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Shark Attacks off the California Islands: Review and Update

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Abstract - Eight white shark attacks on divers are known to have occurred off San Miguel and the Farallon Islands. Details of all eight cases, compiled from personal interviews with victims, witnesses and/or attending physicians are presented. Island and mainland attacks are compared and the behavior of white sharks is discussed.

Introduction

The Farallon Islands off San Francisco and the northern Channel Islands off Santa Barbara have, for decades, provided excellent locales for divers to harvest, photograph, and observe marine organisms. However, this exploration has not been without risk for its participants. Usually errors in judgment or equipment malfunction have caused the few diving accidents reported from these locations. Although ever present, the threat of shark attack did not come to the forefront of public awareness until the mid-1970's when several shark "horror" films were released, in spite of four attacks having been reported from the Farallon Islands prior to that time.

Miller & Collier (1981) reported on 47 unprovoked cases of shark attacks on humans from the coasts of California and Oregon during the period 1926-1979. In their update, Lea & Miller (1985) described an additional 12 cases of shark attacks for the same geographical area. Diver incidents accounted for 34 (57%) of the 59 known shark attack cases which included six from California's islands. Specific details have been published for 16 of the 34 diver attacks, including three cases from the Farallon Islands (Fast 1955; Collier 1964, 1992;

Baldrige, 1974; Follett 1974; Lea & Miller 1985). The white shark, *Carcharodon carcharias*, was positively identified or highly suspect in 30 (88%) of the diver attacks. Since the documentation by Lea & Miller (1985) white shark attacks on divers have occurred at San Miguel Island and Southeast Farallon Island.

Subsequent to the three published Farallon Island shark attack cases additional data has been compiled from personal interviews with victims, witnesses, and/or physicians. To date, eight shark attacks have occurred at the Farallon and northern Channel Islands. They are presented chronologically by location.

Farallon Islands

The Farallon Islands (Fig. 1) are 23 nautical miles west of San Francisco. The nearest mainland is Bolinas Point, Marin County, 17.8 nautical miles northeast of the islands. Southeast Farallon consists of two large islands separated by a narrow, impassable gorge. Middle Farallon is 2.3 nautical miles northwest of Southeast Farallon. North Farallon is 6.5 nautical miles northwest of Southeast Farallon and is comprised of two clusters of bare precipitous islets and rocks. Five species of pinnipeds are known to inhabit the islands: northern elephant seals (*Mirounga angustirostris*); California sea lions (*Zalophus californianus*); Steller's sea lions (*Eumetopias jubatus*); northern fur seals (*Callorhinus ursinus*) and harbor seals (*Phoca vitulina*).

Case 1 - Date: 14 January 1962. Victim: Floyd Pair, Jr. (male, 29 yr). Lat./Long.: 37°41.4'N, 122°55.6'W. Time of Attack: 1030 hours.

Over 100 divers, including Pair, chartered four boats to participate in the Midwater

Farallon Islands spearfishing meet. The *NEW MERRIMAC* anchored about 100 m from shore on the southeast side of Southeast Farallon over 15 m of water. The sky was clear with a light southwest breeze rippling the sea surface. An undetermined number of fishes had been speared by divers before Pair entered the water, with about 20 divers in the water at the time of the attack.

Pair was dressed in a black wet suit with weight belt, face mask, swim fins, scuba tank and carried a spear gun. "Water visibility was over 13 m as I could see the bottom clearly from the surface. I went down to a few feet above the bottom, chased and lost a fish, so I decided to surface. Just as I surfaced it hit me. At first I thought it was a seal, however, when I looked down I saw a large shark had me in its mouth. It hit me on my right side and shook me like a dog plays with a bone. I spit out my mouthpiece and began yelling, shark! shark!. At the same time I was jabbing the shark's head with my spear gun. I must have hit the shark five or six times before it let go and swam off" (F. Pair, pers. comm. 1976). Several divers assisted Pair to the boat. The white shark, described by Pair as "at least 14 feet (4.3 m) long," remained in the area several minutes, swimming at the surface, while the remaining divers were summoned aboard. The shark was observed following a diver towing a string of fish as he swam at the surface to the boat.

A distress call was placed to the United States Coast Guard (USCG) and within minutes Pair was transported, by helicopter, to Franklin Hospital in San Francisco. Attending physicians described his wounds as "serious fang-like lacerations to the right leg with the femoral artery escaping injury by only a few millimeters."

Case 2 - Date: 11 November 1962. *Victim:* Leroy French (male, 24 yr). *Lat./Long.:* 37°44.1'N; 122°02'W. *Time of Attack:* 1245 hours.

