Seasonal Occurrence of the White Shark, *Carcharodon carcharias*, in Waters off the Florida West Coast, with Notes on its Life History

DOUGLAS H. ADAMS, MICHAEL E. MITCHELL, and GLENN R. PARSONS

Introduction

The white shark, *Carcharodon carcharias*, is typically found in cold and warm-temperate waters throughout the world, although occurrences in tropical waters have been documented (Compagno, 1984). In the western North Atlantic Ocean, the species is most commonly encountered in continental shelf waters from Cape Cod to Cape Hatteras (Casey and Pratt, 1985). The white shark is considered rare south of Cape Hatteras and in the Gulf of Mexico (Castro, 1983), although the species is encountered by both commercial and recreational fishermen in these regions.

White sharks caught by commercial longline vessels operating in Florida waters are often sold in a small but lucrative market, primarily for their jaws. The high value of white shark jaws and meat has encouraged "erratic spot fisheries" in New York, California, South Africa, and South Australia (Compagno, 1990). Commercial longline fishermen and seafood dealers on Florida's west coast report that demand for white shark jaws has increased since the late 1980's. The jaws from white sharks collected in Florida waters can sell for up to several thousand dollars in unprepared condition for a large, high-quality set, while fully prepared jaws may yield double that price[1]. A similar market for targeted and incidentally caught white sharks in California waters prompted recent legislation (California Assembly Bill 522, effective 1 January 1994) which restricts landings to prevent white sharks from becoming overfished by commercial and recreational fisheries.

Due to its apparent rarity or low encounter rate in the Gulf of Mexico, very little biological data has been published on the white shark from this region, and verified records are scarce. In this study we will 1) review historical reports of the occurrence of the white shark off the west coast of Florida, 2) include recent verified records from this area, 3) present evidence of seasonal (winter/spring) occurrence in the region, and 4) provide selected life-history data.

Methods and Materials

All white shark specimens examined were captured by commercial fishermen with bottom longline gear designed specifically for targeting coastal-pelagic sharks or grouper/snapper species. The bottom longline fishing gear used off Florida's west coast has evolved since the early 1980's. Initially, the bottom longline fishery in Florida's west coast waters targeted grouper/snapper species and consisted of 4–10 km long stainless steel mainlines with 600–1,500 hooks attached to the mainline with approximately 2 m long monofilament gangions. In the current longline fishery targeting sharks off the west coast of Florida, longline gear typically consists of 8–24 km monofilament (or to a lesser degree, stainless steel) mainlines with approximately 2 m long monofilament gangions.

Total length (TL), fork length (FL), and precaudal length (PCL) of each specimen were recorded according to Compagno (1984). In this paper, total lengths are used unless otherwise specified. Total weights were taken when possible or were estimated according to Mollet and Cailliet (1993). State of maturity was determined by macroscopic examination of the reproductive tract, clasper condition, or by published size-at-maturity estimates (Bigelow and Schroeder, 1953; Casey and Pratt, 1985;

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ABSTRACT—The white shark, Carcharodon carcharias, *is considered rare in the Gulf of Mexico; however, recent longline captures coupled with historical landings information suggest that the species occurs seasonally (winter-spring) within this region. We examined a total of seven adult and juvenile white sharks (185–472 cm total length) captured in waters off the west coast of Florida. Commercial longline fisheries were monitored for white sharks during all months (1981–94), but this species was captured only from January to April. All white sharks were captured in continental shelf waters from 37 to 222 km off the west coast of Florida when sea surface temperatures ranged from 18.7° to 21.6°C. Depths at capture locations ranged from 20 to 164 m. Fishing gear typically used in Gulf of Mexico offshore fisheries may not be effective at capturing this species, and the apparent rarity of white sharks in this area may be, in part, a function of gear bias.*

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Pratt, 1993). Testes from one specimen were examined histologically, and clasper length was measured on all males.

For age determination, vertebrae were removed from the area below the origin of the first dorsal fin on several of the specimens, and vertebral centrum diameters were measured to the nearest millimeter. Determination of vertebral growth bands and age were estimated according to Cailliet et al. (1985) and Parsons (1985). Sea surface temperature (SST) data for continental shelf waters off the west coast of Florida were obtained from the National Oceanic and Atmospheric Administration (NOAA) Oceanographic Monthly Summary series from January 1984 to April 1994.

