records were cross-referenced, and duplicate records were removed. Capture locations were reported as CDFG fishing blocks (10 min. × 10 min.), site names, landmarks, or global positioning system (GPS) coordinates. For analysis, all capture locations were assigned to their respective CDFG fishing blocks.

Records of reported White Shark captures were analyzed by age class, capture month, capture season, fishing gear, and spatially, by CDFG fishing block for all categories. Temporal trends in YOY captures were plotted against trends in fishing effort in the DGN and SGN fisheries from 1981 to 2008. Fishing effort was not available for 2009. We used a chi-squared test of independence to determine whether the age-class distribution of reported White Sharks in entangling net fisheries was the same before (1980–1993) and after (1994–2008) the nearshore-gillnet ban. We also tested for differences in average annual fishing effort (number of net sets) in the DGN and SGN fisheries between the two time periods using an independent two-sample *t* test (assuming unequal variances). Similarly, we used an independent two-sample *t* test to test for differences in average annual YOY White Shark catch per unit effort (CPUE = YOY captures/1,000 sets) in the SGN (assuming unequal variances) and DGN (assuming equal variances) fisheries between the two time periods. YOY CPUE values were square root transformed; however, reported means and 95% confidence limits were back-transformed.

RESULTS

Frequency and Distribution of Reported White Shark Captures

We obtained 369 fishery-dependent records of reported White Shark captures occurring in the Southern California Bight from 1936 to 2009. Of the 369 records analyzed, 35% of the reports provided no indication of size. Of the remaining records, young-of-the-year White Sharks comprised 60% of the reports, followed by juveniles (32%) and subadult/adults (8%). Reports of White Shark captures were sporadic throughout the early and mid-twentieth century but increased from the 1980s through the early 1990s and peaked in 1985 and 2009 (Figure 14.1). Reported captures

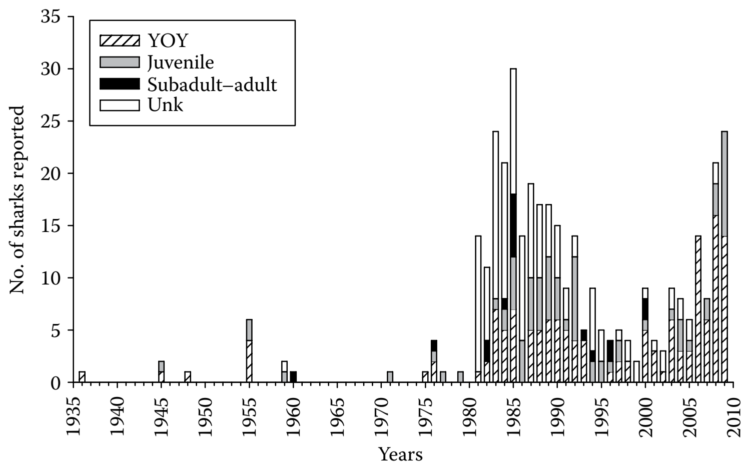


Figure 14.1 Temporal trends in reported Southern California White Shark captures by age class, 1935–2009. YOY, <175 cm TL; juveniles, 176–300 cm TL; subadult/adult, >300 cm TL; and Unk, size unknown.

of juveniles and adults were less frequent, with the majority of reports occurring during the 1980s and 1990s (Figure 14.1). Examination of reports by capture location indicated that YOY were reported along the entire coast of Southern California from Ventura to San Diego, with occasional captures in offshore waters (Figure 14.2a). YOY were most frequently captured along coastal fishing blocks near the ports of Ventura, Los Angeles/Long Beach, Danas Point/San Onofre, and San Diego. Reported captures of juvenile White Sharks were less frequent but showed a similar pattern in distribution and concentration (Figure 14.2b). Adult White Shark captures were even less commonly reported, and although the overall distribution was similar, captures were highest in the Santa Barbara and San Pedro channels (Figure 14.2c). Reports of White Shark captures were highest during the spring and summer months, occurring in the northern and central coastal fishing blocks of the SCB in the spring and extending further south in the summer (Figure 14.3a and b). During fall months, the distribution of reported captures of White Sharks was relatively less frequent than during spring and summer, with fewer sharks appearing off the central coastal areas of the SCB and more appearing just offshore (Figure 14.3c). Reported captures of White Sharks were least common during winter months, and those captures were evenly distributed along the coast and at the islands (Figure 14.3d).

Fishery Interactions

Commercial entangling nets accounted for 81% of all reported White Shark captures in the SCB, followed by recreational hook-and-line fishing (8%; Figure 14.4). YOY were primarily caught in entangling nets, and juvenile captures were dominant among hook-and-line captures. White Shark captures by entangling nets primarily occurred in coastal fishing blocks, with the highest

