

WHITE SHARK PREDATION ON PINNIPEDS IN CALIFORNIA COASTAL WATERS

White sharks, *Carcharodon carcharias*, prey on various fishes, sea turtles, whales, dolphins, and on several species of pinnipeds (Allen 1880; Elliot 1881; McCormick and Allen 1963; Davies 1964; Nishiwaki 1972; Ellis 1976; Ainley et al. 1981; McCosker 1981). Data on pinnipeds preyed upon by sharks in California waters are meager and many aspects of the predator-prey relationship are unknown.

Four types of evidence indicate that sharks prey on pinnipeds: 1) Pinniped remains in the stomachs of dead sharks, 2) observation of seals with injuries inflicted by large sharks, 3) observation of shark attacks on seals, and 4) the presence of sharks near seal rookeries at a time when seals are present. We report evidence of the first two kinds regarding shark predation on northern elephant seals, *Mirounga angustirostris*, and harbor seals, *Phoca vitulina*.

Methods

Five white sharks caught in southern California waters in 1975 and 1976 and two white sharks that washed ashore in central California in 1977 and 1978 were examined. The fresh dead sharks were weighed, measured, and their sex determined. Stomachs were dissected out and contents identified, and in some cases, weighed and measured (Table 1).

From 1968 to 1980, shark-bitten elephant seals on Año Nuevo Island and the adjacent Año Nuevo Mainland in central California were

counted, photographed, and identified individually, and their behavior was monitored. This was accomplished during daily censuses conducted each breeding season from December to mid-March and during weekly censuses conducted during the remainder of the year. Only seals with fresh wounds judged by their pink or bloody appearance to be less than a few days old were included in the sample. This gives us confidence that our subjects were injured near the study area. We did not census animals with old scars or healed injuries, whose origins were difficult to ascertain. Shark injuries were differentiated from other wounds, caused by boat propellers or intraspecific fighting, by their oval shape and the jagged serrations caused by the predator's sharp teeth. Both slight and serious wounds were included. Slight wounds consisted of superficial tooth punctures or scrapes across the skin; serious wounds involved deep bites and tears. Seriously wounded seals had large flaps of flesh exposed or chunks of flesh missing. The dimension of bites was measured on a few dead seals.

We marked and followed 11 females who sustained moderate to severe shark wounds when pregnant just before arriving on the island to give birth. Their pups were marked at birth and the pair was observed until the filial relationship ended. Northern elephant seal females give birth within a week after arriving on the rookery. A female nurses her pup daily for about 4 wk before weaning it and returning to sea (Le Boeuf et al. 1972).

A similar search for shark-bitten harbor seals, which breed at Año Nuevo Island and numerous

TABLE 1.—Stomach contents of white sharks collected off the California coast from 1975 to 1978. Specimens 1-5 were collected by Sea World of San Diego, no. 6 by K. Skaug and M. Riedman, and no. 7 by an anonymous fisherman.

Specimen number	Date of collection	Location	Sex	Total length (m)	Weight of shark (kg)	Stomach contents
1	24 June 1975	8 km northeast of Santa Catalina Island	F	3.9	623.7	Anterior portion of stomach contained harbor seal remains (18.2 kg). Posterior stomach held unidentified pinniped.
2	1 Aug. 1975	110 m west of Laguna Beach	F	2.4	138.8	A 4-in patch of pinniped pelage.
3	6 Sept. 1975	Near Anacapa Island	F	4.9	1,428.8	Harbor seal, well digested.
4	7 Sept. 1975	11.3 km southeast of Anacapa Island	F	5.0	1,560.4	Skull and posterior portion of a juvenile elephant seal, plus large amounts of fur and digested material.
5	13 June 1976	West end of Catalina Island	F	5.5	1,882.4	Nearly digested. Bulk suggested a large animal, probably a marine mammal.
6	3 Feb. 1977	Año Nuevo Bay	F	4.7	?	Approximately one-third of a recently eaten 4-yr-old male elephant seal.
7	25 Sept. 1978	1.6 km offshore near Aptos	M	3.9	540	The head of a harbor seal.

other locations along the California coast, was not conducted.

