

Unprovoked Attacks by White Sharks Off the South African Coast

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Introduction

White sharks *Carcharodon carcharias* range along the entire coast of southern Africa, from Namibia to KwaZulu-Natal and southern Mozambique, but the center of the population appears to be the coastal waters of the western Cape Province of South Africa (Compagno, 1984a).

White sharks have been implicated in attacks on humans in South Africa (Davies, 1961, 1964; Davies and D'Aubrey, 1961a,b; Walleit, 1973, 1983; Compagno, 1984a, 1987; Cliff, 1991; Levine, 1996), and elsewhere (e.g., Baldrige, 1973); including the northwestern Pacific (Collier, 1964, 1992, 1993; McCosker and Lea, Chapter 39; Miller and Collier, 1981), Australia (West, Chapter 41), and the Mediterranean (Fergusson, Chapter 30).

I attempted to assemble accurate information about shark attacks in southern Africa by collecting data on 297 unprovoked attacks and 116 incidents (provoked attacks, attacks on boats, and posthumous scavenging). Various species of sharks were involved, and information on unprovoked attacks was uncovered as far back as 1852. Attacks that had never been recorded in the scientific literature were investigated, and many additional details were revealed in previously documented attacks. Approximately 1200 people were interviewed; these included victims, witnesses, lifesavers, paramedics, physicians, medical examiners, commercial fishermen, and government officials. Information was supplied by the victim or eyewitnesses in all but 20 of the unprovoked attacks (all

species) in South Africa since 1944, and in 10 of the cases before 1944. However, the quality and amount of information regarding attacks prior to 1922 varied considerably; although a few of the attacks had been examined in detail by contemporary researchers, most were not. To prevent distortion by data of variable quality all pre-1922 attacks were excluded from this study. Of the 297 unprovoked attacks, 225 took place from 1922 to July 1994, a period of 72 years; 63 of these cases involved white sharks. This study is limited to these 63 cases.

Methods

A *shark attack* was defined as any incident in which a shark initiated aggressive behavior toward a human and in which physical contact occurred. In some cases divers were struck with force by the sharks, but their wetsuits protected them from abrasions; the divers used their spearguns as billys and/or the shark bit their fins, speared fish, or scuba tank, leaving the diver unharmed. Contacts with riders' boards have been included even when the persons were not bitten; contacts with boats were excluded. When the victims' behavior elicited aggression or the sharks were stressed as the result of shark-fishing activity or capture, the events were considered "provoked"; such incidents were not included.

In addition to the cases discussed here, another 40 attacks may have involved white sharks, but the re-

liability of eyewitnesses was questionable and/or other factors made white shark involvement uncertain. In the 63 valid cases, white shark involvement was determined through (A) recovery of white shark tooth fragments, (B) definitive bite patterns in the victim's body or equipment, (C) reliable eyewitness and/or victim's identification of species, and (D) recovery of body parts and/or bloodstained swimsuit of the victim from the shark's gut. Shark sizes are expressed as total length (TL).

Results

On the basis of the four criteria for inclusion of incidents in this study, sample sizes were as follows: A, 2 cases; B, 15; AB, 2; C, 17; AC, 4; BC, 19; CD, 2; and ABC, 2.

Locations

No unprovoked attacks by white sharks were recorded in the frigid waters of the northern Cape Province. Thirty-one (49.2%) of the 63 attacks took place in the Western Cape; 17 (27%), in the Eastern Cape (1, in

the northern transitional zone formerly known as Transkei); and 15 (23.8%) in the subtropical seas of KwaZulu-Natal (Fig. 1).

Activity of the Victims

The 63 cases include 22 attacks on board riders (18 surfers, 3 bodyboarders, and 1 paddleskier), 21 on divers (16 spear fishermen, 3 skin divers, and 2 scuba divers), and 20 on swimmers (Fig. 2).

Time of Year and Water Temperature

Davies (1963) hypothesized that shark attacks were unlikely in water temperatures $<21-22^{\circ}\text{C}$, because few people swam in chilly water, and those who did so remained in the sea for only a short period. In KwaZulu-Natal, the sea is coldest in winter: the in-shore (<1 nautical mile from shore) sea-surface temperature (SST) averages 19°C . The summer SST averages 24°C , thus encouraging more people to enter the water and for longer periods than in winter. The number of shark attacks, Davies believed, was directly related to the number of swimmers in the sea. Although attacks have taken place in every month,

Locations of unprovoked white shark attacks on humans in South Africa

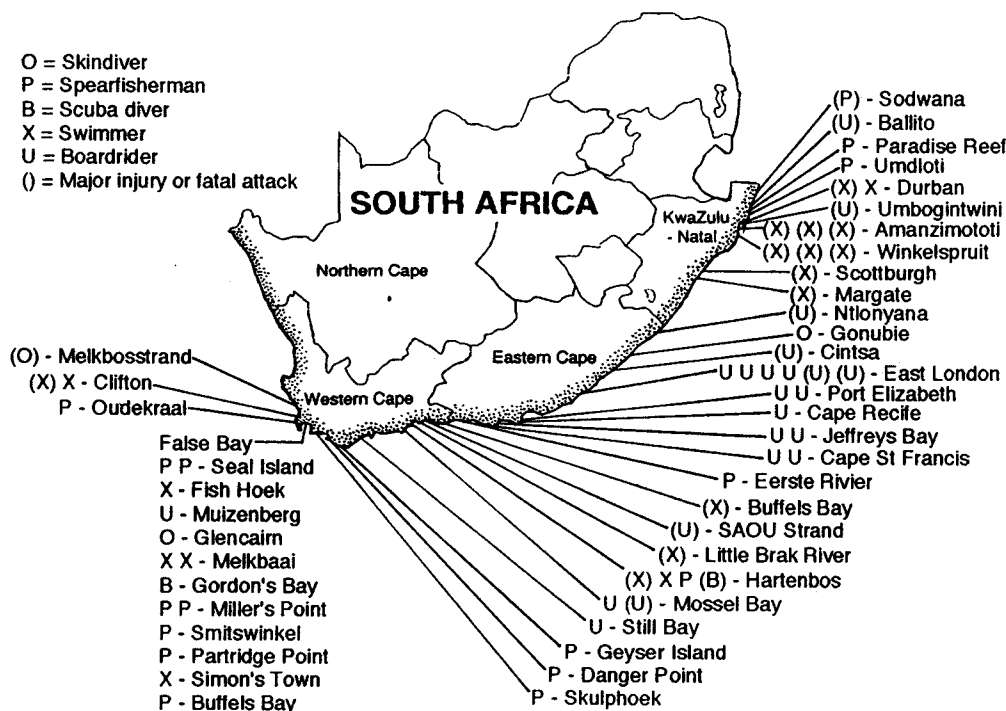


FIGURE 1 The South African coast, showing fatalities, sites, and activities of people bitten by white sharks in unprovoked attacks.

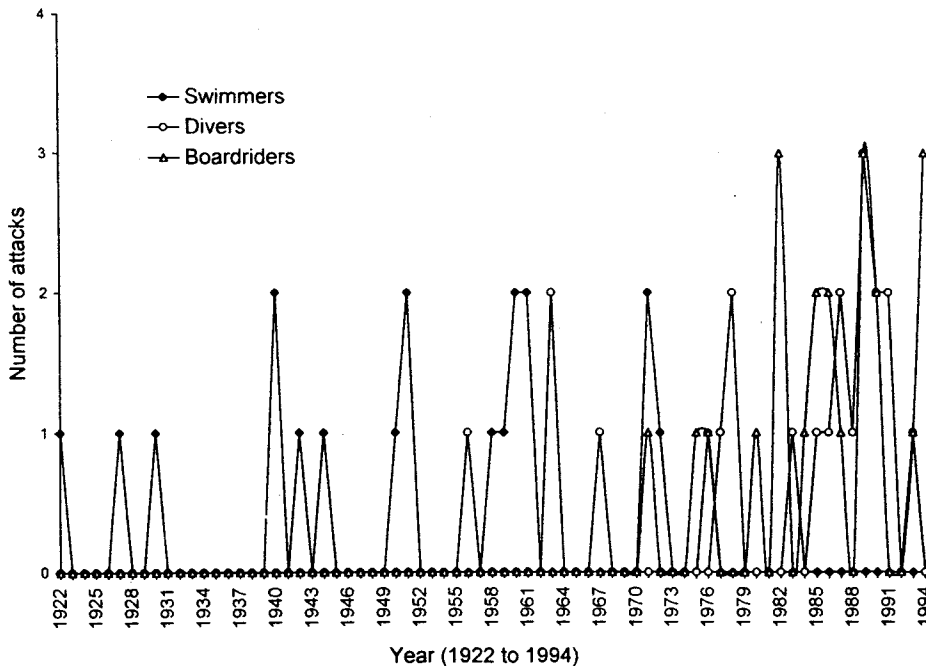


FIGURE 2 The activities of people attacked by white sharks along the coast of South Africa, 1922–1994. Note the shift from swimmers to board riders and divers.

the number of attacks seems to peak in midsummer, and of 27 attacks during midwinter (June–October), only one involved a swimmer (Fig. 3).