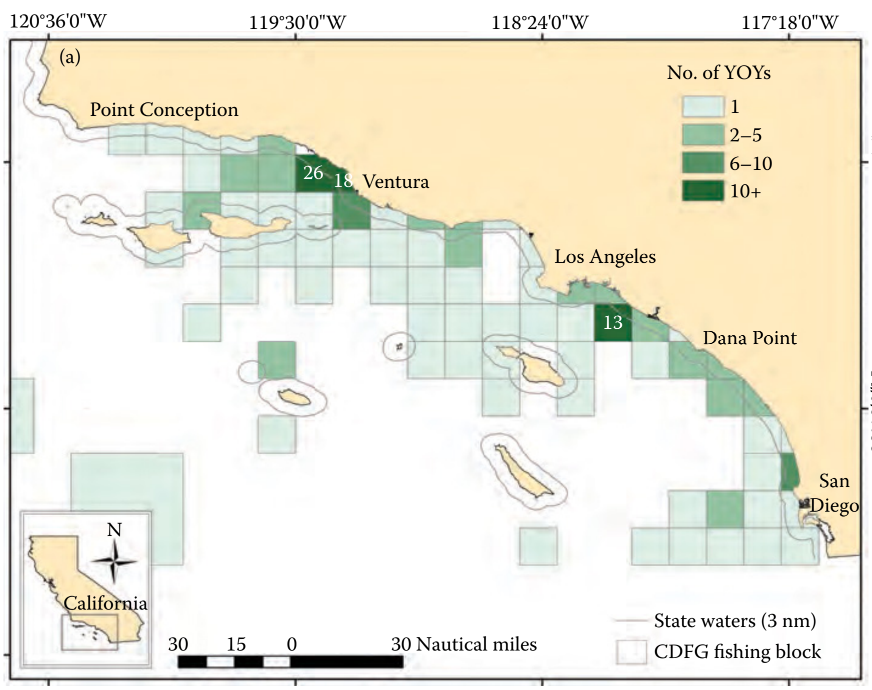
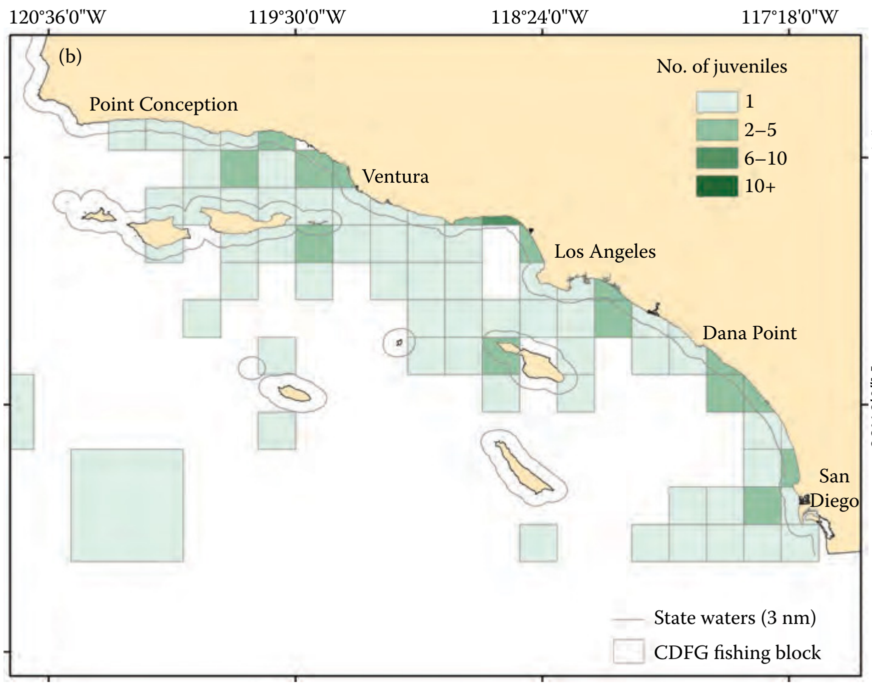


Figure 14.2 Spatial distribution of reported YOY (a), juvenile (b), and adult (c) White Shark captures occurring in Southern California, 1935–2009. The numbers represent sample sizes for fishing blocks (10 min. × 10 min.) with greater than 10 sharks.



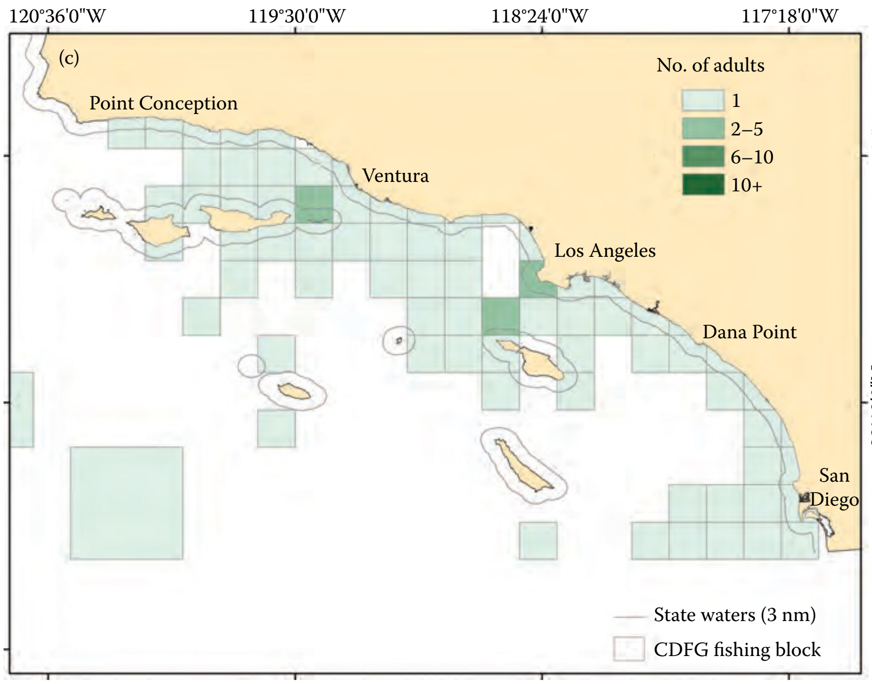


Figure 14.2 (Continued)

