

Pilot study of white sharks (*Carcharodon carcharias*) at Point Reyes Headlands*

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Introduction

Research on white sharks in California has traditionally been conducted at the Farallon Islands and Ano Nuevo Island, sites which have historically large northern elephant seal (*Mirounga angustirostris*) populations. In 1981, elephant seals colonized the remote beaches of the Point Reyes Headlands (Sydeman & Allen, 1999), located within Point Reyes National Seashore (PRNS). The seal population at this location has grown substantially since that time. In recent years, seals at PRNS have started establishing additional satellite colonies away from the main colony, including one site within the sheltered confines of Drake's Bay. Since elephant seals returned to PRNS, there have been frequent reports of pinniped injury and mortality attributed to sharks, though no empirical evidence regarding white shark presence has been collected. The immediate objective of this project has been to conduct a preliminary examination of the population biology of white sharks (*Carcharodon carcharias*) in the vicinity PRNS. Our aims were to estimate the white shark population size and establish the tenure of visits by individual sharks to the seal colony.

Concurrent with the population estimate, we intended to assess the state of environmental contaminants in the local white shark population. Anthropogenic chemicals, such as DDT and PCBs, are known to bio-accumulate in the food chain where they may affect the reproduction and survival of organisms. Some of the highest tissue concentrations of DDT, PCBs and other organochlorines detected anywhere in the world were recorded in California sea lions (*Zalophus californianus*) in the early 1970s (LeBeouf and Bonnell, 1971). Further, chlorinated hydrocarbons and heavy metals have been detected in the livers and muscle of small shark species in California (Fairey *et al.*, 1997). As an apex predator preying on marine mammals, white sharks may be accumulating large amounts of toxins in their systems.

This research also served as a pilot study to determine the feasibility of conducting future research into the ecology and behavior of white sharks and pinnipeds at PRNS. While the Farallon Islands and Ano Nuevo Island are well known for their large numbers of both pinnipeds and white sharks, both of these sites present significant logistical challenges to researchers including frequently adverse weather conditions and distance from support facilities. In contrast, PRNS is a desirable research location due to its relative proximity to support facilities such as Bodega Marine Lab and UC Davis. Additionally, the sheltered location of the satellite colony inside Drake's Bay raises the possibility of year-round deployment of sophisticated Radio Acoustic Positioning buoys, assuming sharks are found to be entering the bay.

Methods

Population size and site tenure were to be determined by a combination of remote sensing and visual surveys. Sharks were attracted to the surface using decoys cut in the silhouette of a elephant seal or sea lion. Small portions of sea lion were attached to the decoys to enhance attractiveness of the decoy in an effort to get the sharks to remain at the surface for a period of time. Sharks thus located were photographed for inclusion in a photo-ID catalog. Individuals may be identified from these photographs on the basis of unique markings (scars, coloration, etc.) and fin morphology. An attempt was also made to bring surfaced sharks near the research boat for tagging. Five sharks were to be tagged with acoustic tags and the remainder with color coded visual tags. Tags were affixed externally to sharks with a stainless steel dart head inserted in the dorsal musculature posterior to the first dorsal fin, and applied by means of a tagging pole.

The acoustic tags transmit a unique ID code pulsed at regular intervals at 69 kHz. This signal may be received by a listening station affixed to a permanent mooring. These small, automated monitors can listen for tags for up to six months before a battery change is necessary. The device records the date and time of day an individual tagged with a coded beacon passes within range – typically 300-500 m, depending upon beacon frequency, signal strength, and noise associated with sea conditions. The streamer tags consisted of a length of wire coded with a

unique combination of colored tubing and beads. The color code was intended to facilitate recognition of previously sighted individuals. Shark population size at PRNS was to be calculated using the Jolly-Seber method for multiple mark-recapture sampling from an open population, utilizing data from the automated monitors as well as sightings and resightings of streamer tagged and photographed individuals.

During the tagging effort, we also attempted to obtain 0.5 gram core tissue biopsies from the dorsum of 12 individual sharks using a veterinary plunge-pole fitted with a punch biopsy instrument. Biopsied tissue was to be assayed by HPLC and gas chromatography for the presence of twenty-seven different organochlorine residues, including o,p' DDT and o,p' DDE, and 43 different PCBs.

Work status

The project started after permits were approved in early October 2000. The majority of effort was expended during the fall when shark numbers were expected to be high. Efforts were reduced with the onset of winter storm activity and now will continue at a reduced rate pending the location of further funding. It is our intent to visit the site at least once a month during this time to record if sharks are present year-round. Intensive effort will be resumed in the fall if funding permits.