Wet suits, however, now permit divers and board

riders to linger in water considerably cooler than 21°C. In the 41 instances in which the SST was measured or estimated, it ranged from 12°C to 26.1°C; 26 (65%) of the attacks took place in water <21°C (Fig. 4).

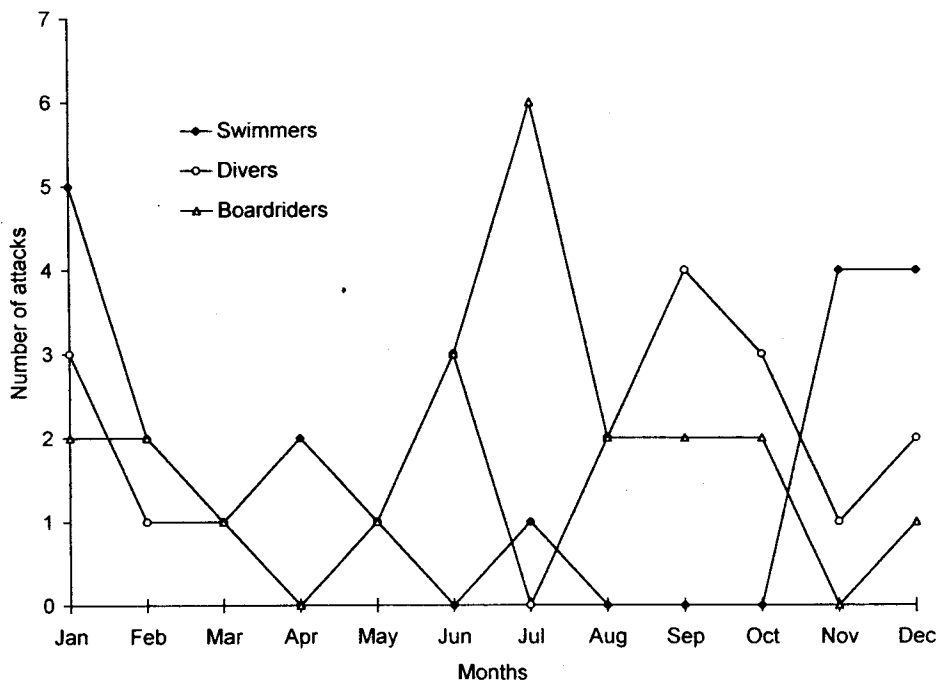


FIGURE 3 The months in which white shark attacks occurred in this study.

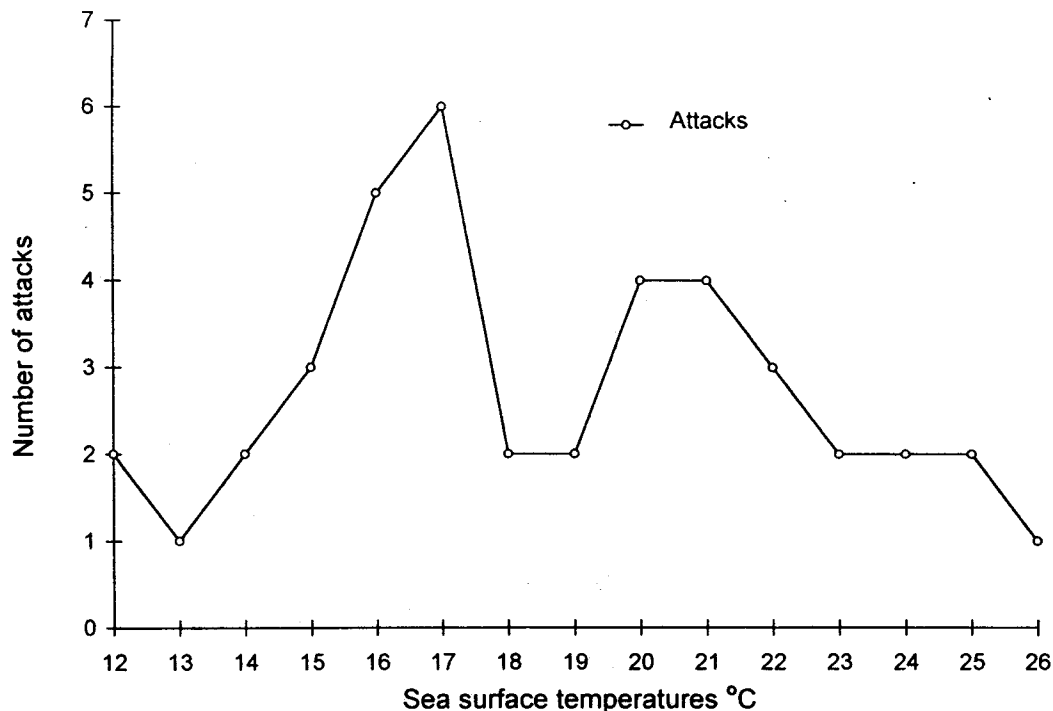


FIGURE 4 Sea-surface temperatures in 41 white shark attacks, when it was measured or estimated; 75% took place in water <21°C.

Time of Day

Anatomical studies indicate that white sharks are capable of color vision (Gruber and Cohen, 1985). Color vision has limited value to nocturnal species, but would be an asset to a species active by day, such as the white shark. Attacks have occurred from 0650 to 1935 hours; with one exception, all took place during daylight hours (see Chapter 21, by Strong). The attacks correspond to recreational use of the sea, with a peak in late morning, 1100–1200 hours. Attacks are spread throughout the afternoon, peaking in the late afternoon, 1530–1659 hours (Fig. 5).

Color

Of the 21 divers attacked by white sharks, 16 (76%) were wearing black wet suits. Eleven (61%) of the 18 surfers were using white boards; three surfboards and the paddleski were blue. However, most surfboards manufactured in South Africa are white (with blue a close second), and the majority of divers wear black wet suits.

Water Visibility

Water visibility is of little importance to swimmers or board riders. However, because good visibility is a

requisite for divers and their face masks permit good vision underwater, divers are more likely to be aware of sharks in the area and are better equipped to take evasive or defensive actions when threatened: 86% of the divers sustained no injuries or minor injuries, compared with board riders (63%) and swimmers (35%).

Distance From Shore and Depth of Water

Among attacks on swimmers, 63% took place <50 m from shore (Fig. 6), and 43% occurred in water <2 m deep (Fig. 7). Among board riders, 60% clashed with the sharks >50 m from shore, and 90% of the attacks occurred in waters 2–5 m deep. Seventy-six percent of the divers encountered the sharks ≥ 100 m from shore. Of significance, however, is that only one incident involving divers (case 400) took place below the surface. Although their activity was described as “diving” when attacked, 20 (95.2%) of the 21 individuals in this category could be considered “swimmers” wearing face masks, although 7 (35%) of the 20 were carrying or towing bleeding fish.