Results

We examined seven white sharks (three males and four females) captured by commercial fishermen off the west coast of Florida from 1986 through 1994 (Table 1). Although we solicited specimens during all seasons between late 1981 and early 1994, white sharks were collected only during winter and spring months (February and March 1986, April 1987, April 1993, January and February 1994). Mean monthly SST of continental shelf waters off the west coast of Florida from January 1984 to April 1994 ranged from 15.7° to 31.0°C, although white sharks were only collected in this region during periods when water temperatures were 18.7° to 21.6°C (Fig. 1). Locations of capture extended from waters off Clearwater, Fla. (lat. 27°58'N), southward to Cape Sable, Fla. (lat. 25°00'N), and ranged from 37 to 222 km offshore. Depths at capture locations ranged from 20 to 164 m.

The three male sharks collected were 185, 275, and 472 cm long and had a clasper index (clasper length/total length × 100) of 3.5, 14.4, and 10.4%, respectively. We histologically sectioned the testes of the 275 cm shark and observed fully developed spermatozoa. Additionally, a large quantity of spermatophores were collected from the seminal vesicles, sectioned, and found to contain low densities of mature spermatozoa. The claspers of the largest (472 cm) shark were 49 cm long and were fully calcified. The smallest specimen (185 cm) had undeveloped testes, uncalcified claspers, and was immature.

The four female sharks were 267, 277, 359, and 391 cm long. The ovary of the immature 277 cm shark contained developing ova. Prominent, partially healed scars were observed above the insertion of the left pectoral fin of the 391 cm female (Fig. 2). These scars cut through the dermal layer and slightly into the muscle tissue. The wound

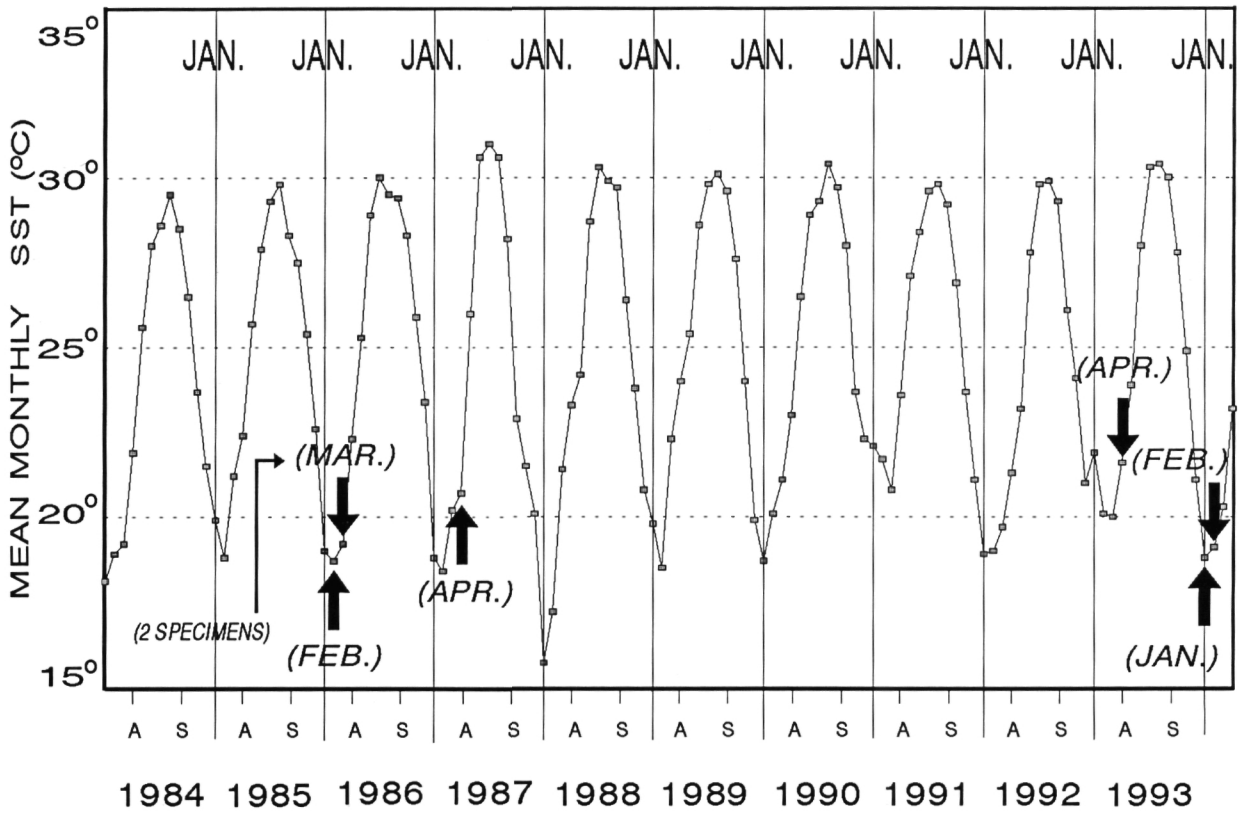

Figure 1. — Mean monthly sea-surface temperatures (SST) for shelf waters off the central west coast of Florida for January 1984 through April 1994 (from NOAA's Oceanographic Monthly Summary series). Vertical lines designate the month of January in each year. Arrows indicate months when white sharks were captured in the study area.

