

WHITE SHARK RESEARCH AT SOUTHEAST FARALLON ISLAND, 2002

REPORT TO THE U.S. FISH AND WILDLIFE SERVICE
FARALLON NATIONAL WILDLIFE REFUGE

by

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BACKGROUND/JUSTIFICATION:

There is much interest and concern over the population size of white sharks in California, as it relates to this predator's role in the marine ecosystem, its effect on the population dynamics of pinnipeds (which in turn affect commercial fish stocks), attacks by sharks on humans, and the status of this potentially-threatened species (Klimley and Ainley 1996). Because of these concerns, a bill was passed in 1994 (and made permanent in 1997) protecting the white shark in California and mandating long-term assessment of its population (Heneman and Glazer 1996). But acquiring accurate abundance estimates has proven difficult due to the white shark's pelagic habits and the few available avenues to monitor its numbers in a standardized manner. Frequency of attacks on humans (Lea and McCosker 1996) may shed some light on white shark abundance, but assessment of these frequencies is confounded by the lack of data on human recreational-activity patterns in coastal waters.

Southeast Farallon Island (SEFI) off San Francisco has proven to be the best place in California to study the white shark (Ainley et al. 1985, Klimley and Ainley 1996). Both analyses of shark-bitten pinniped records from SEFI and the coast (Long et al. 1996), and the continuous monitoring of predation frequency from SEFI (Ainley et al. 1985, Klimley et al. 1992, Pyle 1992, Pyle et al. 1996a) suggest that white sharks may be increasing off California but these results are not yet conclusive (Pyle et al. 1996a). In addition, unique events such as predation on a white shark by killer whales at SEFI in 1997 and 2000, and the subsequent disappearance of white sharks from the island (Pyle et al. 1999) after both predation events, may affect both the short-term and long-term population dynamics of white sharks off California. More years of standardized monitoring from SEFI are needed to adequately assess shark abundance in light of such events, and in response to long-term changes to the marine ecosystem, e.g., those associated with decadal-scale climate regimes (Hare and Mantua 2000) as well as possible disturbances related to increased cage-dive ecotourism activities in 1999-2002.

While several studies at Southeast Farallon Island (SEFI) and Año Nuevo Island have shed light on the life history of seasonally resident white sharks off central California, virtually nothing is known of their long-range movement patterns or breeding biology. At SEFI white sharks occur in August-March (peaking in September-November) but are absent (or virtually so) in April-July. Until very recently (see below), no data existed on where these sharks go in April-July. Distributions of captured and beach-washed white sharks suggested that adults traveled into waters off Baja California to breed in March-June (Klimley 1985), but recent data from SEFI is showing the white shark to be a much wider-ranging species (see below). No pregnant female white shark has ever been observed in the eastern Pacific Ocean. While white sharks are known to occur in remote places in the Pacific (e.g., Chile, New Zealand, Australia, Japan, and Hawaii), it is not known if these populations are isolated from one another or if long-distance migrations between these localities occur. Much can still be learned about the white shark's

migration patterns, and how they affect the predator-prey relationships and conservation of this species.

We will learn a great deal about the movement patterns of white sharks by determining where they are from four to eight months after leaving SEFI waters in fall, and what physical oceanographic parameters they have inhabited along the way. This is especially true for known sharks with previous occurrence data over the last ten years from SEFI. Our data further indicate that females and males may occur on different sides of the island and have other sex-specific movement patterns; e.g., individual females occur every other year whereas males occur every year, suggesting a biennial breeding regime and a slower reproductive rate than previously thought (Anderson and Pyle, in press). Differences in migratory strategies between females and males could illuminate breeding strategies in this little-known species.

In 2002 we continued monitoring white shark activity at SEFI during the fall and we successfully applied two satellite pop-off transmitters, as part of an ongoing study initiated in 1999, to help determine where white sharks occur when they are not at SEFI.