Environmental Factors

In most cases, environmental factors that may have contributed to the attack were present. In 59

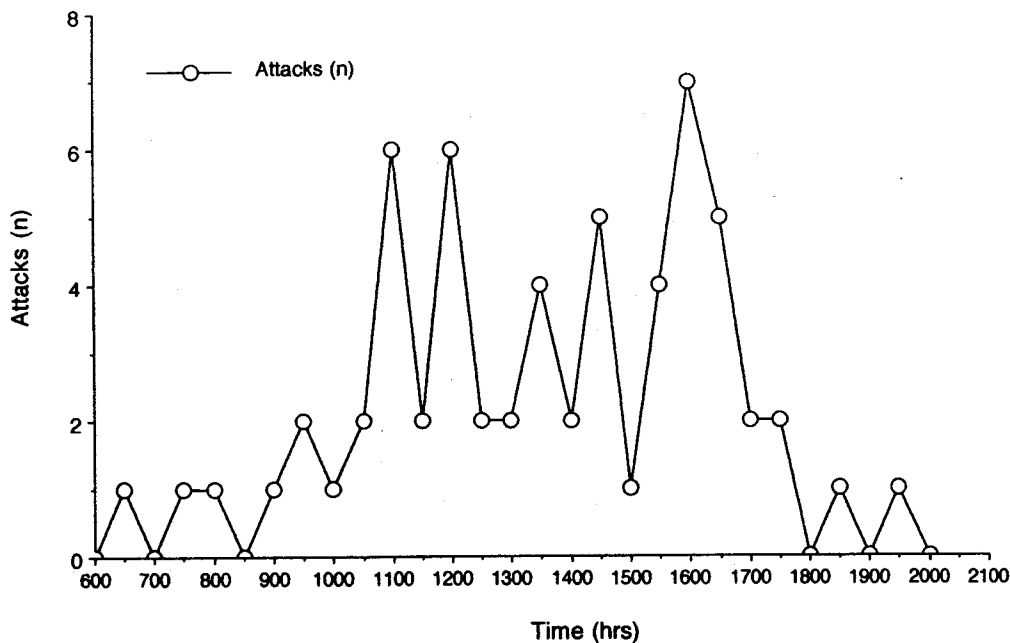


FIGURE 5 The time of day when attacks attributed to white sharks have occurred in this study.

cases, the following environmental factors were present: local rivers were in flood or sewage and/or effluent was present in at least 14; 14 attacks took place close to kelp beds, on a reef, adjacent to an estuary, or near an upwelling of cold water; 15 took place in the vicinity of a pinniped rookery or haul-out; and in 14,

marine mammals were observed in the immediate vicinity close to the time of the attack. In 19 cases, shoals of fish were in the area or there was some fishing activity. The above are elements of habitats favorable to white sharks; some reflect a favorable transitory condition, but in the absence of control

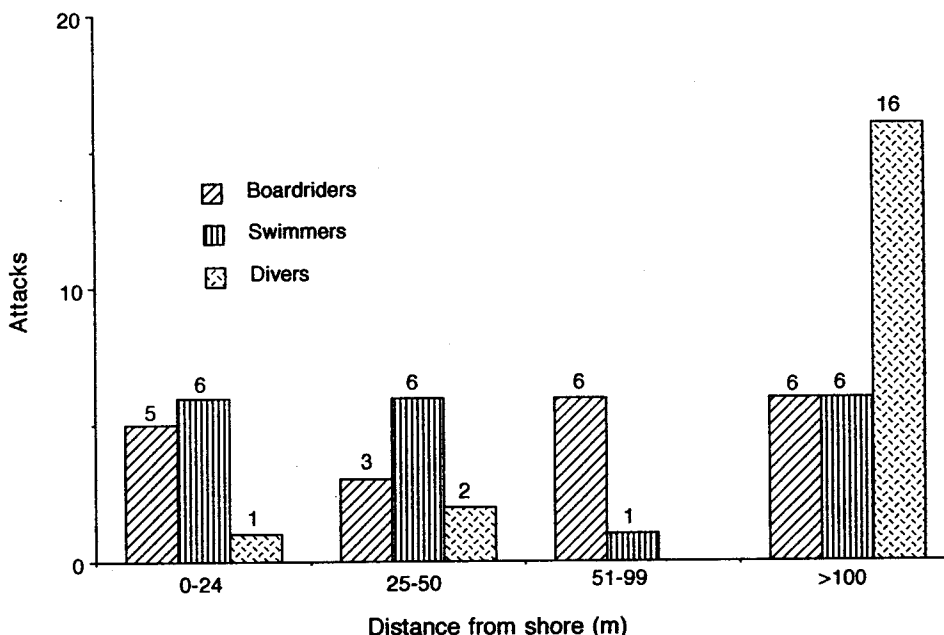


FIGURE 6 The distance from shore in 58 white shark attacks: 63% of attacks on swimmers ≤ 50 m from shore; 60% on boardriders ≥ 50 m from shore; 84% on divers ≥ 100 m from shore.

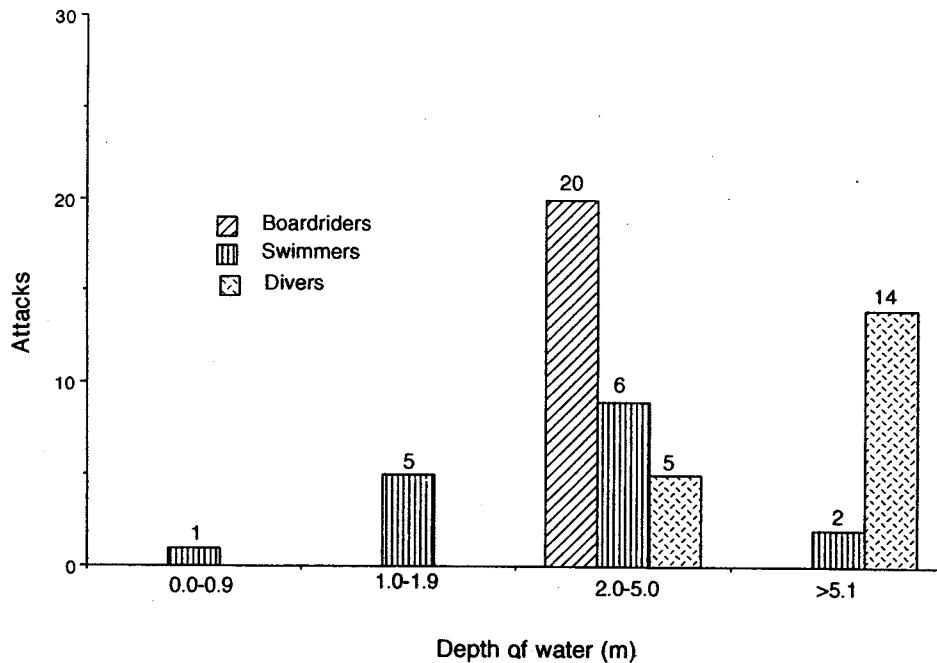


FIGURE 7 The depth of water at attack sites when known: 43% of attacks on swimmers occurred in water <2 m deep.

data (days in which the same conditions exist and no attack takes place), it is not possible to establish the degree of risk these factors represent.

Extent of Injuries

Most of the injuries sustained by the victims were on their body extremities (Fig. 8). Fifteen attacks (23.8%) proved fatal. In 9 cases (14.3%) in which injuries are described as "major," the injury was life-threatening, a significant amount of tissue was removed by the shark, or the injury was so severe that it resulted in permanent disability and/or surgical amputation of a limb. In most cases, the attackers caused far less injury than they were capable of delivering in the course of normal predation. In 29 cases (46%), the victims sustained minor injuries (with no tissue loss); 10 (15.9%) individuals received abrasions and/or bruises, or their sporting gear was bitten.

