4 White Shark, *Carcharodon carcharias*

White shark, *Carcharodon carcharias*. Photo credit: P Klimley, PhD, UC Davis

History of the Fishery

The white shark, *Carcharodon carcharias*, has never been a target of commercial or recreational fisheries off California. Although attempts were made to establish a market for white shark meat in the 1970s and 1980s, the species' reputation for human attacks made this a difficult product to market, and their low relative abundance made fishing in a profitable manner challenging. In 1979, the California Department of Fish and Wildlife (Department) added a market category for white shark; prior to 1979, white sharks were grouped in the unspecified shark market category in landing records.

White shark is taken incidentally in some commercial fisheries, with most interactions occurring in the set gill net and other gill net (drift gill net and trammel net) fisheries (Figure 4-1). An increased appearance of white shark in the commercial catch coincided with an increase in the popularity of gill nets after the introduction of monofilament line in the 1970s.

Since 1994, the directed take of white shark has been prohibited, although incidental landings in the gill net and seine fisheries are allowed (FGC§ 8599). White sharks caught incidentally are primarily sold for research rather than human consumption. The majority of incidental white shark landings occur in the Southern California Bight (SCB), most often in the set gill net fisheries targeting California halibut, Pacific angel shark, and white seabass (Figure 4-1). The SCB is recognized as an important nursery area for white shark in the northeastern Pacific (NEP), and a majority of documented white shark fishery interactions occur within this area and involve juveniles and young of the year (YOY). An additional factor for the predominance of this demographic in the catch data is that larger white sharks are likely able to break through monofilament nets and hook-and-line gear without steel leaders.

In 1994, two significant regulations went into effect that increased protections for the white shark population in California waters. The first was Proposition 132, the Marine Resources Protection Act of 1990 (FGC §8610 et seq.), which, when implemented in 1994, banned entangling nets (set and drift gill nets, and trammel nets) in state waters (<3 nautical miles [5.6 kilometers] from shore) between the California/Oregon border and Point Reyes (Marin County), and around the Farallon Islands. Between Point Reyes and Point Arguello (Santa Barbara County) entangling nets were limited by depth (originally 30 fathoms, currently 60 fathoms [55 and 109 meters, respectively]). Between Point Arguello and the U.S./Mexico border entangling nets were closed in state waters (<3 nautical miles from shore and <1 nautical mile around offshore islands; <5.6 and <1.8 kilometers, respectively). The second was FGC §8599 and Title 14, CCR, §28.06 which prohibits take of white sharks except when taken incidental to legal commercial fishing activity utilizing gill net or roundhaul net (seine net), or under a Scientific Collecting Permit for scientific or educational purposes. These prohibitions and an overall decrease in effort of the set and drift gill net fisheries resulted in significant declines in white shark landings in commercial fisheries through the 1990s and early 2000s (Figure 4-1).

In 2004, white sharks gained federal and international protection in a treaty approved by the United Nations affiliated Convention on International Trade in Endangered Species (CITES). Under CITES, white shark is listed under Appendix II, which includes species not necessarily threatened with extinction, but in which trade must be controlled in order to avoid utilization incompatible with their survival.

The increase in commercial white shark landings since 2005 (Figure 4-1) in conjunction with the continued decrease of commercial gill net effort has been cited in recent literature as a possible sign that the population is increasing and as a result more juveniles are utilizing the SCB in areas where commercial set gill nets fish.