METHODS:

We continued our program initiated by Anderson during 1987-1988 (Klimley et al. 1992) of conducting a standardized effort to observe and record all shark activity, indefinitely, as part of long-term research studies at SEFI. An observer was stationed at the lighthouse atop the island during all daylight hours (visibility and wind conditions permitting) from 1 September to 4 December 2001, to scan the ocean surface for shark activity. When a sighting or predation event was detected, the observer was responsible for: 1) pinpointing the location of the observation with a theodolite mounted near the lighthouse, 2) attempting to identify prey through visual observation, 3) looking for scars or other marks on the shark to identify the individual, 4) completing a standardized form describing the predatory event, and 5) communicating via hand-held radio the predation event location to Anderson, Pyle, and/or Brown. Our primary objectives with these data were to continue to document seasonal patterns of occurrence and predatory behavior of the white shark at SEFI, and to monitor long-term white shark abundance and population trends in the area by calculating predation frequency (e.g. predation events observed/100 hrs observation). Weekly counts of pinnipeds and daily observations of weather and ocean condition were recorded so that these factors could be assessed in relation to predation frequency. Analyses of trends will include linear logistic regression and multiple regression adjusting for environmental factors (see Pyle et al. 1996a, 1996b).

Because of growing concerns about the potential impacts of increasing numbers of “cage-dive” ecotourism operations to view white sharks at the Fararallones, we also began documenting the activities of all such operations during shark monitoring from the lighthouse. Arrival and departure as well as activity start and stop times were recorded for each vessel observed, visibility permitting. Activities recorded included chumming, deployment of cages, presence at shark attacks (along with proximity of boats to attacks),

and trolling and drifting with decoys. During all of these activities the number of “decoys” in the water (along with a description of each decoy) was also recorded.

Since 1993 we have been identifying as many individual white sharks as possible through the use of observation, photographs, and (primarily) underwater video. Once a predatory event has been observed from the lighthouse, it's location is communicated to Anderson, Pyle, and/or Brown, who proceed to the proximity of the event in a 17-foot Boston Whaler (weather permitting), remaining at a safe distance (usually > 10 m) from the event so as not to affect the behavior of the feeding sharks. We have discovered that white sharks routinely investigated our boat or decoys (Anderson et al. 1996b) up to two hours subsequent to predatory events on pinnipeds. This behavior allowed for the extensive use of underwater video recorders to document individual sharks, and enabled us to confirm sex of most individuals by the presence (male) or absence (female) of claspers (Pratt, 1996). We identified and documented individual sharks using size and unique markings such as scars, mutilated fins, natural pigmentation, and notch patterns on the trailing edge of the dorsal fin (Anderson and Goldman 1996, Klimley and Anderson 1996).

In previous years we launched boats from the island when a shark attack was first observed. Due to safety concerns with the equipment at East Landing we changed our protocol in 2002. The shark research boat remained tied to a buoy located in Fisherman's Bay for most of the season (27 September to 16 November 2002). It was brought onto East Landing (hoisted unmanned with the East Landing boom) three times due to storms and twice due to problems with the outboard motor (which wound up being related to a weak battery). On days of favorable weather and tides we launched a zodiac from North Landing and transferred equipment to the research vessel up to three hours prior to a high tide and remained “standing by” in the boat for up to six hours (or until three hours following the high tide). Shark attacks were communicated to researchers standing by in the vessel so that they could proceed to the attack site and collect data as described above.

In continued collaboration with Barbara Block, Andre Boustany, and Kevin Weng of Hopkins Marine Station, we deployed two archival pop-up transmitters onto white sharks. A recall on the tags due to a software problem prevented us from being able to deploy more transmitters, as originally planned. Transmitters were attached below the first dorsal fins (in the dorsal saddle musculature) using an eight-foot dowel pole and a titanium billfish-tagging spear tip. The tags recorded, once every 2-10 minutes, water temperature, depth from surface, and light volume. These data will be stored within the tag for twelve months (according to the programmed pop-off times). Once popped off, they will download these data, along with position of pop off, via satellite to computers at Hopkins Marine Station.