Hazard to Rescuers

In this study, there are no cases in which the attacker actually bit a rescuer attempting to bring a victim to shore, but in a few instances, rescuers sustained abrasions from the rough skin of the shark. Like many other predators, white sharks appear to

concentrate solely on the selected prey item. However, there was one instance in this study in which a white shark, deprived of its initial victim, attacked a second victim with increased aggression. The first victim (case 410), a surfer, managed to repel the shark and escaped by remounting his board and catching a

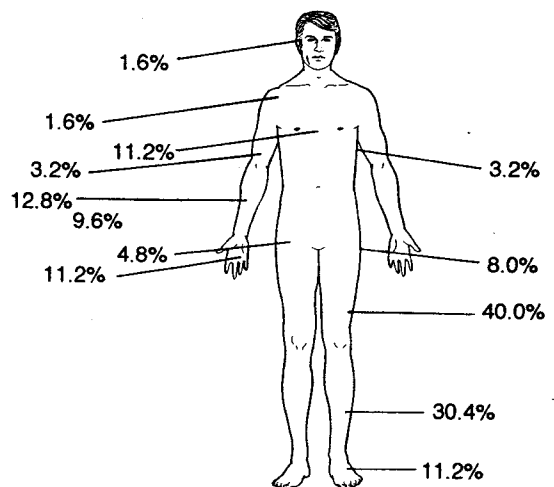


FIGURE 8 Areas of the body injured during unprovoked attacks. The high number of injuries on the hands, forearm, lower legs, and feet include defensive wounds sustained in repelling the sharks. Note that the total exceeds 100% because in some cases more than one body part was bitten.

wave inshore; seconds later, the shark attacked another surfer (case 411) and severed his leg. The same behavior was noted in an attack on March 23, 1994, off Easter Island in the Pacific Ocean; moments after a white shark was repelled by the first victim, it attacked a second victim and severed her leg (see Chapter 39, by McCosker and Lea). This behavior is not confined to white sharks. On February 13, 1974, in KwaZulu-Natal, a carcharinid shark lacerated the shin of a swimmer and was kicked away. A moment later, it bit another swimmer and removed a large amount of tissue, which led to surgical amputation of his lower leg (Wallett, 1983).

Characteristics of White Shark Predatory Attacks

In 43 (74%) of 58 cases in which the direction of approach is known, the shark approached from behind and/or below the victim (Fig. 9). In some cases in which the shark approached from behind or below, the victims suffered tissue loss. This suggests that these attacks may have been motivated by hunger, rather than curiosity.

In 23 cases (36.5%), it appeared that the shark may have intended to feed on the victim. In 5 of the cases, the shark submerged the victim and the body was not recovered. It was assumed that the victims drowned or were exsanguinated (Klimley, 1994) and were at least partly consumed by the shark (Table I).

TABLE I Attacks in Which the Body
Was Not Recovered

| Case no. | Disoriented by shark | Disabled by shark | Submerged by shark | No. of bites | Type of injury | TL (m) |
|----------|----------------------|-------------------|--------------------|--------------|----------------|--------|
| 067 | Yes | Yes | Yes | 2 | Fatal | 4.5 |
| 079 | No | Yes | Yes | >2 | Fatal | |
| 097 | Yes | Yes | Yes | 2 | Fatal | 3.6 |
| 300 | Unknown | Yes | Yes | >3 | Fatal | 2.4 |
| 378 | Unknown | Yes | Yes | >1 | Fatal | |

TL, Total length.

In another 10 cases, the shark removed a considerable amount of tissue from the victim. All of these victims sustained a forceful initial bite that reduced their ability to escape, a strategy also recorded by Tricas and McCosker (1984) and McCosker (1985). All but 1 of the victims were either catapulted above the water and/or submerged by the shark. Five of the victims sustained multiple bites, and 6 died from their injuries (Table II).

There are 8 additional cases in which the behavior of the shark suggests an aborted feeding attempt; in all of these cases, the victims sustained an initial disabling bite. Six of the 8 victims were carried underwater by the shark, and 3 were struck with such force they were temporarily rendered incapable of resistance (Table III).

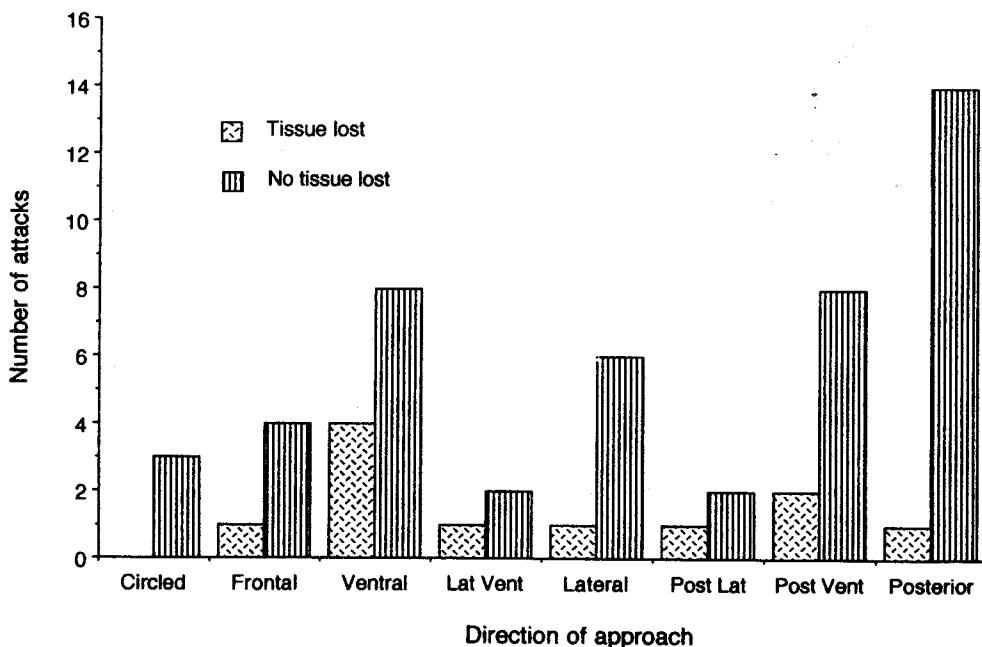


FIGURE 9 The direction of approach by the shark. In 42 cases, the shark approached from behind and/or below the victim. Lat Vent, Lateral ventral; Post Lat, posterior lateral; Post Vent, posterior ventral.

TABLE II -Attacks Resulting in Tissue Loss

| Case no. | Disoriented by shark | Disabled by shark | Submerged by shark | No. of bites | Type of injury | TL (m) |
|----------|----------------------|-------------------|--------------------|--------------|----------------|--------|
| 049 | Yes | Yes | No | >1 | Fatal | 3.0 |
| 106 | No | Yes | No | 1 | Major | 2.8 |
| 122 | Yes | Yes | No | 3 | Fatal | |
| 137 | Yes | Yes | Yes | 3 | Major | 2.2 |
| 140 | Yes | Yes | No | >1 | Fatal | |
| 208 | No | Yes | Yes | >3 | Fatal | |
| 285 | Yes | Yes | No | 1 | Major | |
| 333 | Yes | Yes | Yes | 1 | Major | |
| 386 | No | Yes | Yes | 1 | Fatal | 4.5 |
| 411 | Yes | Yes | No | 1 | Fatal | 4.0 |

TL, Total length.

Discussion

Nature of Predatory Attacks

In 11 of the 23 cases listed in Tables I-III, the shark used its mass to ram and stun the victim. Despite its large size, a shark may weigh little when submerged, due to the buoyancy afforded by displacement of seawater and the oil held in its liver. McCosker (1985) observed that once a prey is sighted, the white shark rapidly ascends and at close range (i.e., less than one-half body length) begins one of several modal action feeding patterns. A transmitter placed on a white shark indicated that it had an average cruising speed of 3.2 km/hour (Carey *et al.*, 1982), but white sharks are capable of short bursts of speed in excess of this (my own unpublished observation; S. D. Anderson,

TABLE III Attacks With No Tissue Lost

| Case no. | Disoriented by shark | Disabled by shark | Submerged by shark | No. of bites | Type of injury | TL (m) |
|----------|----------------------|-------------------|--------------------|--------------|----------------|--------|
| 043 | No | Yes | Yes | 1 | Minor | 3.6 |
| 210 | No | Yes | Yes | 1 | Minor | 2.9 |
| 254 | No | Yes | Yes | 1 | Minor | 4.0 |
| 272 | Yes | Yes | Yes | 1 | Fatal | 2.7 |
| 338 | Yes | Yes | No | 2 | Major | 2.5 |
| 373 | No | Yes | Yes | 1 | Major | >3.0 |
| 381 | No | Yes | Yes | 1 | Major | 5.5 |
| 410 | Yes | Yes | No | 1 | Minor | 4.0 |

TL, Total length.

personal communication). The mass and speed provide momentum, which permit the shark to apply considerable force to prey, stunning or immobilizing it.