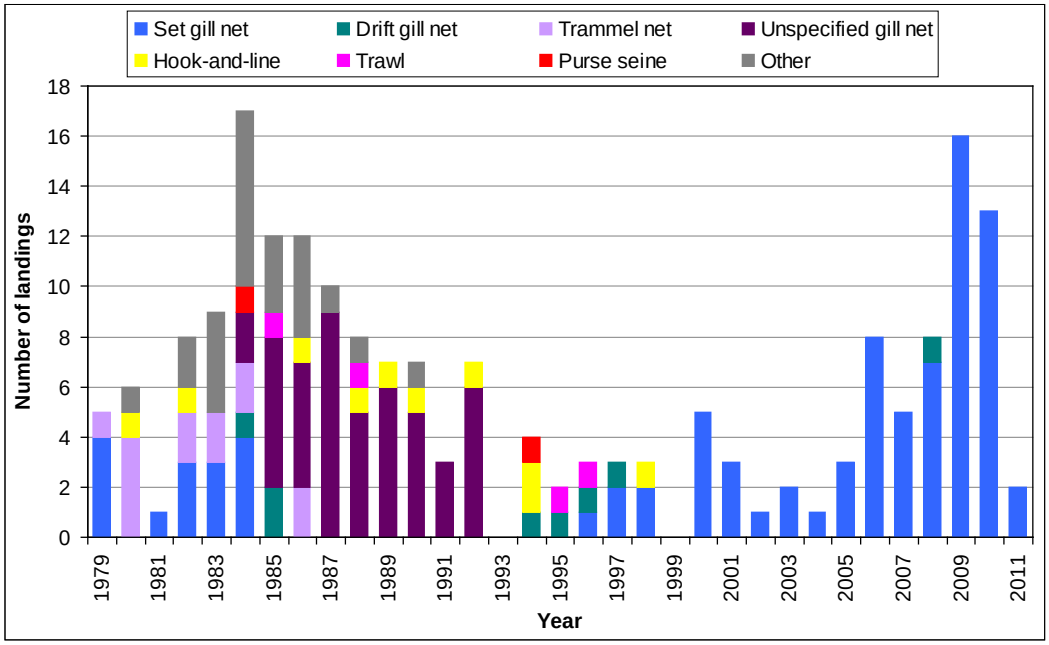

Figure 4-1. White shark incidental commercial landings by gear type, 1979-2011. Data source: Commercial Fisheries Information System (CFIS) data. Data prior to 1979 are not available.

California recreational anglers do not target white shark and rarely catch them, based on available data from the commercial passenger fishing vessel (CPFV) logbook program and the RecFIN database. There have only been seven white shark interactions recorded in CPFV logbook records (Table 4-1), and only one record in the RecFIN database (Marine Recreational Fisheries Statistics Survey [1980-2003] and CRFS [2004-2011]) since these recreational survey efforts began in 1980. These records are not a full accounting of recreational activity, but they do show that this species is not common in the recreational catch.

Table 4-1. White shark CPFV landings, 1980-2011.

Year	Fish	Year	Fish	Year	Fish	Year	Fish
1980	0	**1988**	0	**1996**	0	**2004**	2
1981	0	**1989**	0	**1997**	1	**2005**	0
1982	0	**1990**	0	**1998**	0	**2006**	1
1983	0	**1991**	0	**1999**	0	**2007**	0
1984	0	**1992**	0	**2000**	1	**2008**	0
1985	0	**1993**	1	**2001**	0	**2009**	0
1986	0	**1994**	0	**2002**	0	**2010**	1
1987	0	**1995**	0	**2003**	0	**2011**	0

Data Source: Department CPFV logbook data. Landings in this table include kept and released sharks. Data prior to 1979 are not available.

Status of Biological Knowledge

The study and understanding of the life history of white sharks has been limited until quite recently. White sharks did not come under focused study until the 1970s, and the first species-specific symposium on the biology of white shark research did not occur until May 1983 at the California State University, Fullerton campus. A majority of the presentations from this first meeting were anecdotal and the few quantitative studies were small and limited in scope. Over the next ten years more empirical and experimental studies were conducted, but there was still relatively little mention of white shark in the scientific literature. In March 1993 a symposium on white shark was organized at the Bodega Marine Laboratory of the University of California that drew scientists from six continents, presenting on a broad range of research topics. This meeting presented both traditional scientific papers on the biology of the species, and a forum to discuss and evaluate controversial ideas and misconceptions about the species in the media and public perception. The result of this meeting was a book titled Great White Sharks: The Biology of *Carcharodon carcharias*, which began two decades of increased focus and research on white sharks.

