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THE OCCURRENCE OF THE WHITE SHARK, *CARCHARODON CARCHARIAS*, AT THE POINT REYES HEADLANDS, CALIFORNIA

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We present the results of a pilot study initiated during the fall of 2000 at the Point Reyes Headlands, a potential site for white shark research on the coast of California. The goal of this study was to determine if white sharks occur at this location. Ten sharks were observed during 45 h of sampling conducted between 9 October 2000, and 1 February 2001. Seven sharks were attracted to surface decoys deployed off of the headlands and three sharks were observed feeding on a whale carcass within Drake's Bay. No sharks responded to decoys presented within the Bay. Most sharks were observed early in the project, coincident with the presence of large numbers of young elephant seals.

INTRODUCTION

White sharks, *Carcharodon carcharias,* have long been known to frequent the waters adjacent to the haul-outs and breeding colonies of their pinniped prey (Ainley et al. 1981, 1985). In the eastern Pacific, primary prey species are believed to be Northern elephant seals, *Mirounga angustirostris*, and California sea lion, *Zalophus californianus*, (Ainley et al. 1981, Le Boeuf et al. 1982). Large colonies of these animals can be found at both the Farallon Islands, located 48 km west of San Francisco, and Año Nuevo Island, located 1 km offshore of the coast and 30 km north of Santa Cruz. Consequently, these two locations have been the site of significant white shark research (e.g. Farallon Islands: Klimley et al. 1992; Año Nuevo Island: Klimley et al. 2001a, b).

Recently, attention has been drawn to the Point Reyes Headlands as a potential site for white shark research. Point Reyes is a peninsula in Marin County, California, extending into the Pacific Ocean north of San Francisco. The entire peninsula is encapsulated by Point Reyes National Seashore (PRNS), and the adjacent waters are within the Gulf of the Farallones National Marine Sanctuary (GFNMS). The headlands, located at the extreme southern end of the Point Reyes peninsula, are typified by steep, granite and conglomerate bluffs (Galloway 1977) punctuated by occasional pocket

beaches which are all but inaccessible from land. Sea lions have long colonized the rocks in this area. In 1981, elephant seals colonized one of the headland beaches (see M, Fig. 1) (Allen et al. 1989). The colony started with three individuals, but has grown and now numbers approximately 1500 individuals (S. Allen, National Parks Service, personal communication). In 1986, elephant seals also established a smaller "satellite" colony (see S, Fig. 1) on a large sand beach in the sheltered northern end of Drake's Bay (S. Allen, personal communication). Elephant seals usually appear on this beach later in the season, generally after the primary beach reaches capacity or when winter storm activity forces subordinate animals off the beach. Nonbreeding elephant seals, typically juveniles or subadults, are also found scattered along the coast of Drake's Bay during the winter months. Since colonization, there has been evidence of white shark presence in this area including anecdotal observations of sharks and PRNS observations of seals with shark-inflicted wounds.

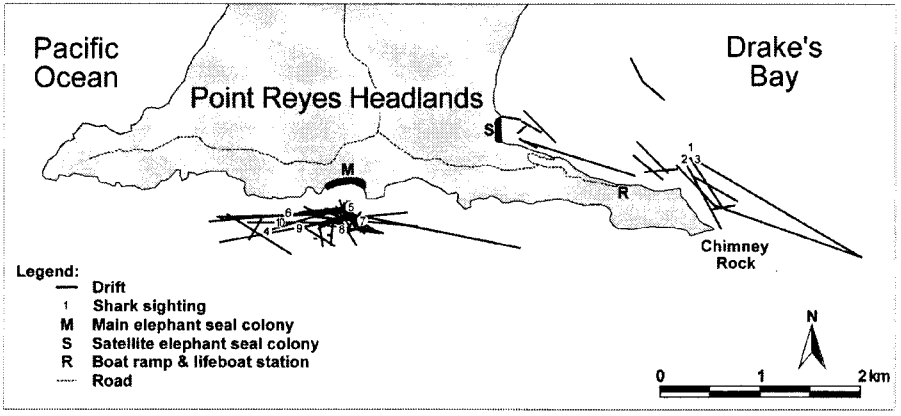

Figure 1. Map of Point Reyes Headlands area showing location of white shark sampling effort during 2000, in relation to elephant seal colonies (dark areas). Dark lines indicate locations of sampling drifts, and numbers indicate shark sightings (refer to *shark* column, Table 2).