RESULTS:

We recorded 56 white shark predation events in 2002: 11 in September, 20 in October, 24 in November, and 1 in December. We logged a total of 658.7 hrs at the lighthouse in

2002, 168.7 hrs in September, 215.2 hrs in October, 242.8 hrs in November, and 32.0 hrs in December. Removing "incidental" predation events (those recorded apart from lighthouse watch times; five in September and one each in October, November, and December), predation event frequency was 7.29 per 100 hours of lighthouse observation. As in past years, this rate increased throughout the main part of the season, from 3.56 in September to 8.83 in October, to 9.47 in November.

The prey species was identified during 28 of the 56 predation events and included four California Sea Lions, 1 Harbor Seal, and 23 immature Northern Elephant Seals. Because sea lion carcasses sink and seal carcasses float, most of the predation events where prey was not identified probably involved sea lions. Assuming this, the proportion of Elephant Seal predation events was 41.1%: 45.5% in September, 30.0% in October, and 52.2% in November. This is a typical proportion of Elephant Seals in comparison with past years data. Mean censuses of immature Elephant Seals on SEFI were close to mean values for the fall: 348 in September, 556 in October, and 582 in November.

Sequences of approximately 58 shark-observations were recorded on video at 22 separate predation events during 21 days spent on the water. The 58 shark-observations involved many of the same sharks at separate events, with an estimated 20-25 different individuals being identified in 2002. Known individuals recorded in 2002 included Bitehead, Cut-tail, Spotty, Two-spot, Cal Ripfin, Kyra, Tipfin, Middle Notch, Emma, and probably more once video recordings have been analyzed in detail. Notable for her absence was White-slash, an "even-year" female that we have observed on multiple occasions every other year since at least 1992.

Two archival pop-up transmitters were deployed in 2002, one on 12 November (into Spotty, a male), and one on 15 November (into Emma, a female). The tags were each programmed to pop up on 10 November 2003.

Seven of the ten tags deployed in 2001 successfully popped up (the other three were from tags with bad components, part of the recall noted earlier) and all ten again indicated that the sharks had traveled far out into the Pacific and had dove as deep as 700 m. The shark that went to Hawaii in spring 2001, Tipfin, was retagged in fall 2001 and he returned to Hawaii again in spring 2002, to the same area that he went in 2001.

We recorded a total of seven individual or ecotourism groups in 2002 attempting to view white sharks at the Farallones through the use of chumming or decoy deployment. The following table summarizes activities by these boats. The 164 hours of unknown activities recorder for "Patriot" were on days for which fog or other island activities prevented us from obtaining accurate data. Visual observation indicated that activities by this boat were roughly the same each day, in which case the 164 hours can be estimated as involving 69 hours of trolling decoys and 95 of drifting with decoys, with 82 hours of cage diving. The overall totals for these activities can thus be estimated as 144 hours of trolling with decoys, 163 of drifting with decoys, and 137 of cage diving. On 23 November Brown radioed the boat "Shiraz" to request they stop chumming and they

obliged after one hour performing this activity. Similar attempts were made to radio “Zodiac” on 4 and 14 December but the radio calls went unanswered.

<u>Boat Name</u>	<u>Dates</u>	<u>Decoy Hours</u>		<u>Hours Chumming</u>	<u>Hours Cage-diving</u>	<u>Unknown Activities</u>	<u>Total Hours*</u>
		<u>Trolling</u>	<u>Drifting</u>				
Patriot	9/14-12/4	47	64	0	55	164	275
El Cid	9/29	1	4	0	0	0	5
Bayliner	10/19	9	0	0	0	0	9
Unknown	10/20	6	0	0	0	0	6
Cortez	11/21	3	0	0	0	0	3
Shiraz	11/23	0	0	1	0	0	1
Zodiac	12/4-14	9	0	5	0	0	14
TOTAL	9/14-12/14	75	68	6	55	164	313

* Cage-dive hours are also tallied under decoy-drifting hours (since all 55 hrs involved decoy deployment) and so are omitted from total hours.