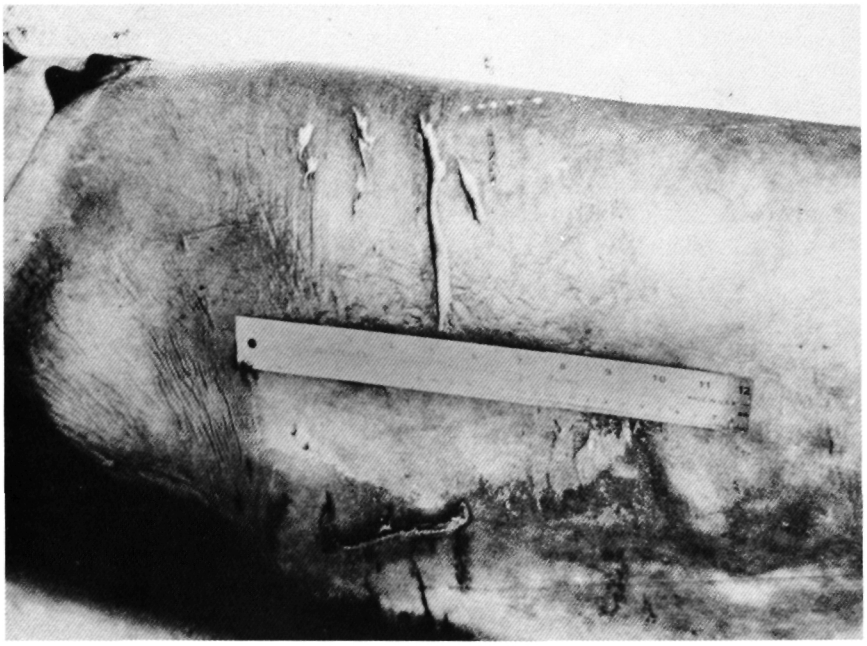

Figure 2. — Lateral view of the partially healed scars above the insertion of the left pectoral fin of the 391 cm TL female white shark. The left edge of the photo shows two posterior gill slits.

shape, orientation, and spacing between parallel punctures, as well as the vertically orientated lacerations, suggested that the wound was caused by a conspecific. The placement of these scars and the similarity to mating scars found on females of other shark species suggest they may have occurred during mating; however, the reproductive behavior of this species is poorly known. Similar scars have been documented on white sharks in South Australian waters, but due to the frequency of bite marks observed on both immature and mature individuals in the area, they could not be confirmed as evidence of mating activity (Bruce, 1992).

Vertebrae were removed from the 277 cm and 391 cm specimens. Six growth bands were counted on vertebrae from the smaller shark (centrum diameter = 31 mm) and ten from the larger specimen (centrum diameter = 53 mm). These values agree closely with those of similar size white sharks examined by Cailliet et al. (1985), but currently no validation information is available to determine the periodicity of these growth zones.

The stomach of the 472 cm male shark contained the remains of a requiem shark, *Carcharhinus* sp. (probably *C. plumbeus*), estimated to be 180 cm long. The stomach of the 391 cm female contained the entire remains (in two sections) of a dolphin (Delphinidae) estimated at 150 cm long. Two of the white shark specimens were eviscerated at sea, so their stomachs could not be examined. The three other stomachs that could be examined were empty, but not everted.

We collected three species of parasitic copepods from the 275 cm male shark and the 391 cm female shark. *Pandarus smithii* and *P. satyrus* were present in the mouth of the male shark, and *Dinamoura latifolia* specimens were attached to the trailing edge of its caudal fin. *Pandarus satyrus* was also collected from the mouth and left pectoral fin of the female.

Table 1.—Biological and capture data for white sharks collected from waters off the west coast of Florida, 1986–1994.