Point Reyes is an ideal field location for a number of logistical and methodological reasons. There is easy mainland access to the area with paved roads leading almost directly to the elephant seal colonies. A small boat, equipment, and personnel can be conveniently transported directly to the field site, eliminating the need for large support boats. There is a boat ramp (see R, Fig. 1) adjacent to the historic lifeboat station in Drake's Bay, and the distance by boat from launch to the main colony is only 5 km. Additionally, there is easy shore access to overlooks from which to observe the seal beaches and the surrounding environs.

We initiated a pilot study of white sharks in this area in the fall of 2000. The goal of this project was to establish whether white sharks indeed occurred at the headlands and if they could be attracted to the surface with sufficient frequency to merit establishing more in-depth projects in the future.

METHODS

Late fall is typically the peak white shark observation and predation season at nearby Southeast Farallon Island (Ainley et al. 1981, Klimley et al. 1992, Pyle et al. 1996), so the pilot study began in October 2000. Two field days a week were scheduled and continued until the winter weather required that we remove our research boat from Drake's Bay. A typical field day began at 0800 hours. Elephant seals at the main seal colony were counted and photographed at this time from the best vantage point on the surrounding bluffs. No point provided a completely unrestricted view of the beach so we could not directly estimate the total number of seals present with complete confidence. However, by making our observations at the same location each day, we considered our estimate to be reflective of the actual number of individuals on the beach. We termed this estimate the Seal Index. Sampling work typically began off of the main colony during the morning hours when winds were typically calmest then moved back into the sheltered bay if conditions deteriorated.

The drifting decoy method (Anderson et al. 1996) was used to attract sharks to the surface. In this method, a wooden silhouette of a seal or sea lion is tethered to a line and drifted 25-30 m behind the research boat. Chum was not used to attract sharks, though in most cases small portions of a sea lion carcass, obtained from animals that had died of natural causes, were bound to the decoy providing some local chemical stimulus in order to entice investigating sharks to remain at the surface for longer periods of time. Sharks were not permitted to consume the carcass material in order to avoid positive reinforcement for the act of visiting objects at the surface. The use of natural prey in this manner was specified in both PRNS and GFNMS permits, and conducted with permission from the National Marine Fisheries Service.

Sampling was conducted primarily within the "high risk zone" (Klimley et al. 1992). This is the area adjacent to a seal colony extending from shore out to approximately 1.3 km, over relatively shallow water (<37 m), in which the majority of white shark predations are observed to occur. A location within this zone was selected based both on wind and ocean conditions and an attempt to sample throughout the research area. Once a location was selected, the decoy was deployed, the engine turned off, and the boat allowed to drift with the prevailing wind and current. Because of this, the duration, direction, and velocity of each drift were variable. Drift duration and distance varied from 7 min to 1.5 h, and 0.02 to 1.74 km, respectively. Latitude and longitude were recorded by GPS at the beginning and end of each drift.

Upon sighting a shark, the time and GPS position of the boat were recorded. The decoy was slowly pulled back to the boat in order to draw the shark closer for better observation as well as to prevent the shark from biting the decoy or feeding on the attached carcass. Observations were recorded on sex and distinguishing markings, focusing in particular on fin shape or unique features such as scars. Total length (TL) in meters was estimated based on comparison with objects of known length such as the decoy and the research boat, which was marked at meter increments for this purpose. Additionally, the shark was photographed while at the surface in order to establish an identification catalog of individual animals. Identification catalogs are a non-intrusive

means of long-term monitoring of white shark populations. Individual sharks may be identified on the basis of unique scars, markings, and dorsal and caudal fin shape (Anderson and Goldman 1996; Klimley and Anderson 1996). Observations continued until the shark departed, at which point the decoy was re-deployed and a new drift started.

RESULTS

Scavenging Event

On 2 October 2000, the fresh carcass of a dead male humpback whale drifted into Drake's Bay accompanied by scavenging white sharks. This was observed from shore until the carcass became beached and the sharks departed. On 9 October, the carcass was dislodged by the tide and began to drift back into the Bay. Fortuitously, our researchers were present at this time, in the process of preparing and launching our research boat for this project. Shortly after the carcass floated into the Bay, three sharks returned to feed (numbers 1, 2, 3 in Fig. 1 and Table 1). Observations of this event will be detailed in a separate paper; however, some results are included here as the sharks present were included in our identification catalog.

Table 1: Summary of white sharks sighted and data collected at Point Reyes, California, 2000.