Work progress

The permits to attract sharks to the surface for tagging, tissue collection and photography were approved on 12 October, 2000; however, non-invasive data collection began 9 October due to the fortuitous appearance of a humpback whale carcass in Drake's Bay. White sharks were observed from shore feeding on the carcass. With the permission of the S. Allen, PRNS research director, we were able to approach the carcass by boat and take photographs of three sharks. No tags were attached at this time.

Sampling while drifting with a baited decoy was conducted twice weekly, ocean conditions permitting, between the dates of 16 October and 12 December, 2000 at which point activities were curtailed. Sampling has been continued intermittently since that time until the present (see Table 1 for summary). Through the end of April we have conducted 14 research trips actively attempting to attract sharks, spending approximately 41 hours on site with decoys in the water (Figure 1). Sample drifts have covered a total distance of 29 linear kilometers. Most of this activity has been in the immediate vicinity of the main elephant seal colony (approximately 33 hrs of decoy soak time over 18 linear km); however a significant amount of effort was also expended attempting to attract sharks within Drake's Bay. (8 hrs, 11 linear km). Seven individual sharks were attracted during this time, all in the waters off of the main colony. No sharks were resighted after the day of initial contact. This represents an overall sampling effort off the main colony of approximately 4.75 hrs drifting per individual sighted. If one includes the time spent in Drake's Bay, this sighting frequency drops to 5.75 hours drifting per individual sighted. Interestingly, six of the sharks observed responded to the sea lion decoy (over a total effort of 20 hrs, or 3.25 hrs/shark) whereas only one shark responded to the elephant seal decoy (13 hrs). This is somewhat unexpected as elephant seals are traditionally considered to be the preferred prey of white sharks. It is possible that the decoys did not present any salient differences to sharks even though they looked different to human observers. Whether this represents a true preference on the part of the sharks or merely a chance occurrence is not clear due to the small sample size and lack of any experimental control.

Photographs and visual observation data were collected during the tagging effort, as well as during observations at the whale carcass. Of the 10 interactions (7 while drifting, 3 at the carcass), sufficient data exist to identify three animals on sight with an extremely high level of confidence. A further three animals may be identifiable after comparison of dorsal and caudal fin

images. All the sharks that were observed were relatively small individuals – estimates varied between 3 to 4.5 meters.

No visual tags were attached during this time, though one shark was tagged with an ultrasonic acoustic tag. No listening stations were deployed (see **Difficulties encountered**), and although we listened for the tag in subsequent weeks using a portable hydrophone on our research boat, the shark was never relocated. Additionally, no tissue biopsies were successfully collected for bio-contaminant analysis.

The number of seals present on the beach during the project was estimated based on visual counts from high resolution digital images of the colony taken from the surrounding bluffs (Figure 2). These represent only a coarse index of seal abundance as no vantage point provided unobstructed sightlines to the beach, and some seals were always hidden from view. Furthermore, images were taken from a significant distance due to the height of the bluffs so it was not possible to accurately determine age class or sex. Peak numbers of seals (about 300 individuals) were recorded on the first week of the project. In subsequent weeks, numbers declined to about 150 individuals and remained at that level throughout the end of the year. The majority of sampling effort ended before large numbers of large adults started to appear on the beach. No seal count data exist for the last completed sampling day (2/1/2001). No seals or sharks were observed by us inside Drake's Bay through December; however, commercial fishermen in the area informed us that elephant seals appeared at the satellite colony in the Bay in January, and that several sharks were observed swimming near the Pt. St. Joseph Fish Company dock.

Difficulties encountered

The most significant difficulties that we encountered were related to inclement weather and boat access. Many field days were cancelled because conditions would not permit safe use of our small research boat. Further, we often had to cut days short due to the unpredictable and rapidly shifting weather for which Point Reyes is notorious. It was not uncommon for a good day to rapidly turn rough and force us off the water. Significant effort was required to get personnel and equipment on site, so the fickle nature of the weather conditions resulted in an inefficient use of manpower. For future work in the area, this could be alleviated by use of a dedicated field crew stationed at Point Reyes for the entire fall during the peak shark season. This would permit researchers to exploit shorter-term weather conditions such as afternoon lulls, rather than require a minimum of a full day of good weather.

We faced an additional difficulty in that we were unable to deploy the automated listening station as planned. The UC Davis Dive Safety Board raised concerns regarding the safety of the divers that would have to retrieve the data. Until those concerns are alleviated, and we are certain that we can recover our data and equipment, we will not deploy listening stations. We are currently working with the Dive Safety Board to resolve this issue to everyone's satisfaction.