Capture date	Sex	Length (cm) TL	FL	PCL	Clasper length (cm)	Weight (kg)	Approx. capture location	Capture depth (m)	Maturity
28 Feb. 1986	F	267	236	208		145[1]	27°20'N 83°27'W	60	Immature
9 Mar. 1986	M	275	263	236	39.5	220.4	27°25'N 84°30'W	162	Mature
Mar. 1986	M	185	170	147	6.4	49.9	27°58'N 83°45'W	57	Immature
13 Apr. 1987	F	277	227	218		167[1]	26°58'N 83°50'W	73	Immature
28 Apr. 1993[2]	F	359	335			498.9	25°00'N 84°15'W	164	Immature
3 Jan. 1994	M	472	440	397	49	998[1]	27°58'N 83°19'W	20	Mature
22 Feb. 1994	F	391	355	321		536[1]	26°54'N 84°12'W	119	Mature

[1] Estimated weight using equation from Mollet and Cailliet (1993).
[2] Shark was cut in thirds before being landed and was put together when measured; weight represents eviscerated weight.

Discussion

The earliest documented white shark report from the west coast of Florida was a female, estimated to be 457 cm, collected with a set line during the winter of 1937–38 off Sarasota (Springer, 1939). A 472 cm specimen was collected with a set line approximately 13 km off Englewood on 1 February 1939 (Springer, 1939). Another specimen, measuring 444 cm, was caught 30–64 km off Sarasota at a depth of 30 m in early 1943 (Clark and Von Schmidt, 1965). On 10 February 1965, a 360 cm female white shark was captured in a net intended to catch bottlenose dolphins, *Tursiops truncatus*, at Mullet Key, near St. Petersburg (Moe and Martin, 1965). A 332 cm female white shark was caught off Sarasota on 21 January 1966 (Cape Haze Marine Laboratory, 1966). On 19 February 1967, a 338 cm male, reportedly mature and weighing 480 kg, was captured on a shark longline 5.6 km west of Midnight Pass, Sarasota (Cape Haze Marine Laboratory, 1967).

Bigelow and Schroeder (1953) estimated that white sharks mature at approximately 366–427 cm. A more recent

estimate indicates that males mature at 360 cm (Pratt, 1993). Four of the seven white sharks examined in this study were immature. The size of the 472 cm male shark and its 49 cm fully calcified claspers indicate that this specimen was mature. The length of the claspers, the presence of mature spermatozoa in the testes, and the presence of spermatophores suggest that the 275 cm male shark examined in this study was mature or maturing. The 391 cm female shark was eviscerated at sea, and therefore no gonads were available to determine state of maturity. However, the total length and presence of possible mating scars on this specimen indicated maturity.

Other large and presumably mature white sharks have been documented in the Florida Keys and waters to the south of peninsular Florida. Among these was a white shark reported to measure 640 cm and to weigh 3,324 kg that was collected approximately 260 km south of Florida near Cojimar, Cuba, in 1945 (Bigelow and Schroeder, 1948). The size of this specimen was later refuted by Randall (1987). A confirmed visual account of a white shark measuring approximately 400 cm was reported on 1 January 1960 off Grassy Key, Fla. (Nelson, 1969). More recently, two white sharks were captured off the Florida Keys: a 206 kg specimen captured in 1988 (Ellis and McCosker, 1991) and a 405 cm, 451 kg specimen landed by rod and reel from a depth of 152 m approximately 30 km off Marathon, Fla., in January 1989.

National Marine Fisheries Service observers reported 35 white sharks as by-catch in the Japanese longline tuna fishery from February through April 1979 in the Gulf of Mexico (Rivas and McClellan, 1982), although no specific information was available. In a study of white shark distribution in the western North Atlantic, Casey and Pratt (1985) compiled 17 reports and sightings of white sharks throughout the Gulf of Mexico. Of these 17 observations, 11 were reported during the months of January, February, and March.

All specimens examined in our study were captured off the west coast of Florida between the months of January and April; all other confirmed sightings and many of the unconfirmed sightings of white sharks in this area were made during this same time period. Longline fishing effort in Florida's west coast waters during 1986–90 was typically lowest during the colder winter and early spring months when compared to fishing effort during the rest of the year[2]. Although fishing effort was reduced during the winter and early spring months, white sharks were principally observed during these periods and not during the warmer months when fishing effort was highest.

The occurrence of this species may be correlated with water temperature (Compagno, 1984; Casey and Pratt, 1985). Sea surface temperatures at the time and location of white shark captures in our study ranged between 18.7° and 21.6°C. In western Atlantic waters to the north, primarily between Cape Cod, Mass., and Cape Hatteras, N.C., white sharks occurred in water temperatures ranging from 11° to 24°C, although 75% of the occurrences in this region were when surface temperatures were from 15° to 22°C (Casey and Pratt, 1985). Similar water temperature ranges (maximum temperatures ≤26°C) for white sharks were recorded in waters near the Farallon Islands, Calif. (Ainley et al., 1981; Ainley et al., 1985), Natal, South Africa (Compagno, 1984; Cliff et al., 1989), and South Australia (Bruce, 1992).