Results

Table 1 summarizes data obtained from the stomachs of seven great white sharks examined shortly after they washed ashore dead or were captured at sea. Four points are worth noting:

- 1) Six stomachs contained seal remains, three of harbor seals and two of northern elephant seals.
- 2) Large prey was consumed. On the basis of tooth annuli and head and proboscis size, we estimate that specimen no. 6 (Fig. 1) contained the remains of a male elephant seal, 4 to 5 yr old. Intact, this seal would have measured approximately 3 m in length and weighed 450 to 680 kg.
- 3) The dimensions of the barely digested material in four of the shark stomachs indicate that the prey had been consumed in large

pieces. For example, the stomach of one specimen contained the entire head, unmarred and severed cleanly at the neck. Both hind-flippers and the tail were covered with hair and still attached to a segment of the sacrum. Also included were both foreflippers, one attached to a large piece of flesh containing the shoulder, a large portion of the midsection including six vertebrae, and several pieces of flesh and fur in various stages of decomposition. The elephant seal material weighed about 225 kg.

- 4) Six of the seven sharks were females.

The majority of the shark-injured elephant seals were observed during the winter breeding season. Only two recently bitten animals were observed on Año Nuevo Island in spring, despite the larger number of animals present at this time compared with the breeding season (Le Boeuf and Bonnell 1980).

Fewer than three victims per breeding season were observed from 1968 to 1976. From 1976 to

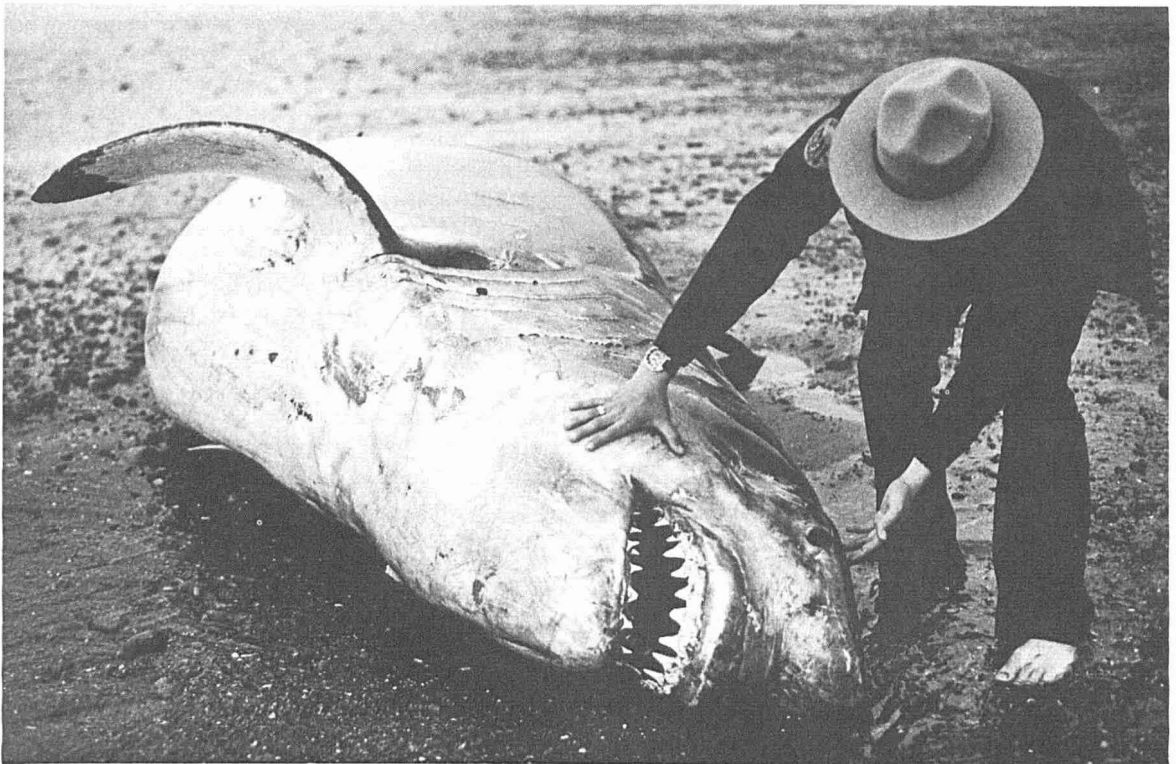


FIGURE 1.—A moribund great white shark (Specimen No. 6 in Table 1) that washed ashore near Año Nuevo Point shortly after having consumed approximately one-third of a young male northern elephant seal.