The *SEA DOG III* was anchored 100 m from Middle Farallon in water about 30 m deep with 15 m of estimated visibility. The sea

was calm and the sky clear. French recorded a surface water temperature of 15.6°C. Accompanied by several divers, French entered the water at 1130 hours to photograph and spear fish. He wore a black wet suit, swim fins, weight belt, triple scuba tanks painted yellow, orange flotation vest and carried a camera and spear gun. Fishes had been speared in the area by other divers, excluding French, prior to the attack.

Surfacing from his dive, French was about 100 m from the boat and 25 m down current from a diver with a speared lingcod (*Ophiodon elongatus*), "oozing plenty of blood" (L. French, pers. comm. 1962). He began swimming toward the boat when the white shark struck, grabbing his left forearm and hand, shaking him violently. Releasing his left arm, the shark circled, biting his right buttocks. During this struggle the shark's caudal fin was observed "thrashing the surface," according to Al Giddings who swam to assist the victim (A. Giddings, pers. comm. 1985). The shark momentarily released French before biting his left thigh, pulling him about 5 m underwater. "It was twisting and biting all the way down my leg as I jabbed it four or five times with my speargun before it let go and swam off" (L. French, pers. comm. 1962). French inflated his life vest surfacing a few feet from Giddings. The two were met half way and assisted aboard the boat by Donald Joslin (victim of a white shark attack at Tamales Point 1969). French's wet suit was removed and a tourniquet applied to his left leg. A USCG helicopter transported the victim to Harbor Emergency Hospital in San Francisco.

Physicians described his wounds as "severe slash, razorlike cuts with numerous tooth punctures to the buttocks and lower left leg. Musculature was stripped away exposing the vascular vessels." French, Giddings and several witnesses estimated the white shark's length between 4.3-4.9 m.

Case 3 - Date: 11 January 1964. *Victim:* Jack Rochette (male, 21 yr). *Lat./Long.:* 37°42'N, 123°01'W. *Time of Attack:* 1200 hours.

