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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

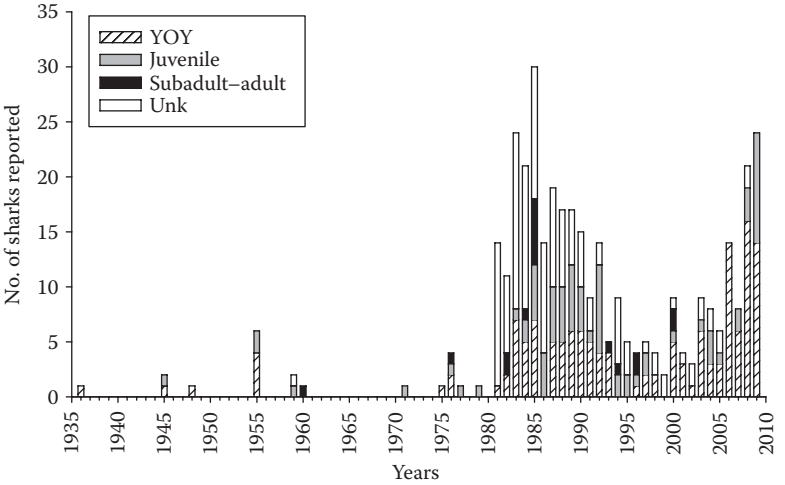

Figure 14.1 Temporal trends in reported Southern California White Shark captures by age class, 1935–2009. YOY, <175 cm TL; juveniles, 176–300 cm TL; subadult/adult, >300 cm TL; and Unk, size unknown.

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

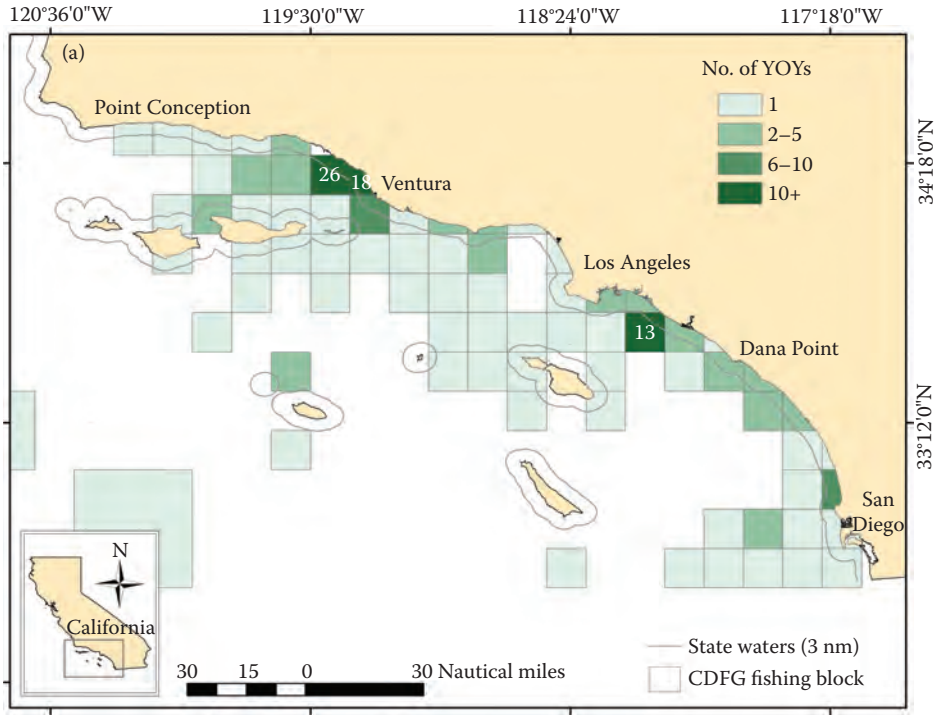

Figure 14.2 Spatial distribution of reported YOY (a), juvenile (b), and adult (c) White Shark captures occurring in Southern California, 1935–2009. The numbers represent sample sizes for fishing blocks (10 min. × 10 min.) with greater than 10 sharks.