Lastly, the current state of the boat ramp at the historic Point Reyes Lifeboat Station in Drake's Bay restricts access to what would otherwise be an excellent field site. We were able to launch our boat from the existing ramp only with great effort and the timely assistance of PRNS rangers. After this experience, it was deemed impossible to recover the craft from the same location. It was necessary to moor the boat in Drake's Bay, which was made possible thanks to the donation of a mooring from Mr. George Nunes. The boat remained in the bay for the duration of the project, at which point we were able to tow it back to Bodega Marine Lab. The current situation has several significant drawbacks. First, it prevents the use of the research craft in other projects, as well as making it difficult to perform routine maintenance. Second, it exposes the boat to risk of loss or damage during storms. This circumstance will be remedied by repair of the

ramp, and we eagerly anticipate this event. A functional ramp will permit rapid deployment and recovery of our boat and equipment, and increase our flexibility and efficiency in the field.

Future goals

The study to date has provided concrete evidence of a significant white shark presence in the vicinity of the Point Reyes elephant seal colony, though insufficient data have been collected to estimate population size and site tenure. We hope to continue sampling in the park in order to build our individual photo ID database and to elucidate patterns of white shark presence throughout the year. Additionally, our experience this year indicates that PRNS is a good field site for future research on white sharks and their prey. Efforts will be aided by the anticipated completion of repairs to the park boat ramp in Drake's Bay. With this improvement, we will be able to take advantage of the potential for PRNS as a world-class site for research into shark and pinniped ecology and behavior.

Permits

This work was conducted under the following permits:

- California Department of Fish and Game 1999 Scientific Collecting Permit 801109-04
- Point Reyes National Seashore Permit 00-21
- Gulf of the Farallones National Marine Sanctuary Permit GFNMS 03-00
- NOAA/NMFS authorization to possess marine mammal carcasses/parts for use in scientific research
- UC Davis Animal Care and Use Protocol #8871

Personnel involved

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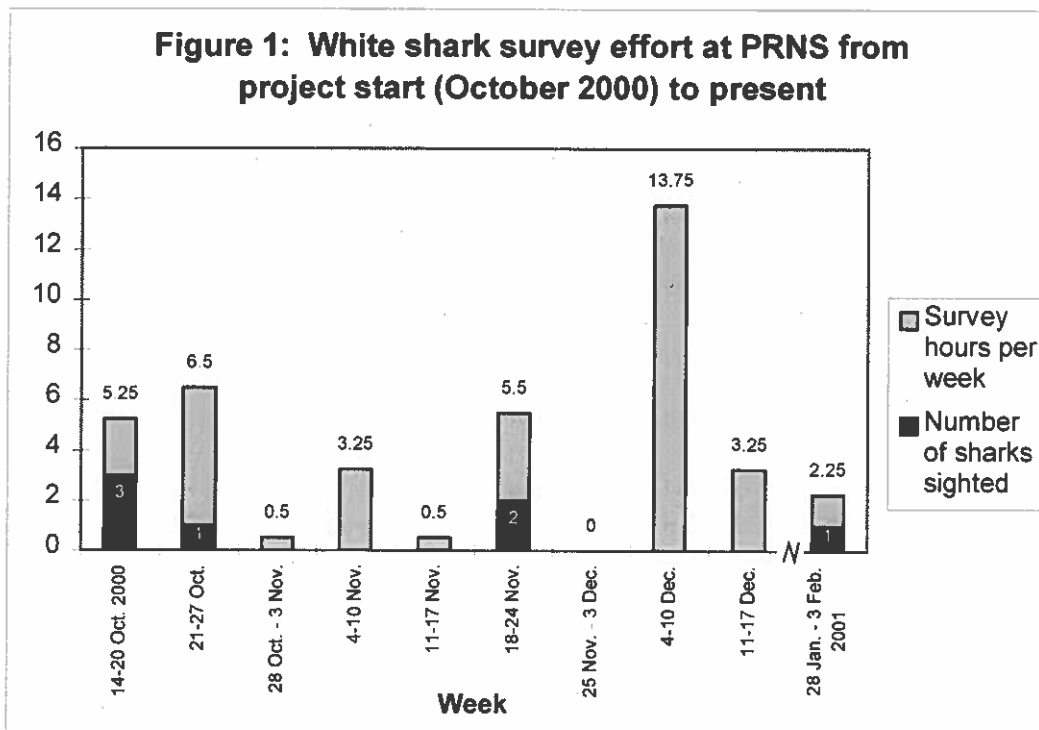


Figure 1: White shark survey effort and results for work conducted off of Pt. Reyes Headlands between 10/14/2000 and 2/3/2001. Gray bars represent the total hours per week actually spent drifting with decoy and bait in the water (black numerals show number of hours). Dark bars indicates the number of sharks sighted during that week (white numerals show number of sharks).