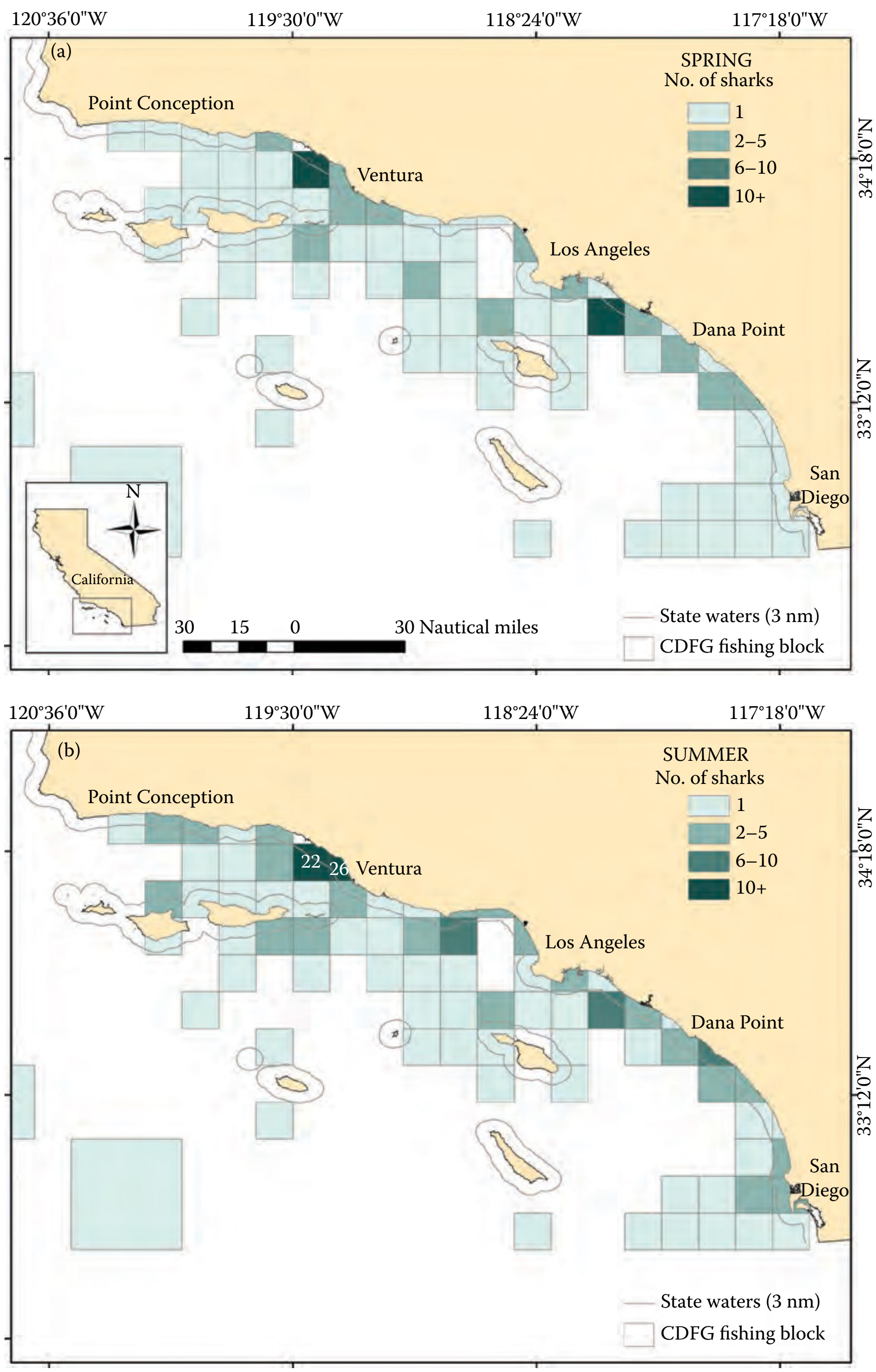
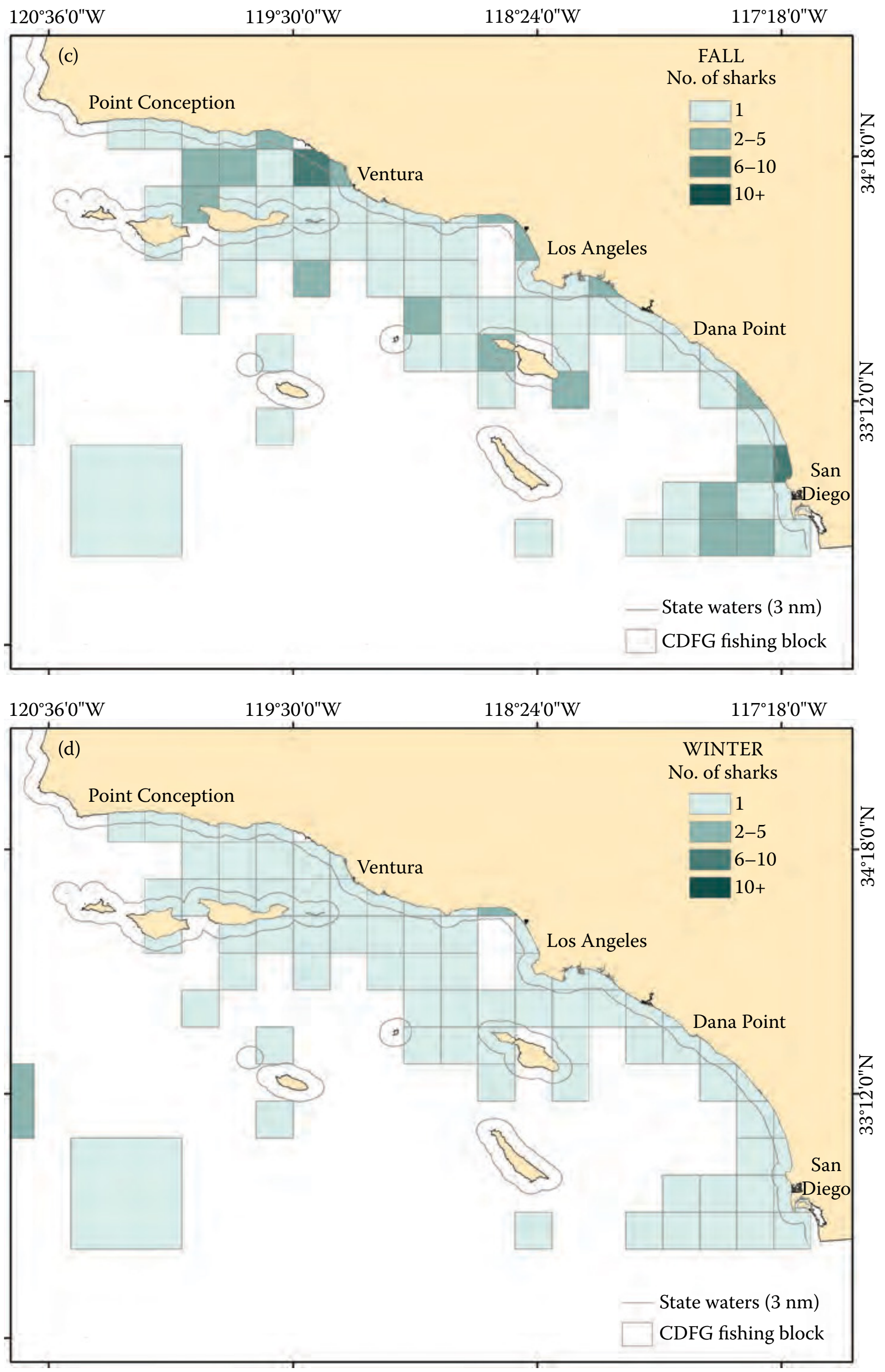


Figure 14.3 Spatial distribution of reported White Shark captures occurring in Southern California during spring (April to June, a), summer (July to September, b), fall (October to December, c), and winter (January to March, d), 1935–2009. The numbers represent sample sizes for fishing blocks with greater than 10 sharks.