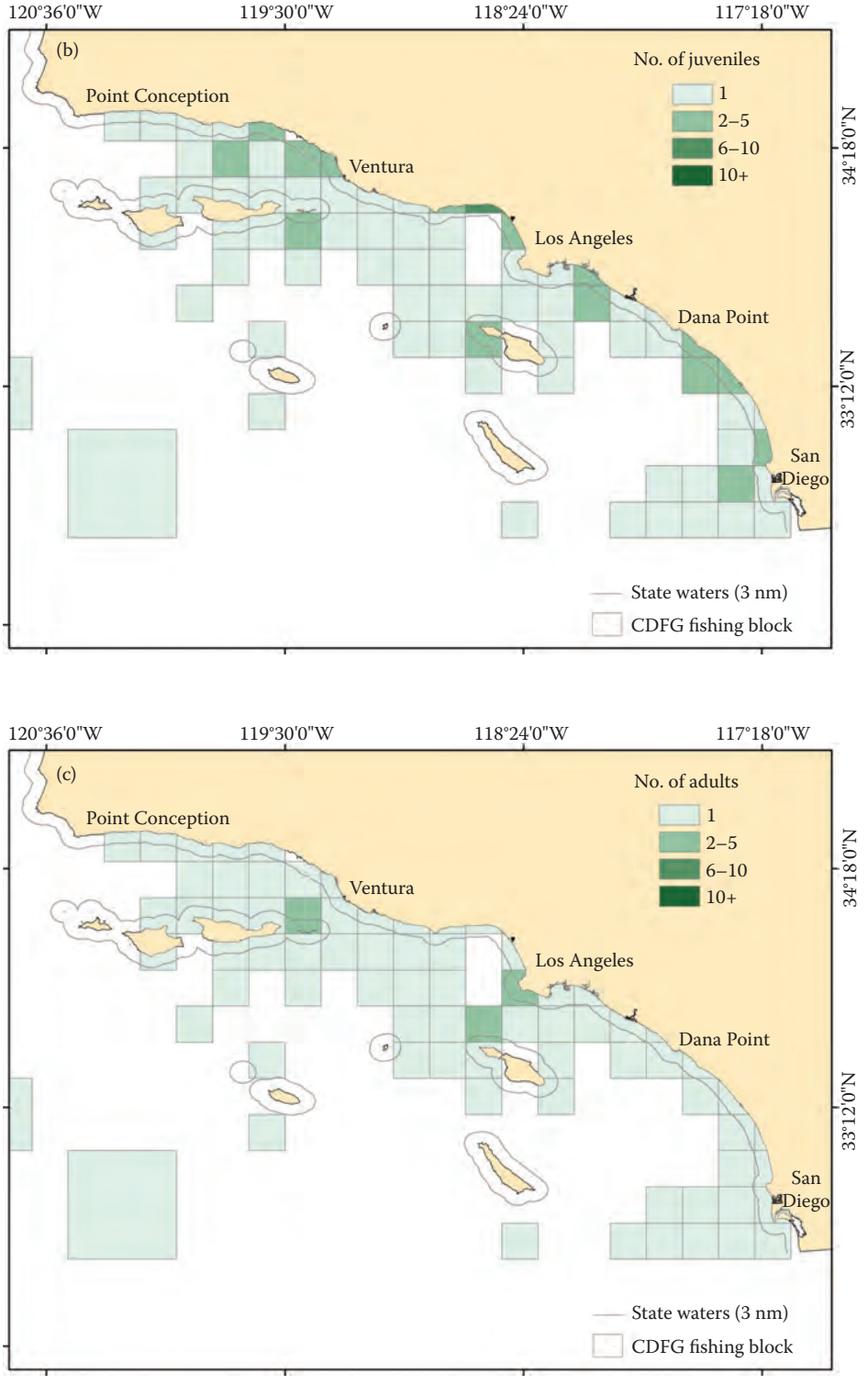

Figure 14.2 (Continued)