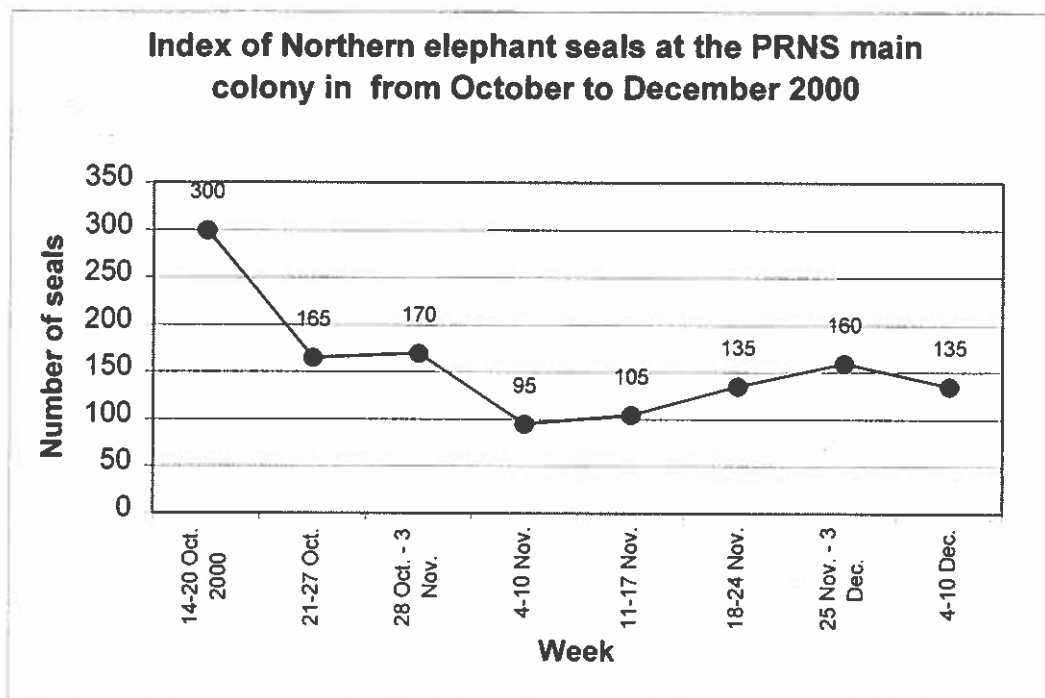


Figure 2: Index of the number of Northern elephant seals observed at the main colony at PRNS during field work conducted between 10/14/2000 and 12/10/2000. Index is based on number of seals counted in high resolution digital images taken from bluffs behind the colony. There was no unobstructed sightline, so the index does not reflect a true count of all seals present; however, the observations were taken in a consistent manner throughout the project and reflects how many seals were on the beach.

Table 1: Summary of field effort at PRNS from start of project on 9 October, 2000 to present.

Year	Month	Day	Location	Total Drift Time (hrs:min)	Linear Distance Covered (km)	Sharks:		Decoy
						Sighted	Tagged	
2000	October	9	Drake's Bay	-	-	3	0	none - naturally occurring whale carcass
		16	Main colony	3:12	2.0	2	0	Zalophus
		17	Main Colony	0:21	0.4	1	1	Zalophus
			Drake's Bay	1:45	4.0	0	0	Zalophus
		23	Drake's Bay	1:42	0.9	0	0	Mirounga
		24	Main Colony	4:40	5.4	1	0	Mirounga
		31	Main Colony	0:30	no data	0	0	Mirounga
	November	7	Main Colony	0:45	0.6	0	0	Mirounga
			Drake's Bay	2:23	4.0	0	0	Mirounga
		13	Main Colony	0:36	0.5	0	0	Mirounga
		20	Main Colony	4:30	1.1	2	0	Zalophus
		22	Drake's Bay	0:56	0.1	0	0	Zalophus
	December	4	Main Colony	4:45	2.9	0	0	Zalophus
		5	Main Colony	4:42	1.1	0	0	Zalophus
		8	Main Colony	4:15	1.9	0	0	Mirounga
		12	Main Colony	2:05	1.9	0	0	Mirounga
			Drake's Bay	1:15	1.9	0	0	Mirounga
2001	February	1	Main Colony	2:19	0.5	1	0	Zalophus
Subtotals		12*	Main colony	32h 40m	18.2	7	1	
		5*	Drake's Bay	8h 01m	10.9	3	0	
Total		14 days		40h 41m	29.1	10	1	

* = at least a portion of field day spent in this area