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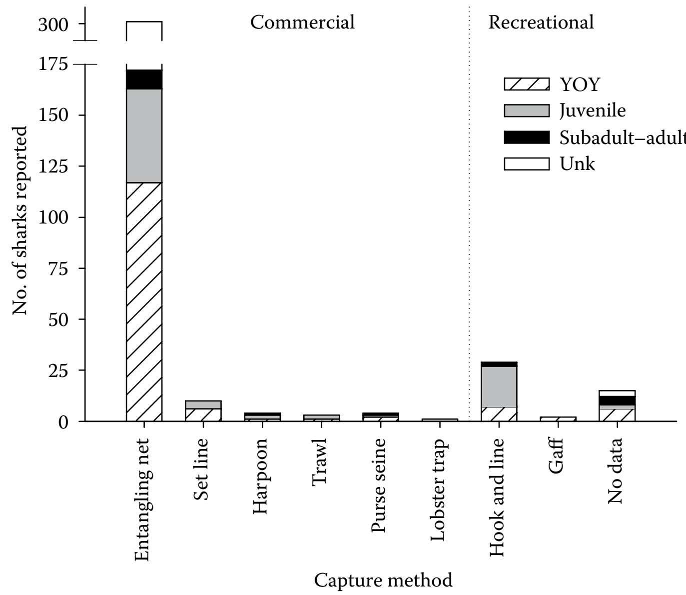

Figure 14.4 Numbers of reported White Shark captures occurring in Southern California by capture method, 1935–2009. Unk, method of capture unknown.

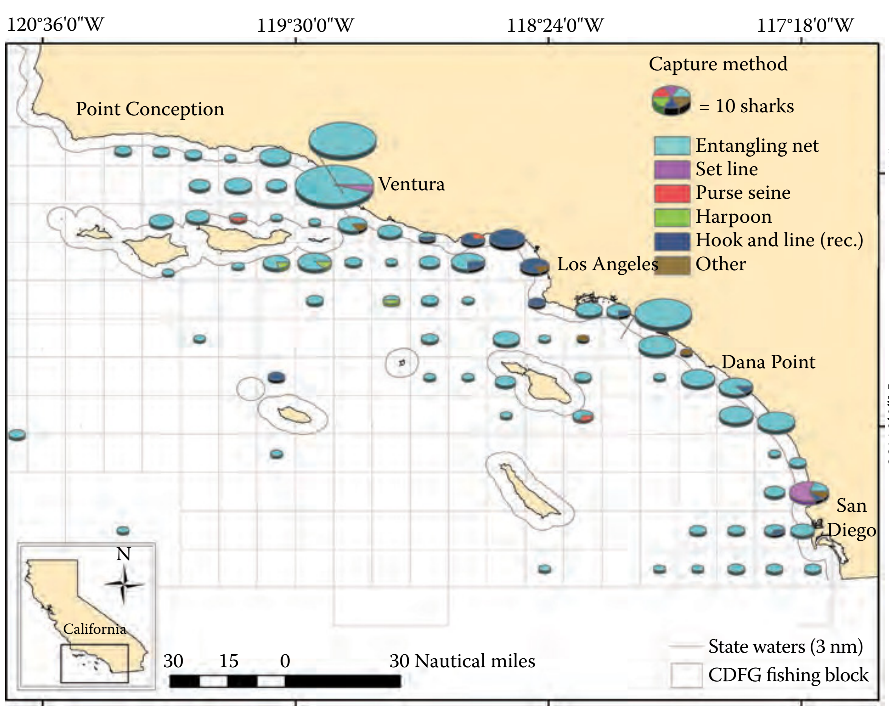

Figure 14.5 Spatial distribution of reported White Shark captures occurring in Southern California by capture method, 1935–2009. Capture methods with three or fewer capture records (e.g. trawl, lobster trap, and gaff) were pooled into the "Other" category.

reports off Ventura Flats and the San Pedro Shelf near the Los Angeles/Long Beach harbor (Figure 14.5). Recreational hook-and-line captures occurred mainly within Santa Monica Bay.

Of the 300 entangling net records, 62% of the reported captures occurred in the set-gillnet fishery targeting California Halibut, Pacific Angel Shark, and/or White Seabass, and 32% occurred in the DGN fishery targeting pelagic sharks and Swordfish; 6% of the reports provided no indication of entangling net fishery type. White Sharks captured in the SGN and DGN gillnet fisheries were reported across all seasons, with a prominent peak in set-gillnet captures occurring from May through July (Figure 14.6). The frequency of reported White Shark captures in the DGN fishery was more evenly distributed from April through November than that of the SGN fishery (Figure 14.6). Reports of White Sharks in entangling net fisheries were dominated by YOY and began in the late 1970s, peaked in 1985, decreased into the late 1990s, and began an upward trend in 2006 (Figure 14.7a).