1980, 44 elephant seals with shark-inflicted injuries were observed (Table 2). Most of the elephant seals bearing recent shark wounds were adults. Males incurred the highest injury rate. Even the largest adult bulls, measuring more than 4.9 m and weighing between 1,800 and 2,700 kg were observed with shark bites (see Figure 2a). This may be due to the male habit of spending more time in the water near the rookery during the breeding season than females.

TABLE 2.—Shark-bitten northern elephant seals observed on Año Nuevo Island and the Año Nuevo Mainland.

Year	Adult males	Adult females	Juveniles	Pups	Total
1976		3			3
1977	3	4		1	8
1978	1	7	1		9
1979	5	1	1		7
1980	16	1			17
Total	25	16	2	1	44

Shark bites were located on diverse areas of the body but rarely on the head (Fig. 2). Possibly, frontal attacks were less successful or head bitten seals simply did not survive the encounter. In many cases, large pieces of blubber were missing or hung loosely from the animal. Some seals lost a foreflipper or hindflipper and in one case most of the proboscis. Some animals were bitten several times.

The majority of injured seals survived and recuperated rapidly. Infected wounds were rarely observed. Only three elephant seals died on the island or on the mainland following shark injury. In September 1976, an 8½-mo-old female was found dead with numerous deep lacerations and teeth marks covering her body. In December 1977, a 1-wk-old pup washed up with its entire sacral region amputated just below the umbilicus. In February 1978, a large 7-yr-old male died on the island's main breeding beach from massive shark wounds incurred within the previous 24 h. The most serious wounds consisted of two large oval chunks of flesh missing from the left side of the thoracic region (Fig. 2e). The bites measured 61 and 69 cm wide, 61 cm high, and 30 cm deep. No bite penetrated the body cavity although some muscle was removed and a rib was partly exposed.

Most female elephant seals bitten by sharks shortly before giving birth failed to wean their pups successfully. One female gave birth to a stillborn and returned to sea immediately. Seven

females either abandoned their pups shortly after parturition or they were unable to care for them adequately. Four of these pups died; the eventual status of the other three pups could not be determined. The three females who were successful in weaning their pups appeared to have sustained the least serious injuries. All injured females remained in the harem for a much shorter period than normal. No injured female was observed to copulate, as uninjured females do, just before returning to sea. Thus, most injured females not only failed to produce a pup during the year of injury, but if they failed to copulate, they did not reproduce in the subsequent year as well.

Discussion

The data on stomach contents of white sharks presented in this paper is conclusive evidence that this shark preys on elephant seals and harbor seals in southern and central California waters.

We hypothesize that shark-inflicted injuries to northern elephant seals at Año Nuevo were caused primarily by white sharks. This hypothesis is supported by:

- 1) Data from a white shark that washed ashore at Año Nuevo Bay whose stomach contained the remains of an elephant seal (Table 2).
- 2) Observation of white sharks in the area. Twice during the summer of 1970 seal researchers saw white sharks measuring about 4.5 m from a dinghy 100 m south of the island. Party boat operators and fishermen reported seeing white sharks in this area several times during the last decade. Anglers report that white sharks occasionally attack large lingcod, *Ophiodon elongatus*, when they are caught on hook and line; the sharks surface and circle boats, especially when fishing stops (Miller and Collier 1980).
- 3) An observed white shark attack of a northern elephant seal near Año Nuevo Island. This occurred on 1 February 1981.
- 4) The large size of shark bites. This indicates that they were caused by large sharks. White sharks may also be responsible for injuries to elephant seals on other rookeries in California (Ainley et al. 1981) and in Mexico (Townsend 1885; B. Le Boeuf, pers. obs.).