DISCUSSION

White shark occurrence at the Farallones was a bit below average. The predation event frequency of 7.3 per 100 hrs of lighthouse observation was below the previous, 14-year mean of 7.70 (8.16 excluding the anomalous 1997 season):

<u>Year</u>	<u>Frequency</u>	<u>Year</u>	<u>Frequency</u>	<u>Year</u>	<u>Frequency</u>
1988	5.7	1993	10.5	1998	6.8
1989	5.5	1994	8.8	1999	8.1
1990	8.5	1995	8.1	2000	10.0*
1991	7.6	1996	7.8	2001	7.5
1992	11.2	1997	1.8*	2002	7.3

* - Seasons abbreviated by orca attacks.

A breakdown of the data by month indicates that all three months, September, October, and November, were slightly below each respective 13-year mean (excluding 1997). The reasons for such inter-annual variation in predation frequencies are not fully understood. Frequencies increase with increased number of Elephant Seals present but the number of seals was close to the mean so this does not provide an explanation for the slightly decreased predation frequencies recorded in 2002. We observed no environmental factors (Pyle et al. 1996a) that may have accounted for the lower frequencies either.

The video sequences will be catalogued for use in future mark-recapture analyses. We plan to begin full-scale cataloguing this coming year, funding permitting.

The data collected from the satellite tags in 2002-3 will be of extreme interest, especially regarding longer-term movement patterns and water-mass preferences. The seven sharks tagged in 2001 consisted of six males and one female. Thus, we have tagged many more known males (15) than known females (4) to date. We currently seek funding for continued tagging in 2003, at which point we hope to deploy tags on more females, such that migrations during their biannual cycle can be ascertained.

This is the first year during which we have recorded data on cage-diving activities at the Farallones. The seven boats observed undertaking such activities represents an increase from five in 2001, four in 2000, two in 1999, and one or less during all previous years. In 2003 we will be summarizing all white-shark related ecotourism activities at the Farallones. These data will be presented at meetings hosted by the Gulf of the Farallones National Marine Sanctuary to consider regulating such activities. We would like to see regulations put in place to protect the white sharks from disturbances to their feeding activities brought on by chumming, use of decoys, and increasing ecotourism activities.

As in the past, results from the white shark project will be published in scientific journals as these data are needed for management or conservation-related issues affecting pinniped populations, commercial fish stocks, or white shark populations off California. Our results have previously been instrumental toward protecting the white shark off California (Heneman and Glazer 1996), and there is a need to continue monitoring these populations to assess the effectiveness of the California protection bill and/or to see if stronger legislation is needed. Populations of white sharks and how they relate to populations of pinnipeds will also be assessed regarding how the very high populations of many pinniped species in California affect our commercial fish stocks.

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LITERATURE CITED AND BIBLIOGRAPHY

- Ainley, D.G., R.P. Henderson, H.R. Huber, R.J. Boekelheide, S.G. Allen, and T.L. McElroy. 1985. Dynamics of white shark / pinniped interactions in the Gulf of the Farallones. *Memoirs South. Calif. Acad. Sci.* 9:109-122.
- Anderson, S. D., and K. J. Goldman. 1996. Photographic evidence of white shark movements in California waters. *California Fish Game* 82:182-186.