Reported captures of YOY mirrored temporal trends in fishing effort (number of sets) in the SGN fisheries from 1981 to 2005 (Figure 14.7b). Fishing effort remained relatively stable in both fisheries from the mid-1990s to 2008; however, following 2005, the incidence of reported White Shark captures steadily increased. During the period prior to the nearshore-gillnet ban (1981–1993), the average (±SD) number of sets per year in the SGN fishery was 10,882 ± 3,964 compared with 5,821 ± 3,251 in the DGN fishery. After the nearshore-gillnet ban (1994–2008), the average number of sets decreased significantly in both fisheries (set gillnets: $\overline{X} \pm SD = 2{,}905 \pm 936$, $t = 2.16$, $p < 0.0001$; drift gillnets: $\overline{X} = 1{,}123 \pm 893$, $t = 2.14$, $p < 0.0001$). We found a significant difference in the age-class distribution of reported White Sharks captured by gillnets before and after the nearshore-gillnet ban in state waters ($X^2 = 6.19$, $p = 0.045$). Prior to the nearshore-gillnet ban, YOY White Sharks accounted for 61% of reported captures in gillnets, whereas after the ban this proportion increased by 16% to 77%. The average reported YOY CPUE (YOY/1,000 sets) in the SGN fishery was significantly higher after the closure ($\overline{X} = 0.93$, 95% confidence interval: 0.22 to 2.11) than before ($\overline{X} = 0.23$, 95% confidence interval: 0.05 to 0.55; $t = 2.12$, $p = 0.02$).

Prior to the nearshore-gillnet ban in state waters, SGN effort was primarily concentrated along the mainland coast (<3 nm from shore) from Point Conception to San Diego (Figure 14.8a). Other areas with concentrated effort included the north and south sides of Santa Rosa Island. Higher numbers of set-gillnet YOY captures appeared to coincide with higher fishing

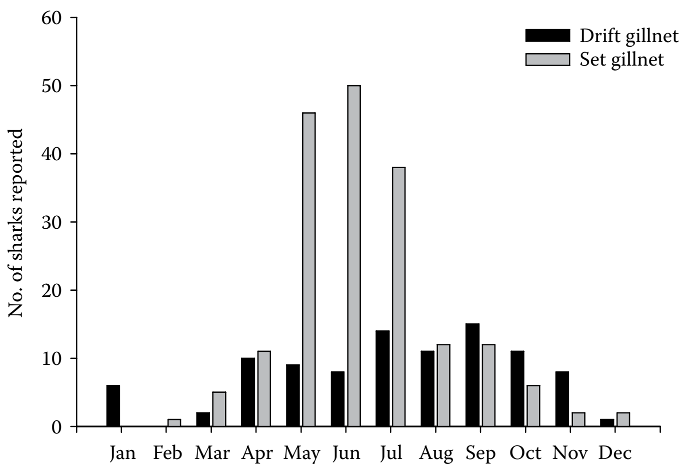

Figure 14.6 Total number of White Shark captures reported per month for the set- and drift-gillnet fisheries in Southern California, 1981–2009.

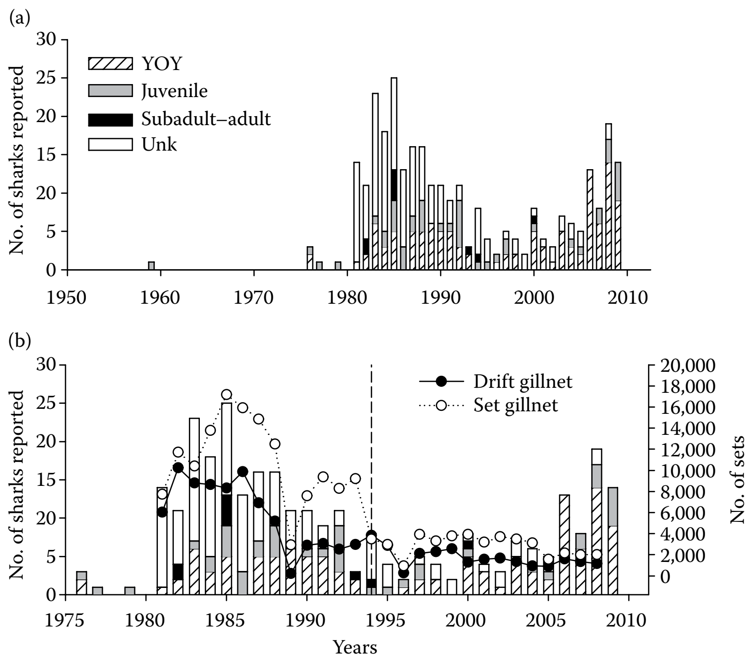

Figure 14.7 Temporal trends in reported White Sharks captured in entangling nets by stage class from a historical perspective, 1950–2009 (a), and relative to fishing effort in the set- and drift-gillnet fisheries, 1981–2008 (b).

effort along the coast of La Jolla, San Onofre, and just to the north off Newport Beach (Figure 14.8a). Following the nearshore-gillnet ban, the distribution of SGN effort changed dramatically (Figure 14.8b). Only four mainland areas (Ventura, Los Angeles/Long Beach, San Onofre, and San Diego) still contained concentrated effort, with slight offshore shifts in effort beyond state waters (Figure 14.8b). Coastal fishing blocks with high SGN effort following the ban coincided with higher reports of entangling net YOY captures occurring off Ventura and Los Angeles/Long Beach harbor (Figure 14.8a and b).

DISCUSSION

Spatial- and temporal-distribution patterns of White Sharks captured in Southern California fisheries follow patterns observed by Klimley (1985) from earlier catch records (1935–1984). However, changes in catch patterns, adjusted for changes in fishing activity and pressure after 1984, may reflect changes in White Shark populations in Southern California.

Despite intensive recreational hook-and-line fishing pressure in Southern California over the last 100 yrs., it is surprising that more White Sharks (8%) were not caught via this fishing method. However, it is likely that the lighter gear used in most nearshore recreational fisheries would reduce the probability of successfully landing even a YOY White Shark and therefore may under-represent the numbers of sharks interacting with the nearshore recreational fishery. The pelagic recreational fishery for sharks, which grew considerably in the late 1990s (Holts et al., 1998), typically uses steel leaders and larger hooks and therefore is much more likely to land White Sharks. However, as the spatial distribution in White Shark catch records suggests, it is also less likely that recreational fishers would encounter YOY or juvenile White Sharks in these pelagic habitats.