Shark	Date	Time	Latitude	Longitude	Site	Sex	Length (m)	Photo
1[a]	9 Oct. 2000	15:30	38°00'00"N	122°58'12"W	D	m	4.5	y
2[a]	9 Oct. 2000	15:30	38°00'00"N	122°58'12"W	D	f	3.5	y
3[a]	9 Oct. 2000	15:30	38°00'00"N	122°58'12"W	D	-	3.5	y
4	16 Oct. 2000	12:57	37°59'24"N	123°00'15"W	H	-	3.5	y
5	16 Oct. 2000	14:20	37°59'32"N	122°59'48"W	H	-	-	n
6	17 Oct. 2000	11:45	37°59'30"N	123°00'08"W	H	-	3.5	y
7	24 Oct. 2000	10:43	37°59'28"N	122°59'44"W	H	-	-	n
8	20 Nov. 2000	9:49	37°59'25"N	122°59'51"W	H	-	3-3.5	n
9	20 Nov. 2000	11:54	37°59'25"N	123°00'05"W	H	f	3.0	y
10	1 Feb. 2001	11:12	37°59'27"N	123°00'11"W	H	-	3.5-4	y

[a] Prior to start of sampling effort

Table key: *Site*: D = Drake's Bay, H = Headlands; *Sex*: sex of shark if known; *Length*: estimated total length if available; *Photo*: was the shark photographed?

Main Survey

Starting on 16 October and continuing through 12 December, field work commenced on the planned schedule. Fourteen days were spent in the field during this period. A break in winter storms permitted an additional field day on 1 February 2001. Daily sampling efforts and results are summarized in Table 1. During these 15 d, approximately 45 h were spent sampling. We define "sampling" to mean time spent actively searching for sharks with the decoy in the water. During this time, we sampled over a linear distance in excess of 29 km, measured between starting and ending points of each drift. Of this, over 32 h covering 18 km were spent at the headlands in the general area of the main seal colony (see M, Fig. 1). An additional 12 h, covering 11 km, were spent within the confines of Drake's Bay (note: this includes 4 h of observation of the whale carcass with no decoy present). The drifts in Drake's Bay were distributed over a greater area than those off the headlands. Some drifts were conducted off the site of the satellite elephant seal colony, though no elephant seals were on the beach during the study period; however, harbor seals, *Phoca vitulina richardsi*, were present. This area is very shallow (<3 m) with a sand bottom. The lack of both preferred habitat and primary prey species convinced us to direct our efforts elsewhere. Other drifts within Drake's Bay occurred along the rocky area between the boat ramp and Chimney Rock, which forms the easternmost spur of the headlands. This region was where the whale scavenging took place, and thus the occurrence of white sharks there was believed to be likely.

A total of 10 white sharks was observed between 9 October 2000, and 1 February 2001 (Table 2). Of these, three sharks were observed feeding on the whale carcass within Drake's Bay. The remaining seven sharks were attracted to our decoy, and all were observed off of the headlands (Fig. 1). This equates to a sighting frequency off the headlands of one shark per 4.75 h of sampling. The number of sharks sighted per week does not appear to be related to the total number of hours spent sampling that week (Fig. 2). For example, in the week of 14-20 October, three sharks were sighted during only 5.25 h of sampling. In contrast, we saw no sharks the week of 4-10 December, despite calm seas and perfect weather, which permitted 14 h of sampling.

The number of sharks sighted was roughly related to the size of the seal colony on the beach (see Seal Index, Fig. 3). The highest number of seals were counted (approximately 300 individuals) during the first week of the project. Most of these seals were yearlings. The index declined sharply in the following weeks to about 100 individuals before beginning to increase again to about 150 as sub-adults and adults began to arrive on the beach. With the exception of one sampling day on 1 February, sampling ended prior to the arrival of the majority of the adults and the commencement of the breeding season. Further, no elephant seals were observed inside Drake's Bay on the weeks for which seal data are available. Coincident with the initially high numbers of juvenile elephant seals, our decoy attracted three of the seven total sharks in the first week, and four of the seven in the first 2 weeks. The arrival of adult seals, first noted during late November, seems to be matched by the sighting of two sharks during the week of 18-24 November. However, we have no explanation for the paucity of sightings in the subsequent weeks, particularly since the weather during one of those weeks (4-10 December) was good, the seas calm, and sharks easily detected, if present.

Table 2: Summary of white shark survey effort at Point Reyes, California, 2000. Effort is subdivided into drifts near the Headlands and within Drake's Bay.