Through the late 1990s understanding of the biology and life history of this species was hindered by its solitary nature and distribution throughout a large range. White sharks are large, aggressive predators and have a naturally small population. Understanding of this species has dramatically increased due to advances in electronic tagging technology over the last decade. Electronic tagging programs and photo-identification studies have increased scientific knowledge and understanding of migration patterns, habitat preference and use, behavior, and have provided a clearer picture of the interaction and segregation of global populations. In addition, recent genetic studies have shown that the NEP population is genetically distinct from other populations of white shark.

Despite these advances, there are still large gaps in our understanding of the basic life history of white sharks such as age, growth, and reproductive biology. Obtaining this knowledge may be slow due to the small population and restrictions imposed by important protections afforded to the species over the last decade. These factors limit samples to opportunistic interactions with commercial fisheries and nonlethal fishery independent methods. The amount of available literature focused on the NEP population of white sharks (the population found off the coast of California) is much greater than what is available for other populations (Australia/New Zealand and western South Africa).

Globally, white sharks are found throughout most seas and oceans with concentrations in temperate coastal waters. The NEP population ranges from Alaska south to Baja California, Mexico and the Gulf of California, Mexico, and as far west as the Hawaiian Islands. Adults of this population have been observed aggregating seasonally at two primary sites along the west coast of North America. One site is a network of hot spots off the coast of central California (CC) west of San Francisco Bay, and the other is off

Guadalupe Island, Mexico (GI). Both of these locations support large breeding colonies of northern elephant seals, California sea lions and other pinniped species. But availability of preferred prey does not account for the density of adult white sharks in the aggregation areas. It is believed the primary reason for these aggregations is mating.

No white sharks have been observed mating anywhere in the world, so a lack of direct observation does not invalidate this theory. Several studies using pop-up archival transmitting (PAT) tags and satellite-linked radio transmitting (SLRT) tags to track individual movements and migration patterns have found significant circumstantial and indirect evidence that these two aggregations are where mating occurs for the NEP population. Near aggregation sites, adult sharks are captured and restrained for sample collection and tagging. Researchers measure the animals, collect blood samples for hormone analysis, take genetic samples and make physical observations of mating activity (condition of claspers on males and presence of conspecific bite marks on females). Observations at both aggregation sites have shown the presence of running-ripe males and females with fresh conspecific bite marks, two possible indicators that mating has occurred. Additional studies tag free swimming sharks attracted to the vessel with decoys and scent, and others photograph identifying markers to track site use by individuals. Tracking data shows sex-specific seasonal migration patterns, with adult males returning annually to aggregation sites (CC or GI) while females usually show a biennial return pattern. This pattern is most likely due to a gestation period of approximately 18 months, as no female observed with conspecific bite marks (evidence of mating) returned the following year.

Adult males from both aggregation sites migrate to a Shared Offshore Foraging Area (SOFA) located midway between North America and the Hawaiian Islands. Adult females migrate offshore in a much more diffuse pattern, and are only found passing through the SOFA while males are absent. This sex-specific difference in use of offshore habitat might be due to a difference in prey preference between males and females during the pelagic portions of their migrations. The SOFA has been characterized as an epipelagic “cold spot” with low epipelagic productivity (epipelagic refers to waters from the surface to 109 fathoms deep [surfact-200 meters]), consisting primarily of sperm whales and three species of mesopelagic squid (mesopelagic refers to waters 109-3280 fathoms deep [200-1000 meters]). It has been suggested that these sharks are feeding on a diet of squid or species that target squid, but this has not been confirmed. In contrast, females do not always return to the aggregation sites annually and can be considered primarily pelagic. While their migration is much more dispersed and less predictable than males, they have been tracked going back and forth between the eastern edge of the SOFA and the continental shelf of North America. Utilization of these areas, where small cetaceans are more frequently encountered, may show a preference for these mammals as a prey source.

Some individuals, both male and female, make a separate and distinct migration to the Hawaiian Islands. This occurs at the same time as the other offshore migrations, but these animals avoid the SOFA altogether passing to the north or south. These sharks

are potentially targeting small cetacean prey not available in the SOFA, but it is unclear why they would migrate such a great distance when similar prey is available near the continental shelf of North America.