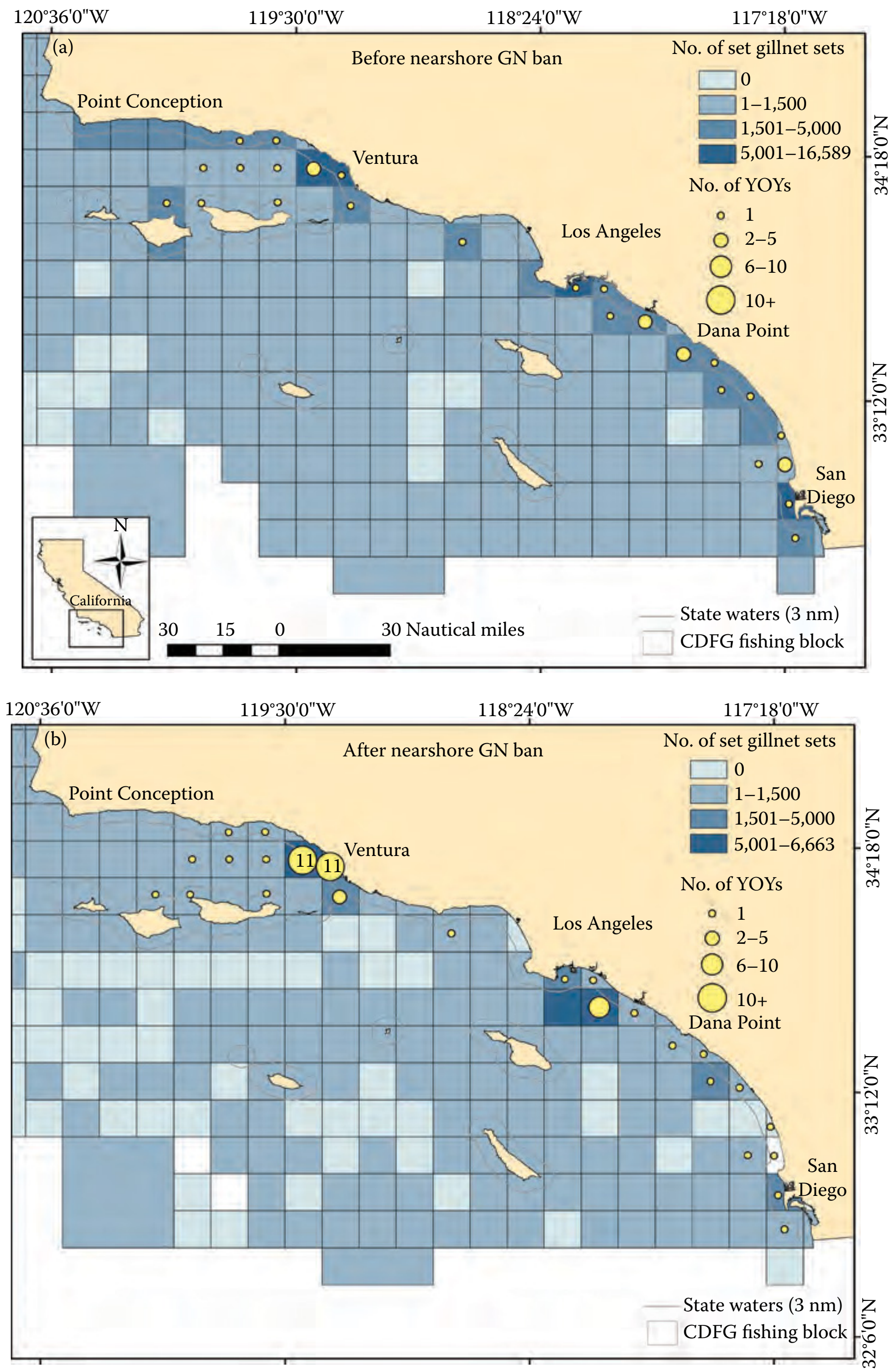

Figure 14.8 Spatial distribution of set-gillnet effort and associated YOY White Shark captures in Southern California before (1981–1993, a) and after (1994–2008, b) the nearshore-gillnet ban. The numbers represent sample sizes for fishing blocks with greater than 10 sharks. GN, gillnet.

Although White Sharks were reported captured in all major commercial fisheries in Southern California (e.g., trawl, entangling net, set line, harpoon, trap), the vast majority of reports (81%) came from entangling net fisheries and thereby provide the greatest source of data for determining White Shark distribution patterns over time. Young-of-the-year White Sharks constituted the greatest proportion of age classes reported caught in Southern California. This is similar to what Klimley (1985) observed from previous catch data, and it is likely that this pattern is influenced by the higher gear susceptibility of YOY White Sharks compared with the larger sharks. Larger sharks are more likely to break through gear (gillnets and set line) and avoid capture and thus be under-reported. Nevertheless, this further supports Klimley's (1985) theory that the SCB is a nursery ground for White Sharks.

More White Sharks were reported caught in nearshore SGN than in offshore DGN. In addition, YOY and juvenile White Sharks were most frequently reported caught in nearshore fishing blocks, particularly prior to 1994. Although this is where a majority of the nearshore SGN fishery for California Halibut, Pacific Angel Shark, and White Seabass took place prior to the nearshore-gillnet ban in 1994, recent aerial observations (J. O'Sullivan, personal observations) and satellite telemetry data from tagged sharks (Weng et al., 2007; J. O'Sullivan et al., unpublished data) indicate that YOY and juvenile White Sharks frequently swim within 100 m of the shoreline. Adult White Sharks were most frequently reported caught offshore or near offshore islands, which is also where a majority of the visual sightings of adult White Sharks occur. Klimley (1985) hypothesized that adult White Sharks may frequent offshore islands that have seal and sea lion rookeries, such as San Miguel and San Nicolas Islands; however, surprisingly few sharks have been reported caught around those islands. Most adults have been reported caught from around Santa Catalina and Anacapa Island, which do not have extensive seal or sea lion rookeries. In addition, significantly less SGN fishing occurs around these offshore islands, mostly because of their distances from ports and the lack of available fishing habitat more than 1 nm from island shorelines. Nevertheless, it is unlikely that SGN gear may catch and hold adult White Sharks.