	Headlands drifts					Drake's Bay drifts					
Date	Start (h:m)	Stop (h:m)	Duration (h:m)	Distance (km)	Sharks	Start (h:m)	Stop (h:m)	Duration (h:m)	Distance (km)	Sharks	Decoy
9 Oct. 2000[a]	-	-	-	-	-	13:30	17:30	4:00	N/A	3	N/A
16 Oct. 2000	10:45	15:18	3:12	2.0	2	-	-	-	-	-	sea lion
17 Oct. 2000	11:24	12:06	0:21	0.4	1	12:44	15:22	1:45	4.0	-	sea lion
23 Oct. 2000	-	-	-	-	-	10:25	14:00	1:42	0.9	-	elephant seal
24 Oct. 2000	9:33	15:40	4:40	5.4	1	-	-	-	-	-	elephant seal
31 Oct. 2000	10:35	11:05	0:30	ND	-	-	-	-	-	-	elephant seal
7 Nov. 2000	9:22	10:35	0:45	0.6	-	11:30	14:45	2:23	4.0	-	elephant seal
13 Nov. 2000	9:21	10:26	0:36	0.5	-	-	-	-	-	-	elephant seal
20 Nov. 2000	9:13	14:10	4:30	1.1	2	-	-	-	-	-	sea lion
22 Nov. 2000	-	-	-	-	-	9:56	11:02	0:56	0.1	-	sea lion
4 Dec. 2000	9:21	14:40	4:45	2.9	-	-	-	-	-	-	sea lion
5 Dec. 2000	9:16	15:14	4:42	1.1	-	-	-	-	-	-	sea lion
8 Dec. 2000	9:12	14:05	4:15	1.9	-	-	-	-	-	-	elephant seal
12 Dec. 2000	10:15	12:50	2:05	1.9	-	13:25	14:58	1:15	1.9	-	elephant seal
1 Feb. 2001	10:28	13:01	2:19	0.5	1	-	-	-	-	-	sea lion
Total			32:40	18.2	7			12:01	10.9	3	

[a] Observations at whale carcass prior to start of sampling effort

Table key: *Start*: time when decoy was first introduced to water; *Stop*: time when decoy was last removed from water; *Duration*: total time spent with decoy in the water; *Distance*: sum of linear distance between drift start and stop points; *Sharks*: number of confirmed observations of white sharks; *Decoy*: shape of silhouette; *N/A*: not applicable; *ND*: no data.

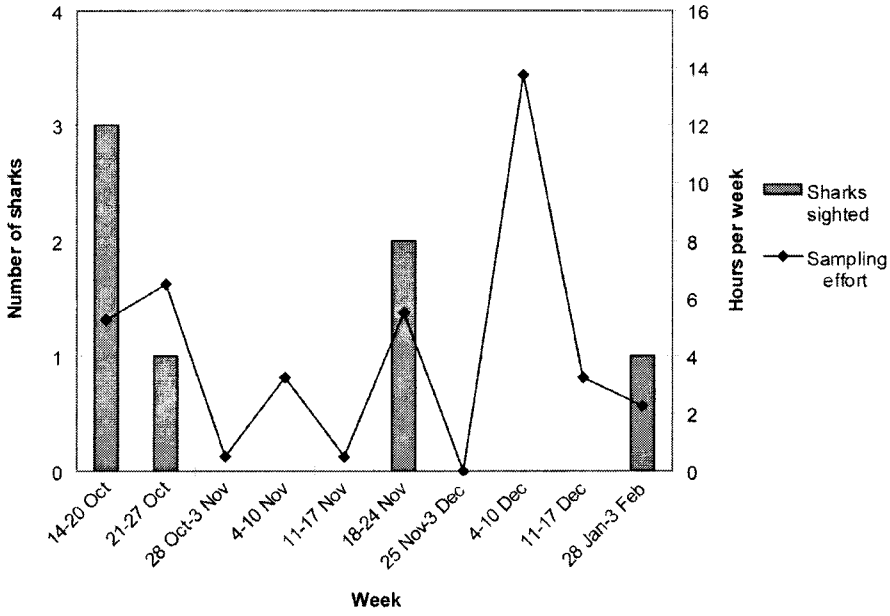

Figure 2. White shark sampling effort at the Point Reyes Headlands, California, 2000. Hours per week (black line) are compared to shark sightings (gray bars).