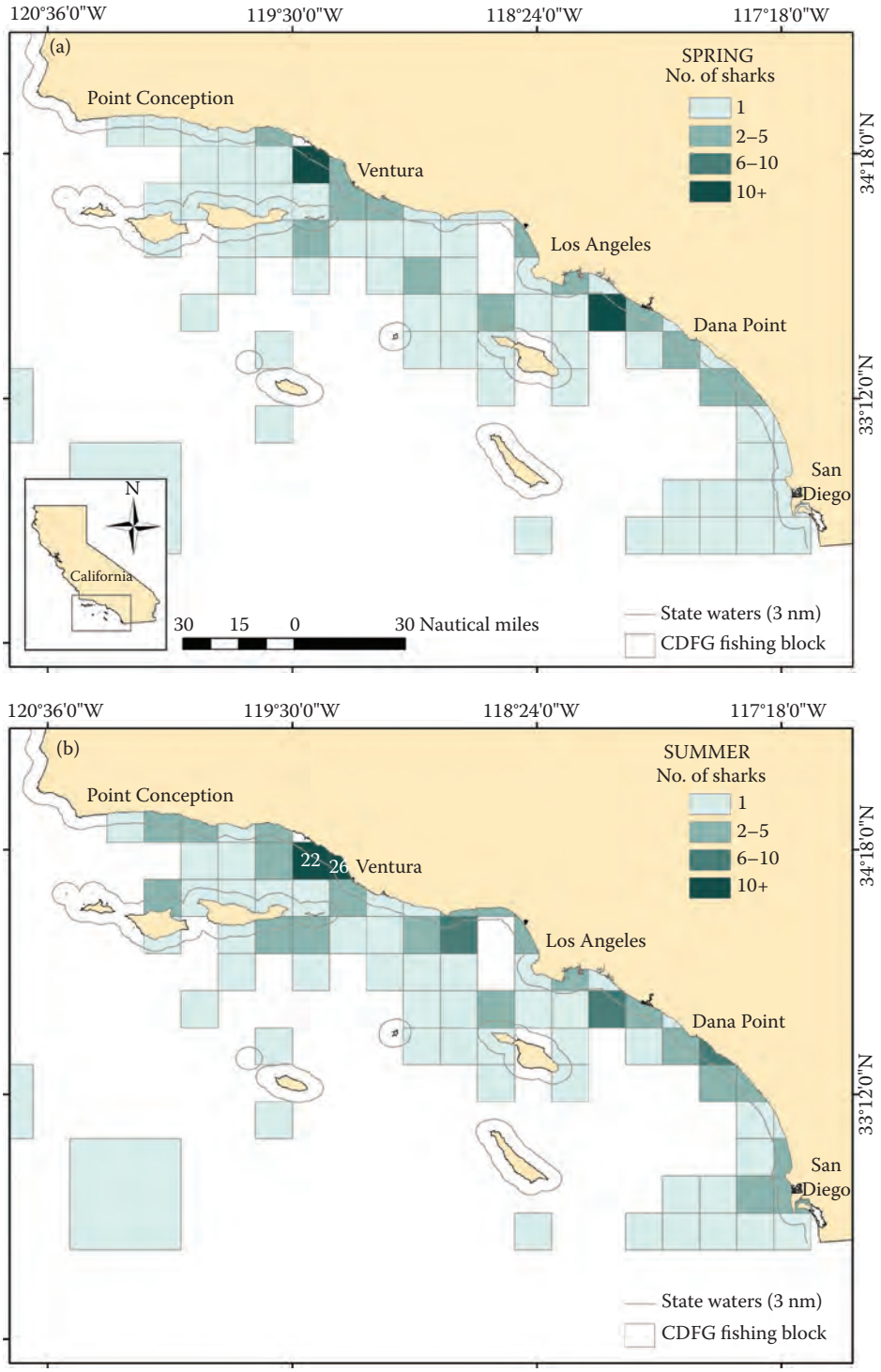

Figure 14.3 Spatial distribution of reported White Shark captures occurring in Southern California during spring (April to June, a), summer (July to September, b), fall (October to December, c), and winter (January to March, d), 1935–2009. The numbers represent sample sizes for fishing blocks with greater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