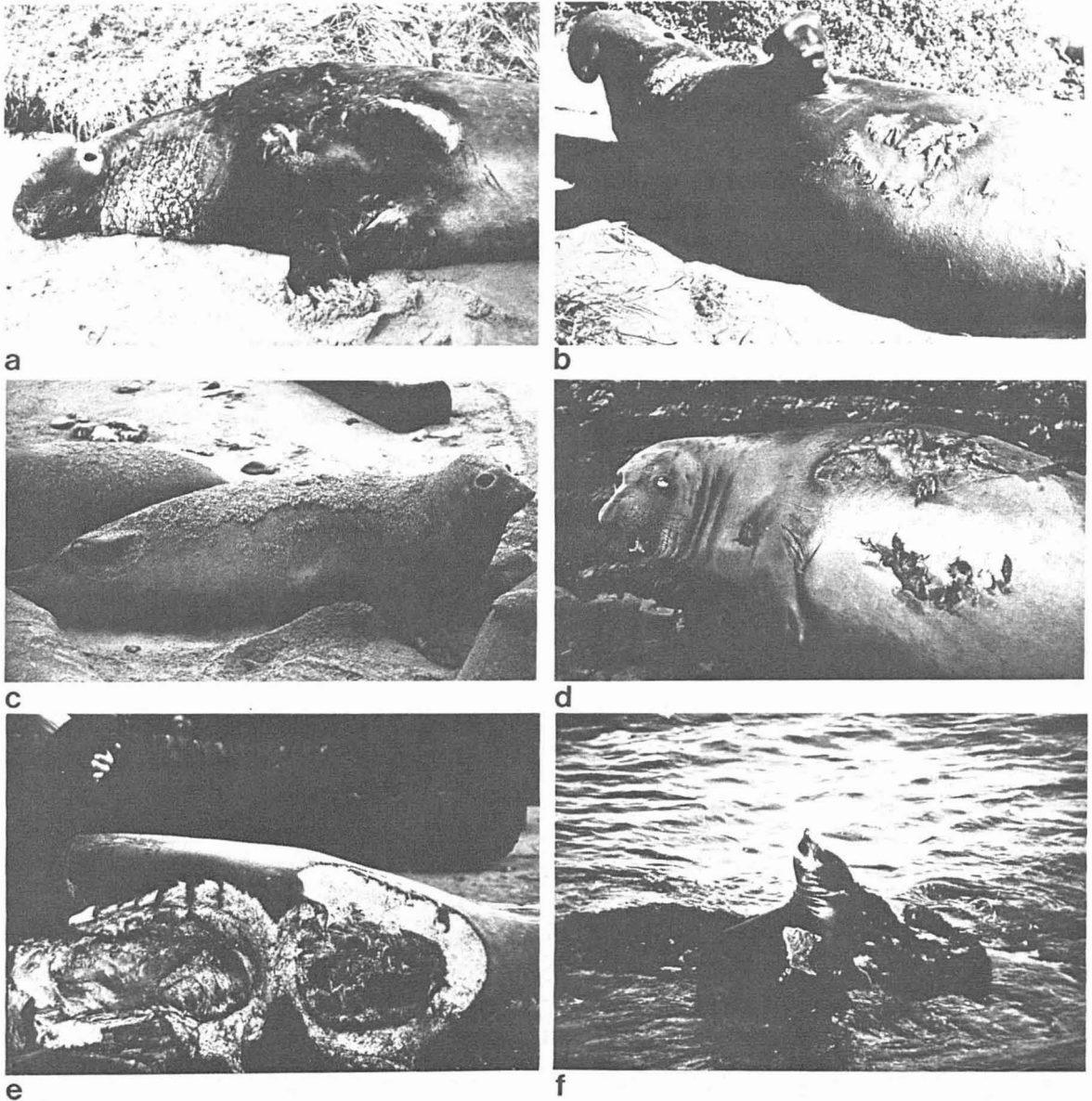


FIGURE 2.—A variety of shark-inflicted wounds observed on elephant seals and sea lions at Año Nuevo. A crescent shaped wound (a) and toothprints (b) on adult male elephant seals. A crescent bite on the dorsal posterior of an adult female elephant seal (c) and a large imprint of both jaws on an adult female with a blind left eye (d). Two large chunks of flesh bitten off the left side of an adult male elephant seal who subsequently died from his wounds (e). A California sea lion bearing a recently inflicted shark injury (f).

The results of this study support and augment those of Ainley et al. (1981) on South Farallon Island near San Francisco, Calif. They found that white sharks were responsible for most of the shark attacks observed on pinnipeds in the waters surrounding the island during the period September 1970 to February 1979. Northern ele-

phant seals were attacked more frequently than harbor seals and sea lions, and shark-bitten female elephant seals exhibited low reproductive success.