The amount of kinetic energy in a moving object is $(\frac{1}{2})MV^2$, where M represents mass and V indicates velocity). A shark of a mass M_s moving at a velocity V_s impacts the prey mass, M_p , and gives it a velocity V_p . In the simplest scenario, a shark strikes the ventral section of prey resting on the surface of the water. Kinetic energy is transferred to the prey. The prey has a velocity upward V_p , which is counteracted by the force of gravity ($g = 9.8$ m/sec), and the prey reaches a maximum height H above the water surface: $V_p = V_s \times (M_s/M_p)^{\frac{1}{2}}$.

Conservation of kinetic energy gives $M_p \times V_p^2 = M_s \times V_s^2$. For example, a shark with a mass of 700 kg, traveling at a speed of 3.2 kph, impacts prey that has a mass of 70 kg. When we know V_s , we can calculate V_p , as $V_p^2 = 10 V_s^2$. Next, we can determine H , as $H = V_p^2/2g = 0.334V_s^2$ (Fig. 10). When the charge of the shark is halted by impact, its kinetic energy is transferred to the prey. And, when the prey is on the surface, the prey may be flung well above the surface of the water.

In at least 11 cases, the shark indeed moved upward at such velocity that, upon impact, the victim was flung out of the water. When this happens, the energy of impact is absorbed, to some degree, by the victim's body. The effect of such contact on human tissue varies considerably. The skin is pliable, strongly resistant to traction forces, and is unlikely to be damaged if the victim is wearing a wetsuit (the rough hide of the shark would, however, cause an abrasion on unprotected skin, as it did in case 140). The subcutaneous tissue cushions the effect of the impact and the elastic muscles usually escape damage, but air in the lungs may be violently compressed. At the very least, the victim is momentarily disoriented and incapable of effective resistance.

In addition to the 12 fatalities listed in Tables I-III, there were 3 other fatal attacks. The victims in cases 063 and 353 sustained a single bite on a flexed leg, but in each, an artery was severed and there was a delay in reaching shore; both died en route to a hospital. In case 062, the victim was swimming alone when his leg was bitten. He reached shore unaided, collapsed on the beach, and died in the hospital 23 hours later.

On the south coast of KwaZulu-Natal, there were also 2 cases, 16 days apart, in which the victims suffered major injuries, but no tissue was removed by the sharks. In case 143, Davis and D'Aubrey (1961b) reported that the shark made a series of "tentative" bites. The shark had ample opportunity to remove tissue from the 1.47-m victim, but it did not. Unfor-

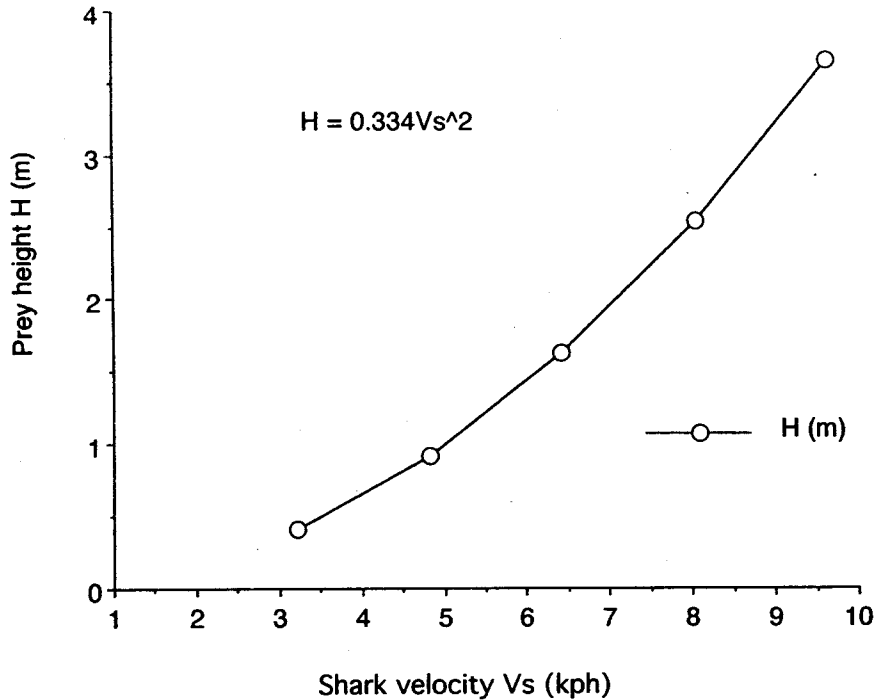


FIGURE 10 The height that a 700-kg shark may fling a 70-kg prey floating stationary, at first, on the surface.

unately, the victim's foot was virtually severed by the shark, and subsequently amputated. In case 144, the shark made a single bite on the victim's flexed leg. Three days later, after an arterial graft failed, the leg was surgically amputated. In both of these cases, the sea was turbid and rivers were in flood; case 144 took place near a channel, and in case 143, the victim was standing on a rock on the rim of a channel. The attacks occurred 27 and 33 km south of Durban in 1961, and it may be worth noting that in 1961 sei whale abundance off Durban, as measured by both catch and sightings data, was at its highest in 14 years (*Union Whaling Company Annual Report, 1962*).

When examining white shark attacks in KwaZulu-Natal it is helpful to be aware of factors that impact on the nearshore marine environment: the annual sardine run, shore-based whaling (1908–1975), the shark-fishing industry (1928–1932), and shark nets (1952–1994). These factors are reviewed below.

Sardine Run

Each summer, vast shoals of sardines *Sardinops ocellata* appear in the northernmost sector of the eastern Cape, and they follow the cold inshore countercurrent northward. The sardines, in turn, provide fodder for hordes of predatory fish: *Pomatomus saltatrix*, *Scomber japonicus*, *Auxis thazard*, *Atractoscion aequidens*, *Thryssa vitrirostris*, *Scomberomorus plurilineatus*, *Trachurus capensis*, and *Lichia amia*; dolphins: *Tursiops ad-*

uncus, *Delphinus delphis*, and *Sousa plumbea*; birds: *Sula capensis*; and sharks: *C. carcharias*, *Isurus oxyrinchus*, *Galeocerdo cuvier*, *Carcharias taurus*, *Carcharhinus leucas*, *C. obscurus*, *C. plumbeus*, *C. brachyurus*, *C. limbatus*, *C. brevipinna*, *Sphyrna mokarran*, *S. zygaena*, *S. lewini*, and *Rhizoprionodon acutus* (Wilson, 1985). The sardine shoals move into southern KwaZulu-Natal coastal waters around June or July. Often, pockets of 1 million fish or more run close inshore, where wind and current drive them into the surf zone. The Natal Sharks Board attempts to remove their nets before the shoals move close to the beach, but during the 1971 run, over 1000 sharks were removed from the nets in 10 days (Wallett, 1983). One of the earliest recorded shark attacks in KwaZulu-Natal occurred during the sardine run of 1897, when a young boy wading after stray fish was taken by a shark, species unknown.

Shore-Based Whaling

There were shore-based whaling stations in KwaZulu-Natal from 1908 to 1975. In that 67 year period, a whale-processing plant was located 60 km south of Durban at Park Rynie, and as many as six whale-processing plants were operating at the same time on Durban's "Bluff," a large sand spit at the harbor entrance (Ellis, 1991). Of the 30 shark attacks (Davies, 1964) at Durban beaches between 1908 and 1975, 2 (cases 097 and 107) involved white sharks at the beach adjacent to the harbor entrance.

Whale-catcher boats towed the dead whales to processing plants along the coast, accompanied by large sharks that fed on the whale carcasses. Of the 33 shark attacks that took place along the catcher boats' inshore route up the southern KwaZulu-Natal coast, at least 8 involved white sharks (cases 062, 063, 106, 122, 137, 140, 143, and 144; Davies, 1961; Davies and D'Aubrey, 1961a,b; Walleit, 1973, 1983; Levine, 1996).

In 1954, the whaling industry became more efficient; spotter planes were used to locate whales (Ellis, 1991). In addition to the southern route, catcher boats were towing dead whales to Durban down the northern coast as well (K. Pinkerton, personal communication). Two white shark attacks on spear fishermen (cases 165 and 195) occurred 24 and 32 km north of Durban in 1963 and 1967, respectively.