More YOY and juvenile White Sharks were reported caught during summer months than other seasons. This may be partly attributed to the higher intensity of nearshore SGN fishing effort during summer months. Klimley (1985) hypothesized that juvenile White Sharks were most common during summer months and based on the presence of yolk scars, may indicate that pupping occurs during the summer. However, adults were thought to move north in the fall and winter months. This pattern of seasonality was not observed in adult White Sharks because they were reported as being captured during all seasons. Recent satellite-tagging data have suggested that YOY White Sharks migrate to Mexican waters during winter months (Weng et al., 2007; Chapter 28, this book). These fishery-independent data further support findings that YOY and juvenile White Sharks are primarily present in Southern California during the summer months. A review of northeastern Pacific White Shark life history (Chapter 16, this book) analyzed a subset of the fishery data presented here, as well as other data, to suggest that the Southern California Bight is indeed a pupping ground, and adults are relatively rare in this region, except for the presence of females during the pupping season.

Although White Sharks were reportedly caught along the entire coastline of Southern California, there were several areas where more White Sharks were reported caught more frequently than other areas. More sharks were caught off Ventura Flats, Santa Monica Bay, San Pedro Shelf, and Dana Point Canyon than at other locations along the coastline. Many of these locations are within close proximity to major fishing ports; however, some of this may be an artifact of the shift in fishing effort following the nearshore-gillnet ban in 1994. These locations represent the few areas along the Southern California coastline and offshore islands where gillnet fishers can effectively fish for California Halibut, Pacific Angel Shark, and White Seabass outside state waters. Satellite-tagging data for YOY and juvenile White Sharks in Southern California indicate that sharks may be using these areas (Ventura Flats, Santa Monica Bay, San Pedro Shelf, and Dana Point Canyon) more than other areas along the coastline, particularly during the summer months (Dewar et al., 2004; Weng et al., 2007; J. O'Sullivan et al., unpublished data).

Overall, there were very few and sporadic reports of White Shark captures prior to the 1980s in Southern California. This level of reporting prior to the 1980s could have been attributed to a lack of interest in White Sharks, lower fishery interaction, or a lower White Shark population. Klimley (1985) hypothesized that significantly reduced marine mammal populations (sea otters, pinnipeds, and cetaceans) along the California coast because of overharvesting could have reduced adult White Shark food availability and thereby lowered the White Shark population. However, two prominent peaks were observed in reported White Shark captures after the federal protection of marine mammals in 1972: one in 1985 and another larger peak in 2009. Klimley (1985) attributed the rise in White Shark reportings in the 1980s to an increased awareness of White Sharks following the movie *Jaws* in 1975 and an interest from Sea World in attempting to display White Sharks in public aquariums. Although there is little doubt that both of these factors increased awareness by commercial fishers and the public of White Sharks in California, entangling net-based commercial fisheries also peaked in the 1980s, which showed peak effort and landings for many targeted species (Methot, 1983; Holts, 1988; Holts et al., 1998; Pondella and Allen, 2008). It is likely that the increased effort of entangling net fisheries (both nearshore SGN and offshore DGN) in the 1980s and early 1990s increased fishery interactions with YOY and juvenile White Sharks in Southern California, thereby increasing the mortality rates of these age classes. Prior to state and federal protection, White Sharks were being landed and sold in California, albeit at low levels compared with other shark species (Holts, 1988; Holts et al., 1998). Although it is unknown to what degree this fishery interaction reduced the White Shark population in Southern California, there was a marked decrease in reported White Shark catch from the peak in 1985 to 1995. Interestingly, this decline coincides with a series of entangling net gear and season restrictions that began shortly after 1985.

Coincidentally, the ban of nearshore gillnets and California protection of White Sharks both began in 1994. Concerns regarding overfishing of Thresher and Mako Sharks and the incidence of marine mammal interactions in the offshore drift-net fishery resulted in substantial restrictions placed on this fishery beginning in the late 1980s (Holts, 1988; Carretta et al., 2004). These fishery restrictions resulted in a significant reduction in nearshore and offshore gillnet fishing effort in California and prohibited landing of any incidentally caught White Sharks. Since the mid-1990s, fishing effort has remained fairly stable or declined in both the SGN and DGN fisheries; however, reported White Shark captures have steadily increased since 2005. One explanation for this increased trend in reported White Shark captures in Southern California may be attributed to the initiation of the Monterey Bay Aquarium White Shark Program, where MBA worked with commercial fishers to coordinate tag and release of incidentally caught sharks. Fishers were paid for their participation in this program, because this process is allowed under the current White Shark protection regulations in the State of California. It is possible that incidentally caught sharks may have been simply released and not reported in logbooks prior to the initiation of this program.

On the other hand, it is also possible that this increase in reported White Shark catch since 2005 is the result of the recovery of the White Shark population following impacts from previous YOY and juvenile mortality in gillnet fisheries prior to the nearshore-gillnet ban and changes in offshore gillnet regulations. Because a majority of the "unknown" age class reports (n = 131) came from the entangling net records, and the majority of the sharks caught in the entangling net fishery were reported as YOY and juveniles, it is likely the data presented under-represent the magnitude of the fishery interaction with these age classes, especially prior to gillnet-fishing restrictions (Figure 14.7). Recovery of other large nearshore-fish populations has also been documented as the result of the nearshore-gillnet ban. Pondella and Allen (2008) found fishery-dependent and fishery-independent evidence of increased abundances of Giant Black Sea Bass (*Stereolepis gigas*), Tope, Leopard Sharks, and White Seabass in Southern California following the nearshore gillnet ban. They also noted that these abundance trends were not correlated with changes in Pacific Decadal

Oscillation or El Niño/Southern Oscillation events. Although there are no fishery-independent data available to corroborate this pattern in White Sharks, there has been a steady increase in reported predation events on Sea Otters (*Enhydra lutris nereis*) off Central and Northern California since 2003. Necropsy results of recovered Sea Otters suggest juvenile White Sharks may be responsible for these mortalities and that the frequency of these mortalities has doubled since 1992 (Kreuder et al., 2003; Ames et al., 1996; M. Harris, personal communication). This pattern may be indicative of a growing number of juvenile sharks, relieved from fishing mortality since the mid-1990s.