Shark attacks on elephant seals of Año Nuevo Island and South Farallon Island (Ainley et al. 1981) appear to be increasing, but more data

based on continued monitoring is necessary to confirm this point. Periodic increases in shark attacks of the magnitude found in these two studies may be related to several possible factors: The well-documented increase in elephant seals (Le Boeuf and Bonnell 1980), an increase in abundance of sharks, or to one or a few relatively inept predators at work.

Acknowledgments

We thank Sea World of San Diego for permitting us to use data from their shark collecting expeditions; Walter Ward for bringing the beached shark to our attention and for providing measurements; Keith Skaug, C. Leo Ortiz, Robert Gisiner, and Anne Hoover in acquiring and examining shark stomach contents; and Jack Ames, Ellen Chu, Daniel Miller, and Breck Tyler for comments on the manuscript. This study was supported in part by the National Science Foundation grant BNS 74-01363 402 to B. J. Le Boeuf.

Literature Cited

- AINLEY, D. G., C. S. STRONG, H. P. HUBER, T. J. LEWIS, AND S. H. MORRELL.
1981. Predation by sharks on pinnipeds at the Farallon Islands. *Fish. Bull.*, U.S. 78:941-945.
- ALLEN, J. A.
1980. History of North American pinnipeds: A monograph of the walruses, sea-lions, sea-bears and seals of North America. Gov. Print. Off., Wash., D.C., 785 p.
- DAVIES, D. H.
1964. About sharks and shark attack. Brown, Davis, and Platt Ltd., Durban, 237 p.
- ELLIOTT, H. W.
1981. The seal-islands of Alaska. Gov. Print. Off., Wash., D.C., 176 p.
- ELLIS, R.
1976. The book of sharks. Grossett and Dunlap, N.Y., 320 p.
- LE BOEUF, B. J., AND M. BONNELL.
1980. Pinnipeds of the California islands: abundance and distribution. In D. Power (editor), *The California Islands: Proceedings of a Multidisciplinary Symposium*. Santa Barbara Museum of Natural History, Santa Barbara, Calif.
- LE BOEUF, B. J., R. J. WHITING, AND R. F. GANTT.
1972. Perinatal behavior of northern elephant seal females and their young. *Behaviour* 43:121-156.
- MCCORMICK, H., AND T. ALLEN.
1963. *Shadows in the sea*. Chilton Books, Phila., 415 p.
- MCCOSKER, J. E.
1981. Great white shark. *Science* 81 2(6):42-51.
- MILLER, D. J., AND R. S. COLLIER.
1980. Shark attacks in California and Oregon, 1926-1979. *Calif. Fish Game* 67(2):76-104.
- NISHIWAKI, M.
1972. General biology. In S. H. Ridgway (editor), *Mam-*

mals of the sea: Biology and medicine, p. 3-204. Charles C. Thomas, Springfield, Ill.

TOWNSEND, C. H.

1885. An account of recent captures of the California sea-elephant, and statistics relating to the present abundance of the species. *Proc. U.S. Natl. Mus.* 8:90-93.

BURNEY J. LE BOEUF

*Center for Coastal Marine Studies and Crown College
University of California, Santa Cruz
Santa Cruz, CA 95064*

MARIANNE RIEDMAN

*Center for Coastal Marine Studies
University of California, Santa Cruz
Santa Cruz, CA 95064*

RAYMOND S. KEYES

*Sea World
1720 South Shores Road
San Diego, CA 92109*

VERTICAL STRATIFICATION OF THREE NEARSHORE SOUTHERN CALIFORNIA LARVAL FISHES (*ENGRAULIS MORDAX*, *GENYONEMUS LINEATUS*, AND *SERIPHUS POLITUS*)

Length measurements of larval fish are most frequently used in describing life stages (Moser and Ahlstrom 1974), and the subsequent development of population estimates (Kumar and Adams 1977). Field and laboratory observations are used to construct growth models of larval fishes, which are useful in predicting rates of growth under various environmental conditions (Hunter 1976). When combined with observations of larval abundance and distribution, length measurements can be indicators of both larval and adult ecology. Larval length-frequency data provide information about adult distribution and abundance, spawning periodicity, food preferences, and behavioral transitions that occur during development (Gjøsaeter and Saetre 1974; Tanaka 1974).

Larval length-frequency distributions of three species of fish were determined in conjunction with a study of the effects of a power plant offshore cooling water intake on local nekton populations. The three species chosen [northern an-