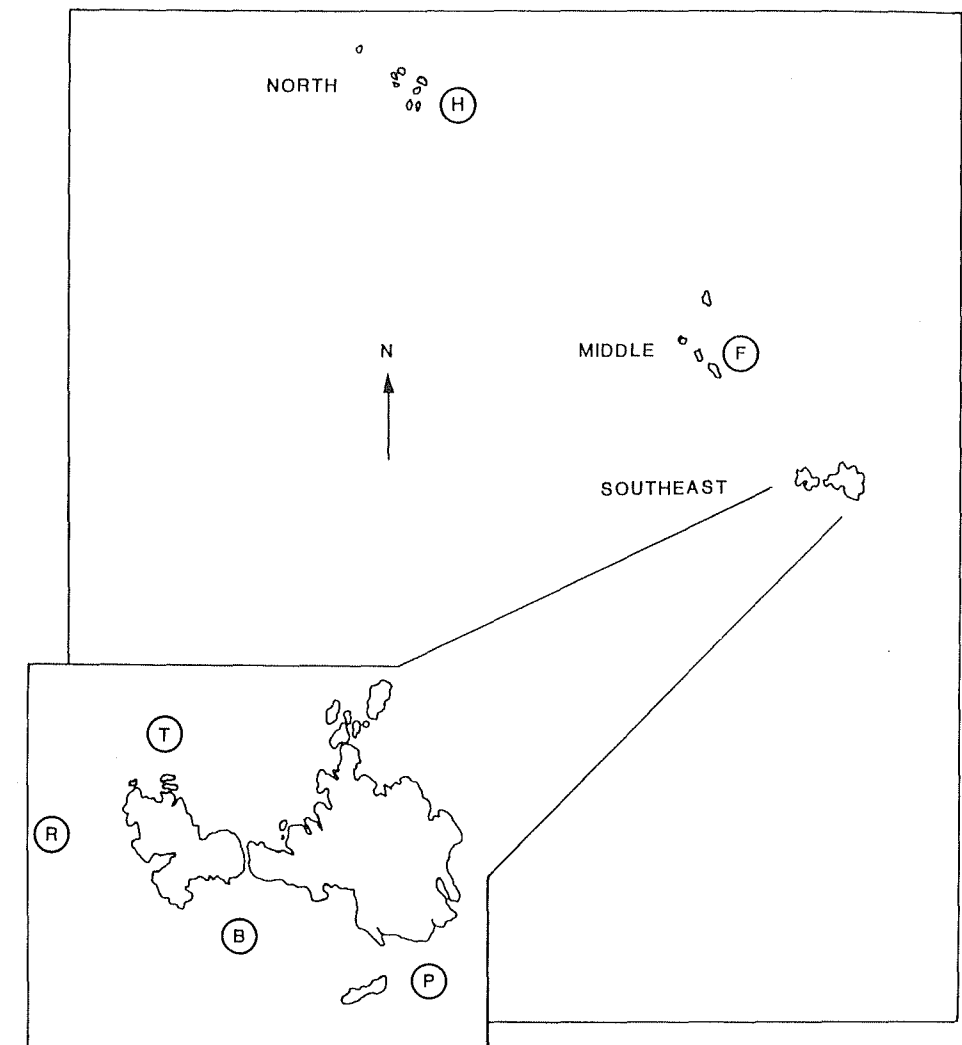


Figure 1. Locations of shark attacks at the Farallon Islands. P, Floyd Pair, Jr.; F, Leroy French; R, Jack Rochette; H, Jon Holcomb; B, Robin Buckley; T, Mark Tisserrand.

The *SALMON QUEEN* anchored 0.6 km off the west side of Southeast Farallon. Rochette, one of 15 divers aboard, dressed in a black neoprene exposure suit with yellow stripping, yellow swim fins, black face mask and twin 42 cubic-foot compressed air tanks, and carried a two-bank spear gun. The water was 15 m deep with a visibility of 12 m. A strong surge prevailed and whitecaps were present on the sea surface. The wind was north northwest between 10-20 knots and the sky was clear.

Rochette had switched to his reserve air supply (enough for about 5 minutes) shortly before spotting a rockfish swimming near an outcropping of rocks on the bottom. He

cornered the fish in a crevice, jabbing it with his spear gun. At that same moment his reserve air supply became exhausted. The moment he surfaced the shark attacked. He first thought one of his diving partners had grabbed him by the legs, however, upon glancing down he saw a large shark had both of his legs, from his upper thighs to the middle of his calf's, in its mouth. The shark vibrated all over, as he slammed his spear gun, with fish attached, into the shark's head, whereupon it released its grip and swam off. He removed the rockfish from his spear as the shark turned making a second advance toward him. Again, he slammed it on the head with his spear gun. This aggressive

behavior by the shark was repeated many times over the next 4-6 minutes. The shark would circle (clockwise) until it was a few feet below Rochette, whereupon he would strike it on the head with his spear gun. Diver Jack Bolger dove from the boat and swam to aid the victim. Finally, the shark left the two men at the surface, focusing its attention on five divers huddled on the bottom. It kept these divers pinned down for about 5 minutes before leaving the area.

Rochette was given first aid and at 1225 hours a USCG helicopter flew him to U.S. Public Health Service Hospital in San Francisco. "He had multiple lacerations to both legs. The most severe a 25 cm laceration to the dorsal side of his right thigh, which extended through the musculature to the femur" (J. Kauth, M.D., pers. comm. 1964). During surgery a 17 mm tooth fragment was extracted from the dorsal right thigh injury positively identifying his attacker as the white shark. Although the victim and witnesses agreed the shark appeared between 6-7.6 m in length, it is possible the prevailing circumstances may have caused them to overestimate its length slightly (Collier 1964).

Case 4 - Date: 14 September 1974. *Victim:* Jon Holcomb (male, 29 yr). *Lat./Long.:* 37°45.1'N, 123°05.1'W. *Time of Attack:* 1335 hours.

The *MOKI* with tender Richard Walker and commercial divers Jon Holcomb and Ron Piatt spent the morning collecting abalones at Southeast Farallon. At 1200 hours they moved to the southeast end of North Farallon where Holcomb dove alone for about 1.5 hr. He wore a black wet suit, weight belt, swim fins, and was attached to a hookah air line with regulator. The regulator was malfunctioning producing a low frequency vibration with every breathing cycle. The sky was clear and the sea calm. The water was about 11 m deep but quickly dropped off to a depth of 18 m, with estimated visibility of 9 m. The ocean floor was covered with many rocks, some 0.9-1.2 m in diameter. Scattered areas of small stature algae covered

some of their surfaces, but no large kelps were present. Pinnipeds were observed in the water 100 m north of his location. There was a conspicuous absence of fishes, except for one or two occasionally seen at the extreme edge of visibility. "The fish were very spooky" (J. Holcomb, pers. comm. 1974).