- Anderson, S.D., R.P. Henderson, and P. Pyle. 1996b. Observations of white shark reactions to unbaited decoys. Pp. 223-228 in A.P. Klimley and D.G. Ainley (Eds.), *The Ecology and Behavior of the White Shark*. Academic Press, San Diego.
- Anderson, S.D., A.P. Klimley, P. Pyle, and R.P. Henderson. 1996a. Tidal height and white shark predation at the South Farallon Islands, California. Pp. 275-280 in A.P. Klimley and D.G. Ainley (Eds.), *The Ecology and Behavior of the White Shark*. Academic Press, San Diego.
- Anderson, S.D., and P. Pyle. In press. A temporal, sex-specific occurrence pattern among white sharks (*Carcharodon carcharias*) at the South Farallon Islands, California. California Fish and Game.
- Boustany, A., S.F. Davis, P. Pyle, S.D. Anderson, B.J. LeBoeuf, and B.A. Block. 2002. Expanded niche for great white sharks. *Nature* 415:35-36.
- Goldman, K.J., S.D. Anderson, J.E. McCosker, and A.P. Klimley. 1996. Temperature, swimming depth, and movements of a white shark at the South Farallon Islands, California. Pp. 111-120 in A.P. Klimley and D.G. Ainley (Eds.), *The Ecology and Behavior of the White Shark*. Academic Press, San Diego.
- Hare, S.R., and N.J. Mantua. 2000. Empirical evidence for North Pacific regime shifts in 1977 and 1989. *Progress in Oceanography* 47:103-145.
- Heneman, B. and M. Glazer. 1996. More rare than dangerous: A case study of white shark conservation in California. Pp. 481-491 in A.P. Klimley and D.G. Ainley (Eds.), *The Ecology and Behavior of the White Shark*. Academic Press, San Diego.
- Klimley, A.P. 1985. The areal distribution and autoecology of the white shark, *Carcharodon carcharias* off the west coast of North America. *Memoirs of the Southern California Academy of Sciences* 9:15-40.
- Klimley, A.P. and D.G. Ainley, Eds. 1996. *The Ecology and Behavior of the White Shark*. Academic Press, San Diego.
- Klimley, A.P. and S.D. Anderson. 1996. Residency patterns of white sharks at the South Farallon Islands, California. Pp. 365-374 in A.P. Klimley and D.G. Ainley (Eds.), *The Ecology and Behavior of the White Shark*. Academic Press, San Diego.
- Klimley, A.P., S.D. Anderson, P. Pyle, and R.P. Henderson. 1992. Spatiotemporal patterns of white shark (*Carcharodon carcharias*) predation at the South Farallon Islands, California. *Copeia* 1992:680-690.
- Klimley, A.P., P. Pyle, and S.D. Anderson. 1996a. The behavior of white sharks and their pinniped prey during predatory attacks. Pp. 175-192 in A.P. Klimley and D.G. Ainley (Eds.), *The Ecology and Behavior of the White Shark*. Academic Press, San Diego.
- Klimley, A.P., P. Pyle, and S.D. Anderson. 1996b. Tail slap and breach: Agonistic displays among white sharks? Pp. 241-256 in A.P. Klimley and D.G. Ainley (Eds.), *The Ecology and Behavior of the White Shark*. Academic Press, San Diego.
- Lea, R.N. and J.E. McCosker. 1996. White shark attacks in the Eastern Pacific Ocean: An update and analysis. Pp. 419-434 in A.P. Klimley and D.G. Ainley (Eds.), *The Ecology and Behavior of the White Shark*. Academic Press,

San Diego.

- Long, D.J., K. Hanni, P. Pyle, J. Roletto, R.E. Jones and R. Bandar. 1996. Geographical and temporal patterns of white shark predation on four pinniped species along central California, 1970-1992. Pp. 263-274 *in* A.P. Klimley and D.G. Ainley (Eds.), *The Ecology and Behavior of the White Shark*. Academic Press, San Diego.
- Pyle, P. 1992. Sympathy for a predator: White shark studies at Southeast Farallon. *Observer* 93:1-11.
- Pyle, P., S.D. Anderson, and D.G. Ainley. 1996a. Trends in white shark predation at the South Farallon Islands, 1968-1993. Pp. 375-380 *in* A.P. Klimley and D.G. Ainley (Eds.), *The Ecology and Behavior of the White Shark*. Academic Press, San Diego.
- Pyle, P., S.D. Anderson, A.P. Klimley, R.P. Henderson, and D.G. Ainley. 1996b. Environmental factors affecting the occurrence and behavior of white sharks at the South Farallon Islands, California. Pp. 281-292 *in* A.P. Klimley and D.G. Ainley (Eds.), *The Ecology and Behavior of the White Shark*. Academic Press, San Diego.
- Pyle, P., M.J. Schramm, C. Keiper, and S.D. Anderson. 1999. Predation on a white shark by a killer whale and a possible case of competitive exclusion. *Marine Mammal Sci.* 15:563-568.