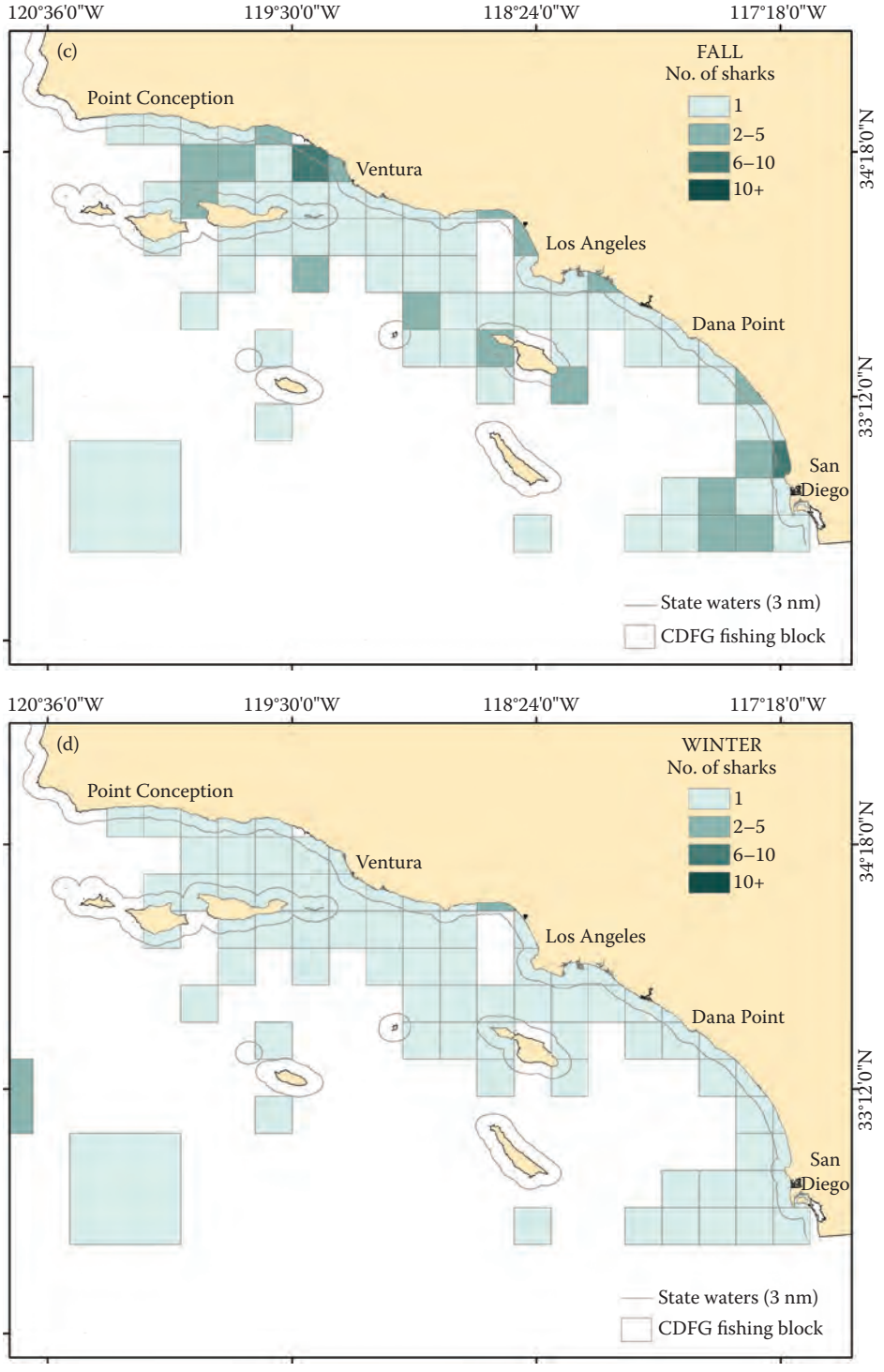

Figure 14.3 (Continued)