"I was moving quickly over the bottom, looking for grazers (exposed red abalone) and was unaware of the shark. I was violently struck on my right side, then grabbed by my right arm and shaken for 3-5 seconds then released. Then the 4-5 m white shark started bumping me on my chest with its nose. It bumped me three or four times before grabbing my left arm, shaking me for another 3-5 seconds. After releasing me the shark turned to swim away as I picked up my abalone iron which I had dropped, and struck the shark on its side as it swam past. After being struck by me, the shark traveled about 5 m from me, then bending in half as though made of rubber, turned and charged again. As it bumped me and passed, I grabbed the corner of its open mouth hoping to keep it from biting me again. The shark swam off as I held on. Its speed must have been 5 or 10 knots as it pulled my face mask down to my chin. I saw light above me, like I was near the surface, and let go. I surfaced about 12 m from my boat, spit out my regulator and screamed 'shark! pull me in!'. Piatt headed for me as I swam toward my oncoming boat. Without slowing, Piatt reached over the side and pulled me onto the deck. Walker applied several towels to my injured arms as we headed for Southeast Farallon where we could summon aid, as our radio wasn't working" (J. Holcomb, pers. comm. 1974).

Holcomb was flown, by USCG helicopter, to Letterman Army Medical Center in San Francisco. "There were three lacerations to the right forearm, 3.5-5 cm in length and from the left elbow to medial forearm a laceration 8-10 cm in length with a single laceration 7.5 cm in length to the left thigh. There were multiple disruptions of musculature and nerves to both arms. Holcomb was discharged 24 September

1974, both arms in long arm casts" (C. Baker, Cpt., Medical Corps, pers. comm. 1974).

Case 5 - Date: 6 December 1975. *Victim:* Robin Buckley (male, 27 yr). *Lat./Long.:* 37°41.5'N, 123°00'W. *Time of Attack:* 1200 hours.

Robin Buckley and eight companion divers were about 100 m from Southeast Farallon anchored over 12 m of water with 15 m of visibility. The sky was clear, however, 1 m ground swells and white caps prevailed from a brisk west wind. Except for a royal blue breast pocket and knee pads, Buckley's diving equipment was black and consisted of a wet suit, weight belt, swim fins, face mask and snorkel, pole spear and a scuba tank with regulator.

Splitting into two groups, Buckley and four companions entered the water and proceeded to the bottom, followed shortly by the second group. Upon reaching bottom the two groups headed in opposite directions. Ursula Bernhart, a member of the second group noted: "A large number of fish in the area appeared totally undisturbed by our presence, as did the several seals swimming nearby" (U. Bernhart, pers. comm. 1975). Members of the second dive group never saw or were aware of the shark's presence.

Buckley's group traveled about 10 m from their original location before the divers began scouting alone. Several minutes passed before Buckley located and speared a lingcod, which struggled dislodging itself from his spear. Shortly thereafter he speared a second lingcod and headed slowly towards the surface. He recounted: "As I looked up this big shark was about 6 m from me as it slowly turned and swam toward me. I began swimming backwards so I could keep the oncoming shark in front of me. When the shark was about 4-5 m from me, I dropped my spear with the lingcod still attached, hoping the shark would follow it to the bottom. However, the shark ignored the spear and kept coming at me. I pulled my legs up to my chest as the shark drew very close. I was 5 m from the surface when the shark

opened its mouth, closed it on my lower left leg for 3-5 seconds then released me. It never thrashed or applied much pressure. I surfaced, yelled for help, then dove underwater to keep sight of the shark. I saw four companions huddled on the bottom near a large rock and headed for their location. The shark reappeared about 6 m off the bottom and 9 m from our location. My friends and I swam along the bottom until we saw our boat's silhouette, then surfaced. I was helped aboard and the Coast Guard radioed for help" (R. Buckley, pers. comm. 1975). Buckley and his four companions estimated the white shark to be 5-6 m in length.

AUSCG helicopter flew Buckley to Letterman Army Medical Center in San Francisco." He (Buckley) was admitted alert but in a mild state of distress. There were four tooth punctures, 3.8-7.5 cm in length to the lower left leg. They extend through subcutaneous tissue into musculature, but caused no neurovascular damage. He was given antibiotics daily, for five days, and on 17 December 1975 was discharged from this hospital, ambulatory on crutches" (R. Bothwell, M.D., pers. comm. 1975).

Case 6 - Date: 9 September 1989. *Victim:* Mark Tisserrand (male, 38 yr). *Lat./Long.:* 37°42'N, 123°00'W. *Time of Attack:* 1230 hours.