Tagging and photo-identification studies also show that white sharks in the NEP exhibit philopatric behaviors (i.e., returning to the same area annually) and usually return to the same aggregation site where they were tagged. This provides strong evidence that the NEP population is demographically isolated from populations near Australia/New Zealand and western South Africa. In addition the NEP population has also been shown to be genetically distinct. When returning to the adult aggregation sites (CC and GI) males generally arrive over a few weeks from late July through early August, while most females return in October.

There is limited information available on pregnant females and embryonic specimens, but white sharks are believed to be ovoviviparous with oophagy, meaning the embryos hatch from egg capsules inside the mother, are nourished first by a yolk sac (in egg capsule and possibly a short time after hatching) and then by consuming unfertilized eggs produced by the mother and born live. It has been speculated that females give birth to live litters of 4 to 14 pups, but this is based on a very limited number of pregnant females that have been caught and examined worldwide. Size at birth depends on the size and physical condition of the mother, but is believed to range from 3.9-4.9 feet (1.2-1.5 meters) total length (TL). Unlike males that generally migrate directly between offshore areas and aggregation sites, pregnant females will migrate to the nearshore waters of the SCB and Baja California, Mexico to give birth before returning to the adult aggregation sites. Appearance of YOY in scientific collections and as incidental catch in the set gill net fishery suggests that parturition (i.e., birth) occurs May through October, peaking in July with only a minimal amount occurring after August. Young of the year remain in these shallow, warm-water nursery areas for their first summer and fall, feeding on fish and invertebrates. As water temperatures cool in the fall the YOY migrate south to Baja California, Mexico.

As juveniles, the sharks continue to migrate north and south in nearshore waters from the SCB to the Gulf of California, staying in warmer water until they are large enough to exploit colder water areas. Juveniles prey on a variety of fish, invertebrates and opportunistically scavenge marine mammal carcasses. In their third year, at approximately 6.6 feet (2 meters) TL, juveniles begin to venture north of Point Conception, into central California. Sub-adults range widely from Oregon to the Gulf of California, Mexico. They will begin to visit aggregation sites and make inshore/offshore migrations, but little is known about how they locate these sites, or when and how they switch behavior patterns and begin their migrations. It has been suggested that this may be a time when mixing occurs between the CC and GI populations. As sub-adults grow in size and skill, they will also start to actively prey on small marine mammals. This change in prey preference is considered common, but recent research looking at feeding ecology using isotopic analysis of vertebrae suggests that some animals may retain a fish-based diet throughout their lives.

Research focused on YOY and juveniles occurs primarily in the SCB and includes tagging for mark-recapture and tracking, and tissue sampling for contaminant levels and genetic analysis. In addition, the Monterey Bay Aquarium White Shark Program conducts a short term captivity program of YOY white sharks for display, and study of captive feeding and growth, oxygen consumption, other biological measures and post-release behavior.

Only rough estimates can be given for length at which individuals become sexually mature, as a wide range of maturities have been seen amongst sharks of similar size. Given this variance most males become sexually mature at 11.8-15.1 feet (3.6-4.6 meters) TL and females at 14.8-16.4 feet (4.5-5.0 meters) TL. Females are usually larger than males and have been documented with certainty to grow to a maximum of 19.7 feet (6 meters) TL and males to 18 feet (5.5 meters) TL. There are records and reports of larger individuals, but a recent examination of these accounts has shown them to be erroneous or unsubstantiated.

Status of Population

There are no historic estimates of the NEP white shark population. White sharks are challenging to study and have a naturally low abundance. Additionally, The protections afforded white shark and the low natural abundance make it difficult to obtain sufficient data as sampling is limited to nonlethal fishery independent methods (tagging program) and opportunistic interactions with commercial fisheries. As a result, only recently have studies been conducted to estimate the populations of adults and sub-adults utilizing the primary aggregation sites. The occurrence of incidental fishing interactions, habitat loss, other negative pressures on the population, and a lack of effective population estimates may leave the population susceptible to undetected decline until after a significant decrease has occurred. This makes current and future research on migration patterns, individual identification for population estimates, recruitment and general life history, crucial to our understanding of the species and our ability to protect the population from anthropogenic and environmental impacts.