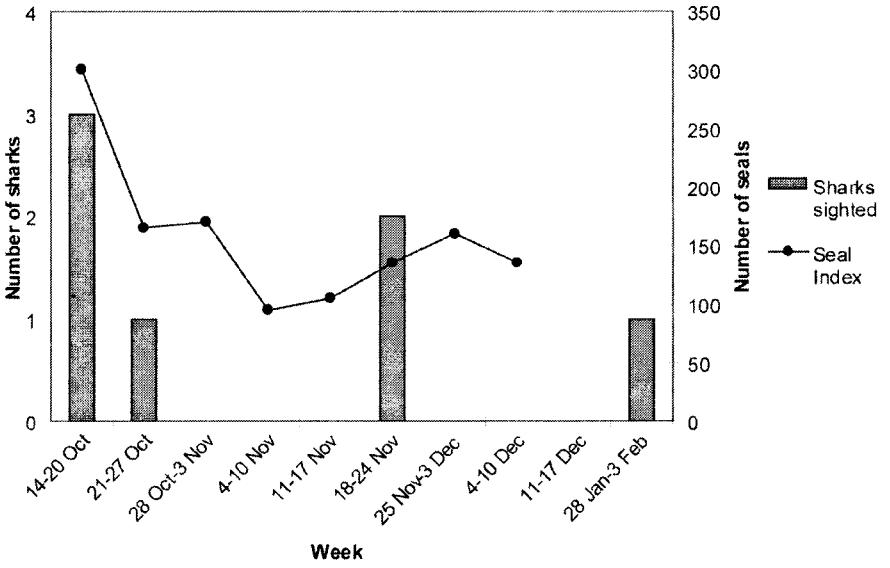

Figure 3. Seal Index (black line) recorded at the Point Reyes Headlands, California, main elephant seal colony during fall 2000 contrasted with shark sightings (gray bars) during the same period. Seal Index data are not available for the final two weeks of the project.

DISCUSSION

White sharks are clearly present at the Point Reyes Headlands. Further, it is apparent that they can be attracted to the surface using conventional techniques. We sighted an average of one shark for every 4.75 h spent sampling. This equates to roughly one shark per day on the water; however, the shark sightings were not distributed evenly over time (Fig. 2). It must be cautioned, too, that the sample size thus far is too small to draw final conclusions; however, some trends are suggested and are worth noting.

One point of interest is that white sharks are present in these waters beyond the time period from September to December when yearling elephant seals are typically present. We expected shark occurrence to peak with the return to shore of these naïve animals, as has been reported at the Farallon Islands (Ainley et al. 1981, 1985). Our project began during this season, and there appears to be some correlation between the Seal Index and the number of sharks sighted (Fig. 3). However, one shark was attracted to the surface as late as 1 February 2001, during only 2.25 h of sampling. This suggests that while shark numbers may peak during early fall, some animals are present much later. This raises the question of whether or not white sharks are in fact present year round, perhaps targeting resident sea lions or harbor seals as prey. Such a pattern was first suggested by Ainley et al. (1985) at Double Point and has been noted at the Farallon Islands (P. Pyle, Point Reyes Bird Observatory, personal communication). Of interest, then, would be to determine if the sharks observed at the headlands during the elephant seal haul-out season were the same animals observed in that area the rest of the year, or if there are different aggregations of sharks present at different times of year.

Another point worth noting is that all white sharks observed in this project were smaller animals (Table 2). The largest, a male of approximately 4.5 m, was sighted at the whale carcass; however, the majority of the sharks were in the range of 3.5 to 4 m, with one small individual of approximately 3 m. It is likely that at least the smallest shark, believed to be female, was subadult based on a reported size at maturity of 3.5 m for males (Pratt 1996) and 4.5 m or greater for females (Francis 1996). This is in contrast to regular sightings of adult individuals of 5-6 m at Southeast Farallon Island, approximately 33 km to the south. It unknown whether the small size of the sharks at PRNS is an artifact of the small number of observations, or if this reflects an unusual feature of the shark population in that area.

The results of this study raise a number of intriguing questions, each meriting further study. Are white sharks present at the Point Reyes Headlands year round or seasonally? How long do individual sharks remain in the area? Do sharks sighted at the headlands appear at the Farallon Islands too? Are the same sharks present for the yearling elephant seal haul-out season as are present for the adult seal breeding season or the harbor seal breeding season? Do the headlands actually attract smaller sharks than nearby sites, and if so, for what reason? Are larger sharks excluding smaller sharks from the rich hunting grounds of the Farallon Islands, forcing the younger individuals to the smaller colony at Point Reyes?

The many conveniences offered by the location, and the success we met in locating sharks, suggest that Point Reyes can be an excellent site for future research on white sharks and their prey. We look forward to expanding on what we have already begun as well as initiating more detailed studies, and believe that the development of this new location will compliment other established sites in California and further our understanding of this important marine predator.

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