In 1967, the Durban-based Union Whaling Company reported that their catches of baleen whales had plummeted, resulting in severe financial loss. The next year, the company reduced its fleet and personnel by 50%, concentrated on sperm whales, and turned a small profit. (*Union Whaling Company Annual Report*, 1968). Stocks of sperm whales remained unchanged, and whaling was profitable until 1975. As company policy, Union Whaling Company had decided that whaling would be abandoned before sustained financial losses occurred. The rise in fuel prices in the mid-1970s resulted in a decision to cease whaling in 1976.

In 1967, when the whalers recorded the decline in baleen whales, the shark anglers of Durban also noted a sudden decline in large white sharks. From 1947 to 1975, the Bowman Trophy was awarded annually for the heaviest shark landed by a shore-based fisherman in South Africa (Mara, 1985). Without exception, the trophy shark was caught with whale meat bait and landed 2 km from the whale-processing plant at Durban's South Pier. For 19 years, 1947-1966, all but one of the Bowman Trophy winners was a white shark (Fig. 11). During the next 8 years, 1967-1975, only one was a white shark, and when whaling ceased in 1975, the shark anglers caught no more trophy sharks off South Pier.

Shark Fishing Industry

Shark attacks were recorded in KwaZulu-Natal prior to establishment of the shore-based whaling industry in Durban in 1908; in 1907, the city erected a large bathing enclosure to protect bathers from sharks (Davies, 1963). By the time the enclosure was demolished in 1928, an intensive shark-fishing industry had developed alongside the whaling factories on Durban's Bluff. One company processed 6681 sharks in the first 10 months of operation (*Natal Fisheries Department Annual Report*, 1931). The floating factory

ship of another company was capable of dealing with 500 sharks per day (Archives of the Local History Museum, Durban; *Saturday Magazine*, July 15, 1939). By 1932, stocks of resident species were depleted, the industry collapsed, and the shark-fishing fleet was scuttled (*Natal Advertiser*, November 11, 1932). Shark stocks began to recover in the 1940s, and shark-human encounters increased off Durban beaches until 1952, when barrier nets were installed (Davies, 1964).

Shark Nets

During the 1957-1958 holiday season, no swimmers were attacked by sharks at Durban, but there were 8 shark attacks at beaches south of the city. As a result, a number of coastal resorts installed gill nets and protective barriers. In time, their maintenance became a financial burden to the local authorities, and in 1964, the Provincial Government created the Natal Anti-Shark Measures Board (now the Natal Sharks Board) to supervise the installation and maintenance of the shark nets (Walleit, 1973; Compagno, 1987). As the number of coastal resorts grew, the number of net installations increased, but the catch per unit of effort of white sharks declined between 1966 and 1990 (Cliff, 1991). From 1974 to 1988, annual catches of white sharks ranged from 22 to 61, or 2.7% of the total species caught in the nets (Cliff *et al.*, 1989). To date, however, there has been only one white shark attack (case 285) at a netted beach (Walleit, 1983). Although it is not possible to measure the degree to which shore-based whaling and the annual sardine run have contributed to shark attacks in KwaZulu-Natal, nor the degree that shark fisheries and shark nets have contributed to the reduction of shark attacks, it is probable that all have had significant roles.

In KwaZulu-Natal, the earliest attack in which white shark involvement could be confirmed took place in 1940. Between 1940 and 1975, there were at least 22 white shark attacks in South African waters: 12 (55%) were in KwaZulu-Natal and 10 (45%) in the Cape provinces. When whaling ceased in 1975, shark nets had already been installed at 39 beaches in KwaZulu-Natal (Walleit, 1983). With the cessation of shore-based whaling, statistics changed dramatically; from 1975 to 1994, there were 39 white shark attacks—only 3 (8%) were in KwaZulu-Natal, and the remainder (92%) were in the Cape provinces.

Attacks on Swimmers

Following the installation of gill nets and the cessation of whaling, white shark attacks on swimmers ceased in KwaZulu-Natal, although there were 7 unprovoked attacks by other shark species. The last white shark attack on a swimmer in Cape waters took

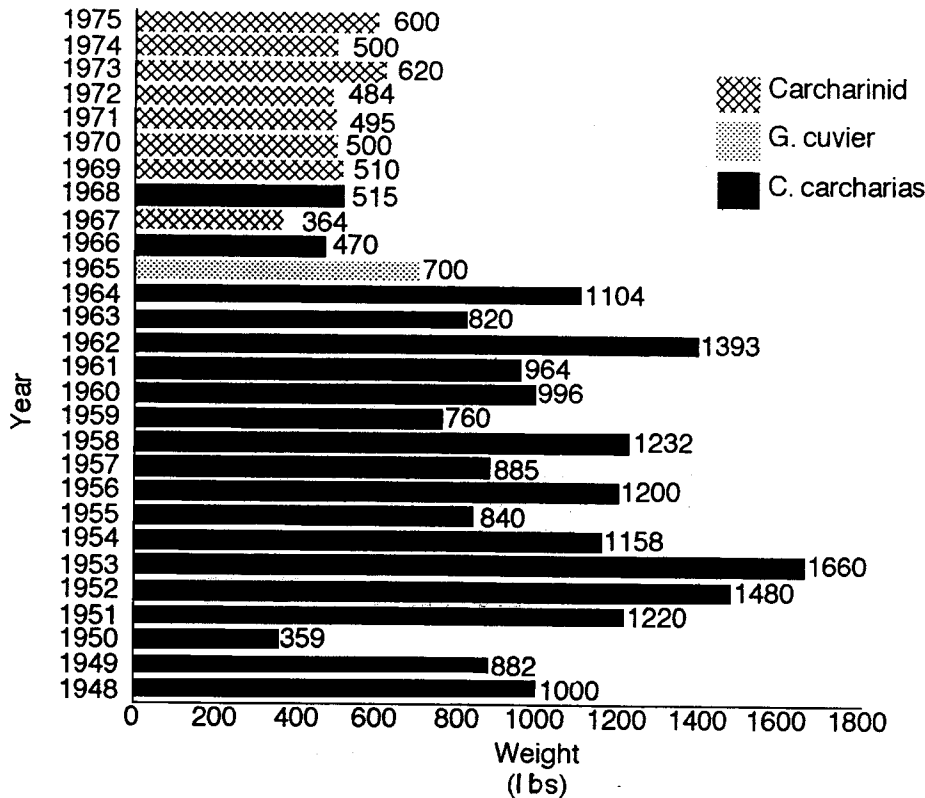


FIGURE 11 The size and species of the largest shark caught in the Bowman Trophy shark derby, by year. *G. cuvier*, *Galeocerdo cuvier*; *C. carcharias*, *Carcharodon carcharias*. All of these sharks were caught at Durban.

place in 1976, but since that time, there have been 12 attacks on swimmers by other species (Levine, 1996).

Attacks on Divers

Despite the increasing popularity of diving in the subtropical waters of KwaZulu-Natal, there have been no white shark attacks on divers since 1978. This suggests that there are fewer white sharks in the areas where diving activity has been taking place. In KwaZulu-Natal, diving takes place seaward of the shark nets, but there are no pinniped rookeries or haul-outs in the province. There have been 3 white shark attacks on divers in Natal; 2 occurred prior to 1975, and 1 took place in 1978. By comparison, there were 2 white shark attacks on divers in Cape waters prior to 1975, and 17 attacks from 1976 to 1994.

Compared to spear fishing, scuba diving was slow to develop as a sport in South Africa. By the mid-1960s, the SAUU was training divers, and by the late 1970s, international certification agencies (NAUI, PADI, and CMAS) were active in the country. Although there are no official statistics, Tim Condon (personal communication), publisher of South Africa's dive magazine *Underwater*, estimates that there are 100,000 active free divers and spear fishermen,

and 20,000–25,000 scuba divers. In this study, the ratio of attacks on free divers and spear fishermen to scuba divers is 19:2. However, all of the free divers and spear fishermen were on the surface when attacked. This was true, too, of one scuba diver, who suffered severe blood and tissue loss during the attack, and died soon afterward. The other scuba diver (case 400) was submerged and was not injured when the shark mouthed his tank. In 8 (38%) of the cases involving divers, the victim described the behavior of the shark as "investigatory." These include cases 355 and 370, in which a shark grabbed a diver's hand/forearm, towed him along the surface for a short distance, and then departed; both incidents involved a 2.5-m white shark, but they took place 856 days and 440 km apart.