Management Concerns

White shark is not a federally managed species, but is listed in the federal Highly Migratory Species Fishery Management Plan as a prohibited species. Under California law, take of white sharks is prohibited except when taken incidental to legal commercial fishing activity utilizing gill net or roundhaul net (seine net), or under a Scientific Collecting Permit for scientific or educational purposes. Further protections are afforded the species through federal and state bans and restrictions on the practice of shark finning, and the possession, trade and sale of shark fins. Internationally, white shark is listed in CITES as an Appendix II species, which restricts trade of a species that may become threatened with extinction to avoid utilization incompatible with their survival. This includes whole carcasses or their parts.

Although this species has strict protections under state and federal laws, concerns have been raised over the status of the population off California. In February 2013, the California Fish and Game Commission (Commission) declared white shark a candidate species under the California Endangered Species Act (CESA) (FGC §2074.6 (a)(2)), in response to a petition to list NEP white shark as threatened or endangered in the state of California. During the twelve month candidacy period white shark is afforded the same protections as a listed species under CESA, including the prohibition of all take, except where authorized under permit by the Department (FGC §2081 (a & b). At the end of the candidacy period, the Department will provide the Commission with a report on white shark and the Commission will determine whether or not to list white shark as threatened or endangered under CESA.

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Further Reading

Domeier ML, editor. 2012. Global perspectives on the biology and life history of the white shark. Boca Raton, FL: CRC Press, Taylor & Francis Group, LLC. 567 p.

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White shark incidental commercial landings by gear, 1979-2011.

Year	Set gill net	Drift gill net	Trammel net	Unspecified gill net	Hook-and-line	Trawl	Purse seine	Other	Total
1979	4	0	1	0	0	0	0	0	5
1980	0	0	4	0	1	0	0	1	6
1981	1	0	0	0	0	0	0	0	1
1982	3	0	2	0	1	0	0	2	8
1983	3	0	2	0	0	0	0	4	9
1984	4	1	2	2	0	0	1	7	17
1985	0	2	0	6	0	1	0	3	12
1986	0	0	2	5	1	0	0	4	12
1987	0	0	0	9	0	0	0	1	10
1988	0	0	0	5	1	1	0	1	8
1989	0	0	0	6	1	0	0	0	7

White shark incidental commercial landings by gear, 1979-2011.									
Year	Set gill net	Drift gill net	Trammel net	Unspecified gill net	Hook-and-line	Trawl	Purse seine	Other	Total
1990	0	0	0	5	1	0	0	1	7
1991	0	0	0	3	0	0	0	0	3
1992	0	0	0	6	1	0	0	0	7
1993	0	0	0	0	0	0	0	0	0
1994	0	1	0	0	2	0	1	0	4
1995	0	1	0	0	0	1	0	0	2
1996	1	1	0	0	0	1	0	0	3
1997	2	1	0	0	0	0	0	0	3
1998	2	0	0	0	1	0	0	0	3
1999	0	0	0	0	0	0	0	0	0
2000	5	0	0	0	0	0	0	0	5
2001	3	0	0	0	0	0	0	0	3
2002	1	0	0	0	0	0	0	0	1
2003	2	0	0	0	0	0	0	0	2
2004	1	0	0	0	0	0	0	0	1
2005	3	0	0	0	0	0	0	0	3
2006	8	0	0	0	0	0	0	0	8
2007	5	0	0	0	0	0	0	0	5
2008	7	1	0	0	0	0	0	0	8
2009	16	0	0	0	0	0	0	0	16
2010	13	0	0	0	0	0	0	0	13
2011	2	0	0	0	0	0	0	0	2

Data source: CFIS data. Data prior to 1979 are not available.