Preliminary data and observations from the MBA Juvenile White Shark Tagging Program have indicated that YOY and juvenile White Sharks exhibit fairly high postrelease survival after being caught in gillnet gear and, in some cases, being held in on-board fish totes for periods of up to several hours (Chapter 28, this book). This indicates that despite continued fishery interactions, release of incidentally caught White Sharks has likely reduced YOY and juvenile mortality of sharks and that postcapture release can be considered an effective conservation tool. Although there are numerous problems with using fishery-dependent data for estimating population trends, future fishery-independent methods such as telemetry tagging, aerial surveys, and better observer-based records could help substantiate some of the hypotheses put forth in this study. Nevertheless, increases in marine mammal populations, protection of YOY and juvenile food base, and reduced fishing mortality has probably enabled the White Shark population to increase in California in recent years.

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Next Generation Science Standards (NGSS)

This lesson is building toward:

PERFORMANCE EXPECTATION (PE)	
MS-ESS3-4	Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems. [Clarification Statement: Examples of evidence include grade-appropriate databases on human populations and the rates of consumption of food and natural resources (such as freshwater, mineral, and energy). Examples of impacts can include changes to the appearance, composition, and structure of Earth's systems as well as the rates at which they change. The consequences of increases in human populations and consumption of natural resources are described by science, but science does not make the decisions for the actions society takes.]
A note from the authors: Students work towards this PE through the lens of researching white shark populations as they interpret data and read researchers' analyses of fisher logs. They learn about and interpret the effect of legislation on the population of white sharks and the marine environment. In collaborative groups, students construct an argument, supported by evidence, for how human's actions, e.g. legislation, has affected white shark populations.	

NGSS Lead States. 2013. Next Generation Science Standards: For States, By States. Washington, DC: The National Academies Press.

SCIENCE AND ENGINEERING PRACTICES (SEP)

Asking Questions and Defining Problems

- Ask questions that arise from careful observation of phenomena, models, or unexpected results, to clarify and/or seek additional information.

Analyzing and Interpreting Data

- Use graphical displays (e.g., maps, charts, graphs, and/or tables) of large data sets to identify temporal ~~and spatial~~ relationships.
- Analyze and interpret data to provide evidence for phenomena.

Constructing Explanations and Designing Solutions

- Construct an explanation that includes qualitative or quantitative relationships between variables that predicts and/or describes phenomena.

Engaging in Argument from Evidence

- Construct, use, and/or present an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation ~~or a model~~ for a phenomenon or a solution to a problem.

Obtaining, Evaluating, and Communicating Information

- Critically read scientific texts adapted for classroom use to determine the central ideas and/or obtain scientific and/or technical information to describe patterns in and/or evidence about the natural and designed world(s).

Appendix 8.3

DISCIPLINARY CORE IDEAS (DCI)
ESS3.C: Human Impacts on Earth Systems
• Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise.

CROSSCUTTING CONCEPTS (CCC)
Patterns
• Graphs, charts, and images can be used to identify patterns in data.
Cause and Effect
• Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation.
• Cause and effect relationships may be used to predict phenomena in natural systems or designed systems.
• Phenomena may have more than one cause, ~~and some cause and effect relationships in systems can only be described using probability.~~

Common Core State Standards (CCSS)

CCSS ELA WRITING
CCSS.ELA-LITERACY.WHST.6-8.9
Draw evidence from informational texts to support analysis, reflection, and research.
CCSS ELA SCIENCE & TECHNICAL SUBJECTS
CCSS.ELA-LITERACY.RST.6-8.1
Cite specific textual evidence to support analysis of science and technical texts.

Appendix 8.3

California English Language Development (ELD) Standards

CA ELD		
Part 1.3 Offering and justifying opinions, negotiating with and persuading others in communicative exchanges		
EMERGING	**EXPANDING**	**BRIDGING**
P1.8.3 Negotiate with or persuade others in conversations (e.g., to gain and hold the floor or to ask for clarification) using learned phrases (e.g., I think … Would you please repeat that?) and open responses.	**P1.8.3** Negotiate with or persuade others in conversations (e.g., to provide counter-arguments) using learned phrases (I agree with X, but …) and open responses.	**P1.8.3** Negotiate with or persuade others in conversations using an appropriate register (e.g., to acknowledge new information and justify views) using a variety of learned phrases, indirect reported speech (e.g., I heard you say X, and that's a good point. I still think Y, though, because …) and open responses.
In addition to the standard above, you may find that you touch on the following standards in this lesson as well: **1.8.1**: Exchanging information and ideas with others through oral collaborative discussions on a range of social and academic topics **1.8.4**: Offering and justifying opinions, negotiating with and persuading others in communicative exchanges **1.8.5**: Listening actively to spoken English in a range of social and academic contexts **1.8.6**: Reading closely literary and informational texts and viewing multimedia to determine how meaning is conveyed explicitly and implicitly through language **1.8.12**: Selecting and applying varied and precise vocabulary and other language resources to effectively convey ideas **2.8.6**: Connecting ideas **2.8.7**: Condensing ideas		

California's Environmental Principles and Concepts (EP&Cs)

EP&C		
	Principle 2 People Influence Natural Systems	The long-term functioning and health of terrestrial, freshwater, coastal, and marine ecosystems are influenced by their relationships with human societies.
	Principle 3 Natural Systems Change in Ways that People Benefit From and Can Influence	Natural systems proceed through cycles that humans depend upon, benefit from, and can alter.
	Principle 5 Decisions Affecting Resources and Natural Systems are Complex and Involve Many Factors	Decisions affecting resources and natural systems are based on a wide range of considerations and decision making processes.

California Education and the Environment Initiative. 2016. California's Environmental Principles and Concepts. https://californiaeei.org/epc/