Attacks on Board Riders

In the late 1960s, the surfing beaches of South Africa gained international fame, and as the numbers of surfers, bodyboarders, and windsurfers increased, so did shark attacks involving board riders. In part, the increase may be due to insulated clothing, which permits board riders (and divers) to remain in the water for extended periods and, in part, also due to the

evolution of surfboard design. Early surfboards were long and cumbersome, but they offered protection from sharks because the surfer's entire body remained atop the board. In the early 1970s, shorter boards came into vogue, and surfers sustained more severe injuries from sharks. Body boarders fared even worse; their boards offered little or no protection whatsoever from a shark. Of the three bodyboarders in this study, one was killed by the shark, and two sustained major injuries.

Increased Survival Rates of Victims

Due to improved trauma care protocols, today's shark attack victims have a higher rate of survival than those attacked earlier in this century. In December 1957, a special trauma kit for the treatment of shark attack victims came into use in South Africa (Wallett, 1983). Known as the Feinberg Pack, after the doctor who devised it, these kits were kept at all beaches served by the Surf Life Saving Service, and lifeguards were trained in their use. The kit contains equipment to stop arterial bleeding, and intravenous fluids to prevent shock. Oxygen is also available at all Surf Life Saving stations. Prior to the introduction of the Feinberg Pack, 54.6% of the victims attacked by white sharks died of their injuries. From 1958 to 1994, only 17.3% of the attacks proved fatal.

Future Efforts

Of the 225 shark attack victims previously mentioned, 75% did not suffer any tissue loss; and in the 63 cases involving white sharks, 62% of victims sustained no such loss. This supports Baldridge's (1988a) hypothesis that in some cases hunger is not the causal factor in an attack. In virtually all cases, however, the victim immediately ceased his or her activity. The victims in this study were spearfishing, diving, surfing, swimming, floating, treading water, wading, or standing in the water. However, we have defined these activities, not the shark. We need to decipher what the shark perceives. If born blind, we cannot truly understand color; born deaf, we cannot experience a symphony; and born without an electric sense, we are ill equipped to comprehend the integral sensory information provided to the shark. However, we can grasp some general principles (Levine, 1994).

Shark attacks may have a devastating financial impact on communities that rely heavily on tourism. Because attacks are rare, it has been difficult to assemble a useful database to counter public hysteria (Gifford, 1993). A multidisciplinary approach to the subject is needed; attacks must be actively investigated and input must be assembled from forensic scientists,

medical practitioners, marine biologists, shark taxonomists, shark ethologists, and commercial fishermen. Victims and witnesses must be interviewed, environmental data gathered and assessed, the sequence and extent of injuries require interpretation by a forensic scientist, and the species of attacking shark needs to be identified. Through interdisciplinary cooperation, it may be possible to identify factors that predispose attack or that trigger attacks. Achieving insights into shark attacks is by no means the same as discovering effective means of preventing attacks, but it is one of the requisite conditions. However, we have learned some ways of lessening the risk of an attack: high-risk areas and seasons can be identified, and recreational use of the sea can be restricted when the risk of shark attack is highest.

Summary

White sharks *C. carcharias* were involved in 63 of 225 unprovoked shark attacks off the South African coast during 72 years, 1922–July 1994. Victims included 18 surfers, 3 bodyboarders, 1 paddleskier, 16 spear fishermen, 3 skin divers, 2 scuba divers, and 20 swimmers. Fifteen of the attacks were fatal, and 9 other victims suffered major injuries. In 29 cases, the victims were bitten, but sustained no tissue loss. In another 10 cases, the individuals sustained bruises and abrasions, or their sporting gear was damaged by the shark. By geographic area, most attacks took place in the temperate waters of the Western Cape (N = 31); others occurred off the Eastern Cape (N = 17) and in the subtropical seas of KwaZulu–Natal (N = 15).

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APPENDIX 1 White Shark Attacks along the Coast of South Africa

| Case no. | Name of victim | Sex | Age | Activity ^a | Date of attack | Location of attack | Time of attack (hrs) | SST ^a (°C) | Water visibility (m) | Injury | Location of bite | Method of species ident. ^a | Size of shark (m) |
|----------|----------------|-----|-----|-----------------------|----------------|----------------------------|----------------------|-----------------------|----------------------|--------|--------------------|---------------------------------------|-------------------|
| 043 | Pells | M | 18 | SW | May 6, 1922 | Simon's Town, False Bay | A.M. | ? | Clear | Minor | Abdomen, thigh | T, W | 3.6 |
| 049 | Heyns | M | 17 | SW | Dec. 28, 1927 | Little Brak River | 1100 | Warm | Clear | Fatal | Leg | W, A | 4.4 |
| 052 | LeRoux | M | 23 | SW | Jan. 16, 1930 | Meikbaai, False Bay | 1730 | ? | ? | Minor | Torso, arm | W, B | |
| 062 | Lund | M | 17 | SW | Feb. 22, 1940 | Amanzimtoti | 1630 | 23.8 | Clear | Fatal | Thigh, knee | B | |
| 063 | Lees | M | 25 | SW | March 31, 1940 | Winkelspruit | 1100 | ? | Clear | Fatal | Calf | B | |
| 067 | Bergh | M | 18 | SW | Nov. 1, 1942 | Clifton | 1230 | Cold | Clear | Fatal | Body not recovered | W | 4.5 |
| 079 | Schmidt | M | 17 | SW | Jul. 22, 1944 | Hartenbos | 1630 | Warm | ? | Fatal | Body not recovered | W | |
| 097 | Dumayne | M | 14 | SW | Feb. 11, 1950 | Durban | 1430 | ? | None | Fatal | Body not recovered | W | 3.7 |
| 106 | Plowman | M | 24 | SW | Nov. 28, 1951 | Winkelspruit | 1715 | ? | Clear | Major | Leg severed | W | 2.4 |
| 107 | Tait | M | 23 | SW | Nov. 29, 1951 | Durban | 1300 | ? | Turbid | Minor | Thigh abraded | W | 1.8 |
| 114 | Smith | M | 29 | SK | Oct. 27, 1956 | Glencairn, False Bay | ? | 18* | Clear | Minor | Foot | W | |
| 122 | Prinsloo | M | 42 | SW | Jan. 9, 1958 | Scottburgh | 0730 | ? | None | Fatal | Multiple | W, A | ** |
| 129 | Schreuder | M | 18 | SW | Jan. 15, 1959 | Meikbaai, False Bay | 1615 | 19* | Clear | Minor | Thigh | W | 1.9 |
| 137 | Hely | M | 16 | SW | April 30, 1960 | Amanzimtoti | 1535 | 23.0 | <1.0 | Major | Multiple | B | 2.1 |
| 140 | Sithole | M | 25 | SW | Dec. 24, 1960 | Margate | 1630 | 24.0 | Poor | Fatal | Legs severed | T | 3.0 |
| 143 | Land | M | 13 | SW | Jan. 6, 1961 | Winkelspruit | 1935 | 24* | Turbid | Major | Legs | B | |
| 144 | Murphy | M | 15 | SW | Jan. 22, 1961 | Amanzimtoti | 1420 | 26.1 | Turbid | Major | Thigh | B | |
| 165 | Passmore | M | 24 | SP | Jan. 6, 1963 | Umdloti | 1600 | 21.0 | 6.5 | Minor | Arm | B | |
| 169 | Coetzee | M | ? | SP | Dec. 20, 1963 | Hartenbos | 1200 | ? | 6.0 | Minor | Foot | W, B | 1.7 |
| 195 | Jones | M | 32 | SP | Mar. 19, 1967 | Paradise Reef | 0650 | 21* | 7.0 | Minor | Buttock/fish | W | 3.0 |
| 208 | Klein | M | >50 | SW | April 11, 1971 | Buffels Bay | 1100 | Cold | 3.5 | Fatal | Multiple | W, B | |
| 210 | Scheltema | M | 21 | SU | Jun. 30, 1971 | Mossel Bay | 1535 | 16.4 | Clear | Minor | Leg/surfboard | T, W, B | 2.9 |
| 213 | Teague | F | 16 | SW | Dec. 16, 1971 | Fish Hoek, False Bay | 1445 | 19.5 | Clear | Minor | Forearm | W, B | 3.0 |
| 218 | Brink | M | ? | SW | Dec. 24, 1972 | Hartenbos | 0900 | Cool | 1.5 | None | Swim fin | W, B | >3.0 |
| 246 | Robertson | M | 19 | SU | Aug. 17, 1975 | Cape St. Francis | 1330 | 16* | Clear | Minor | Leg/surfboard | B | 2.5 |
| 254 | Flanagan | M | 20 | SU | Oct. 6, 1976 | Cape St. Francis | 1100 | Cold | >3.0 | Minor | Thigh/surfboard | T, B | 3.5 |
| 258 | Spence | M | 19 | SW | Nov. 27, 1976 | Clifton | 1605 | 17.0 | 30.0 | Minor | Torso | W, B | 3.0 |
| 263 | Hartman | M | 25 | SP | Oct. 30, 1977 | Partridge Point, False Bay | 1600 | ? | 5.0 | None | Fish | W | 5.0 |
| 270 | Lombard | M | 27 | SP | Sep. 27, 1978 | Miller's Point, False Bay | 1600 | Warm | 6.0 | None | Fish | W | 3.7 |
| 272 | Steenkamp | M | 23 | SP | Dec. 12, 1978 | Sodwana | 1645 | cold | 12.0 | Fatal | Legs | T, W | 2.3 |
| 285 | Wright | M | 24 | B | Jan. 31, 1980 | Ballito | 1445 | 25.0 | 5.5 | Major | Foot | B | 2.8 |
| 300 | Macun | M | 27 | SU | Jun. 29, 1982 | Ntlonyana | 0930 | Warm | Clear | Fatal | Surfboard, No body | W, B | 2.4 |
| 301 | Plumb | M | 38 | P | July 24, 1982 | Nahoon, East London | 1600 | 16* | Turbid | None | Paddleski | T | 2.4 |
| 303 | Fawkes | M | 16 | SU | Sep. 30, 1982 | Nahoon, East London | 1450 | 17.0 | 3.0 | None | Surfboard | B | 2.8 |