Commercial divers Mark Tisserrand and Scott Smith were aboard the *KANDY LOU* about 70 m from shore on the northwest side of Southeast Farallon over 12 m of water with a visibility of 3-4 m. The sky was overcast with a 10-15 knot wind occasionally causing white caps on the 1-1.5 m ground swells. A group of 20 sea lions were observed 30-40 m southeast of their location with a second group of 15-20 individuals mid-way between their boat and shore. Both groups were tightly huddled and appeared to be in an agitated or distressed state. Numerous individuals were "barking as well as looking quickly about the surface and below water" (M. Tisserrand, pers. comm. 1989). At about 1200 hours the divers made an exploratory dive with Tisserrand dressed in a

black wet suit, swim fins, face mask with snorkel, and carried an abalone net basket, pry bar and a bang stick. He was attached to a yellow hookah air line with regulator. Smith wore a blue wet suit, black swim fins, face mask, and utilized scuba tanks painted yellow. Tisserrand recounted: "The bottom was rocky and reef-like with many small caves with short kelps covering most of the bottom. I saw about 15 or 20 sea lions on or very near the bottom. They appeared distressed by something as they kept looking up toward the surface, while remaining on the bottom in the kelp grass. Some moved slowly thru the kelp grass by using their front flippers to pull themselves along the bottom. I felt very uncomfortable and returned to the boat after about 10 minutes" (M. Tisserrand, pers. comm. 1989). Tisserrand and Smith discussed moving to a new location because of their apprehension, however, after a 15-20 minute discussion and rest period, decided to dive the area.

Tisserrand entered the water descending vertically, feet first, with Smith following some 15-20 seconds later. Tisserrand was about 3-4 m from the bottom when, "suddenly I felt a vise-like pressure on my left leg and knew immediately what had happened" (M. Tisserrand, pers. comm. 1989). The 4-5 m white shark shook him for 10-15 seconds, as Tisserrand struck the shark's head with the handle of the bang stick as he was unable to release the safety pin in order to discharge the spear head. The shark released its grip on Tisserrand about the same time Smith was entering the water. At about mid-depth Smith saw Tisserrand rapidly ascending and about 3-4 m below him observed a white shark slowly swimming away.

Smith observed the white shark three times during their 30 m swim to the boat. The shark swam slowly and smoothly and did not attempt to bite either diver again. Aboard the boat a tourniquet was applied to Tisserrand's left leg and the USCG radioed for assistance. Within 30 minutes the victim was enroute to Peninsula Hospital in Burlingame.

Upon admittance to the hospital's emergency room Tisserrand was alert but in a state of mild shock. He had suffered "multiple tooth punctures to the lower left leg with a traumatic compound fracture dislocation of the left ankle with only 30-40% of the tissue and epidermis on the inside of the ankle intact" (J. Leonard, M.D., pers. comm. 1989). Following several surgical procedures and treatment with antibiotics, Tisserrand was released 19 September 1989.

Northern Channel Islands

San Miguel Island (Fig. 2) is the western most of the islands that comprise the Channel Islands National Park. It is located 23 nautical miles south southeast of Point Conception. The remaining islands in the Park are: Anacapa Island, Santa Cruz Island, Santa Rosa Island and Santa Barbara Island. There are six species of pinnipeds which occur in varying numbers on one or more of the islands. They are: Guadalupe fur seals (*Arctocephalus townsendi*); Steller's sea lions, northern fur seals, northern elephant seals, California sea lions and harbor seals.

Case 7 - Date: 18 December 1976. **Victim:** Jay Worrell (male, 29 yr). **Lat./Long.:** 34°03'N, 120°25'W. **Time of Attack:** 0900 hours.

Commercial diver Jay Worrell, aboard his boat *KAREN*, was south of Castle Rock, 100 m from the west end of San Miguel Island over 11 m of water with an estimated visibility of 6 m. The sky was overcast and there was a mild northeast breeze. He entered the water in a black wet suit, weight belt, swim fins, face mask, and utilized a chrome regulator attached to a red hookah air line of 30 m length.

While slowly descending toward the bottom, Worrell noticed an unusual absence of fishes and pinnipeds. This condition had been reported the previous day as well by several divers who had been in the area (P. Howorth & J. Worrell, pers. comm. 1976). Worrell was seized on the right hip and buttocks about 5 m from the bottom. "I felt a vise-like pressure

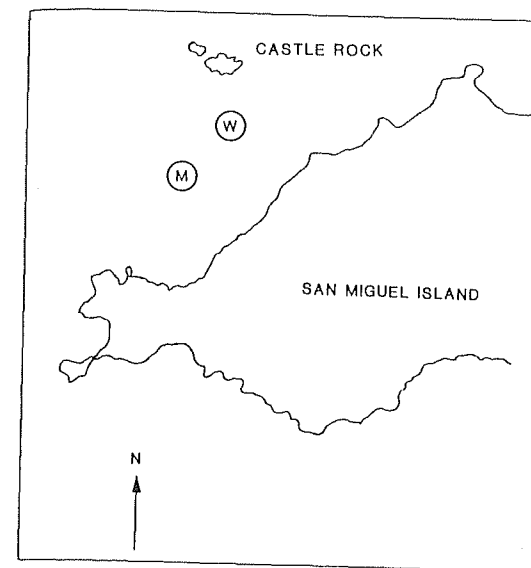


Figure 2. Locations of shark attacks at the west end of San Miguel Island. W, Jay Worrell; M, Chris Massahos.