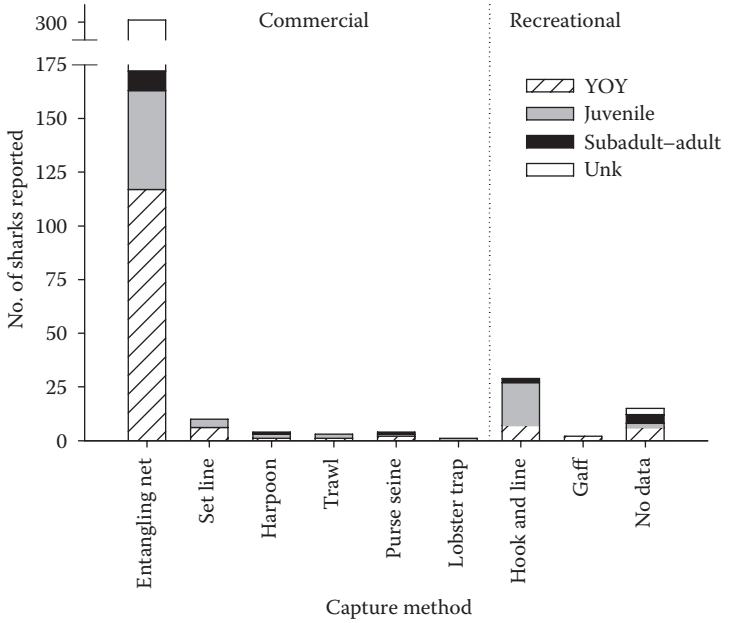

Figure 14.4 Numbers of reported White Shark captures occurring in Southern California by capture method, 1935–2009. Unk, method of capture unknown.

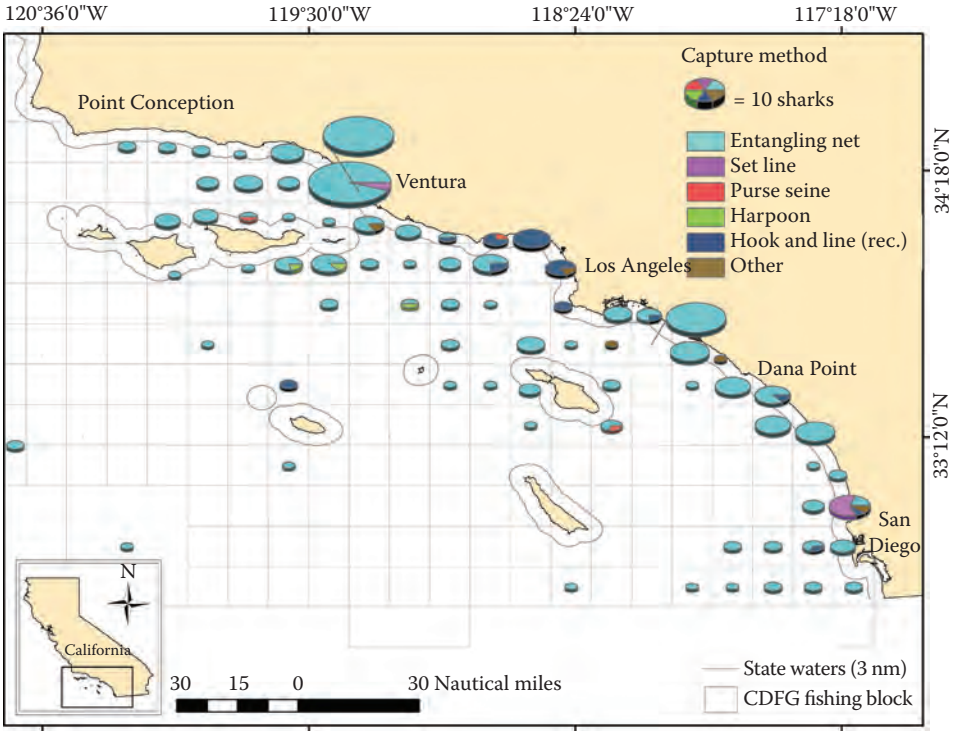

Figure 14.5 Spatial distribution of reported White Shark captures occurring in Southern California by capture method, 1935–2009. Capture methods with three or fewer capture records (e.g. trawl, lobster trap, and gaff) were pooled into the "Other" category.