(continues)

APPENDIX 1 (Continued)

| Case no. | Name of victim | Sex | Age | Activity ^a | Date of attack | Location of attack | Time of attack (hrs) | SST ^b (°C) | Water visibility (m) | Injury | Location of bite | Method of species ident. ^a | Size of shark (m) |
|----------|----------------|-----|-----|-----------------------|----------------|---------------------------|----------------------|-----------------------|----------------------|--------|------------------|---------------------------------------|-------------------|
| 316 | Louw | M | 29 | SP | Aug. 20, 1983 | Seal Island, False Bay | 1000 | 12* | 5.0 | Minor | Thigh | W | 5.0 |
| 328 | Doran | M | 27 | SU | Jun. 15, 1984 | Muizenberg, False Bay | 1730 | 12* | Turbid | None | Surfboard | T, W | 2.4 |
| 332 | James | M | 34 | SP | Jan. 4, 1985 | Buffels Bay, False Bay | 1130 | 20* | 10.0 | Minor | Torso | W, B | 3.5 |
| 333 | Eldridge | M | 18 | SU | Jan. 17, 1985 | Umbogintwini | 1830 | 25* | 1.0 | Major | Thigh, calf | T, W | 2.5 |
| 338 | Gee | M | 22 | B | Oct. 24, 1985 | East London | 0800 | 17.0 | 4.0 | Major | Thigh, calf | T, B | >2.4 |
| 344 | Carcary | M | 21 | SU | Feb. 18, 1986 | East London | 1200 | >22.0 | 6.0 | None | Surfboard | W | |
| 349 | deBruyn | M | 35 | SP | Aug. 10, 1986 | Geyser Island | 1100 | Cold | 20.0 | None | Fish | W | |
| 353 | Olls | M | 21 | B | Dec. 22, 1986 | SAOU Strand | 1700 | 21.0 | 6.0 | Fatal | Thigh/calf | B | 3.0 |
| 355 | Botha | M | 30 | SP | Jan. 28, 1987 | Eerste Rivier | 1200 | 20* | 8.0 | Minor | Hand, fish | W, B | >2.5 |
| 356 | McCallum | M | 24 | SU | Sep. 13, 1987 | Still Bay | 1100 | 21* | Clear | Minor | Torso | B | 3.5 |
| 359 | Smit | M | 21 | SP | Oct. 11, 1987 | Seal Island, False Bay | 1215 | 15* | 7.0 | Minor | Thigh, calf | W, B | |
| 367 | v.Rensburg | M | 36 | SP | Jun. 19, 1988 | Skulphoek | 0945 | 14* | 9.0 | Minor | Arm | W, B | |
| 370 | Krouse | M | 28 | SK | Jun. 3, 1989 | Gonubie | 1530 | 17* | >2.0 | Minor | Forearm | W, B | 2.5 |
| 371 | Jacobs | M | 16 | SU | July 5, 1989 | Jeffreys Bay | 1615 | 22.0 | >1.0 | None | Surfboard | W, B | 3.0 |
| 372 | Razanno | M | 34 | SU | July 20, 1989 | Jeffreys Bay | 1035 | 14.0 | Turbid | Minor | Torso | B | 2.5 |
| 373 | v.Broembsen | M | 21 | SU | Aug. 22, 1989 | Mossel Bay | 1045 | ? | 2.0 | Major | Multiple | W, B | >3.4 |
| 377 | v.Niekerk | M | 29 | SP | Sept. 17, 1989 | Smitswinkel, False Bay | 1430 | 17* | 10.0 | Minor | Torso | B | |
| 378 | v.Niekerk | M | 29 | SK | Nov. 18, 1989 | Melkbosstrand | 1205 | ? | Clear | Fatal | Leg recovered | B | |
| 379 | Botha | M | 23 | SU | March 14, 1990 | Cape Recife | 1400 | 20* | 2.5 | Minor | Lower leg | B | 2.3 |
| 381 | Forrester | M | 22 | SU | May 6, 1990 | Cintisa | 1200 | 22.0 | 10.0 | Major | Thigh | T, W, B | 5.5 |
| 386 | Price | F | 21 | SC | Jun. 24, 1990 | Hartenbos | 1545 | 18* | 3.0 | Fatal | Thigh | W, B | 4.5 |
| 387 | Gasant | M | 26 | SP | Sep. 15, 1990 | Oudekraal | 1320 | 13* | 9.0 | Minor | Hand | W | 5.0 |
| 401 | Hayman | M | 20 | SP | Feb. 12, 1991 | Miller's Point, False Bay | 1230 | 16* | 6.0 | Minor | Foot | W | 5.5 |
| 400 | Marais | M | 32 | SC | May 19, 1991 | Gordon's Bay, False Bay | 1330 | 15* | 6.0 | None | Scuba tank | W | 3.5 |
| 405 | LeRoux | M | 28 | SU | July 30, 1993 | Port Elizabeth | 1500 | 16.0 | 1.5 | Minor | Torso, surfboard | W, B | 4.0 |
| 406 | Bouwer | M | 36 | SP | Sep. 26, 1993 | Danger Point | 1130 | 15* | 4.0 | Minor | Calf | W | 4.0 |
| 408 | Anderson | M | 15 | SU | Feb. 12, 1994 | Port Elizabeth | 1630 | 20* | 1.0 | Minor | Leg, surfboard | W, B | 3.0 |
| 410 | Carter | M | 31 | SU | July 9, 1994 | Nahoon, East London | 1335 | 17* | Turbid | Minor | Leg, surfboard | W, B | 4.0 |
| 411 | Corby | M | 22 | SU | July 9, 1994 | Nahoon, East London | 1336 | 17* | Turbid | Fatal | Leg severed | W, B | 4.0 |

^a Abbreviations: Activity, B = bodyboarder, P = paddleskier, SC = scuba diver, SK = skindiver, SP = spearfisherman, SU = surfer, SW = swimmer; temperature, SST = sea-surface temperature, method of species identification, A = artifacts from shark's gut, B = bite pattern, T = tooth pattern, W = witnesses.

*Estimated value.

**Body mass = 126 kg.