The fact that white sharks captured in our study were taken when longline fishing effort was the lowest and when sea-surface temperatures were the lowest, suggest that white sharks move into the Gulf of Mexico or into Florida shelf waters during the winter and early spring months when water temperatures drop below 22°C. Unconfirmed sightings of white sharks in the Gulf of Mexico during the summer months may be misidentifications. We have examined mako sharks, *Isurus* spp., that were misidentified as small white sharks by Florida fishermen (Personal observ., G. Parsons and D. Adams), and other sharks found in the western North Atlantic have also been misidentified by fishermen as white sharks (Casey and Pratt, 1985).

Although water temperature may influence the distribution of white sharks (Compagno, 1984; Casey and Pratt, 1985), prey availability may also influence the apparent seasonal occurrence of this species off the west coast of Florida. In coastal waters off central California, inshore/offshore movements of white sharks were related to seasonal abundances of pinniped prey species (Ainley et al., 1985). Marine mammals, both dead and alive, are thought to be an important food source for white sharks throughout their range (Arnold, 1972; Pratt et al., 1982; Castro, 1983; Casey and Pratt, 1985; Long, 1991; and others). Marine mammal mortalities in Gulf of Mexico waters, as indicated by stranding records, are highest during winter and spring months (Wells et al., 1980; Jones, 1987; Weigle et al., 1991). Dolphins in Gulf of Mexico waters have had shark-bite scars on as many as 22% of specimens observed (Jones, 1987; Wells[3]). Movements of dolphins out of estuarine and bay habitats and into coastal waters during winter and spring have also been documented (Wells et al., 1980; Scott et al., 1990). Increased abundance of marine mammals, marine mammal carcasses, and other prey off the west coast of Florida during these periods may provide a seasonally abundant food source for white sharks.

Principal methods used to capture white sharks in the northwestern Atlantic were longline gear, rod and reel, and harpoon (Casey and Pratt, 1985). Commercial longline gear is the primary gear used in the Gulf of Mexico which is capable of capturing this species. Four of the seven specimens examined in this study and many of the historical specimens reported from the west coast of Florida were tangled in longline gear and were not actually captured by terminal hooks. Commercial longline fisheries in Florida typically use monofila-

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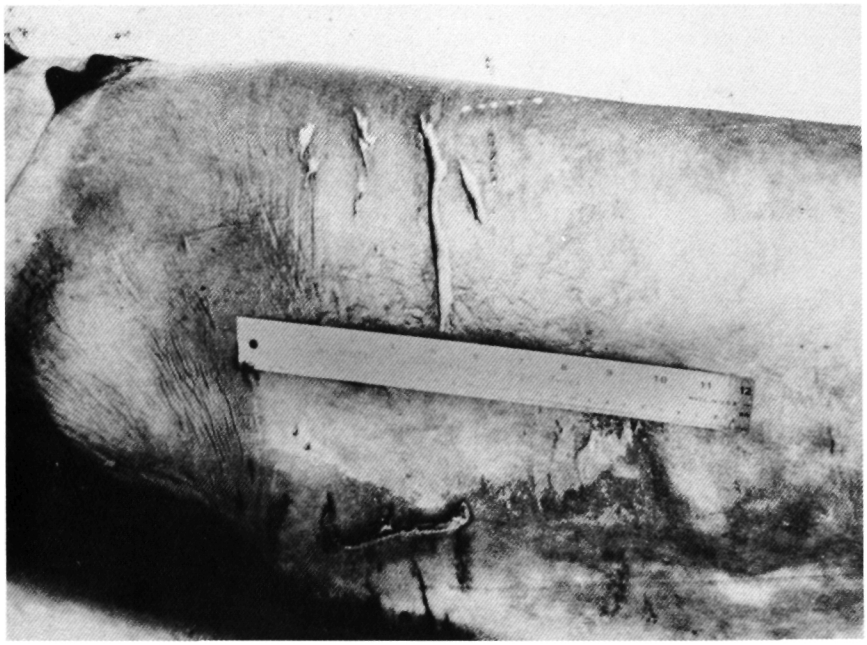

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ment gangions, which are routinely severed by large sharks (Berkeley and Campos, 1988). Thus, commercial fishing gear commonly used in west-coast Florida waters may not be effective in capturing white sharks, and the apparent rarity of white sharks in the Gulf of Mexico may be, in part, a function of gear biases. In addition, the results of this study suggest that the occurrence of white sharks is seasonal in this region and that their distribution/availability is limited by water temperature, food resources, or other factors.

Acknowledgments

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