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: $\overline{X} \pm \text{SD} = 2{,}905 \pm 936$, $t = 2.16$, $p < 0.0001$; 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

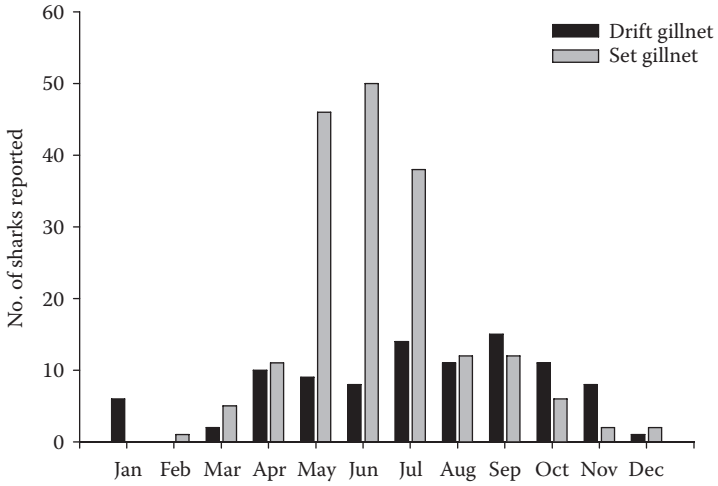

Figure 14.6 Total number of White Shark captures reported per month for the set- and drift-gillnet fisheries in Southern California, 1981–2009.

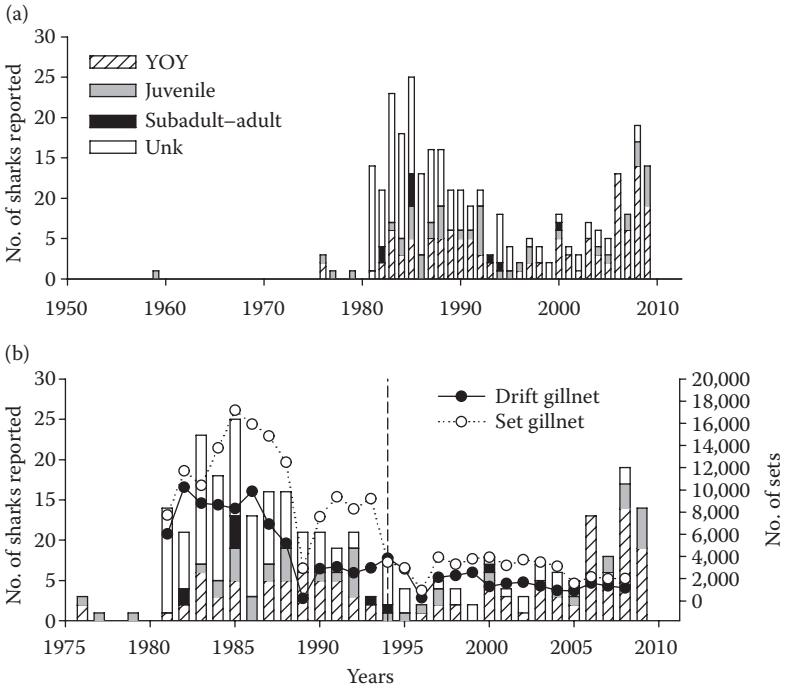

Figure 14.7 Temporal trends in reported White Sharks captured in entangling nets by stage class from a historical perspective, 1950–2009 (a), and relative to fishing effort in the set- and drift-gillnet fisheries, 1981–2008 (b).

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.