around my side for about 10 seconds, then my air line was cut and the shark let go. The shark swam to a few feet in front of me and I noticed a lot of bubbles coming from its mouth and gills. It started opening and closing its mouth as if it were trying to spit out something. As the shark came closer to me I struck it under the left eye with my abalone iron and it swam off" (J. Worrell, pers. comm. 1976). Air supply gone Worrell surfaced yelling "shark!", then swimming about 10 m to his boat was pulled aboard by his tender John Houghton. Houghton radioed other dive boats in the area for assistance and to warn them of the shark's presence. Hookah diver Kenny Gray (white shark attack victim at Point Purisima 1972) pulled alongside to assist with first aid. Towels were shredded and placed inside Worrell's wet suit to control the hemorrhaging. He was transported to Goleta Valley Community Hospital in Santa Barbara by USCG helicopter.

Worrell's physicians described his injury's as "a serious crescent-shaped laceration to the right buttocks and hip extending 275-300 mm across the buttocks and 100-125 mm into the

musculature. There is a razor-like cut to the inner surface of the left thigh, 80-90 mm in length and 40-50 mm deep. There were no major vessels or nerves involved, however, over 150 sutures were required for closure" (R. Parker, M.D., pers. comm. 1976).

John E. Fitch (former Research Director, California Department of Fish and Game, Long Beach) and I examined Worrell's diving equipment 10 days following the attack. The 6.4 kg weight belt had two cuts, 16 and 34 mm in length, 412 mm from the buckle. one lead weight had a slash 12 mm in length and 5 mm deep. There were four tooth punctures to the right buttocks of the wet suit jacket, with corresponding punctures in the pants. Aligning the wet suit jacket, pants and weight belt revealed five upper jaw tooth punctures which measured: jacket - 17, 20, 22 and 13 mm (partial); pants - 4 (partial), 18, 19, 22 and 22 mm. To determine the approximate size of the attacking white shark, Gordon Hubbell (Director, Metro Zoo, Miami) related these measurements to white shark jaws in his collection. Comparison revealed the white shark to be approximately 5 m in length.

Case 8 - Date: 18 February 1985. **Victim:** Chris Massahos (male, 29 yr). **Lat./Long.:** 34°02.6'N, 120°26.1'W. **Time of Attack:** 1245 hours.

Chris Massahos had been scuba diving for California spiny lobster for about 1 hr off the west end of San Miguel Island. He wore a two-tone blue/black wet suit with black gloves, swim fins, a green game bag and a single air tank with regulator. The *TRUTH* was anchored over 14 m of water with a visibility of 12 m. The sky was clear and the sea calm.

While traveling 1 m above a 3 m wide ledge, his attention was drawn to a large object at the extreme edge of visibility. "At first I thought one of the elephant seals or California sea lions I had seen earlier near the boat was coming in to investigate. However I was soon able to distinguish the outline of a large shark. When it was about 3 m from me I was able to identify it as a white shark 4-5 m in length. It swam

parallel to me, about 3 m away, for about 10 m, then it turned and swam off" (C. Massahos, pers. comm. 1985). Abandoning his search for lobster, he swam along the bottom towards his boat continually scouting for the shark. He had almost reached the boat when his air supply became exhausted. He surfaced, yelled for help, then placed his face in the water to try and locate the shark. He saw the shark rapidly approaching, curled into a ball and was struck on his right shoulder by the shark's head. The force of the impact spun him around, "it felt like being hit by a car going 20 mph" (C. Massahos, pers. comm. 1985). He was safely brought aboard the boat and the shark was not seen again. It is interesting to note that a large white shark had been seen in the same area the week before by several sport divers (P. Howorth & R. Lea, pers. comm. 1985).

Massahos sustained several bruises to his back and right shoulder, with several deep slashes present on his scuba tank, presumably caused by the shark's teeth.