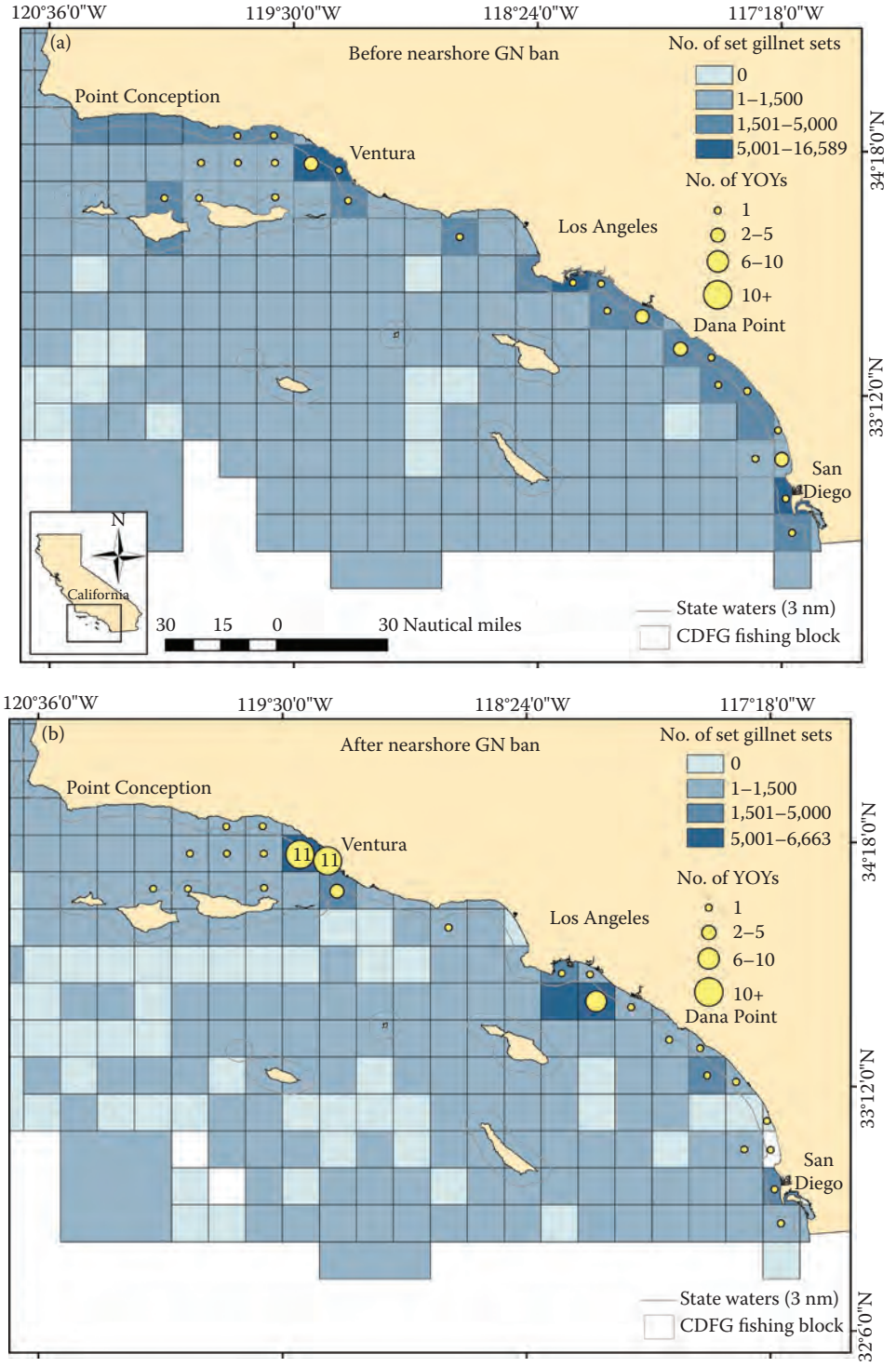

Figure 14.8 Spatial distribution of set-gillnet effort and associated YOY White Shark captures in Southern California before (1981–1993, a) and after (1994–2008, b) the nearshore-gillnet ban. The numbers represent sample sizes for fishing blocks with greater than 10 sharks. GN, gillnet.

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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