Discussion

Miller & Collier (1981) described dissimilar shark attack patterns for the areas north and south of Point Conception/San Miguel Island. In their study, they considered the white shark to be responsible for probably all of the attacks from Point Conception/San Miguel Island north. As these eight cases fall within this northern area, comparisons will be made with *only* the 32 reported shark attacks on divers from Point Conception/San Miguel Island north to the Oregon border. Further because of the different equipment and techniques utilized by commercial (hookah), scuba, and freedivers (breath-hold), I separated divers into two groups: 1) freedivers having no air supply and 2) divers that were air supplied (scuba and hookah).

Current knowledge of white shark biology does not permit a positive determination of the motive for their attacks on divers. However, several authors have postulated hypotheses

based on examination of capture records, shark attacks on humans and prey species and personal observations of carrion feeding (baited) sharks. To date, divers have only been attacked (bitten) at islands at or north of Point Conception, although many white shark encounters (no physical contact between shark and diver) have been reported from several islands in the southern area (Collier, unpubl. data). Klimley (1985) suggested a north/south and offshore/onshore seasonal migration for adult white sharks based on capture records for 109 individuals. Adult white sharks were found to inhabit both the mainland and offshore islands in central and northern California but were somewhat restricted to the offshore islands in southern California. However, large white sharks have been observed close inshore in southern California (J. Goldsmith, Curator, Marineland, pers. comm. 1977). This species is also highly suspect in the 28 January 1989 fatal attack on a young woman kayaker in the Malibu/Paradise Cove area (Collier, unpubl. data).

Ainley & co-authors (1985) described 74 white shark predatory attacks on pinnipeds at the Farallon Islands from 1970-1983, demonstrating an offshore/onshore seasonal migration in their predator/prey relationship with resident pinnipeds at the islands and along the mainland. This study also suggested that "the same seasonally resident sharks may have been frequenting the Farallones" (Ainley *et al.* 1985). Baldrige & Williams (1969), following their study of 1700 shark attack cases worldwide, purposed that perhaps 50-75% of all documented shark attacks might have been motivated by drives other than feeding. Baldrige (1988) classified these attacks as nonforaging aggressions where the victims possibly appeared as a threat or competition, interfered with the sharks pupping or courtship, and/or trespassed the shark's territorial limits. Miller & Collier (1981) analyzed 47 unprovoked shark attacks from California and Oregon and reached the general conclusion that most of the attacks "resembled the feeding behavior of an

isolated large shark that appeared to be investigating an object." This behavior might explain crab pot buoys and other non-food items being bitten by white sharks off California's coast (Collier, unpubl. data; R. Warner, Dept. Fish & Game, pers. comm. 1984). Tricas & McCosker (1984) and McCosker (1985, 1991) described the predatory behavior of the white shark and postulated a 'bite and spit' attack adaptation which they believed reduced injury to the shark when preying upon pinnipeds. This 'bite and spit' behavior was credited for the high survival (escape) rate of white shark attack victims.

Specifically in the cases of Pair and Buckley, the shark's movements were described as slow and deliberate without violent shaking and could exemplify an investigatory behavior by the shark as proposed by Miller & Collier (1981). The attacks on Worrell, Massahos and Tisserrand were violent, high velocity incidents possibly demonstrating a predatory behavior (attack) by the shark on something that either resembled or acted like a prey species. Although these three cases appear to be the 'bite and spit' predatory behavior described by Tricas & McCosker (1984) and McCosker (1985, 1991), it should be noted that any prey item too large to be consumed in a single bite might be released (spit out). In the attacks on French, Holcomb and Rochette the initial contact by the shark might possibly have been motivated by predation or investigation, however, the sharks continued aggression towards the victims, following their striking out at the shark, might better be explained as the 'fighting' behavior postulated by Baldrige & Williams (1969) and Baldrige (1988).

The number of surface attacks for all divers, 15 of 32 (47%), is of questionable significance. Unlike the analysis of Miller & Collier (1981) which included attacks near the surface with surface attacks, for this discussion I considered only those attacks at the surface to be surface attacks. To date 8 of 16 (50%) freedivers have been assaulted at the surface while 9 of 16 (56%) air supplied divers, including all five hookah divers, were attacked below the surface.

I suggest these data support locations (depths) where the two diver groups spend a majority of their dive time and not a preferred, or critical, depth for attacking white sharks. Although four of the eight California Island shark attack victims were at the surface, two were struck immediately upon surfacing and two within moments of reaching the surface, suggesting the shark may have been following (stalking) the victim. A more meaningful statistic might be the length of time at the surface prior to a white shark attack on a diver.

In terms of the victims behavior towards the shark, Miller & Collier (1981) found for those who did resist (*i.e.*, faced the attacking shark and aggressively kicked at or struck the shark), there was a slightly greater number of instances in which the shark remained in the area and attempted to bite rather than retreat. To date, diver resistance has been reported in 18 cases, encompassing 9 freedivers and 9 air supplied divers (Miller & Collier 1981; Lea & Miller 1985). Continued aggression by the shark, following the initial contact, was reported in 3 (33%) freediver cases and 6 (66%) cases involving air supplied divers. Although continued aggression by the shark in several freediver attacks was not possible, even if the shark remained in the area, as the victims were removed from the water within moments of their attacks. Conversely, the higher number of cases with continued shark aggression for air supplied divers might be due to their venturing further from their dive entry site, increasing the time needed to reach safety. Specifically for the California Island shark attacks, six of the eight divers resisted the shark and in three cases (50%) the shark returned, with two (33%) of the victims sustaining multiple bites.

Unusual behavior of fishes and/or pinnipeds, including their conspicuous absence, was reported in three of the California Island shark attacks, all involving hookah divers (Holcomb, Worrell and Tisserrand). This phenomenon also was reported for several diver/white shark encounters off California's coast (Collier, unpubl. data). The eight island attacks occurred

near active pinniped populations and at sites free of canopy forming macro-algae (kelp) as noted by Miller & Collier (1981).

Until such time as white shark behavior is understood I would suggest that divers exercise common sense while pursuing their recreational or vocational diving. If possible, avoid diving near pinniped haul-out sites and pinniped rookeries, and swimming lengthy distances at the surface when returning to a boat or shore. Remove captured marine organisms from the water immediately and don't remain in the water if you feel uncomfortable or if fishes and marine mammals are displaying unusual behavior or are conspicuously absent. Always dive with a buddy.

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Dedication

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Annual and Spatial Variation of the Kelp Forest Fish Assemblage at San Nicolas Island, California

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Introduction

The kelp forests along the west coast of North America provide some of the richest habitat for fishes in this region (Quast 1968; Feder *et al.* 1974; Ebeling *et al.* 1980a, b). Within this habitat, the diversity and abundance of the fish assemblages may be strongly influenced by the various physical and biological components of the kelp forest community (Ebeling *et al.* 1980a). It generally has been accepted that rocky reefs with high physical relief will support more fishes than one with little relief (Quast 1968; Miller & Geibel 1973; Ebeling *et al.* 1980a) and that an area with kelp, particularly canopy forming species, will support more fishes than one without kelp (Quast 1968; Miller & Geibel 1973; Larson & DeMartini 1984; Ebeling & Laur 1988; Laur & Ebeling 1988; Bodkin 1988). Additionally, latitudinal changes in species composition occur, changing from the colder, temperate water fauna north of Pt. Conception, to a warm water fauna in southern California and off Baja California, Mexico (see Miller & Geibel 1973; Quast 1968).

Around the California Islands, kelp forests are a dominant habitat. The structural nature of these kelp forests vary around the islands, resulting in among-site variation in the abundance of fishes (*e.g.*, Santa Cruz Island, Ebeling *et al.* 1980a). Small-scale differences among islands with respect to species composition may be as large as large scale latitudinal differences that reflect the major current patterns. Such processes may be particularly important in a transition area such as San Nicolas Island. The proximity of San Nicolas Island to both the southward flowing California Current and the outer edge of the northward flow of the Southern California Eddy

Abstract - The kelp forest fishes of San Nicolas Island, California were studied from 1981-1986 to examine the causes of among-site and among-year variation in the fish assemblages. Fish counts and seven physical and biological variables were recorded at six sites around the island every spring and fall. Over the study period, a total of 45 fish species from 18 families were recorded, though members of nine families dominated at all sites. Among-site variation was considerable with two sites on the south side of the island having two to four times as many non-schooling fishes as the other four sites. Three variables, based on stepwise multiple regression techniques, were important predictors of site-specific fish abundance: 1) vertical relief; 2) sand cover and 3) understory algal cover. The total number of fishes varied interannually by a factor of three. Due to recruitment occurring each spring, there was a strong seasonal component to the variation in fish abundance. The extent of seasonal and interannual variation of fish abundance is an indication of the variable nature of recruitment to this area. Over the 6 yr period, there were three distinct groupings of fish assemblages corresponding to pre- (Fall 1981 - Fall 1982), during (Spring 1983 - Spring 1984) and post-El Niño (Fall 1984 - Fall 1986) sampling dates. During the El Niño sampling period, there was considerable recruitment of southern affinity fish species, increasing both the abundance and diversity of the fish assemblages. Large-scale oceanographic processes, coupled with site-specific features of the reef habitat, produce a moderately diverse, though relatively abundant fish fauna at San Nicolas Island.